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SEL-351S Relay

Relay, Meter, Control, Fault Locator

Instruction Manual

20080103

SCHWEITZER ENGINEERING LABORATORIES, INC.

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⚠CAUTION

The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

⚠CAUTION

There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.

⚠CAUTION

Never apply voltage signals greater than 9 V peak-peak to the low-level test interface (J10) or equipment damage may result.

⚠CAUTION

On models with auxiliary trip/close pushbuttons, the front-panel breaker LED default labeling matches the rear-panel labeling. If the front-panel breaker LED **CLOSED** and **OPEN** labeling is changed, the front-panel breaker labeling will no longer match the rear-panel breaker labeling.

⚠DANGER

Removal of relay front panel exposes circuitry which may cause electrical shock that can result in injury or death.

⚠DANGER

Contact with instrument terminals can cause electrical shock that can result in injury or death.

⚠WARNING

This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

⚠WARNING

SEL-351S Relay features such as Hot Line Tag and Synchronism Check do not supervise the auxiliary close pushbutton.

⚠ATTENTION

Le relais contient des pièces sensibles aux décharges électrostatiques. Quand on travaille sur le relais avec les panneaux avant ou du dessus enlevés, toutes les surfaces et le personnel doivent être mis à la terre convenablement pour éviter les dommages à l'équipement.

⚠ATTENTION

Il y a un danger d'explosion si la pile électrique n'est pas correctement remplacée. Utiliser exclusivement Ray-O-Vac® No. BR2335 ou un équivalent recommandé par le fabricant. Se débarrasser des piles usagées suivant les instructions du fabricant.

⚠ATTENTION

Au risque de causer des dommages à l'équipement, ne jamais appliquer un signal de tension supérieur à 9 V crête à crête à l'interface de test de bas niveau (J10).

⚠ATTENTION

Sur les modèles avec bouton-poussoirs auxilaires ouverture/fermeture, l'étiquette par défaut du voyant lumineux (LED) du disjoncteur correspond à l'étiquette du panneau arrière. Si l'étiquette du disjoncteur du panneau avant **FERMÉ** et **OUVERT** est changée, l'étiquette du disjoncteur sur le panneau avant ne correspondra plus à l'étiquette du disjoncteur sur le panneau arrière.

⚠DANGER

Le contact avec les bornes de l'instrument peut causer un choc électrique pouvant entraîner des blessures ou la mort.

⚠DANGER

Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessuers ou la mort.

⚠AVERTISSEMENT

Cet appareil est expédié avec des mots de passe par défaut. A l'installation, les mots de passe par défaut devront être changés pour des mots de passe confidentiels. Dans le cas contraire, un accés non-autorisé á l'équipement peut être possible. SEL décline toute responsabilité pour tout dommage résultant de cet accés non-autorisé.

⚠AVERTISSEMENT

Les caractéristiques du relais SEL-351S telles que le VOYANT DE LIGNE SOUS-TENSION et la VERIFICATION DE SYNCHRONISME ne supervisent pas le bouton-poussoir auxiliaire de fermeture.

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The information in this manual is provided for informational use only and is subject to change without notice. Schweitzer Engineering Laboratories, Inc. has approved only the English language manual.

This product is covered by the standard SEL 10-year warranty. For warranty details, visit www.selinc.com or contact your customer service representative.

PM351S-01

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Preface

Overview

This manual provides information and instructions for installing, setting, configuring, and operating the SEL-351S Relay. The manual is for use by power engineers and others experienced in protective relaying applications. Included are detailed technical descriptions of the relay and application examples.

An overview of each manual section and section topics follows.

Preface. Describes the manual organization and conventions used to present information.

Section 1: Introduction and Specifications. Includes an explanation of SEL-351S models; a diagram showing how the relay can be applied in a power system; hardware connection features; communications connections; and specifications.

Section 2: Installation. Describes mounting and wiring the SEL-351S; connections for numerous applications; operation of circuit board jumpers; and relay front and rear panels.

Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements. Describes the operation of instantaneous/definite-time overcurrent elements (phase, neutral ground, residual ground, and negative-sequence); time-overcurrent elements (phase, neutral ground, residual ground, and negative-sequence); voltage elements (single-phase, phase-to-phase, etc.); synchronism check elements; frequency elements; power elements (in Firmware Version 7); and voltage sag/swell/interruption elements (in Firmware Version 7).

Section 4: Loss-of-Potential, Load Encroachment, and Directional Element Logic. Describes the operation of loss-of-potential logic and its effect on directional elements; load-encroachment logic and its application to phase overcurrent elements; voltage-polarized and current-polarized directional elements; and *Best Choice Ground Directional*™ logic and automatic settings

Section 5: Trip and Target Logic. Describes the operation of general trip logic; switch-onto-fault trip logic; communications-assisted trip logic; and front-panel target LEDs.

Most tripping applications (not requiring switch-onto-fault or communications-assisted tripping) require only SELOGIC® control equation trip setting TR and unlatch trip setting ULTR in the general trip logic (see *Figure 5.1*).

Section 6: Close and Reclose Logic. Describes the close logic operation for automatic reclosures and other close conditions (e.g., manual close initiation via serial port or optoisolated inputs).

Section 7: Inputs, Outputs, Timers, and Other Control Logic. Describes the operation of optoisolated inputs **IN101**–**IN106** and **IN201**–**IN208** (extra I/O board); local control switches (local bit outputs LB1–LB16); remote control switches (remote bit outputs RB1–RB16); latch control switches (latch bit outputs LT1–LT16); multiple setting groups (six

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available); programmable timers (timer outputs SV1T–SV16T); output contacts **OUT101**–**OUT107** and **ALARM** and **OUT201**–**OUT212** (extra I/O board); and rotating default displays.

Section 8: Breaker Monitor, Metering, and Load Profile Functions. Describes the operation of breaker monitor; demand, energy, and max./min. metering; and load profile (in Firmware Versions 6 and 7)

Section 9: Setting the Relay. Explains how to enter settings and also contains the following setting reference information:

- Time-overcurrent curves (5 US, 5 IEC, and 38 recloser curves)
- Relay Word bit table and definitions (Relay Word bits are used in SELOGIC control equation settings)
- *SEL-351S Settings Sheets* for general relay, SELOGIC control equation, global, SER, text label, and serial port settings

  The Settings Sheets can be photocopied and filled out to set the SEL-351S. Note that these sheets correspond to the serial port **SET** commands listed in *Table 9.1*.

Section 10: Serial Port Communications and Commands. Describes serial port connector pinout/terminal functions; communications cables; communications protocol; and serial port commands.

See *SHO Command (Show/View Settings) on page 10.27* for a list of **factory default settings** set for a standard relay shipment.

Section 11: Front-Panel Interface. Describes the front-panel operation of pushbuttons and correspondence to serial port commands; local control switches (local bit outputs LB1–LB16); rotating default displays; and operator controls.

Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER. Describes standard 15- and 30-cycle event reports; sequential events recorder (SER) report; and voltage sag/swell/interruption (SSI) report (in Firmware Version 7).

Section 13: Testing and Troubleshooting. Describes general testing philosophy, methods, and tools; and relay self-tests and troubleshooting.

Section 14: Appendices. Contains the following appendices:

- *Appendix A: Firmware and Manual Versions*
- *Appendix B: SEL-300 Series Relays Firmware Upgrade Instructions*
- *Appendix C: SEL Distributed Port Switch Protocol*
- *Appendix D: Configuration, Fast Meter, and Fast Operate Commands*
- *Appendix E: Compressed ASCII Commands*
- *Appendix F: Setting Negative-Sequence Overcurrent Elements*
- *Appendix G: Setting SELOGIC Control Equations*
- *Appendix H: Distributed Network Protocol*
- *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*
- *Appendix J: SEL-351S Fast SER Protocol*

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- *Appendix K: acSELerator QuickSet SEL-5030 Software*
- *Appendix L: SEL Synchrophasors*

The *SEL-351S Relay Command Summary* briefly describes the serial port commands that are described in detail in *Section 10: Serial Port Communications and Commands*.

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Conventions

Typographic Conventions

There are three ways to communicate with the SEL-351S:

- Using a command line interface on a PC terminal emulation window.
- Using the front-panel menus and pushbuttons.
- Using ACSELERATOR® QuickSet™ SEL-5030 Software.

The instructions in this manual indicate these options with specific font and formatting attributes. The following table lists these conventions.

Typographic Conventions

Example	Description
STATUS	Commands, command options, and command variables typed at a command line interface on a PC.
n **SHO *n***	Variables determined based on an application (in bold if part of a command).
<Enter>	Single keystroke on a PC keyboard.
<Ctrl+D>	Multiple/combination keystroke on a PC keyboard.
Start > Settings	PC software dialog boxes and menu selections. The > character indicates submenus.
{CLOSE}	Relay front-panel pushbuttons.
ENABLE	Relay front- or rear-panel labels.
MAIN > METER	Relay front-panel LCD menus. The > character indicates sub-menus.
Are you sure?	Relay responses visible on the PC screen.

Cross References

Cross-references are formatted as described below in both the hard copy and electronic documentation for the SEL-351S. In the electronic documentation, clicking with the mouse on cross-references takes you to the referenced location.

- References to figures, tables, examples, and equations include only the referenced item:
  - *Table 3.1* (*3* indicates the section number)
  - *Figure 4.5* (*4* indicates the section number)
- References to headings on another page include the heading title and the page number:
  - *Disconnect Monitoring on page 3.8*

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the SEL-351S. These examples are for demonstration purposes only; the firmware identification information or settings values included in these examples may not necessarily match those in the current version of your SEL-351S.

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Safety Information

This manual uses three kinds of hazard statements, formatted as follows:

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, may result in minor or moderate injury or equipment damage.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

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Section 1
Introduction and Specifications

This section includes the following overviews of the SEL-351S Relay:

SEL-351S Models on page 1.2

Applications on page 1.5

Hardware Connection Features on page 1.6

Communications Connections on page 1.9

Specifications on page 1.10

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SEL-351S Models

This instruction manual covers the following SEL-351S models:

Table 1.1 SEL-351S Models

Model Number	Rear-Panel Connection Type	Output Contact Type	Number of Isolated I/O Contacts	Reference Figures
0351S*x*1	screw-terminal block	standard	6/8 (main board)	*Figure 1.2*, *Figure 2.3*, *Figure 2.4*, *Figure 2.5*, *Figure 7.1*, *Figure 7.27*
		standard or high-current interrupting	8/12 (extra I/O board)	*Figure 1.4*, *Figure 2.3*, *Figure 2.5*, *Figure 7.2*, *Figure 7.28*
0351S*x*Y	plug-in connectors	standard	6/8 (main board)	*Figure 1.2*, *Figure 2.2*, *Figure 2.6*, *Figure 7.1*, *Figure 7.27*
		standard or high-current interrupting	8/12 (extra I/O board)	*Figure 1.3*, *Figure 2.2*, *Figure 2.6*, *Figure 7.2*, *Figure 7.28*

The model numbers are derived from the SEL-351S ordering information sheet. The model numbers in *Table 1.1* are only the first part of an actual ordering number—enough to distinguish one model type from another. The *x* field indicates the firmware version (see *Table 1.2*). These numbers should not be used to order an SEL-351S. To order an SEL-351S, refer to the actual ordering information sheets.

Models 0351S*x*1 and 0351S*x*Y can be ordered with a horizontal rack mount or horizontal/vertical panel mount. Standard models come with six optoisolated inputs and eight output contacts. Extra I/O boards can be ordered on any SEL-351S model. (See *Figure 2.2*–*Figure 2.6*.)

Any SEL-351S model can be ordered with the more sensitive neutral channel (**IN**) current input options (0.2 A or 0.05 A nominal). *Table 4.3* and accompanying note show the particular ground directional elements available with different options of the neutral channel (**IN**) current input. The 0.05 A nominal neutral channel (**IN**) current input option is a legacy nondirectional sensitive earth fault (SEF) option (the 0.2 A nominal neutral channel (**IN**) current input option can provide the same SEF function and additional directional options, as detailed in *Table 4.3*).

Throughout this instruction manual, when differences among the SEL-351S models in *Table 1.1* are explained, model numbers are referenced for clarity.

Differences between model 0351S*x*1 and 0351S*x*Y show up in references to optoisolated inputs, output contacts, and board jumpers. *Figure 2.32*–*Figure 2.35* and *Table 2.3*–*Table 2.8* show the labeling differences between the board jumpers.

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Table 1.2 SEL-351S Firmware Versions

Model Number	Firmware Version	Relay Features
0351S5	5	Standard features.
0351S6	6	Standard features plus MIRRORED BITS® and load profiling.
For an additional cost, SEL-351S relays with firmware version 5 can be upgraded to firmware version 6 or 7, and firmware version 6 can be upgraded to firmware version 7.		
0351S7	7	Includes firmware version 6 features plus power and voltage sag/swell/interruption elements.
SEL-351S relays with firmware version 5, 6, or 7 come with 300 Vac voltage inputs only (connect any voltage up to 300 Vac, line-to-neutral).		

Auxiliary {TRIP} and {CLOSE} Pushbuttons

The SEL-351S part number indicates whether the relay has auxiliary **{TRIP}** and **{CLOSE}** pushbuttons. These pushbuttons are shown in *Figure 2.5* and *Figure 2.6*. These features are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

- Part numbers 0351S*xxx*3 and 0351S*xxx*4 designate relays **without** the auxiliary **{TRIP}** and **{CLOSE}** pushbuttons. These models will be referred to as 0351S*xxx*3/4 throughout this instruction manual.
- Part numbers 0351S*xxx*5, 0351S*xxx*6, 0351S*xxx*A, and 0351S*xxx*B designate relays **with** the auxiliary **{TRIP}** and **{CLOSE}** pushbuttons. These models will be referred to as 0351S*xxx*5/6/A/B throughout this instruction manual.

The different final digits in the above part numbers represent various combinations of user-configurable labels and pushbutton guards that are available (see *User-Configurable Label Option for the Front Panel on page 2.9*). The lowercase *x*s in the above part numbers represent fields that contain other values that are not important in determining the operator controls of the relay. Refer to the Model Option Tables for either the SEL-351S-5, -6, -7 Relay (with Conventional Terminal Blocks), or the SEL-351S-5, -6, -7 Connectorized® Relay, for complete part number details. These tables are available on the SEL website or from the factory.

CT Saturation Protection

The SEL-351S phase instantaneous overcurrent elements normally operate using the output of a cosine filter algorithm. During heavy fault currents when the relay detects severe CT saturation, the overcurrent elements can operate on the adaptive current algorithm.

The adaptive current algorithm is only used for phase instantaneous overcurrent elements if and only if the corresponding pickup setting is greater than eight times the nominal phase current. For example, if 50P1P = 45 A (in a 5 Amp nominal phase current relay), then the 50P1, 50A1, 50B1, and 50C1 elements operate on the adaptive current algorithm. However, if 50P1P = 35 A, then the 50P1, 50A1, 50B1, and 50C1 elements operate on the output of a cosine filter algorithm. No other overcurrent elements use the adaptive current algorithm.

Based on the level of a “harmonic distortion index,” the adaptive current is either the output of the cosine filter or the output of the bipolar peak detector. When the harmonic distortion index exceeds the fixed threshold that indicates

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severe CT saturation, the adaptive current is the output of the bipolar peak detector. When the harmonic distortion index is below the fixed threshold, the adaptive current is the output of the cosine filter.

The cosine filter provides excellent performance in removing dc offset and harmonics. However, the bipolar peak detector has the best performance in situations of severe CT saturation when the cosine filter magnitude estimation is significantly degraded. Combining the two filters provides an elegant solution for ensuring dependable phase instantaneous overcurrent element operation.

Potential Transformer Connections

Firmware revisions prior to R107 (inclusive) operate with wye-connected (line-to-neutral) voltages only. The **VER** command (available at Access Level 2) identifies these relays as "wye-connected." In these earlier firmware revisions, the auxiliary voltage channel **VS** can only be used for synchronism check or as a general-purpose voltage input. See *Access Level 2 Commands on page 10.40* for details on the **VER** command.

Firmware revisions numbered R108 or higher can be configured via global setting PTCONN to accept either wye (line-to-neutral) or delta (line-to-line) voltages using the open-delta connection. The **VER** command identifies these relays as "wye or delta connected." See *Potential Transformer Inputs on page 2.18* for details on the open-delta connection.

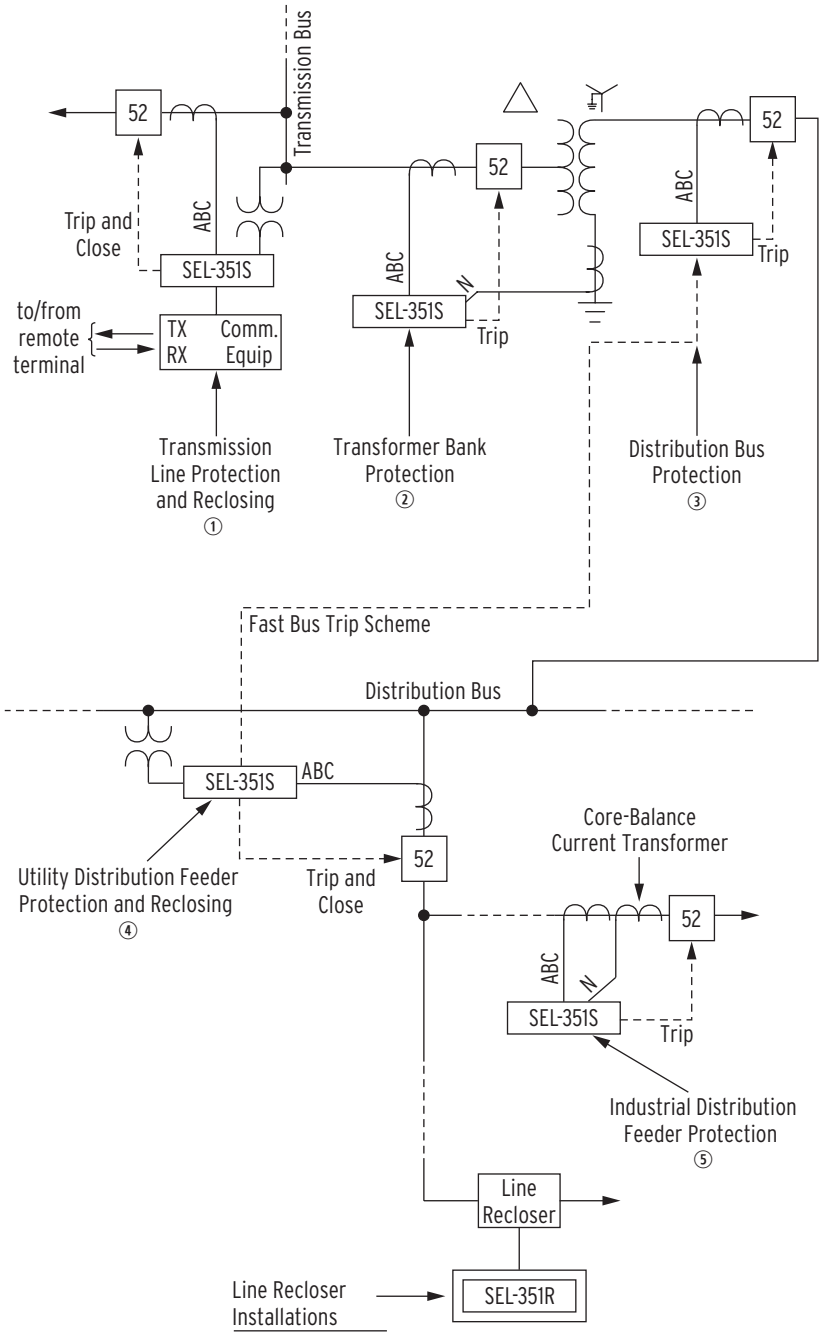
Also in firmware revisions numbered R108 or higher, the auxiliary voltage channel **VS** can be configured via global setting VSCONN = VS to accept a synchronism check or general-purpose voltage input or via VSCONN = 3V0 to accept a broken-delta residual voltage connection to be used in the zero-sequence voltage polarized ground directional elements. See *Potential Transformer Inputs* for details on the broken-delta connection, and other relay elements that are affected by setting VSCONN = 3V0.

The connection type setting (wye or delta) does not affect the voltage input rating of the relay voltage terminals. For example, a relay with 300 Vac voltage inputs can accept up to 300 Vac line-to-neutral in the wye configuration and up to 300 Vac line-to-line in the delta configuration. The auxiliary voltage channel **VS** is similarly rated.

When using a broken-delta connection, if the maximum possible zero-sequence voltage $3V_0$ exceeds the **VS** channel rating, an external step-down instrumentation transformer may be required. See *Terminal Connections on page 1.10* for details on the input ratings. See *Figure 2.28* for an example connection that uses a step-down transformer.

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Applications



① See Figure 2.19 and Figure 2.20, ② See Figure 2.21 and Figure 2.22, ③ See Figure 2.18, ④ See Figure 2.17 and Figure 2.25–Figure 2.29, ⑤ See Figure 2.23.

Figure 1.1 SEL-351S Relays Applied Throughout the Power System

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Hardware Connection Features

See subsection *Specifications*: *General on page 1.10* and *Section 2: Installation* for more information on hardware and connections.

CHANNEL IN:

Table 4.4 and accompanying note show the particular ground directional elements available with different options of the neutral channel (**IN**) current input. Nondirectional sensitive earth fault (SEF) protection is also available with the 0.2 A and 0.05 A nominal neutral channel (**IN**) current input options.

VOLTAGE INPUTS VA, VB, VC:

Firmware revisions numbered R108 or higher can be configured via global setting PTCONN to accept either wye (line-to-neutral) or delta (line-to-line) voltages using the open-delta connection. The relay rear panel markings and the internal connections of terminals **Z09–Z12** are not changed. See Potential Transformer Inputs on page 2.18 for details on the open-delta connection.

AUXILIARY VOLTAGE CHANNEL VS:

The **VS** channel in firmware revisions numbered R108 or higher can be configured via global setting VSCONN = VS to accept a synchronism check or general-purpose voltage input or via VSCONN = 3V0 to accept a broken-delta residual voltage connection. The relay rear-panel markings and the internal connections of terminals **Z13** and **Z14** are not changed. See Potential Transformer Inputs for details on the broken-delta connection.

AUXILIARY TRIP/CLOSE PUSHBUTTONS AND BREAKER STATUS LEDS:

The auxiliary **{TRIP}/{CLOSE}** pushbuttons and breaker status LEDs in models 0351Sxxx5/6/A/B are electrically separate from the rest of the relay and are not shown in Figure 1.2. Figure 2.5 and Figure 2.6 show these auxiliary pushbuttons and LEDs and their rear-panel connections. Figure 2.31 shows the typical application for these auxiliary pushbuttons and LEDs.

The Figure 1.2 **{CLOSE}/{BREAKER CLOSED}** and **{TRIP}/{BREAKER OPEN}** operator control pushbuttons are replaced by **{AUX 3}** and **{AUX 4}**.

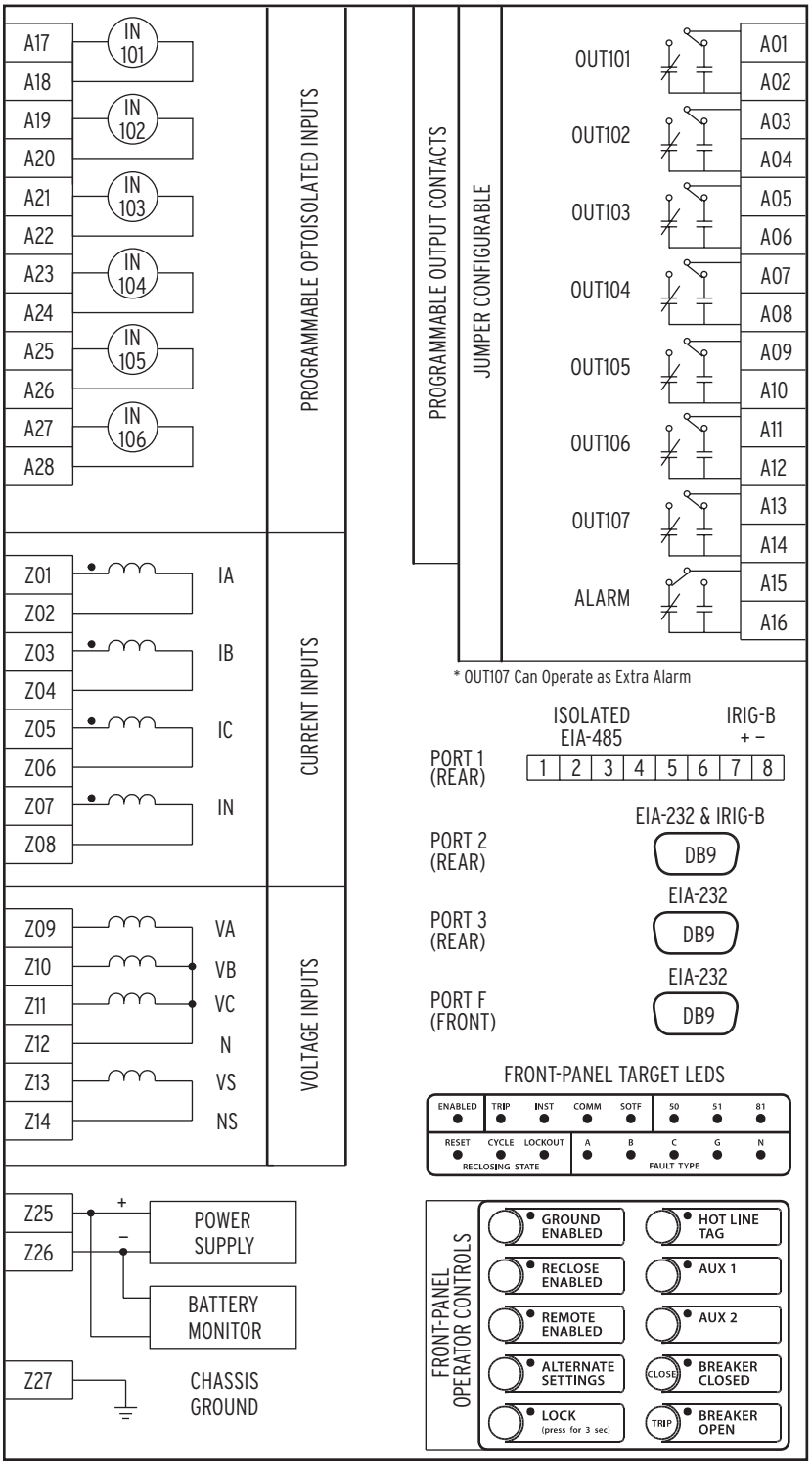


Figure 1.2 Inputs, Outputs, and Communications Ports (Extra I/O Boards in Figure 1.3 and Figure 1.4)

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OUTPUT CONTACTS:
If the output contacts are high-current interrupting output contacts, they are **polarity dependent**. See Table 1.1 for information on SEL-351S models with the high-current interrupting output contact option. See Output Contacts on page 2.16 for more information on the polarity dependence of high-current interrupting output contacts.

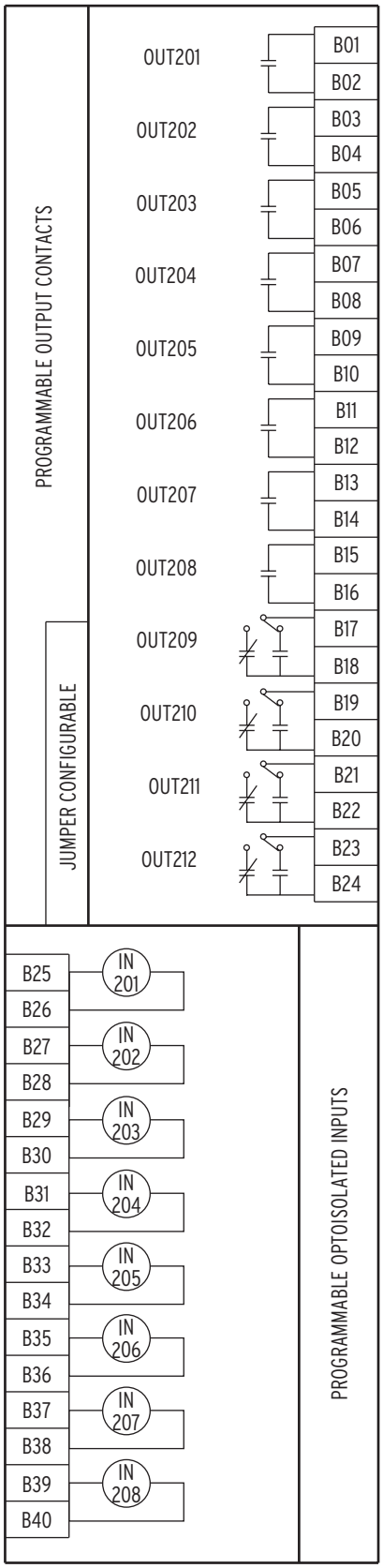


Figure 1.3 Extra I/O Board (Model 0351SxY, Plug-In Connector Version; Main Board Shown in Figure 1.2)

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OUTPUT CONTACTS:
If the output contacts are high-current interrupting output contacts, they are **polarity dependent**. See Table 1.1 for information on SEL-351S models with the high-current interrupting output contact option. See Output Contacts on page 2.16 for more information on the polarity dependence of high-current interrupting output contacts.

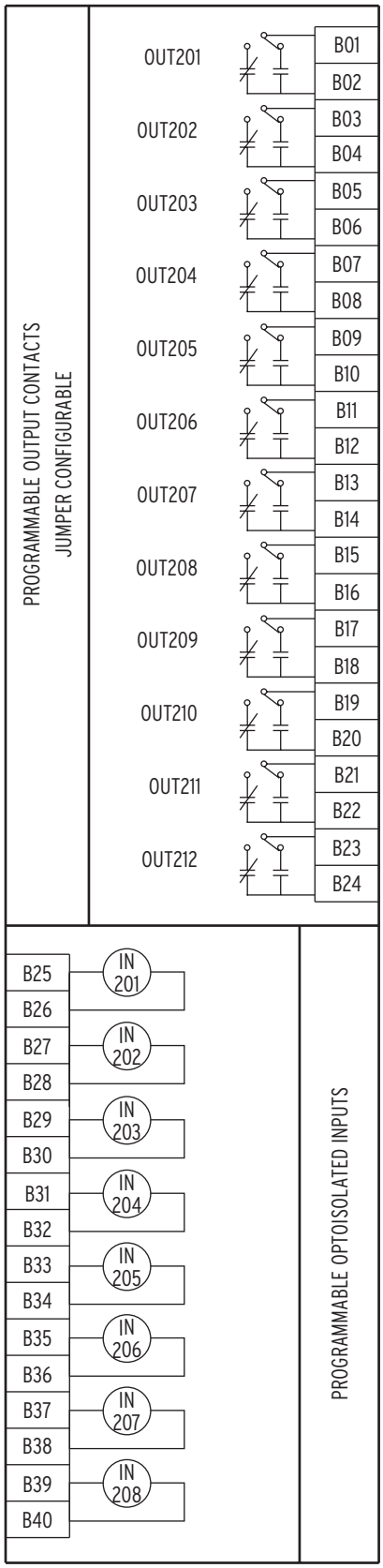


Figure 1.4 Extra I/O Board (Model 0351Sx1, Screw-Terminal Block Version; Main Board Shown in Figure 1.2)

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Communications Connections

See *Port Connector and Communications Cables on page 10.2* for more communications connections information.

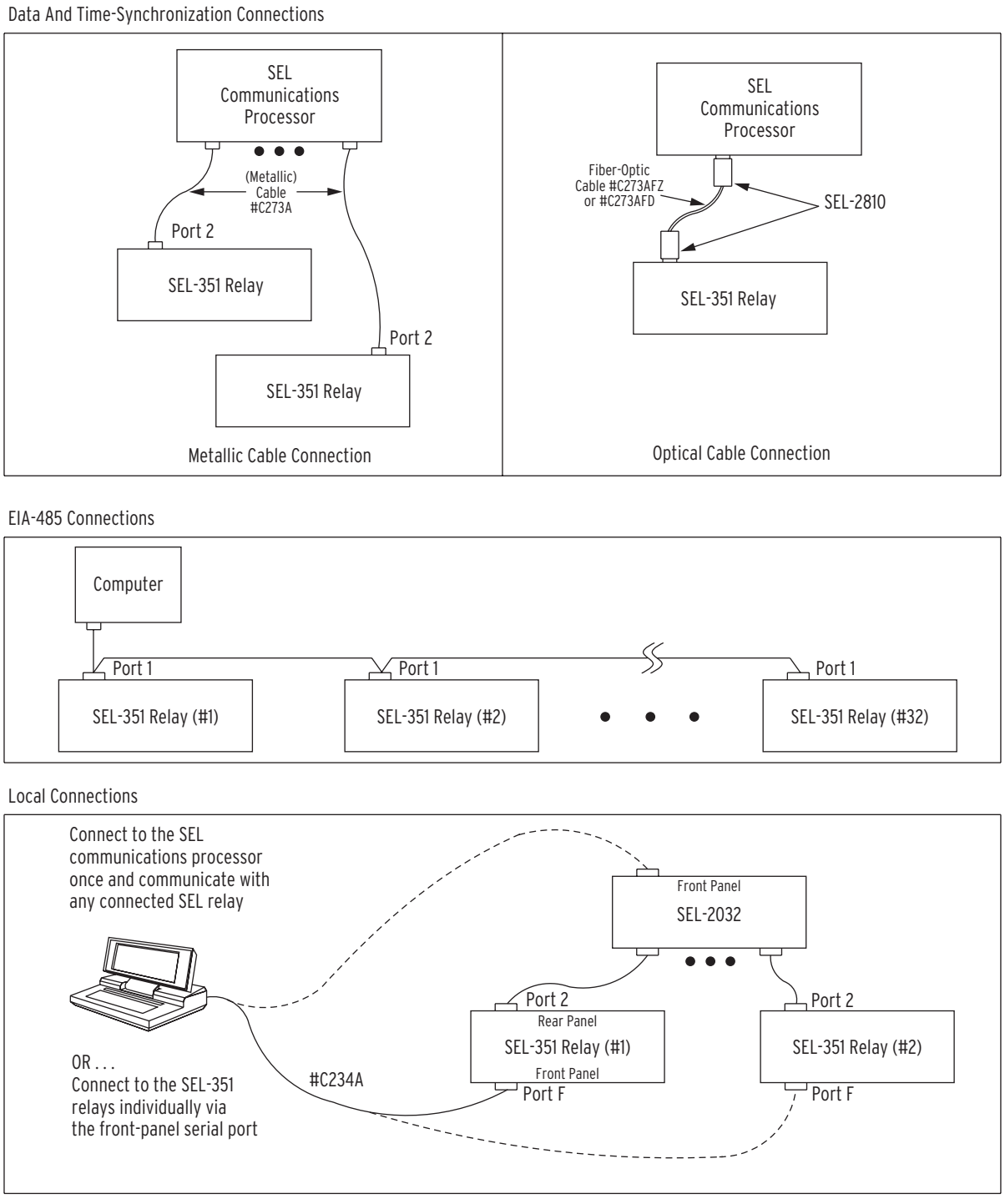


Figure 1.5 Communications Connections Examples

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Specifications

Important: Do not use the following specification information to order an SEL-351S. Refer to the actual ordering information sheets.

General

Terminal Connections

Note: Terminals or stranded copper wire. Ring terminals are recommended. Minimum temperature rating of 105ºC.

Tightening Torque, Terminal Block:

Minimum:	8 in-lb (0.9 Nm)
Maximum:	12 in-lb (1.4 Nm)

Tightening Torque, Connectorized®:

Minimum:	4.4 in-lb (0.5 Nm)
Maximum:	8.8 in-lb (1.0 Nm)

AC Voltage Inputs

300 V_{L-N}, three-phase four-wire (wye) connection or 300 V_{L-L}, three-phase three-wire (open-delta) connection (when available, by global setting PTCONN=DELTA)

Continuous:	300 V (connect any voltage from 0 to 300 Vac) 600 Vac for 10 seconds
Burden:	0.03 VA @ 67 V; 0.06 VA @ 120 V; 0.8 VA @ 300 V

AC Current Inputs

IA, IB, IC, and neutral channel IN:

5 A nominal:	15 A continuous, 500 A for 1 s, linear to 100 A symmetrical, 1250 A for 1 cycle
Burden:	0.27 VA @ 5 A, 2.51 VA @ 15 A
1 A nominal:	3 A continuous, 100 A for 1 s, linear to 20 A symmetrical, 250 A for 1 cycle
Burden:	0.13 VA @ 1 A, 1.31 VA @ 3 A

Additional neutral channel IN options

0.2 A nominal neutral channel (IN) current input:	15 A continuous, 500 A for 1 second, linear to 5.5 A symmetrical 1250 A for 1 cycle
Burden:	0.002 VA @ 0.2 A, 1.28 VA @ 15 A
0.05 A nominal neutral channel (IN) current input:	1.5 A continuous, 20 A for 1 second, linear to 1.5 A symmetrical 100 A for 1 cycle
Burden:	0.0004 VA @ 0.05 A, 0.36 VA @ 1.5 A

Note: The 0.2 A nominal neutral channel IN option is used for directional control on low-impedance grounded, Petersen Coil grounded, and ungrounded/ high-impedance grounded systems (see *Table 4.3*). The 0.2 A nominal channel can also provide non-directional sensitive earth fault (SEF) protection.
The 0.05 A nominal neutral channel IN option is a legacy non-directional SEF option.

Power Supply

Rated:	125/250 Vdc or Vac
Range:	85–350 Vdc or 85–264 Vac
Burden:	<25 W
Rated:	48/125 Vdc or 125 Vac
Range:	38–200 Vdc or 85–140 Vac
Burden:	<25 W
Rated:	24/48 Vdc
Range:	18–60 Vdc polarity dependent
Burden:	<25 W

Frequency and Rotation

Note: 60/50 Hz system frequency and ABC/ACB phase rotation are user-settable.

Frequency tracking range:	40.1–65 Hz (V_A or V_1 [positive-sequence voltage] required for frequency tracking; tracking switches to V_1 if V_A <20 V).

Output Contacts

Standard:

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1s Rating:	50 A
MOV Protected:	270 Vac/360 Vdc/40 J
Pickup Time:	Less than 5 ms
Dropout Time:	Less than 5 ms, typical

Breaking Capacity (10000 operations):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Cyclic Capacity (2.5 cycle/second):

24 V	0.75 A	L/R = 40 ms
48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Note: Make per IEEE C37.90-1989.
Note: Breaking and Cyclic Capacity per IEC 60255-0-20:1974.
Note: EA certified relays do not have MOV protected standard output contacts.

High-Current Interruption Option for Extra I/O Board:

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1s Rating:	50 A
MOV Protection:	330 Vdc/130 J
Pickup Time:	Less than 5 ms
Dropout Time:	Less than 8 ms, typical

Breaking Capacity (10000 operations):

24 V	10 A	L/R = 40 ms
48 V	10 A	L/R = 40 ms
125 V	10 A	L/R = 40 ms
250 V	10 A	L/R = 20 ms

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Cyclic Capacity (4 cycles in 1 second, followed by 2 minutes idle for thermal dissipation):

24 V	10 A	L/R = 40 ms
48 V	10 A	L/R = 40 ms
125 V	10 A	L/R = 40 ms
250 V	10 A	L/R = 20 ms

Note: Make per IEEE C37.90-1989.
Note: Do not use high-current interrupting output contacts to switch ac control signals. These outputs are polarity dependent.
Note: Breaking and Cyclic Capacity per IEC 60255-0-20:1974.

Auxiliary Trip/Close Pushbuttons (0351Sxxx5/6/A/B models only)

Resistive DC or AC Outputs with Arc Suppression Disabled (see *Table 2.9* and *Table 2.10*):

Make:	30 A
Carry:	6 A continuous carry
1s Rating:	50 A
MOV Protection:	250 Vac/330 Vdc/130 J

Breaking Capacity (10000 operations):

48 V	0.50 A	L/R = 40 ms
125 V	0.30 A	L/R = 40 ms
250 V	0.20 A	L/R = 40 ms

Note: Make per IEEE C37.90-1989.

High Interrupt DC Outputs with Arc Suppression Enabled:

Make:	30 A
Carry:	6 A continuous carry
1s Rating:	50 A
MOV Protection:	330 Vdc/130 J

Breaking Capacity (10000 operations):

48 V	10 A	L/R = 40 ms
125 V	10 A	L/R = 40 ms
250 V	10 A	L/R = 20 ms

Note: Make per IEEE C37.90-1989.

Breaker Open/Closed LEDs:

250 Vdc:	on for 150–300 Vdc;	192–288 Vac
125 Vdc:	on for 80–150 Vdc;	96–144 Vac
48 Vdc:	on for 30–60 Vdc;	
24 Vdc:	on for 15–30 Vdc	

Note: With nominal control voltage applied, each LED draws 8 mA (max.). Jumpers may be set to 125 Vdc for 110 Vdc input and set to 250 Vdc for 220 Vdc input.

Optoisolated Input Ratings

When used with dc control signals:

250 Vdc:	on for 200–300 Vdc;	off below 150 Vdc
220 Vdc:	on for 176–264 Vdc;	off below 132 Vdc
125 Vdc:	on for 105–150 Vdc;	off below 75 Vdc
110 Vdc:	on for 88–132 Vdc;	off below 66 Vdc
48 Vdc:	on for 38.4–60 Vdc;	off below 28.8 Vdc
24 Vdc:	on for 15–30 Vdc	

When used with ac control signals:

250 Vdc:	on for 170.6–300 Vac;	off below 106.0 Vac
220 Vdc:	on for 150.3–264.0 Vac;	off below 93.2 Vac
125 Vdc:	on for 89.6–150.0 Vac;	off below 53.0 Vac
110 Vdc:	on for 75.1–132.0 Vac;	off below 46.6 Vac
48 Vdc:	on for 32.8–60.0 Vac;	off below 20.3 Vac
24 Vdc:	on for 12.8–30.0 Vac	

Note: AC mode is selectable for each input via Global settings IN101D–IN106D; IN201D–IN208D. AC input recognition delay from time of switching: 0.75 cycles maximum pickup; 1.25 cycles maximum dropout.
Note: 24, 48, 125, 220, and 250 Vdc optoisolated inputs draw approximately 5 mA of current, 110 Vdc inputs draw approximately 8 mA of current. All current ratings are at nominal input voltages.

Time-Code Input

Relay accepts demodulated IRIG-B time-code input at Ports 1 or 2.

Synchronization (specification is with respect to the accuracy of the time source)

Synchrophasor:	±10 µs
Other:	±5 ms

Communications Ports

EIA-232:	1 front, 2 rear
EIA-485:	1 rear with 2100 Vdc of isolation
Per Port Baud Rate Selections:	300, 1200, 2400, 4800, 9600, 19200, 38400 (38400 is not available on Port 1)

Dimensions

Refer to *Figure 2.1*.

Weight

16 lbs (7.24 kg)—3U rack unit height relay

Operating Temperature

–40° to +185°F (–40° to +85°C)
(LCD contrast impaired for temperatures below –20ºC.)

Type Tests

Environmental Tests

Cold:	IEC 60068-2-1:1990 Basic Environmental testing procedures, Part 2: Tests – Test Ad: Cold
Damp Heat Cyclic:	IEC 60068-2-30:1980 Basic environmental testing procedures, Part 2: Tests, Test Db and guidance: Damp heat, cyclic (12 + 12-hour cycle), (six-day type test) IEC 60529:1989 [EN 60529–1992] Degrees of Protection Provided by Enclosures (IP code): Object penetration and dust ingress, IP30 for category 2 equipment.
Dry Heat:	IEC 60068-2-2:1974 Basic environmental testing procedures, Part 2: Tests – Test Bd: Dry Heat

Routine Dielectric and Impulse Tests

Current inputs, optoisolated inputs, and output contacts:	2500 Vac for 10 s
Power supply:	3100 Vdc for 10 s

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IEC 60255-5 Dielectric Tests: 1977
2500 Vac for 2 seconds on analog inputs, optoisolated inputs, and output contacts
3100 Vdc for 2 seconds on power supply

Impulse: IEC 60255-5:1977 Electrical relays, Part 5: Insulation tests for electrical relays, Section 6: Dielectric Tests, Series C (2500 Vac on analog inputs; 3000 Vdc on power supply, contact inputs, and contact outputs). Section 8: Impulse Voltage Tests, 0.5 Joule 5 kV

Electrostatic Discharge Test

ESD: IEC 60255-22-2:1996 Electrical disturbance tests for measuring relays and protective equipment, Section 2: Electrostatic discharge tests, Severity Level 4 (8 kV contact discharge all points except serial ports, 15 kV air discharge to all other points)

RFI and Interference Tests

Surge Withstand: IEEE C37.90.1-1989 IEEE SWC Tests for Protective Relays and Relay Systems (3 kV oscillatory, 5 kV fast transient)

Fast Transient Disturbance: IEC 60255-22-4:1992 Electrical disturbance tests for measuring relays and protection equipment, Section 4: Fast transient disturbance test, Severity Level 4 kV at 2.5 kHz and 5 kHz

Radiated EMI: IEC 60255-22-3:1989 Electrical relays, Section 3: Radiated electromagnetic field disturbance tests, Severity Level 3 (10 V/m)
IEEE C37.90.2-IEEE Trial-Use Standard, Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers, 35 V/m (type test).
Exceptions:
5.5.2(2) Performed with 200 frequency steps per octave.
5.5.3 Digital Equipment Modulation Test not performed.
5.5.4 Test signal turned off between frequency steps to simulate keying.

Surge Withstand: IEC 60255-22-1:1988 Electrical disturbance tests for measuring relays and protection equipment, Part 1: 1 MHz burst disturbance tests. Severity Level 3 (2.5 kV common mode, 2.5 kV differential)
IEEE C37.90.1-1989
3.0 kV oscillatory; 5.0 kV fast transient

Vibration and Shock Tests

Shock and Bump: IEC 60255-21-2:1988 Electrical relays, Part 21: Vibration, shock, bump, and seismic tests on measuring relays and protection equipment, Section Two: Shock and bump tests, Class 1
IEC 60255-21-3:1993 Electrical relays, Part 21: Vibration, shock, bump, and seismic tests on measuring relays and protection equipment, Section Three: Seismic tests, Class 2

Sinusoidal Vibration: IEC 60255-21-1:1988 Electrical relays, Part 21: Vibration, shock, bump, and seismic tests on measuring relays and protection equipment, Section One: Vibration tests (sinusoidal), Class 1

Certifications

ISO: Relay is designed and manufactured to an ISO-9001 certified quality program.
UL/CSA: UL recognized to the requirements of *UL-508; CSA C22.2, N.14 for Industrial Control Equipment*; and *UL-1053, Ground-Fault Sensing and Relay Equipment*.
CE: CE Mark

Processing Specifications

AC Voltage and Current Inputs

16 samples per power system cycle, 3 dB low-pass filter cut-off frequency of 560 Hz

Digital Filtering

One cycle cosine after low-pass analog filtering.
Net filtering (analog plus digital) rejects dc and all harmonics greater than the fundamental.

Protection and Control Processing

4 times per power system cycle

Relay Element Pickup Ranges and Accuracies

Instantaneous/Definite-Time Overcurrent Elements

Pickup Range:
0.25–100.00 A, 0.01 A steps (5 A nominal)
1.00–170.00 A, 0.01 A steps (5 A nominal—for phase-to-phase elements)
0.050–100.000 A, 0.010 A steps (5 A nominal—for residual ground elements)
0.05–20.00 A, 0.01 A steps (1 A nominal)
0.20–34.00 A, 0.01 A steps (1 A nominal—for phase-to-phase elements)
0.010–20.000 A, 0.002 A steps (1 A nominal—for residual ground elements)
0.005–2.500 A, 0.001 A steps (0.2 A nominal neutral channel (IN) current input)
0.005–1.500 A, 0.001 A steps (0.05 A nominal neutral channel (IN) current input)

Steady-State Pickup Accuracy:
±0.05 A and ±3% of setting (5 A nominal)
±0.01 A and ±3% of setting (1 A nominal)
±0.001 A and ±3% of setting (0.2 A nominal neutral channel (IN) current input)
±0.001 A and ±5% of setting (0.05 A nominal neutral channel (IN) current input)

Transient Overreach: ±5% of pickup

Time Delay: 0.00–16,000.00 cycles, 0.25 cycle steps

Timer Accuracy: ±0.25 cycle and ±0.1% of setting

Note: See pickup and reset time curves in *Figure 3.5* and *Figure 3.6*.

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Time-Overcurrent Elements

Pickup Range:
0.25–16.00 A, 0.01 A steps (5 A nominal)
0.10–16.00 A, 0.01 A steps (5 A nominal—for residual ground elements)
0.05–3.20 A, 0.01 A steps (1 A nominal)
0.02–3.20 A, 0.01 A steps (1 A nominal—for residual ground elements)
0.005–0.640 A, 0.001 A steps (0.2 A nominal neutral channel (IN) current input)
0.005–0.160 A, 0.001 A steps (0.05 A nominal neutral channel (IN) current input)

Steady-State Pickup Accuracy:
±0.05 A and ±3% of setting (5 A nominal)
±0.01 A and ±3% of setting (1 A nominal)
±0.005 A and ±3% of setting (0.2 A nominal neutral channel (IN) current input)
±0.001 A and ±5% of setting (0.05 A nominal neutral channel (IN) current input)

Time Dial Range:
0.50–15.00, 0.01 steps (US)
0.05–1.00, 0.01 steps (IEC)
0.10–2.00, in 0.01 steps (recloser curves)

Curve Timing Accuracy:
±1.50 cycles and ±4% of curve time for current between 2 and 30 multiples of pickup
±3.50 cycles and ±4% of curve time for current between 2 and 30 multiples of pickup for 0.05 A nominal neutral channel (IN) current input

Under- and Overvoltage Elements

Pickup Ranges:

Wye-connected (Global setting PTCONN=WYE):
0.00–200.00 V, 0.01 V steps (negative-sequence element)
0.00–300.00 V, 0.01 V or 0.02 V steps (various elements)
0.00–520.00 V, 0.02 V steps (phase-to-phase elements)

Open-delta connected (when available, by Global setting PTCONN=DELTA):
0.00–120.00 V, 0.01 V steps (negative-sequence elements)
0.00–170.00 V, 0.01 V steps (positive-sequence element)
0.00–300.00 V, 0.01 V steps (various elements)

Steady-State Pickup Accuracy:
±0.5 V plus ±1% for 12.5–300.00 V (phase and synchronizing elements)
±0.5 V plus ±2% for 12.5–300.00 V (negative-, positive-, and zero-sequence elements, phase-to-phase elements)

Transient Overreach:
±5% of pickup

Synchronism-Check Elements

Slip Frequency Pickup Range:
0.005–0.500 Hz, 0.001 Hz steps

Slip Frequency Pickup Accuracy:
±0.003 Hz

Phase Angle Range:
0–80°, 1° steps

Phase Angle Accuracy:
±4°

Under- and Overfrequency Elements

Pickup Range:
40.10–65.00 Hz, 0.01 Hz steps

Steady-State **plus** Transient Overshoot:
±0.01 Hz

Time Delay:
2.00–16,000.00 cycles, 0.25-cycle steps

Timer Accuracy:
±0.25 cycle and ±0.1% of setting

Undervoltage Frequency Element Block Range:
25.00–300.00 V_{LN} (wye) or V_{LL} (open-delta)

Timers

Pickup Ranges:
0.00–999,999.00 cycles, 0.25-cycle steps (reclosing relay and some programmable timers)
0.00–16,000.00 cycles, 0.25-cycle steps (some programmable and other various timers)

Pickup and dropout accuracy for all timers:
±0.25 cycle and ±0.1% of setting

Substation Battery Voltage Monitor

Pickup Range:
20–300 Vdc, 1 Vdc steps

Pickup accuracy:
±2% of setting ±2 Vdc

Metering Accuracy

Accuracies are specified at 20°C and at nominal system frequency unless noted otherwise.

Voltages V_A, V_B, V_C:
±0.2% (67.0–300 V; wye-connected)

Voltages V_{AB}, V_{BC}, V_{CA}:
±0.4% (67.0–300 V; delta-connected)

Voltage V_S:
±0.2% (67.0–300 V)

Voltages $3V_0$, V_1, V_2: [$3V_0$ not available with delta-connected inputs]
±0.6% (67.0–300 V)

Currents I_A, I_B, I_C
±2 mA and ±0.1% (0.5–100 A) (5 A nominal)
±0.5 mA and ±0.1% (0.1–20 A) (1 A nominal)
Temperature coefficient: $[(0.0002\%)/(°C)^2] \bullet (__°C - 20°C)^2$ (see example below)

Currents I_N:
±0.05 A and ±3% (0.5–100 A) (5 A nominal)
±0.01 A and ±3% (0.1–20 A) (1 A nominal)
±0.08 mA and ±0.1% (0.005–4.5 A) (0.2 A nominal channel IN current input)
±1 mA and ±5% (0.01–1.5 A) (0.05 A nominal channel IN current input)

Currents I_1, $3I_0$, $3I_2$:
±0.05 A and ±3% (0.5–100 A) (5 A nominal)
±0.01 A and ±3% (0.1–20 A) (1 A nominal)

Phase Angle Accuracy: I_A, I_B, I_C, V_S V_A, V_B, V_C (wye-connected voltages) V_{AB}, V_{BC}, V_{CA} (delta connected voltages)
±0.5°

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MW / MVAR (A, B, C, and 3-phase; 5 A nominal; wye connected voltages) MW / MVAR(3-phase; 5 A nominal; open-delta connected voltages; balanced conditions)	
Accuracy (MW / MVAR)	**at load angle**
for 0.5 A sec. ≤ phase current < 1.0 A sec.:	
0.70% / –	0° or 180° (unity power factor)
0.75% / 6.50%	±8° or ±172°
1.00% / 2.00%	±30° or ±150°
1.50% / 1.50%	±45° or ±135°
2.00% / 1.00%	±60° or ±120°
6.50% / 0.75%	±82° or ±98°
– / 0.70%	±90° (power factor = 0)
for phase current ≥ 1.0 A sec.:	
0.35% / –	0° or 180° (unity power factor)
0.40% / 6.00%	±8 or ±172°
0.75% / 1.50%	±30° or ±150°
1.00% / 1.00%	±45° or ±135°
1.50% / 0.75%	±60° or ±120°
6.00% / 0.40%	±82° or ±98°
– / 0.35%	±90° (power factor = 0)

Metering accuracy calculation example for currents I_A, I_B, and I_C is based on preceding stated temperature coefficient:
For temperature of 40°C, the **additional** error for currents I_A, I_B, and I_C is:
$[(0.0002\%)/(°C)^2] \bullet (40°C - 20°C)^2 = 0.08\%$

Synchrophasor Accuracy

(Specification is with respect to **MET PM** command and SEL Fast Message Synchrophasor Protocol.)

Voltages (33.5–150 V; 45–65 Hz) (150 V nominal)
(33.5–300 V; 45–65 Hz) (300 V nominal)

Magnitudes: ±2%

Angles: ±1°

Currents (0.50–1.25 A; 45–65 Hz) (5 A nominal)
(0.10–0.25 A; 45–65 Hz) (1 A nominal)

Magnitudes: ±4%

Angles: ±1.5° at 25°C
±2.0° over the full temperature range

Currents (1.25–7.50 A; 45–65 Hz) (5 A nominal)
(0.25–2.50 A; 45–65 Hz) (1 A nominal)

Magnitudes: ±2%

Angles: ±1.0° at 25°C
±1.5° over the full temperature range

Power Element Accuracy

Single-phase power elements:

Pickup:

Pickup setting 0.33–2 VA {5 A nominal}, 0.07–0.4 VA {1 A nominal}: ±0.05 A • (L-N voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element {5 A nominal}
±0.01 A • (L-N voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element {1 A nominal}

Pickup setting 2–13000 VA {5 A nominal}, 0.4–2600 VA {1 A nominal}: ±0.025 A • (L-N voltage secondary) and ±5% of setting at unity power factor {5 A nom}
±0.005 A • (L-N voltage secondary) and ±5% of setting at unity power factor {1 A nom}

Three-phase power elements:

Pickup:

Pickup setting 1–6 VA {5 A nominal}, 0.2–1 VA {1 A nominal}: ±0.05 A • (L-L voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element {5 A nominal}
±0.01 A • (L-L voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element {1 A nominal}

Pickup setting 6–39000 VA {5 A nominal}, 1–7800 VA {1 A nominal}: ±0.025 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element {5 A nominal}
±0.005 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element {1 A nominal}

The quoted three-phase power element accuracy specifications are applicable as follows:

Wye-connected voltages (PTCONN = WYE): any conditions

Open-delta connected voltages (PTCONN = DELTA), with properly configured broken-delta 3V0 connection (VSCONN = 3V0): any conditions

Open-delta connected voltages, without broken-delta 3V0 connection (VSCONN = VS): balanced conditions only

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Section 2
Installation

Design your installation using the mounting and connection information in this section. Options include rack or panel mounting and terminal block or plug-in connector (Connectorized®) wiring. This section also includes information on configuring the relay for your application.

Relay Mounting

Rack Mount

We offer the SEL-351S Relay in a rack-mount version that bolts easily into a standard 19-inch rack. See *Figure 2.1*. From the front of the relay, insert four rack screws (two on each side) through the holes on the relay mounting flanges.

Reverse the relay mounting flanges to cause the relay to project 3.55 inches (90.2 mm) from the front of your mounting rack and provide additional space at the rear of the relay for applications where the relay might otherwise be too deep to fit.

Panel Mount

We also offer the SEL-351S in a panel-mount version for a clean look. Panel-mount relays have sculpted front-panel molding that covers all installation holes. See *Figure 2.1*. Cut your panel and drill mounting holes according to the dimensions in *Figure 2.1*. Insert the relay into the cutout, aligning four relay mounting studs on the rear of the relay front panel with the drilled holes in your panel, and use nuts to secure the relay to the panel.

The projection panel-mount option covers all installation holes and maintains the sculpted look of the panel-mount option; the relay projects 3.55 inches (90.2 mm) from the front of your panel. This ordering option increases space at the rear of the relay for applications where the relay would ordinarily be too deep to fit your cabinet.

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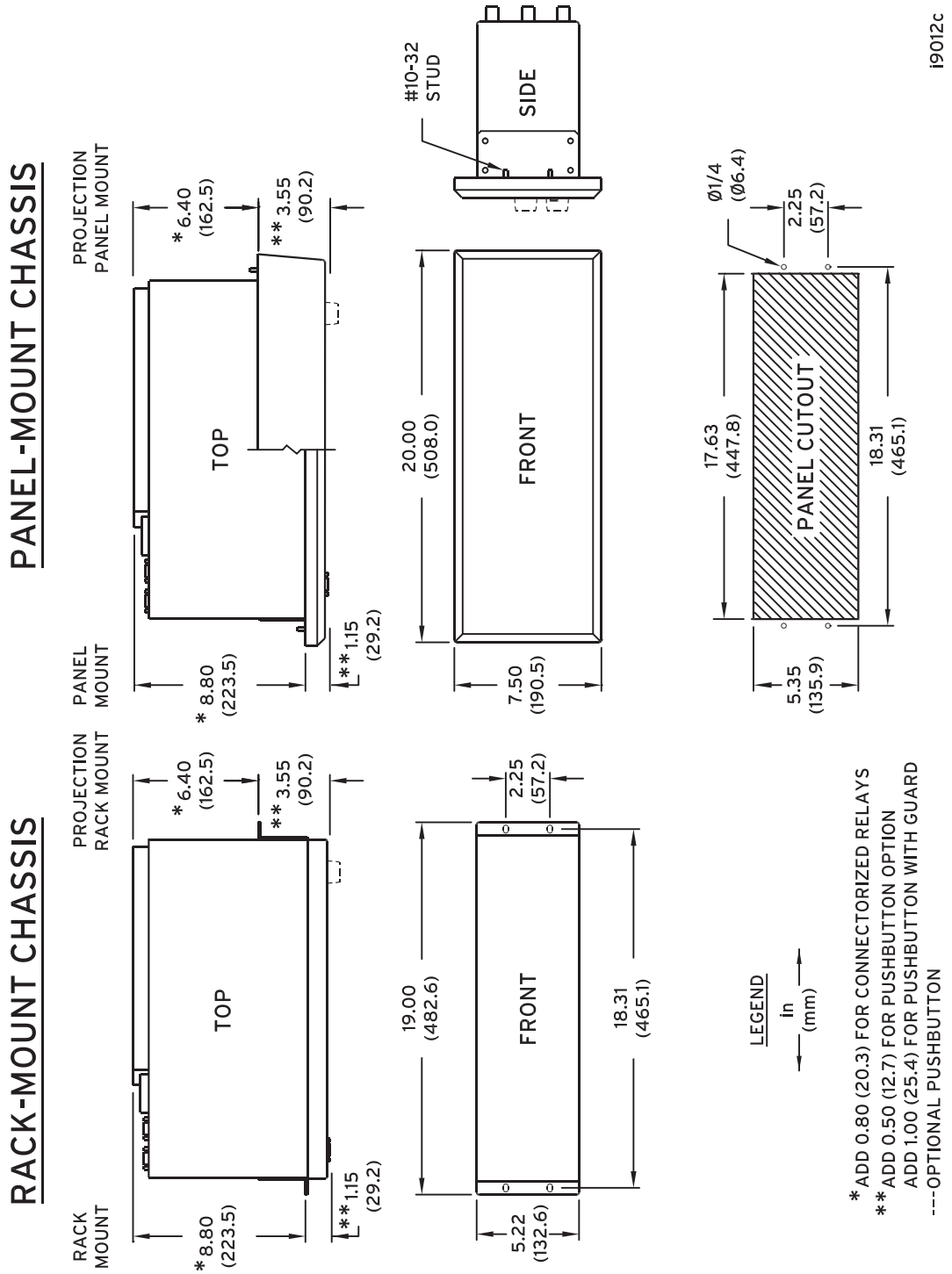


Figure 2.1 SEL-351S Dimensions for Rack-Mount and Panel-Mount Models

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Front-Panel and Rear-Panel Connection Diagrams

Figure 2.2–*Figure 2.6* represent examples of different relay configurations. All units can be ordered with either conventional terminal blocks or plug-in connectors. For model options, view the SEL-351S Model Option Tables on our website or contact your local SEL sales representative.

Figure 2.2–*Figure 2.5* show the various front-panel configurations available for the SEL-351S.

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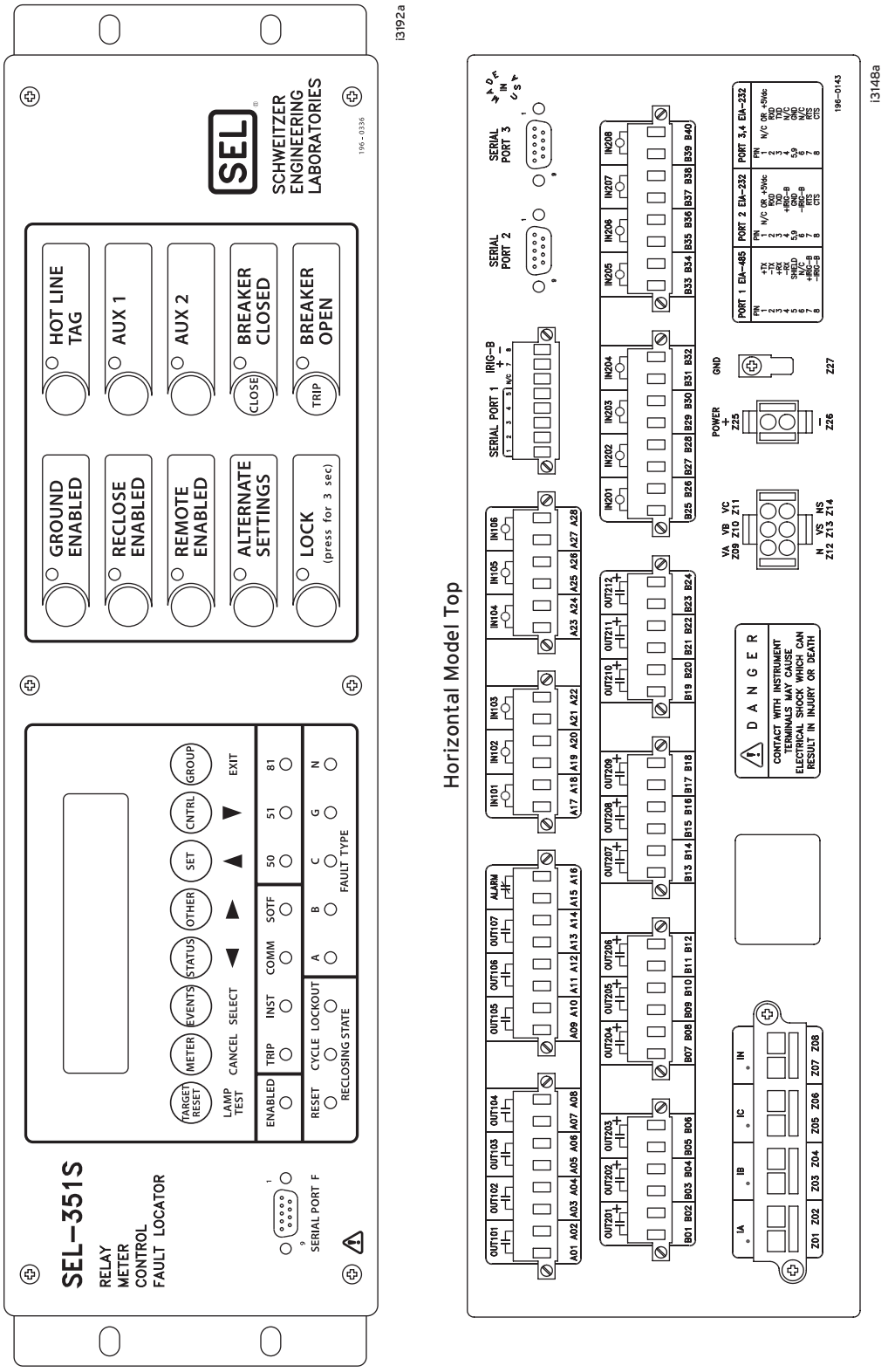


Figure 2.2 SEL-351S Front- and Rear-Panel Drawings (Model 0351SxYH3xxxx6x); Horizontal Rack Mount Example, (Connectorized, With Additional I/O Board)

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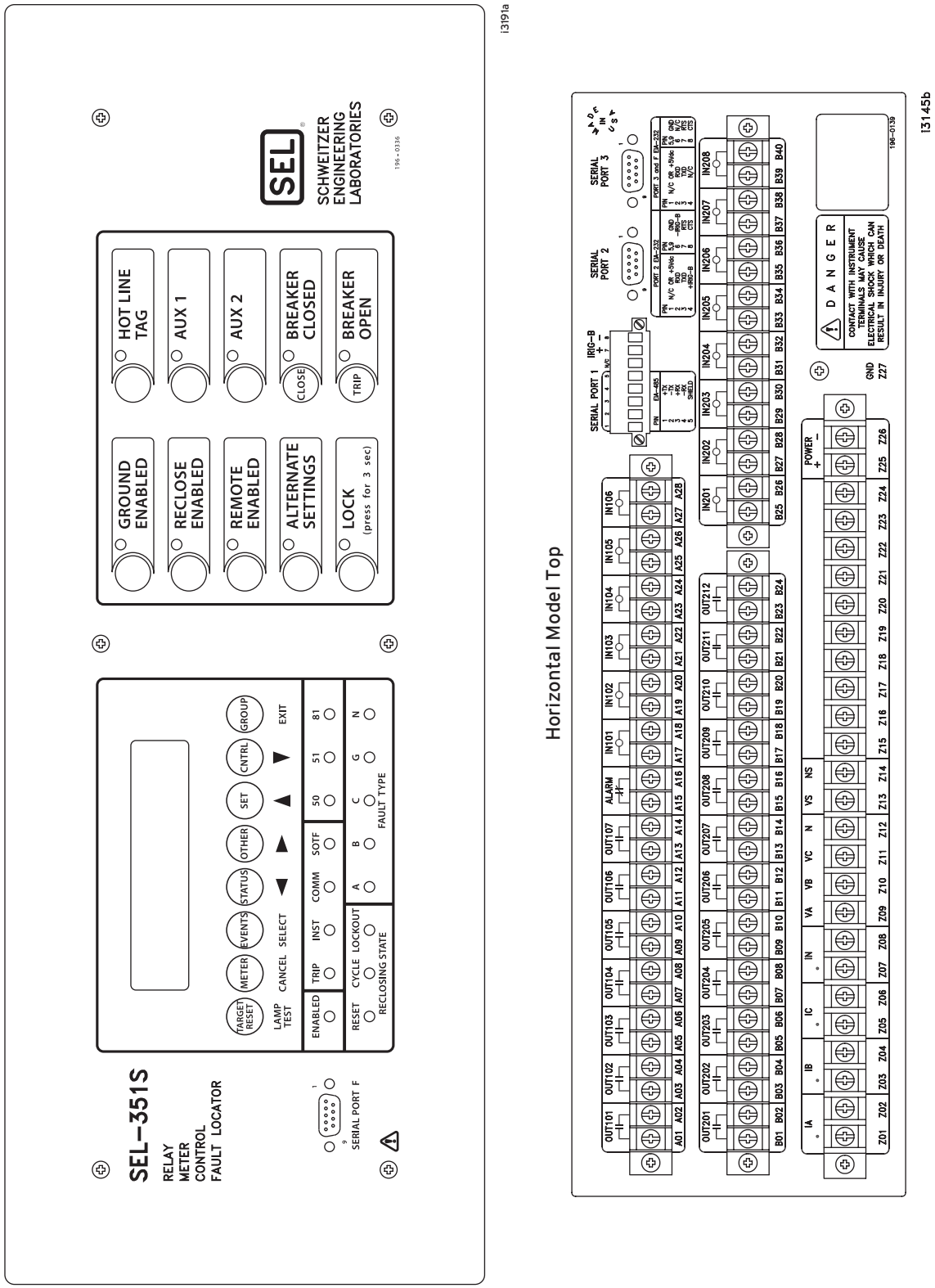


Figure 2.3 SEL-351S Front- and Rear-Panel Drawings (Model 0351Sx133xxxx2x); Horizontal Panel Mount Example, (Conventional Terminal Blocks, With Additional I/O Board)

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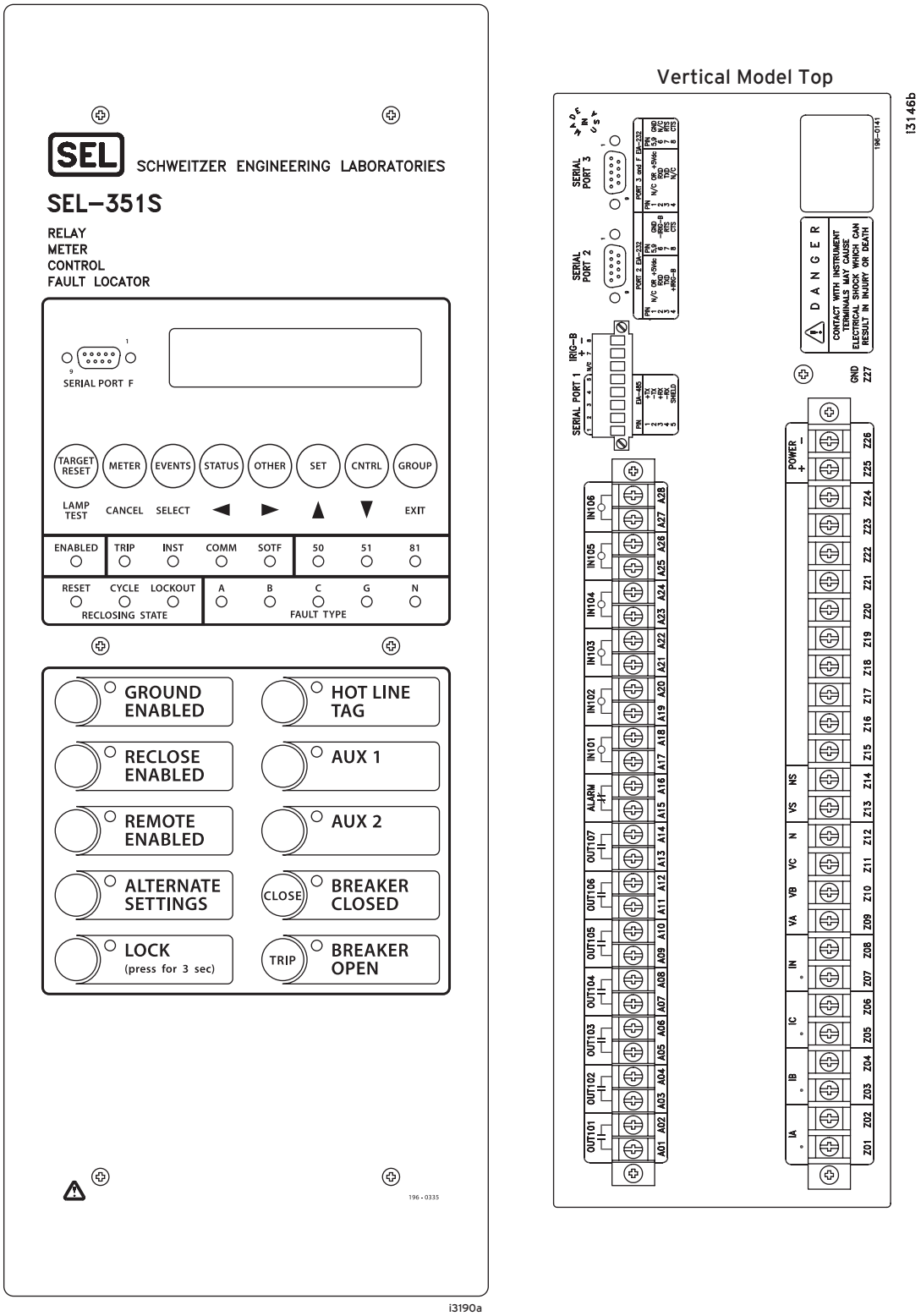


Figure 2.4 SEL-351S Front- and Rear-Panel Drawings (Model 0351Sx143xxxxXx); Vertical Panel Mount Example, (Conventional Terminal Blocks, No Additional I/O Board)

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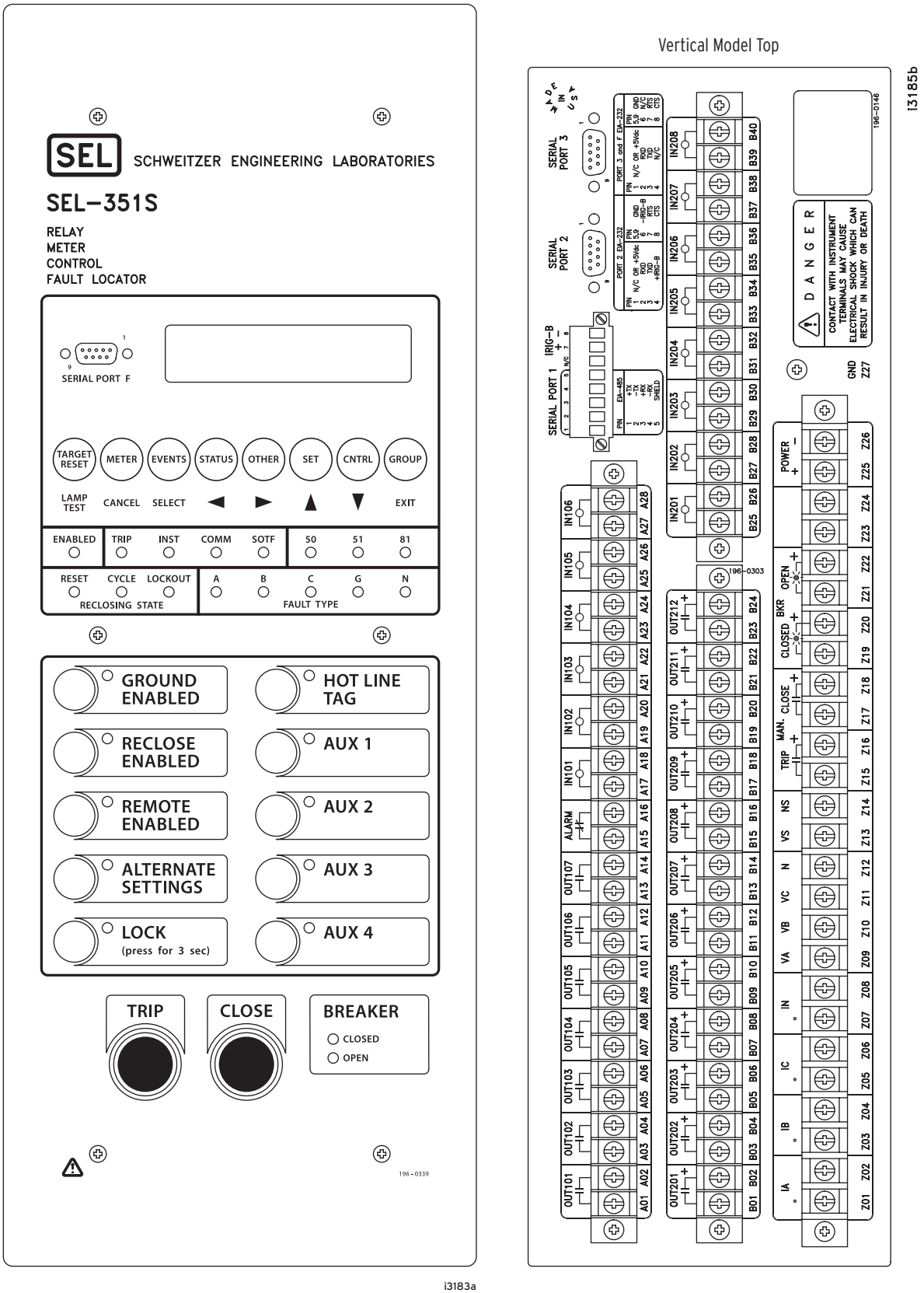


Figure 2.5 SEL-351S with Auxiliary {TRIP}/{CLOSE} Pushbuttons (Model 0351Sx145xxxx6x); Vertical Panel-Mount Example, (Conventional Terminal Blocks, With Additional I/O Board)

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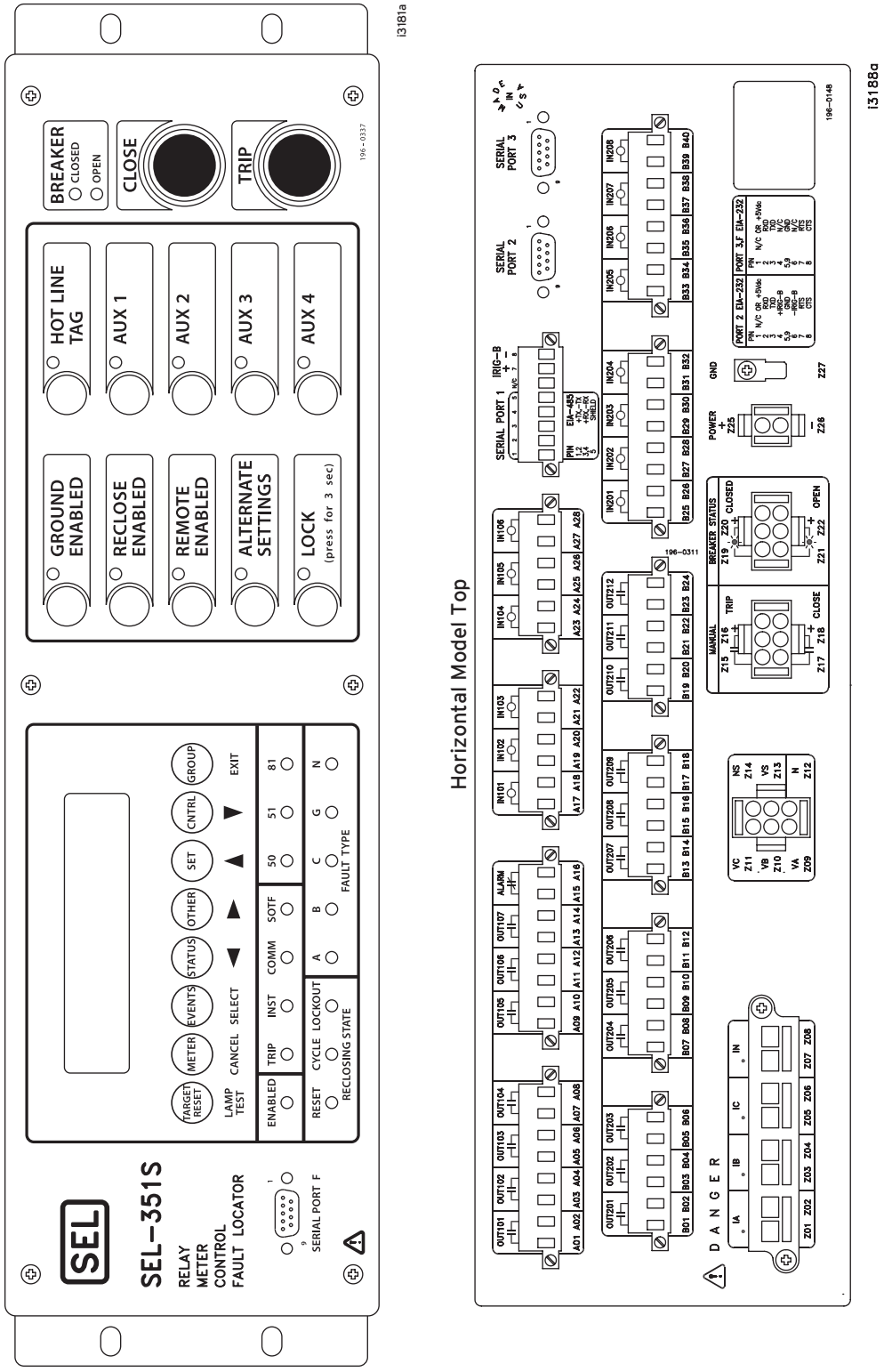


Figure 2.6 SEL-351S with Auxiliary {TRIP}/{CLOSE} Pushbuttons (Model 0351SxYH5xxxx2x); Horizontal Rack-Mount Example, (Connectorized, With Additional I/O Board)

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User-Configurable Label Option for the Front Panel

SEL-351S relays with front-panel user-configurable labels have three (or four, depending on the model) pockets for slide-in labels: one for the target LED label, one for the breaker LEDs (for models with auxiliary **{TRIP}/{CLOSE}** pushbuttons), and two for the operator-control labels. Relays are shipped with default labels installed, as shown in *Figure 2.7* and *Figure 2.9*. The front-panel pocket areas and openings for the SEL-351S (Horizontal) With User-Configurable Default Labels are indicated in *Figure 2.7*. The front-panel pocket areas and openings for the SEL-351S (Vertical) With User-Configurable Default Labels are indicated in *Figure 2.9*. Part numbers 0351S*xxx*4/6/B designate relay models with user-configurable labels.

Dashed lines indicate the pocket areas. The operator-control slide-in labels and front-panel pockets are keyed for left and right placement. Vertical and horizontal relays have different blank slide-in label sets. See *Figure 2.8* and *Figure 2.10* for a view of the blank slide-in label sets for the horizontal and vertical units. Blank breaker LED labels are included in all sets, and should be discarded if the 351S model does not have auxiliary **{TRIP}/{CLOSE}** pushbuttons.

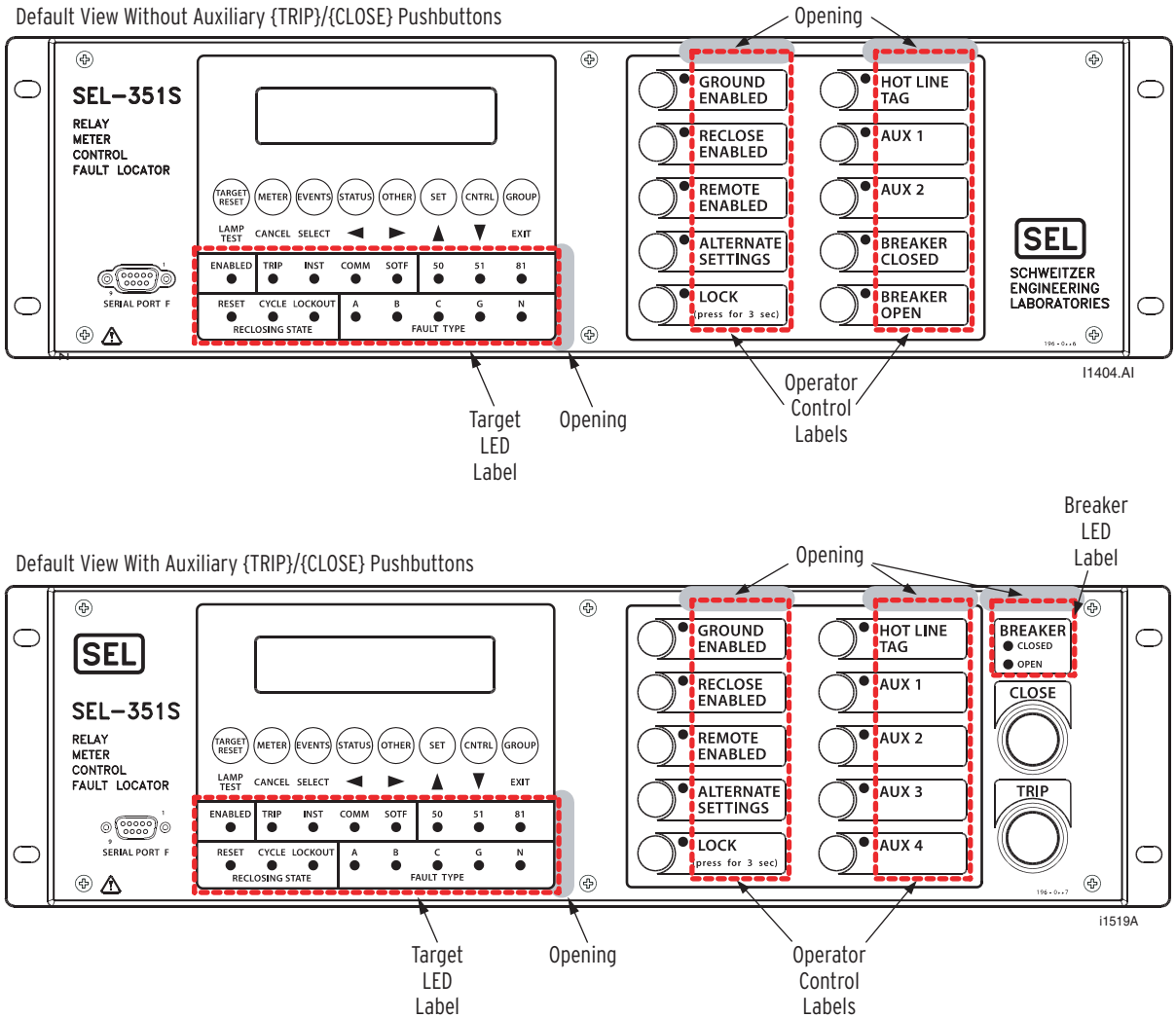


Figure 2.7 SEL-351S (Horizontal) With User-Configurable Default Labels

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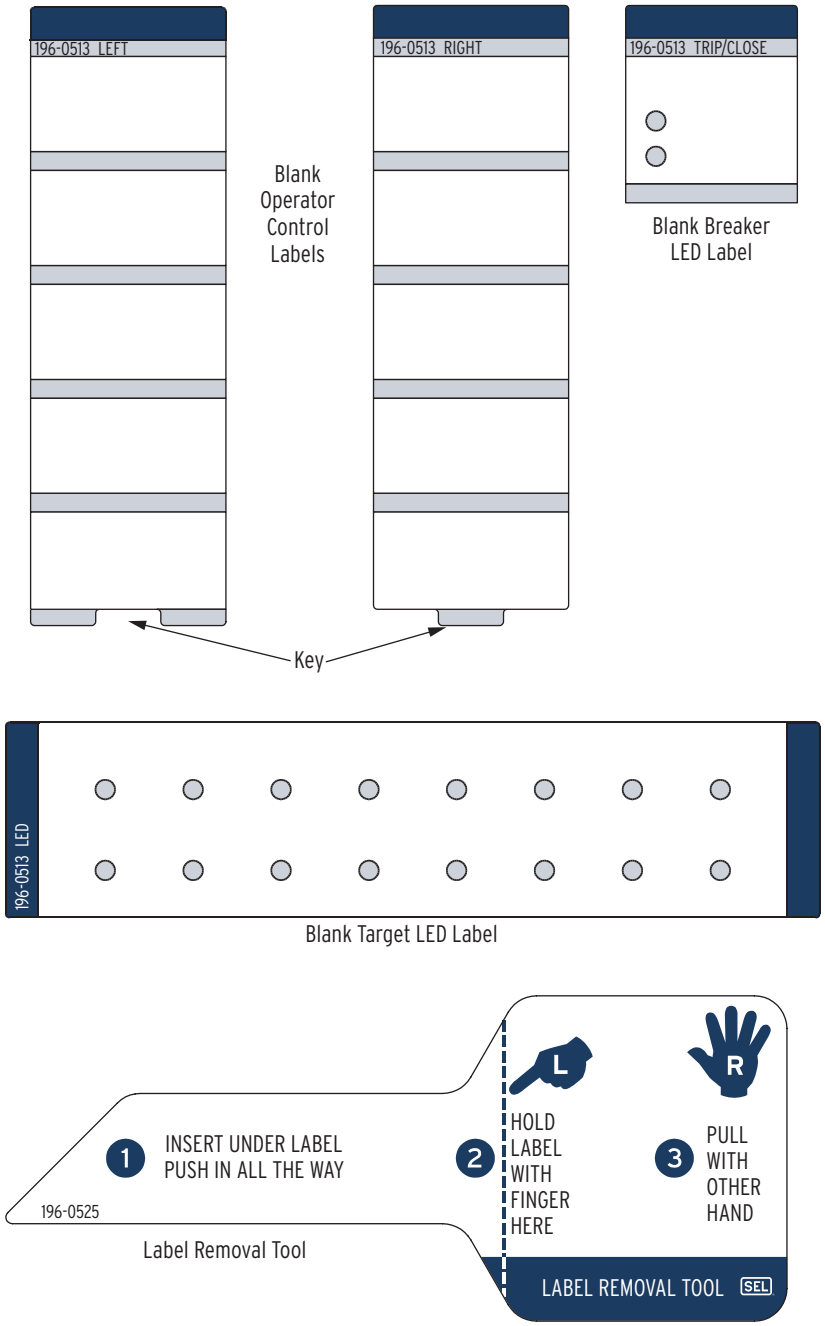


Figure 2.8 SEL-351S (Horizontal) Blank Slide-In Label Set and Label Removal Tool

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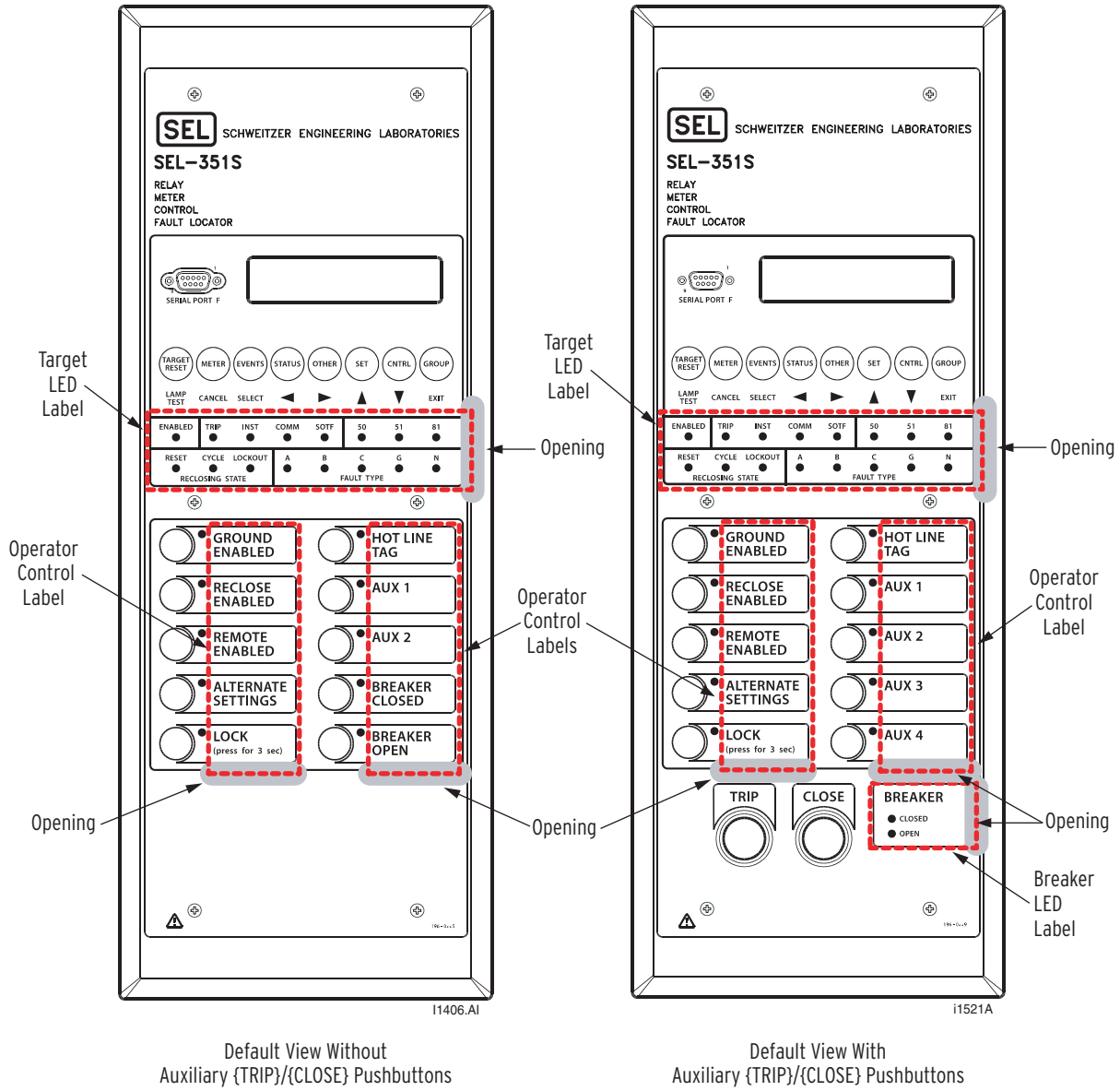


Figure 2.9 SEL-351S (Vertical) With User-Configurable Default Labels

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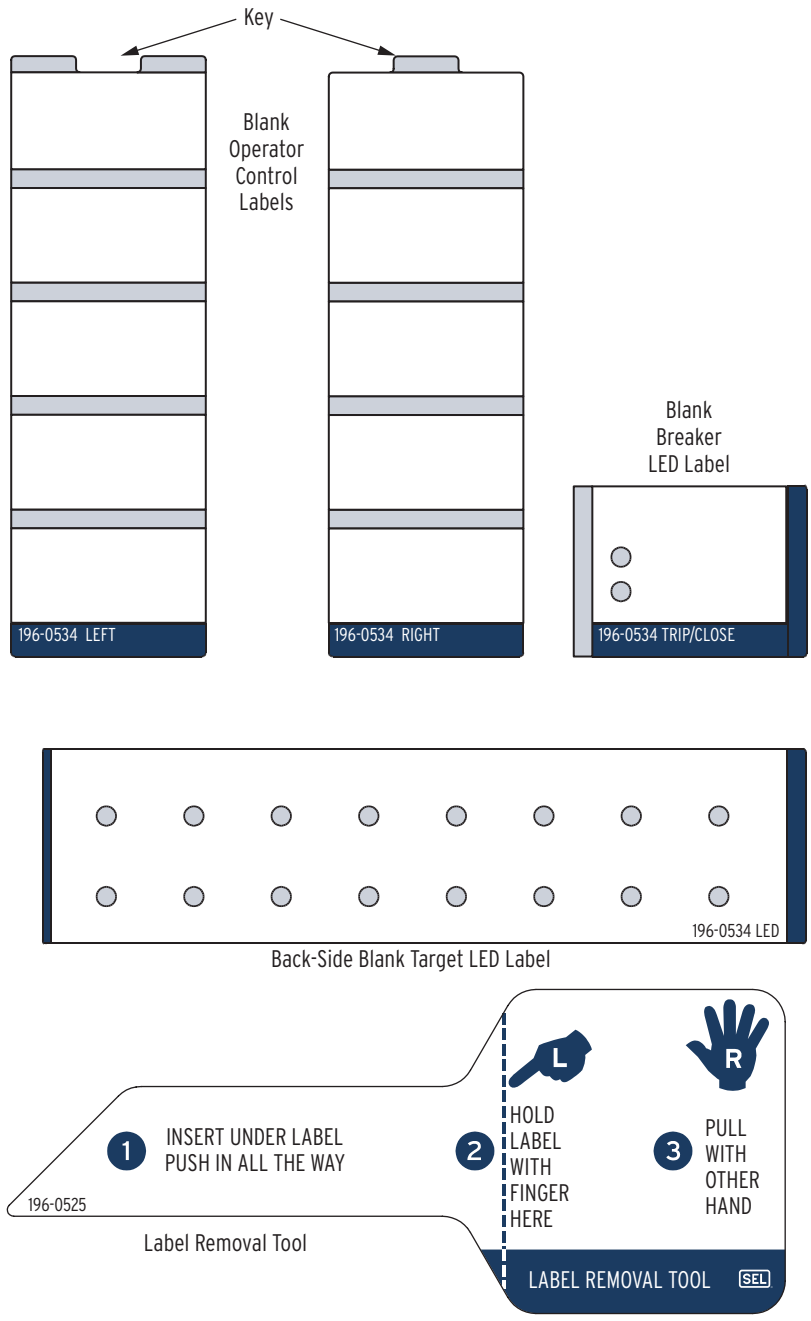


Figure 2.10 SEL-351S (Vertical) Blank Slide-In Label Set and Label Removal Tool

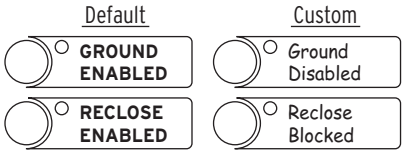
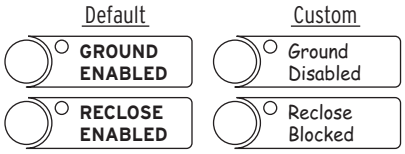
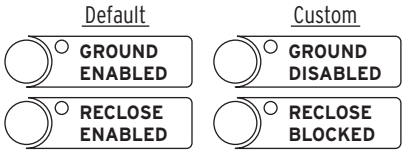
⚠WARNING

The SEL-351S comes with default labels and settings. Any change in the front-panel default labels may require that relay settings be modified and verified to match the customized target LED, breaker LED, and operator-control labels.

Table 2.1 lists the various options, with explanations, available for custom labeling of the SEL-351S Front Panel. The operator-control label examples in *Table 2.1* show a common application for user-configurable labels: the change from **ENABLED** (factory default) to **Disabled/Blocked** (custom). Operator-control labels can also be completely reconfigured to result in totally different functions. Remember, however, that any changes may require modification of relay settings.

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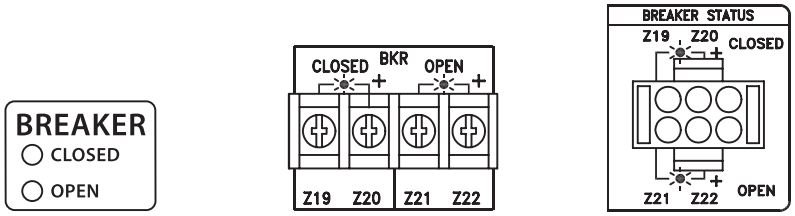
Table 2.1 Options and Explanations for the User-Configurable Front-Panel Labels

Default Labels Use the default labels supplied with the relay.	See *Figure 2.7* and *Figure 2.9*
Handwritten Labels—reusing default labels Using the Label Removal Tool, remove the default labels and write o the backside of the label with a Sharpie® permanent marker. Reinsert the labels in the appropriate pockets.	
Handwritten Labels—using blank labels Write on the blank labels with a Sharpie permanent marker. Using the Label Removal Tool, replace the default labels with the handwritten labels in the appropriate pockets.	
Laser-Printed Labels—using perforated paper Create on a computer with the templates contained on the CD. Print to a laser printer on the perforated paper. The User-Configurable Label Customization kit includes instructions for Laser-Printed Labels.	

Rear-Panel Labeling for Breaker Status LEDs

On models with auxiliary trip/close pushbuttons, the front-panel breaker LED default labeling matches the rear-panel labeling. Although the front-panel breaker LED default labeling is configurable, the rear-panel labeling is not configurable. Remember that if the front-panel breaker LED **CLOSED** and **OPEN** labeling is changed, the front-panel breaker labeling will no longer match the rear-panel breaker labeling. See *Figure 2.11* to view the front- and rear-panel breaker default labels.

⚠CAUTION
On models with auxiliary trip/close pushbuttons, the front-panel breaker LED default labeling matches the rear-panel labeling. If the front-panel breaker LED **CLOSED** and **OPEN** labeling is changed, the front-panel breaker labeling will no longer match the rear-panel breaker labeling.



Front-Panel Breaker Default Labeling

Rear-Panel Breaker Labeling With Conventional Terminal Blocks

Connectorized Rear-Panel Breaker Status Labeling

Figure 2.11 Breaker LED Front-Panel Default Labels and Rear-Panel Labels

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Making Rear-Panel Connections

Refer to *Figure 2.17–Figure 2.31* for wiring examples of typical applications.

Refer to *Table 2.1* and *Figure 2.2–Figure 2.6*. Notice the two types of rear-panel hardware connections. Reference is made to the model numbers in discussing rear-panel connection differences in the following text.

Required Equipment/ General Connection Information

Models 0351SxY (Plug-In Connectors)

Tools: Small slotted-tip screwdriver, wire strippers.

Parts: SEL-WA0351 Wiring Harness for 0351S*x*Y*x*3/4 models.
SEL-WA0351S Wiring Harness for 0351S*x*Y*x*5/6/A/B models

Wiring Harness

The wiring harness includes all connectors necessary for relay installation. All connectors requiring special termination come prewired from the factory.

The SEL-WA0351 Wiring Harness includes the following connectors (not prewired):

- (2) 8-position female plug-in connectors for output contacts **OUT101**–**ALARM**.
- (2) 6-position female plug-in connectors for optoisolated inputs **IN101**–**IN106**.
- (1) 8-position female plug-in connectors for EIA-485/IRIG-B Serial Port 1.
- (4) 6-position female plug-in connectors for output contacts **OUT201**–**OUT212**.
- (2) 8-position female plug-in connectors for optoisolated inputs **IN201**–**IN208**.

These connectors accept wire size AWG 24 to 12. Strip the wires 0.31 inches (8 mm) and install with a small slotted-tip screwdriver. Secure each 8-position connector to the relay chassis with the screws located on either end of the connector. The 8-position connectors are coded at the factory to prevent swapping connectors during installation. Refer to *Figure 2.12* for the standard input/output connector coding.

The wiring harness includes the following prewired connectors:

- (1) CT shorting connector for current inputs **IA**, **IB**, **IC**, and **IN**.
- (1) connector for voltage inputs **VA**, **VB**, **VC**, and **VS**.
- (1) connector for **POWER** inputs (+ and –).
- (1) spade connector for **GROUND** connection (chassis ground).
- (2) connectors for auxiliary **{TRIP}** and **{CLOSE}** pushbuttons and LEDs (for 0351S*x*Y*x*5/6/A/B models Only)

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These prewired connectors (and the serial port connector) are unique and may only be installed in one orientation.

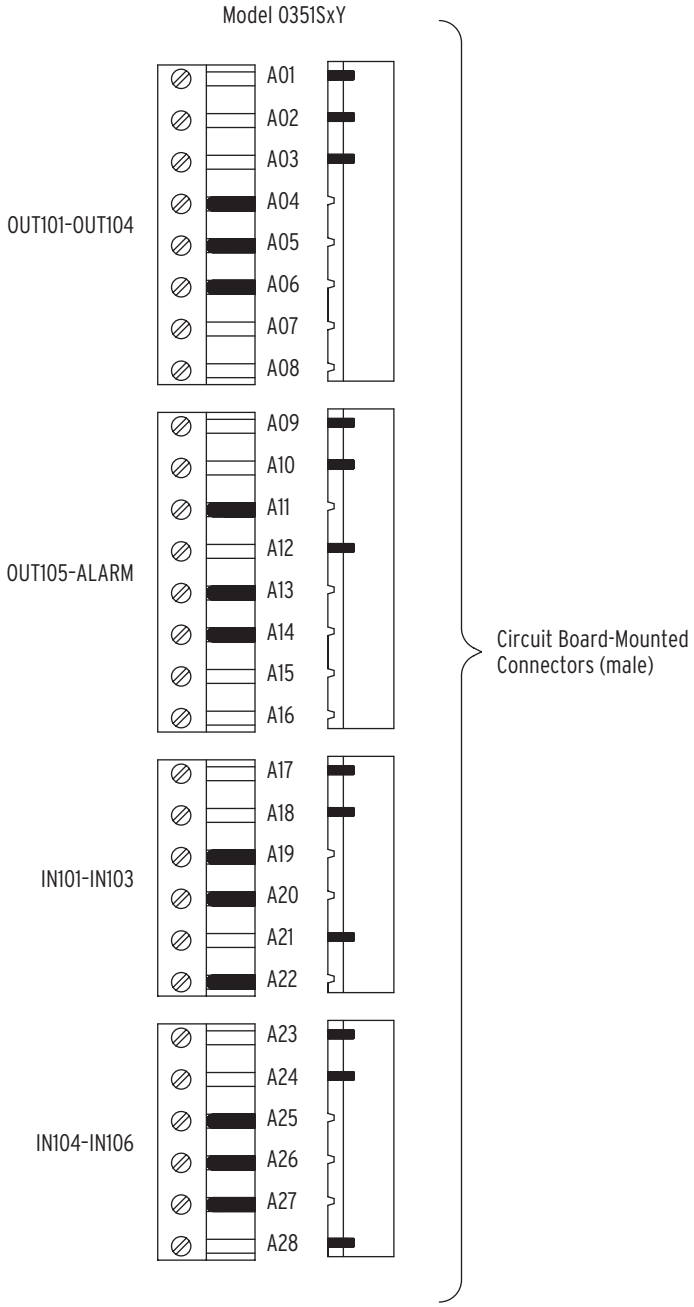


Figure 2.12 SEL-351S Plug-In Connector Coding (Top View; Model 0351SxY)

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Model 0351Sx1 (Screw-Terminal Blocks)

Tools: Phillips® or slotted-tip screwdriver.

Parts: All screws are size #6-32. Locking screws can be requested from the factory.

Chassis Ground

Model 0351SxY

Ground the relay chassis at terminal **Z27** with the spade connector provided in the previously discussed wiring harness (tab size 0.250 inches x 0.032 inches). If the tab on the chassis is removed, the chassis ground connection can be made with the size #6-32 screw.

Model 0351Sx1

Ground the relay chassis at terminal **Z27**.

Power Supply

Model 0351SxY

The power supply wiring harness includes a two-position connector and factory-installed wire. Note the polarity indicators on terminals **Z25(+)** and **Z26(–)**. Control power passes through these terminals to a fuse and to the switching power supply. The control power circuitry is isolated from the relay chassis ground.

Plug the power supply connector into terminals **Z25** and **Z26**. The connector locks in place upon insertion.

Refer to *Specifications on page 1.10* for power supply ratings. The relay power supply rating is listed on the serial number sticker on the relay rear panel.

Model 0351Sx1

Connect control voltage to the **POWER** terminals. Note the polarity indicators on terminals **Z25(+)** and **Z26(–)**. Control power passes through these terminals to a fuse and to the switching power supply. The control power circuitry is isolated from the relay chassis ground.

Refer to *Specifications* for power supply ratings. The relay power supply rating is listed on the serial number sticker on the relay rear panel.

Output Contacts

All relays come with nonpolarity-dependent standard contacts for **OUT101**–**ALARM**.

Standard output contacts are not polarity dependent.

Extra I/O

OUT201–**OUT212** can be ordered with standard or high-current output contacts.

Refer to *Specifications on page 1.10* for output contact ratings. To determine the type of output contacts on the extra I/O board of your Model 0351S relay, refer to the part number on the serial number sticker on the relay rear panel.

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Standard Output Contacts

Model 0351S part number with a numeral “2” in the field bolded below (sample part numbers) indicate standard output contacts on the extra I/O board (**OUT201**–**OUT212**):

0351S71H325122X

0351S6Y334564**2**X

Standard output contacts are not polarity-dependent.

High-Current Interrupting Output Contacts

Models 0351S with a numeral “6” in the field bolded below (sample part numbers) indicate high-current interrupting output contacts on the extra I/O board (**OUT201**–**OUT212**):

0351S7Y432592**6**X

0351S71H325526X

NOTE: Do not use the high-current interrupting output contacts to switch ac control signals.

High-current interrupting output contacts are polarity-dependent. Note the **+** polarity markings above even-numbered terminals **B02**, **B04**, **B06**, ..., **B24** in *Figure 2.2* and *Figure 2.5*. The extra I/O board of the relays in *Figure 2.3* and *Figure 2.6* do not show these **+** polarity markings (because they are relays with an extra I/O board with standard output contacts).

Optoisolated Inputs

The optoisolated inputs in any of the SEL-351S models (e.g., **IN102**, **IN207**) are not polarity dependent. With nominal control voltage applied, each optoisolated input draws approximately 4 mA of current. Refer to *Specifications on page 1.10* for optoisolated input ratings.

Inputs can be configured to respond to ac or dc control signals via Global settings IN101D–IN106D and IN201D–IN208D.

Refer to the serial number sticker on the relay rear panel for the optoisolated input voltage rating (listed under label: **LOGIC INPUT**).

SEL-351S Model 0351Sxxx5/6/A/B Auxiliary {TRIP}/ {CLOSE} Pushbuttons and OPEN/CLOSED LEDs

Relay models 0351S*xxx*5/6/A/B feature auxiliary **{TRIP}** and **{CLOSE}** pushbuttons and **OPEN** and **CLOSED** LED indicators. These features are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

The pushbuttons and LEDs can be hard-wired into a substation trip and close control circuit and operate the same as a separate installation of external trip/close switches and LED indicators. *Figure 2.31* shows example trip and close circuit connections for a control scheme configuration with a dc substation voltage source. The pushbutton switches come set from the factory for dc operation (arc suppression enabled). To use an ac trip or close potential, the arc suppression must be disabled for one or both pushbuttons (see *Table 2.10*). The voltage operating ranges of the LEDs are selected by jumpers (see *Table 2.9*).

⚠WARNING
SEL-351S features such as Hot Line Tag and Synchronism Check do not supervise the auxiliary close pushbutton.

Since the trip and close buttons are functionally separate from the relay, a manual trip or close cannot be distinguished from an external protection or automation-initiated operation. Unless provisions are made in the control wiring, the action of the close pushbutton is unsupervised.

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Current Transformer Inputs

Model 0351SxY

The wiring harness includes a prewired eight-position CT shorting connector. Note the polarity dots above terminals **Z01**, **Z03**, **Z05**, and **Z07**. Refer to *Figure 2.17–Figure 2.30* for typical CT wiring examples.

Plug the CT shorting connector into terminals **Z01–Z08**. Secure the connector to the relay chassis with the two screws located on either end of the connector. When removing the CT shorting connector, pull it straight out away from the rear panel. With the CT shorting connector removed from the rear panel, internal mechanisms in the connector separately short out each individual power system current transformer.

The connector accepts wire size AWG 16 to 10. A special tool is used at the factory to attach the wire to the connector.

Refer to the serial number sticker on the relay rear panel for the nominal current ratings (5 A or 1 A) for the phase (**IA**, **IB**, **IC**) and neutral (**IN**) current inputs (listed under label: **AMPS AC**). The neutral (**IN**) current input also has the 0.05 A and 0.2 A nominal current options. The selection of the neutral current input rating is often determined by the desired ground directional element (see *Table 4.3* and accompanying note).

Models 0351Sx1

Note the polarity dots above terminals **Z01**, **Z03**, **Z05**, and **Z07**. Refer to *Figure 2.17–Figure 2.30* for typical CT wiring examples.

Refer to the serial number sticker on the relay rear panel for the nominal current ratings (5 A or 1 A) for the phase (**IA**, **IB**, **IC**) and neutral (**IN**) current inputs (listed under label: **AMPS AC**). The neutral (**IN**) current input also has the 0.05 A and 0.2 A nominal current options. The selection of the neutral current input rating is often determined by the desired ground directional element (see *Table 4.3* and accompanying note).

Potential Transformer Inputs

Model 0351SxY

The PT wiring harness includes a prewired six-position connector. Plug the connector into terminals **Z09–Z14**. The connector is keyed uniquely and locks in place upon insertion.

Note the signal labels (**VA**, **VB**, **VC**, **N**, **VS**, **NS**) on terminals **Z09–Z14**. *Figure 1.2* shows the internal connection for terminals **VA**, **VB**, **VC**, and **N**. Note also that **VS-NS** is a separate single-phase voltage input.

Model 0351Sx1

Note the signal labels (**VA**, **VB**, **VC**, **N**, **VS**, **NS**) on terminals **Z09–Z14**. *Figure 1.2* shows the internal connection for terminals **VA**, **VB**, **VC**, and **N**. Note also that **VS-NS** is a separate single-phase voltage input.

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Voltage Input Rating

The serial number sticker on the relay rear panel indicates the continuous voltage input rating, which is 300 Vac for the SEL-351S.

This voltage rating applies to the three-phase voltage inputs (**VA-N**, **VB-N**, **VC-N**) as well as to the **VS-NS** voltage input. The voltage rating is in units of V_{LN} when the relay is wye connected (three-phase, four-wire), or V_{LL} when the relay is delta connected (three-phase, three-wire). The following two subsections explain the wye and delta voltage input connections.

The part number sticker on SEL-351S relays manufactured with firmware revision R108 (or higher) indicates "300 V Wye/Delta." The part number sticker on previously manufactured SEL-351S relays indicates "300 V Wye." If older SEL-351S relays (with firmware revisions R102 through R107) are upgraded to R108 (or higher) firmware, they too can be wye connected or delta connected, provided that the voltage rating is not exceeded.

Wye-Connected Voltages (Global Setting PTCONN = WYE)

Any single voltage input (i.e., **VA-N**, **VB-N**, **VC-N**, or **VS-NS**) can be connected to voltage up to 300 V continuous. *Figure 2.17*–*Figure 2.22* and *Figure 2.25*–*Figure 2.27* show examples of wye-connected voltages. System frequency is determined from voltage connected to voltage input **VA-N**. Additionally, voltage input **VS-NS** measures frequency on the other side of an open breaker for synchronism check applications. See subsections *Synchronism Check Elements on page 3.36* and *Frequency Elements on page 3.49*.

Delta-Connected Voltages (Global Setting PTCONN = DELTA)

SEL-351S relays with firmware revision R108 (or higher) can be configured via Global Setting PTCONN = DELTA to accept an open-delta PT connection. Phase-to-phase voltage up to 300 V continuous can be connected to the relay when it is connected as shown in *Figure 2.28* or *Figure 2.29*. This connection requires an external jumper between **VB** (terminal **Z10**) and **N** (terminal **Z12**).

In this configuration, the relay cannot measure zero-sequence voltage ($3V_0$) because the open-delta connection blocks zero-sequence voltage information. Relay functions that require $3V_0$ voltage may be disabled, unless another $3V_0$ voltage source is supplied to the relay via voltage input **VS-NS** (see *Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20*).

Referring to *Figure 2.28* and *Figure 2.29*, when Global Setting PTCONN = DELTA, the relay interprets the voltage signal detected across voltage input **VA-N** as V_{AB}, and the voltage signal detected across voltage input **VC-N** as V_{CB} (or $-V_{BC}$). Phase-to-phase voltage V_{CA} is derived internally ($V_{CA} = V_{CB} - V_{AB}$). The relay does not use the voltage signal detected across voltage input **VB-N**, which should effectively be zero due to the jumper between **VB** and **N**. Unfiltered (raw) event reports are the only means by which signals applied to relay voltage terminals **VA-N**, **VB-N**, and **VC-N** can be directly observed. See *Unfiltered Event Reports With PTCONN = DELTA on page 12.8*.

System frequency is determined from voltage connected to voltage input **VA-N**. Additionally, voltage input **VS-NS** measures frequency on the other side of an open breaker for synchronism check applications. See subsections *Synchronism Check Elements on page 3.36* and *Frequency Elements on page 3.49*.

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Throughout this instruction manual, relay functions, specifications, or features that are different for delta-connected and wye-connected PTs are identified, either with “wye-connected” and “delta-connected” text, or with “PTCONN = WYE” and “PTCONN = DELTA” text.

Synchronism Check VS Connection (Global Setting VSCONN = VS)

When setting VSCONN = VS, voltage input **VS-NS** operates in its traditional role of voltage input for the synchronism check elements. *Figure 2.17*, *Figure 2.20*, *Figure 2.29*, and *Figure 2.30* show examples of synchronism check voltage inputs applied to voltage input **VS-NS**. See *Synchronism Check Elements on page 3.36*.

SEL-351S relays with firmware revisions R107 and earlier do not have a VSCONN setting. In these relays, voltage input **VS-NS** operates in its traditional role of voltage input for synchronism check (as if setting VSCONN = VS).

Broken-Delta VS Connection (Global Setting VSCONN = 3V0)

In SEL-351S relays with firmware revision R108 or higher, global setting VSCONN = 3V0 adjusts the relay to accept a $3V_0$ zero-sequence voltage signal connected to voltage input **VS-NS**. This signal is usually derived from PTs connected wye (primary)/broken-delta (secondary):

$$V_S = V_A + V_B + V_C = 3V_0.$$

This signal is passed to certain relay functions that require zero-sequence voltage, such as zero-sequence voltage-polarized ground directional elements or wattmetric and incremental conductance elements (for Petersen Coil grounded systems). Because setting VSCONN = 3V0, these elements use the $3V_0$ zero-sequence voltage measured by the **VS-NS** voltage input, even if wye-connected PTs are connected to voltage inputs **VA-VB-VC-N** (PTCONN = WYE; see *Figure 2.13*). With this wye-connection, $3V_0$ zero-sequence voltage is calculated from voltages V_A, V_B, and V_C ($3V_0 = V_A + V_B + V_C$) for metering, but this calculated $3V_0$ is not used elsewhere when VSCONN = 3V0.

To prevent a broken-delta voltage source from exceeding the rated voltage of the relay voltage inputs, some applications require an external step-down transformer. *Figure 2.13*, *Figure 2.15*, and *Figure 2.28* show the PT wiring, including an instrumentation step-down transformer, for using voltage input **VS-NS** as a zero-sequence voltage source. Group setting PTRS accommodates the ratio of the step-down transformer. See *Settings Explanations on page 9.48* for an example setting of PTRS when VSCONN = 3V0. For a complete listing of the changes caused by setting VSCONN = 3V0, see *Table 9.8*, *Table 9.9*, and related discussions.

Selecting global setting VSCONN = 3V0 disables the synchronism check element. Therefore, input terminals **VS-NS** cannot be used for $3V_0$ zero-sequence voltage measurement and as a synchronism check voltage input, at the same time.

Polarity Check for VSCONN = 3V0

Refer to *Figure 2.13* (wye-connected PTs) or *Figure 2.15* (open-delta connected PTs). With setting VSCONN = 3V0, voltage input **VS-NS** expects $3V_0$ voltage ($V_S = 3V_0 = V_A + V_B + V_C$) with the polarity shown. However, in a nonfault, balanced system condition, voltage $V_S = 3V_0 \approx 0$. The result is that

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a polarity problem with voltage input **VS-NS**, such as when secondary wires are on the wrong terminals, will not necessarily be apparent until a ground fault occurs or testing is performed.

Wye-Connected PT Example

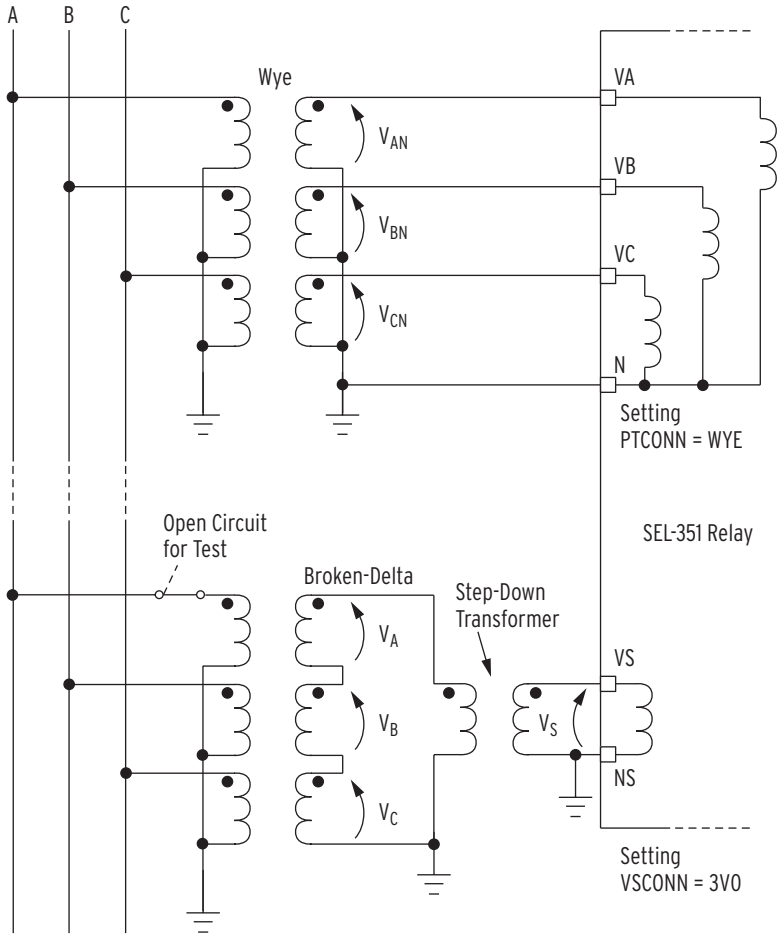


Figure 2.13 Broken-Delta Secondary Connection to Voltage Input VS, Wye-Connected PTs

To verify the correct polarity on voltage input **VS-NS**, perform the following test on the primary side of one of the PTs connected in broken-delta secondary (refer to *Figure 2.13*) and observe the resultant voltage phase angle differences:

Open circuit the primary side of the PT connected to power system phase A. With the resultant collapse of secondary voltage V_A ($V_A = 0$) in the broken-delta secondary circuit, the voltage at voltage input **VS-NS** is:

$$V_S = 3V_0 = V_A + V_B + V_C = V_B + V_C$$

Figure 2.14 shows the resultant voltage V_S, with respect to the wye-connected power system voltages connected to the voltage inputs **VA-VB-VC-N** (ABC rotation used in this example). For this scenario of the collapse of secondary voltage V_A ($V_A = 0$) in the broken-delta secondary, note that voltage V_S is 180 degrees out-of-phase with voltage V_A (from voltage input **VA-N**).

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Use the **METER** command (via serial port or front panel) to compare these voltage phase angles. If the phase angle difference between V_S and V_A is 180 degrees (within a few degrees), then the polarity of voltage input **VS** is deemed correct. If the phase angle difference between V_S and V_A is 0 degrees (again, within a few degrees), then the secondary wires from the broken-delta secondary in *Figure 2.13* need to be swapped in connection to voltage input **VS-NS**.

NOTE: "3VO" in the **METER** command (via serial port or front panel) is derived internally from the **VA-VB-VC-N** voltage inputs, not from voltage input **VS-NS**, regardless of setting VSCONN.

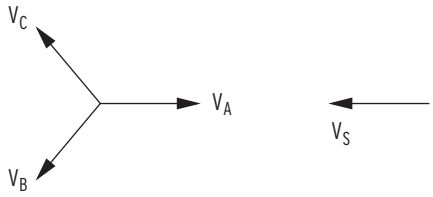


Figure 2.14 Resultant Voltage V_S From the Collapse of Voltage V_A in the Broken-Delta Secondary (Compared to the Wye-Connected Power System Voltages

Open-Delta Connected PT Example

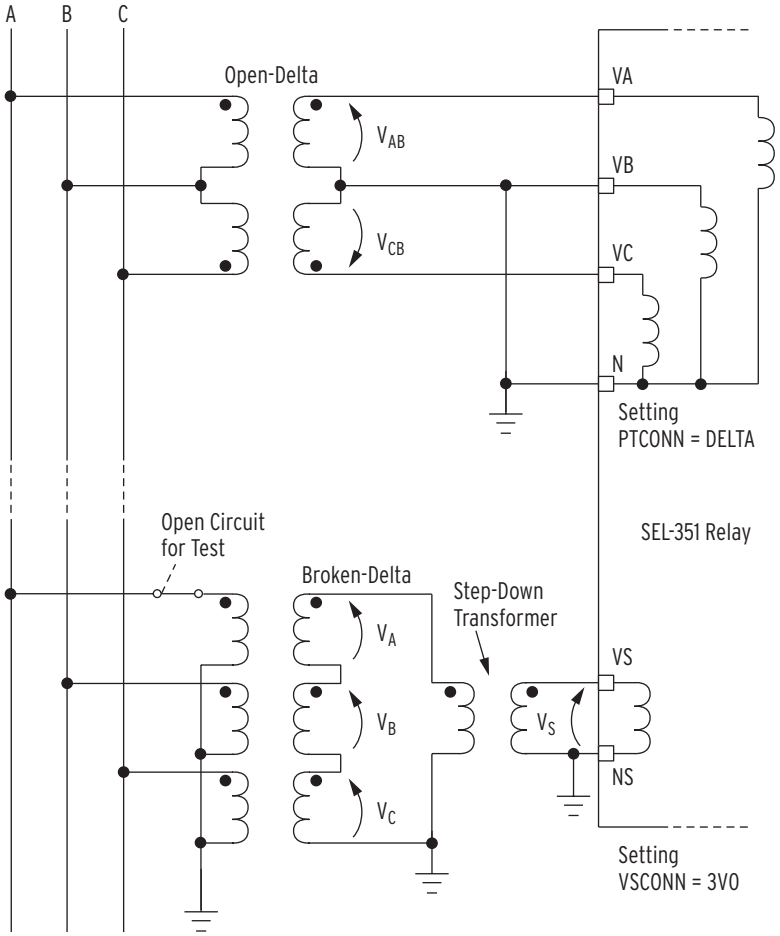


Figure 2.15 Broken-Delta Secondary Connection to Voltage Input VS, Open-Delta Connected PTs

To verify the correct polarity on voltage input **VS-NS**, perform the following test on the primary side of one of the PTs connected in broken-delta secondary (refer to *Figure 2.15*) and observe the resultant voltage phase angle differences:

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Open circuit the primary side of the PT connected to power system phase A. With the resultant collapse of secondary voltage V_A ($V_A = 0$) in the broken-delta secondary circuit, the voltage at voltage input **VS-NS** is:

$$V_S = 3V_0 = V_A + V_B + V_C = V_B + V_C$$

Figure 2.16 shows the resultant voltage V_S, with respect to the delta-connected power system voltages connected to the voltage inputs **VA-VB-VC-N** (ABC rotation used in this example). For this scenario of the collapse of secondary voltage V_A ($V_A = 0$) in the broken-delta secondary, note that voltage V_S is 150 degrees out-of-phase with voltage V_{AB} (from voltage input **VA-N**).

Use the **METER** command (via serial port or front panel) to compare these voltage phase angles. If the phase angle difference between V_S and V_A is 150 degrees (within a few degrees), then the polarity of voltage input **VS** is deemed correct. If the phase angle difference between V_S and V_A is 30 degrees (again, within a few degrees), then the secondary wires from the broken-delta secondary in *Figure 2.15* need to be swapped in connection to voltage input **VS-NS**.

The relay will use voltage V_{AB} as the phase angle reference (zero degrees) when a sufficient voltage signal is present. The phasors in *Figure 2.16* could have been drawn rotated clockwise by 30 degrees.

NOTE: When the relay is connected to open-delta PTs and Global setting PTCONN = DELTA, there is no "3VO" value in the **METER** command (via serial port or front panel).

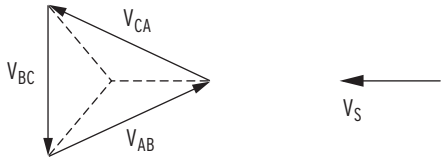


Figure 2.16 Resultant Voltage V_S From the Collapse of Voltage V_A in the Broken-Delta Secondary (Compared to the Open-Delta Connected Power System Voltages)

Serial Ports

Serial **PORT 1** on all the SEL-351S models is an EIA-485 port (4-wire). The serial **PORT 1** plug-in connector accepts wire size AWG 24 to 12. Strip the wires 0.31 inches (8 mm) and install with a small slotted-tip screwdriver. Serial **PORT 1** connector has extra positions for IRIG-B time-code signal input (see *Table 10.2*; see following discussion on IRIG-B time code input).

All EIA-232 ports accept 9-pin D-subminiature male connectors. **PORT 2** on all the SEL-351S models includes the IRIG-B time-code signal input (see *Table 10.1*; see following discussion on IRIG-B time code input).

The pin definitions for all the ports are given on the relay rear panel and detailed in *Table 10.1*–*Table 10.3*.

Refer to *Table 2.2* for a list of cables available from SEL for various communication applications. Refer to *Section 10: Serial Port Communications and Commands* for detailed cable diagrams for selected cables (cable diagrams precede *Table 10.3*).

NOTE: Listing of devices not manufactured by SEL in Table 2.2 is for the convenience of our customers. SEL does not specifically endorse or recommend such products, nor does SEL guarantee proper operation of those products, or the correctness of connections, over which SEL has no control.

For example, to connect any EIA-232 port to the 9-pin male connector on a laptop computer, order cable number C234A and specify the length needed (standard length is eight feet). To connect the SEL-351S **PORT 2** to the SEL-2032 Communications Processor that supplies the communication link and the IRIG-B time synchronization signal, order cable number C273A. For connecting devices at distances over 100 feet, SEL offers fiber-optic

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transceivers. The SEL-2800 family of transceivers provides fiber-optic links between devices for electrical isolation and long distance signal transmission. Contact SEL for further information on these products.

Table 2.2 Communication Cables to Connect the SEL-351S to Other Devices

SEL-351S EIA-232 Serial Ports	Connect to Device (gender refers to the device)	SEL Cable No.
all EIA-232 ports	PC, 25-Pin Male (DTE)	C227A
all EIA-232 ports	Laptop PC, 9-Pin Male (DTE)	C234A
all EIA-232 ports	SEL-2032/2030/2020/2100 without IRIG-B	C272A
2	SEL-2032/2030/2020/2100 with IRIG-B	C273A
all EIA-232 ports	SEL-PRTU	C231
all EIA-232 ports	SEL-DTA2	C272A
2[a] 3[a]	StarComm® Modem, 5 Vdc Powered	C220[a]
all EIA-232 ports	Standard Modem, 25-Pin Female (DCE)	C222
all EIA-232 ports	RFL-9660	C245A

[a] A corresponding main board jumper must be installed to power the StarComm Modem with +5 Vdc (0.5 A limit) from the SEL-351S. See Figure 2.32 and Table 2.8.

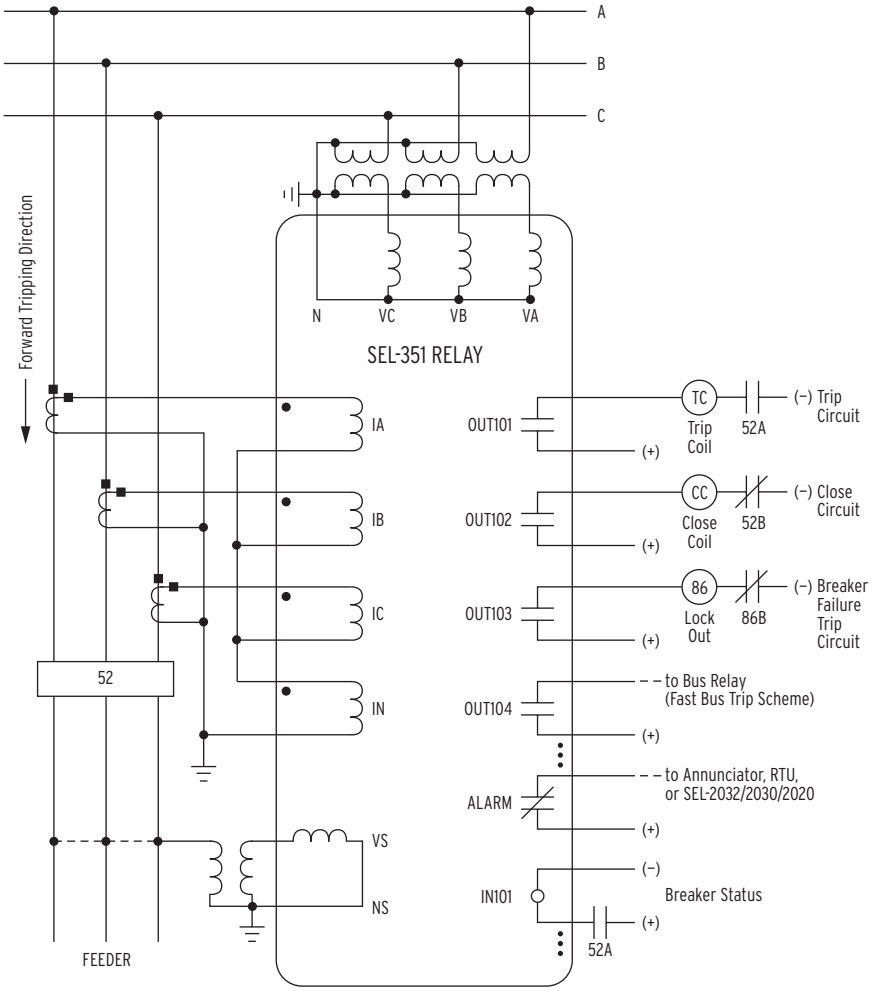
IRIG-B Time-Code Input

The SEL-351S accepts a demodulated IRIG-B time signal to synchronize the relay internal clock with some external source. The demodulated IRIG-B time signal can come via the SEL-2032, SEL-2030, or SEL-2020 Communications Processor or the SEL-2100 Logic Processor listed in *Table 2.2,* as well as the SEL-2407 or SEL-2401 Satellite-Sychronized Clock. The IRIG-B time signal can be input to either **PORT 1** or **PORT 2**, but not both.

A demodulated IRIG-B time code can be input into serial **PORT 2** by connecting serial **PORT 2** of the SEL-351S to an SEL-2032, SEL-2030, or SEL-2020 Communications Processor using Cable C273A.

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SEL-351S AC/DC Connection Diagrams for Various Applications

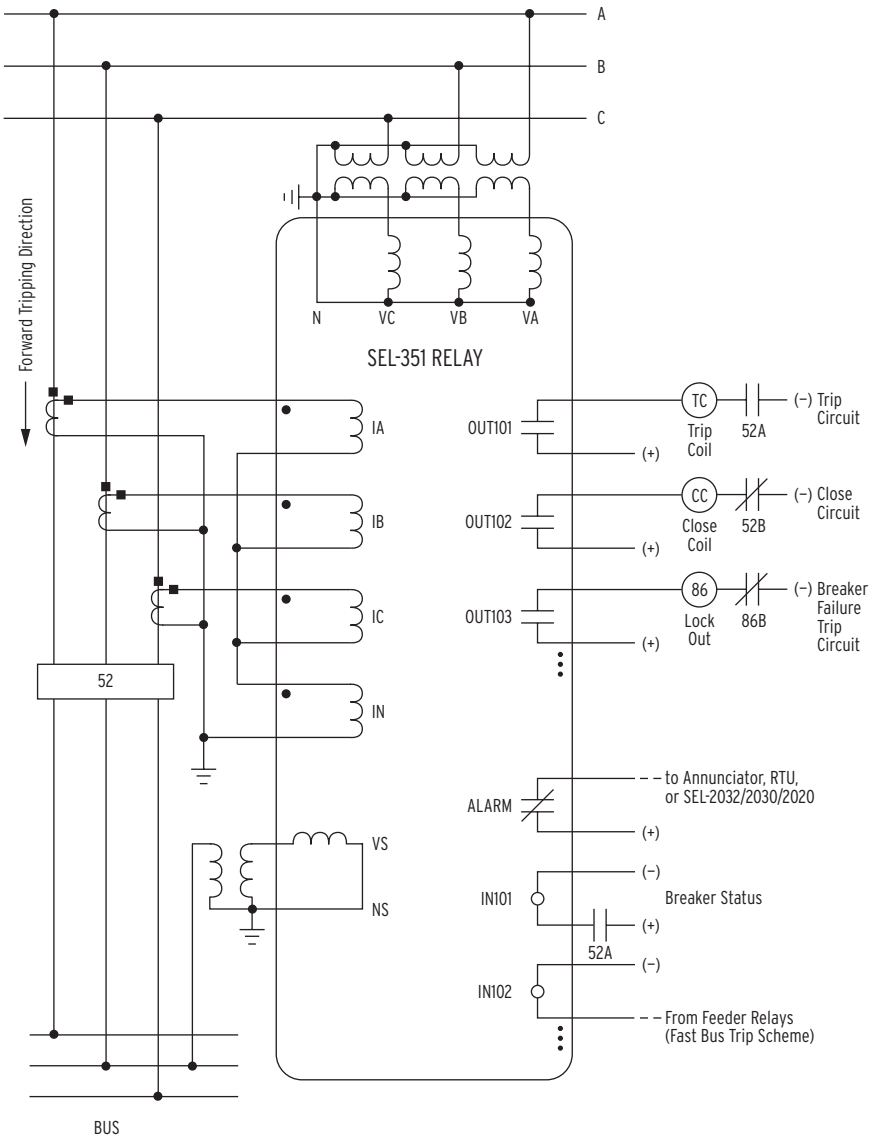


The voltage inputs do not need to be connected. Voltage is needed for voltage elements, synchronism check elements, frequency elements, voltage-polarized directional elements, fault location, metering (i.e., voltage, MW, MVAR), and frequency tracking. Voltage Channel **VS** is shown connected for use in voltage and synchronism check elements and voltage metering. See Synchronism Check VS Connection (Global Setting VSCONN = VS) and Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.17 SEL-351S Provides Overcurrent Protection and Reclosing for a Utility Distribution Feeder (Includes Fast Bus Trip Scheme) (Wye-Connected PTs)

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The fast bus trip scheme is often referred to as a reverse-interlocking or zone-interlocking scheme.

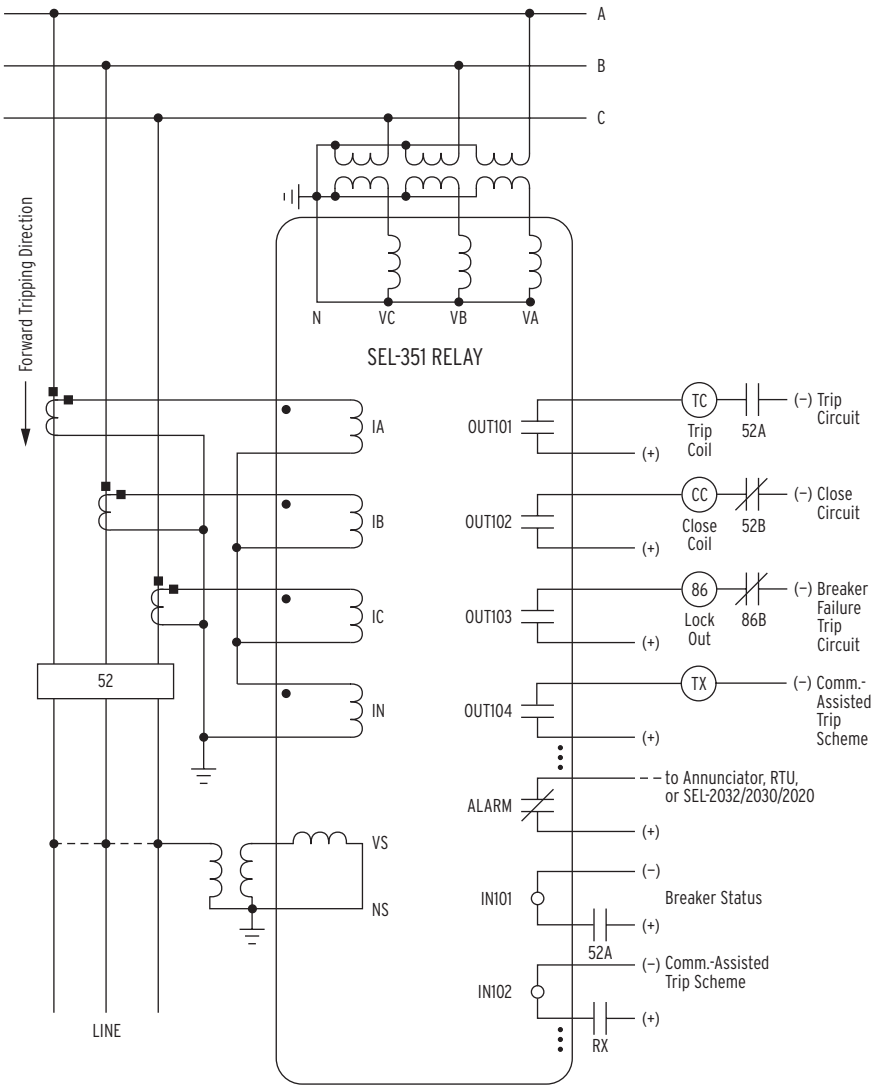
The voltage inputs do not need to be connected. Voltage is needed for voltage elements, synchronism check elements, frequency elements, voltage-polarized directional elements, fault location, metering (i.e., voltage, MW, MVAR), and frequency tracking. Voltage Channel **VS** is shown connected for use in voltage and synchronism check elements and voltage metering. See Synchronism Check VS Connection (Global Setting VSCONN = VS) and Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20. In this example, terminals **VS**-**NS** are connected B-phase-to-neutral.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Although automatic reclosing is probably not needed in this example, output contact **OUT102** can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision (e.g., synchronism check).

Figure 2.18 SEL-351S Provides Overcurrent Protection for a Distribution Bus (Includes Fast Bus Trip Scheme) (Wye-Connected PTs)

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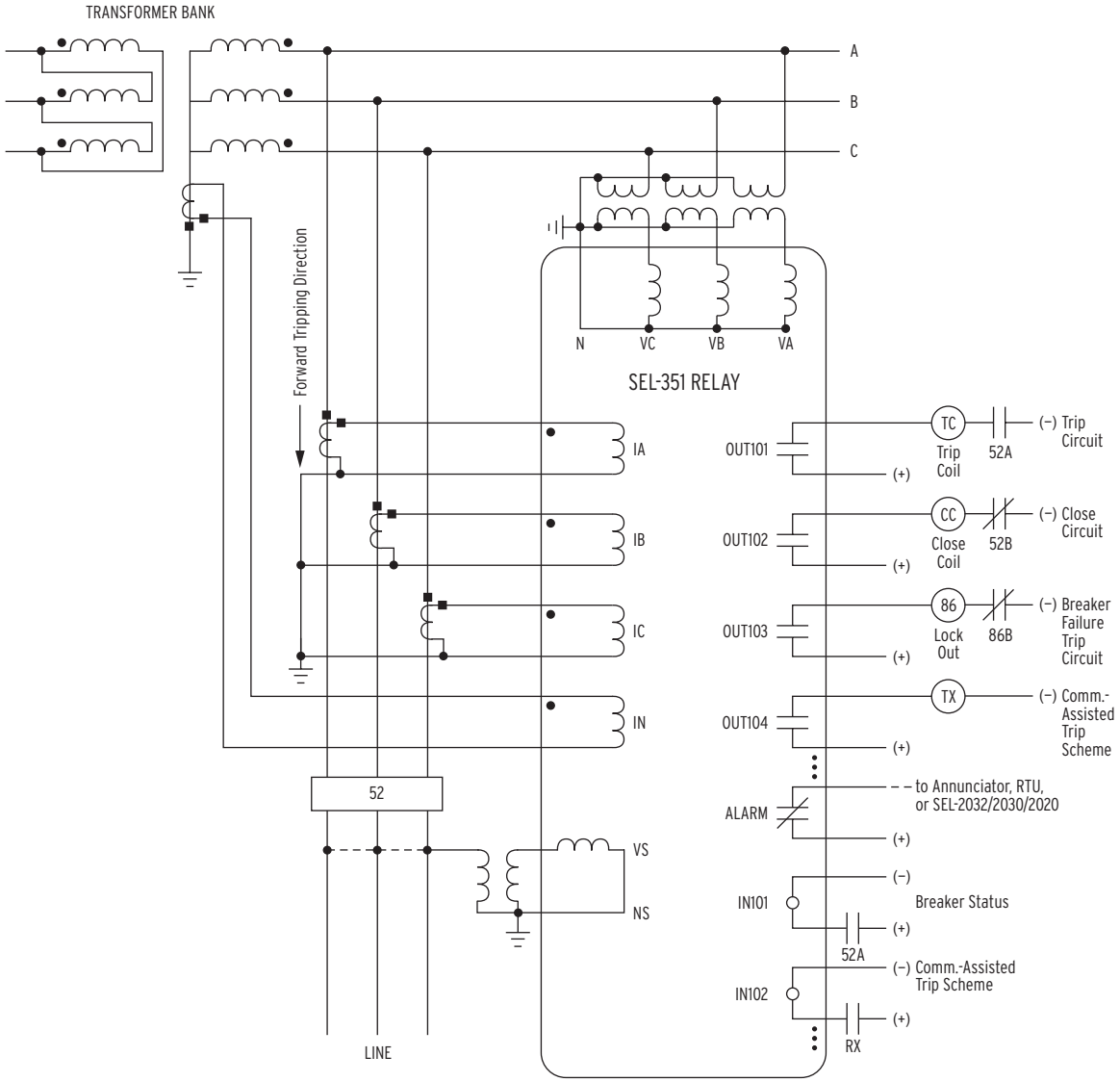


Voltage Channel **VS** does not need to be connected. Here, it is shown connected for use in voltage and synchronism check elements and voltage metering. See Synchronism Check VS Connection (Global Setting VSCONN = VS) and Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.19 SEL-351S Provides Directional Overcurrent Protection and Reclosing for a Transmission Line (Wye-Connected PTs)

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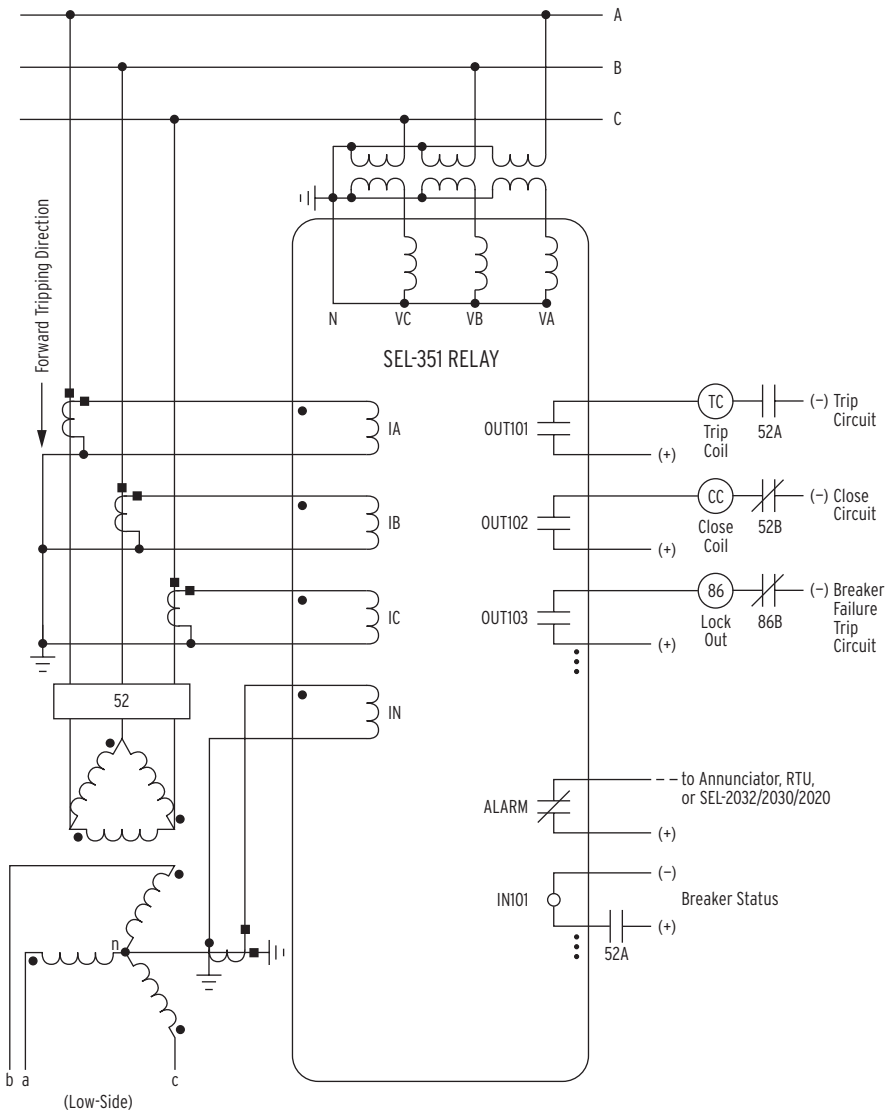


Voltage Channel **VS** does not need to be connected. Here, it is shown connected for use in voltage and synchronism check elements and voltage metering. See Synchronism Check VS Connection (Global Setting VSCONN = VS) and Broken-Delta VS Connection (Global Setting VSCONN = 3VO) on page 2.20.

In this example, current Channel **IN** provides current polarization for a directional element used to control ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$).

Figure 2.20 SEL-351S Provides Directional Overcurrent Protection and Reclosing for a Transmission Line (Current-Polarization Source Connected to Channel IN) (Wye-Connected PTs)

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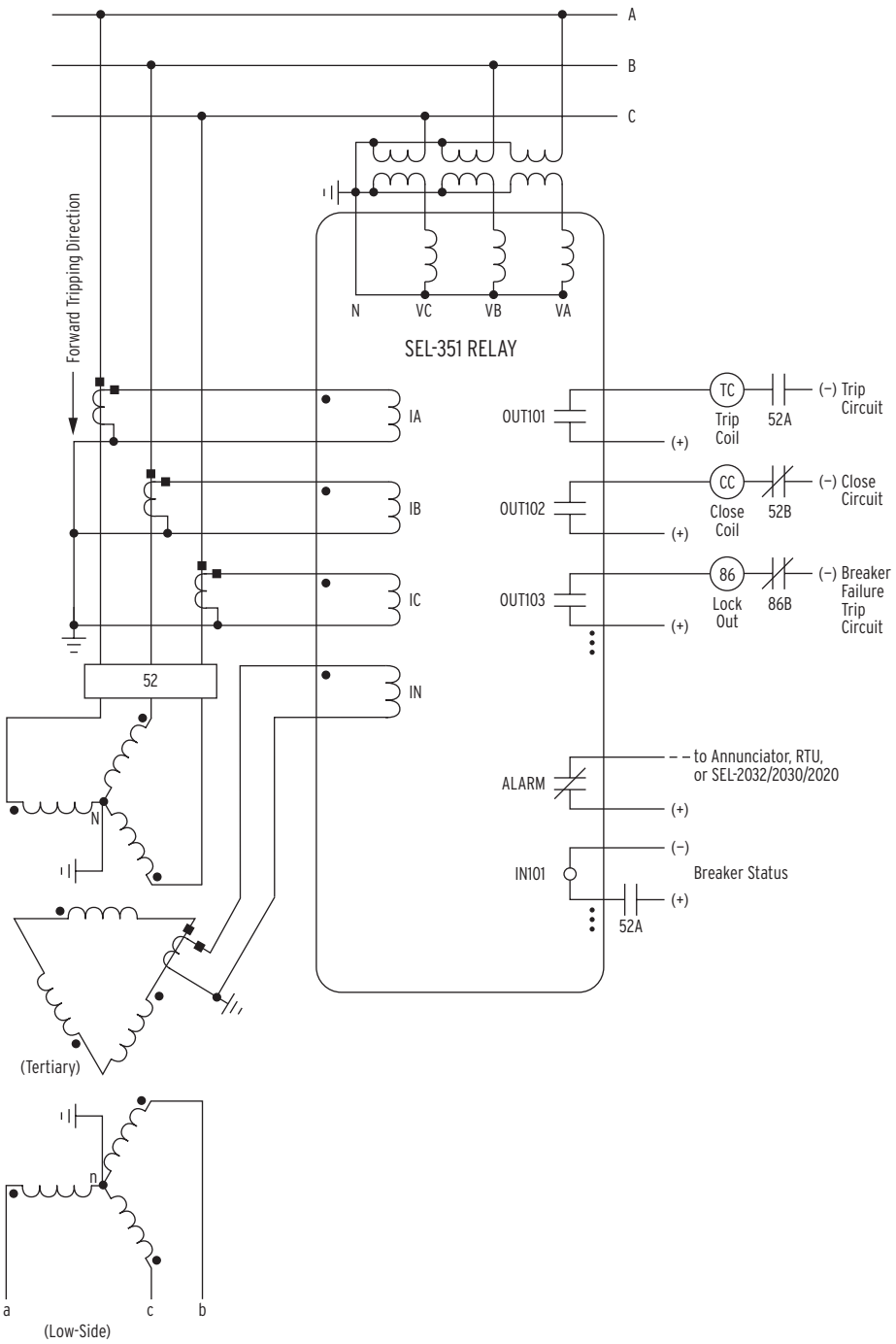
The voltage inputs do not need to be connected. Voltage is needed for voltage elements, synchronism check elements, frequency elements, voltage-polarized directional elements, fault location, metering (i.e., voltage, MW, MVAR), and frequency tracking.

Although automatic reclosing is probably not needed in this example, output contact **OUT102** can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision (e.g., hot bus check).

For sensitive earth fault (SEF) applications, the SEL-351S should be ordered with Channel **IN** rated at 0.2 A or 0.05 A nominal. See current input specifications in the subsection Specifications: General on page 1.10. See neutral ground overcurrent element pickup specifications in Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements. See also the note following Table 4.3.

Figure 2.21 SEL-351S Provides Overcurrent Protection for a Delta-Wye Transformer Bank (Wye-Connected PTs)

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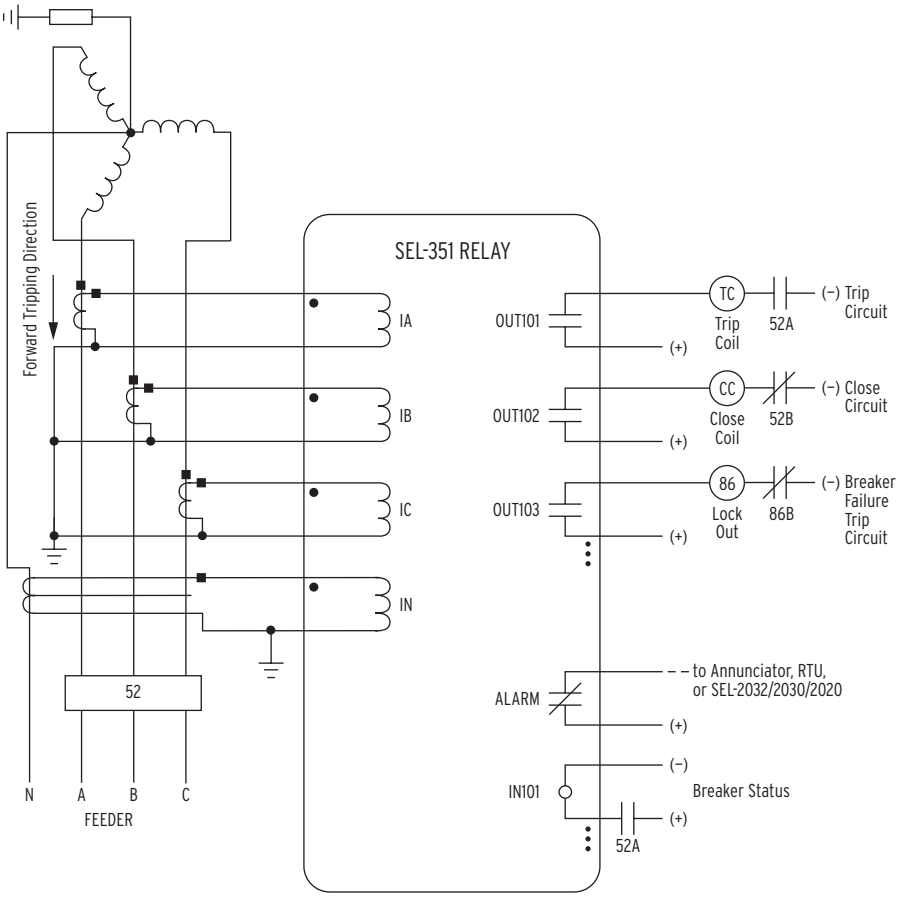


The voltage inputs do not need to be connected. Voltage is needed for voltage elements, synchronism check elements, frequency elements, voltage-polarized directional elements, fault location, metering (i.e., voltage, MW, MVAR), and frequency tracking.

Although automatic reclosing is probably not needed in this example, output contact **OUT102** can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision (e.g., hot bus check).

Figure 2.22 SEL-351S Provides Overcurrent Protection for a Transformer Bank With a Tertiary Winding (Wye-Connected PTs)

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A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

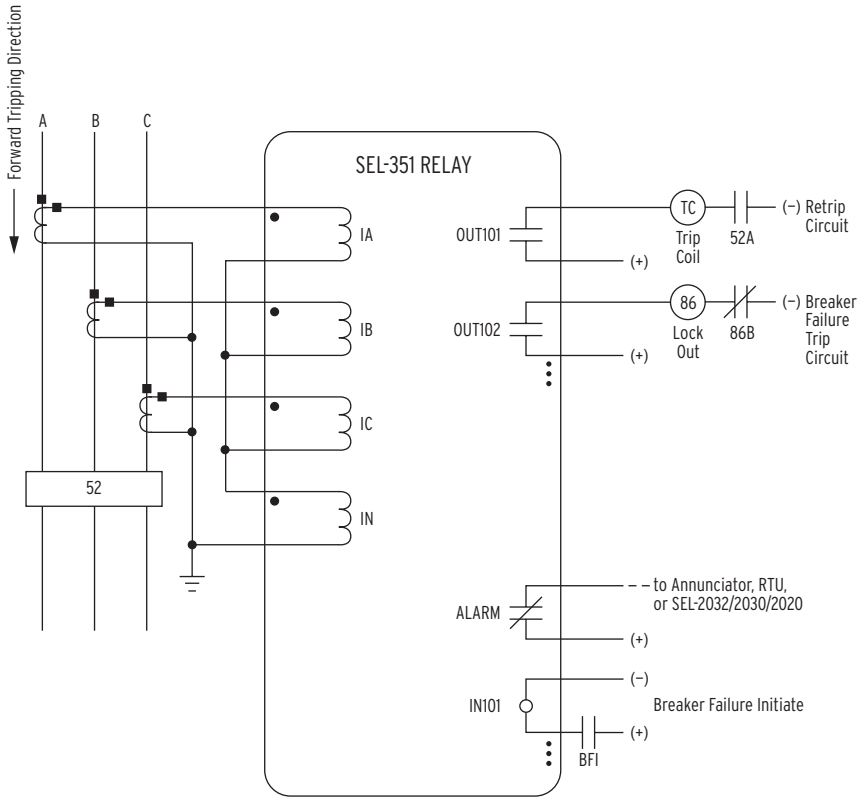
Pass neutral (N) through the core-balance CT only if the neutral is brought out and it is grounded only at the source.

Although automatic reclosing is probably not needed in this example, output contact **OUT102** can close the circuit breaker via initiation from various means (serial port communications, optoisolated input assertion, etc.), with desired supervision.

For sensitive earth fault (SEF) applications, the SEL-351S should be ordered with Channel **IN** rated at 0.2 A or 0.05 A nominal. See current input specifications in subsection Specifications: General on page 1.10. See neutral ground overcurrent element pickup specifications in Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements. See also the note following Table 4.3.

Figure 2.23 SEL-351S Provides Overcurrent Protection for an Industrial Distribution Feeder (Core-Balance Current Transformer Connected to Channel IN)

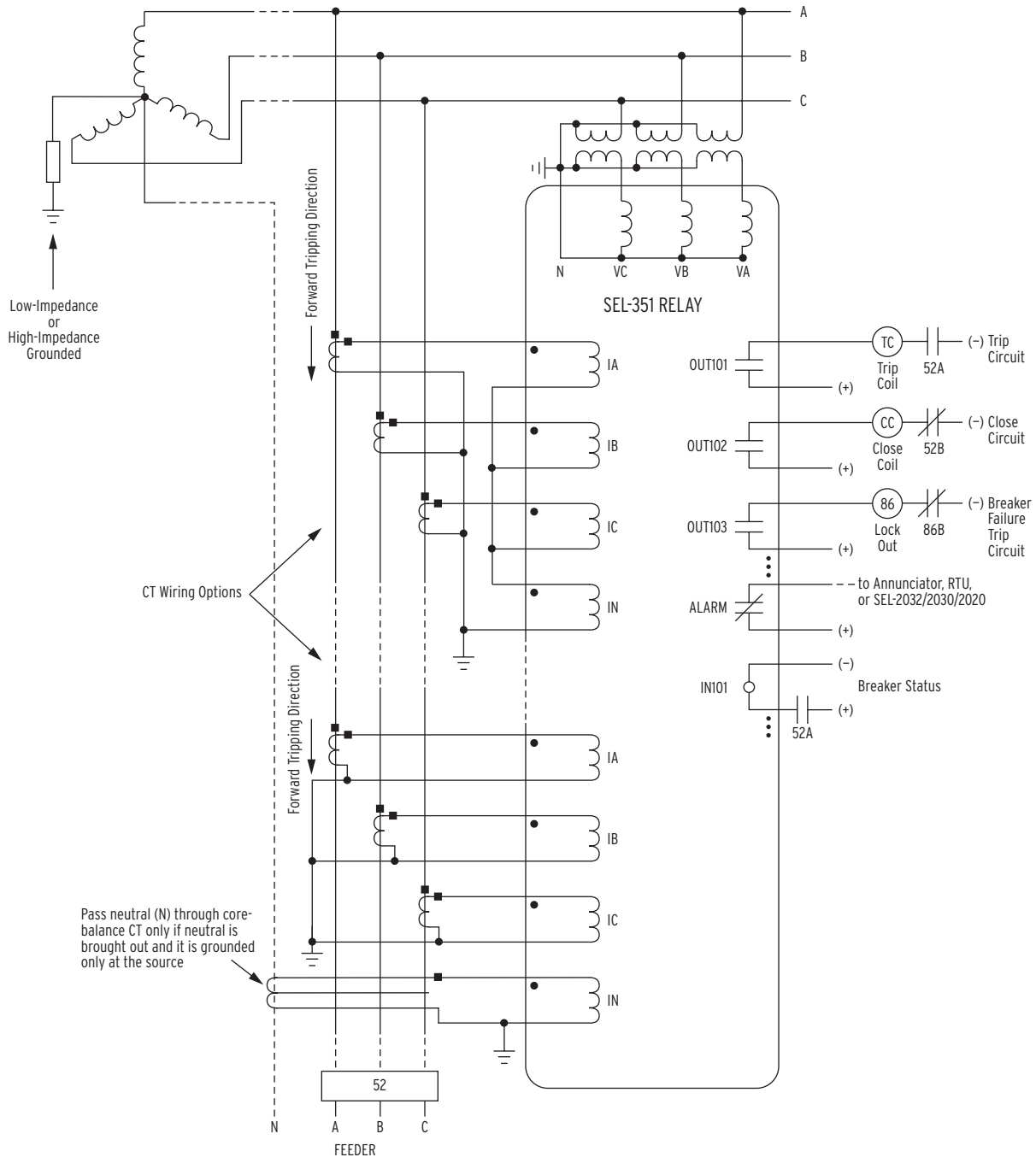
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Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.24 SEL-351S Provides Dedicated Breaker Failure Protection

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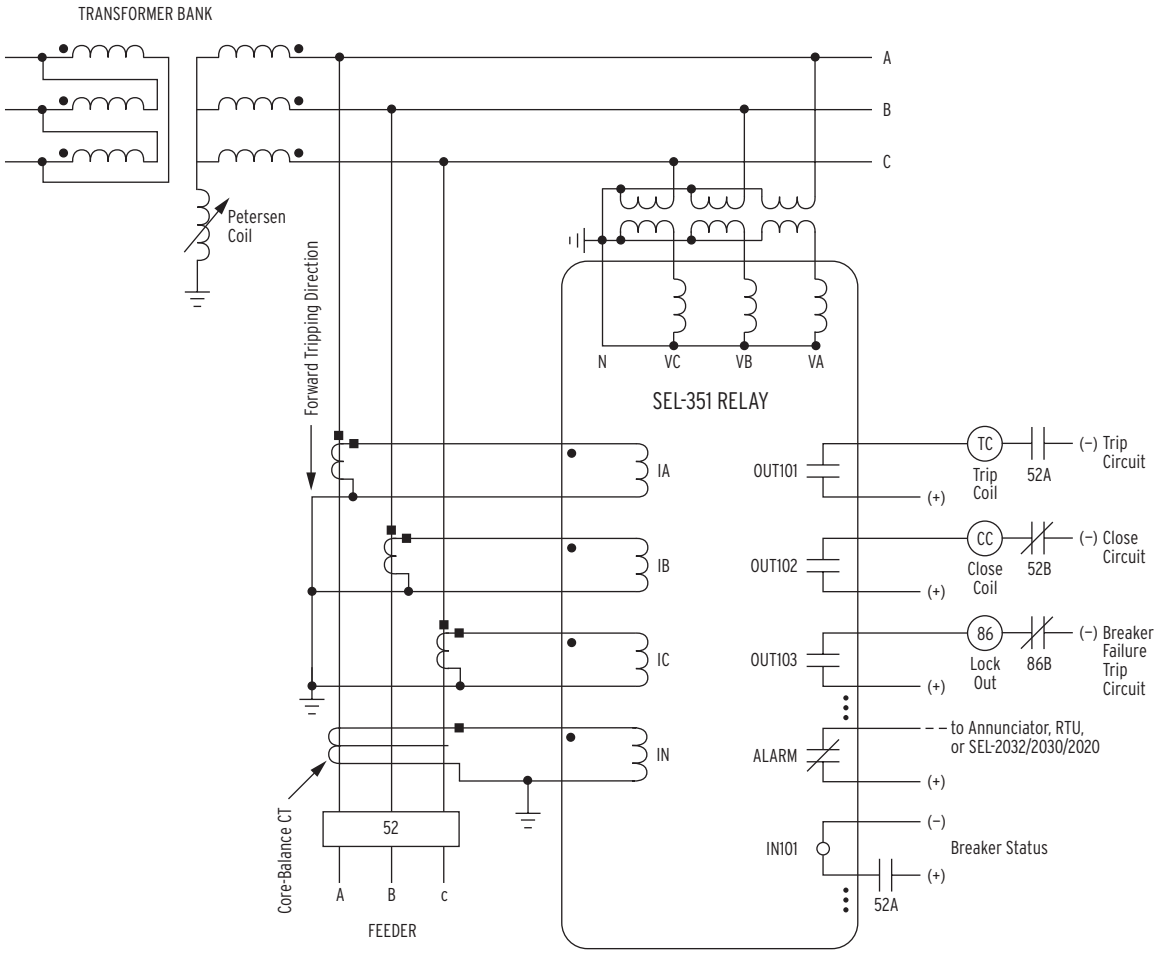
A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

The lower CT wiring option (with the core-balance current transformer) is the preferred option (greater sensitivity; no false residual currents due to CT saturation, etc.).

Directional control for a low-impedance grounded system is selected with setting ORDER containing S. Directional control for a high-impedance grounded system is selected with setting ORDER=U (see Table 4.3–Table 4.5). Nondirectional sensitive earth fault (SEF) protection is also available.

Figure 2.25 SEL-351S Provides Overcurrent Protection for a High-Impedance or Low-Impedance Grounded System (Wye-Connected PTs)

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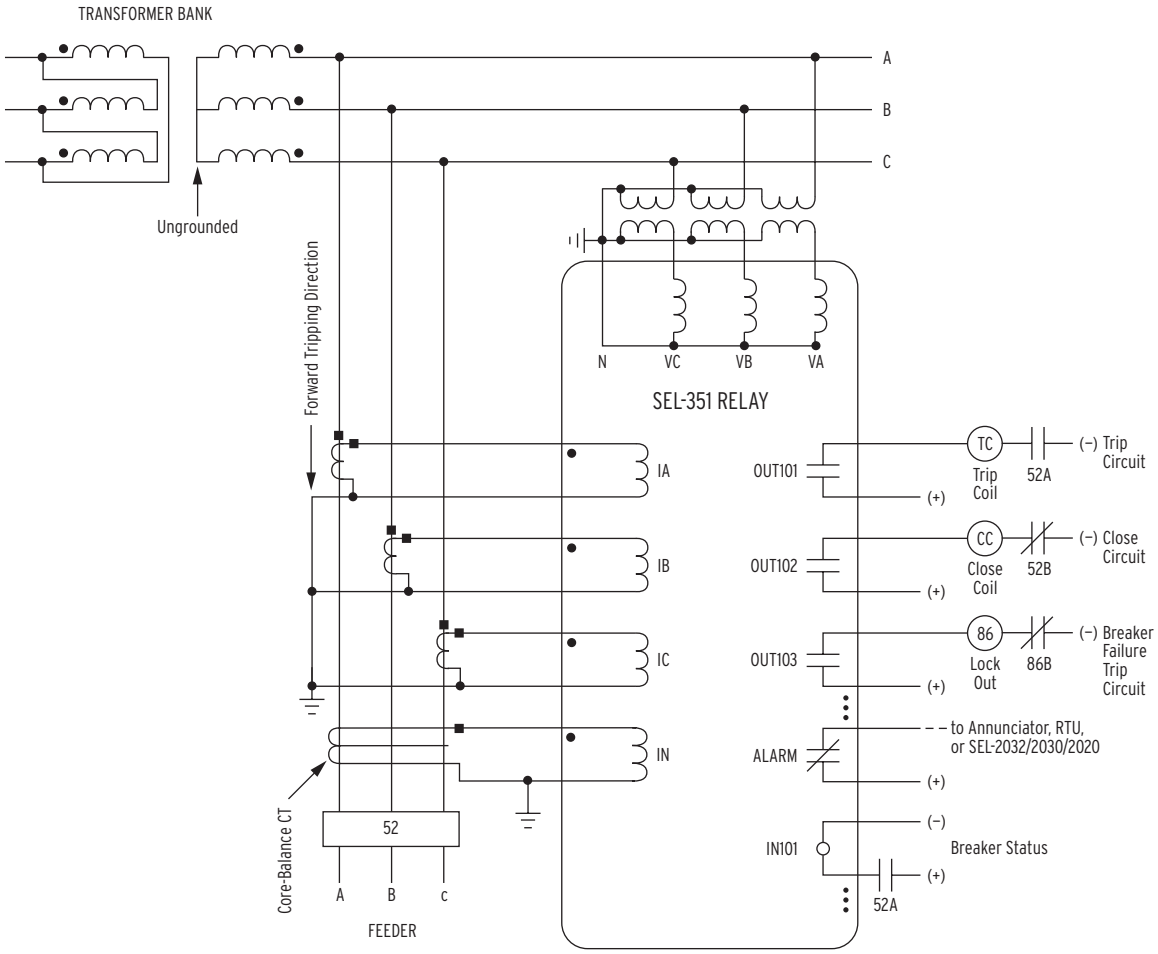


A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

Directional control for a Petersen Coil grounded system is selected with setting ORDER containing P (see Table 4.3–Table 4.5). Nondirectional sensitive earth fault (SEF) protection is also available.

Figure 2.26 SEL-351S Provides Overcurrent Protection for a Petersen Coil Grounded System (Wye-Connected PTs)

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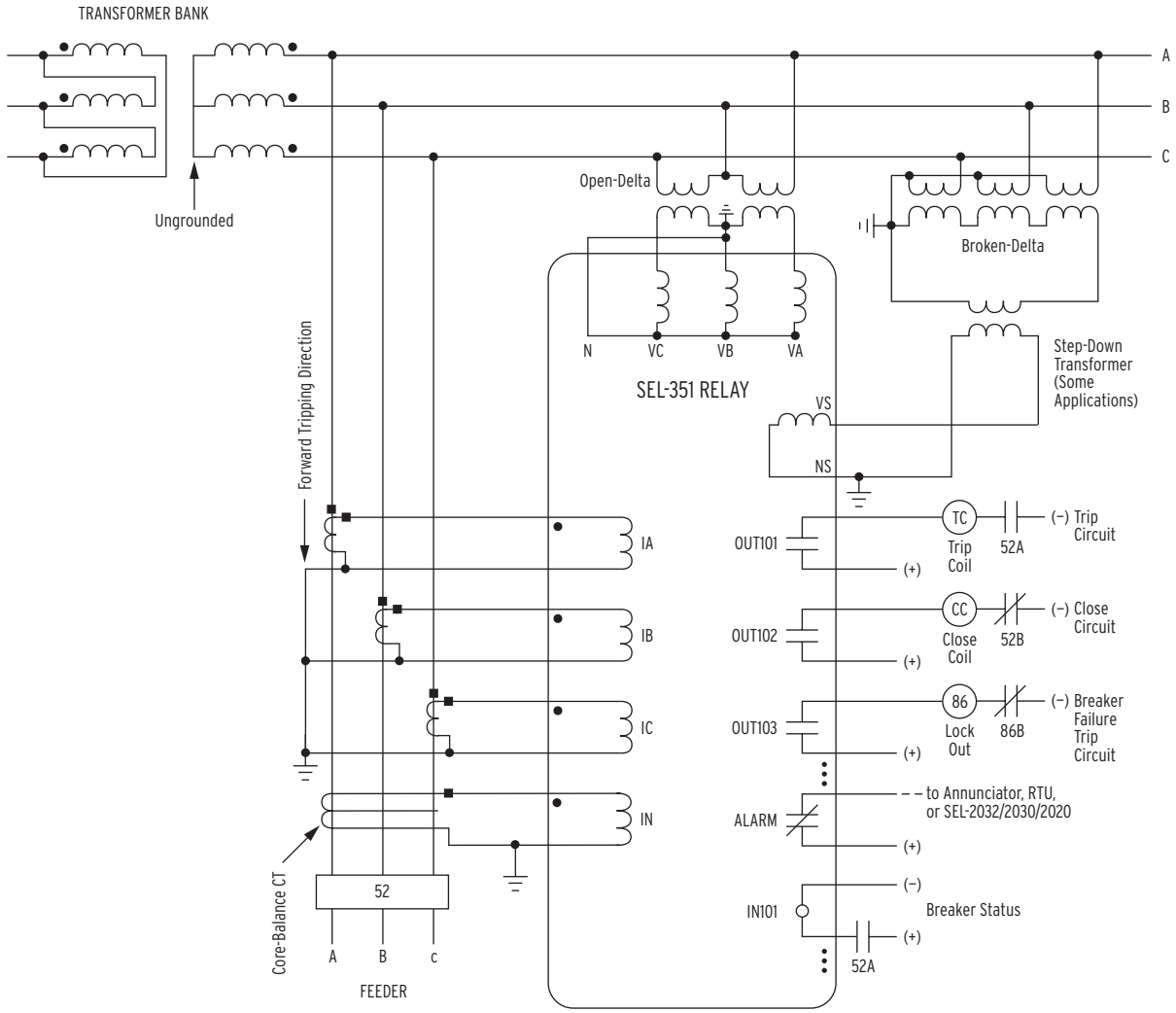


A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

Directional control for an ungrounded system is selected with setting ORDER=U (see Table 4.3–Table 4.5). Nondirectional sensitive earth fault (SEF) protection is also available.

Figure 2.27 SEL-351S Provides Overcurrent Protection for an Ungrounded System (Wye-Connected PTs)

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A core-balance current transformer is often referred to as a zero-sequence, ground fault, or window current transformer.

Directional control for an ungrounded system is selected with setting ORDER=U (see Table 4.3–Table 4.5). Nondirectional sensitive earth fault (SEF) protection is also available.

The voltage inputs can accept open-delta PT (three-wire) connection (as shown) when Global setting PTCONN = DELTA.

VB (terminal **Z10**) must be externally tied to **N** (terminal **Z12**), as shown. (For Connectorized relays, this connection must be made at the remote end of the wiring harness.)

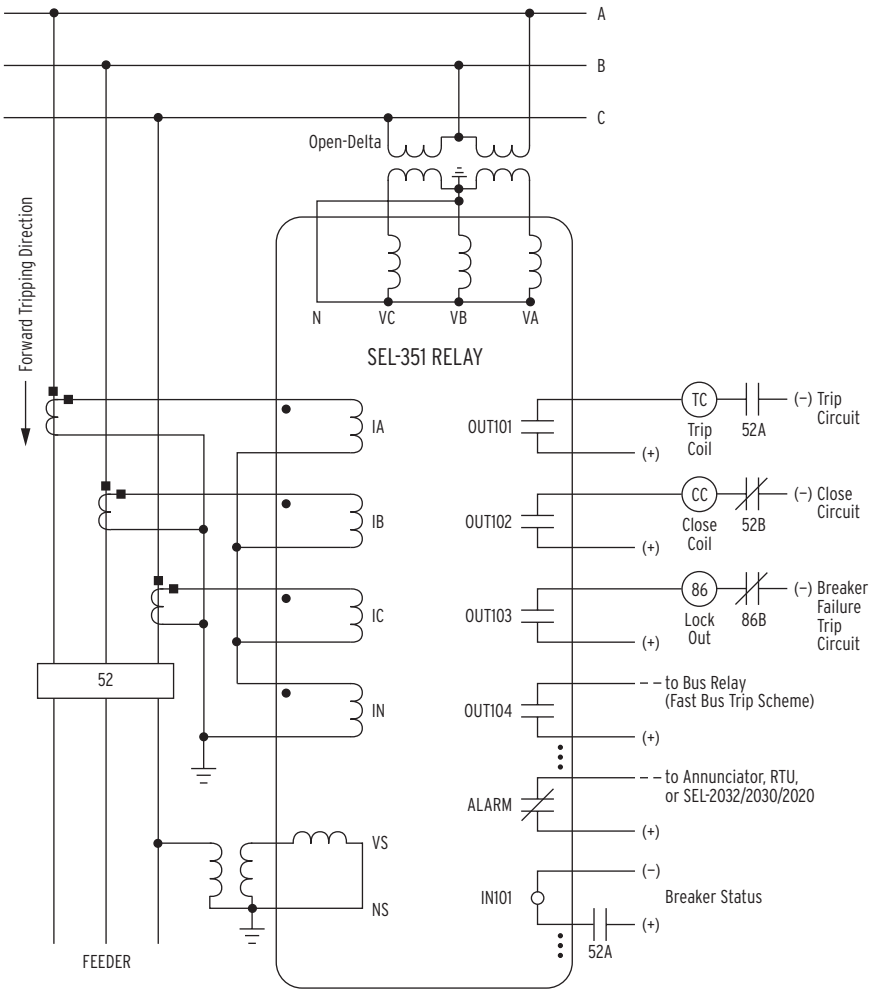
The zero-sequence voltage $3V_0$ (from the "broken-delta" connection) is shown coming from a step-down instrumentation transformer, and connecting to voltage input **VS-NS** (terminals **Z13** and **Z14**, respectively). To use this connection, make global setting VSCONN = 3V0. Make group setting PTRS as shown in Section 9: Setting the Relay.

The step-down transformer is required when the maximum expected residual voltage exceeds the relay voltage channel rating. See Voltage Input Rating on page 2.19.

The polarity of voltage input **VS-NS** connection should be verified prior to placing the relay into service. See Polarity Check for VSCONN = 3V0 on page 2.20 for a suggested procedure.

Figure 2.28 SEL-351S Provides Overcurrent Protection for an Ungrounded System (Open-Delta Connected PTs, Broken-Delta 3V0 Connection)

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The voltage inputs can accept open-delta PT (three-wire) connection (as shown) when Global setting PTCONN = DELTA.

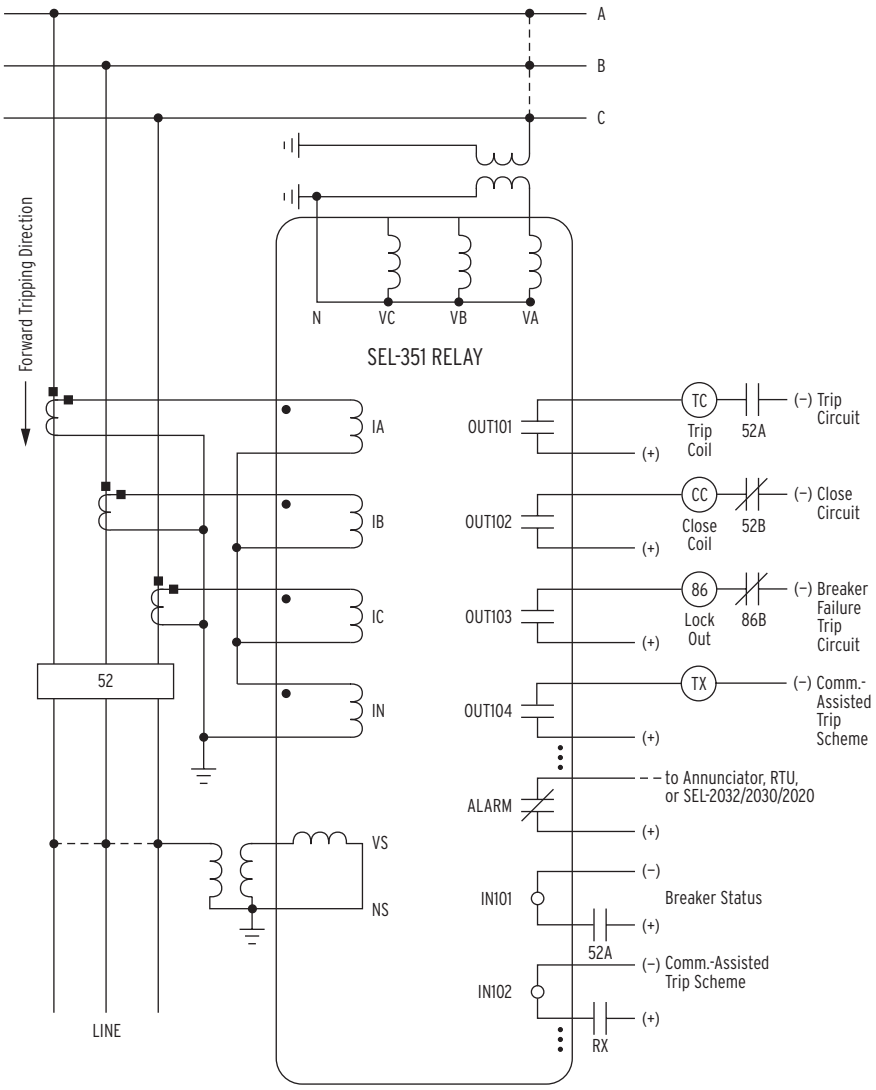
VB (terminal **Z10**) must be externally tied to **N** (terminal **Z12**), as shown. (For Connectorized relays, this connection must be made at the remote end of the wiring harness.)

Voltage channel **VS**-**NS** is shown connected for use in voltage and synchronism check elements and voltage metering. See Synchronism Check VS Connection (Global Setting VSCONN = VS) on page 2.20. The synchronism check voltage is shown coming from C-phase, via a line-to-ground connection. To account for the phase difference between V_C and V_{AB}, use group setting SYNCP = 270 (degrees lagging V_{AB}, with ABC rotation). See Synchronism Check Elements on page 3.36.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But, in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.29 SEL-351S Provides Overcurrent Protection and Reclosing for a Utility Distribution Feeder (Open-Delta Connected PTs and Line-to-Ground Synch-Check Connection)

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Voltage must be applied between relay terminals **VA** and **N** (**Z09** and **Z12**, respectively) in order for the underfrequency elements to operate. Make group setting VNOM = OFF to allow the undervoltage block for the frequency elements to operate off one phase only (if only connecting one phase voltage to the relay).

The phase of the single-phase voltage connected to **VA-N** does not matter. For example, it could come from **VB**, **VCA**, or from a station service transformer (suitably fused). It should come from the same bus section that the associated breaker is connected, preferably from the "normally hot" side.

In the configuration shown, only non-directional overcurrent protection is possible. The fault locator logic and the load encroachment element are also disabled.

Voltage Channel **VS** does not need to be connected. Here, it is shown connected for use in voltage and synchronism check elements and voltage metering. See Synchronism Check VS Connection (Global Setting VSCONN = VS) and Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20.

Current Channel **IN** does not need to be connected. Channel **IN** provides current I_N for the neutral ground overcurrent elements. Separate from Channel **IN**, the residual ground overcurrent elements operate from the internally derived residual current I_G ($I_G = 3I_0 = I_A + I_B + I_C$). But, in this residual connection example, the neutral ground and residual ground overcurrent elements operate the same because $I_N = I_G$.

Figure 2.30 SEL-351S Provides Underfrequency Load Shedding, Overcurrent Protection, and Reclosing for a Utility Distribution Feeder (Single Voltage Connection)

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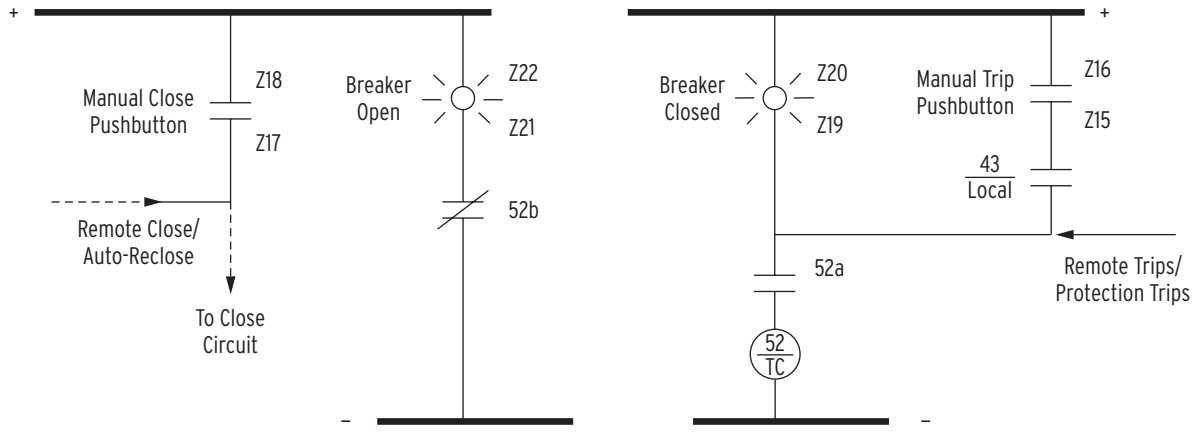


Figure 2.31 SEL-351S Example Wiring Diagram Using the Auxiliary {TRIP}/{CLOSE} Pushbuttons for 0351Sxxx5/6/A/B Models

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Circuit Board Connections

Accessing the Relay Circuit Boards

To change circuit board jumpers or replace the clock battery on the relay main board, refer to *Figure 2.32–Figure 2.35* and perform the following steps:

Step 1. De-energize the relay.

On plug-in connector versions this can be easily accomplished by removing the connector at rear-panel terminals **Z25** and **Z26**.

Step 2. Remove any cables connected to serial ports on the front and rear panels.

Step 3. Loosen the six front-panel screws (they remain attached to the front panel), and remove the relay front panel.

⚠CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with front or top cover removed, work surfaces and personnel must be properly grounded or equipment damage may result.

Step 4. Remove the 64-pin ribbon cable from the front panel by pushing the extraction ears away from the connector.

Step 5. Remove the ribbon cable connected to the front panel DB9 connector.

Step 6. Remove the auxiliary pushbutton and LED connectors from the magnetics/auxiliary pushbutton board, if equipped.

NOTE: Be sure to place the front panel on an ESD-safe workstation to prevent ESD damage.

Step 7. Each circuit board corresponds to a row of rear-panel terminal blocks or connectors and is affixed to a drawout tray. Identify which drawout tray needs to be removed.

The main board on the SEL-351S is the top board in the chassis. If the relay has an extra I/O board it is located underneath the main board. The magnetics/auxiliary pushbutton board and power supply are mounted to the bottom of the chassis. It is **not** necessary to remove the magnetics/auxiliary pushbutton board from the chassis to access the associated circuit board jumpers.

Step 8. On plug-in connector versions, remove the rear-panel connectors that correspond to the circuit board you wish to remove by loosening the screws on either end of each connector. Removal of the extra I/O board also requires removal of the main board.

Step 9. Disconnect circuit board cables as necessary to allow the desired board and drawout tray to be removed. Removal of the extra I/O board requires removal of the main board first. Ribbon cables can be removed by pushing the extraction ears away from the connector. The 6-conductor power cable can be removed by grasping the power connector wires and pulling away from the circuit board.

Step 10. Grasp the drawout assembly of the board and pull the assembly from the relay chassis.

Step 11. Locate the jumper(s) or battery to be changed (refer to *Figure 2.32–Figure 2.35*).

Make the desired changes. Note that the output contact jumpers are soldered in place.

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Step 12. When finished, slide the drawout assembly into the relay chassis.

Step 13. Reconnect the cables removed in *Step 5*, *Step 8*, and *Step 9*, and replace the relay front-panel cover.

Step 14. Replace any cables previously connected to serial ports.

Step 15. Replace any rear-panel connectors removed in *Step 6*.

Step 16. Reenergize the relay. (On plug-in connector versions, replace the power connector at rear-panel terminals **Z25** and **Z26**.)

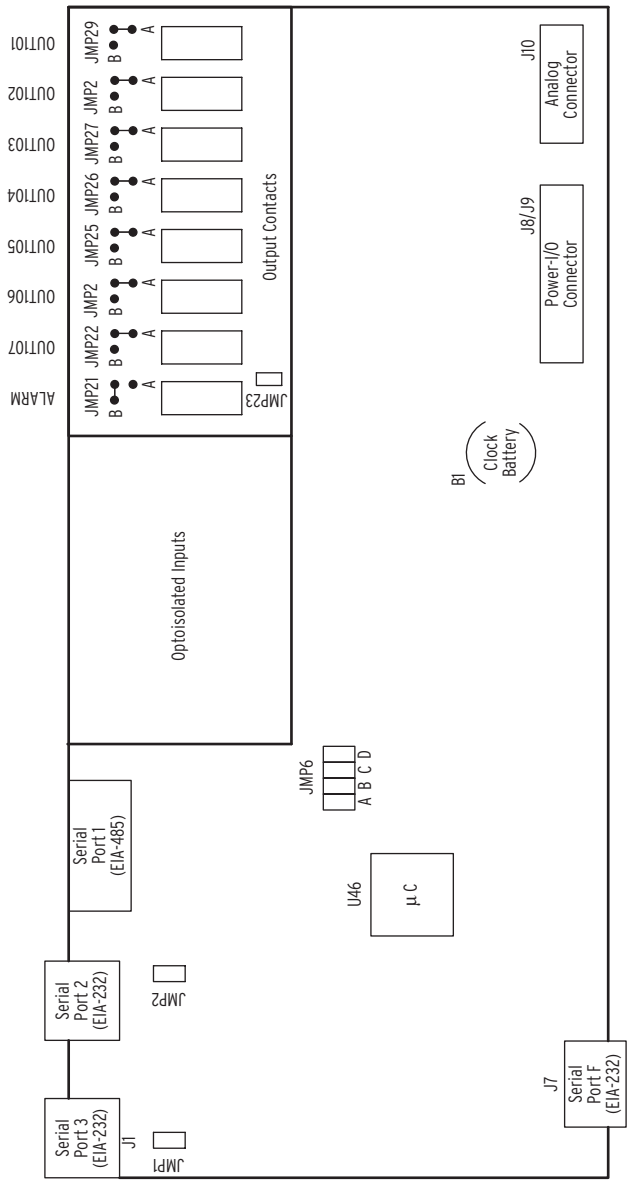


Figure 2.32 Jumper, Connector, and Major Component Locations on the SEL-351S Main Board

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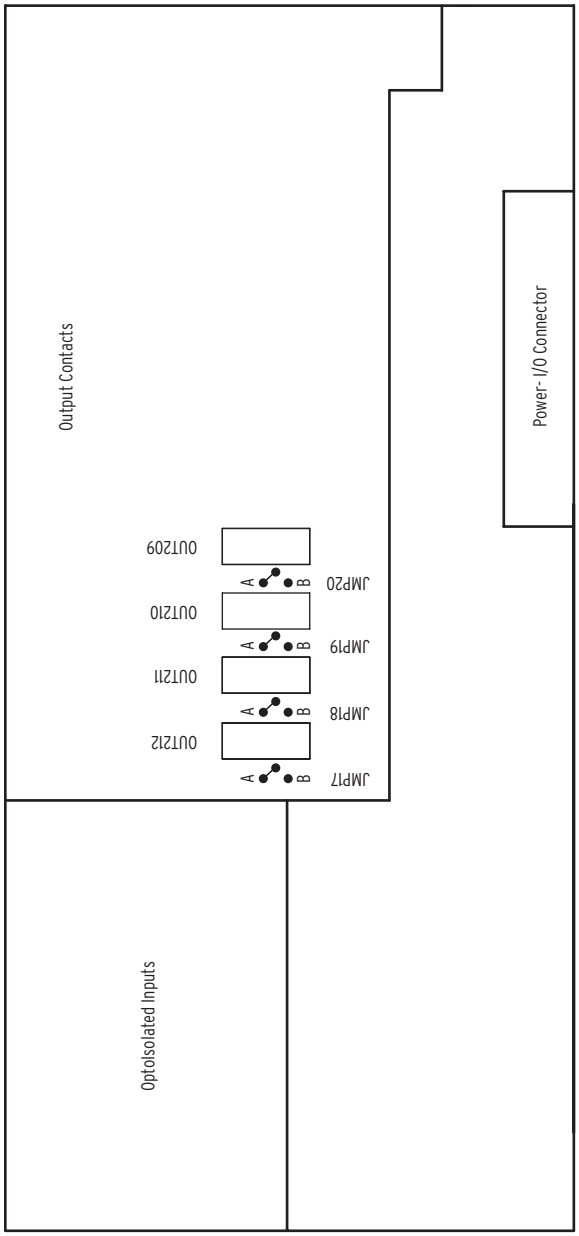


Figure 2.33 Jumper, Connector, and Major Component Locations on the SEL-351SxY Extra I/O Board (Plug-In Connector Version)

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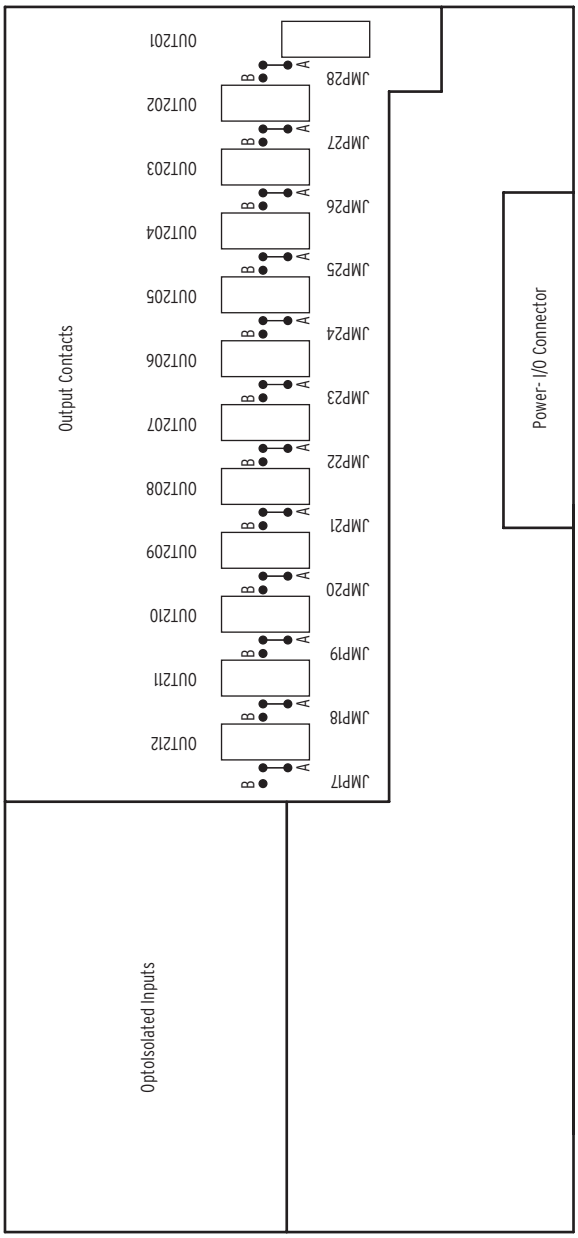


Figure 2.34 Jumper, Connector, and Major Component Locations on the SEL-351Sx1 Extra I/O Board (Screw Terminal Block Version)

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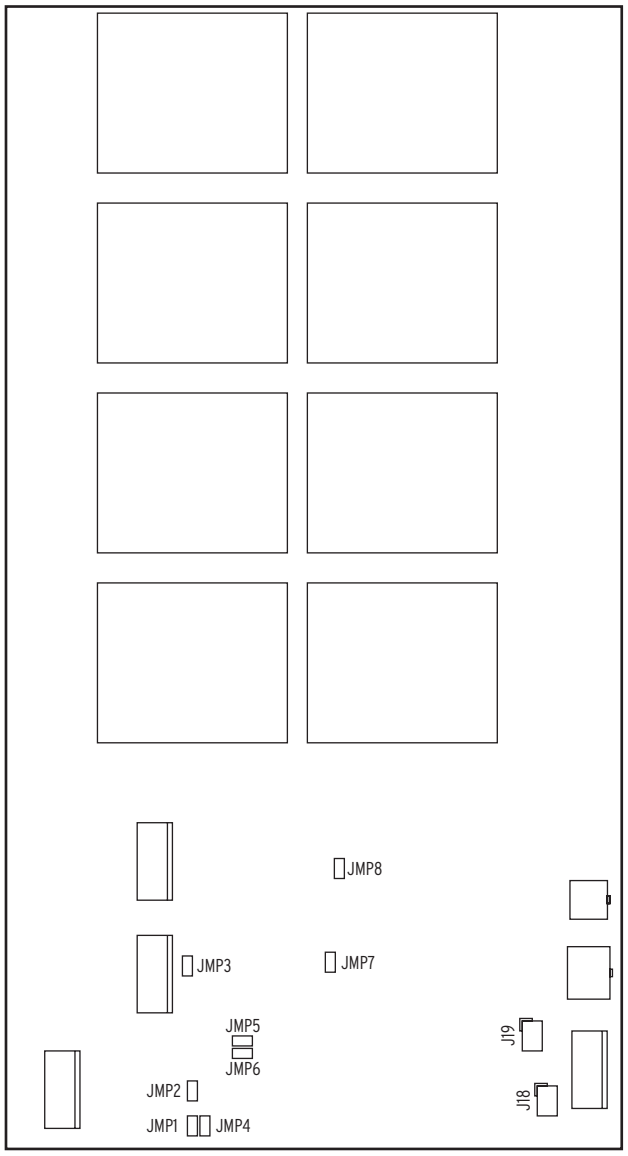


Figure 2.35 Jumper Locations for the 0351Sxxx5/6/A/B Model Magnetics/ Auxiliary Pushbutton Board

Output Contact Jumpers

Table 2.3 shows the correspondence between output contact jumpers and the output contacts they control. The referenced figures show the exact location and correspondence. With a jumper in the A position, the corresponding output contact is an “a” type output contact. An “a” type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. With a jumper in the B position, the corresponding output contact is a “b” type output contact. A “b” type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized. These jumpers are soldered in place.

In the figures referenced in *Table 2.3*, note that the **ALARM** output contacts are “b” type output contacts and the other output contacts are all “a” type output contacts. This is how these jumpers are configured in a standard relay shipment. Refer to corresponding *Figure 7.27*–*Figure 7.28* for examples of output contact operation for different output contact types.

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Table 2.3 Output Contact Jumpers and Corresponding Output Contacts

SEL-351S Model Number	Output Contact Jumpers	Corresponding Output Contacts	Reference Figures
0351S*x*1, 0351S*x*Y	JMP21–JMP29 (but not JMP23)	ALARM–OUT101	*Figure 2.32*
0351S*x*Y	JMP17–JMP20	OUT212–OUT209	*Figure 2.33*
0351S*x*1	JMP17–JMP28	OUT212–OUT201	*Figure 2.34*

"Extra Alarm" Output Contact Control Jumper

The SEL-351S has dedicated alarm output contacts (labeled **ALARM**—see *Figure 2.2*–*Figure 2.6*). Often more than one alarm output contact is needed for such applications as local or remote annunciation, backup schemes, etc. An extra alarm output contact can be programmed without the addition of any external hardware.

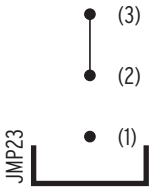
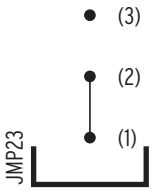
The output contact next to the dedicated **ALARM** output contact can be converted to operate as an "extra alarm" output contact by moving a jumper on the main board (see *Table 2.4*).

Table 2.4 "Extra Alarm" Output Contacts and Corresponding Controlling Jumpers

"Extra Alarm" Output Contact	Controlling Jumper	Reference Figures
OUT107	JMP23	*Figure 2.32*, *Figure 7.27*

The position of the jumper controls the operation of the output contact next to the dedicated **ALARM** output contact. With the jumper in one position, the output contact operates regularly. With the jumper in the other position, the output contact is driven by the same signal that operates the dedicated **ALARM** output contact (see *Table 2.5*).

Table 2.5 Required Position of Jumper JMP23 for Desired Output Contact OUT107 Operation (Models 0351Sx1, and 0351SxY)

Position	Output Contact OUT107 Operation
	Regular output contact **OUT107** (operated by Relay Word bit OUT107). Jumper JMP23 comes in this position in a **standard relay shipment** (see *Figure 7.27*).
	"Extra Alarm" output contact (operated by alarm logic/circuitry). Relay Word bit OUT107 does not have any effect on output contact **OUT107** when jumper JMP23 is in this position (see *Figure 7.27*).

If an output contact is operating as an "extra alarm" (driven by the same signal that operates the dedicated **ALARM** output contact), it will be in the **opposite state** of the dedicated **ALARM** output contact in a **standard relay shipment**. In a standard relay shipment, the dedicated **ALARM** output contact comes as a "b" type output contact and all the other output contacts (including the "extra alarm") come as "a" type output contacts.

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The output contact type for any output contact can be changed (see preceding subsection *Output Contact Jumpers on page 2.44*). Thus, the dedicated **ALARM** output contact and the "extra alarm" output contact can be configured as the same output contact type if desired (e.g., both can be configured as "b" type output contacts).

Password and Breaker Jumpers

Table 2.6 Password and Breaker Jumper Positions for Standard Relay Shipments

Password Jumper/ Position (for standard relay shipments)	Breaker Jumper/Position (for standard relay shipments)	Reference Figure
JMP6-A = OFF	JMP6-B = ON	*Figure 2.32*

Table 2.7 Password and Breaker Jumper Operation

Jumper Type	Jumper Position	Function
Password	ON (in place)	disable password protection[a] for serial ports and front panel
	OFF (removed/not in place)	enable password protection[a] for serial ports and front panel
Breaker	ON (in place)	enable serial port commands **OPEN**[b], **CLOSE**[b], and **PULSE**[c]
	OFF (removed/not in place)	disable serial port commands **OPEN**[b], **CLOSE**[b], and **PULSE**[c]

[a] View or set the passwords with the **PASSWORD** command (see Section 10: Serial Port Communications and Commands).
[b] Also controls Fast Operate Breaker Control Open/Close Commands (see Appendix D: Configuration, Fast Meter, and Fast Operate Commands).
[c] The **OPEN**, **CLOSE**, and **PULSE** commands are used primarily to assert output contacts for circuit breaker control or testing purposes (see Section 10: Serial Port Communications and Commands).

Note that JMP6 in *Figure 2.32* has multiple jumpers A through D. Jumpers A and B are used (see *Table 2.6* and *Table 2.7*). Since jumpers C and D are not used, the positions (ON or OFF) of jumpers C and D are of no consequence.

EIA-232 Serial Port Voltage Jumpers

The jumpers listed in *Table 2.8* connect or disconnect +5 Vdc to Pin 1 on the corresponding EIA-232 serial ports. The +5 Vdc is rated at 0.5 A maximum for each port. See *Table 10.2* for EIA-232 serial port pin functions.

In a standard relay shipment, the jumpers are "OFF" (removed/not in place) so that the +5 Vdc is not connected to Pin 1 on the corresponding EIA-232 serial ports. Put the jumpers "ON" (in place) so that the +5 Vdc is connected to Pin 1 on the corresponding EIA-232 serial ports.

Table 2.8 EIA-232 Serial Port Voltage Jumper Positions for Standard Relay Shipments

EIA-232 Serial Port 2 (rear panel)	EIA-232 Serial Port 3 (rear panel)	Reference Figures
JMP2 = OFF	JMP1 = OFF	*Figure 2.32*

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Condition of Acceptability for North American Product Safety Compliance

To meet product safety compliance for end-use applications in North America, use an external fused rated 3 A or less in-line with the +5 Vdc source on Pin 1. SEL fiber-optic transceivers include a fuse that meets this requirement.

Auxiliary {TRIP}/{CLOSE} Pushbutton and Breaker Status LED Jumpers (0351Sxxx5/6/A/B models only)

The jumpers listed in *Table 2.9* are used to select the proper control voltage for breaker open/closed indicating LEDs on the front panel of the relay. *Figure 2.35* shows the jumper locations on the magnetics/auxiliary pushbutton board. The jumpers come preset from the factory with the voltage range set the same as the control input voltage, as determined by the part number at order time.

The voltage setting can be different for each LED. To access these jumpers, the relay front cover, top cover, main board, and any additional I/O board (if present) must first be removed. See instructions and precautions in the subsection *Accessing the Relay Circuit Boards on page 2.40*.

Table 2.9 Jumper Positions for Breaker OPEN/CLOSE Indication

Option (ac/dc)	BREAKER OPEN LED[a]			BREAKER CLOSED LED[a]		
	JMP4	JMP1	JMP2	JMP6	JMP5	JMP3
24 V	Installed	Installed	Installed	Installed	Installed	Installed
48 V	Not Installed	Installed	Installed	Not Installed	Installed	Installed
110/125 V	Not Installed	Not Installed	Installed	Not Installed	Not Installed	Installed
220/250 V	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed	Not Installed

[a] The front-panel label for these Breaker Status LEDs may differ from the factory default names if user-configurable labels are used. See User-Configurable Label Option for the Front Panel on page 2.9.

Table 2.10 shows how to enable or disable the arc suppression feature of the {TRIP} and {CLOSE} pushbuttons. If ac control power is used to operate the breaker, then the corresponding arc suppression jumper must be removed. If dc control power is used to operate the breaker, then the arc suppression is strongly recommended to break inductive loads. The arc suppression comes enabled from the factory. *Figure 2.35* shows the jumper locations on the magnetics/auxiliary pushbutton board.

NOTE: With arc suppression enabled, the corresponding output polarity marks must be followed when wiring the control.

NOTE: Arc suppression should be disabled when activating high impedance (> 100 kΩ) loads.

Table 2.10 Jumper Positions for Arc Suppression

Option	{TRIP} pushbutton	{CLOSE} pushbutton
	JMP8	JMP7
Arc Suppression Enabled (Factory Default) dc operation only	Installed	Installed
Arc Suppression Disabled ac operation	Not Installed	Not Installed

Clock Battery

Refer to *Figure 2.32* for clock battery location (front of main board). A lithium battery powers the relay clock (date and time) if the external dc source is lost or removed. The battery is a 3 V lithium coin cell. At room temperature (25°C), the battery will nominally operate for 10 years at rated load.

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If the dc source is lost or disconnected, the battery powers the clock. When the relay is powered from an external source, the battery only experiences a low self-discharge rate. Thus, battery life can extend well beyond the nominal 10 years because the battery rarely has to discharge after the relay is installed. The battery cannot be recharged.

If the relay does not maintain the date and time after power loss, replace the battery. Follow the instructions in the previous subsection *Accessing the Relay Circuit Boards on page 2.40* to remove the relay main board.

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.

Remove the battery from beneath the clip and install a new one. The positive side (+) of the battery faces up. Reassemble the relay as described in *Accessing the Relay Circuit Boards*. Set the relay date and time via serial communications port or front panel (see *Section 10: Serial Port Communications and Commands* or *Section 11: Front-Panel Interface*, respectively).w

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Section 3

Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements

Instantaneous/Definite-Time Overcurrent Elements

Phase Instantaneous/ Definite-Time Overcurrent Elements

Four levels of phase instantaneous/definite-time overcurrent elements are available. Two additional levels of phase instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50P enable setting, as shown in *Figure 3.1*, *Figure 3.2*, and *Figure 3.3*.

Level 2 element 67P2S in *Figure 3.3* is used in directional comparison blocking schemes (see *Directional Comparison Blocking (DCB) Logic on page 5.27*). All the other phase instantaneous/definite-time overcurrent elements are available for use in any tripping or control scheme.

Settings Ranges

Setting range for pickup settings 50P1P–50P6P:

0.25–100.00 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)
0.05–20.00 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Setting range for definite-time settings 67P1D–67P4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67P2SD (used in the DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

Accuracy

Pickup:	±0.05 A secondary and ±3% of setting (5 A nominal phase current inputs, **IA**, **IB**, **IC**)
	±0.01 A secondary and ±3% of setting (1 A nominal phase current inputs, **IA**, **IB**, **IC**)
Timer:	±0.25 cycles and ±0.1% of setting
Transient Overreach:	±5% of setting

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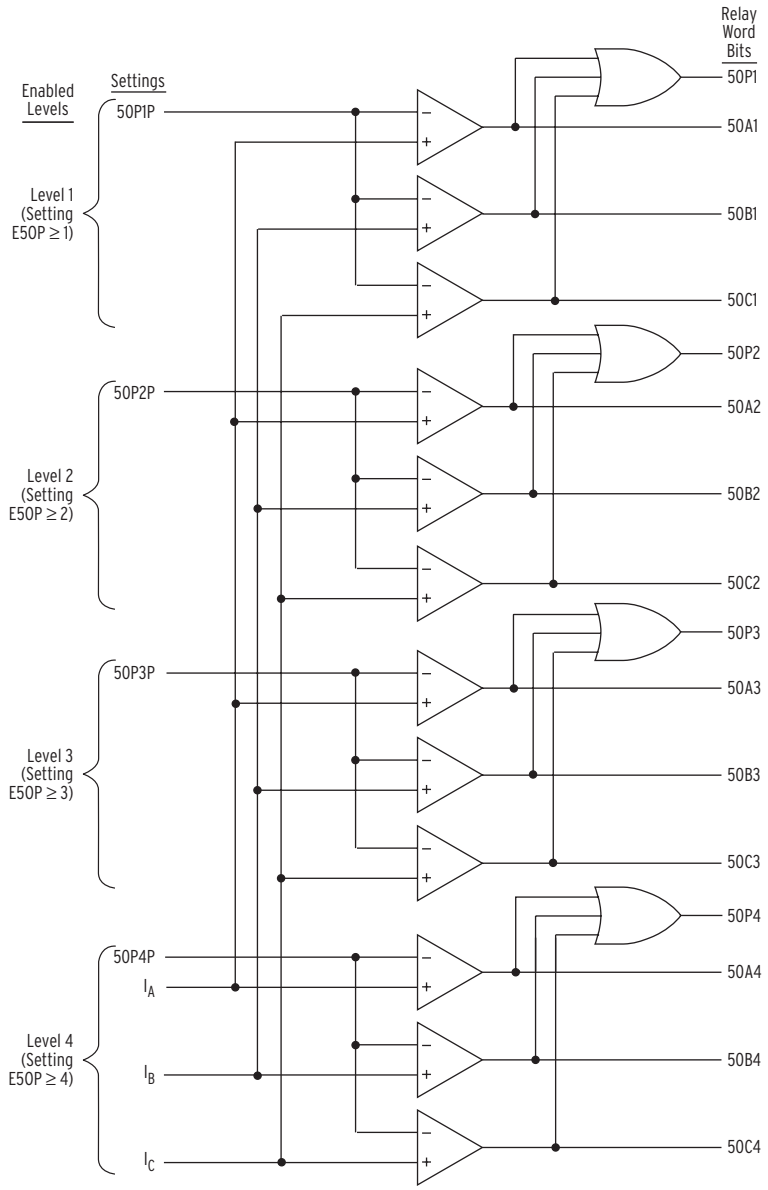


Figure 3.1 Levels 1–4 Phase Instantaneous Overcurrent Elements

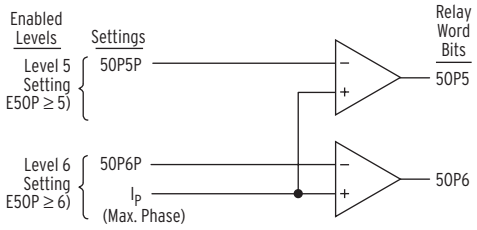


Figure 3.2 Levels 5–6 Phase Instantaneous Overcurrent Elements

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Pickup Operation

The phase instantaneous/definite-time overcurrent element logic begins with *Figure 3.1* and *Figure 3.2*. The pickup settings for each level (50P1P–50P6P) are compared to the magnitudes of the individual phase currents I_A, I_B, and I_C. The logic outputs in *Figure 3.1* and *Figure 3.2* are Relay Word bits and operate as follows (Level 1 example shown):

50A1 = 1 (logical 1), if I_A > pickup setting 50P1P
= 0 (logical 0), if $I_A \leq$ pickup setting 50P1P

50B1 = 1 (logical 1), if I_B > pickup setting 50P1P
= 0 (logical 0), if $I_B \leq$ pickup setting 50P1P

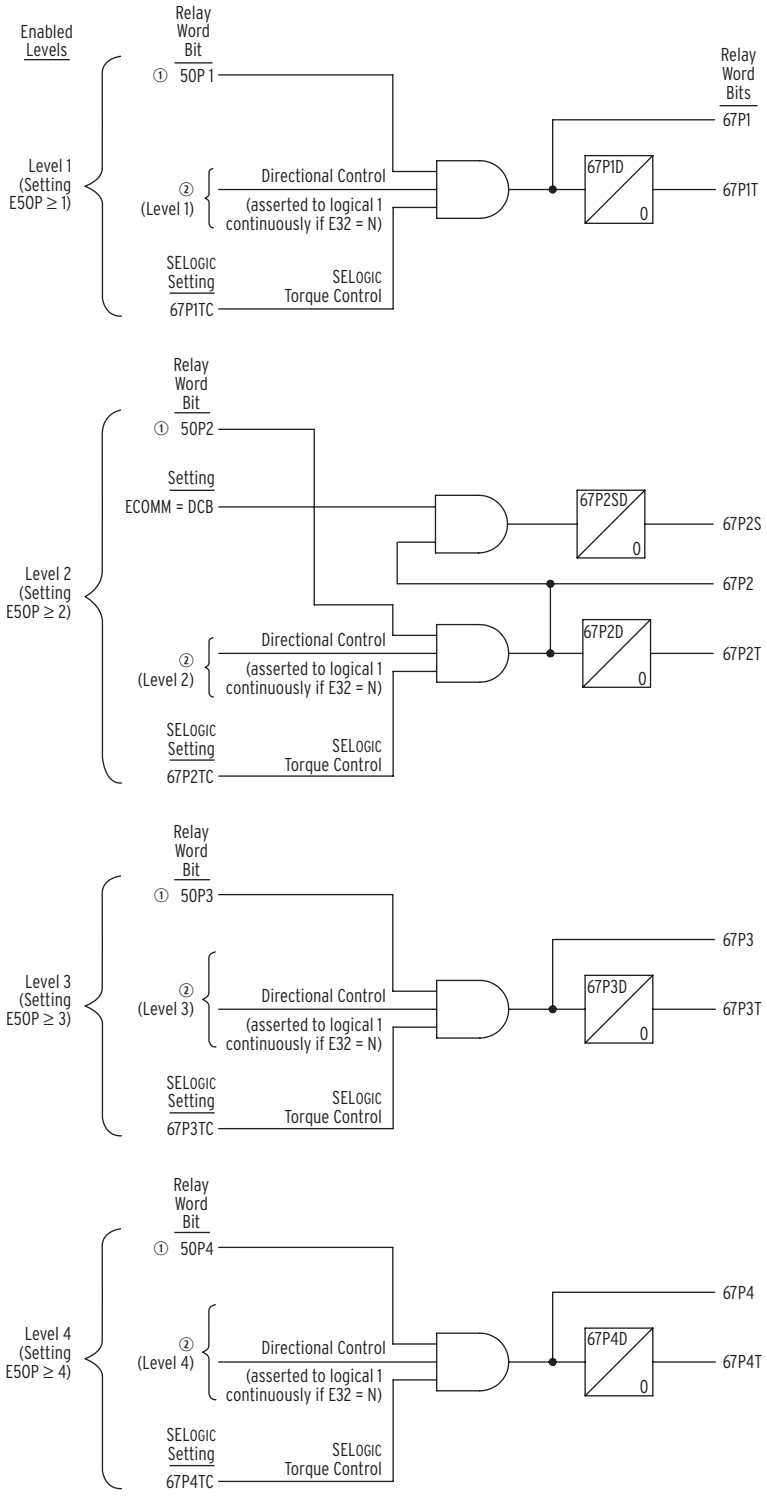
50C1 = 1 (logical 1), if I_C > pickup setting 50P1P
= 0 (logical 0), if $I_C \leq$ pickup setting 50P1P

50P1 = 1 (logical 1), if at least one of the Relay Word bits 50A1, 50B1, or 50C1 is asserted (e.g., 50B1 = 1)
= 0 (logical 0), if all three Relay Word bits 50A1, 50B1, and 50C1 are deasserted (50A1 = 0, 50B1 = 0, and 50C1 = 0)

Note that single-phase overcurrent elements are not available in Levels 5 and 6 (see *Figure 3.2*).

Ideally, set 50P1P > 50P2P > 50P3P > 50P4P so that instantaneous overcurrent elements 67P1–67P4 will display in an organized fashion in event reports (see *Figure 3.3* and *Table 12.3*).

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① From Figure 3.1; ② from Figure 4.24.

Figure 3.3 Levels 1–4 Phase Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

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Directional Control Option

The phase instantaneous overcurrent element Relay Word bit outputs in *Figure 3.1* (50P1, 50P2, 50P3, and 50P4) are inputs into the phase instantaneous/definite-time overcurrent element logic in *Figure 3.3*.

Levels 1–4 in *Figure 3.3* have corresponding directional control options. See *Figure 4.24* for more information on this optional directional control. If the directional control enable setting E32 is set:

E32 = **N**

then directional control is defeated, and the directional control inputs into all four phase instantaneous/definite-time overcurrent element levels in *Figure 3.3* are asserted to logical 1 continuously. Then only the corresponding SELOGIC® control equation torque control settings have to be considered in the control of the phase instantaneous/definite-time overcurrent elements.

For example, consider the Level 1 phase instantaneous/definite-time overcurrent elements 67P1/67P1T in *Figure 3.3*. If the directional control enable setting E32 is set:

E32 = **N**

then the directional control input from *Figure 4.24* (Level 1) is asserted to logical 1 continuously. Then only the corresponding SELOGIC control equation torque control setting 67P1TC has to be considered in the control of the phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

Torque Control

Levels 1–4 in *Figure 3.3* have corresponding SELOGIC control equation torque control settings 67P1TC–67P4TC. SELOGIC control equation torque control settings cannot be set directly to logical 0. The following are torque control setting examples for Level 1 phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

NOTE: All overcurrent element SELOGIC control equation torque control settings are set directly to logical 1 (e.g., 67P1TC = 1) for the factory default settings. See SHO Command (Show/View Settings) on page 10.27 for a list of the factory default settings.

67P1TC = 1 Setting 67P1TC set directly to logical 1:

Then only the corresponding directional control input from *Figure 4.24* has to be considered in the control of phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

If directional control enable setting E32 = N, then phase instantaneous/definite-time overcurrent elements 67P1/67P1T are enabled and nondirectional.

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67P1TC = IN105 Input **IN105** deasserted (67P1TC = IN105 = logical 0):

Then phase instantaneous/definite-time overcurrent elements 67P1/67P1T are defeated and nonoperational, regardless of any other setting.

Input **IN105** asserted (67P1TC = IN105 = logical 1):

Then only the corresponding directional control input from *Figure 4.24* has to be considered in the control of phase instantaneous/definite-time overcurrent elements 67P1/67P1T.

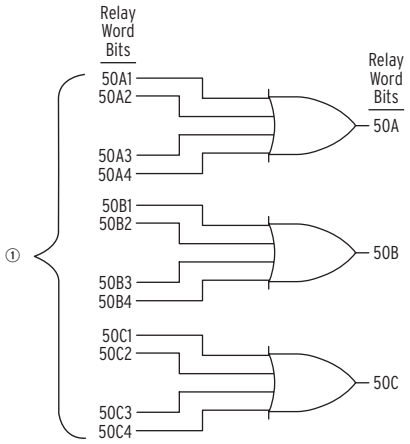
If directional control enable setting E32 = N, then phase instantaneous/ /definite-time overcurrent elements 67P1/67P1T are enabled and nondirectional.

Sometimes SELOGIC control equation torque control settings are set to provide directional control. See *Directional Control Provided by Torque Control Settings on page 4.58*.

Combined Single-Phase Instantaneous Overcurrent Elements

The single-phase instantaneous overcurrent element Relay Word bit outputs in *Figure 3.1* are combined together in *Figure 3.4* on a per phase basis, producing Relay Word bit outputs 50A, 50B, and 50C.

Relay Word bits 50A, 50B, and 50C can be used to indicate the presence or absence of current in a particular phase.



① From Figure 3.1.

Figure 3.4 Combined Single-Phase Instantaneous Overcurrent Elements

Pickup and Reset Time Curves

Figure 3.5 and *Figure 3.6* show pickup and reset time curves applicable to all nondirectional instantaneous overcurrent elements in the SEL-351S Relay (60 Hz or 50 Hz relays). These times do **not** include output contact operating time and, thus, are accurate for determining element operation time for use in internal SELOGIC control equations. Output contact pickup/dropout time is approximately 4 ms (0.25 cycle for a 60 Hz relay; 0.20 cycle for a 50 Hz relay).

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If instantaneous overcurrent elements are made directional, the pickup time curve in *Figure 3.5* is adjusted as follows:

multiples of pickup setting ≤4: add 0.25 cycle

multiples of pickup setting >4: add 0.50 cycle

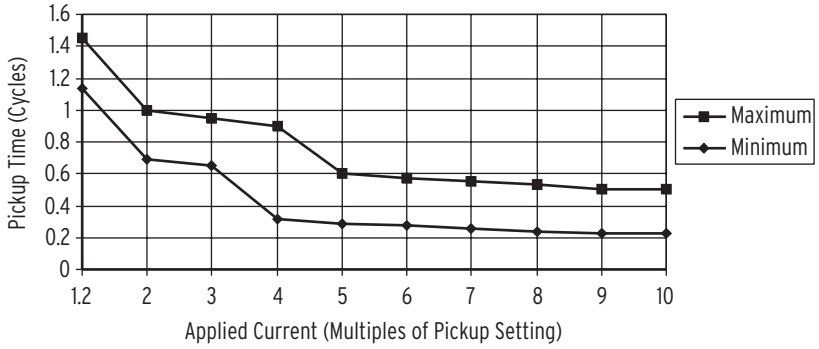


Figure 3.5 SEL-351S Nondirectional Instantaneous Overcurrent Element Pickup Time Curve

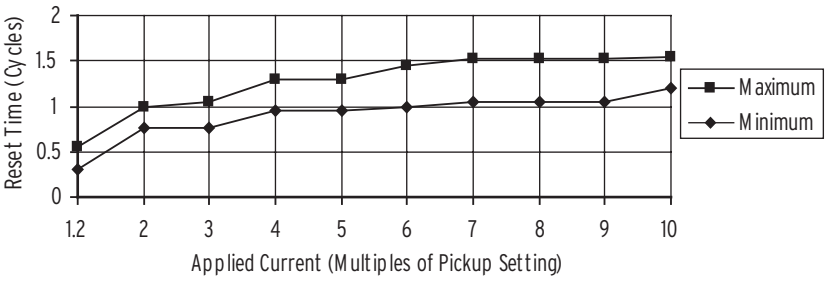


Figure 3.6 SEL-351S Nondirectional Instantaneous Overcurrent Element Reset Time Curve

Phase-to-Phase Instantaneous Overcurrent Elements

Four levels of phase-to-phase instantaneous overcurrent elements are available. The different levels are enabled with the E50P enable setting, as shown in *Figure 3.7*.

Setting Range

Setting range for pickup settings 50PP1P–50PP4P:

1.00–170.00 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)
0.20–34.00 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Accuracy

Pickup: ±0.05 A secondary and ±3% of setting
(5 A nominal phase current inputs, **IA**, **IB**, **IC**)

±0.01 A secondary and ±3% of setting
(1 A nominal phase current inputs, **IA**, **IB**, **IC**)

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Pickup Operation

The pickup settings for each level (50PP1P–50PP4P) are compared to the magnitudes of the individual phase-to-phase difference currents I_{AB}, I_{BC}, and I_{CA}. The logic outputs in *Figure 3.7* are the following Relay Word bits (Level 1 example shown):

50AB1 = 1 (logical 1), if I_{AB} > pickup setting 50PP1P
= 0 (logical 0), if $I_{AB} \leq$ pickup setting 50PP1P

50BC1 = 1 (logical 1), if I_{BC} > pickup setting 50PP1P
= 0 (logical 0), if $I_{BC} \leq$ pickup setting 50PP1P

50CA1 = 1 (logical 1), if I_{CA} > pickup setting 50PP1P
= 0 (logical 0), if $I_{CA} \leq$ pickup setting 50PP1P

Pickup and Reset Time Curves

See *Figure 3.5* and *Figure 3.6*.

Neutral Ground Instantaneous/ Definite-Time Overcurrent Elements

Four levels of neutral ground instantaneous/definite-time overcurrent elements are available. Two additional levels of neutral ground instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50N enable setting, as shown in *Figure 3.8* and *Figure 3.9*.

Level 2 element 67N2S in *Figure 3.8* is used in directional comparison blocking schemes (see *Directional Comparison Blocking (DCB) Logic on page 5.27*). All the other neutral ground instantaneous/definite-time overcurrent elements are available for use in any tripping or control scheme.

To understand the operation of *Figure 3.8* and *Figure 3.9*, follow the explanation given for *Figure 3.1*, *Figure 3.2*, and *Figure 3.3* in the preceding subsection *Phase Instantaneous/Definite-Time Overcurrent Elements on page 3.1*, substituting current I_N (Channel **IN** current) for phase currents and substituting like settings and Relay Word bits.

See *Table 4.3* and accompanying note for a list of the directional features available with each neutral Channel (**IN**) rating.

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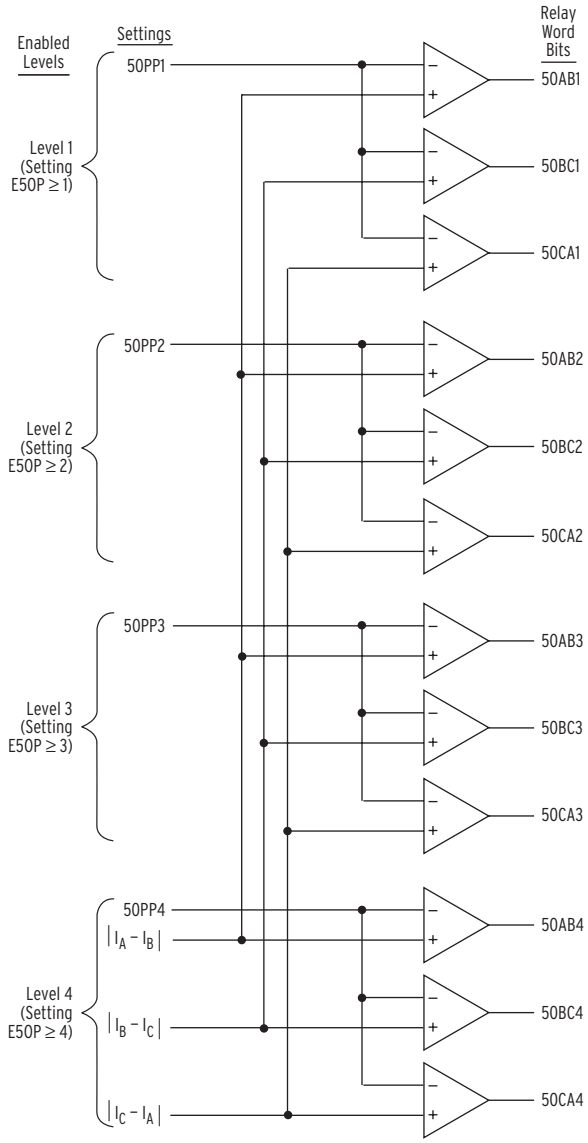
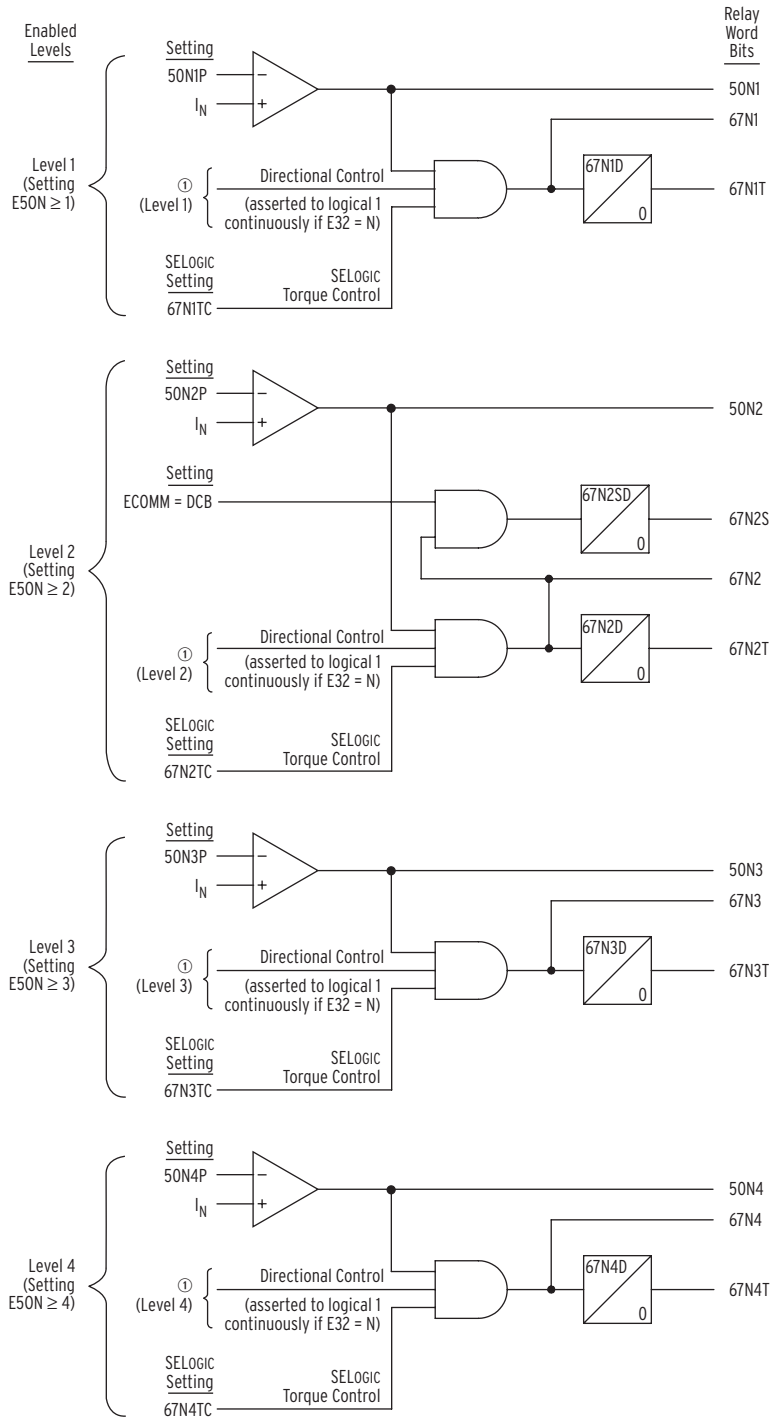


Figure 3.7 Levels 1–4 Phase-to-Phase Instantaneous Overcurrent Elements

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① From Figure 4.18.

Figure 3.8 Levels 1–4 Neutral Ground Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

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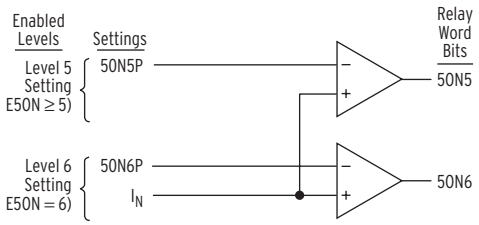


Figure 3.9 Levels 5–6 Neutral Ground Instantaneous Overcurrent Elements

Settings Ranges

Setting range for pickup settings 50N1P–50N6P:

0.250–100.00 A secondary (5 A nominal channel **IN** current input)

0.050–20.00 A secondary (1 A nominal channel **IN** current input)

0.005–2.500 A secondary (0.2 A nominal channel **IN** current input)

0.005–1.500 A secondary (0.05 A nominal channel **IN** current input)

Setting range for definite-time settings 67N1D–67N4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67N2SD (used in DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

NOTE: If channel IN is rated 0.2 A nominal or 0.05 A nominal, then there is an additional 2-cycle time delay on all the neutral ground instantaneous (50N1–50N6, 67N1–67N6) and definite-time (67N1T–67N4T) elements. Any time delay provided by the definite-time settings (67N1D–67N4D) is in **addition** to this 2-cycle time delay.

Accuracy

Pickup:	±0.05 A secondary and ±3% of setting (5 A nominal channel **IN** current input)
	±0.01 A secondary and ±3% of setting (1 A nominal channel **IN** current input)
	±1 mA secondary and ±3% of setting (0.2 A nominal channel **IN** current input)
	±1 mA secondary and ±5% of setting (0.05 A nominal channel **IN** current input)
Timer:	±0.25 cycles and ±0.1% of setting
Transient Overreach:	±5% of setting

Pickup and Reset Time Curves

See *Figure 3.5* and *Figure 3.6*.

Residual Ground Instantaneous/ Definite-Time Overcurrent Elements

Four levels of residual ground instantaneous/definite-time overcurrent elements are available. Two additional levels of residual ground instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50G enable setting, as shown in *Figure 3.10* and *Figure 3.11*.

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Level 2 element 67G2S in *Figure 3.10* is used in directional comparison blocking schemes (see *Directional Comparison Blocking (DCB) Logic on page 5.27*). All the other residual ground instantaneous/definite-time overcurrent elements are available for use in any tripping or control scheme.

To understand the operation of *Figure 3.10* and *Figure 3.11*, follow the explanation given for *Figure 3.1*, *Figure 3.2*, and *Figure 3.3* in the preceding subsection *Phase Instantaneous/Definite-Time Overcurrent Elements on page 3.1*, substituting residual ground current I_G ($I_G = 3I_0 = I_A + I_B + I_C$) for phase currents and substituting like settings and Relay Word bits.

Settings Ranges

NOTE: For pickup settings below:

0.25 A secondary (5 A nominal)

0.05 A secondary (1 A nominal)

an additional 2-cycle time delay is added on all residual ground instantaneous (50G1–50G6, 67G1–67G6) and definite-time (67G1T–67G6T) overcurrent elements. Any time delay provided by the definite-time settings (67G1D–67G4D) is in **addition** to this 2-cycle time delay.

Setting range for pickup settings 50G1P–50G6P:

0.050–100.000 A secondary in 0.010 A steps
(5 A nominal phase current inputs, **IA**, **IB**, **IC**)

0.010–20.000 A secondary in 0.002 A steps
(1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Setting range for definite-time settings 67G1D–67G4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67G2SD (used in DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

Accuracy

Pickup: ±0.05 A secondary and ±3% of setting
(5 A nominal phase current inputs, **IA**, **IB**, **IC**)

±0.01 A secondary and ±3% of setting
(1 A nominal phase current inputs, **IA**, **IB**, **IC**)

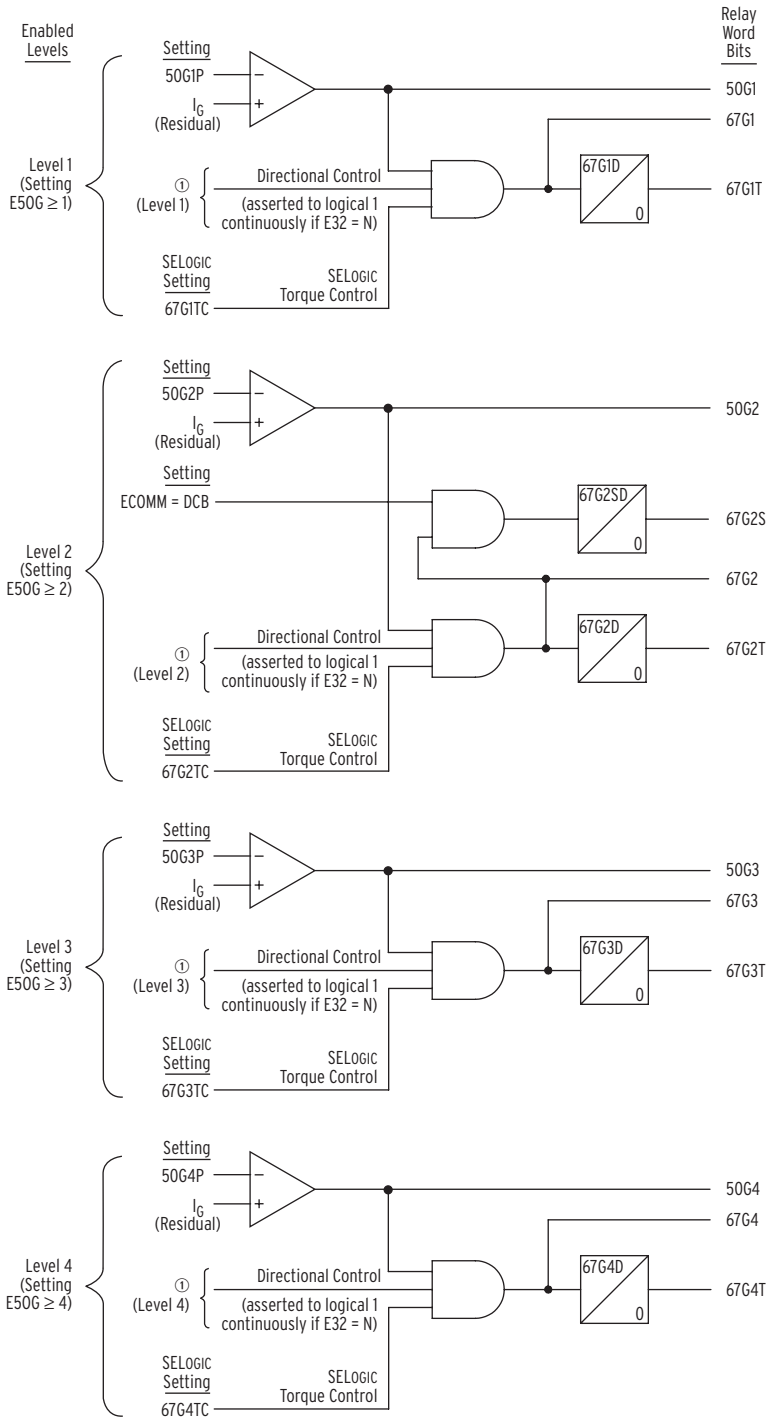
Timer: ±0.25 cycles and ±0.1% of setting

Transient Overreach: ±5% of setting

Pickup and Reset Time Curves

See *Figure 3.5* and *Figure 3.6*.

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① From Figure 4.17.

Figure 3.10 Levels 1–4 Residual Ground Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

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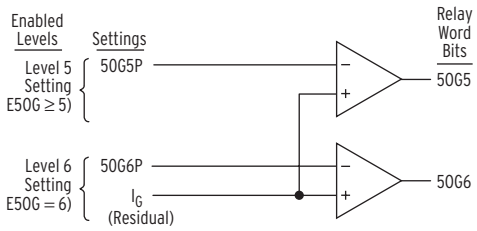


Figure 3.11 Levels 5–6 Residual Ground Instantaneous Overcurrent Elements

Negative-Sequence Instantaneous/ Definite-Time Overcurrent Elements

IMPORTANT: See *Appendix F: Setting Negative-Sequence Overcurrent Elements* for information on setting negative-sequence overcurrent elements.

Four levels of negative-sequence instantaneous/definite-time overcurrent elements are available. Two additional levels of negative-sequence instantaneous overcurrent elements (Levels 5 and 6) are also available. The different levels are enabled with the E50Q enable setting, as shown in *Figure 3.12* and *Figure 3.13*.

Level 2 element 67Q2S in *Figure 3.12* is used in directional comparison blocking schemes (see *Directional Comparison Blocking (DCB) Logic on page 5.27)*. All the other negative-sequence instantaneous/definite-time overcurrent elements are available for use in any tripping or control scheme.

To understand the operation of *Figure 3.12* and *Figure 3.13*, follow the explanation given for *Figure 3.1*, *Figure 3.2*, and *Figure 3.3* in the preceding subsection *Phase Instantaneous/Definite-Time Overcurrent Elements on page 3.1*, substituting negative-sequence current $3I_2$ [$3I_2 = I_A + a^2 \cdot I_B + a \cdot I_C$ (ABC rotation), $3I_2 = I_A + a^2 \cdot I_C + a \cdot I_B$ (ACB rotation), where $a = 1 \angle 120°$ and $a^2 = 1 \angle -120°$] for phase currents and substituting like settings and Relay Word bits.

Settings Ranges

Setting range for pickup settings 50Q1P–50Q6P:

0.25–100.00 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)
0.05–20.00 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

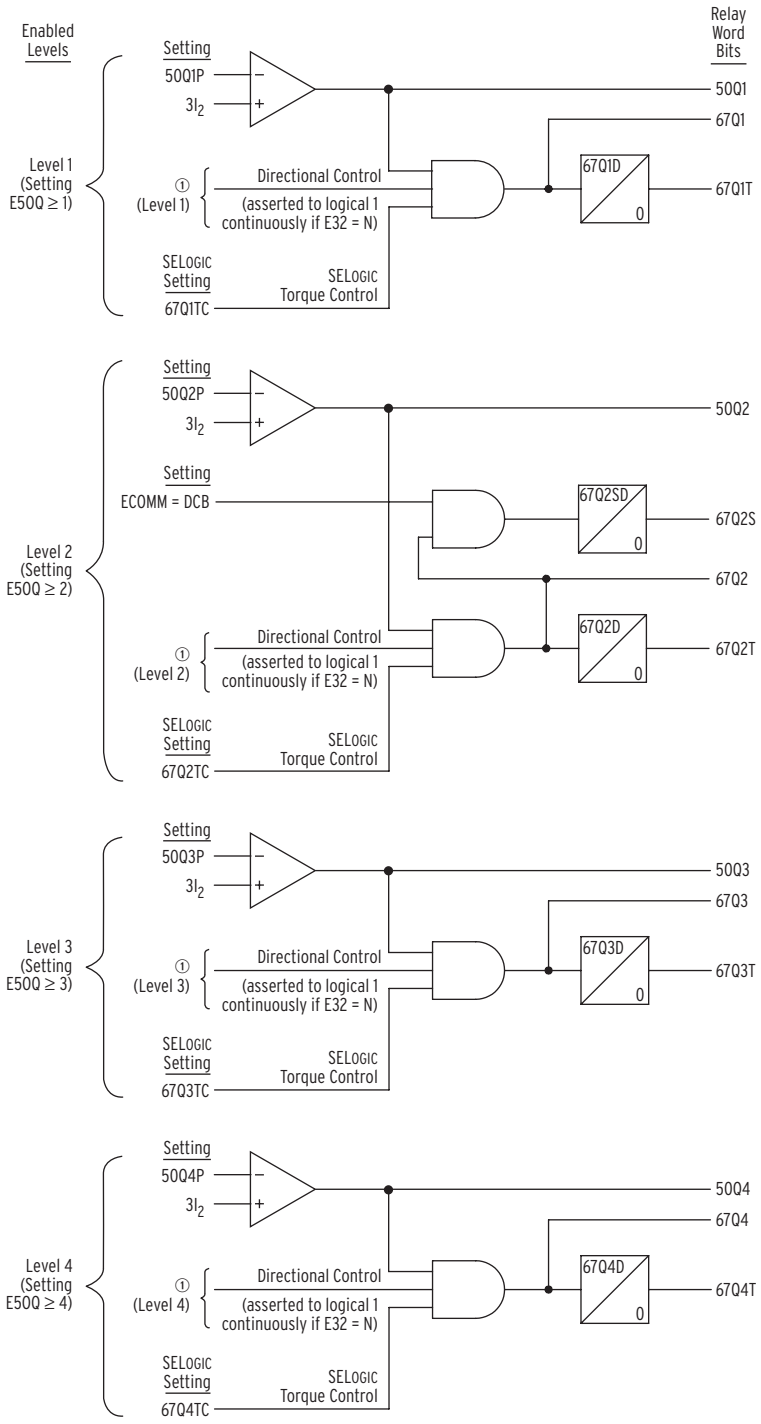
Setting range for definite-time settings 67Q1D–67Q4D:

0.00–16000.00 cycles, in 0.25-cycle steps

Setting range for definite-time setting 67Q2SD (used in DCB logic):

0.00–60.00 cycles, in 0.25-cycle steps

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① From Figure 4.23.

Figure 3.12 Levels 1–4 Negative-Sequence Instantaneous/Definite-Time Overcurrent Elements (With Directional Control Option)

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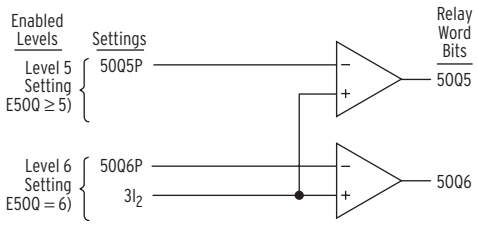


Figure 3.13 Levels 5–6 Negative-Sequence Instantaneous Overcurrent Elements

Accuracy

Pickup:	±0.05 A secondary and ±3% of setting (5 A nominal phase current inputs, **IA**, **IB**, **IC**)
	±0.01 A secondary and ±3% of setting (1 A nominal phase current inputs, **IA**, **IB**, **IC**)
Timer:	±0.25 cycles and ±0.1% of setting
Transient Overreach:	±5% of setting

Pickup and Reset Time Curves

See *Figure 3.5* and *Figure 3.6*.

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Time-Overcurrent Elements

Phase Time-Overcurrent Elements

Two phase time-overcurrent elements, 51P1T and 51P2T, are available. The elements are enabled with the E51P enable setting as follows:

Table 3.1 Available Phase Time-Overcurrent Elements

Time-Overcurrent Element	Enabled With Setting	Operating Current	See Figure
51P1T 51P2T	E51P = 1 or 2 E51P = 2	I_P, maximum of A-, B-, and C-phase currents	*Figure 3.14* *Figure 3.15*

The following is an example of 51P1T element operation. 51P2T is similar.

Settings Ranges

Besides the settings involved with the Torque Control Switch operation in *Figure 3.14* and *Figure 3.15*, the 51P1T and 51P2T phase time-overcurrent elements have the following settings:

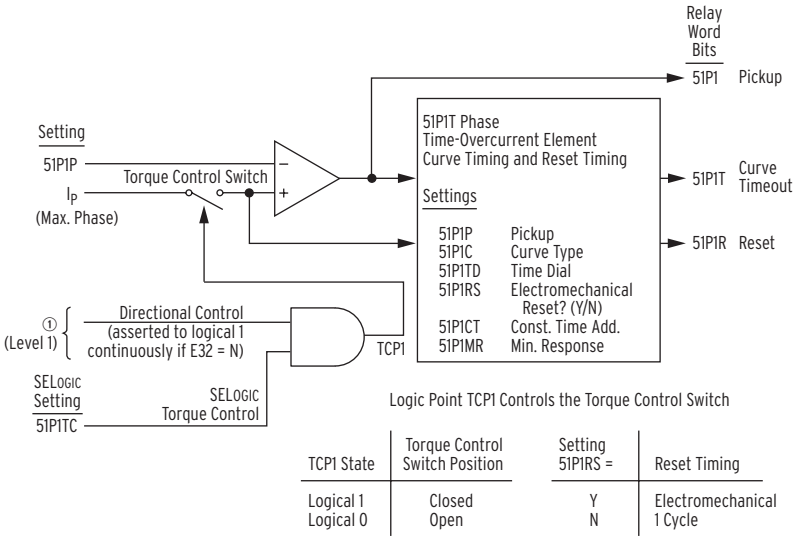
Table 3.2 Phase Time-Overcurrent Elements Settings

Setting	Definition	Range
51P1P 51P2P	pickup	0.25–16.00 A secondary (5 A nominal phase current inputs, IA, IB, IC) 0.05–3.20 A secondary (1 A nominal phase current inputs, IA, IB, IC)
51P1C 51P2C	curve type	U1–U5 (US curves), C1–C5 (IEC curves), recloser curves (*Table 9.5*)—see *Figure 9.1–Figure 9.20*
51P1TD 51P2TD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (US curves), 0.05–1.00 (IEC curves)—see *Figure 9.1–Figure 9.10*; 0.10–2.00 (recloser curves)
51P1RS 51P2RS	electromechanical reset timing	Y, N[a]
51P1CT 51P2CT	constant time adder—adds additional time to curve	0.00–60.00 cycles (no effect if set = 0.00)
51P1MR 51P2MR	minimum response time—flattens curve at set time; curve can operate no faster than this set time	0.00–60.00 cycles (no effect if set = 0.00)
51P1TC 51P2TC	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table 9.6* or set directly to logical 1 (=1)[b]

[a] The electromechanical reset setting (51P1RS) is not available when the curve selection setting (51P1C) is set to a recloser curve. In this situation, 51P1RS is effectively set to "N" internally. Similarly, setting 51P2RS is not available when setting 51P2C is set to a recloser curve.
[b] SELOGIC control equation torque control setting (e.g., 51P1TC) cannot be set directly to logical 0.

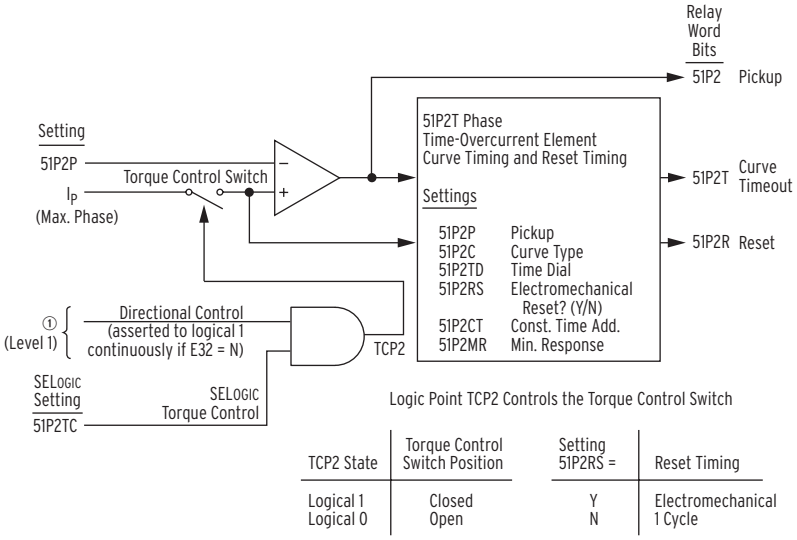
See *Section 9: Setting the Relay* for additional time-overcurrent element setting information.

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① From Figure 4.24.

Figure 3.14 Phase Time-Overcurrent Element 51P1T (With Directional Control Option)



① From Figure 4.24.

Figure 3.15 Phase Time-Overcurrent Element 51P2T (With Directional Control Option)

Accuracy

Pickup: ±0.05 A secondary and ±3% of setting
(5 A nominal phase current inputs, **IA**, **IB**, **IC**)

±0.01 A secondary and ±3% of setting
(1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Curve Timing: ±1.50 cycles and ±4% of cure time for currents between (and including) 2 and 30 multiples of pickup

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Logic Outputs (51P1T Element Example)

The resultant logic outputs in *Figure 3.14* are the following Relay Word bits:

Table 3.3 Phase Time-Overcurrent Element (maximum phase) Logic Outputs

Relay Word Bit	Definition/Indication	Application
51P1	Maximum phase current, I_P, is greater than phase time-overcurrent element pickup setting 51P1P.	Element pickup testing or other control applications. See *Trip Logic on page 5.1*.
51P1T	Phase time-overcurrent element is timed out on its curve.	Tripping and other control applications. See *Trip Logic*.
51P1R	Phase time-overcurrent element is fully reset.	Element reset testing or other control applications.

Torque Control Switch Operation (51P1T Element Example)

Torque Control Switch Closed

The pickup comparator in *Figure 3.14* compares the pickup setting (51P1P) to the maximum phase current, I_P if the Torque Control Switch is closed. I_P is also routed to the curve timing/reset timing functions. The Relay Word Bits logic outputs operate as follows with the Torque Control Switch closed:

51P1 = 1 (logical 1), if I_P > pickup setting 51P1P and the phase time-overcurrent element is timing or is timed out on its curve
= 0 (logical 0), if $I_P \leq$ pickup setting 51P1P

51P1T = 1 (logical 1), if I_P > pickup setting 51P1P and the phase time-overcurrent element is timed out on its curve
= 0 (logical 0), if I_P > pickup setting 51P1P and the phase time-overcurrent element is timing, but not yet timed out on its curve
= 0 (logical 0), if $I_P \leq$ pickup setting 51P1P

51P1R = 1 (logical 1), if $I_P \leq$ pickup setting 51P1P and the phase time-overcurrent element is fully reset
= 0 (logical 0), if $I_P \leq$ pickup setting 51P1P and the phase time-overcurrent element is timing to reset (not yet fully reset)
= 0 (logical 0), if I_P > pickup setting 51P1P and the phase time-overcurrent element is timing or is timed out on its curve

Torque Control Switch Open

If the Torque Control Switch in *Figure 3.14* is open, maximum phase current, I_P, **cannot** get through to the pickup comparator (setting 51P1P) and the curve timing/reset timing functions. For example, suppose that the Torque Control Switch is closed, I_P is:

I_P > pickup setting 51P1P

and the phase time-overcurrent element is timing or is timed out on its curve. If the Torque Control Switch is then opened, I_P effectively appears as a magnitude of zero (0) to the pickup comparator:

I_P = 0 A (effective) < pickup setting 51P1P

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resulting in Relay Word bit 51P deasserting to logical 0. I_P also effectively appears as a magnitude of zero (0) to the curve timing/reset timing functions, resulting in Relay Word bit 51P1T also deasserting to logical 0. The phase time-overcurrent element then starts to time to reset. Relay Word bit 51P1R asserts to logical 1 when the phase time-overcurrent element is fully reset.

Control of Logic Point TCP1

Refer to *Figure 3.14*.

The Torque Control Switch is controlled by logic point TCP1. Logic point TCP1 is controlled by directional control (optional) and SELOGIC control equation torque control setting 51P1TC.

If logic point TCP1 = logical 1, the Torque Control Switch is closed and maximum phase current, I_P, is routed to the pickup comparator (setting 51P1P) and the curve timing/reset timing functions.

If logic point TCP1 = logical 0, the Torque Control Switch is open and maximum phase current, I_P, **cannot** get through to the pickup comparator and the curve timing/reset timing functions. The maximum phase current, I_P, effectively appears as a magnitude of zero (0) to the pickup comparator and the curve timing/reset timing function.

Directional Control Option

Refer to *Figure 3.14*.

See *Figure 4.24* for more information on the optional directional control. If the directional control enable setting E32 is set:

E32 = **N**

then directional control is defeated, and the directional control input into logic point TCP1 in *Figure 3.14* is asserted to logical 1 continuously. Then, only the corresponding SELOGIC control equation torque control setting 51P1TC has to be considered in the control of logic point TCP1 (and, thus, in the control of the Torque Control Switch and phase time-overcurrent element 51P1T).

Torque Control

Refer to *Figure 3.14*.

SELOGIC control equation torque control settings (e.g., 51P1TC) cannot be set directly to logical 0. The following are setting examples of SELOGIC control equation torque control setting 51P1TC for phase time-overcurrent element 51P1T.

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NOTE: Some of the overcurrent element SELOGIC control equation torque control settings are set directly to logical 1 (e.g., 51QTC = 1) for the factory default settings. See SHO Command (Show/View Settings) on page 10.27 for a list of the factory default settings.

51P1TC = 1 Setting 51P1TC set directly to logical 1:

Then only the corresponding directional control input from *Figure 4.24* has to be considered in the control of logic point TCP1 (and, thus, in the control of the Torque Control Switch and phase time-overcurrent element 51P1TC).

If directional control enable setting E32 = N, then logic point TCP1 = logical 1 and, thus, the Torque Control Switch closes and phase time-overcurrent element 51P1TC is enabled and nondirectional.

51P1TC = IN105 Input IN105 deasserted (51P1TC = IN105 = logical 0):

Then logic point TCP1 = logical 0 and, thus, the Torque Control Switch opens and phase time-overcurrent element 51P1T is defeated and nonoperational, regardless of any other setting.

Input IN105 asserted (51P1TC = IN105 = logical 1):

Then only the corresponding directional control input from *Figure 4.24* has to be considered in the control of logic point TCP1 (and, thus, in the control of the Torque Control Switch and phase time-overcurrent element 51P1T).

If directional control enable setting E32 = N, then logic point TCP1 = logical 1 and, thus, the Torque Control Switch closes and phase time-overcurrent element 51P1T is enabled and nondirectional.

Sometimes SELOGIC control equation torque control settings are set to provide directional control. See *Directional Control Provided by Torque Control Settings on page 4.58*.

Reset Timing Details (51P1T Element Example)

Refer to *Figure 3.14*.

Any time current I_P goes above pickup setting 51P1P and the phase time-overcurrent element starts timing, Relay Word bit 51P1R (reset indication) = logical 0. If the phase time-overcurrent element times out on its curve, Relay Word bit 51P1T (curve time-out indication) = logical 1.

Setting 51P1RS = Y

If electromechanical reset timing setting 51P1RS = Y, the phase time-overcurrent element reset timing emulates electromechanical reset timing. If maximum phase current, I_P, goes above pickup setting 51P1P (element is timing or already timed out) and then current I_P goes below 51P1P, the element starts to time to reset, emulating electromechanical reset timing. Relay Word bit 51P1R (resetting indication) = logical 1 when the element is fully reset.

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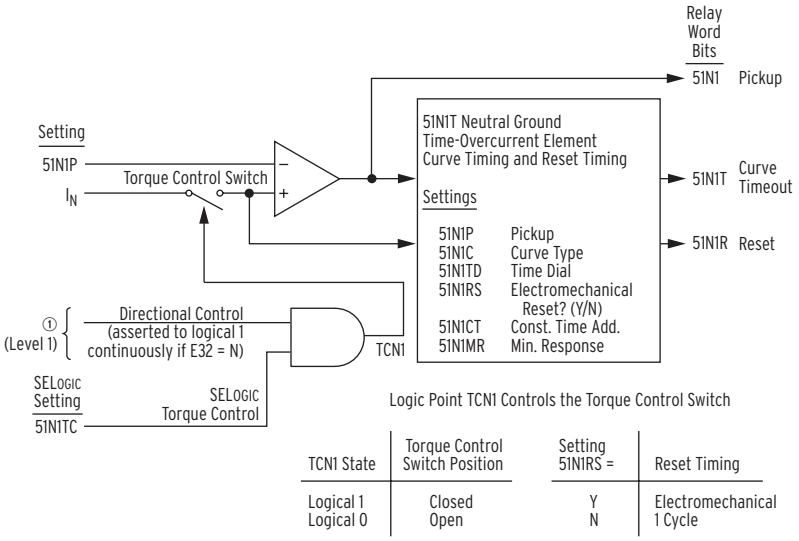
Setting 51P1RS = N

If reset timing setting 51P1RS = N, element 51P1T reset timing is a 1-cycle dropout. If current I_P goes above pickup setting 51P1P (element is timing or already timed out) and then current I_P goes below pickup setting 51P1P, there is a 1-cycle delay before the element fully resets. Relay Word bit 51P1R (reset indication) = logical 1 when the element is fully reset.

Neutral Ground Time-Overcurrent Elements

To understand the operation of *Figure 3.16* and *Figure 3.17*, follow the explanation given for *Figure 3.14* in the preceding subsection *Phase Time-Overcurrent Elements on page 3.17*, substituting current I_N (channel IN current) for maximum phase current I_P and substituting like settings and Relay Word bits.

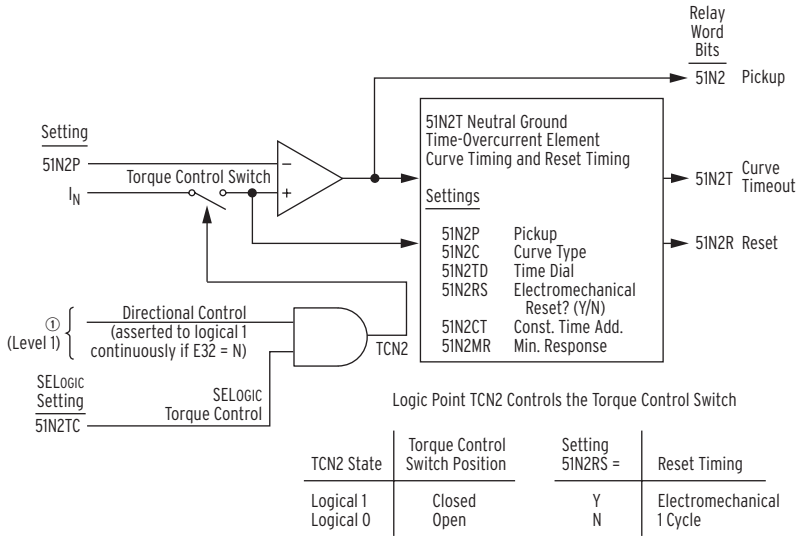
See *Table 4.3* and the accompany note for a list of the directional features available with each neutral channel (**IN**) rating.



① From Figure 4.18.

Figure 3.16 Neutral Ground Time-Overcurrent Element 51N1T (With Directional Control Option)

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① From Figure 4.18.

Figure 3.17 Neutral Ground Time-Overcurrent Element 51N2T (With Directional Control Option)

Settings Ranges

Table 3.4 Neutral Ground Time-Overcurrent Elements Settings

Setting	Definition	Range
51N1P 51N2P	pickup	0.500–16.000 A secondary (5 A nominal channel IN current input) 0.100–3.200 A secondary (1 A nominal channel IN current input) 0.005–0.640 A secondary (0.2 A nominal channel IN current input) 0.005–0.160 A secondary (0.05 A nominal channel IN current input)
51N1C 51N2C	curve type	U1–U5 (US curves), C1–C5 (IEC curves), recloser curves (*Table 9.5*) see *Figure 9.1*–*Figure 9.20*
51N1TD 51N2TD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (US curves), 0.05–1.00 (IEC curves)—see *Figure 9.1*–*Figure 9.10*; 0.10–2.00 (recloser curves)
51N1RS 51N2RS	electromechanical reset timing	Y, N[a]
51N1CT 51N2CT	constant time adder—adds additional time to curve	0.00–60.00 cycles (no effect if set = 0.00)
51N1MR 51N2MR	minimum response time—flattens curve at set time; curve can operate no faster than this set time	0.00–60.00 cycles (no effect if set = 0.00)
51N1TC 51N2TC	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table 9.6* or set directly to logical 1 (=1) or logical 0 (= 0)[b]

[a] The electromechanical reset setting (51N1RS) is not available when the curve selection setting (51N1C) is set to a recloser curve. In this situation, 51N1RS is effectively set to "N" internally. Similarly, setting 51N2RS is not available when setting 51N2C is set to a recloser curve.

[b] SELOGIC control equation torque control setting (e.g., 51N1TC) cannot be set directly to logical 0.

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See *Section 9: Setting the Relay* for additional time-overcurrent element setting information.

Accuracy

Pickup: ±0.05 A secondary and ±3% of setting
(5 A nominal channel **IN** current input)

±0.01 A secondary and ±3% of setting
(1 A nominal channel **IN** current input)

±5 mA secondary and ±3% of setting
(0.2 A nominal channel **IN** current input)

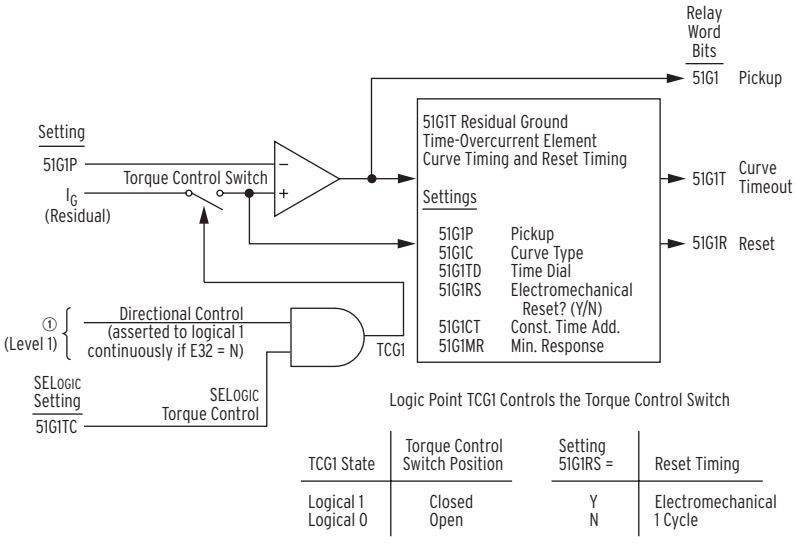
±1 mA secondary and ±5% of setting
(0.05 A nominal channel **IN** current input)

Curve Timing: ±1.50 cycles and ±4% of curve time for currents between (and including) 2 and 30 multiples of pickup.

±3.50 cycles and ±4% of curve time for currents between (and including) 2 and 30 multiples of pickup for 0.05 A nominal channel **IN** current input.

Residual Ground Time-Overcurrent Elements

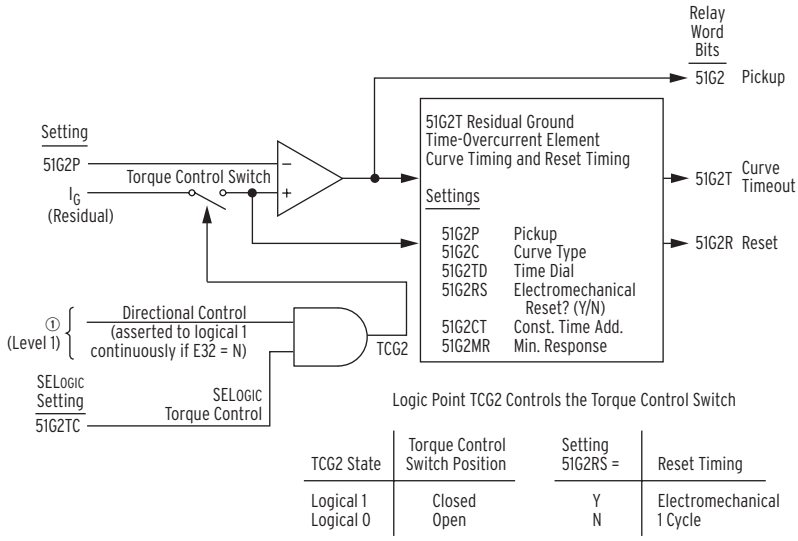
To understand the operation of *Figure 3.18* and *Figure 3.19*, follow the explanation given for *Figure 3.14* in the preceding subsection *Phase Time-Overcurrent Elements on page 3.17*, substituting residual ground current I_G ($I_G = 3I_0 = I_A + I_B + I_C$) for maximum phase current I_P and substituting like settings and Relay Word bits.



① From Figure 4.17.

Figure 3.18 Residual Ground Time-Overcurrent Element 51G1T (With Directional Control Option)

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① From Figure 4.17.

Figure 3.19 Residual Ground Time-Overcurrent Element 51G2T (With Directional Control Option)

Settings Ranges

Table 3.5 Residual Ground Time-Overcurrent Elements Settings

Setting	Definition	Range
51G1P 51G2P	pickup	0.10–16.00 A secondary (5 A nominal phase current inputs, IA, IB, IC) 0.02–3.20 A secondary (1 A nominal phase current inputs, IA, IB, IC)
51G1C 51G2C	curve type	U1–U5 (US curves), C1–C5 (IEC curves), recloser curves (*Table 9.5*)—see *Figure 9.1–Figure 9.20*
51G1TD 51G2TD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (US curves), 0.05–1.00 (IEC curves)—see *Figure 9.1–Figure 9.10*; 0.10–2.00 (recloser curves)
51G1RS 51G2RS	electromechanical reset timing	Y, N[a]
51G1CT 51G2CT	constant time adder—adds additional time to curve	0.00–60.00 cycles (no effect if set = 0.00)
51G1MR 51G2MR	minimum response time—flattens curve at set time; curve can operate no faster than this set time	0.00–60.00 cycles (no effect if set = 0.00)
51G1TC 51G2TC	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table 9.6* or set directly to logical 1 (=1) or logical 0 (= 0)[b]

[a] The electromechanical reset setting (51G1RS) is not available when the curve selection setting (51G1C) is set to a recloser curve. In this situation, 51G1RS is effectively set to "N" internally. Similarly, setting 51G2RS is not available when setting 51G2C is set to a recloser curve.

[b] SELOGIC control equation torque control setting (e.g., 51G1TC) cannot be set directly to logical 0.

See *Section 9: Setting the Relay* for additional time-overcurrent element setting information.

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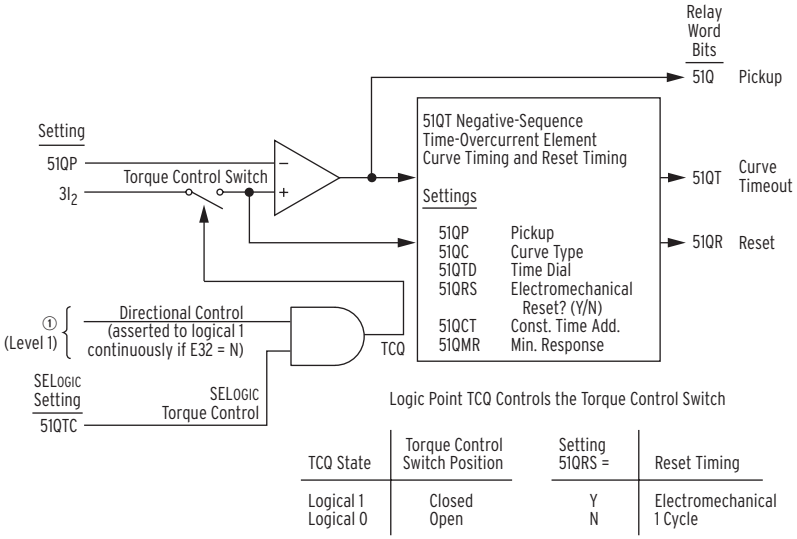
Accuracy

Pickup: ±0.05 A secondary and ±3% of setting
(5 A nominal phase current inputs, **IA**, **IB**, **IC**)

±0.01 A secondary and ±3% of setting
(1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Curve Timing: ±1.50 cycles and ±4% of curve time for currents between (and including) 2 and 30 multiples of pickup.

Negative-Sequence Time-Overcurrent Element



① From Figure 4.23.

Figure 3.20 Negative-Sequence Time-Overcurrent Element 51QT (with Directional Control Option)

IMPORTANT: See *Appendix F: Setting Negative-Sequence Overcurrent Elements* for information on setting negative-sequence overcurrent elements.

To understand the operation of *Figure 3.20*, follow the explanation given for *Figure 3.14* in the preceding subsection *Phase Time-Overcurrent Elements on page 3.17*, substituting negative-sequence current $3I_2$ [$3I_2 = I_A + a^2 \cdot I_B + a \cdot I_C$ (ABC rotation), $3I_2 = I_A + a^2 \cdot I_C + a \cdot I_B$ (ACB rotation), where $a = 1 \angle 120°$ and $a^2 = 1 \angle -120°$] for maximum phase current I_P and like settings and Relay Word bits.

Settings Ranges

Table 3.6 Negative-Sequence Time-Overcurrent Elements Settings
(Sheet 1 of 2)

Setting	Definition	Range
51QP	pickup	0.25–16.00 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**) 0.05–3.20 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)
51QC	curve type	U1–U5 (US curves), C1–C5 (IEC curves), recloser curves (*Table 9.5*)—see *Figure 9.1–Figure 9.20*

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Table 3.6 Negative-Sequence Time-Overcurrent Elements Settings (Sheet 2 of 2)

Setting	Definition	Range
51QTD	time dial (has no multiplying effect on constant time adder or minimum response time)	0.50–15.00 (US curves), 0.05–1.00 (IEC curves)—see *Figure 9.1*–*Figure 9.10*; 0.10–2.00 (recloser curves)
51QRS	electromechanical reset timing	Y, N[a]
51QCT	constant time adder—adds additional time to curve	0.00–60.00 cycles (no effect if set = 0.00)
51QMR	minimum response time—flattens curve at set time; curve can operate no faster than this set time	0.00–60.00 cycles (no effect if set = 0.00)
51QTC	SELOGIC control equation torque control setting	Relay Word bits referenced in *Table 9.6* or set directly to logical 1 (=1) or logical 0 (= 0)[b]

[a] The electromechanical reset setting (51QRS) is not available when the curve selection setting (51QC) is set to a recloser curve. In this situation, 51QRS is effectively set to "N" internally.
[b] SELOGIC control equation torque control setting (e.g., 51QTC) cannot be set directly to logical 0.

See *Section 9: Setting the Relay* for additional time-overcurrent element setting information.

Accuracy

Pickup: ±0.05 A secondary and ±3% of setting
(5 A nominal phase current inputs, IA, IB, IC)

±0.01 A secondary and ±3% of setting
(1 A nominal phase current inputs, IA, IB, IC)

Curve Timing: ±1.50 cycles and ±4% of curve time for currents between (and including) 2 and 30 multiples of pickup.

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Voltage Elements

Enable numerous voltage elements by making the enable setting:

EVOLT = **Y**

Voltage Values

The voltage elements operate off of various voltage values shown in *Table 3.7*.

Table 3.7 Voltage Values Used by Voltage Elements

Voltage	Description
V_A	A-phase voltage, from SEL-351S rear-panel voltage input **VA**[a]
V_B	B-phase voltage, from SEL-351S rear-panel voltage input **VB**[a]
V_C	C-phase voltage, from SEL-351S rear-panel voltage input **VC**[a]
V_{AB}	Phase-to-phase voltage[b]
V_{BC}	Phase-to-phase voltage[b]
V_{CA}	Phase-to-phase voltage
$3V_0$	Zero-sequence voltage[a]
V_2	Negative-sequence voltage
V_1	Positive-sequence voltage
V_S	Synchronism check voltage, from SEL-351S rear-panel voltage input **VS**[c]

[a] Not available when delta connected (PTCONN=DELTA).
[b] Measured directly when delta connected.
[c] Voltage VS can be used in the synchronism check elements when global setting VSCONN = VS (see Synchronism Check Elements on page 3.36). Voltage VS can be connected to a zero-sequence voltage source (typically a broken-delta connection) when global setting VSCONN = 3VO (see Broken-Delta VS Connection (Global Setting VSCONN = 3VO) on page 2.20). Voltage VS is also used in the three voltage elements listed in Table 3.9 and in Figure 3.25, **independent** of the VSCONN setting.
Voltage VS cannot be used for 3VO measurement and as a synchronism check input at the same time.

Voltage Element Settings

Table 3.8–Table 3.10 list available voltage elements and the corresponding voltage inputs and settings ranges for SEL-351S Relays (also refer to *Figure 1.2*).

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NOTE: Voltage element pickup settings should not be set near zero, because they can assert or deassert due to noise when no signal is applied. SEL recommends a minimum setting of 2.00 V.

Table 3.8 Voltage Elements Settings and Settings Ranges (Wye-Connected PTs)

Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
27A1	V_A	27P1P 0.00–300.00 V secondary	*Figure 3.21*
27B1	V_B		
27C1	V_C		
3P27 = 27A1 * 27B1 * 27C1			
27A2	V_A	27P2P 0.00–300.00 V secondary	
27B2	V_B		
27C2	V_C		
59A1	V_A	59P1P 0.00–300.00 V secondary	
59B1	V_B		
59C1	V_C		
3P59 = 59A1 * 59B1 * 59C1			
59A2	V_A	59P2P 0.00–300.00 V secondary	
59B2	V_B		
59C2	V_C		
27AB	V_{AB}	27PP 0.00–520.00 V secondary	*Figure 3.22*
27BC	V_{BC}		
27CA	V_{CA}		
59AB	V_{AB}	59PP 0.00–520.00 V secondary	
59BC	V_{BC}		
59CA	V_{CA}		
59N1	$3V_0$	59N1P 0.00–300.00 V secondary	
59N2	$3V_0$	59N2P 0.00–300.00 V secondary	
59Q	V_2	59QP 0.00–200.00 V secondary	
59V1	V_1	59V1P 0.00–300.00 V secondary	

Table 3.9 Voltage Elements Settings and Settings Ranges (VS Channel)

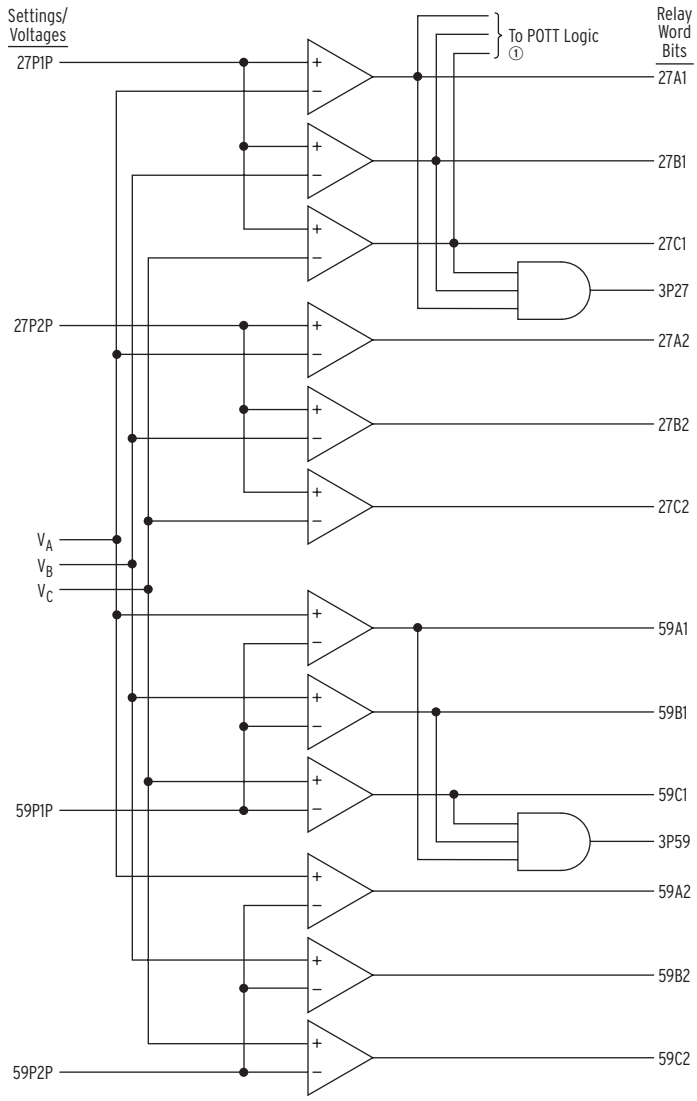
Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
27S	V_S	27SP 0.00–300.00 V secondary	*Figure 3.25*
59S1	V_S	59S1P 0.00–300.00 V secondary	
59S2	V_S	59S2P 0.00–300.00 V secondary	

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Table 3.10 Voltage Elements Settings and Settings Ranges (Delta-Connected PTs)

Voltage Element (Relay Word Bits)	Operating Voltage	Pickup Setting/Range	See Figure
27AB	V_{AB}	27PP 0.00–300.00 V secondary	*Figure 3.23*
27BC	V_{BV}		
27CA	V_{CA}		
3P27 = 27AB * 27BC * 27CA			
27AB2	V_{AB}	27PP2P 0.00–300.00 V secondary	
27BC2	V_{BC}		
27CA2	V_{CA}		
59AB	V_{AB}	59PP 0.00–300.00 V secondary	
59BC	V_{BC}		
59CA	V_{CA}		
3P59 = 59AB * 59BC * 59CA			
59AB2	V_{AB}	59PP2P 0.00–300.00 V secondary	
59BC2	V_{BC}		
59CA2	V_{CA}		
59Q	V_2	59QP 0.00–120.00 V secondary	*Figure 3.24*
59Q2	V_2	59QP2 0.00–120.00 V secondary	
59V1	V_1	59V1P 0.00–170.00 V secondary	

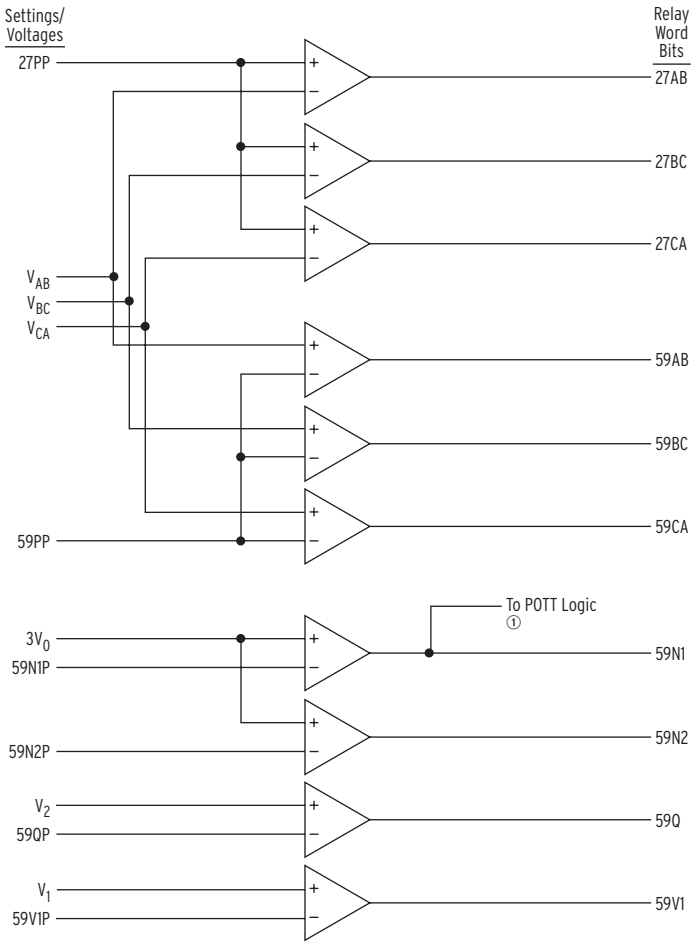
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① Figure 5.6.

Figure 3.21 Single-Phase and Three-Phase Voltage Elements (Wye-Connected PTs)

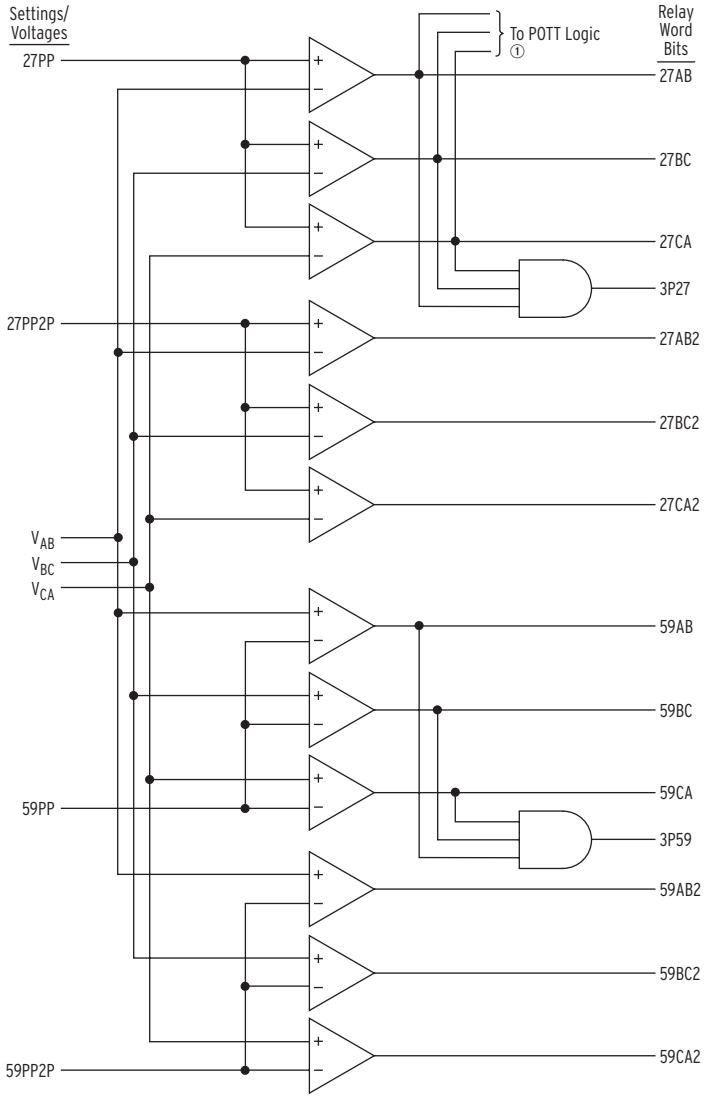
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① Figure 5.6.

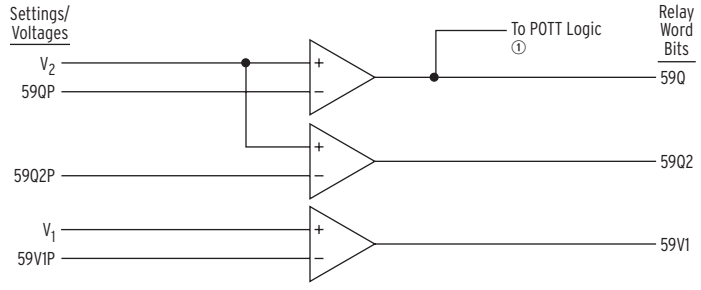
Figure 3.22 Phase-to-Phase and Sequence Voltage Elements (Wye-Connected PTs)

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① Figure 5.6.

Figure 3.23 Phase-to-Phase Voltage Elements (Delta-Connected PTs)



① Figure 5.6.

Figure 3.24 Sequence Voltage Elements (Delta-Connected PTs)

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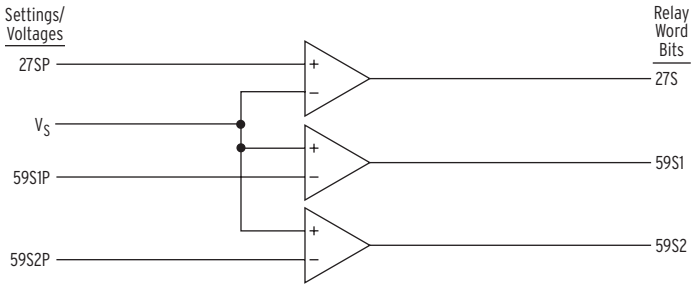


Figure 3.25 Channel VS Voltage Elements (Wye- or Delta-Connected PTs)

Accuracy

Steady-State Pickup Accuracy:	±2 V and ±2% of setting (phase and synchronizing elements) ±2 V and ±4% of setting (negative-, positive-, and zero-sequence elements, phase-to-phase elements)
Transient Overreach:	±5% of pickup

Voltage Element Operation

Note that the voltage elements in *Table 3.8*–*Table 3.10*, and *Figure 3.21*–*Figure 3.25* are a combination of "undervoltage" (Device 27) and "overvoltage" (Device 59) type elements. Undervoltage elements (Device 27) assert when the operating voltage goes **below** the corresponding pickup setting. Overvoltage elements (Device 59) assert when the operating voltage goes **above** the corresponding pickup setting.

Undervoltage Element Operation Example

Refer to *Figure 3.21* (top of the figure).

Pickup setting 27P1P is compared to the magnitudes of the individual phase voltages V_A, V_B, and V_C. The logic outputs in *Figure 3.21* are the following Relay Word bits:

27A1 = 1 (logical 1), if V_A <pickup setting 27P1P
= 0 (logical 0), if V_A ≥pickup setting 27P1P

27B1 = 1 (logical 1), if V_B <pickup setting 27P1P
= 0 (logical 0), if V_B ≥pickup setting 27P1P

27C1 = 1 (logical 1), if V_C <pickup setting 27P1P
= 0 (logical 0), if V_C ≥pickup setting 27P1P

3P27 = 1 (logical 1), if all three Relay Word bits 27A1, 27B1, and 27C1 are asserted (27A1 = 1, 27B1 = 1, and 27C1 = 1)
= 0 (logical 0), if at least one of the Relay Word bits 27A1, 27B1, or 27C1 is deasserted (e.g., 27A1 = 0)

Overvoltage Element Operation Example

Refer to *Figure 3.21* (bottom of the figure).

Pickup setting 59P1P is compared to the magnitudes of the individual phase voltages V_A, V_B, and V_C. The logic outputs in *Figure 3.21* are the following Relay Word bits:

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59A1 = 1 (logical 1), if V_A >pickup setting 59P1P
= 0 (logical 0), if V_A ≤pickup setting 59P1P

59B1 = 1 (logical 1), if V_B >pickup setting 59P1P
= 0 (logical 0), if V_B ≤pickup setting 59P1P

59C1 = 1 (logical 1), if V_C >pickup setting 59P1P
= 0 (logical 0), if V_C ≤pickup setting 59P1P

3P59 = 1 (logical 1), if all three Relay Word bits 59A1, 59B1, and 59C1 are asserted (59A1 = 1, 59B1 = 1, and 59C1 = 1)
0 (logical 0), if at least one of the Relay Word bits 59A1,
= 59B1, or 59C1 is deasserted (e.g., 59A1 = 0)

Voltage Elements Used in POTT Logic

Refer to *Figure 3.21* and *Figure 3.22* for wye-connected voltage inputs. Note that voltage elements 27A1, 27B1, 27C1, and 59N1 are also used in the weak-infeed portion of the POTT logic, if the weak-infeed logic is enabled (see *Figure 5.6*).

Refer to *Figure 3.23* and *Figure 3.24* for delta-connected voltage inputs. Note that voltage elements 27AB, 27BC, 27CA, and 59Q are also used in the weak-infeed portion of the POTT logic, if the weak-infeed logic is enabled (see *Figure 5.6*).

If the weak-infeed portion of the POTT logic is enabled (setting EWFC = Y) and these voltage elements are used in the logic, they can still be used in other applications (if the settings are applicable). If the weak-infeed portion of the POTT logic is not enabled, these voltage elements can be used in any desired application.

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Synchronism Check Elements

Enable the two single-phase synchronism check elements by making the enable setting:

E25 = **Y**

NOTE: If Global Setting VSCONN = 3V0, the synchronism check elements are unavailable and E25 = N is the only possible setting. See Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20 for details.

Figure 2.17–*Figure 2.20*, *Figure 2.29*, and *Figure 2.30* in *Section 2: Installation* show examples where synchronism check can be applied. Synchronism check voltage input **VS** is connected to one side of the circuit breaker, on any desired phase. The other synchronizing phase (**VA**, **VB**, or **VC** voltage inputs) on the other side of the circuit breaker is setting-selected.

The two synchronism check elements use the same voltage window (to assure healthy voltage) and slip frequency settings (see *Figure 3.26*). They have separate angle settings (see *Figure 3.27*).

If the voltages are static (voltages not slipping with respect to one another) or setting TCLOSD = 0.00, the two synchronism check elements operate as shown in the top of *Figure 3.27*. The angle settings are checked for synchronism check closing.

If the voltages are not static (voltages slipping with respect to one another), the two synchronism check elements operate as shown in the bottom of *Figure 3.27*. The angle difference is compensated by breaker close time, and the breaker is ideally closed at a zero degree phase angle difference, to minimize system shock.

These synchronism check elements are explained in detail in the following text.

Voltage Input VS Connected Phase-to-Phase or Beyond Delta-Wye Transformer

Sometimes synchronism check voltage V_S cannot be in phase with voltage V_A, V_B, or V_C (wye-connected PTs); or V_{AB}, V_{BC}, or V_{CA} (delta-connected PTs). This happens in applications where voltage input **VS** is connected

- Phase-to-phase when using a wye-connected relay
- Phase-to-neutral when using a delta-connected relay
- Beyond a delta-wye transformer

For such applications requiring V_S to be at a constant phase angle difference from any of the possible synchronizing voltages (V_A, V_B, or V_C; V_{AB}, V_{BC}, or V_{CA}), an angle setting is made with the SYNCP setting (see *Table 3.11* and the SYNCP setting discussion that follows).

Synchronism Check Elements Settings

Table 3.11 Synchronism Check Elements Settings and Settings Ranges (Sheet 1 of 2)

Setting	Definition	Range
25VLO	low voltage threshold for “healthy voltage” window	0.0–300.0 V secondary
25VHI	high voltage threshold for “healthy voltage” window	0.0–300.0 V secondary
25SF	maximum slip frequency	0.005–0.500 Hz
25ANG1	synchronism check element 25A1 maximum angle	0°–80°
25ANG2	synchronism check element 25A2 maximum angle	0°–80°

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Table 3.11 Synchronism Check Elements Settings and Settings Ranges (Sheet 2 of 2)

Setting	Definition	Range
SYNCP	synchronizing phase or the number of degrees that synchronism check voltage V_S constantly lags voltage V_A (wye-connected voltages) or V_{AB} (delta-connected voltages)	**VA**, **VB**, or **VC** (wye-connected voltages) **VAB**, **VBC**, or **VCA** (delta-connected voltages) 0°–330°, in 30° steps
TCLOSD	breaker close time for angle compensation	0.00–60.00 cycles
BSYNCH	SELOGIC control equation block synchronism check setting	Relay Word bits referenced in *Table 9.6*

Setting SYNCP

Wye-Connected Voltages

The angle setting choices (0, 30, …, 300, or 330 degrees) for setting SYNCP are referenced to V_A, and they indicate how many degrees V_S constantly lags V_A. In any synchronism check application, voltage input **VA-N** always has to be connected to determine system frequency on one side of the circuit breaker (to determine the slip between V_S and V_A). V_A always has to meet the "healthy voltage" criteria (settings 25VHI and 25VLO—see *Figure 3.26*). Thus, for situations where V_S cannot be in phase with V_A, V_B, or V_C, it is most straightforward to have the angle setting choices (0, 30, …, 300, or 330 degrees) referenced to V_A.

Note on setting SYNCP = 0:

> Settings SYNCP = 0 and SYNCP = VA are effectively the same (voltage V_S is directly synchronism checked with voltage V_A; V_S does not lag V_A). The relay will display the setting entered (SYNCP = VA or SYNCP = 0).

Delta-Connected Voltages

The angle setting choices (0, 30, …, 300, or 330 degrees) for setting SYNCP are referenced to V_{AB}, and they indicate how many degrees V_S constantly lags V_{AB}. In any synchronism check application, voltage input **VA-VB** always has to be connected to determine system frequency on one side of the circuit breaker (to determine the slip between V_S and V_{AB}). V_{AB} always has to meet the "healthy voltage" criteria (settings 25VHI and 25VLO—see *Figure 3.26*). Thus, for situations where V_S cannot be in phase with V_{AB}, V_{BC}, or V_{CA}, it is most straightforward to have the angle setting choices (0, 30, …, 300, or 330 degrees) referenced to V_{AB}.

Note on setting SYNCP = 0:

> Settings SYNCP = 0 and SYNCP = VAB are effectively the same (voltage V_S is directly synchronism checked with voltage V_{AB}; V_S does not lag V_{AB}). The relay will display the setting entered (SYNCP = VAB or SYNCP = 0).

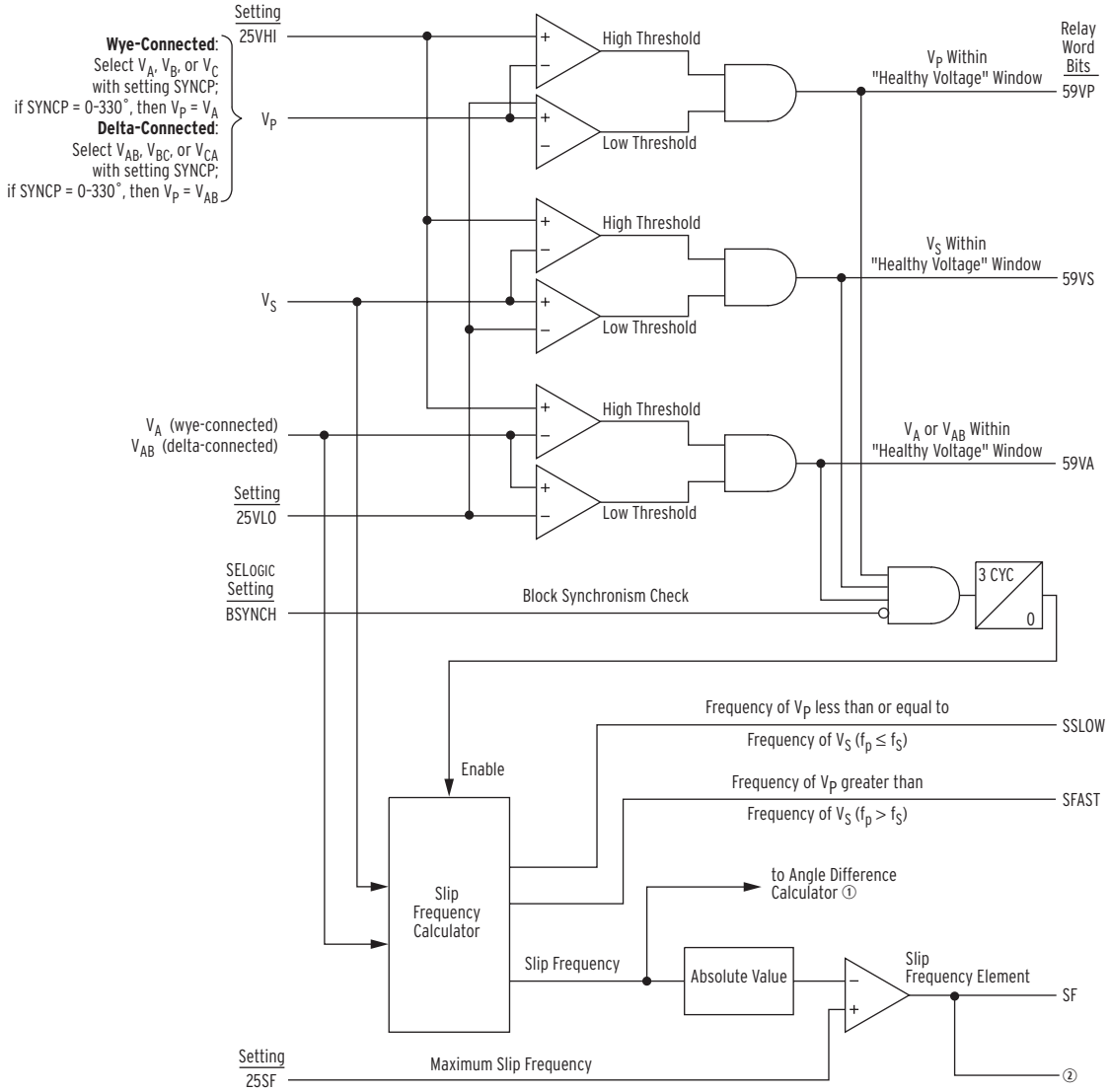
Figure 2.29 shows a relay wired with delta-connected phase PTs, and a C-phase-to-ground connected **VS-NS** input. With ABC rotation, the correct SYNCP setting for this example is 270 degrees, the amount that V_C lags V_{AB}.

See SEL *Application Guide 2002-02, Compensate for Constant Phase Angle Difference in Synchronism Check with the* SEL-*351 Relay Family* for more information on setting SYNCP with an angle setting.

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Accuracy

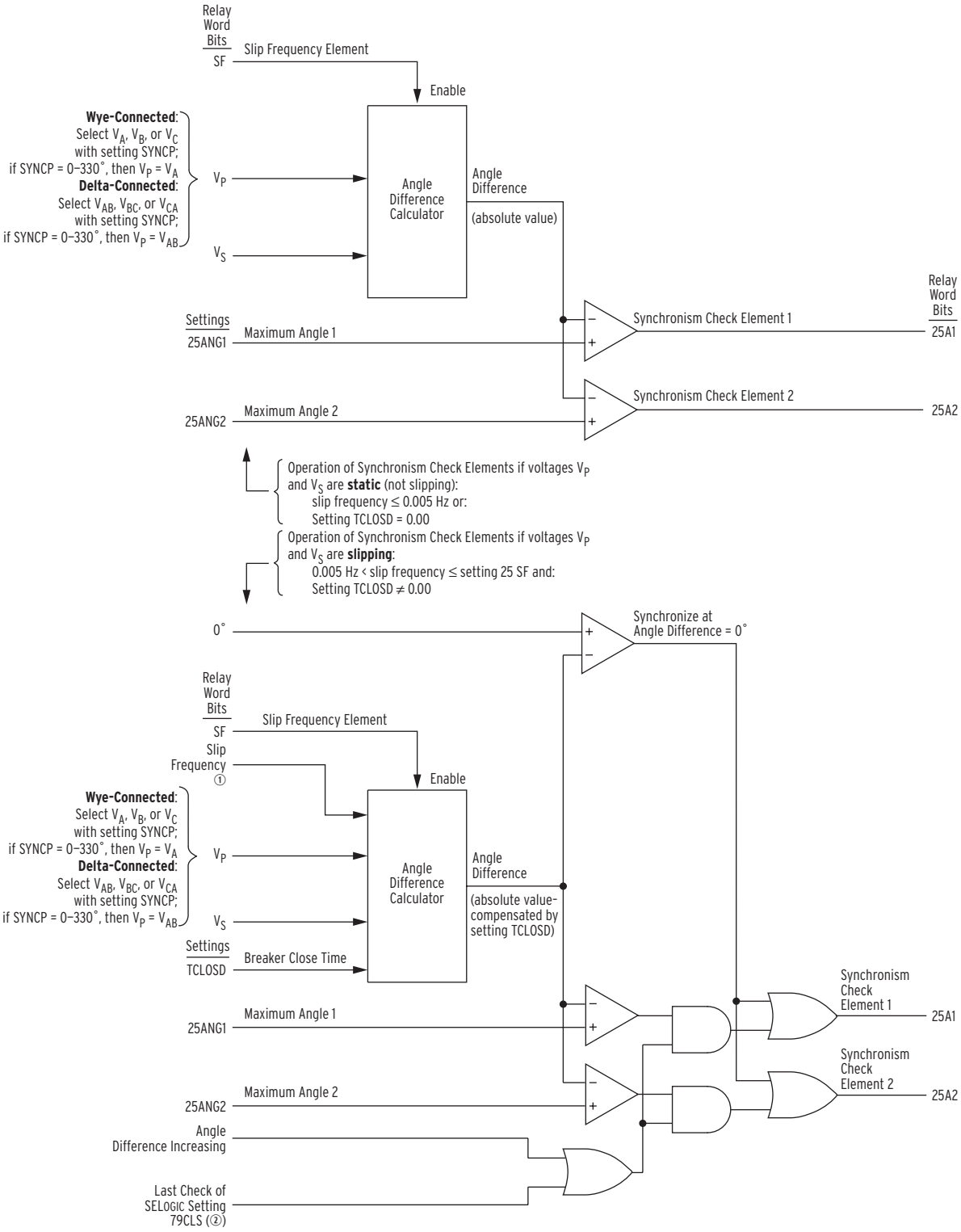
Voltage Pickup:	±2 V and ±2% of setting
Voltage Transient Overreach:	±5% of setting
Slip Pickup:	0.003 Hz
Angle Pickup:	±4°



① See bottom of Figure 3.27; ② to Figure 3.27.

Figure 3.26 Synchronism Check Voltage Window and Slip Frequency Elements

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① From Figure 3.26; ② see Figure 6.6.

Figure 3.27 Synchronism Check Elements

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Synchronism Check Elements Voltage Inputs

The two synchronism check elements are single-phase elements, with single-phase voltage inputs V_P and V_S used for both elements:

V_P Phase input voltage (V_A, V_B, or V_C for wye-connected voltages; V_{AB}, V_{BC}, V_{CA} for delta-connected voltages), designated by setting SYNCP (e.g., if SYNCP = VB, then $V_P = V_B$)

V_S Synchronism check voltage, from SEL-351S rear-panel voltage input **VS**

For example, if V_P is designated as phase input voltage V_B (setting SYNCP = VB) [or V_{BC} (setting SYNCP = VBC) for delta], then rear-panel voltage input **VS-NS** is connected to B-phase (or BC phase-to-phase for delta) on the other side of the circuit breaker. The voltage across terminals **VB-N** (or **VB-VC** for delta) is synchronism checked with the voltage across terminals **VS-NS** (see *Figure 1.2*, *Figure 2.17*–*Figure 2.20*, *Figure 2.29*, and *Figure 2.30*).

System Frequencies Determined From Voltages V_A (or V_{AB} for Delta) and V_S

To determine slip frequency, first determine the system frequencies on both sides of the circuit breaker. Voltage V_S determines the frequency on one side. Voltage V_A (for wye-connected voltage inputs) or voltage V_{AB} (for delta-connected voltage inputs) determines the frequency on the other side. Thus, voltage terminals **VA-N** (or **VA-VB** for delta) have to be connected, even if another voltage (e.g., voltage V_B for wye or V_{BC} for delta) is to be synchronized with voltage V_S.

In most applications, all three voltage inputs **VA**, **VB**, and **VC** are connected to the three-phase power system and no additional connection concerns are needed for voltage connection **VA-N** (or **VA-VB** for delta). The presumption is that the frequency determined for A-phase (or AB phase-to-phase for delta) is also valid for B- and C-phase (or BC and CA phase-to-phase for delta) in a three-phase power system.

However, for example, if voltage V_B (or V_{BC} for delta) is to be synchronized with voltage V_S and plans were to connect only voltage terminals **VB-N** and **VS-NS** (or voltage terminals **VB-VC** and **VS-NS** for delta) then voltage terminals **VA-N** (or **VA-VB** for delta) will also have to be connected for frequency determination. If desired, voltage terminals **VA-N** can be connected in parallel with voltage terminals **VB-N** (or voltage terminals **VB-VA** connected in parallel with voltage terminals **VB-VC** for delta; connect voltage terminal **VA** to **VC**). In such a nonstandard parallel connection, remember that voltage terminals **VA-N** are monitoring Phase B (or voltage terminals **VB-VA** are monitoring BC phase-to-phase for delta). This understanding helps prevent confusion when observing metering and event report information or voltage element operation.

Another possible solution to this example for wye-connected relays (synchronism check voltage input **VS-NS** connected to V_B) is to make setting SYNCP = 120 (the number of degrees that synchronism check voltage V_S constantly lags voltage V_A) and connect voltage input **VA-N** to V_A. Voltage inputs **VB** and **VC** do not have to be connected.

For delta-connected relays (synchronism check voltage input **VS-NS** connected to V_{BC}), make setting SYNCP = 120 (the number of degrees that synchronism check voltage V_S constantly lags voltage V_{AB}) and connect voltage inputs **VA-VB** to V_{AB}. Voltage input **VC** does not have to be connected.

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System Rotation Can Affect Setting SYNCP

The solution in the preceding paragraph:

- Voltage input **VA** connected to Phase A
- Voltage input **VS** connected to Phase B
- Setting SYNCP = 120 degrees (V_S constantly lags V_A by 120°)

presumes ABC system rotation. If voltage input connections are the same, but system rotation is ACB, then setting SYNCP = 240 degrees (V_S constantly lags V_A by 240°). See the SEL *Application Guide 2002-02, Compensate for Constant Phase Angle Difference in Synchronism Check with the* SEL-*351 Relay Family* for more information on setting SYNCP with an angle setting.

Synchronism Check Elements Operation

Refer to *Figure 3.26* and *Figure 3.27*.

Voltage Window

Refer to *Figure 3.26*.

Single-phase voltage inputs V_P and V_S are compared to a voltage window, to verify that the voltages are "healthy" and lie within settable voltage limits 25VLO and 25VHI. If both voltages are within the voltage window, the following Relay Word bits assert:

59VP indicates that voltage V_P is within voltage window setting limits 25VLO and 25VHI

59VS indicates that voltage V_S is within voltage window setting limits 25VLO and 25VHI

As discussed previously, voltage V_A determines the frequency on the voltage V_P side of the circuit breaker. Voltage V_A is also run through voltage limits 25VLO and 25VHI to ensure "healthy voltage" for frequency determination, with corresponding Relay Word bit output 59VA.

Other Uses for Voltage Window Elements

If voltage limits 25VLO and 25VHI are applicable to other control schemes, Relay Word bits 59VP, 59VS, and 59VA can be used in other logic at the same time they are used in the synchronism check logic.

If synchronism check is not being used, Relay Word bits 59VP, 59VS, and 59VA can still be used in other logic, with voltage limit settings 25VLO and 25VHI set as desired. Enable the synchronism check logic (setting E25 = Y) and make settings 25VLO and 25VHI. Apply Relay Word bits 59VP, 59VS, and 59VA in the desired logic scheme, using SELOGIC control equations. Even though synchronism check logic is enabled, the synchronism check logic outputs (Relay Word bits SF, 25A1, and 25A2) do not need to be used.

Block Synchronism Check Conditions

Refer to *Figure 3.26*.

The synchronism check element slip frequency calculator runs if both voltages V_P and V_S are healthy (59VP and 59VS asserted to logical 1) and the SELOGIC control equation setting BSYNCH (Block Synchronism Check) is

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deasserted (= logical 0). Setting BSYNCH is most commonly set to block synchronism check operation when the circuit breaker is closed (synchronism check is only needed when the circuit breaker is open):

BSYNCH = **52A** (see *Figure 6.3* and *Figure 7.1*)

In addition, synchronism check operation can be blocked when the relay is tripping:

BSYNCH = ... + TRIP

Slip Frequency Calculator

Refer to *Figure 3.26*.

The synchronism check element Slip Frequency Calculator in *Figure 3.26* runs if voltages V_P, V_S, and V_A (or V_{AB} for delta) are healthy (59VP, 59VS, and 59VA asserted to logical 1) and the SELOGIC control equation setting BSYNCH (Block Synchronism Check) is deasserted (= logical 0). The Slip Frequency Calculator output is:

Slip Frequency = $f_P - f_S$ (in units of Hz = slip cycles/second)

f_P = frequency of voltage V_P (in units of Hz = cycles/second)

[determined from V_A (or V_{AB} for delta)]

f_S = frequency of voltage V_S (in units of Hz = cycles/second)

A complete slip cycle is one single 360-degree revolution of one voltage (e.g., V_S) by another voltage (e.g., V_P). Both voltages are thought of as revolving phasor-wise, so the "slipping" of V_S past V_P is the **relative** revolving of V_S past V_P.

For example, in *Figure 3.26*, if voltage V_P has a frequency of 59.95 Hz and voltage V_S has a frequency of 60.05 Hz, the difference between them is the slip frequency:

Slip Frequency = 59.95 Hz – 60.05 Hz = –0.10 Hz = –0.10 slip cycles/second

The slip frequency in this example is negative, indicating that voltage V_S is not "slipping" **behind** voltage V_P, but in fact "slipping" **ahead** of voltage V_P. In a time period of one second, the angular distance between voltage V_P and voltage V_S changes by 0.10 slip cycles, which translates into:

0.10 slip cycles/second • (360°/slip cycle) • 1 second = 36°

Thus, in a time period of one second, the angular distance between voltage V_P and voltage V_S changes by 36 degrees.

The absolute value of the Slip Frequency output is run through a comparator and if the slip frequency is less than the maximum slip frequency setting, 25SF, Relay Word bit SF asserts to logical 1.

Generator Application for SSLOW and SFAST

Relay Word bits SSLOW and SFAST in *Figure 3.26* indicate the relative slip of voltages V_P and V_S:

$f_P < f_S$:SSLOW = logical 1, SFAST = logical 0

$f_P > f_S$:SSLOW = logical 0, SFAST = logical 1

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An application idea for SSLOW and SFAST is a small generator installation: V_P is from the generator side and V_S is from the system side (other side of the open circuit breaker). With some logic (perhaps to create pulsing signals), SSLOW and SFAST are used as signals (via output contacts) to the generator governor. "SSLOW" indicates that the generator (V_P) is slower than (or equal in frequency to) the system (V_S), while "SFAST" indicates that the generator (V_P) is faster than the system (V_S). If the enable into the slip frequency calculator in *Figure 3.26* is disabled (e.g., SELOGIC setting BSYNCH asserts because the breaker closes; BSYNCH = 52A + …), then both SSLOW = logical 0 and SFAST = logical 0, regardless of slip frequency.

Angle Difference Calculator

The synchronism check element Angle Difference Calculator in *Figure 3.27* runs if the slip frequency is less than the maximum slip frequency setting 25SF (Relay Word bit SF is asserted).

Voltages V_P and V_S are "Static"

Refer to top of *Figure 3.27*.

If the slip frequency is less than or equal to 0.005 Hz, the Angle Difference Calculator does **not** take into account breaker close time—it presumes voltages V_P and V_S are "static" (not "slipping" with respect to one another). This would usually be the case for an open breaker with voltages V_P and V_S that are paralleled via some other electric path in the power system. The Angle Difference Calculator calculates the angle difference between voltages V_P and V_S:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S)\right|$$

For example, if SYNCP = 90 (indicating V_S constantly lags $V_P = V_A$ by 90 degrees), but V_S actually lags V_A by 100 angular degrees on the power system at a given instant, the Angle Difference Calculator automatically accounts for the 90 degrees and:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S)\right| = 10^\circ$$

Also, if breaker close time setting TCLOSD = 0.00, the Angle Difference Calculator does not take into account breaker close time, even if the voltages V_P and V_S are "slipping" with respect to one another. Thus, synchronism check elements 25A1 or 25A2 assert to logical 1 if the Angle Difference is less than corresponding maximum angle setting 25ANG1 or 25ANG2.

Voltages V_P and V_S are "Slipping"

Refer to bottom of *Figure 3.27*.

If the slip frequency is greater than 0.005 Hz and breaker close time setting TCLOSD ≠ 0.00, the Angle Difference Calculator takes the breaker close time into account with breaker close time setting TCLOSD (set in cycles; see *Figure 3.28*). The Angle Difference Calculator calculates the Angle Difference between voltages V_P and V_S, compensated with the breaker close time:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{TCLOSD} \bullet \left(\frac{1\ \text{second}}{60\ \text{cycles}}\right) \bullet \left(\frac{360^\circ}{\text{slip cycle}}\right)\right]\right|$$

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Angle Difference Example (Voltages V_p and V_s are "Slipping")

Refer to bottom of *Figure 3.27*.

For example, if the breaker close time is 10 cycles, set TCLOSD = 10. Presume the slip frequency is the example slip frequency calculated previously. The Angle Difference Calculator calculates the angle difference between voltages V_P and V_S, compensated with the breaker close time:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{TCLOSD} \bullet \left(\frac{1 \text{ second}}{60 \text{ cycles}}\right) \bullet \left(\frac{360^\circ}{\text{slip cycle}}\right)\right]\right|$$

Intermediate calculations:

$(f_P - f_S) = (59.95 \text{ Hz} - 60.05 \text{ Hz}) = -0.10 \text{ Hz} = -0.10 \text{ slip cycles/second}$

TCLOSD • (1 second/60 cycles) = 10 cycles • (1 second/60 cycles)
= 0.167 second

Resulting in:

$$\text{Angle Difference} = \left|(\angle V_P - \angle V_S) + \left[(f_P - f_S) \bullet \text{TCLOSD} \bullet \left(\frac{1 \text{ second}}{60 \text{ cycles}}\right) \bullet \left(\frac{360^\circ}{\text{slip cycle}}\right)\right]\right|$$

$$= \left|(\angle V_P - \angle V_S) + [-0.10 \bullet 0.167 \bullet 360^\circ]\right|$$

$$= \left|(\angle V_P - \angle V_S) - 6^\circ\right|$$

NOTE: The angle compensation in Figure 3.28 appears much greater than six degrees. Figure 3.28 is for general illustrative purposes only.

During the breaker close time (TCLOSD), the voltage angle difference between voltages V_P and V_S changes by six degrees. This six degree angle compensation is applied to voltage V_S, resulting in derived voltage V_S*, as shown in *Figure 3.28*.

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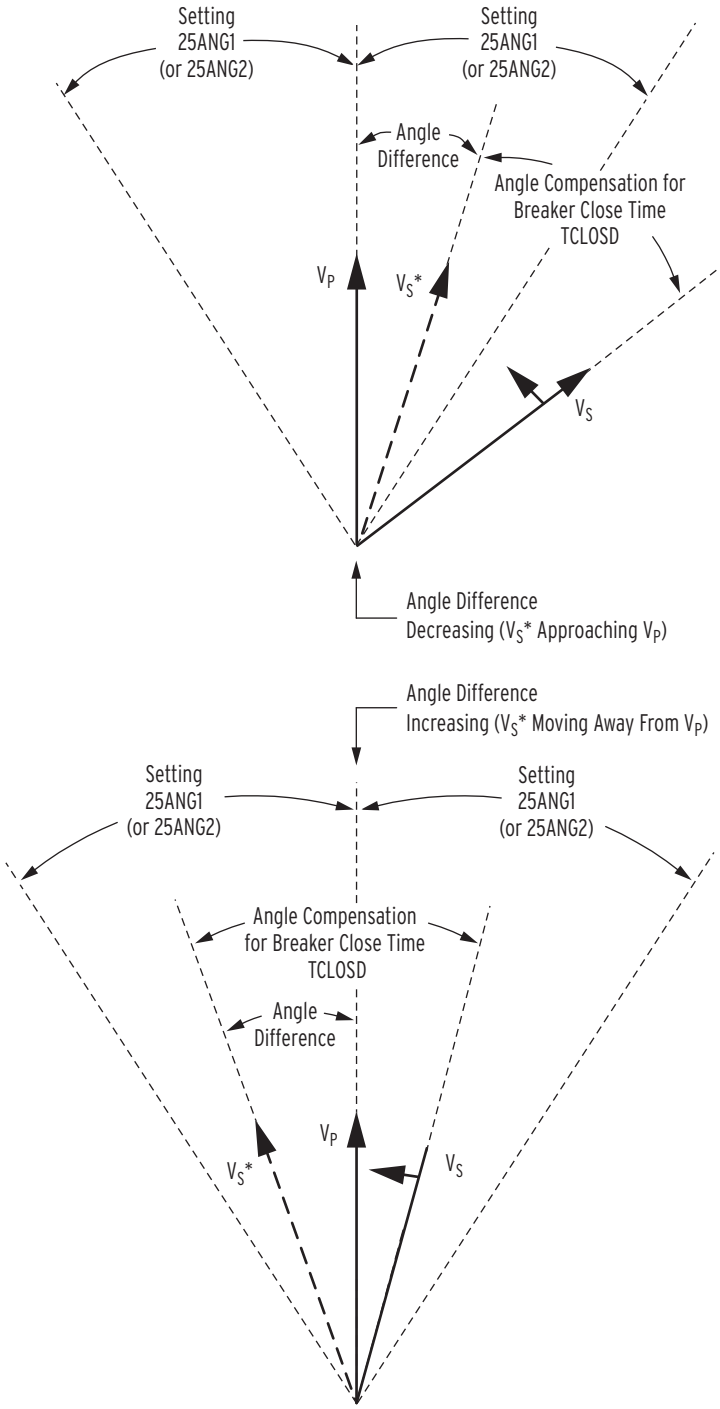


Figure 3.28 Angle Difference Between V_P and V_S Compensated by Breaker Close Time ($f_P < f_S$ and V_P Shown as Reference in This Example)

The top of *Figure 3.28* shows the Angle Difference **decreasing**—V_S* is approaching V_P. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P, minimizing system shock.

The bottom of *Figure 3.28* shows the Angle Difference **increasing**—V_S* is moving away from V_P. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in phase with V_P. But in this case,

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V_S* has already moved past V_P. In order to initiate circuit breaker closing when V_S* is in phase with V_P (Angle Difference = 0 degrees), V_S* has to slip around another revolution, relative to V_P.

Synchronism Check Element Outputs

Synchronism check element outputs (Relay Word bits 25A1 and 25A2 in *Figure 3.27*) assert to logical 1 for the conditions explained in the following text.

Voltages V_P and V_S are "Static" or Setting TCLOSD = 0.00

To implement a single fixed-angle synchronism check scheme, set TCLOSD = 0 and 25SF = 0.500. With these settings, the synchronism check is performed as described in the top of *Figure 3.27*.

If there is the possibility of a high slip frequency, exercise caution if synchronism check elements 25A1 or 25A2 are used to close a circuit breaker. A high slip frequency and a slow breaker close could result in closing the breaker outside the synchronism check window. Qualify the breaker close command with a time delay, such as:

SV1 = **25A1**

CL = **CC * SV1T**

Set SV1PU with enough pickup delay to insure that the slip frequency is low enough for the circuit breaker to close within the synchronism check window.

Voltages V_P and V_S are "Slipping" and Setting TCLOSD ≠ 0.00

Refer to bottom of *Figure 3.27*. If V_P and V_S are "slipping" with respect to one another and breaker close time setting ≠ 0.00, the Angle Difference (compensated by breaker close time TCLOSD) changes through time. Synchronism check element 25A1 or 25A2 asserts to logical 1 for any one of the following three scenarios.

1. The top of *Figure 3.28* shows the Angle Difference **decreasing**—V_S* is approaching V_P. When V_S* is in phase with V_P (Angle Difference = 0 degrees), synchronism check elements 25A1 and 25A2 assert to logical 1.
2. The bottom of *Figure 3.28* shows the Angle Difference **increasing**—V_S* is moving away from V_P. V_S* was in phase with V_P (Angle Difference = 0 degrees), but has now moved past V_P. If the Angle Difference is **increasing**, but the Angle Difference is still less than maximum angle settings 25ANG1 or 25ANG2, then corresponding synchronism check elements 25A1 or 25A2 assert to logical 1.

   In this scenario of the Angle Difference increasing, but still being less than maximum angle settings 25ANG1 or 25ANG2, the operation of corresponding synchronism check elements 25A1 and 25A2 becomes **less restrictive**. Synchronism check breaker closing does not have to wait for voltage V_S* to slip around again in phase with V_P (Angle Difference = 0 degrees). There might not be enough time to wait for this to happen. Thus, the "Angle Difference = 0 degrees" restriction is eased for this scenario.

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3. Refer to *Reclose Supervision Logic on page 6.7*.

   Refer to the bottom of *Figure 6.5*. If timer 79CLSD is set greater than zero (e.g., 79CLSD = 60.00 cycles) and it times out without SELOGIC control equation setting 79CLS (Reclose Supervision) asserting to logical 1, the relay goes to the Lockout State (see top of *Figure 6.6*).

   Refer to the top of *Figure 6.5*. If timer 79CLSD is set to zero (79CLSD = 0.00), SELOGIC control equation setting 79CLS (Reclose Supervision) is checked only once to see if it is asserted to logical 1. If it is not asserted to logical 1, the relay goes to the Lockout State.

   Refer to the top of *Figure 3.28*. Ideally, circuit breaker closing is initiated when V_S* is in phase with V_P (Angle Difference = 0 degrees). Then when the circuit breaker main contacts finally close, V_S is in-phase with V_P, minimizing system shock. But with time limitations imposed by timer 79CLSD, this may not be possible. To try to avoid going to the Lockout State, the following logic is employed:

   If 79CLS has not asserted to logical 1 while timer 79CLSD is timing (or timer 79CLSD is set to zero and only one check of 79CLS is made), the synchronism check logic at the bottom of *Figure 3.27* becomes **less restrictive** at the "instant" timer 79CLSD is going to time out (or make the single check). It drops the requirement of waiting until the **decreasing** Angle Difference (V_S* approaching V_P) brings V_S* in phase with V_P (Angle Difference = 0 degrees). Instead, it just checks to see that the Angle Difference is less than angle settings 25ANG1 or 25ANG2.

   If the Angle Difference is less than angle setting 25ANG1 or 25ANG2, then the corresponding Relay Word bit, 25A1 or 25A2, asserts to logical 1 for that "instant" (asserts for 1/4 cycle).

   For example, if SELOGIC control equation setting 79CLS (Reclose Supervision) is set as follows:

   79CLS = 25A1 + ...

   and the angle difference is less than angle setting 25ANG1 at that "instant," setting 79CLS asserts to logical 1 for 1/4 cycle, allowing the sealed-in open interval time-out to propagate on to the close logic in *Figure 6.1*. Element 25A2 operates similarly.

Synchronism Check Applications for Automatic Reclosing and Manual Closing

Refer to *Close Logic on page 6.2* and *Reclose Supervision Logic on page 6.7*.

For example, set 25ANG1 = 15 degrees and use the resultant synchronism check element in the reclosing relay logic to supervise automatic reclosing:

79CLS = **25A1 + ...** (see *Figure 6.5*)

Set 25ANG2 = 25° and use the resultant synchronism check element in manual close logic to supervise manual closing (e.g., assert **IN106** to initiate manual close):

CL = **IN106 * (25A2 + ...)** (see *Figure 6.2*)

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In this example, the angular difference across the circuit breaker can be greater for a manual close (25 degrees) than for an automatic reclose (15 degrees).

A single output contact (e.g., OUT102 = CLOSE) can provide the close function for both automatic reclosing and manual closing (see *Figure 6.1* logic output).

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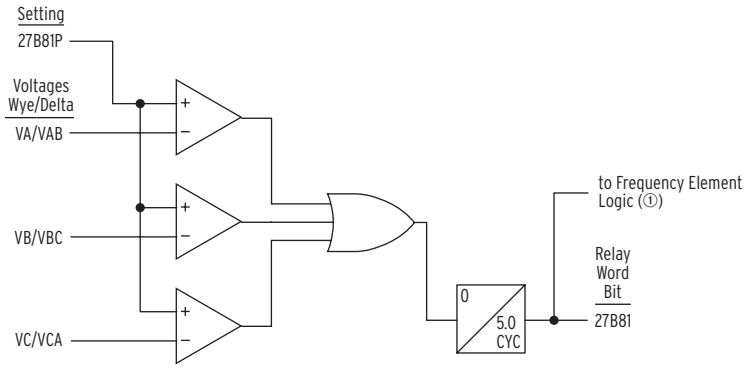
Frequency Elements

Six frequency elements are available. Enable the desired number of frequency elements with the E81 enable setting:

E81 = **N** (none), 1–6

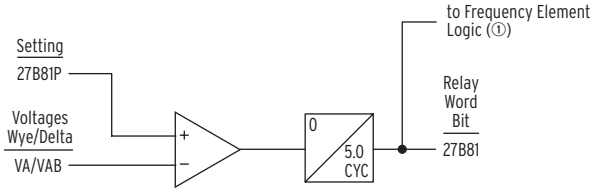
as shown in *Figure 3.31*. Frequency is determined from the voltage connected to voltage terminals **VA-N**.

Frequency Element Settings



① Figure 3.31.

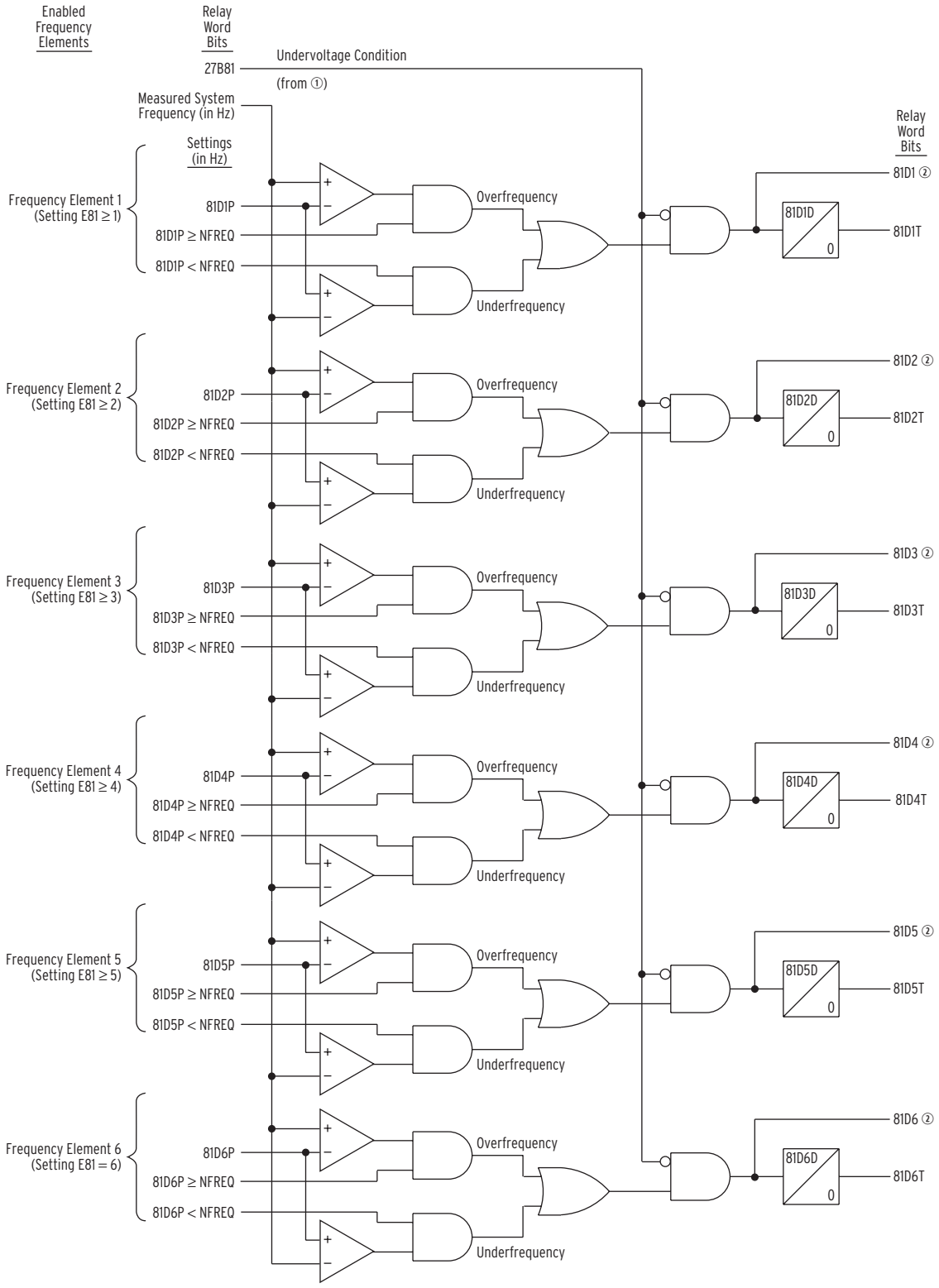
Figure 3.29 Undervoltage Block for Frequency Elements (Group Setting VNOM ≠ OFF)



① Figure 3.31.

Figure 3.30 Undervoltage Block for Frequency Elements (Group Setting VNOM = OFF)

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① Figure 3.29 or Figure 3.30; ② 81D1–81D6 are for testing purposes only.

Figure 3.31 Levels 1–6 Frequency Elements

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Table 3.12 Frequency Elements Settings and Settings Ranges

Setting	Definition	Range
27B81P	undervoltage frequency element block (responds to V_{LN} when Global setting PTCONN = WYE, responds to V_{LL} when Global setting PTCONN = DELTA)	25.00–300.00 V secondary
81D1P	frequency element 1 pickup	40.10–65.00 Hz
81D1D[a]	frequency element 1 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D2P	frequency element 2 pickup	40.10–65.00 Hz
81D2D[a]	frequency element 2 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D3P	frequency element 3 pickup	40.10–65.00 Hz
81D3D[a]	frequency element 3 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D4P	frequency element 4 pickup	40.10–65.00 Hz
81D4D[a]	frequency element 4 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D5P	frequency element 5 pickup	40.10–65.00 Hz
81D5D[a]	frequency element 5 time delay	2.00–16000.00 cycles, in 0.25-cycle steps
81D6P	frequency element 6 pickup	40.10–65.00 Hz
81D6D[a]	frequency element 6 time delay	2.00–16000.00 cycles, in 0.25-cycle steps

[a] Frequency element time delays are best set no less than 5 cycles. Frequency is determined by a zero-crossing technique on voltage V_A. If voltage waveform offset occurs (e.g., due to a fault), then frequency can be off for a few cycles. A 5-cycle or greater time delay (e.g., 81D1D = 6.00 cycles) overrides this occurrence.

Accuracy

Pickup: ±0.01 Hz

Timer: ±0.25 cycles and ±0.1% of setting

Create Over- and Underfrequency Elements

Refer to *Figure 3.31*.

Note that pickup settings 81D1P–81D6P are compared to setting NFREQ. NFREQ is the nominal frequency setting (a global setting), set to 50 or 60 Hz.

Overfrequency Element

For example, make settings:

NFREQ = 60 Hz	(nominal system frequency is 60 Hz)
E81≥1	(enable frequency element 1)
81D1P = 61.25 Hz.	(frequency element 1 pickup)

With these settings: 81D1P≥NFREQ

the overfrequency part of frequency element 1 logic is enabled. 81D1 and 81D1T operate as overfrequency elements. 81D1 is used in **testing only**.

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Underfrequency Element

For example, make settings:

NFREQ = 60 Hz	(nominal system frequency is 60 Hz)
E81≥2	(enable frequency element 2)
81D2P = 5.65 Hz	(frequency element 2 pickup)

With these settings: 81D2P < NFREQ

the underfrequency part of frequency element 2 logic is enabled. 81D2 and 81D2T operate as underfrequency elements. 81D2 is used in **testing only**.

Frequency Element Operation

Refer to *Figure 3.31*.

Overfrequency Element Operation

With the previous overfrequency element example settings, if system frequency is **less than or equal to** 61.25 Hz (81D1P = 61.25 Hz), frequency element 1 outputs:

81D1 = logical 0	(instantaneous element)
81D1T = logical 0	(time delayed element)

If system frequency is **greater than** 61.25 Hz (81D1P = 61.25 Hz), frequency element 1 outputs:

81D1 = logical 1	(instantaneous element)
81D2T = logical 1	(time delayed element)

Relay Word bit 81D1T asserts to logical 1 only after time delay 81D1D.

Underfrequency Element Operation

With the previous underfrequency element example settings, if system frequency is **less than or equal to** 59.65 Hz (81D2P = 59.65 Hz), frequency element 2 outputs:

81D2 = logical 1	(instantaneous element)
81D2T = logical 1	(time delayed element)

Relay Word bit 81D2T asserts to logical 1 only after time delay 81D2D.

If system frequency is **greater than** 59.65 Hz (81D2P = 59.65 Hz), frequency element 2 outputs:

81D2 = logical 0	(instantaneous element)
81D2T = logical 0	(time delayed element)

Frequency Element Voltage Control

Refer to *Figure 3.29*, *Figure 3.30*, and *Figure 3.31*.

Note that all six frequency elements are controlled by the same undervoltage element (Relay Word bit 27B81). For example, when group setting VNOM ≠ OFF, and Global setting PTCONN = WYE, Relay Word bit 27B81 asserts to

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logical 1 and blocks the frequency element operation if any voltage (V_A, V_B, or V_C) goes below voltage pickup 27B81P. This control prevents erroneous frequency element operation following fault inception.

However, if group setting VNOM = OFF, Relay Word bit 27B81 is only affected by the voltage applied to the **VA-N** terminals. This is useful in applications where there is only single-phase voltage available to the relay.

Other Uses for Undervoltage Element 27B81

If voltage pickup setting 27B81P is applicable to other control schemes, Relay Word bit 27B81 can be used in other logic at the same time it is used in the frequency element logic.

If frequency elements are not being used, Relay Word bit 27B81 can still be used in other logic, with voltage setting 27B81P set as desired. Enable the frequency elements (setting E81≥1) and make setting 27B81P. Apply Relay Word bit 27B81 in the desired logic scheme, using SELOGIC control equations. Even though frequency elements are enabled, the frequency element outputs (Relay Word bits 81D1T–81D6T) do not have to be used.

Frequency Element Uses

The instantaneous frequency elements (81D1–81D6) are used in **testing only**.

The time-delayed frequency elements (81D1T–81D6T) are used for underfrequency load shedding, frequency restoration, and other schemes.

Underfrequency Loadshedding

For example, to implement underfrequency loadshedding with time-delayed frequency element 81D1T, make the SELOGIC control equations trip setting:

TR = **... + 81D1T**

The following settings should also be made:

79DTL = **... + 81D1T** (drive-to-lockout—see *Figure 6.10* and following explanation)

LED18 = **81D1T** (**81** target LED—see *Table 5.1*)

See the note at the end of the *Trip Logic on page 5.1* for background on making these two settings when making trip settings changes/modifications.

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Voltage Sag, Swell, and Interruption Elements (Available in Firmware Version 7)

The SEL-351S-7 has three types of elements to detect voltage disturbances. These elements detect voltage sags, swells, and interruptions (abbreviated as "VSSI" or "SSI"). These elements are enabled by group setting ESSI = Y and controlled by the VINT, VSWELL, and VSAG settings.

Enter the VSSI element threshold settings VSAG, VSWELL, and VINT in percentage units, which relate to the Positive-Sequence Reference Voltage: Vbase. The use of percentage settings instead of absolute voltage limits allows the SSI elements to perform better in systems that have a range of nominal voltages, with no need to adjust settings for seasonal loading or to set them far apart to accommodate the action of a tap-changing transformer. The SSI elements respond to phase-to-neutral voltages when the relay is wye connected, and phase-to-phase voltages when the relay is delta connected, as determined by Global setting PTCONN.

The Positive-Sequence Reference Voltage is discussed in its own subsection.

The Voltage Sag, Swell, Interruption Recorder automatically uses the SSI elements. These elements are also available as Relay Word bits, so they can be used in any SELOGIC control equation. See *Sag/Swell/Interruption (SSI) Report (Available in Firmware Version 7) on page 12.36.*

Voltage Sag Elements

As shown in *Figure 3.32*, if the magnitude of a voltage drops below the voltage sag pickup threshold for one cycle, the corresponding SAG Relay Word bit for that phase (or phase-to-phase pair) asserts (SAGA, SAGB, or SAGC, wye connected; SAGAB, SAGBC, SAGCA, delta connected). If all three SAG__ elements assert, an additional Relay Word bit asserts—SAG3P. The SAG elements remain asserted until the magnitude of the corresponding voltage rises and remains above the sag dropout threshold for one cycle.

The sag pickup and dropout thresholds depend on Vbase and the VSAG setting.

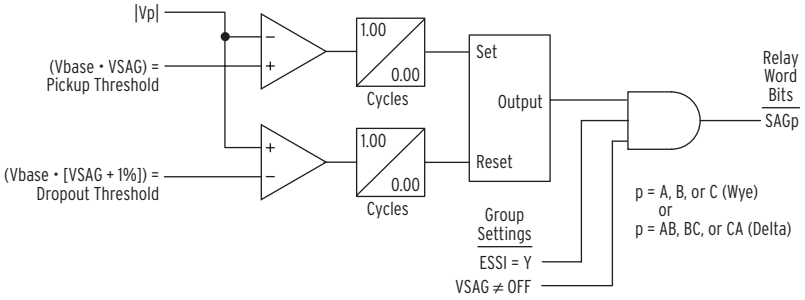


Figure 3.32 Voltage Sag Elements

Voltage Swell Elements

As shown in *Figure 3.33*, if the magnitude of a voltage rises above the voltage swell pickup threshold for one cycle, the corresponding SW Relay Word bit for that phase (or phase-to-phase pair) asserts (SWA, SWB, or SWC, wye connected; SWAB, SWBC, SWCA, delta connected). If all three SW__ elements assert, an additional Relay Word bit asserts—SW3P. The SW elements remain asserted until the magnitude of the corresponding voltage drops and remains below the swell dropout threshold for one cycle.

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The swell pickup and dropout thresholds depend on Vbase and the VSWELL setting.

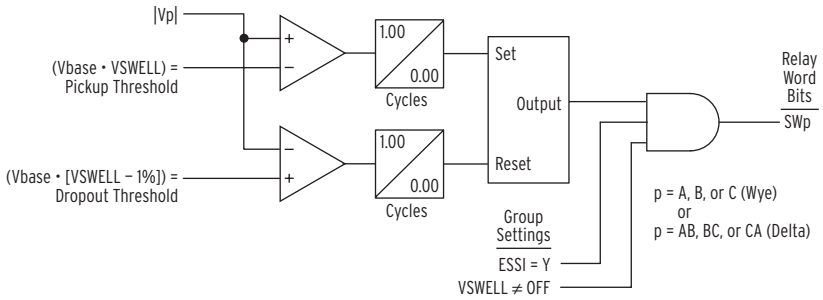


Figure 3.33 Voltage Swell Elements

Voltage Interruption Elements

As shown in *Figure 3.34*, if the magnitude of a voltage drops below the voltage interruption pickup threshold for one cycle, the corresponding INT Relay Word bit for that phase (or phase-to-phase pair) asserts (INTA, INTB, or INTC, wye connected; INTAB, INTBC, INTCA, delta connected). If all three INT__ elements assert, an additional Relay Word bit asserts—INT3P. The INT elements remain asserted until the magnitude of the corresponding voltage rises and remains above the interruption dropout threshold for one cycle.

The interruption pickup and dropout thresholds depend on Vbase and the VINT setting.

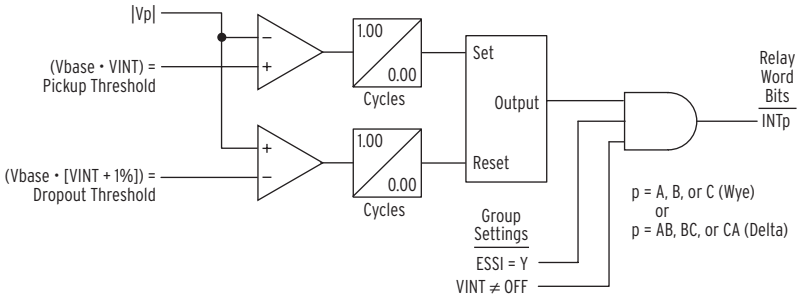


Figure 3.34 Voltage Interruption Elements

Voltage Sag, Swell, and Interruption Elements Settings

The settings ranges for the SSI thresholds are shown in *Table 3.13*.

The factory default settings match the Interruption, Sag, and Swell definitions in IEEE Standard 1159-1995 “Classifications of RMS Variations.”

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Table 3.13 Sag/Swell/Interruption Elements Settings (must first set ESSI = Y)

Settings	Definition	Range	Default
VINT[a]	Percentage of memory voltage compared to phase-to-neutral or phase-to-phase voltage to assert INT elements	OFF, 5–95% of reference voltage, Vbase	10.00%
VSAG	Percentage of memory voltage compared to phase-to-neutral or phase-to-phase voltage to assert SAG elements	OFF, 10–95% of reference voltage, Vbase	90.00%
VSWELL	Percentage of memory voltage compared to phase-to-neutral or phase-to-phase voltage to assert SW elements	OFF, 105–180% of reference voltage, Vbase (300 V secondary maximum upper limit)	110.00%

[a] VINT cannot be set higher than VSAG.

Positive-Sequence Reference Voltage, Vbase

The relay converts the positive-sequence voltage quantity, |V1|, to a reference voltage, Vbase, that has a thermal demand characteristic with a time constant of 100 seconds. This allows the Vbase quantity to slowly track normal system voltage variations (tap changer operations and load effects), but not follow fast system voltage changes (unless the change is held for several seconds).

In a balanced three-phase system, |V1| is the average of the three phase-to-neutral voltages.

For wye-connected systems, Vbase tracks |V1|, and represents the average phase-to-neutral voltage.

For delta-connected systems, Vbase tracks $\sqrt{3} \bullet |V1|$, and represents the average phase-to-phase voltage.

The present value of Vbase can be viewed by issuing the **MET X** command. See *MET Command (Metering Data) on page 10.20*.

Vbase Thermal Element Block

To prevent the Vbase quantity from tracking during transient voltage conditions, the calculation of the Vbase thermal element is blocked during the assertion of any of the SAG*p*, SW*p*, or INT*p* Relay Word bits or the FAULT SELOGIC control equation setting. When blocked, the Vbase quantity will not change. This allows the SAG, SWELL, and INT elements voltage comparisons to be made with the reference Vbase locked at a "healthy" system voltage level. Once the disturbance is over and all of the SAG*p*, SW*p*, and INT*p* Relay Word bits deassert, and the FAULT SELOGIC control equation setting deasserts, the thermal element for Vbase is unblocked.

Figure 3.35 shows an example of how Vbase tracking is suspended during a voltage disturbance (wye connected). The example voltage disturbance is the result of an overload condition (three-phase sag), followed by a source-side breaker operation (three-phase interruption). To illustrate the dynamic nature of the VSSI thresholds, the Interrupt, Sag, and Swell pickup levels are also plotted, using the factory default settings for VINT, VSAG, and VSWELL. For this hypothetical three-phase disturbance, V1 has the same magnitude as V_A, V_B, and V_C (as shown). Single-phase disturbances are handled in a similar fashion, except that the phases and V1 will have different voltage magnitudes.

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The use of a VSAG setting higher than 90 percent, at the same time as a VSWELL setting lower than 110 percent, should be carefully considered. Moving these thresholds too close together increases the probability that an end of disturbance condition is missed. This could create a false sag or swell condition that may not clear itself until the next disturbance, thus causing the Vbase thermal element to remain blocked.

Vbase thermal element blocking by the FAULT Relay Word bit is programmable via SELOGIC setting FAULT. SELOGIC control equation setting FAULT also controls other relay functions, see subsection *SELOGIC Control Equation Setting FAULT on page 5.37*.

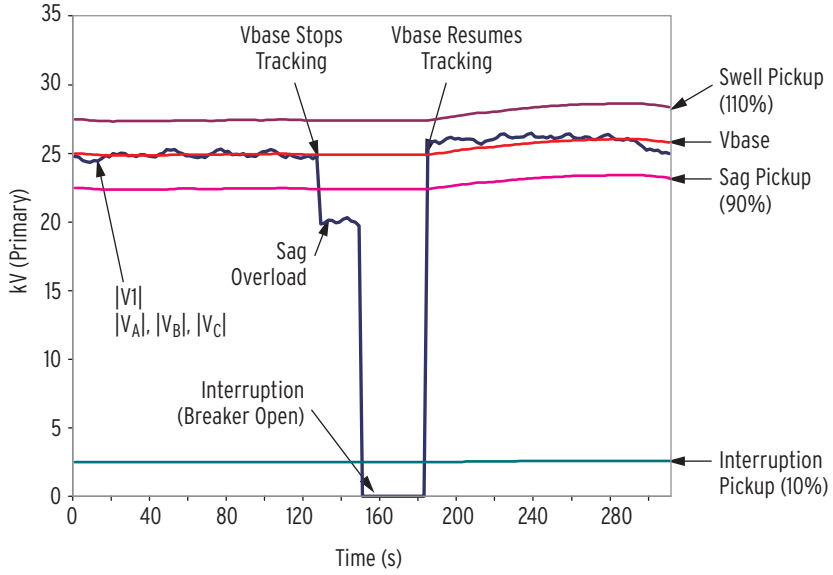


Figure 3.35 Vbase Tracking Example (Three-Phase Disturbance, Wye Connected)

Vbase Initialization

The Vbase thermal element is automatically initialized when the relay is powered up, and also after a settings change or group change that results in a new ESSI = Y condition.

Vbase can also be forced to initialize by issuing the **SSI R** command (Access Level 1).

During initialization, the SSI elements are deasserted and the SSI Recorder is disabled until all of the following conditions are met:

- |V1| > |3V2| (correct phase rotation check)
- |V1| > |3V0| (correct phase connection check) (wye connected only)
- V_A, V_B, V_C are all greater than 25 V secondary (wye connected)
  V_{AB}, V_{BC}, V_{CA} are all greater than 43.3 V secondary (delta connected)
- SELOGIC control equation setting FAULT is deasserted
- |V1| is within three percent of the calculated Vbase value (wye connected)

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- |V1| is within three percent of the calculated Vbase value/ $\sqrt{3}$ (delta connected)
- At least 12 seconds have elapsed

As soon as the above Vbase initialization conditions are satisfied, the SSI Relay Word bits will be allowed to change state according to their settings and the present voltage conditions, and the SSI Recorder will be enabled.

Vbase Tracking Range

The Vbase quantity will track the positive-sequence voltage over a large range of system voltages. The tracking limits are explained below. In normal relay use, these limits are not likely to be reached, because one of the Sag, Swell, or Interruption Relay Word bits would most likely assert for a large voltage deviation, thus blocking the Vbase thermal element from tracking to one of the range limits.

The minimum value that Vbase can achieve is equivalent to a positive-sequence (V1) value of 25 volts secondary. In primary units, the lowest value depends on the global setting PTCONN:

When PTCONN = WYE: minimum Vbase = $\frac{25\text{V} \bullet \text{PTR}}{1000}$ kV.

When PTCONN = DELTA: minimum Vbase = $\frac{43.3\text{V} \bullet \text{PTR}}{1000}$ kV.

The maximum value that Vbase can achieve is equivalent to 300 volts secondary divided by VSWELL, so the maximum Vbase in primary kV is:

$$\frac{300\text{V} \bullet \text{PTR} \bullet 100}{\text{VSWELL} \bullet 1000} = \frac{30\text{V} \bullet \text{PTR}}{\text{VSWELL}}$$

The upper limit for Vbase is not affected by the PTCONN Global Setting.

If the expected higher end of the “normal” system voltage range is close to 300 V, secondary, then the VSWELL setting may need to be reduced, or turned “OFF,” in order to allow Vbase to track the actual system voltage and not run into the maximum value limit. For example, if connecting to an industrial service rated at 277 V_{LN} / 480 V_{LL}, using the wye connection (with no PTs), and the normal operating range goes up to 285 V_{LN}, then the maximum VSWELL setting that will allow for proper Vbase tracking is 105 percent.

SSI Reset Command

After commissioning tests or other maintenance activities that have applied test voltages to the SEL-351S, the Vbase element may have locked onto a test voltage. Use the **SSI R** (reset) command once normal system voltages are restored on the voltage terminals. Powering up the relay automatically performs this reset.

See *Resetting the SSI Recorder Logic on page 12.41* for more details.

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Power Elements (Available in Firmware Version 7)

Four independent power elements are available. For wye-connected systems, either single-phase power elements or three-phase power elements may be enabled (but not both). For delta-connected systems, only three-phase power elements may be enabled. The group setting EPWR setting determines how many (and what type of) power elements are enabled:

EPWR = **N** (none), 1, 2, 3, 4 (single-phase); 3P1, 3P2, 3P3, 3P4 (three-phase) {wye-connected voltages}

EPWR = **N** (none), 3P1, 3P2, 3P3, 3P4 (three-phase) {delta-connected voltages}

Each enabled power element can be set to detect real power or reactive power. With SELOGIC control equations, the power elements provide a wide variety of protection and control applications. Typical applications are:

- Overpower and/or underpower protection/control
- Reverse power protection/control
- VAR control for capacitor banks

Power Elements Settings

Table 3.14 Single-Phase Power Element Settings and Setting Ranges (EPWR = 1, 2, 3, or 4)

Settings	Definition	Range
PWR1P, PWR2P, PWR3P, PWR4P	Power element pickup	OFF, 0.33–13000.00 VA secondary, single-phase (5 A nominal phase current inputs, **IA**, **IB**, **IC**) OFF, 0.07–2600.00 VA secondary, single-phase (1 A nominal phase current inputs, **IA**, **IB**, **IC**)
PWR1T, PWR2T, PWR3T, PWR4T	Power element type	+WATTS, –WATTS, +VARS, –VARS
PWR1D, PWR2D, PWR3D, PWR4D	Power element time delay	0.00–16000 cycles, in 0.25-cycle steps

Table 3.15 Three-Phase Power Element Settings and Setting Ranges (EPWR = 3P1, 3P2, 3P3, or 3P4)

Settings	Definition	Range
3PWR1P, 3PWR2P, 3PWR3P, 3PWR4P	Power element pickup	OFF, 1.00–39000.00 VA secondary, three-phase (5 A nominal phase current inputs, **IA**, **IB**, **IC**) OFF, 0.20–7800.00 VA secondary, three-phase (1A nominal phase current inputs, **IA**, **IB**, **IC**)
PWR1T, PWR2T, PWR3T, PWR4T	Power element type	+WATTS, –WATTS, +VARS, –VARS
PWR1D, PWR2D, PWR3D, PWR4D	Power element time delay	0.00–16000 cycles, in 0.25-cycle steps

The power element type settings are made in reference to the **load** convention:

+WATTS: positive or forward real power
–WATTS: negative or reverse real power
+VARS: positive or forward reactive power (lagging)
–VARS: negative or reverse reactive power (leading)

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Power Element Time Delay Setting Considerations

The four power element time delay settings (PWR1D–PWR4D) can be set to have no intentional delay for testing purposes. For protection applications involving the power element Relay Word bits, SEL recommends a minimum time delay setting of 5.00 cycles for general applications. The classical power calculation is a product of voltage and current, to determine the real and reactive power quantities. During a system disturbance, because of the high sensitivity of the power elements, the changing system phase angles and/or frequency shifts may cause transient errors in the power calculation.

Using Power Elements in the Relay Trip Equation

The power elements are not supervised by any relay elements other than the minimum voltage checks shown in *Figure 3.36* and *Figure 3.37*. If the protection application requires overcurrent protection in addition to the power elements, there may be a race condition during a fault between the overcurrent element(s) and the power element(s) if the power element(s) are still receiving sufficient operating quantities. In some protection schemes this may jeopardize coordination. One method of accommodating this is to increase the power element time delay settings. Another method is to supervise the power element Relay Word bit(s) with the overcurrent element pickup. For example, if the application requires that the relay trip the attached circuit breaker when a forward power flow threshold is exceeded, and a phase definite-time overcurrent element is also in the relay trip equation, extra security can be achieved with these SELOGIC control equation settings:

TR = **... + ... + SV1T + 67P1T**

SV1 = **3PWR1 * !67P1**

And group settings:

E50P = **1**

ESV = **1**

EPWR = **1**

50P1P = **5.00 A**

67P1D = **10.00 cycles**

SV1PU = **1.00 cycle**

SV1DO = **0.00 cycles**

3PWR1P = **360.00 VA**

PWR1T = **+WATTS**

PWR1D = **5.00 cycles**

During a fault that can pick-up both the power element and the overcurrent element, these settings will ensure that the definite-time overcurrent element (67P1T) will trip the relay for the fault, even if the PWR1D setting is set to a smaller time delay than the 67P1D setting. Relay Word bit 3PWR1 is ANDed with Relay Word bit NOT(67P1), which effectively blocks 3PWR1 when 67P1 is asserted. The SELOGIC variable timer SV1T is employed in this example to avoid another race condition that could occur if the fault was cleared by another device before the definite-time element time-out, which could potentially deassert 67P1 a few quarter-cycles before 3PWR1 deasserts. Without this timer, an incorrect trip operation may occur.

See *Instantaneous/Definite-Time Overcurrent Elements on page 3.1* and *SELOGIC Control Equation Variables/Timers on page 7.28* for details on the operation of these functions and their settings.

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Accuracy

Single-Phase Power Elements (EPWR = 1, 2, 3, or 4)

Pickup:

Pickup setting 0.33–2VA {5 A nominal}, 0.07–0.4 VA {1 A nominal}	±0.05 A • (L-N voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element {5 A nominal}
	±0.01 A • (L-N voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element {1 A nominal}
Pickup setting 2–13000 VA {5 A nominal}, 0.4–2600 VA {1 A nominal}	±0.025 A • (L-N voltage secondary) and ±5% of setting at unity power factor {5 A nom}
	±0.005 A • (L-N voltage secondary) and ±5% of setting at unity power factor {1 A nom}

Three-Phase Power Elements (EPWR = 3P1, 3P2, 3P3, or 3P4)

Pickup:

Pickup setting 1–6 VA {5 A nominal}, 0.2–1 VA {1 A nominal}:	±0.05 A • (L-L voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element {5 A nominal}
	±0.01 A • (L-L voltage secondary) and ±10% of setting at unity power factor for power elements and zero power factor for reactive power element {1 A nominal}
Pickup setting 6–39000 VA {5 A nominal}, 1–7800 VA {1 A nominal}:	±0.025 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element {5 A nominal}
	±0.005 A • (L-L voltage secondary) and ±5% of setting at unity power factor for power elements and zero power factor for reactive power element {1 A nominal}

The quoted three-phase power element accuracy specifications are applicable as follows:

- Wye-connected voltages (PTCONN = WYE): any conditions,
- Open-delta connected voltages (PTCONN = DELTA), with properly configured broken-delta 3V0 connection (VSCONN = 3V0): any conditions,
- Open-delta connected voltages, **without** broken-delta 3V0 connection (VSCONN = VS): balanced conditions only.

Timer: ±0.25 cycles and ±0.1% of setting

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Single-Phase Power Element Calculations

The numeric method used in the single-phase power elements uses line-to-neutral voltage and phase current quantities. Each phase is calculated separately, with the resulting power quantities subject to the minimum voltage and current tests shown in the lower half of *Figure 3.36*.

Three-Phase Power Element Calculations

The numeric method used in the three-phase power elements uses line-to-line voltage and phase current quantities, corrected with zero-sequence voltage and current when unbalanced. The following discussion assumes that all three phase currents (I_A, I_B, and I_C) are connected to the relay.

The resulting power quantities are subject to the minimum voltage and current tests shown in the lower half of *Figure 3.37*.

For wye-connected relays (Global Setting PTCONN = WYE), the three-phase power is the same as the sum of the single-phase powers under any conditions of unbalance, because the zero-sequence voltage (and current) is available.

For delta-connected relays (Global Setting PTCONN = DELTA) with a broken delta 3V0 connection (Global Setting VSCONN = 3V0), the three-phase power is the same as the sum of the theoretical single-phase powers under any conditions of unbalance, because the zero-sequence voltage is available via the **VS-NS** terminals (provided the 3V0 source is on the same bus section as the three-phase voltage inputs, the two signal sources cannot be isolated by switching action, and the PTR and PTRS settings are properly entered).

For delta-connected relays (Global Setting PTCONN = DELTA) with no broken delta 3V0 connection (Global Setting VSCONN = VS), the three-phase power is the same as the sum of the theoretical single-phase powers only in balanced conditions (either |3V0| = 0, or |3I0| = 0, or both). For unbalanced conditions, the three-phase power element value will include an error term that is proportional to the amount of unbalance.

Power Elements Logic Operation

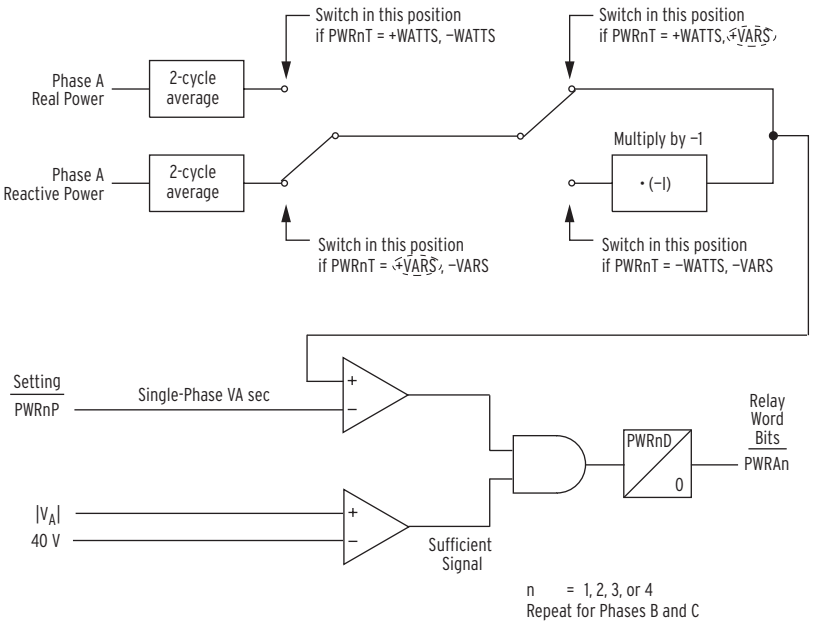


Figure 3.36 Single-Phase Power Elements Logic (+VARS Example Shown)

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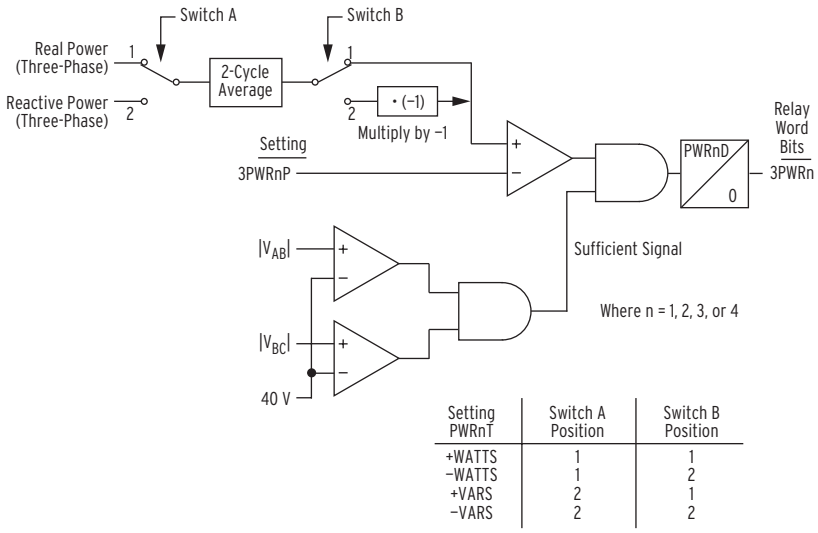


Figure 3.37 Three-Phase Power Elements Logic

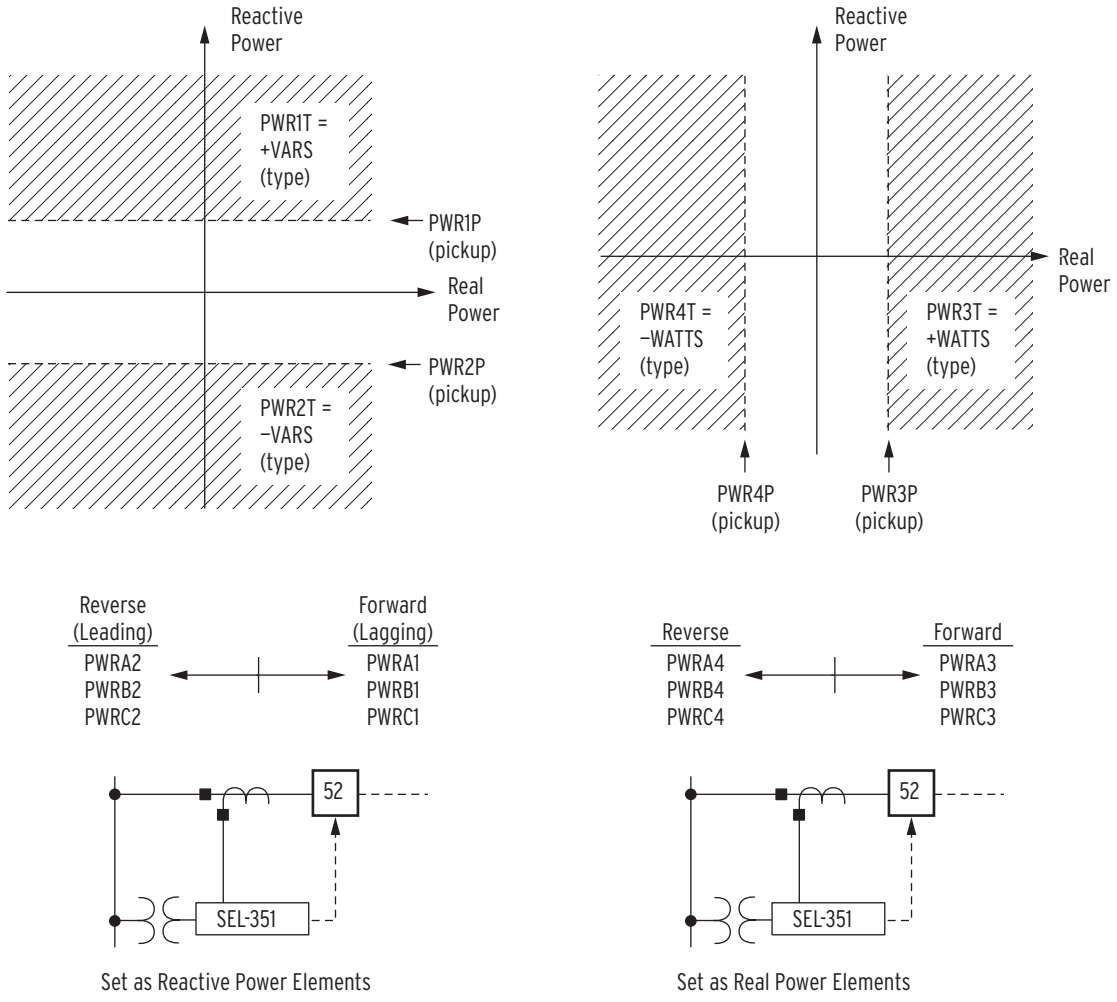


Figure 3.38 Power Elements Operation in the Real/Reactive Power Plane

In *Figure 3.36*, an example is shown with setting PWR*n*T = +VARS. This corresponds to the settings PWR1P (pickup) and PWR1T (type) in *Figure 3.38*.

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In *Figure 3.38*, if the Phase A reactive power level is above pickup setting PWR*n*P, Relay Word bit PWRA*n* asserts (PWRA*n* = logical 1) after time delay setting PWR*n*D (*n* = 1–4), subject to the "sufficient signal" conditions.

Pickup setting PWR*n*P is always a positive number value (see *Table 3.14*). Thus, if –WATTS or –VARS are chosen with setting PWR*n*T, the corresponding real or reactive power values have to be multiplied by –1 so that element PWRA*n* asserts for negative real or reactive power.

Power Elements Application—VAR Control for a Capacitor Bank

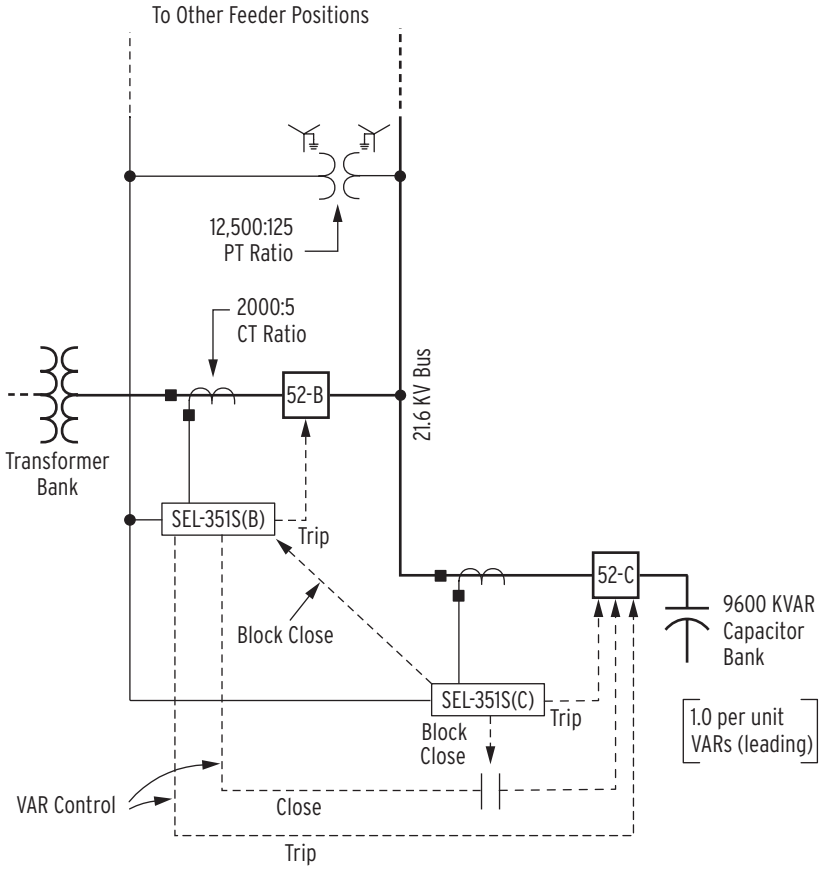


Figure 3.39 SEL-351S(B) Provides VAR Control for 9600 kVAR Capacitor Bank

The 9600 kVAR capacitor bank in *Figure 3.39* is put on-line and taken off-line according to the VAR loading on the transformer bank feeding the 21.6 kV bus. The VAR loading is measured with the SEL-351S(B) located at bus circuit breaker 52-B.

Two SEL-351S relays control the capacitor bank—both relays are connected to capacitor bank circuit breaker 52-C. The SEL-351S(C) provides capacitor overcurrent protection and trips circuit breaker 52-C for a fault in the capacitor bank. The SEL-351S(B) provides VAR control and automatically puts the capacitor bank on-line (closes circuit breaker 52-C) or takes it off-line (trips circuit breaker 52-C) according to the measured VAR level. The SEL-351S(B) also provides bus overcurrent protection and trips circuit breaker 52-B for a fault on the 21.6 kV bus.

In *Figure 3.39*, if the SEL-351S(C) trips circuit breaker 52-C for a fault in the capacitor bank, then a block close signal is sent from the SEL-351S(C) to the SEL-351S(B). This prevents the SEL-351S(B) from issuing an automatic close to circuit breaker 52-C.

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For additional security, the close circuit from the SEL-351S(B) to circuit breaker 52-C is supervised by a block close output contact from the SEL-351S(C). This block close output contact opens if the SEL-351S(C) trips circuit breaker 52-C for a fault in the capacitor bank—no automatic closing can then take place.

These block close signals seal in when the SEL-351S(C) trips circuit breaker 52-C for a fault in the capacitor bank. Automatic closing of circuit breaker 52-C with the SEL-351S(B) can then take place only after the block close signals are reset. The exact implementation of this block close logic requires an application note beyond the scope of this discussion.

The rest of this discussion focuses on the determination of VAR levels (and corresponding power element settings) for automatic tripping and closing of circuit breaker 52-C with the SEL-351S(B).

Convert three-phase 9600 kVAR (kVA) to single-phase VA (voltamperes) secondary:

9600 kVA/(21.6 kV•√3) = 256.6 A primary
256.6 A primary • (5/2000) = 0.64 A secondary
0.64 A secondary • 125 V secondary = 80.0 VA secondary (single-phase)

The three-phase 9600 kVAR capacitor is converted to 1.0 per unit VARs (leading) for demonstration convenience in *Figure 3.39*. *Figure 3.40* shows the per unit VAR levels for putting on-line (closing circuit breaker 52-C) or taking off-line (tripping circuit breaker 52-C) the capacitor bank.

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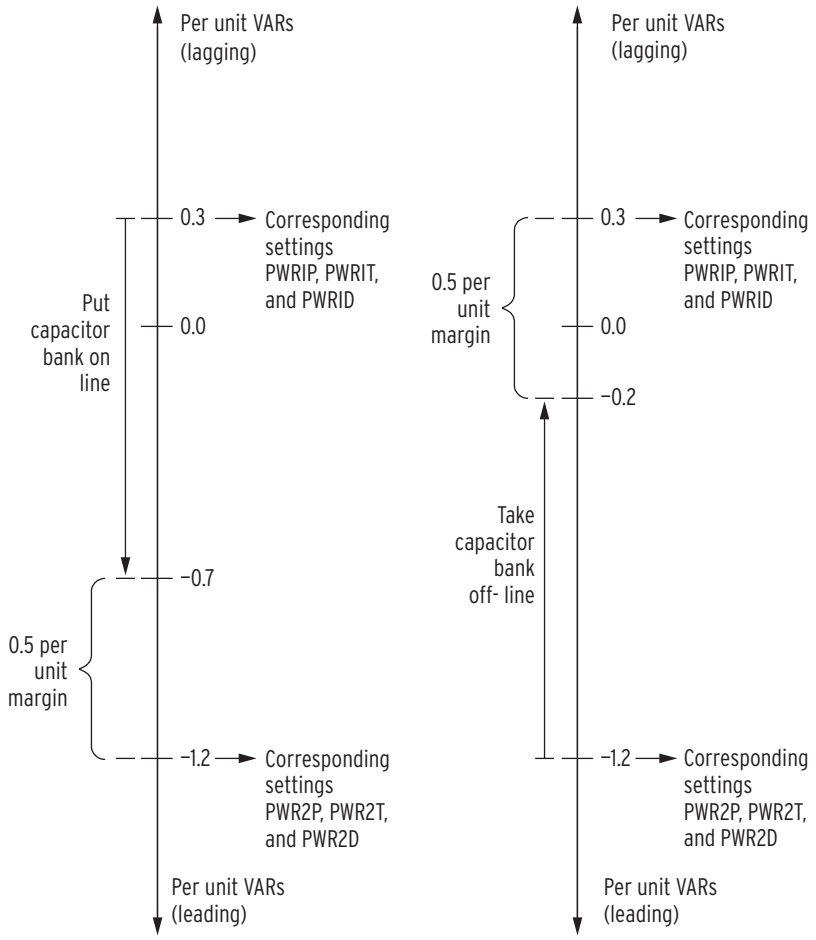


Figure 3.40 Per Unit Setting Limits for Switching 9600 kVAR Capacitor Bank On- and Off-Line

The capacitor bank is put on-line at the 0.3 per unit VAR level (lagging) on the bus. The per unit VAR level immediately changes to the –0.7 per unit VAR level (leading) when the capacitor bank is put on-line (0.3 – 1.0 = –0.7). There is a margin of 0.5 per unit VARs until the capacitor bank is then taken off-line (–0.7 – 0.5 = –1.2).

The capacitor bank is taken off-line at the –1.2 per unit VAR level (leading) on the bus. The per unit VAR level immediately changes to –0.2 per unit VAR level (leading) when the capacitor bank is taken off-line (–1.2 + 1.0 = –0.2). There is a margin of 0.5 per unit VARs until the capacitor bank is put on-line again (–0.2 + 0.5 = 0.3).

Settings for Single-Phase Power Elements

From preceding calculations and figures:

9600 kVAR ≈ 1.0 per unit VARs ≈ 80.0 VA secondary (single-phase)

Convert the per unit VAR levels 0.3 and –1.2 to single-phase VA (voltamperes) secondary:

0.3 • 80.0 VA secondary (single-phase) = 24.0 VA secondary (single-phase)

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–1.2 • 80.0 VA secondary (single-phase) = –96.0 VA secondary (single-phase)

Make the following power element settings for the SEL-351S(B):

EPWR = **2** (enable two power elements)

PWR1P = **24.0** (power element pickup; VA secondary [single-phase])
(power element type; lagging VARs)

PWR1T = **+VARS** (power element time delay; cycles)

PWR1D = **_____**

PWR2P = **96.0** (power element pickup; VA secondary [single-phase])
(power element type; leading VARs)

PWR2T = **–VARS** (power element time delay; cycles)

PWR2D = **_____**

To override transient reactive power conditions, set the above power element time delay settings equivalent to several seconds (or perhaps minutes).

Resulting single-phase power elements PWRA1, PWRB1, and PWRC1 assert when the lagging VAR level exceeds the 0.3 per unit VAR level (lagging) for each respective phase (see *Figure 3.40* and left-hand side of *Figure 3.38*). These elements are used in close logic in the SEL-351S(B) to automatically put the 9600 kVAR capacitor bank on-line.

Resulting single-phase power elements PWRA2, PWRB2, and PWRC2 assert when the leading VAR level exceeds the –1.2 per unit VAR level (leading) for each respective phase (see *Figure 3.40* and left-hand side of *Figure 3.38*). These elements are used in trip logic in the SEL-351S(B) to automatically take the 9600 kVAR capacitor bank off-line.

Settings for Three-Phase Power Elements

Following the single-phase derivation, the resulting power element setting values need to be multiplied by three.

EPWR = **3P2**

3PWR1P = **72.0**

PWR1T = **+VARS**

PWR1D = **____**

3PWR2P = **288.0**

PWR1T = **–VARS**

PWR1D = **____**

The exact implementation of this capacitor close and trip logic in SELOGIC control equations in the SEL-351S(B) is not shown.

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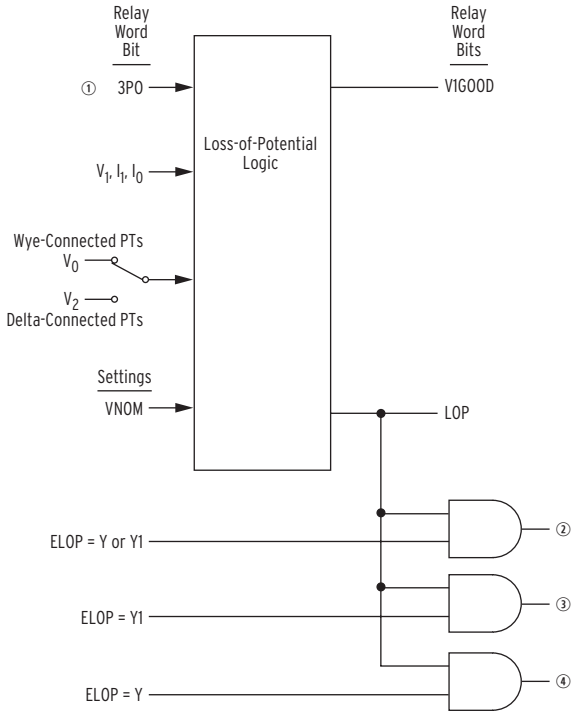
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Section 4

Loss-of-Potential, Load Encroachment, and Directional Element Logic

Loss-of-Potential Logic

The loss-of-potential (LOP) logic operates as shown in *Figure 4.1*.



① From Figure 5.3; ② to Figure 4.6, Figure 4.7, Figure 4.8, and Figure 4.21; ③ to Figure 5.6; ④ to Figure 4.15, Figure 4.16, and Figure 4.22.

Figure 4.1 Loss-of-Potential Logic

Inputs into the LOP logic are described in *Table 4.1*:

Table 4.1 LOP Logic Inputs (Sheet 1 of 2)

Input	Description
3PO	Three-pole open condition (indicates circuit breaker open condition; see *Figure 5.3*).
V_1	Positive-sequence voltage (V secondary).
I_1	Positive-sequence current (A secondary).
I_0	Zero-sequence current (A secondary).

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Table 4.1 LOP Logic Inputs (Sheet 2 of 2)

Input	Description
V_0	Zero-sequence voltage (V secondary) {wye-connected PTs}.
V_2	Negative-sequence voltage (V secondary) {delta-connected PTs}.
VNOM	PT nominal voltage setting (line-to-neutral {wye-connected PTs} or line-to-line {delta-connected PTs}, secondary).

The circuit breaker has to be closed (Relay Word bit 3PO = logical 0) for the LOP logic to operate.

Loss-of-potential is declared (Relay Word bit LOP = logical 1) when a 10 percent or larger drop in V_1 is detected, with no corresponding change in I_1 or I_0. If the LOP condition persists for 60 cycles, it latches in.

When the relay is configured for wye-connected PTs, LOP resets (Relay Word bit LOP = logical 0) when V_1 returns above 75 percent of setting VNOM (Relay Word bit V1GOOD also asserts) and V_0 is less than 7.8 percent of setting VNOM.

When the relay is configured for delta-connected PTs, LOP resets (Relay Word bit LOP = logical 0) when V_1 returns above 43 percent of setting VNOM (Relay Word bit V1GOOD also asserts) and V_2 is less than 4.5 percent of setting VNOM.

The loss-of-potential enable setting, ELOP, does not enable or disable the LOP logic. It just routes the LOP Relay Word bit to different logic, as shown in *Figure 4.1* and explained in the remainder of this subsection.

LOP is disabled while 3PO is asserted (breaker open). If an input potential is lost during this time, LOP will not assert when 3PO deasserts (breaker close) since the 10 percent drop in V_1 has already occurred. This is the case for systems using either line-side or bus-side potential transformers.

Setting VNOM = OFF

If setting VNOM = OFF, the loss-of-potential logic is disabled (Relay Word bits LOP and V1GOOD are forced to logical 0), and setting ELOP can only be set to "N." See *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings on page 9.53* for more details on the VNOM setting.

Setting ELOP = Y or Y1

If setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts to logical 1), all internal enables (see NOTE 1) (except for 32IE) are disabled (see *Figure 4.6*, *Figure 4.7*, *Figure 4.8*, and *Figure 4.21*). The loss-of-potential condition makes the voltage-polarized directional elements (which are controlled by these internal enables) unreliable. Thus, they are disabled. The overcurrent elements controlled by these voltage-polarized directional elements are disabled also (unless overridden by conditions explained in *Setting ELOP = Y on page 4.3*).

The channel **IN** current-polarized directional element (*Figure 4.11*) is controlled by internal enable 32IE (*Figure 4.7*). This directional element is not voltage polarized and thus a loss-of-potential condition does not disable the element.

> **NOTE 1:** When global setting VSCONN = 3V0, the various ground-directional elements that rely on zero-sequence voltage quantities (ORDER settings V, S, P, and U) are not disabled by a loss-of-potential condition on relay inputs **VA**, **VB**, and **VC**, because these directional elements use the $3V_0$ zero-sequence voltage that comes directly from voltage input **VS**, rather than the zero-sequence voltage calculated from

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voltage inputs **VA**, **VB**, and **VC** (wye-connected PTs). This difference is shown in *Figure 4.7* and *Figure 4.8*, where Relay Word bit 3V0 is used as a block signal for the loss-of-potential signal. Relay Word bit 3V0 is asserted (= logical 1) whenever global setting VSCONN = 3V0. Refer to *Settings for Voltage Input Configuration on page 9.50*.

Setting ELOP = Y

Additionally, if setting ELOP = Y and a loss-of-potential condition occurs (Relay Word bit LOP asserts to logical 1), overcurrent elements set direction forward (see NOTE 2) are enabled (see *Figure 4.15*, *Figure 4.16*, and *Figure 4.22*). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

As detailed previously, voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. However, this disable condition is overridden for the overcurrent elements set direction forward if setting ELOP = Y.

NOTE 2: When global setting VSCONN = 3V0, the various ground-directional elements that rely on zero-sequence voltage quantities (ORDER settings V, S, P, and U) are not affected by a loss-of-potential condition on relay inputs **VA**, **VB**, and **VC**, because these elements use the $3V_0$ zero-sequence voltage that comes directly from voltage input **VS**, rather than the zero-sequence voltage calculated from voltage inputs **VA**, **VB**, and **VC** (wye-connected PTs). This difference is shown in *Figure 4.15* and *Figure 4.16*, where Relay Word bit 3V0 is combined with Relay Word bits 32NE and 32VE to create a block signal for the loss-of-potential signal. When LOP is asserted and setting ELOP = Y1, the relay will not force an enable of the ground elements that are set direction-forward when Relay Word bit 3V0 is asserted (= logical 1) and one of the zero-sequence voltage-polarized ground directional element enables (32VE or 32NE) is asserted. Refer to *Settings for Voltage Input Configuration on page 9.50*.

Setting ELOP = N

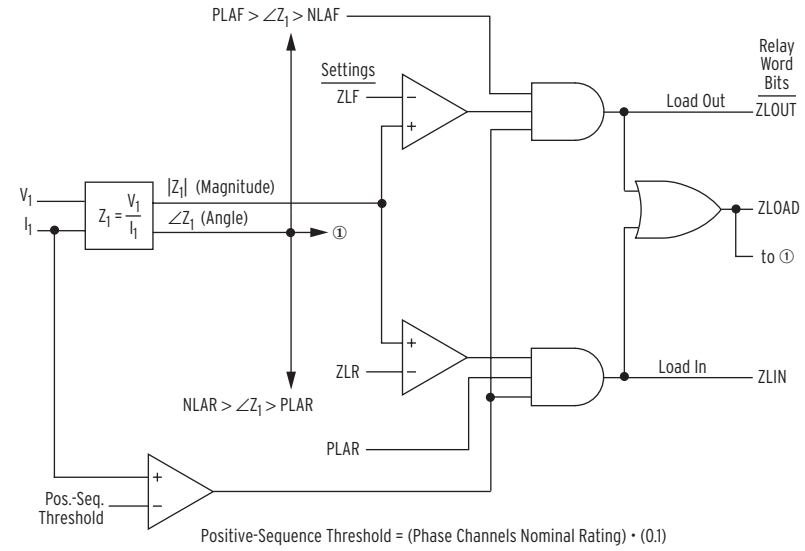
If setting ELOP = N, the loss-of-potential logic still operates (Relay Word bit LOP asserts to logical 1 for a loss-of-potential condition) but does not disable any voltage-based directional elements (as occurs with ELOP = Y or Y1) or enable overcurrent elements set direction forward (as occurs with ELOP = Y).

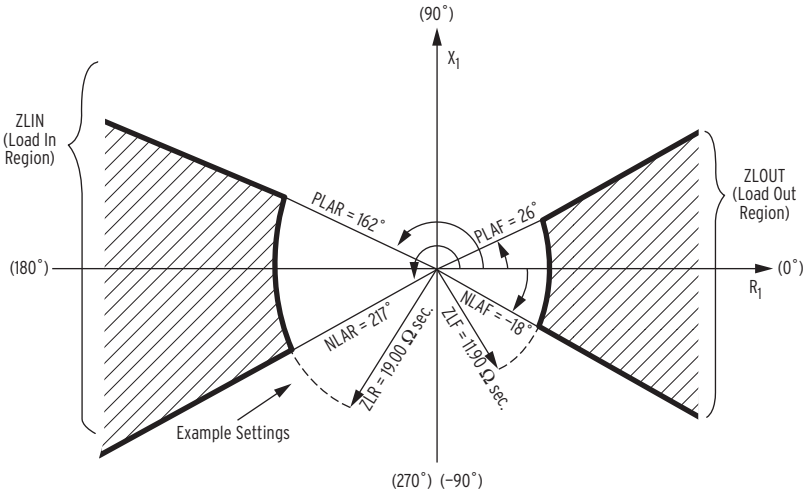
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Load-Encroachment Logic

The load-encroachment logic (see *Figure 4.2*) and settings are enabled/disabled with setting ELOAD (= Y or N). (If group setting VNOM = OFF, then ELOAD can only be set to "N." See *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings on page 9.53* for more details on the VNOM setting.)

The load-encroachment feature allows phase overcurrent elements to be set without regard for load levels. This is especially helpful in bus overcurrent applications. A bus relay sees the cumulative currents of all the feeders but still has to provide overcurrent backup protection for all these feeders. If the phase elements in the bus relay are set to provide adequate backup, they often are set close to maximum bus load current levels. This runs the risk of tripping on bus load current. The load-encroachment feature prevents this from happening as shown in the example that follows in this subsection.





① To Figure 4.21.

Figure 4.2 Load-Encroachment Logic

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Note that a positive-sequence impedance calculation (Z_1) is made in the load-encroachment logic in *Figure 4.2*. Load is largely a balanced condition, so apparent positive-sequence impedance is a good load measure. The load-encroachment logic operates only if the positive-sequence current (I_1) is greater than the Positive-Sequence Threshold defined in *Figure 4.2*. For a balanced load condition, I_1 = phase current magnitude.

Forward load (load flowing out) lies within the hatched region labeled ZLOUT. Relay Word bit ZLOUT asserts to logical 1 when the load lies within this hatched region.

Reverse load (load flowing in) lies within the hatched region labeled ZLIN. Relay Word bit ZLIN asserts to logical 1 when the load lies within this hatched region.

Relay Word bit ZLOAD is the OR-combination of ZLOUT and ZLIN:

ZLOAD = ZLOUT + ZLIN

Settings Ranges

Refer to *Figure 4.2*.

Table 4.2 Load-Encroachment Settings Ranges

Setting	Description and Range
ZLF	Forward Minimum Load Impedance—corresponding to maximum load flowing out.
ZLR	Reverse Minimum Load Impedance—corresponding to maximum load flowing in. 0.10–128.00 Ω secondary (5 A nominal phase current inputs, IA, IB, IC) 0.50–640.00 Ω secondary (1 A nominal phase current inputs, IA, IB, IC)
PLAF	Maximum Positive Load Angle Forward (–90° to +90°)
NLAF	Maximum Negative Load Angle Forward (–90° to +90°)
PLAR	Maximum Positive Load Angle Reverse (+90° to +270°)
NLAR	Maximum Negative Load Angle Reverse (+90° to +270°)

Load-Encroachment Setting Example

Example system conditions:

Nominal Line-Line Voltage:	230 kV
Maximum Forward Load:	800 MVA
Maximum Reverse Load:	500 MVA
Power Factor (Forward Load):	0.90 lag to 0.95 lead
Power Factor (Reverse Load):	0.80 lag to 0.95 lead
CT ratio:	2000/5 = 400
PT ratio:	134000/67 = 2000

The PTs are connected line-to-neutral.

Convert Maximum Loads to Equivalent Secondary Impedances

Start with maximum forward load:

800 MVA • (1/3)	267 MVA per phase
230 kV • (1/√3) =	132.8 kV line-to-neutral
267 MVA • (1/132.8 kV) • (1000kV/MV) =	2010 A primary

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$$\begin{aligned} 2010 \text{ A primary} \bullet (1/\text{CT ratio}) &= 2010 \text{ A primary} \bullet (1 \text{ A secondary}/400 \text{ A primary}) \\ &= 5.03 \text{ A secondary} \\ 132.8 \text{ kV} \bullet (1000 \text{ V/kV}) &= 132800 \text{ V primary} \\ 132800 \text{ V primary} \bullet (1/\text{PT ratio}) &= 132800 \text{ V primary} \bullet (1 \text{ V secondary}/2000 \text{ V primary}) \\ &= 66.4 \text{ V secondary} \end{aligned}$$

Now, calculate the equivalent secondary impedance:

$$\frac{66.4 \text{ V secondary}}{5.03 \text{ A secondary}} = 13.2 \ \Omega \text{ secondary}$$

This secondary value can be calculated more expediently with the following equation:

$$\frac{(\text{line-line voltage in kV})^2 \bullet \text{CT ratio}}{3\text{-phase load in MVA} \bullet \text{PT ratio}}$$

Again, for the maximum forward load:

$$\frac{230^2 \bullet 400}{800 \bullet 2000} = 13.2 \ \Omega \text{ secondary}$$

To provide a margin for setting ZLF, multiply by a factor of 0.9:

$$\begin{aligned} \text{ZLF} &= 13.2 \ \Omega \text{ secondary} \bullet 0.9 \\ &= 11.90 \ \Omega \text{ secondary} \end{aligned}$$

For the maximum reverse load:

$$\frac{230^2 \bullet 400}{500 \bullet 2000} = 21.1 \ \Omega \text{ secondary}$$

Again, to provide a margin for setting ZLR:

$$\begin{aligned} \text{ZLR} &= 21.1 \text{ secondary} \bullet 0.9 \\ &= 19.00 \ \Omega \text{ secondary} \end{aligned}$$

Convert Power Factors to Equivalent Load Angles

The power factor (forward load) can vary from 0.90 lag to 0.95 lead.

Setting PLAF = $\cos^{-1}(0.90) = 26^\circ$

Setting NLAF = $\cos^{-1}(0.95) = -18^\circ$

The power factor (reverse load) can vary from 0.80 lag to 0.95 lead.

Setting PLAR = $180^\circ - \cos^{-1}(0.95) = 180^\circ - 18^\circ = 162^\circ$

Setting NLAR = $180^\circ + \cos^{-1}(0.80) = 180^\circ + 37^\circ = 217^\circ$

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Apply Load-Encroachment Logic to a Phase Time-Overcurrent

Again, from *Figure 4.2*:

ZLOAD = ZLOUT + ZLIN

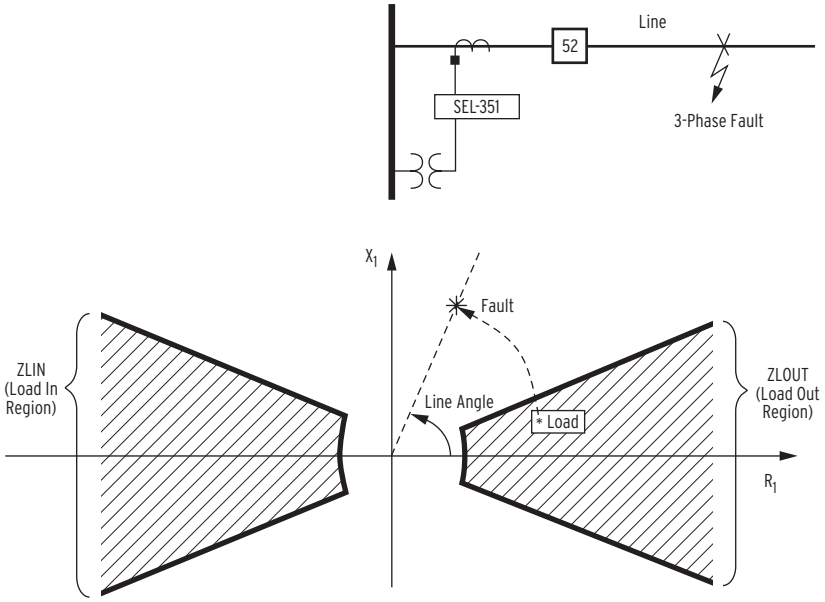


Figure 4.3 Migration of Apparent Positive-Sequence Impedance for a Fault Condition

Refer to *Figure 4.3*. In a load condition, the apparent positive-sequence impedance is **within** the ZLOUT area, resulting in:

$$\begin{aligned} \text{ZLOAD} &= \text{ZLOUT} + \text{ZLIN} \\ &= \text{logical 1} + \text{ZLIN} \\ &= \text{logical 1} \end{aligned}$$

If a fault occurs, the apparent positive-sequence impedance moves **outside** the ZLOUT area (and stays outside the ZLIN area, too), resulting in:

$$\begin{aligned} \text{ZLOAD} &= \text{ZLOUT} + \text{ZLIN} \\ &= \text{logical 0} + \text{logical 0} \\ &= \text{logical 0} \end{aligned}$$

Refer to *Figure 3.14*. To prevent phase time-overcurrent element 51P1T from operating for high load conditions, make the following SELOGIC® control equation torque control setting:

51P1TC = **!ZLOAD*!LOP + 50P6(=NOT[ZLOAD]*NOT[LOP] + 50P6)**

As shown in *Figure 4.2*, load-encroachment logic is a positive-sequence calculation. During LOP conditions (loss-of-potential; see *Figure 4.1*), positive-sequence voltage (V_1) can be substantially depressed in magnitude or changed in angle. This change in V_1 can possibly cause ZLOAD to deassert (= logical 0), erroneously indicating that a “fault condition” exists. Thus, !ZLOAD should be supervised by !LOP in a torque control setting. This also effectively happens in the directional element in *Figure 4.21*, where ZLOAD and LOP are part of the logic.

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In the above setting example, phase instantaneous overcurrent element 50P6 is set above any maximum load current level—if 50P6 picks up, there is assuredly a fault. For faults below the pickup level of 50P6, but above the pickup of phase time-overcurrent element 51P1T, the !ZLOAD*!LOP logic discriminates between high load and fault current. If an LOP condition occurs (LOP = logical 1), the pickup level of 50P6 becomes the effective pickup of phase time-overcurrent element 51P1T (51P1T loses its sensitivity when an LOP condition occurs):

51P1TC = **!ZLOAD*!LOP + 50P6**
= !ZLOAD*NOT[LOP] + 50P6
= !ZLOAD*NOT[logical 1] + 50P6
= 50P6

If phase time-overcurrent element 51P1T is used in a directional application, then this special torque control logic is not used and the corresponding torque control setting is set directly to logical 1 (51P1TC = 1), unless additional control is desired.

Embedded logic handles load encroachment concerns for directional phase overcurrent elements. Directional control for phase overcurrent elements comes from *Figure 4.24*, which refers back to *Figure 4.22*, which in turn refers back to *Figure 4.20* and *Figure 4.21*. In *Figure 4.21*, notice that the "!ZLOAD*!LOP" condition is effectively embedded in the positive-sequence voltage-polarized directional element logic. The 32QE Relay Word bit input into the negative-sequence voltage-polarized directional element logic (*Figure 4.20*) also has LOP control embedded in it (see *Figure 4.6*). And both these directional elements (*Figure 4.20* and *Figure 4.21*) have overcurrent fault detectors (50QF/50QR and 50P23P, respectively).

Use the SEL-321 Relay Application Guide for the SEL-351S Relay

The load-encroachment logic and settings in the SEL-351S are the same as those in the SEL-321. Refer to SEL *Application Guide 93-10 (*SEL-*321 Relay Load-Encroachment Function Setting Guidelines)* for applying the load-encroachment logic in the SEL-351S. Note that *Application Guide AG93-10* discusses applying the load-encroachment feature to phase distance elements in the SEL-321. The SEL-351S does not have phase distance elements, but the principles and settings example are still applicable to the SEL-351S.

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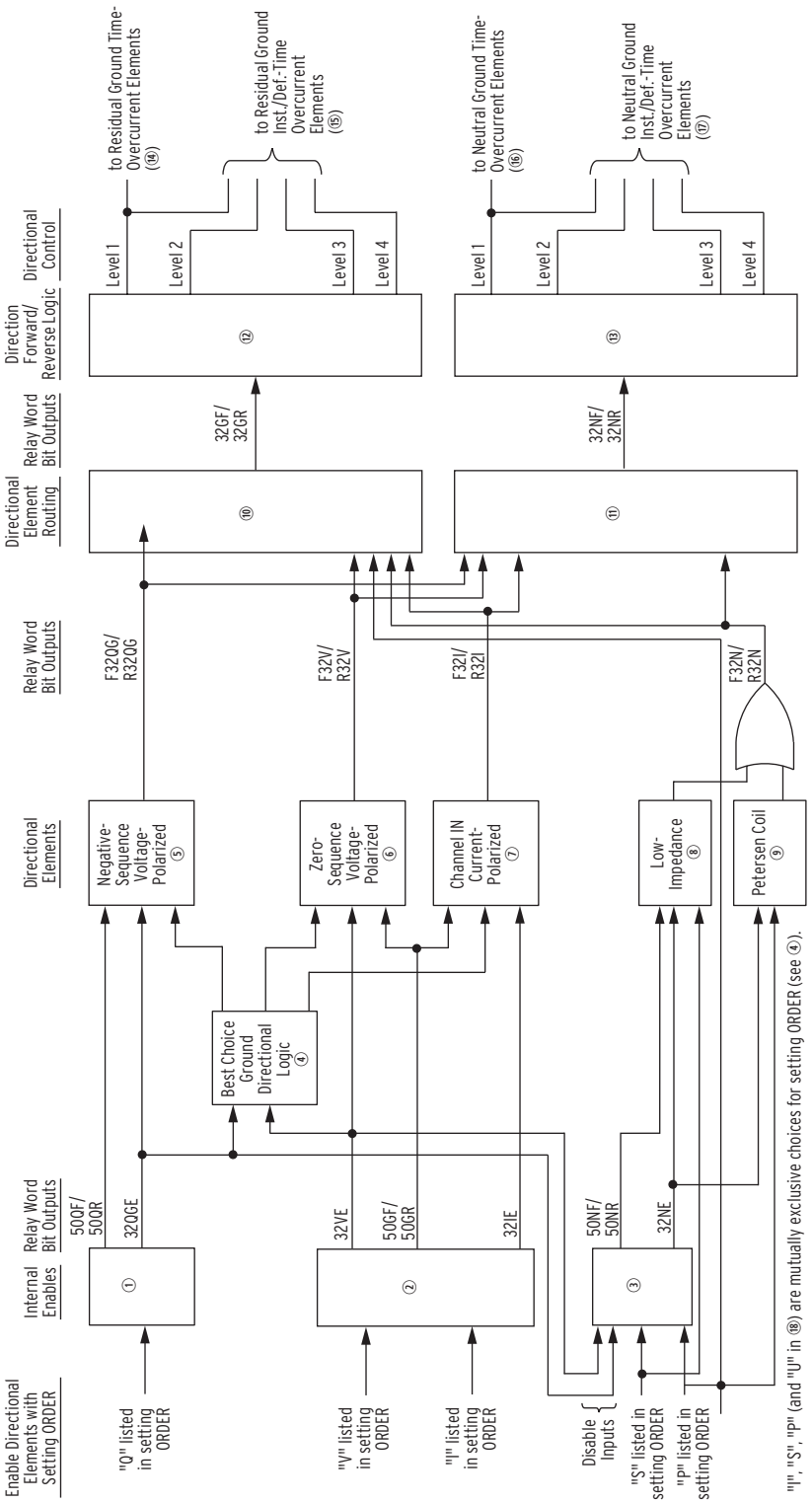
Directional Control for Neutral Ground and Residual Ground Overcurrent Elements

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 and other directional control settings are described in the following subsection *Directional Control Settings on page 4.39*.

Six directional elements are available to control the neutral ground and residual ground overcurrent elements (not all available simultaneously). These six directional elements are:

- Negative-sequence voltage-polarized directional element
- Zero-sequence voltage-polarized directional element
- Channel IN current-polarized directional element
- Zero-sequence voltage-polarized directional element (low-impedance grounded system)
- Wattmetric and incremental conductance directional elements (Petersen Coil grounded system)
- Zero-sequence voltage-polarized directional element (ungrounded/high-impedance grounded system)

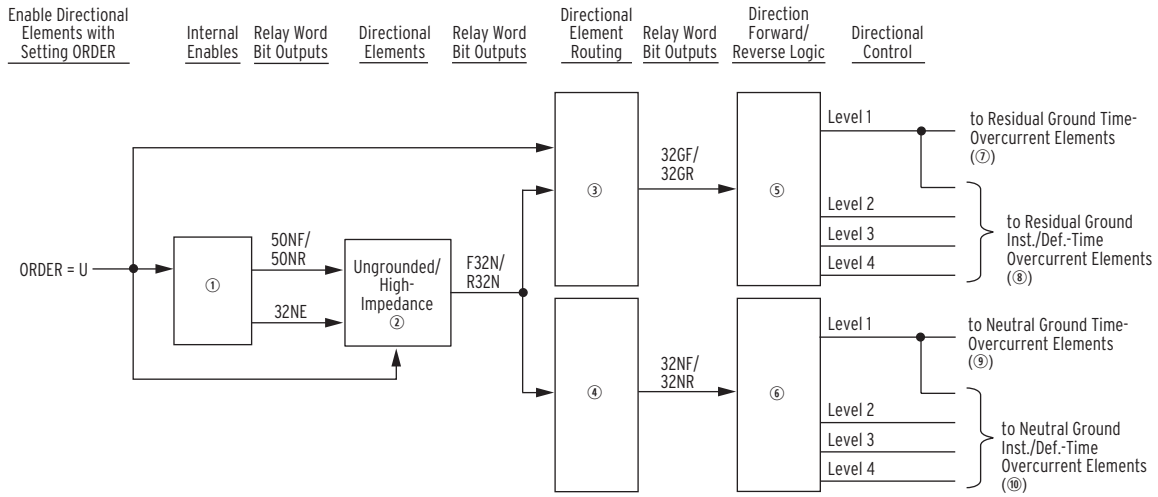
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① Figure 4.6; ② Figure 4.7; ③ Figure 4.8; ④ Table 4.3 and Table 4.4; ⑤ Figure 4.9; ⑥ Figure 4.10; ⑦ Figure 4.11; ⑧ Figure 4.12; ⑨ Figure 4.13; ⑩ Figure 4.15; ⑪ Figure 4.16; ⑫ Figure 4.17; ⑬ Figure 4.18; ⑭ Figure 3.18 and Figure 3.19; ⑮ Figure 3.10; ⑯ Figure 3.16 and Figure 3.17; ⑰ Figure 3.8; ⑱ Figure 4.5.

Figure 4.4 General Logic Flow of Directional Control for Neutral Ground and Residual Ground Overcurrent Elements (Excluding Ungrounded/High-Impedance Grounded Systems)

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① Figure 4.8; ② Figure 4.14; ③ Figure 4.15; ④ Figure 4.16; ⑤ Figure 4.17; ⑥ Figure 4.18; ⑦ Figure 3.18 and Figure 3.19; ⑧ Figure 3.10; ⑨ Figure 3.16 and Figure 3.17; ⑩ Figure 3.8.

Figure 4.5 General Logic Flow of Directional Control for Neutral Ground and Residual Ground Overcurrent Elements (Ungrounded/High-Impedance Grounded Systems; ORDER = U)

Table 4.3 Available Ground Directional Elements

ORDER Setting Choices	Corresponding Ground Directional Element (and System Grounding)	Corresponding Internal Enables (and System Grounding)	Corresponding Figures	Availability
Q	Negative-sequence voltage-polarized	32QGE	*Figure 4.6*, *Figure 4.9*	All models (not dependent on neutral channel [IN])
V	Zero-sequence voltage-polarized	32VE	*Figure 4.7*, *Figure 4.10*	
I	Channel IN current polarized	32IE	*Figure 2.20*, *Figure 4.7*, *Figure 4.11*	Models with a 1 A or 5 A nominal neutral channel (IN)
S	Zero-sequence voltage-polarized (Low-impedance)	32NE (Low-Impedance)	*Figure 2.25*, *Figure 4.8*, *Figure 4.12*	Models with a 0.2 A nominal neutral channel (IN) **NOTE:** S, P, and U are mutually exclusive—they cannot be listed together in the ORDER setting.
P	Wattmetric and incremental conductance (Petersen Coil)	32NE (Petersen Coil)	*Figure 2.26*, *Figure 4.8*, *Figure 4.13*	
U	Zero-sequence voltage-polarized (Ungrounded/ High-Impedance)	32NE (Ungrounded/ High-Impedance)	*Figure 2.25*, *Figure 2.27*, *Figure 2.28*, *Figure 4.8*, *Figure 4.14*	

NOTE: The neutral channel (IN) can also be ordered as a 0.05 A nominal neutral channel. Such a rated neutral channel provides no special directional element options, like those listed above. The 0.05 A nominal neutral channel is a legacy nondirectional sensitive earth fault (SEF) option (a 0.2 A nominal neutral channel can provide the same SEF function and more). See Figure 3.8, Figure 3.9, and Figure 3.18 and accompanying settings ranges explanation.

Table 4.4 Best Choice Ground Directional™ Logic (Sheet 1 of 2)

ORDER Setting Combinations	Resultant ground directional element preference (indicated below with corresponding internal enables; run element that corresponds to highest choice internal enable that is asserted; system grounding in parentheses)			ORDER Setting Combination Availability
	1st Choice	2nd Choice	3rd Choice	
OFF	No ground directional elements enabled			All models (not dependent on neutral channel [IN])
Q	32QGE			
QV	32QGE	32VE		
V	32VE			
VQ	32VE	32QGE		

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Table 4.4 Best Choice Ground Directional™ Logic (Sheet 2 of 2)

ORDER Setting Combinations	Resultant ground directional element preference (indicated below with corresponding internal enables; run element that corresponds to highest choice internal enable that is asserted; system grounding in parentheses)			ORDER Setting Combination Availability
	1st Choice	2nd Choice	3rd Choice	
I	32IE			Additional setting combinations for models with a 1 A or 5 A nominal neutral channel (IN)
IQ	32IE	32QGE		
IQV	32IE	32QGE	32VE	
IV	32IE	32VE		
IVQ	32IE	32VE	32QGE	
QI	32QGE	32IE		
QIV	32QGE	32IE	32VE	
QVI	32QGE	32VE	32IE	
VI	32VE	32IE		
VIQ	32VE	32IE	32QGE	
VQI	32VE	32QGE	32IE	
VS	32VE	32NE (Low-Impedance)		Additional setting combinations for models with a 0.2 A nominal neutral channel (IN) **NOTE:** S, P, and U are mutually exclusive and are the last (or only) listed choice for the ORDER setting
VQS	32VE	32QGE	32NE (Low-Impedance)	
QVS	32QGE	32VE	32NE (Low-Impedance)	
P	32NE (Petersen Coil)			
QP	32QGE	32NE (Petersen Coil)		
QVP	32QGE	32VE	32NE (Petersen Coil)	
VP	32VE	32NE (Petersen Coil)		
VQP	32VE	32QGE	32NE (Petersen Coil)	
U	32NE (Ungrounded/ High-Impedance)			

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Table 4.5 Ground Directional Element Availability by Voltage Connection Settings

Element designation in ORDER setting	Availability[a] when VNOM ≠ OFF VSCONN = VS		Availability[a] when VNOM ≠ OFF VSCONN = 3V0	Availability[a] when VNOM = OFF VSCONN = VS	Availability[a] when VNOM = OFF VSCONN = 3V0
	PTCONN = WYE	PTCONN = DELTA	PTCONN = WYE or PTCONN = DELTA	PTCONN = WYE or PTCONN = DELTA	PTCONN = WYE or PTCONN = DELTA
Q	Yes	Yes	Yes	No[b]	No[b]
V	Yes	No	Yes	No[b]	Yes
I	Yes	Yes	Yes	Yes	Yes
S	Yes	No	Yes	No[b]	Yes
P	Yes	No	Yes	No[b]	Yes
U	Yes	No	Yes	No[b]	Yes

[a] Subject to Availability of Elements by Relay Model shown in Table 4.3 and Table 4.4.
[b] The displayed setting range for the ORDER setting may show these element choices, but the relay will not accept these choices when a settings save is attempted.

Figure 4.4 and *Figure 4.5* give an overview of how these directional elements are enabled and routed to control the neutral ground and residual ground overcurrent elements.

Note that in *Figure 4.4* and *Figure 4.5* that setting ORDER enables the directional elements. Setting ORDER can be set with the elements listed and defined in *Table 4.3*, subject to the setting combination constraints in *Table 4.4*. Note that *Table 4.3* and *Table 4.4* also list the directional element availability, per model (according to the neutral channel [**IN**] rating).

Table 4.5 details the availability of the ground directional elements for the various combinations of the PTCONN, VSCONN, and VNOM settings. If none of the ground directional elements are available (per *Table 4.3*–*Table 4.5*), group setting E32 (directional control enable) can only be set to N. Refer to *Settings for Voltage Input Configuration on page 9.50* for information on these settings.

Also, note that *Table 4.3*–*Table 4.5* (and lower left-hand corner of *Figure 4.4*) detail the mutual exclusivity of ORDER setting choices I, S, P, and U. If particular directional elements are not available (due to model type) or are not listed in setting ORDER, these non-available or non-listed directional elements are **defeated** and **non-operational**.

For example, suppose that setting choice S is listed in setting ORDER. By virtue of not being available or not being listed in setting ORDER, the directional elements corresponding to setting choices I, P, and U (see *Table 4.1*, *Figure 4.4*, and *Figure 4.5*) are **defeated** and **non-operational**. So, for non-available setting choice I, corresponding internal enable 32IE = logical 0 and directional outputs F32I = logical 0 and R32I = logical 0. Similarly, for the directional elements corresponding to non-listed setting choices P and U, the logic outputs are at a logical 0 state.

The **order** in which these directional elements are listed in setting ORDER determines the priority in which they operate to provide Best Choice Ground Directional logic control. See the discussion on setting ORDER in the *Directional Control Settings on page 4.39*.

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Internal Enables

Refer to *Figure 4.4*, *Figure 4.5*, *Figure 4.6*, *Figure 4.7*, and *Figure 4.8*.

Table 4.3 lists the internal enables and their correspondence to the ground directional elements.

Note that *Figure 4.6* has extra internal enable 32QE, which is used in the directional element logic that controls negative-sequence and phase overcurrent elements (see *Figure 4.19*).

Additionally, note that if enable setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts), all the internal enables (except for 32IE) are disabled (see *Figure 4.6*, *Figure 4.7*, and *Figure 4.8*).

There is an exception when global setting VSCONN = 3V0, which causes Relay Word bit 3V0 to be asserted. In that case, the directional element enables in *Figure 4.7* and *Figure 4.8* are not affected by LOP. This is explained in *Loss-of-Potential Logic on page 4.1*. The channel **IN** current-polarized directional element (with corresponding internal enabled 32IE; *Figure 4.7*) does not use voltage in making direction decisions, thus a loss-of-potential condition does not disable the element. Refer to *Figure 4.1* and accompanying text for more information on loss-of-potential.

The settings involved with the internal enables (e.g., settings a2, k2, a0, a0N) are explained in *Directional Control Settings on page 4.39*.

Switch Between I_N and I_G for Low-Impedance Grounded and Ungrounded/High-Impedance Grounded Systems

If an ungrounded or high-impedance grounded system (setting ORDER = U) has appreciable circuit length, the capacitance levels can be such that appreciable current flows for a ground fault. A low-impedance grounded system (setting ORDER contains S) can also have appreciable current flow for a ground fault.

Refer to *Figure 4.8*. The 0.2 A nominal neutral channel (**IN**) can discriminate up to 5 A secondary. If neutral channel current I_N exceeds 5 A secondary, then the logic in *Figure 4.8* (and *Figure 4.12* and *Figure 4.14*) switches from monitoring neutral channel current I_N to monitoring residual ground current I_G (residual ground current I_G is derived internally from phase current channels **IA**, **IB**, and **IC**; I_G is effectively $3I_0$ and has a much higher upper range than neutral channel current I_N).

Of course, this switching of currents (from I_N to I_G) requires the following 50NFP/50NRP settings (based on current I_N) in the *Figure 4.8* logic to be effectively changed to the new I_G base (done internally with CT ratio settings):

50NFP • CTRN/CTR	(I_G base)
50NRP • CTRN/CTR	(I_G base)

If the logic in *Figure 4.8* (and *Figure 4.12*, and *Figure 4.14*) operates on neutral current I_N, then settings 50NFP and 50NRP are not adjusted, and just operate as:

50NFP	(I_N base)
50NRP	(I_N base)

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This transition is "seamless" if the lower detection threshold of the residual ground current I_G (0.05 A secondary for 5 A nominal phase; 0.01 A secondary for 1 A nominal) effectively overlaps with the upper detection threshold of neutral channel current I_N (5 A secondary):

CTR/CTRN ≤ (5 A/0.05 A) = 100	(5 A nominal)
CTR/CTRN ≤ (5 A/0.01 A) = 500	(1 A nominal)

There is no effective overlap if

CTR/CTRN > 100	(5 A nominal)
CTR/CTRN > 500	(1 A nominal)

With no effective overlap, as the neutral channel current I_N exceeds the upper detection threshold of neutral channel **IN** (5 A secondary), the unit still operates on the neutral channel current I_N until the lower detection threshold of the residual ground current I_G (0.05 A secondary for 5 A nominal phase; 0.01 A secondary for 1 A nominal) is reached. It is better to have effective overlap:

CTR/CTRN ≤ 100	(5 A nominal)
CTR/CTRN ≤ 500	(1 A nominal)

Relay Word bit GNDSW indicates whether the directional element for low-impedance grounded or ungrounded/high-impedance grounded systems is operating on neutral channel (**IN**) current I_N (GNDSW = logical 1) or on residual ground current I_G instead (GNDSW = logical 0).

This I_N to I_G (or I_G to I_N) current switching discussed for *Figure 4.8* (and *Figure 4.12* and *Figure 4.14*) also has an effect on zero-sequence impedance settings Z0F and Z0R (see *Figure 4.12* and *Figure 4.14*). Z0F and Z0R (Ω secondary) are set in reference to the phase current inputs (**IA**, **IB**, and **IC**; residual current I_G is derived internally from these phase currents), as are the negative-sequence impedance settings Z2F and Z2R. However, settings Z0F and Z0R are applied to *Figure 4.12* and *Figure 4.14*, where neutral current I_N (from neutral current channel **IN**) is also applied. Settings Z0F and Z0R are adjusted internally (with CT ratio settings) to operate on this I_N current base:

Z0F • CTRN/CTR	(I_N base)
Z0R • CTRN/CTR	(I_N base)

If the logic in *Figure 4.8* (and *Figure 4.12*, and *Figure 4.14*) operates on residual current I_G, as a result of current switching, then settings Z0F and Z0R are not adjusted, and just operate as:

Z0F	(I_G base)
Z0R	(I_G base)

Zero-Sequence Voltage Sources

The directional elements that rely on zero-sequence voltage $3V_0$ (ORDER setting choices V, S, P, and U, shown in *Figure 4.10* and *Figure 4.12*–*Figure 4.14*) may use either a calculated $3V_0$ from the wye-connected voltages V_A, V_B, and V_C, or a measured $3V_0$ from the **VS** channel, typically connected to a broken-delta PT secondary. The global setting VSCONN selects the zero-sequence voltage source to be used by the affected directional elements.

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When VSCONN = 3V0, the measured voltage on terminals **VS-NS** is scaled by the ratio of group settings PTRS/PTR to convert it to the same voltage base as the **VA**, **VB**, and **VC** terminals, and the resulting signal is applied to the directional element $3V_0$ inputs.

When VSCONN = VS, the calculated zero-sequence voltage from terminals **VA**, **VB**, and **VC** is applied to the directional element "$3V_0$" inputs, provided that the relay is connected to wye-connected PTs (Global Setting PTCONN = WYE). If the relay is connected to open-delta PTs (Global Setting PTCONN = DELTA), $3V_0$ cannot be calculated from the **VA**, **VB**, and **VC** terminals, and the directional elements that require zero-sequence voltage are unavailable.

When testing the relay, it is important to note that the **METER** command 3V0 quantity, when available, is always the calculated value from the wye-connected PT inputs. The **METER** command **VS** quantity is always the measured value from the **VS-NS** terminals.

See *Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20*, and *Settings for Voltage Input Configuration on page 9.50*.

Best Choice Ground Directional Logic

The Best Choice Ground Directional logic determines which directional element should be enabled to operate. The neutral ground and residual ground overcurrent elements set for directional control are then controlled by this enabled directional element.

Table 4.4 is the embodiment of the Best Choice Ground Directional logic. Note in *Table 4.4* that any of the directional elements that operate on 0.2 A nominal neutral channel (**IN**) are listed last (or by themselves) in any of the available setting combinations for the ORDER setting (directional elements corresponding to S, P, or U). This is because preference is given to selected directional elements that operate off of bigger signals (i.e., directional elements corresponding to Q and V: setting choice I cannot be listed with S, P, or U).

Figure 4.4 shows no control emanating from the Best Choice Ground Directional logic to the directional elements corresponding to S or P (*Figure 4.12*, and *Figure 4.13*, respectively). This Best Choice Ground Directional logic for the directional elements corresponding to S or P is effectively handled with the disable inputs (internal enables 32QGE and 32VE) running into the internal enable logic of *Figure 4.8*. If neither 32QGE nor 32VE are asserted (and thus their corresponding directional elements are not enabled), then the internal enable logic of *Figure 4.8* is free to run for the last directional element selected in setting ORDER (if S or P is the last element listed in setting ORDER).

Setting choice U (ungrounded/high-impedance grounded) can only be listed by itself (ORDER = U), so Best Choice Ground Directional logic is irrelevant in this case (as it is also essentially irrelevant when Q, V, I, or P are listed by themselves in setting ORDER).

Directional Elements

Refer to *Figure 4.4*, *Figure 4.5*, and *Figure 4.9–Figure 4.14*.

The Best Choice Ground Directional logic in *Table 4.4* determines which directional element will run.

Note in *Figure 4.13* that the incremental conductance directional element outputs F32C/R32C do not propogate to directional outputs F32N/R32N, respectively, as do the wattmetric directional element outputs F32W/R32W. Incremental conductance elements are used more for alarming purposes than for controlling overcurrent elements for tripping. Incremental conductance

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elements provide more sensitivity for detecting high-resistance faults on Petersen coil grounded systems (as compared to the wattmetric elements). For more information on the operation and application of incremental conductance elements for Petersen Coil (resonant) grounded systems, see the paper: "Review of Ground Fault Protection Methods for Grounded, Ungrounded, and Compensated Distribution System," by Jeff Roberts, Hector Altuve, Daqing Hou, presented at the 28th Annual Western Protective Relay Conference, Spokane, Washington, October 22–24, 2001.

Directional Element Routing

Refer to *Figure 4.4*, *Figure 4.5*, *Figure 4.15*, and *Figure 4.16*.

The directional element outputs are routed to the forward (Relay Word bits 32GF and 32NF) and reverse (Relay Word bits 32GR and 32NR) logic points and then on to the direction forward/reverse logic in *Figure 4.17* and *Figure 4.18*.

Loss-of-Potential

Note that if **all** of the following are true,

- Enable setting ELOP = Y,
- Global setting VSCONN = VS,
- A loss-of-potential condition occurs (Relay Word bit LOP asserts),
- And internal enable 32IE (for channel IN current-polarized directional element) is not asserted

then the forward logic point (Relay Word bit 32GF in *Figure 4.15* and 32NF in *Figure 4.16*) asserts to logical 1, thus enabling the residual ground (*Figure 4.17*) and neutral ground (*Figure 4.18*) overcurrent elements that are set direction forward (with settings DIR1 = F, DIR2 = F, etc.). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

If global setting VSCONN = 3V0 and group setting ELOP = Y, the LOP condition will not cause the forward directional outputs to assert when either directional element enable 32VE or 32NE is asserted, as shown at the top of *Figure 4.15* and *Figure 4.16*. In this situation, the elements that are enabled by signals 32VE and 32NE are still able to operate reliably during a loss-of-potential condition, so there is no need to force the forward outputs to assert. However, when 32VE or 32NE are not asserted, a standing LOP condition will force the forward outputs to assert continuously. Consider this when determining residual- and neutral-ground overcurrent element pickup settings and time delay settings, so that load conditions do not cause a forward-set ground directional overcurrent element to pickup and start timing.

As detailed previously in *Internal Enables on page 4.14*, some or all of the voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. However, this disable condition is overridden for these overcurrent elements set direction forward if setting ELOP = Y.

Refer to *Figure 4.1* and accompanying text for more information on loss-of-potential.

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Direction Forward/ Reverse Logic

Refer to *Figure 4.4*, *Figure 4.5*, *Figure 4.17*, and *Figure 4.18*.

The forward (Relay Word bit 32GF in *Figure 4.17* and 32NF in *Figure 4.18*) and reverse (Relay Word bit 32GR in *Figure 4.17* and 32NR in *Figure 4.18*) logic points are routed to the different levels of overcurrent protection by the level direction settings DIR1–DIR4.

Table 4.7 shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 4.7* that all the time-overcurrent elements (51_T elements) are controlled by the DIR1 level direction setting.

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

Level 1 overcurrent elements set direction forward (DIR1 = F)

Level 2 overcurrent elements set direction forward (DIR2 = F)

Level 3 overcurrent elements set direction reverse (DIR3 = R)

If a level direction setting (e.g., DIR1) is set as follows,

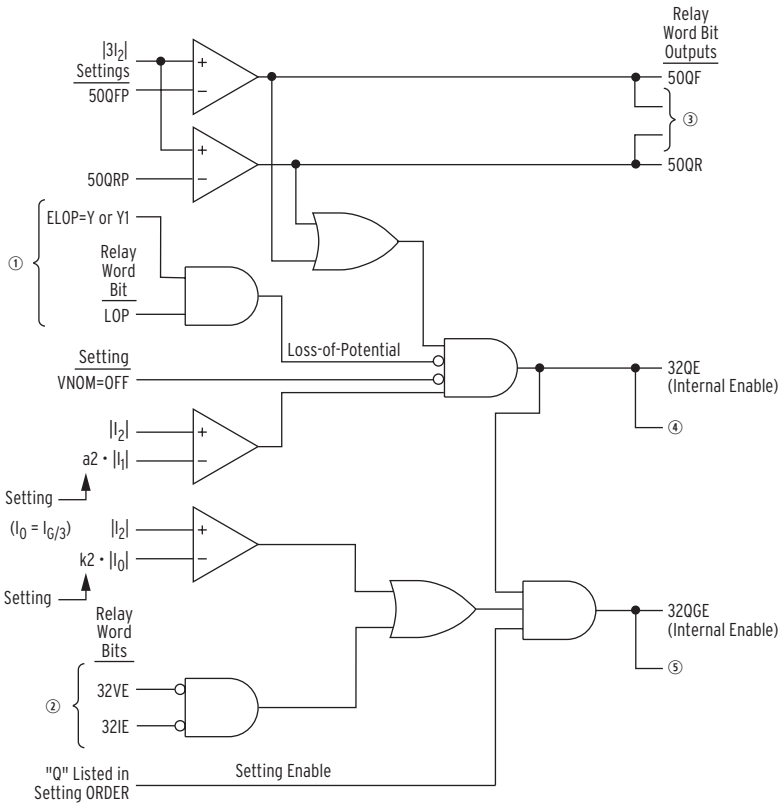
DIR1 = **N** (nondirectional)

then the corresponding Level 1 directional control outputs in *Figure 4.17* and *Figure 4.18* assert to logical 1. The referenced Level 1 overcurrent elements in *Figure 4.17* and *Figure 4.18* are then not controlled by the directional control logic.

See the beginning of *Directional Control Settings on page 4.39* for discussion of the operation of level direction settings DIR1–DIR4 when the directional control enable setting E32 is set to E32 = N.

In some applications, level direction settings DIR1–DIR4 are not flexible enough in assigning the desired direction for certain overcurrent elements. Subsection *Directional Control Provided by Torque Control Settings on page 4.58* describes how to avoid this limitation for special cases.

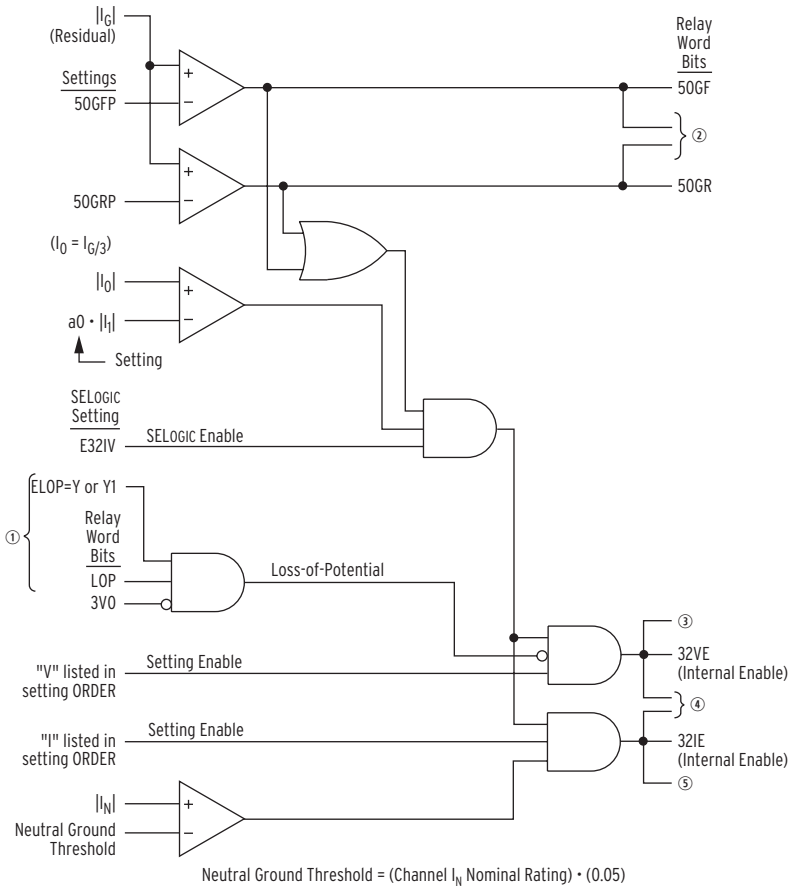
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① From Figure 4.1; ② from Figure 4.7; ③ to Figure 4.9 and Figure 4.20; ④ to Figure 4.20 and Figure 4.21; ⑤ to Figure 4.9, Table 4.3, and Table 4.4.

Figure 4.6 Internal Enables (32QE and 32QGE) Logic for Negative-Sequence Voltage-Polarized Directional Elements

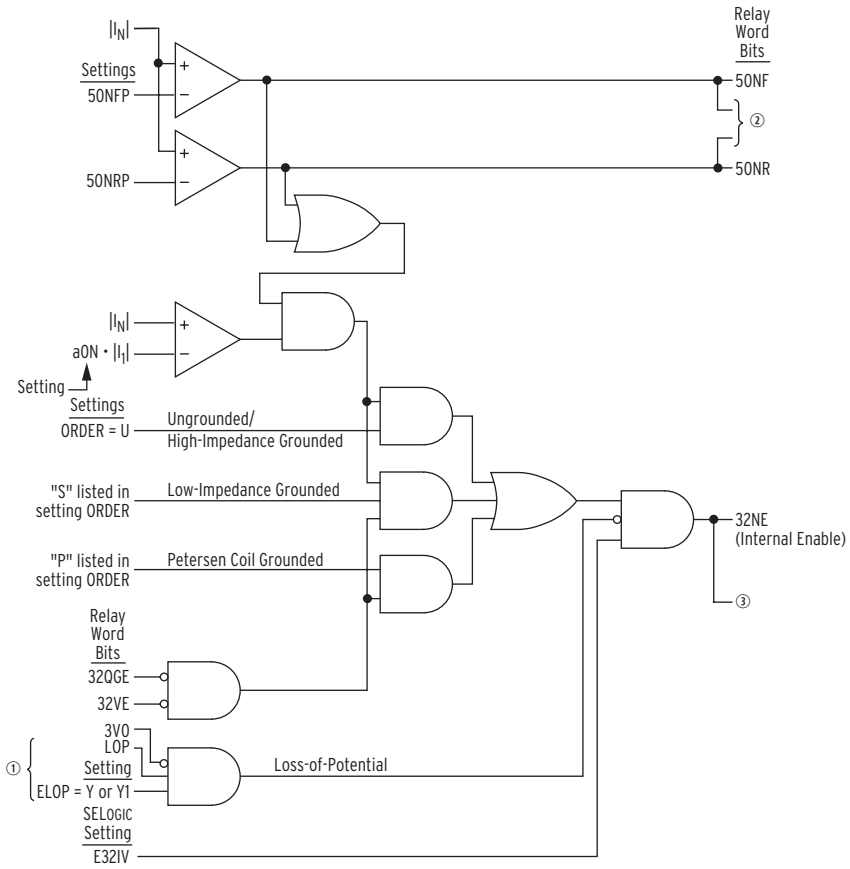
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① From Figure 4.1; ② to Figure 4.10 and Figure 4.11; ③ to Figure 4.10; ④ to Figure 4.6, Table 4.3, and Table 4.4; ⑤ to Figure 4.11, Figure 4.15, and Figure 4.16.

Figure 4.7 Internal Enables (32VE and 32IE) Logic for Zero-Sequence Voltage-Polarized and Channel IN Current-Polarized Directional Elements

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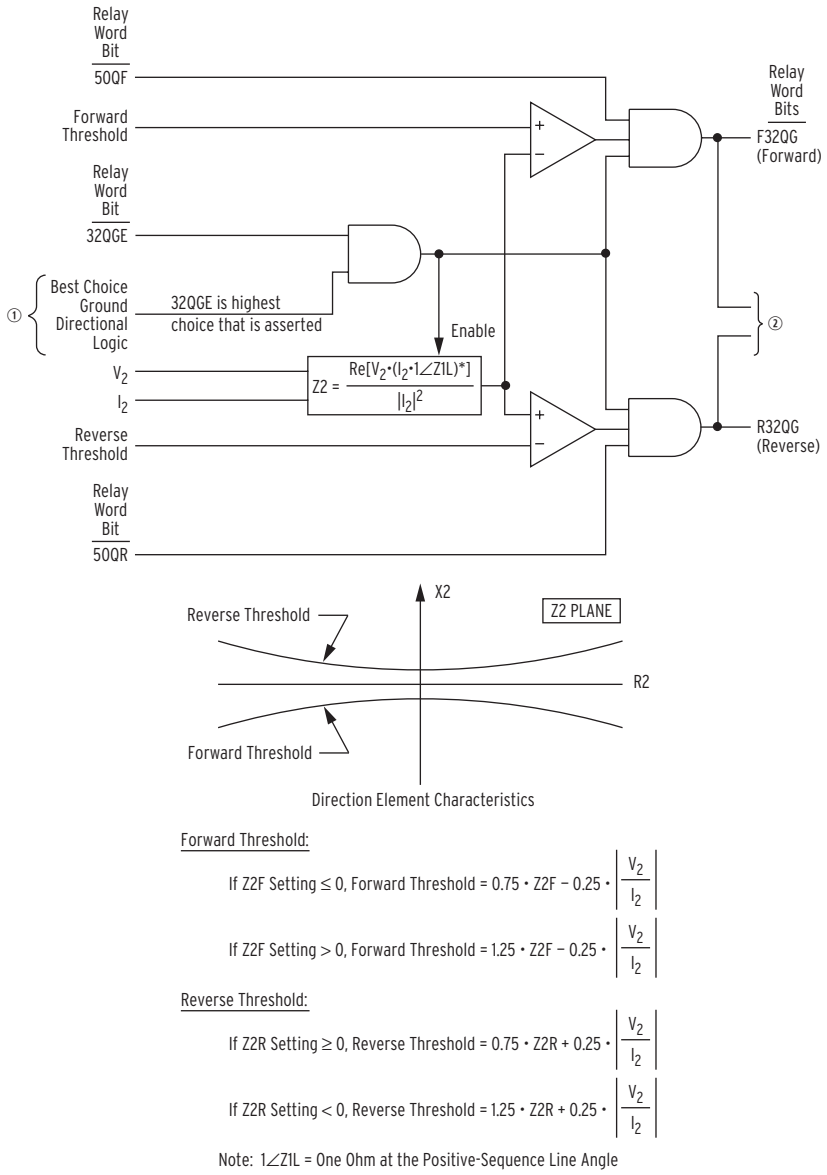


① From Figure 4.1; ② to Figure 4.12 and Figure 4.14; ③ to Figure 4.12, Figure 4.13, Figure 4.14, Table 4.3, and Table 4.4.

Figure 4.8 Internal Enable (32NE) Logic for Zero-Sequence Voltage-Polarized Directional Elements (Low-Impedance Grounded, Petersen Coil Grounded, and Ungrounded/High-Impedance Grounded Systems)

Refer to the setting ideas for SELOGIC setting E32IV, near the back of this section, especially if setting ORDER = U (ungrounded or high-impedance grounded system).

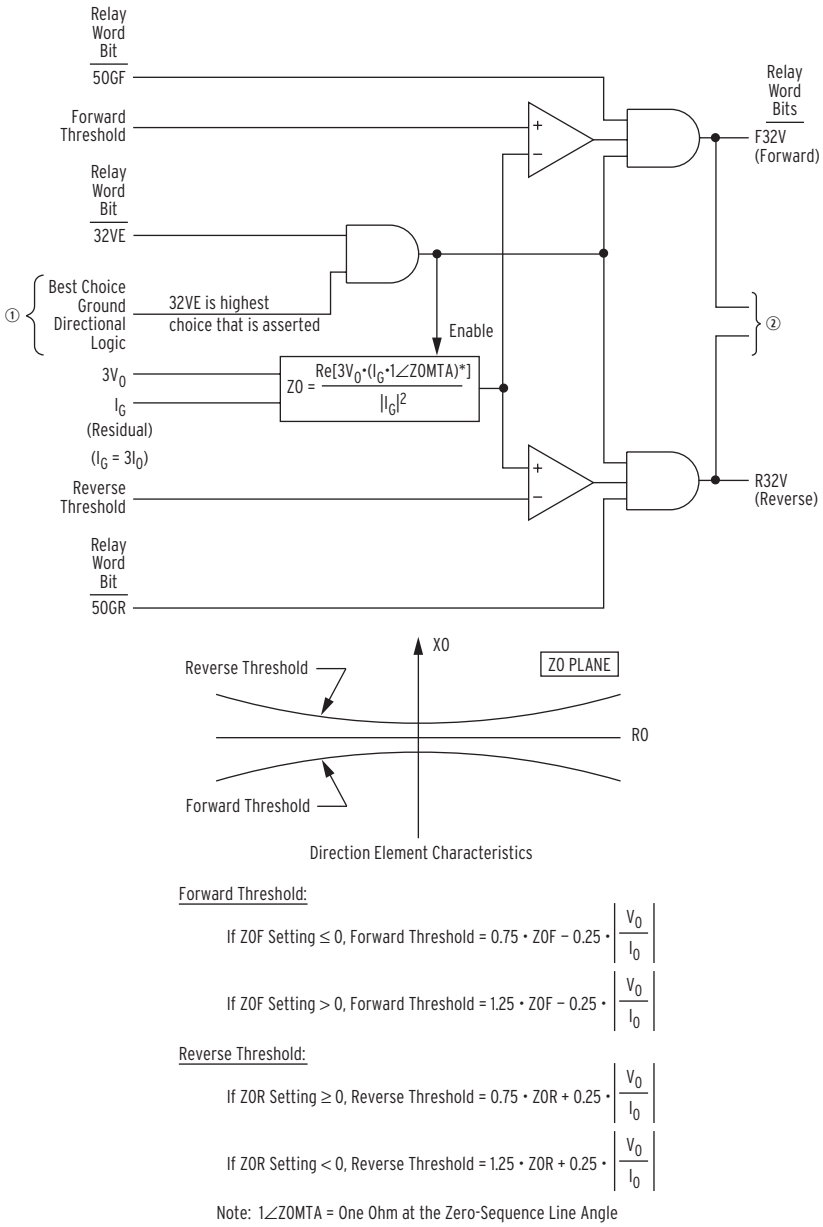
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① From Table 4.4; ② to Figure 4.15 and Figure 4.16.

Figure 4.9 Negative-Sequence Voltage-Polarized Directional Element for Neutral Ground and Residual Ground Overcurrent Elements

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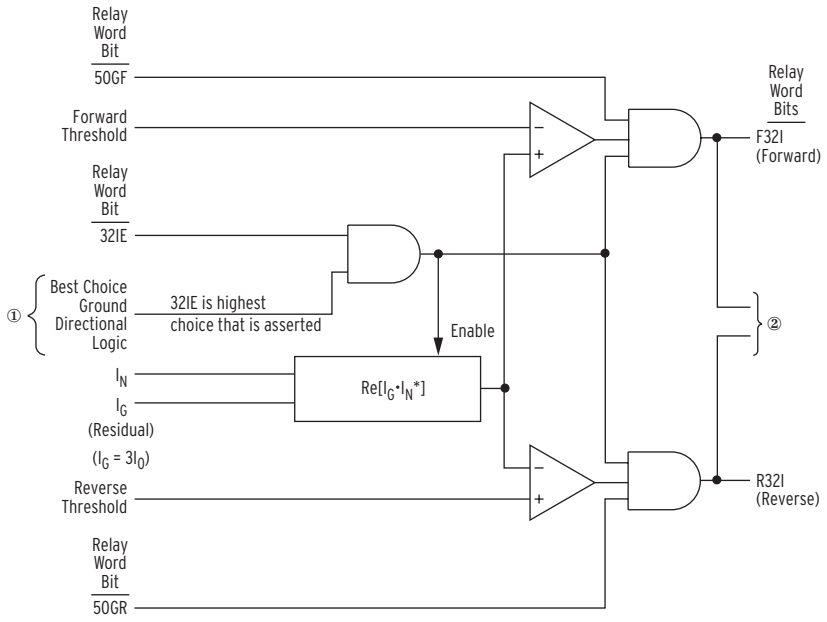


① From Table 4.4; ② to Figure 4.15 and Figure 4.16.

Figure 4.10 Zero-Sequence Voltage-Polarized Directional Element

The $3V_0$ input to *Figure 4.10* may be either a calculated value (when global settings VSCONN = VS and PTCONN = WYE) or a measured value (when global setting VSCONN = 3V0). See *Zero-Sequence Voltage Sources on page 4.15*.

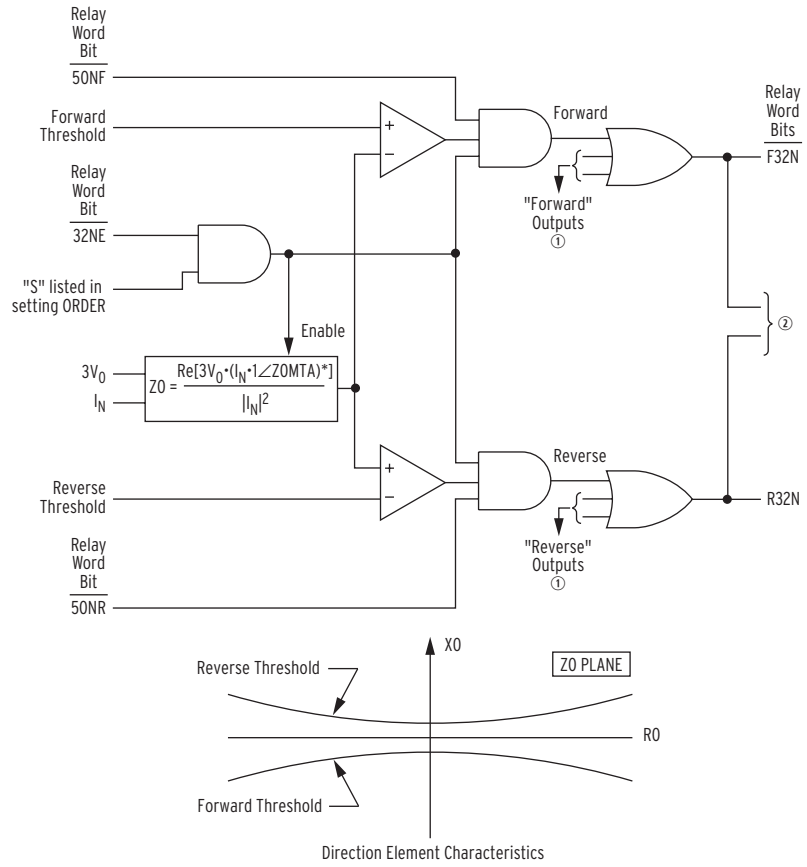
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① From Table 4.4; ② to Figure 4.15 and Figure 4.16.

Figure 4.11 Channel IN Current-Polarized Directional Element

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Forward Threshold:

If Z0F Setting ≤ 0, Forward Threshold = $0.75 \cdot Z0F - 0.25 \cdot \left|\frac{3V_0}{I_0}\right|$

If Z0F Setting > 0, Forward Threshold = $1.25 \cdot Z0F - 0.25 \cdot \left|\frac{3V_0}{I_0}\right|$

Reverse Threshold:

If Z0R Setting ≥ 0, Reverse Threshold = $0.75 \cdot Z0R + 0.25 \cdot \left|\frac{3V_0}{I_0}\right|$

If Z0R Setting < 0, Reverse Threshold = $1.25 \cdot Z0R + 0.25 \cdot \left|\frac{3V_0}{I_0}\right|$

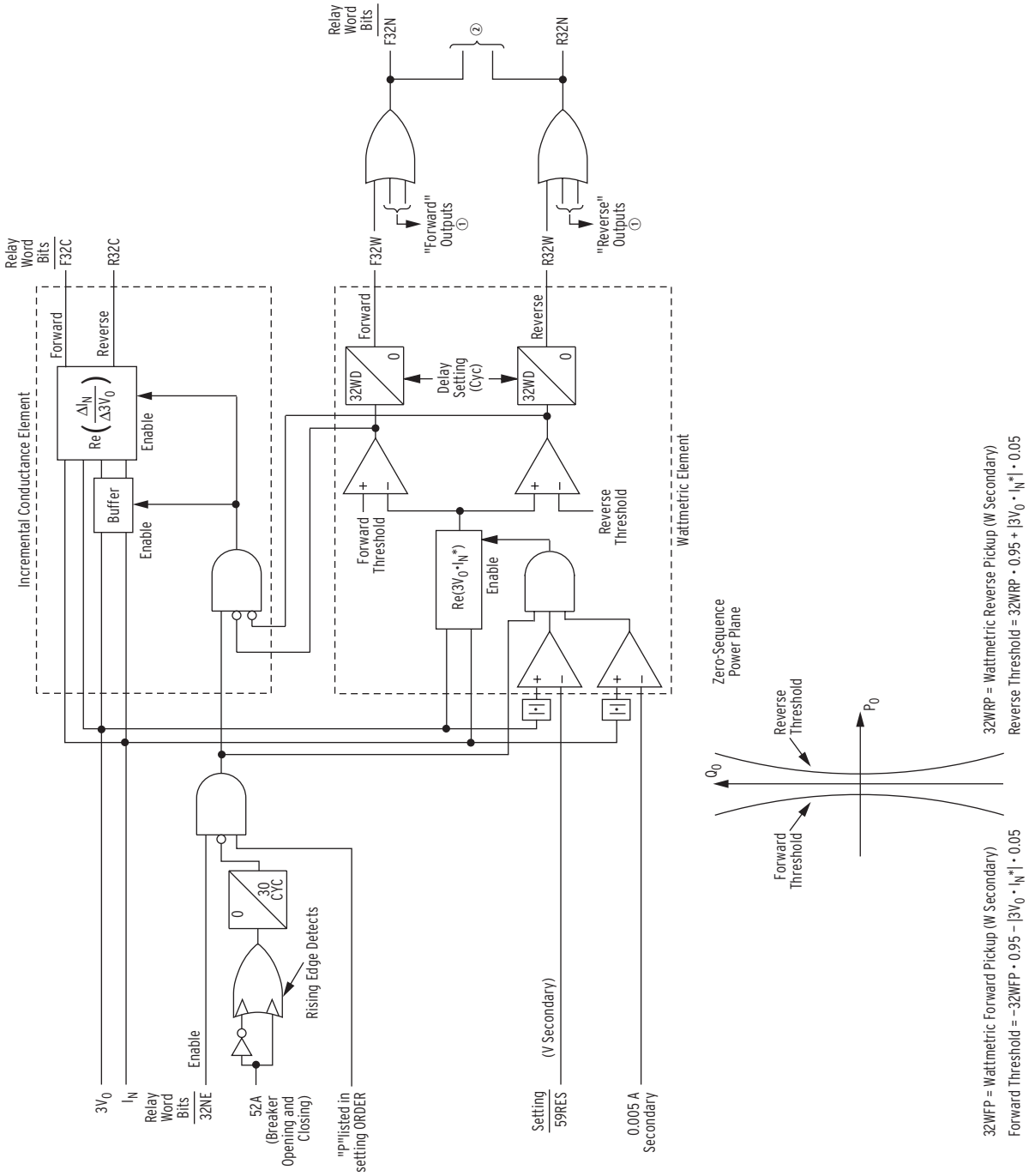
Note: 1∠Z0MTA = One Ohm at the Zero-Sequence Line Angle

① From Figure 4.13 and Figure 4.14; ② to Figure 4.15 and Figure 4.16.

Figure 4.12 Zero-Sequence Voltage-Polarized Directional Element (Low-Impedance Grounded Systems)

The $3V_0$ input to *Figure 4.12* may be either a calculated value (when Global Settings VSCONN = VS and PTCONN = WYE) or a measured value (when Global Setting VSCONN = 3V0). See *Zero-Sequence Voltage Sources on page 4.15* earlier in this section.

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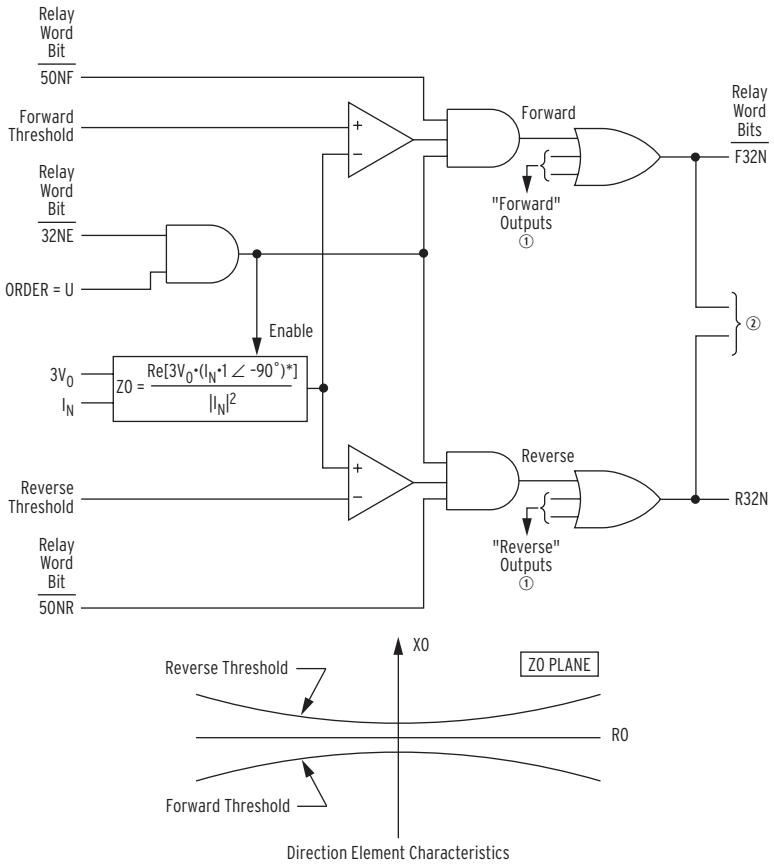


① From Figure 4.12 and Figure 4.14; ② to Figure 4.15 and Figure 4.16.

Figure 4.13 Wattmetric and Incremental Conductance Directional Elements (Petersen Coil Grounded Systems)

The $3V_0$ input to *Figure 4.13* may be either a calculated value (when Global Settings VSCONN = VS and PTCONN = WYE) or a measured value (when Global Setting VSCONN = 3V0). See *Zero-Sequence Voltage Sources on page 4.15* and *Directional Control Settings on page 4.39*.

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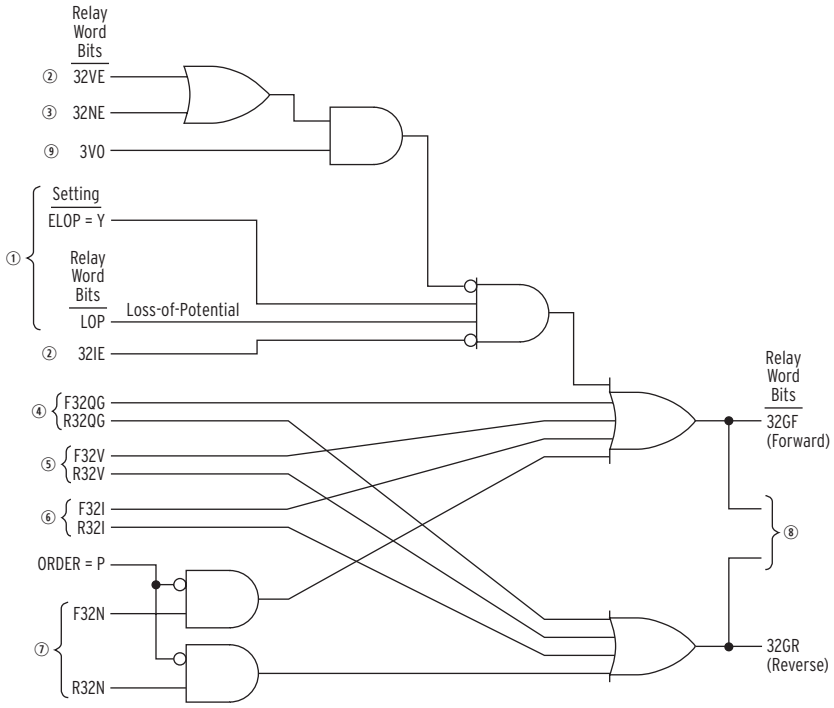


① From Figure 4.12 and Figure 4.13; ② to Figure 4.15 and Figure 4.16.

Figure 4.14 Zero-Sequence Voltage-Polarized Directional Element (Ungrounded/High-Impedance Grounded Systems)

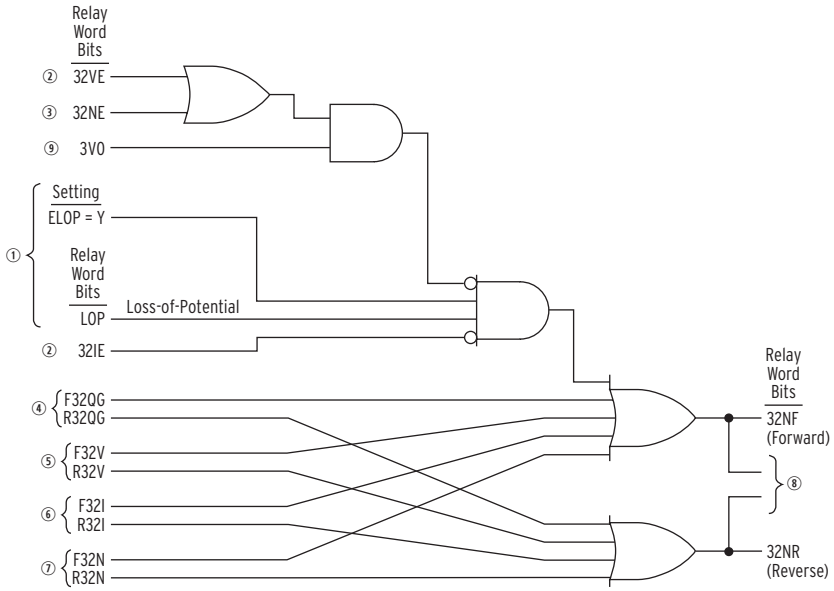
The $3V_0$ input to *Figure 4.14* may be either a calculated value (when Global Settings VSCONN = VS and PTCONN = WYE) or a measured value (when Global Setting VSCONN = 3V0). See *Zero-Sequence Voltage Sources on page 4.15*.

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① From Figure 4.1; ② from Figure 4.7; ③ from Figure 4.8; ④ from Figure 4.9; ⑤ from Figure 4.10; ⑥ from Figure 4.11; ⑦ from Figure 4.12, Figure 4.13, and Figure 4.14; ⑧ To Figure 4.17; ⑨ from Figure 9.21.

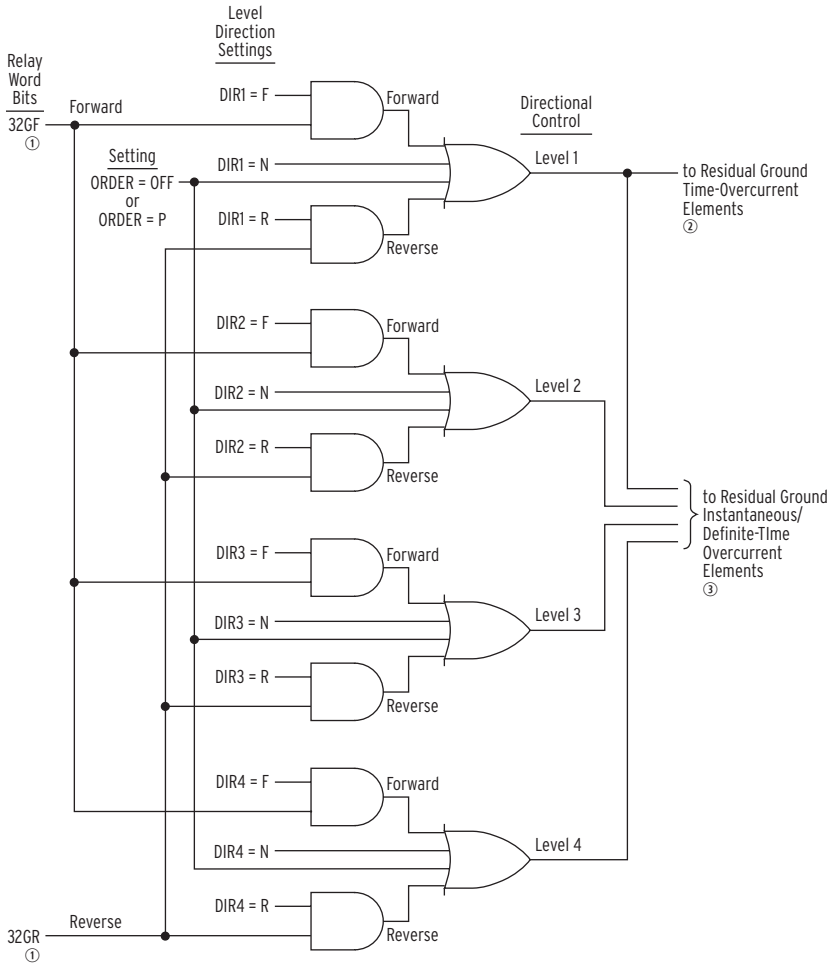
Figure 4.15 Routing of Directional Elements to Residual Ground Overcurrent Elements



① From Figure 4.1; ② from Figure 4.7; ③ from Figure 4.8; ④ from Figure 4.9; ⑤ from Figure 4.10; ⑥ from Figure 4.11; ⑦ from Figure 4.12, Figure 4.13, and Figure 4.14; ⑧ to Figure 4.18; ⑨ from Figure 9.21.

Figure 4.16 Routing of Direction Elements to Neutral Ground Overcurrent Elements

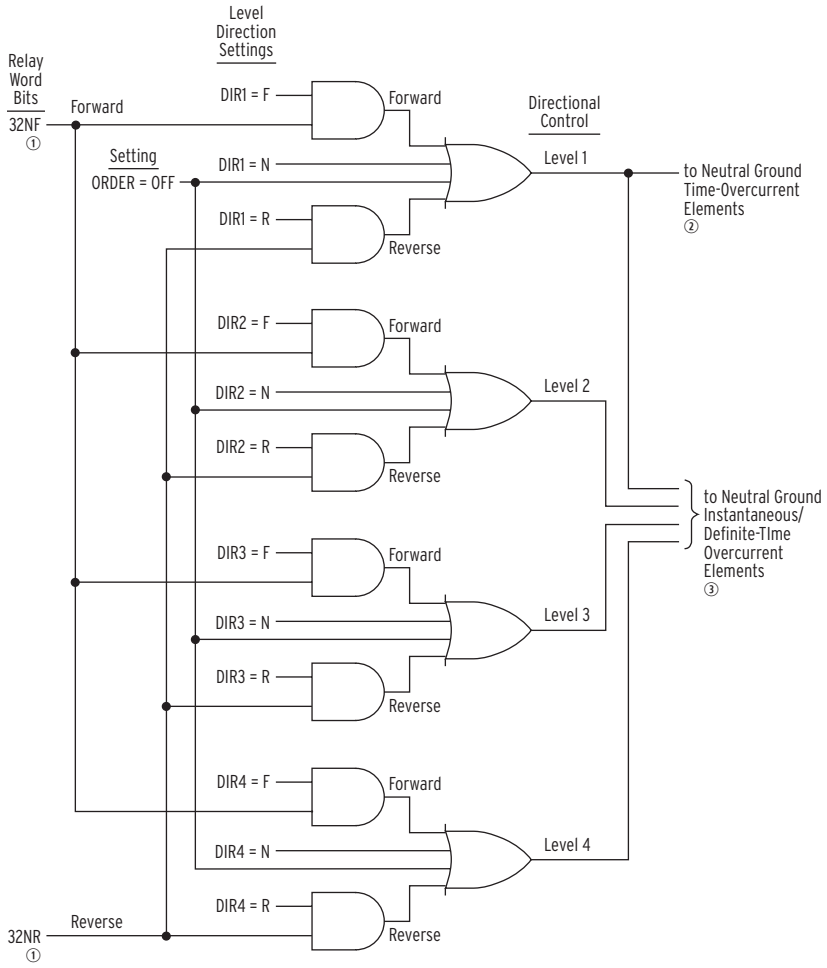
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① From Figure 4.15; ② Figure 3.18 and Figure 3.19; ③ Figure 3.10.

Figure 4.17 Direction Forward/Reverse Logic for Residual Ground Overcurrent Elements

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① From Figure 4.16; ② Figure 3.16 and Figure 3.17; ③ Figure 3.8.

Figure 4.18 Direction Forward/Reverse Logic for Neutral Ground Overcurrent Elements

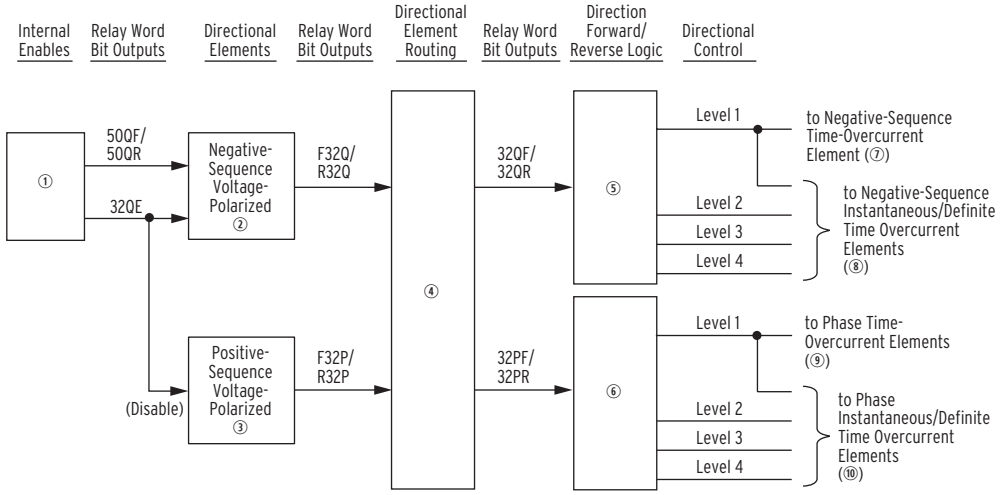
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Directional Control for Negative-Sequence and Phase Overcurrent Elements

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 and other directional control settings are described in *Directional Control Settings on page 4.39*.

The negative-sequence voltage-polarized directional element controls the negative-sequence overcurrent elements. Negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements control the phase overcurrent elements. *Figure 4.19* gives an overview of how the negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements are enabled and routed to control the negative-sequence and phase overcurrent elements.

If three-phase voltage signals are not available, make the group setting VNOM = OFF. This prevents the negative-sequence voltage-polarized and positive-sequence voltage-polarized elements from operating on false voltage quantities, yet still allows the Best Choice Ground Directional logic to operate if available. This shut-down logic is shown in the center portions of *Figure 4.6* and *Figure 4.21*. See *Settings for Voltage Input Configuration on page 9.50* for a complete list of changes caused by setting VNOM = OFF.



① Figure 4.6; ② Figure 4.20; ③ Figure 4.21; ④ Figure 4.22; ⑤ Figure 4.23; ⑥ Figure 4.24; ⑦ Figure 3.20; ⑧ Figure 3.12; ⑨ Figure 3.14 and Figure 3.15; ⑩ Figure 3.3.

Figure 4.19 General Logic Flow of Directional Control for Negative-Sequence and Phase Overcurrent Elements

The negative-sequence voltage-polarized directional element has priority over the positive-sequence voltage-polarized directional elements in controlling the phase overcurrent elements. The negative-sequence voltage-polarized directional element operates for unbalanced faults, while the positive-sequence voltage-polarized directional element operates for three-phase faults.

Internal Enables

Refer to *Figure 4.6* and *Figure 4.19*.

The internal enable 32QE corresponds to the negative-sequence voltage-polarized directional element.

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Note that *Figure 4.6* has extra internal enable 32QGE, which is used in the directional element logic that controls the neutral ground and residual ground overcurrent elements (see *Figure 4.4*).

The settings involved with internal enable 32QE in *Figure 4.6* (e.g., settings a2, k2) are explained in *Directional Control Settings on page 4.39*.

Directional Elements

Refer to *Figure 4.19*, *Figure 4.20*, and *Figure 4.21*.

If enable setting ELOP = Y or Y1 and a loss-of-potential condition occurs (Relay Word bit LOP asserts), the negative-sequence voltage-polarized and positive-sequence voltage-polarized directional elements are disabled (see *Figure 4.6* and *Figure 4.21*).

Refer to *Figure 4.1* and accompanying text for more information on loss-of-potential.

Note in *Figure 4.19* and *Figure 4.21* that the assertion of internal enable 32QE (for the negative-sequence voltage-polarized directional element) disables the positive-sequence voltage-polarized directional element. The negative-sequence voltage-polarized directional element has priority over the positive-sequence voltage-polarized directional elements in controlling the phase overcurrent elements. The negative-sequence voltage-polarized directional element operates for unbalanced faults while the positive-sequence voltage-polarized directional element operates for three-phase faults.

Note also in *Figure 4.21* that the assertion of ZLOAD disables the positive-sequence voltage-polarized directional element. ZLOAD asserts when the relay is operating in a user-defined load region (see *Figure 4.2*).

Directional Element Routing

Refer to *Figure 4.19* and *Figure 4.22*.

The directional element outputs are routed to the forward (Relay Word bits 32QF and 32PF) and reverse (Relay Word bits 32QR and 32PR) logic points and then on to the direction forward/reverse logic in *Figure 4.23* and *Figure 4.24*.

Loss-of-Potential

Note if **both** of the following are true:

- Enable setting ELOP = Y,
- A loss-of-potential condition occurs (Relay Word bit LOP asserts),

then the forward logic points (Relay Word bits 32QF and 32PF) assert to logical 1, thus enabling the negative-sequence and phase overcurrent elements that are set direction forward (with settings DIR1 = F, DIR2 = F, etc.). These direction forward overcurrent elements effectively become nondirectional and provide overcurrent protection during a loss-of-potential condition.

As detailed previously (in *Figure 4.6* and *Figure 4.21*), voltage-based directional elements are disabled during a loss-of-potential condition. Thus, the overcurrent elements controlled by these voltage-based directional elements are also disabled. But this disable condition is overridden for the overcurrent elements set direction forward if setting ELOP = Y.

Refer to *Figure 4.1* and accompanying text for more information on loss-of-potential.

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Direction Forward/ Reverse Logic

Refer to *Figure 4.19*, *Figure 4.23*, and *Figure 4.24*.

The forward (Relay Word bits 32QF and 32PF) and reverse (Relay Word bits 32QR and 32PR) logic points are routed to the different levels of overcurrent protection by the level direction settings DIR1–DIR4.

Table 4.7 shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 4.7* that all the time-overcurrent elements (51_T elements) are controlled by the DIR1 level direction setting.

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

Level 1 overcurrent elements set direction forward (DIR1 = F)
Level 2 overcurrent elements set direction forward (DIR2 = F)
Level 3 overcurrent elements set direction reverse (DIR3 = R)

If a level direction setting (e.g., DIR1) is set:

DIR1 = **N** (nondirectional)

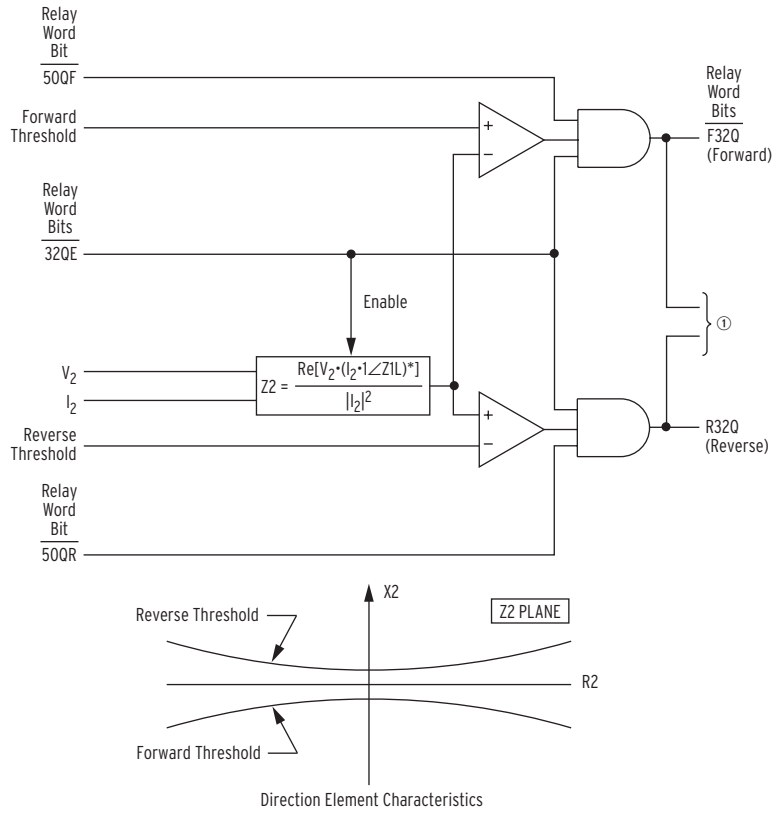
then the corresponding Level 1 directional control outputs in *Figure 4.23* and *Figure 4.24* assert to logical 1. The referenced Level 1 overcurrent elements in *Figure 4.23* and *Figure 4.24* are then not controlled by the directional control logic.

If group setting VNOM = OFF, then the directional control outputs in *Figure 4.23* and *Figure 4.24* assert to logical 1. This effectively makes the phase and negative-sequence elements nondirectional.

See *Directional Control Settings on page 4.39* for a discussion of the operation of level direction settings DIR1–DIR4 when the directional control enable setting E32 is set to E32 = N.

In some applications, level direction settings DIR1–DIR4 are not flexible enough in assigning the desired direction for certain overcurrent elements. *Directional Control Provided by Torque Control Settings on page 4.58* describes how to avoid this limitation for special cases.

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Forward Threshold:

$$\text{If Z2F Setting} \le 0,\ \text{Forward Threshold} = 0.75 \cdot Z2F - 0.25 \cdot \left|\frac{V_2}{I_2}\right|$$

$$\text{If Z2F Setting} > 0,\ \text{Forward Threshold} = 1.25 \cdot Z2F - 0.25 \cdot \left|\frac{V_2}{I_2}\right|$$

Reverse Threshold:

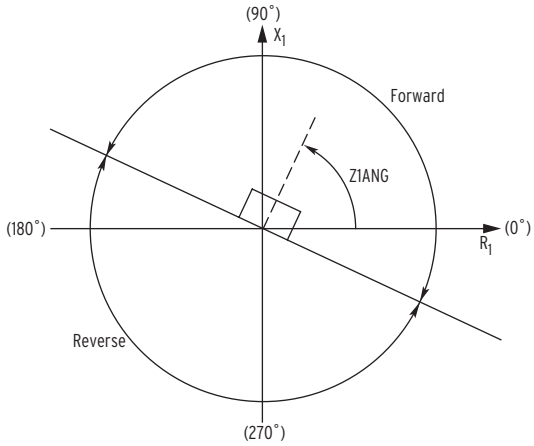
$$\text{If Z2R Setting} \ge 0,\ \text{Reverse Threshold} = 0.75 \cdot Z2R + 0.25 \cdot \left|\frac{V_2}{I_2}\right|$$

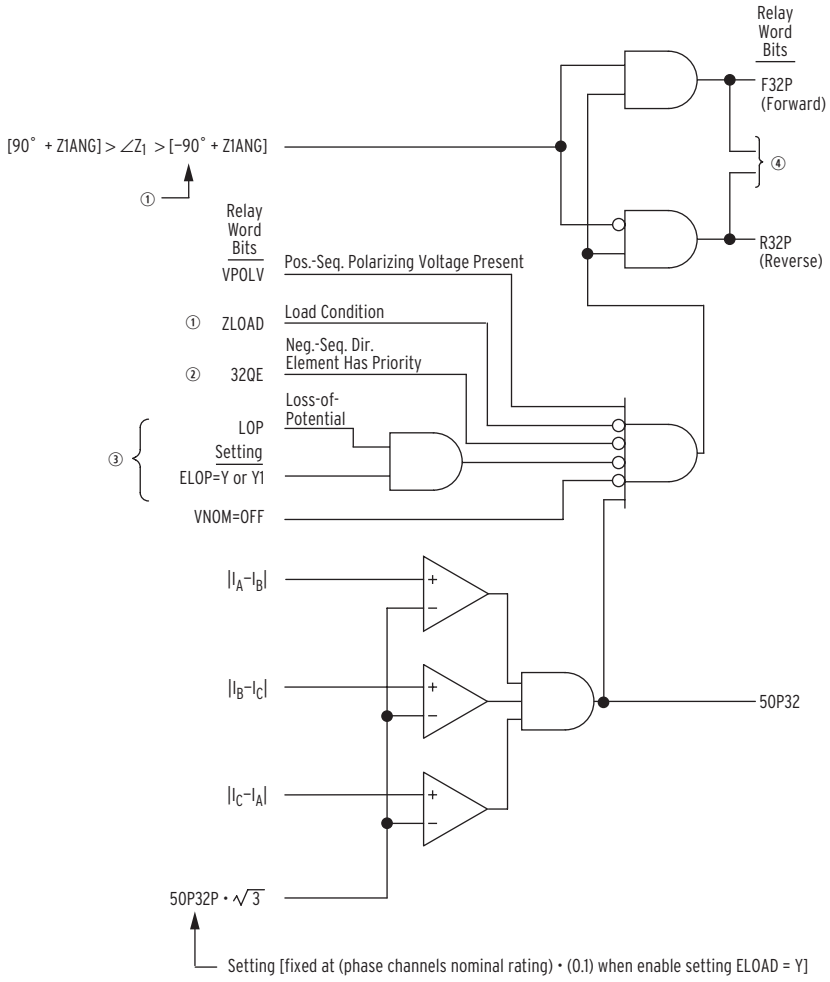
$$\text{If Z2R Setting} < 0,\ \text{Reverse Threshold} = 1.25 \cdot Z2R + 0.25 \cdot \left|\frac{V_2}{I_2}\right|$$

① To Figure 4.22.

Figure 4.20 Negative-Sequence Voltage-Polarized Directional Element for Negative-Sequence and Phase Overcurrent Elements

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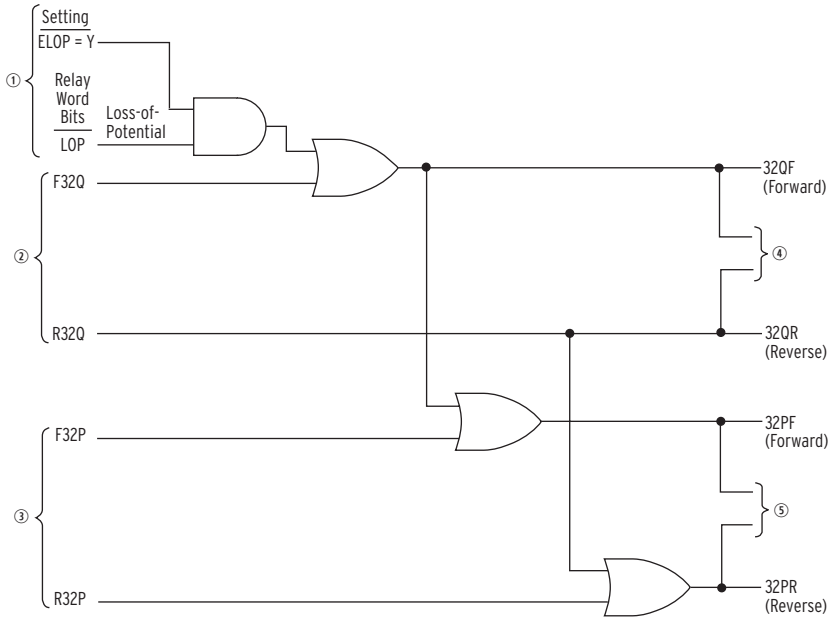




① From Figure 4.2; ② from Figure 4.6; ③ from Figure 4.1; ④ to Figure 4.22.

Figure 4.21 Positive-Sequence Voltage-Polarized Directional Element for Phase Overcurrent Elements

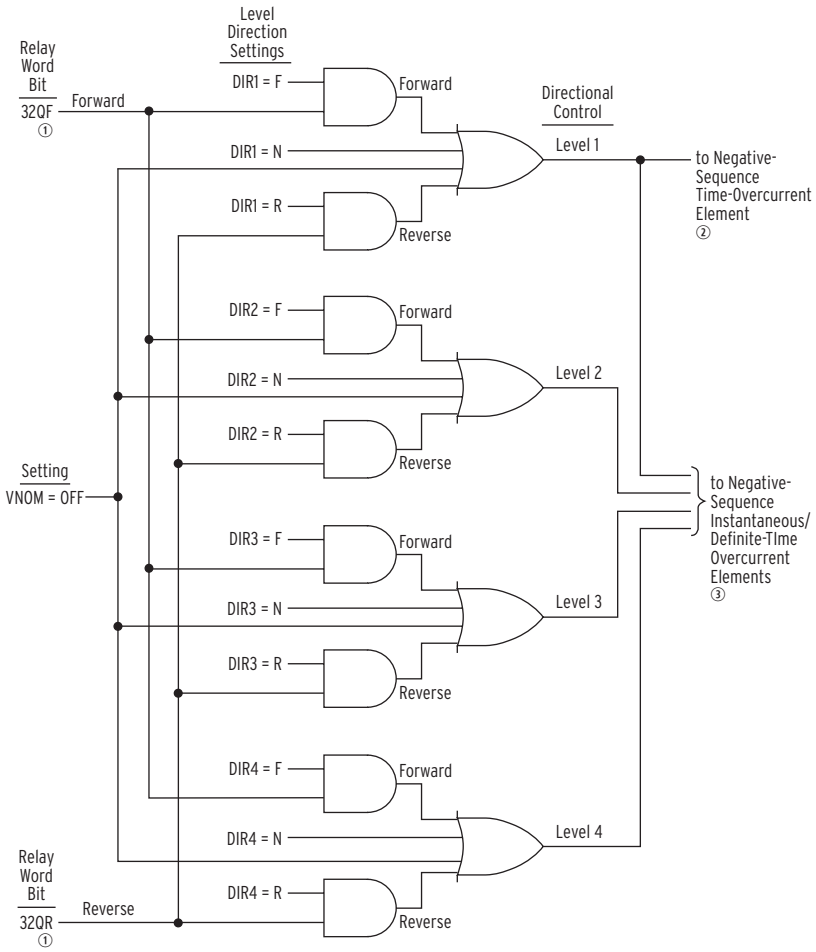
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① From Figure 4.1; ② from Figure 4.20; ③ from Figure 4.21; ④ to Figure 4.23; ⑤ to Figure 4.24.

Figure 4.22 Routing of Directional Elements to Negative-Sequence and Phase Overcurrent Elements

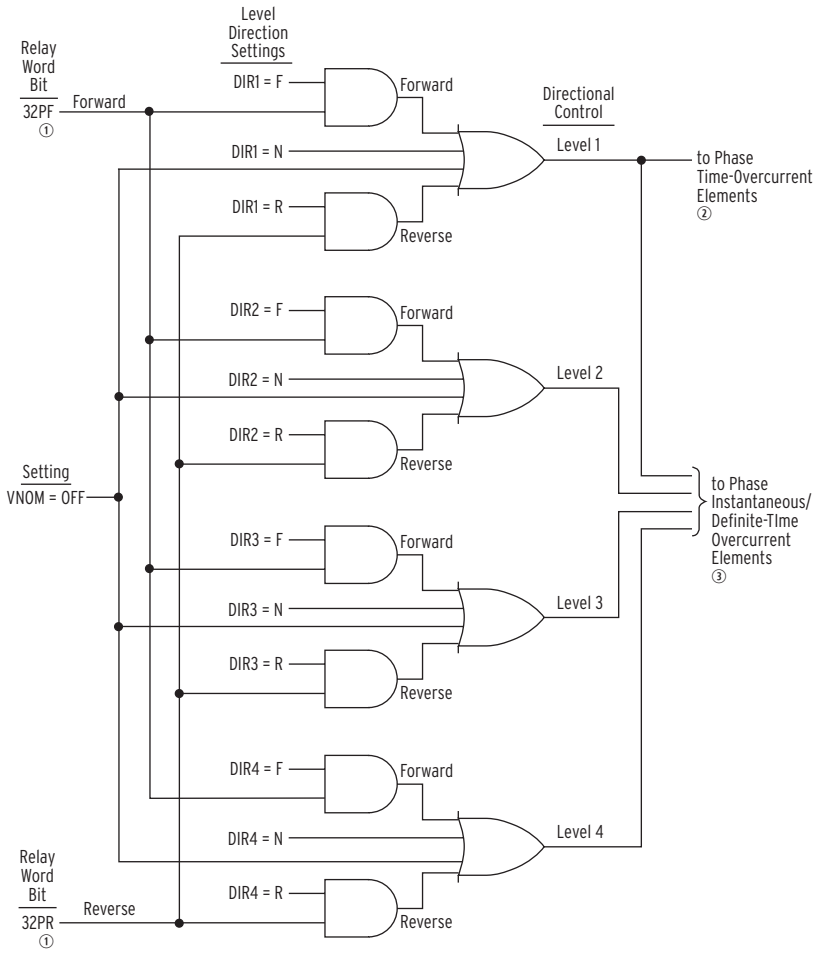
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① From Figure 4.22; ② Figure 3.20; ③ Figure 3.12.

Figure 4.23 Direction Forward/Reverse Logic for Negative-Sequence Overcurrent Elements

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① From Figure 4.22; ② Figure 3.14 and Figure 3.15; ③ Figure 3.3.

Figure 4.24 Direction Forward/Reverse Logic for Phase Overcurrent Elements

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Directional Control Settings

The directional control for overcurrent elements is enabled by making directional control enable setting E32. Setting E32 has setting choices:

Y	Enable directional control
N	Disable directional control
AUTO	Enable directional control and set many of the directional element settings automatically

If directional control enable setting E32 = N, directional control is disabled and no directional control settings are made. All level direction settings are set internally as:

DIR1 = N	(no directional control for Level 1 overcurrent elements)
DIR2 = N	(no directional control for Level 2 overcurrent elements)
DIR3 = N	(no directional control for Level 3 overcurrent elements)
DIR4 = N	(no directional control for Level 4 overcurrent elements)

With the above settings, the directional control outputs in *Figure 4.17*, *Figure 4.18*, *Figure 4.23*, and *Figure 4.24* assert to logical 1. The overcurrent elements referenced in *Figure 4.17*, *Figure 4.18*, *Figure 4.23*, and *Figure 4.24* are then not controlled by the directional control logic.

There is one case that does not allow group setting E32 = Y or AUTO. If all three of the following are true, E32 can only be set to N.

- The relay model has a 0.2 A or 0.05 A nominal neutral channel.
- Global Setting VSCONN = VS.
- Group Setting VNOM = OFF.

Settings Made Automatically

If the directional control enable setting E32 is set:

E32 = **AUTO**

then the following directional control settings are calculated and set automatically:

Z2F, Z2R, 50QFP, 50QRP, a2, k2, 50GFP, 50GRP, a0, Z0F, Z0R, and Z0MTA

If E32 = AUTO, then Z0MTA is set equal to Z0ANG and Z0MTA is hidden.

Once these settings are calculated automatically, they can only be modified if the user goes back and changes the directional control enable setting to E32 = Y.

The remaining directional control settings are **not** set automatically if setting E32 = AUTO. They have to be set by the user, whether setting E32 = AUTO or Y. These settings are:

DIR1, DIR2, DIR3, DIR4, ORDER, 50P32P, 50NFP, 50NRP, a0N, 59RES, 32WFP, 32WRP, 32WD, and E32IV (E32IV is a SELOGIC setting)

All these settings are explained in detail in the remainder of this subsection.

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Not all these directional control settings (set automatically or by the user) are used in every application. The following are particular directional control settings that are hidden/not made for particular conditions:

Table 4.6 Directional Control Settings Not Made for Particular Conditions

Settings hidden/not made:	for condition:
50P32P	setting ELOAD = Y
50GFP, 50GRP, a0	setting ORDER does not contain V or I
Z0F, Z0R, Z0MTA	setting ORDER does not contain V or S
59RES, 32WFP, 32WRP, 32WD,	setting ORDER does not contain P or model does not have a 0.2 A nominal neutral channel (**IN**)
50NFP, 50NRP, a0N	setting ORDER does not contain S or U or model does not have a 0.2 A nominal neutral channel (**IN**)

Settings

DIR1–Level 1 Overcurrent Element Direction Setting

DIR2–Level 2 Overcurrent Element Direction Setting

DIR3–Level 3 Overcurrent Element Direction Setting

DIR4–Level 4 Overcurrent Element Direction Setting

Setting Range:

F = Direction Forward

R = Direction Reverse

N = Nondirectional

Table 4.7 shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 4.7* that all the time-overcurrent elements (51_T elements) are controlled by the DIR1 level direction setting. *Figure 4.17*, *Figure 4.18*, *Figure 4.23*, and *Figure 4.24* show the logic implementation of the control listed in *Table 4.7*.

Table 4.7 Overcurrent Elements Controlled by Level Direction Settings DIR1–DIR4 (Corresponding Overcurrent Element Figure Numbers in Parentheses)

Level Direction Settings	Phase	Neutral Ground	Residual Ground	Negative-Sequence
DIR1	67P1 (*Figure 3.3*) 67P1T (*Figure 3.3*) 51P1T (*Figure 3.14*) 51P2T (*Figure 3.15*)	67N1 (*Figure 3.8*) 67N1T (*Figure 3.8*) 51N1T (*Figure 3.16*) 51N2T (*Figure 3.17*)	67G1 (*Figure 3.10*) 67G1T (*Figure 3.10*) 51G1T (*Figure 3.18*) 51G2T (*Figure 3.19*)	67Q1 (*Figure 3.12*) 67Q1T (*Figure 3.12*) 51QT (*Figure 3.20*)
DIR2	67P2 (*Figure 3.3*) 67P2T (*Figure 3.3*) 67P2S (*Figure 3.3*)	67N2 (*Figure 3.8*) 67N2T (*Figure 3.8*) 67N2S (*Figure 3.8*)	67G2 (*Figure 3.10*) 67G2T (*Figure 3.10*) 67G2S (*Figure 3.10*)	67Q2 (*Figure 3.12*) 67Q2T (*Figure 3.12*) 67Q2S (*Figure 3.12*)
DIR3	67P3 (*Figure 3.3*) 67P3T (*Figure 3.3*)	67N3 (*Figure 3.8*) 67N3T (*Figure 3.8*)	67G3 (*Figure 3.10*) 67G3T (*Figure 3.10*)	67Q3 (*Figure 3.12*) 67Q3T (*Figure 3.12*)
DIR4	67P4 (*Figure 3.3*) 67P4T (*Figure 3.3*)	67N4 (*Figure 3.8*) 67N4T (*Figure 3.8*)	67G4 (*Figure 3.10*) 67G4T (*Figure 3.10*)	67Q4 (*Figure 3.12*) 67Q4T (*Figure 3.12*)

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In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

Level 1 overcurrent elements set direction forward (DIR1 = F)

Level 2 overcurrent elements set direction forward (DIR2 = F)

Level 3 overcurrent elements set direction reverse (DIR3 = R)

In some applications, level direction settings DIR1–DIR4 are not flexible enough in assigning the desired direction for certain overcurrent elements. Subsection *Directional Control Provided by Torque Control Settings on page 4.58* describes how to avoid this limitation for special cases.

ORDER–Ground Directional Element Priority Setting

Setting ORDER can be set with the elements listed and defined in *Table 4.3*, subject to the setting combination constraints in *Table 4.4* and *Table 4.5*. Note that *Table 4.3* and *Table 4.4* also list directional element availability per model (according to the neutral channel [**IN**] rating). *Table 4.5* lists the ground directional element availability as a result of the voltage connection settings.

The **order** in which the directional elements are listed in setting ORDER determines the priority in which these elements operate to provide Best Choice Ground Directional logic control.

For example, if setting:

ORDER = **QVS**

then the first listed directional element (Q = negative-sequence voltage-polarized directional element; see *Figure 4.9*) is the first priority directional element to provide directional control for the neutral ground and residual ground overcurrent elements.

If the negative-sequence voltage-polarized directional element is not operable (i.e., it does not have sufficient operating quantity as indicated by its internal enable, 32QGE, not being asserted; see *Figure 4.6*), then the second listed directional element (V = zero-sequence voltage-polarized directional element; see *Figure 4.10*) provides directional control for the neutral ground and residual ground overcurrent elements.

If the zero-sequence voltage-polarized directional element is not operable (i.e., it does not have sufficient operating quantity as indicated by its internal enable, 32VE, not being asserted; see *Figure 4.7*), then the third listed directional element (S = zero-sequence voltage-polarized directional element [low-impedance]; see *Figure 4.12*) provides directional control for the neutral ground and residual ground overcurrent elements.

If the zero-sequence voltage-polarized directional element (low-impedance) is not operable (i.e., it does not have sufficient operating quantity as indicated by its internal enable, 32NE [low-impedance], not being asserted; see *Figure 4.8*), then no directional control is available. The neutral ground and residual ground overcurrent elements will not operate, even though these elements are designated with the DIR*n* (*n* = 1–4) settings to be directionally controlled (see *Figure 4.17* and *Figure 4.18*).

Another example, if setting:

ORDER = **V**

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then the zero-sequence voltage-polarized directional element (V = zero-sequence voltage-polarized directional element; see *Figure 4.10*) provides directional control for the neutral ground and residual ground overcurrent elements at all times (assuming it has sufficient operating quantity). If there is not sufficient operating quantity during an event (i.e., internal enable 32VE is not asserted; see *Figure 4.7*), then no directional control is available. The neutral ground and residual ground overcurrent elements will not operate, even though these elements are designated with the DIR*n* (*n* = 1–4) settings to be directionally controlled (see *Figure 4.17* and *Figure 4.18*).

If setting:

ORDER = **OFF**

then all of the ground directional elements are inoperable. Note in *Figure 4.17* and *Figure 4.18* that setting ORDER = OFF effectively makes the neutral ground and residual ground overcurrent elements nondirectional (the directional control outputs of *Figure 4.17* and *Figure 4.18* are continuously asserted to logical 1).

Petersen Coil Considerations for Setting ORDER

Note in *Figure 4.17* that if setting ORDER = P, the residual ground overcurrent elements are not controlled by the directional control logic (much like when ORDER = OFF). In such a scenario, where only the wattmetric directional element provides ground overcurrent element directional control (setting ORDER = P), presumably there is no bypass around the Petersen Coil. With the tuned Petersen Coil in place (and not shorted out by a bypass), very little current flows for a ground fault. With such low current levels, the neutral-ground overcurrent elements (referenced in *Figure 4.18*) are the elements that detect the ground fault, not the residual-ground overcurrent elements (referenced in *Figure 4.17*). The residual ground overcurrent elements (including forward and reverse fault detectors 50GF and 50GR, respectively; see *Figure 4.7*) should be set above any ground fault current level with the Petersen Coil in place.

If there is a bypass around the Petersen Coil and the bypass is used at times (i.e., shorting out the Petersen Coil), much higher currents can flow for a ground fault when the bypass is closed. In such a scenario, setting ORDER should be set something like ORDER = QP or ORDER = QVP (see *Table 4.4*). Then, the residual ground elements (*Figure 4.17*) are controlled by the directional control logic and provide directional protection for higher ground fault currents.

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50P32P—Phase Directional Element Three-Phase Current Pickup

Setting Range:

0.50–10.00 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

0.10–2.00 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

The 50P32P setting is set to pick up for all three-phase faults that need to be covered by the phase overcurrent elements. It supervises the positive-sequence voltage-polarized directional elements F32P and R32P (see *Figure 4.21*).

If the load-encroachment logic is enabled (enable setting ELOAD = Y), then setting 50P32P is not made or displayed, but is fixed internally at:

0.5 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

0.1 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Z2F—Forward Directional Z2 Threshold

Z2R—Reverse Directional Z2 Threshold

Setting Range:

–128.00 to 128.00 Ω secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

–640.00 to 640.00 Ω secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

Z2F and Z2R are used to calculate the Forward and Reverse Thresholds, respectively, for the negative-sequence voltage-polarized directional elements (see *Figure 4.9* and *Figure 4.20*).

If enable setting E32 = Y, settings Z2F and Z2R (negative-sequence impedance values) are calculated by the user and entered by the user, but setting Z2R must be greater in value than setting Z2F by 0.1 Ω secondary.

Z2F and Z2R Set Automatically

If enable setting E32 = AUTO, settings Z2F and Z2R (negative-sequence impedance values) are calculated automatically, using the positive-sequence line impedance magnitude setting Z1MAG as follows:

Z2F = **Z1MAG/2** (Ω secondary)

Z2R = **Z1MAG/2 + z** (Ω secondary; z listed in *Table 4.8* below)

NOTE: If the above calculation of Z2F and Z2R exceeds the setting range, the quantity is set to the upper limit of the setting range.

Table 4.8 z Constant for Z2R Setting

Relay Configuration	z (Ω secondary)
5 A nominal current, 300 V voltage inputs	0.2
1 A nominal current, 300 V voltage inputs	1.0

Figure 4.25 and *Figure 4.26* and supporting text concern the zero-sequence impedance network, relay polarity, and the derivation of settings Z0F and Z0R. The same general approach outlined for deriving settings Z0F and Z0R can also be applied to deriving settings Z2F and Z2R in the negative-sequence impedance network, though the preceding method of automatically making settings Z2F and Z2R usually suffices.

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50QFP—Forward Directional Negative-Sequence Current Pickup

50QRP—Reverse Directional Negative-Sequence Current Pickup

Setting Range:

0.25–5.00 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

0.05–1.00 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

The 50QFP setting ($3I_2$ current value) is the pickup for the forward fault detector 50QF of the negative-sequence voltage-polarized directional elements (see *Figure 4.6*). Ideally, the setting is above normal load unbalance and below the lowest expected negative-sequence current magnitude for unbalanced forward faults.

The 50QRP setting ($3I_2$ current value) is the pickup for the reverse fault detector 50QR of the negative-sequence voltage-polarized directional elements (see *Figure 4.6*). Ideally, the setting is above normal load unbalance and below the lowest expected negative-sequence current magnitude for unbalanced reverse faults.

50QFP and 50QRP Set Automatically

If enable setting E32 = AUTO, settings 50QFP and 50QRP are set automatically at:

50QFP = 0.50 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

50QRP = 0.25 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

50QFP = 0.10 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

50QRP = 0.05 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

a2—Positive-Sequence Current Restraint Factor, I_2/I_1

Setting Range:

0.02–0.50 (unitless)

Refer to *Figure 4.6*.

The a2 factor increases the security of the negative-sequence voltage-polarized directional elements. It keeps the elements from operating for negative-sequence current (system unbalance), which circulates due to line asymmetries, CT saturation during three-phase faults, etc.

a2 Set Automatically

If enable setting E32 = AUTO, setting a2 is set automatically at:

a2 = **0.1**

For setting a2 = 0.1, the negative-sequence current (I_2) magnitude has to be greater than 1/10 of the positive-sequence current (I_1) magnitude in order for the negative-sequence voltage-polarized directional elements to be enabled ($|I_2| > 0.1 \bullet |I_1|$).

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k2–Zero-Sequence Current Restraint Factor, I_2/I_0

Setting Range:

0.10–1.20 (unitless)

Note the internal enable logic outputs in *Figure 4.6*:

32QE internal enable for the negative-sequence voltage-polarized directional element that controls the negative-sequence and phase overcurrent elements

32QGE internal enable for the negative-sequence voltage-polarized directional element that controls the neutral ground and residual ground overcurrent elements

The k2 factor is applied to internal enable 32QGE. The negative-sequence current (I_2) magnitude has to be greater than the zero-sequence current (I_0) magnitude multiplied by k2 in order for the 32QGE internal enable (and following negative-sequence voltage-polarized directional element in *Figure 4.9*) to be enabled:

$$|I_2| > k2 \bullet |I_0|$$

This check assures that the relay uses the most robust analog quantities in making directional decisions for the neutral ground and residual ground overcurrent elements.

The zero-sequence current (I_0), referred to in the above application of the k2 factor, is from the residual current (I_G), which is derived from phase currents I_A, I_B, and I_C:

$I_0 = I_G/3$ $3I_0 = I_G = I_A + I_B + I_C$

If both of the internal enables:

32VE internal enable for the zero-sequence voltage-polarized directional element that controls the neutral ground and residual ground overcurrent elements

32IE internal enable for the channel IN current-polarized directional element that controls the neutral ground and residual ground overcurrent elements

are deasserted, then factor k2 is ignored as a logic enable for the 32QGE internal enable. This effectively puts less restrictions on the operation of the negative-sequence voltage-polarized directional element.

k2 Set Automatically

If enable setting E32 = AUTO, setting k2 is set automatically at:

k2 = **0.2**

For setting k2 = 0.2, the negative-sequence current (I_2) magnitude has to be greater than 1/5 of the zero-sequence current (I_0) magnitude in order for the negative-sequence voltage-polarized directional elements to be enabled ($|I_2$ 0.2 • $|I_0|$). Again, this presumes at least one of the internal enables 32VE or 32IE is asserted.

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50GFP—Forward Directional Residual Ground Current Pickup

50GRP—Reverse Directional Residual Ground Current Pickup

Setting Range:

0.05–5.00 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

0.01–1.00 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

If preceding setting ORDER does not contain V or I (no zero-sequence voltage-polarized or channel **IN** current-polarized directional elements are enabled), then settings 50GFP and 50GRP are not made or displayed.

The 50GFP setting ($3I_0$ current value) is the pickup for the forward fault detector 50GF of the zero-sequence voltage-polarized and channel **IN** current-polarized directional elements (see *Figure 4.7*). Ideally, this setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced forward faults.

The 50GRP setting ($3I_0$ current value) is the pickup for the reverse fault detector 50GR of the zero-sequence voltage-polarized and channel **IN** current-polarized directional elements (see *Figure 4.7*). Ideally, this setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced reverse faults.

See *Petersen Coil Considerations for Setting ORDER on page 4.42* for more information on setting 50GFP and 50GRP for a Petersen Coil grounded system.

50GFP and 50GRP Set Automatically

If enable setting E32 = AUTO, settings 50GFP and 50GRP are set automatically at:

50GFP = 0.50 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

50GRP = 0.25 A secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

50GFP = 0.10 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

50GRP = 0.05 A secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

a0—Positive-Sequence Current Restraint Factor, I_0/I_1

Setting Range:

0.02–0.50 (unitless)

If preceding setting ORDER does not contain V or I (no zero-sequence voltage-polarized or channel **IN** current-polarized directional elements are enabled), then setting a0 is not made or displayed.

Refer to *Figure 4.7*.

The a0 factor increases the security of the zero-sequence voltage-polarized and channel **IN** current-polarized directional elements. This factor keeps the elements from operating for zero-sequence current (system unbalance), which circulates due to line asymmetries, CT saturation during three-phase faults, etc.

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The zero-sequence current (I_0), referred to in the application of the a0 factor, is from the residual current (I_G), which is derived from phase currents I_A, I_B, and I_C:

$$I_0 = I_G/3 \qquad 3I_0 = I_G = I_A + I_B + I_C$$

a0 Set Automatically

If enable setting E32 = AUTO, setting a0 is set automatically at:

a0 = **0.1**

For setting a0 = 0.1, the zero-sequence current (I_0) magnitude has to be greater than 1/10 of the positive-sequence current (I_1) magnitude in order for the zero-sequence voltage-polarized and channel **IN** current-polarized directional elements to be enabled ($|I_0 > 0.1 \bullet |I_1|$).

Z0F—Forward Directional Z0 Threshold

Z0R—Reverse Directional Z0 Threshold

Setting Range:

–128.00 to 128.00 Ω secondary (5 A nominal phase current inputs, **IA**, **IB**, **IC**)

–640.00 to 640.00 Ω secondary (1 A nominal phase current inputs, **IA**, **IB**, **IC**)

If preceding setting ORDER does not contain V or S (no zero-sequence voltage-polarized directional element is enabled), then settings Z0F and Z0R are not made by the user or displayed.

Z0F and Z0R are used to calculate the Forward and Reverse Thresholds, respectively, for the zero-sequence voltage-polarized directional elements (see *Figure 4.10* and *Figure 4.12*).

If enable setting E32 = Y, settings Z0F and Z0R (zero-sequence impedance values) are calculated by the user and entered by the user, but setting Z0R must be greater in value than setting Z0F by 0.1 Ω secondary.

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Z0F and Z0R Set Automatically

If enable setting E32 = AUTO, settings Z0F and Z0R (zero-sequence impedance values) are calculated automatically, using the zero-sequence line impedance magnitude setting Z0MAG as follows:

Z0F = **Z0MAG/2** (Ω secondary)

Z0R = **Z0MAG/2 + z** (Ω secondary; z listed in *Table 4.9*)

Table 4.9 z Constant for Z0R Setting

Relay Configuration	z (Ω secondary)
5 A nominal current, 300 V voltage inputs	0.2
1 A nominal current, 300 V voltage inputs	1.0

NOTE: If the above calculation of Z0F and Z0R exceeds the setting range, the quantity is set to the upper limit of the setting range.

NOTE: Z0F and Z0R (Ω secondary) are set in reference to the phase current channels **IA**, **IB**, and **IC**, as are settings Z2F and Z2R. However, settings Z0F and Z0R are applied to Figure 4.12, and Figure 4.14, where neutral current I_N, from neutral current channel **IN**, is also applied. Settings Z0F and Z0R are adjusted internally (with CT ratio settings) to operate on this I_N current base, when needed (effectively, Z0F•CTRN/CTR and Z0R•CTRN/CTR). See Internal Enables on page 4.14.

If setting ORDER = U (ungrounded or high-impedance grounded system; see *Figure 4.14*), the following settings are made internally and hidden:

Z0F = –0.10 Ω secondary
Z0R = 0.10 Ω secondary

Deriving Z0F and Z0R Settings

Figure 4.25 shows the voltage and current polarity for an SEL-351S in a zero-sequence impedance network (the same approach can be instructive for negative-sequence impedance analysis, too). For a forward fault, the SEL-351S effectively sees the sequence impedance behind it as:

$Z_M = V_0/(-I_0) = -(V_0/I_0)$
$V_0/I_0 = -Z_M$ (what the relay sees for a forward fault)

For a reverse fault, the SEL-351S effectively sees the sequence impedance in front of it:

$Z_N = V_0/I_0$
$V_0/I_0 = Z_N$ (what the relay sees for a reverse fault)

If the system in *Figure 4.25* is a solidly-grounded system (mostly inductive; presume uniform system angle), and load-connected line to neutral, the impedance plot (in the R + jX plane) would appear as in *Figure 4.26a*, with resultant Z0F and Z0R settings as in *Figure 4.26b*. The zero-sequence line angle noted in *Figure 4.26a* (∠Z0MTA) is the same angle found in *Figure 4.10* and *Figure 4.12* (in the equation box with the Enable line).

The preceding method of automatically making settings Z0F and Z0R (where both Z0F and Z0R are positive values; still Z0R>Z0F) usually suffices for mostly inductive systems—*Figure 4.25* and *Figure 4.26* just provide a theoretic background.

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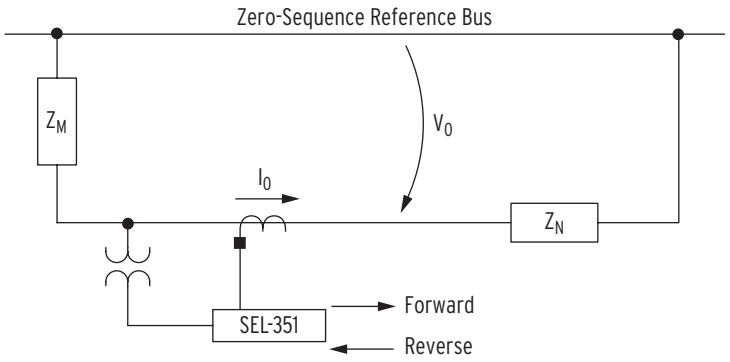


Figure 4.25 Zero-Sequence Impedance Network and Relay Polarity

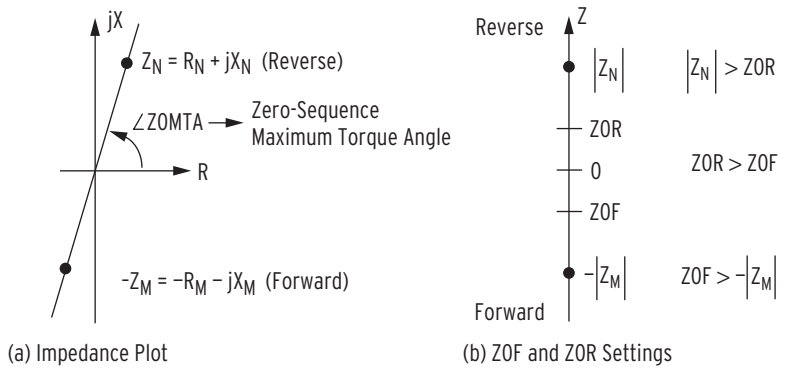


Figure 4.26 Zero-Sequence Impedance Plot for Solidly-Grounded, Mostly Inductive System

Z0MTA–Zero-Sequence Maximum Torque Angle

Setting Range:

–90.00 to –5.00 degrees

5.00 to 90.00 degrees

If enable setting E32 = Y and ORDER contains a V or S, setting Z0MTA should be set. Z0MTA must be set to compensate for the neutral ground resistor and is used in the Best Choice Ground Directional Logic™ to make proper forward and reverse fault determination (see *Figure 9.22*).

If enable setting E32 = AUTO, then Z0MTA is set equal to Z0ANG and Z0MTA is hidden.

50NFP–Forward Directional Neutral Ground Current Pickup

50NRP–Reverse Directional Neutral Ground Current Pickup

Setting Range:

0.005–5.00 A secondary (0.2 A nominal neutral channel input, **IN**)

If preceding setting ORDER does not contain S or U (zero-sequence voltage-polarized directional elements: low-impedance or ungrounded/high-impedance grounded, are not enabled) or the model does not have a 0.2 A nominal neutral channel (**IN**), then settings 50NFP and 50NRP are not made or displayed.

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NOTE: 50NFP and 50NRP (A secondary) are set in terms of the neutral current IN, from neutral current channel IN. However, as discussed in Internal Enables on page 4.14, settings 50NFP and 50NRP are applied to Figure 4.8, Figure 4.12, and Figure 4.14, where residual current IG (derived from phase current channels IA, IB, and IC) can be applied, depending on current magnitudes. Settings 50NFP and 50NRP are adjusted internally to operate on this residual current IG base, when needed (effectively, 50NFP • CTRN/CTR and 50NRP • CTRN/CTR).

The 50NFP setting (I_N current value) is the pickup for the forward fault detector 50NF of the zero-sequence voltage-polarized directional elements: low-impedance or ungrounded/high-impedance grounded (see *Figure 4.8*). Ideally, this setting is above normal load unbalance and below the lowest expected zero-sequence current magnitude for unbalanced forward faults.

The 50NRP setting (I_N current value) is the pickup for the reverse fault detector 50NR of the zero-sequence voltage-polarized directional elements: low-impedance or ungrounded/high-impedance grounded (see *Figure 4.8*). Ideally, this setting is above normal load/system unbalance and below the lowest expected zero-sequence current magnitude for unbalanced reverse faults.

a0N–Positive-Sequence Current Restraint Factor, I_N/I_1

Setting Range:

0.0–0.500 (unitless)

If preceding setting ORDER does not contain S or U (zero-sequence voltage-polarized directional elements: low-impedance grounded or ungrounded/high-impedance grounded, are not enabled) or the model does not have a 0.2 A nominal neutral channel (**IN**), then setting a0N is not made or displayed.

Refer to *Figure 4.8*. The following comparison is made as part of internal enable 32NE (for low-impedance grounded and ungrounded/high-impedance grounded systems):

$$|I_N| > a0N \bullet |I_1|$$

I_N is the secondary current measured by neutral channel **IN**. I_1 is the positive-sequence secondary current derived from the phase current channels **IA**, **IB**, and **IC**. Presumably, channel **IN** is connected in such a manner that it sees the system zero-sequence current (e.g., channel **IN** is connected to a core-balance CT through which the three phase conductors pass; in such a connection, channel **IN** sees $3I_0$ zero-sequence current, $I_N = 3I_0$; see *Figure 2.25*, *Figure 2.27*, and *Figure 2.28*).

If a core-balance current transformer is connected to neutral channel **IN**, it most likely has a different ratio, compared to the current transformers connected to the phase current channels **IA**, **IB**, and **IC** (CT ratio settings CTRN and CTR, respectively).

From a primary system study, load profile values, or metering values, derive a0N as follows:

$$a0N = (3I_0 \text{ pri.}/I_1 \text{ pri.}) \bullet (CTR/CTRN)$$

$3I_0$ pri. = standing system unbalance current (zero-sequence; A primary)

I_1 pri. = maximum load current (positive-sequence; A primary)

Adjust the final setting value of a0N from the above derived value of a0N, depending on your security philosophy, etc.

The a0N factor increases the security of the zero-sequence voltage-polarized directional elements: low-impedance grounded or ungrounded/high-impedance grounded. It keeps the elements from operating for zero-sequence current (system unbalance), which circulates due to line asymmetries, etc.

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59RES–Wattmetric $3V_0$ Overvoltage Pickup (Petersen Coil Grounded System)

Setting Range:

1.00–430.00 V secondary (300 V nominal voltage inputs, **VA**, **VB**, **VC**)

If preceding setting ORDER does not contain P (Petersen Coil directional element is not enabled) or the model does not have a 0.2 A nominal neutral channel (**IN**), then setting 59RES is not made or displayed.

Setting 59RES should be set greater than the value of $3V_0$ zero-sequence voltage present for normal system unbalance. It is part of the enabling logic for the wattmetric element part of the Petersen Coil directional element (see *Figure 4.13*).

The $3V_0$ input to *Figure 4.13* may come either from a calculation or from a direct measurement, as described in *Zero-Sequence Voltage Sources on page 4.15*. When using a broken-delta PT connection to terminals **VS**-**NS** as the zero-sequence voltage source (global setting VSCONN = 3V0), there are some special considerations in making the 59RES setting that are related to the scaling of the VS-NS input signal. The 59RES setting must be entered on the same secondary base as the voltage terminals **VA**, **VB**, and **VC**. See *Settings Considerations for Petersen Coil Grounded Systems on page 4.54* for an example.

32WFP and 32WRP–Wattmetric Forward and Reverse Pickups (Petersen Coil Grounded System)

Setting Range:

0.001–150.000 W secondary (300 V nominal voltage inputs, **VA**, **VB**, **VC**; 0.2 A nominal neutral channel input, **IN**)

If preceding setting ORDER does not contain P (Petersen Coil directional element is not enabled) or the model does not have a 0.2 A nominal neutral channel (**IN**), then settings 32WFP and 32WRP are not made or displayed.

Quantities needed to make the 32WFP and 32WRP wattmetric pickups calculations are:

$3V_0$ zero-sequence voltage in secondary (from inputs, **VA**, **VB**, **VC**; or input **VS** when VSCONN = 3V0)

I_N current in secondary (from 0.2 A nominal neutral channel input, **IN**)

The $3V_0$ input to *Figure 4.13* may come either from a calculation or from a direct measurement, as described in *Zero-Sequence Voltage Sources on page 4.15*. When using a broken-delta PT connection to terminals **VS**-**NS** as the zero-sequence voltage source (global setting VSCONN = 3V0), there are some special considerations in making the 32WFP and 32WRP settings that are related to the scaling of the **VS**-**NS** input signal. The 32WFP and 32WRP settings must be entered on the same secondary base as the voltage terminals **VA**, **VB**, and **VC**. See *Settings Considerations for Petersen Coil Grounded Systems on page 4.54* for an example.

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I_N is the current measured by current channel **IN**. Channel **IN** is connected in such a manner that it monitors the system zero-sequence current (e.g., channel **IN** is connected to a window CT through which the three phase conductors pass and thus monitors $3I_0$ zero-sequence current, see *Figure 2.26*). With such a connection:

$$I_N = 3I_0$$

In *Figure 2.26*, only one feeder position is shown, but one can imagine the bus extending to the right, with other feeder positions. The Petersen Coil in the transformer neutral is tuned to cancel out the cumulative zero-sequence line capacitance of all the connected feeders. The Petersen Coil and the zero-sequence line capacitance are a parallel LC circuit. In a "tuned state," they create a high impedance circuit and thus a power system that is essentially ungrounded (with much less current flow than a traditional ungrounded system). In such an optimum tuned state, little current flows through the Petersen Coil. Some Petersen Coils are continually adjusted automatically, as load levels/system topology change, so that tuning remains optimum. The "tuned circuit" resists sustaining an arc, so many ground faults are self-extinguished by the circuit itself (no circuit breaker operation necessary).

Consider a permanent line-to-ground fault out on the feeder in *Figure 2.26* (refer to the relay and feeder shown in *Figure 2.26* as Relay 1 and Feeder 1, respectively. Other feeders on the same bus, though not shown in *Figure 2.26*, are then Relay 2/Feeder 2, etc.). In the zero-sequence network view in *Figure 4.27*, Relay 2 (on unfaulted Feeder 2) sees mostly capacitance in front of it. Assuming a "tuned circuit," $I_0 = 0$ at the fault. Thus, the entire zero-sequence capacitance shown in *Figure 4.27* is canceled out by the inductance of the Petersen Coil. So, with Feeder 1 capacitance C_1 in front of Relay 1, the system behind Relay 1 appears net inductive.

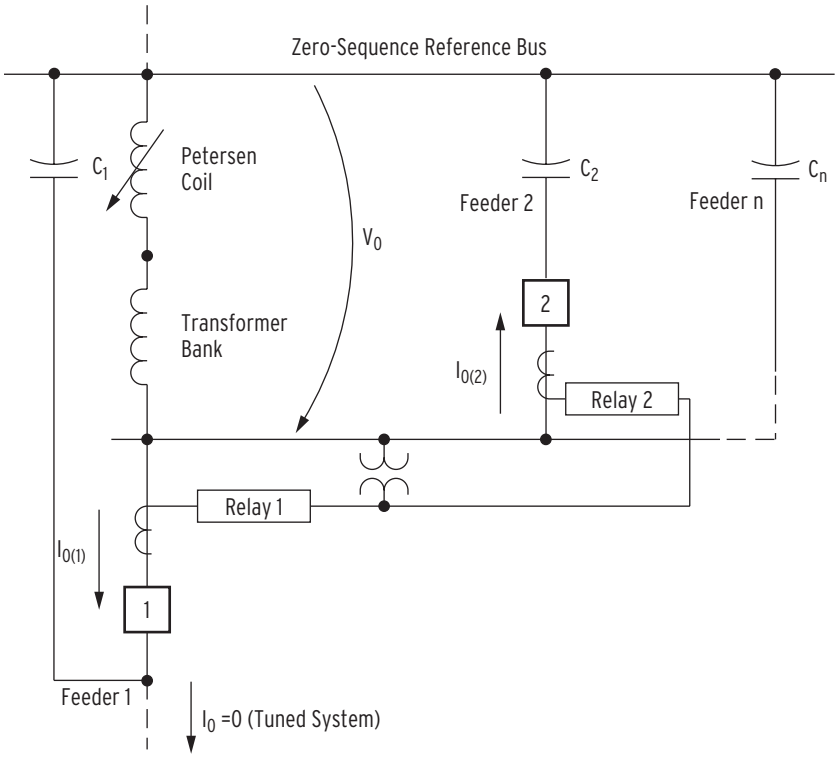


Figure 4.27 Zero-Sequence Impedance Network for Ground Fault on Feeder 1

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Figure 4.28 shows the zero-sequence vector relationships described above for *Figure 4.27* (note: the zero-sequence currents $I_{0(1)}$ and $I_{0(2)}$ are what the relays respectively "see," per standard current transformer connections—see *Figure 2.26*). The vectors shown in *Figure 4.28* are perhaps somewhat overdramatic as far as angle differences—they are primarily for illustrative purposes.

There is always some resistance in a circuit and thus the V_0 and I_0 vector relationship is not 90 degrees, as shown in *Figure 4.28*. This system resistance provides the "real power component" with which the wattmetric directional element (*Figure 4.13*) operates. Whether the zero-sequence network behind Relay 1 appears net capacitive or net inductive, the wattmetric (real power) portion for Relay 1/faulted Feeder 1 (labeled "WF") is polar-opposite of the wattmetric (real power) portion for Relay 2/unfaulted Feeder 2 (labeled "WR"). The calculations for the 32WFP and 32WRP wattmetric pickups are made as follows:

$$\begin{aligned} \text{Real}\{3V_0 \bullet \text{conjugate}\,(3I_0)\} &= |3V_0| \bullet |3I_0| \bullet \cos(\angle 3V_0 - \angle 3I_0) \\ &= |3V_0| \bullet |I_N| \bullet \cos(\angle 3V_0 - \angle I_N) \end{aligned}$$

The cosine part of the above calculation reveals forward or reverse fault direction: forward faults produce negative calculation values and reverse faults produce positive calculation values on Petersen Coil grounded systems. Calculate the 32WFP and 32WRP wattmetric pickup settings (in watts secondary), with a margin of more sensitivity than the minimum detected ground faults (forward and reverse, respectively). Enter wattmetric settings as positive values.

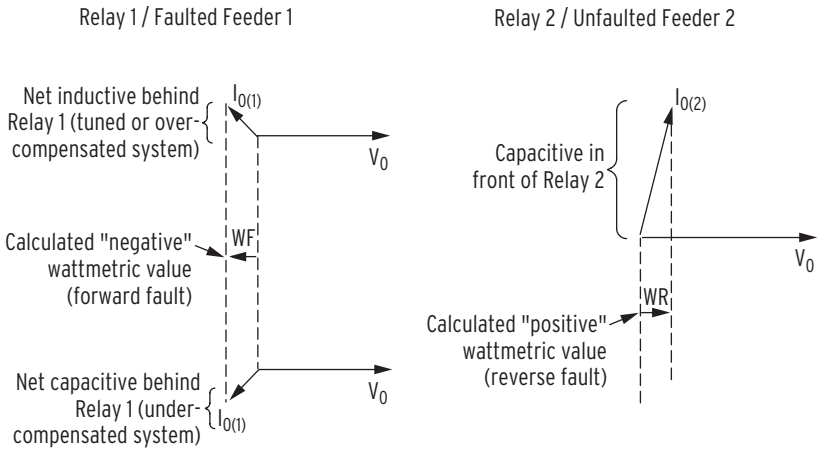


Figure 4.28 Wattmetric Element Operation for Ground Fault on Feeder 1

The sum of settings 32WFP and 32WRP must be 0.1 watts secondary or greater:

$$32WFP + 32WRP \geq 0.1 \text{ watts secondary}$$

In *Figure 4.28*, the calculated wattmetric value for a forward fault is a negative value (shown as WF), while that for a reverse fault is a positive value (shown as WR). Again, corresponding settings 32WFP and 32WRP are both entered as positive values, with some margin of sensitivity. The above "0.1 watts secondary" rule is effectively the minimum distance between settings 32WFP and 32WRP in the wattmetric plane (setting 32WFP is put on the "negative" side of the wattmetric plane: i.e., "–32WFP"; see *Figure 4.13*).

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32WD—Wattmetric Delay (Petersen Coil Grounded System)

Setting Range:

30.00–999,999.00 cycles

If preceding setting ORDER does not contain P (Petersen Coil directional element is not enabled) or the model does not have a 0.2 A nominal neutral channel (**IN**), then setting 32WD is not made or displayed.

Settings Considerations for Petersen Coil Grounded Systems

The Petersen Coil elements require a zero-sequence voltage source, which is calculated from voltages V_A, V_B, and V_C when the relay is wye connected (Global Setting PTCONN = WYE and VSCONN = VS), or which is measured from the **VS** channel when the relay is connected to a broken-delta $3V_0$ source and global setting VSCONN = 3V0. Three of the required Petersen Coil element settings, 59RES, 32WFP, and 32WRP, depend on the type of $3V_0$ voltage source and on the PTR and PTRS group settings.

When VSCONN = VS and the relay is wye connected (PTCONN = WYE), the $3V_0$ source is in secondary volts on the **VA**, **VB**, **VC** input terminal base. In fact, $3V_0$ is calculated from the measured V_A, V_B, and V_C voltages. The 59RES, 32WFP, and 32WRP settings are set in terms of this same base.

An example system similar to *Figure 2.26*, with wye-connected PTs (PT ratio 7200:120; setting PTR = 7200/120 = 60) and a core-flux summation CT (CT ratio 50:5; setting CTRN = 50/5 =10), is used to demonstrate the required setting scaling.

If the desired zero-sequence voltage pickup for the wattmetric element in primary $3V_0$ is 400 V primary, obtain the proper setting for 59RES by dividing the primary voltage by the PT ratio for voltage inputs **VA**, **VB**, and **VC**:

$$59RES = \frac{V\ primary}{PTR} = \frac{400\ V\ primary}{60} = 6.67\ V\ secondary$$

If the desired forward wattmetric element threshold is 24 kW primary, and the desired reverse threshold is 10 kW primary, the correct settings are:

$$32WFP = \frac{W\ primary}{PT \bullet CTRN} = \frac{24000\ W\ primary}{60 \bullet 10} = 40.000\ W\ secondary$$

$$32WRP = \frac{W\ primary}{PTR \bullet CTRN} = \frac{10000\ W\ primary}{60 \bullet 10} = 16.667\ W\ secondary$$

When VSCONN = 3V0, with a broken-delta $3V_0$ voltage source connected to the **VS** channel (terminals **VS-NS**), group setting PTRS must be properly set to give the signal on the **VS** channel the correct scaling in primary units, as displayed under VS in the **METER** command response, available via serial port or front panel. The example value PTRS = 96, as shown in *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings on page 9.53*, is used for subsequent examples.

The relay internally converts the **VS** channel signal to the **VA**, **VB**, **VC** voltage base before using it as the $3V_0$ quantity, as shown in *Table 4.10*. Thus, when the zero-sequence voltage pickup for the wattmetric element is known in terms of the system primary voltage level, the required calculation for setting

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59RES is the same as the calculation for the VSCONN = VS example shown previously, which converts the primary zero-sequence voltage value into a secondary value on the **VA**, **VB**, **VC** input terminal base.

Using the example quantities from the VSCONN = VS subsection:

$$59RES = \frac{V\ primary}{PTR} = \frac{400\ V\ primary}{60} = 6.67\ V\ secondary$$

Note that the primary voltage is divided by the PTR setting, **not** the PTRS setting.

Similarly, the derivation of the 32WFP and 32WRP settings, if they are known in primary Watts, follows the same formula as before:

$$32WFP = \frac{W\ primary}{PTR \bullet CTRN} = \frac{24000\ W\ primary}{60 \bullet 10} = 40.000\ W\ secondary$$

$$32WRP = \frac{W\ primary}{PTR \bullet CTRN} = \frac{10000\ W\ primary}{60 \bullet 10} = 16.667\ W\ secondary$$

However, if the desired voltage pickup for the wattmetric element is known in terms of **VS** channel volts (secondary), then the setting value must be scaled by PTRS/PTR prior to entry. This pre-scaling makes the 59RES setting match the scaling the relay does when it internally converts the **VS** channel value to the **VA**, **VB**, **VC** voltage base.

For our example system, the desired $3V_0$ pickup in terms of the voltage applied to channel **VS** is:

$$Voltage\ value(VS\ channel\ base) = \frac{V\ primary}{PTRS}$$

The example $3V_0$ pickup value in terms of the voltage applied to channel **VS** is:

$$Voltage\ value(VS\ channel\ base) = \frac{400\ V\ primary}{96}$$
$$= 4.167\ V\ secondary$$

The 59RES setting is determined as follows:

$$59RES = V\ secondary(VSbase) \bullet \frac{PTRS}{PTR}$$
$$= 4.167 \bullet \frac{96}{60}$$
$$= 6.67\ V\ secondary$$

As expected, this is the same value as before.

Similarly, if the desired wattmetric pickup for the wattmetric element is known in terms of **VS** channel volts (secondary) and **IN** channel current (secondary), then the setting value must be scaled by PTRS/PTR prior to entry. This pre-scaling makes the 32WFP and 32WRP settings match the scaling the relay does when it converts the **VS** value into the **VA**, **VB**, **VC** voltage base.

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For our example system, the desired wattmetric pickup in terms of the voltage applied to channel **VS** and the current applied to channel **IN** is:

$$\text{Wattmetric value(VS and IN base)} = \frac{\text{W primary}}{\text{PTRS} \bullet \text{CTRN}}$$

Forward = 24000 W / (96 • 10) = 25 W secondary
Reverse = 10000 W / (96 • 10) = 10.417 W secondary

The 32WFP and 32WRP settings are determined as follows:

$$\begin{aligned} 32\text{WFP} &= \text{W secondary(VS and IN base)} \bullet \frac{\text{PTRS}}{\text{PTR}} \\ &= 25\text{W} \bullet \frac{96}{60} \\ &= 40.000 \text{ W secondary (VA, VB, VC, and IN base)} \end{aligned}$$

$$\begin{aligned} 32\text{WRP} &= \text{W secondary(VS and IN base)} \bullet \frac{\text{PTRS}}{\text{PTR}} \\ &= 10.417 \text{ W} \bullet \frac{96}{60} \\ &= 16.667 \text{ W secondary (VA, VB, VC, and IN base)} \end{aligned}$$

These details are important in relay testing, when the signal applied to the **VS-NS** terminals represents a $3V_0$ zero-sequence voltage signal, and Global Setting VSCONN = 3V0. When making test settings or interpreting test results, remember that the relay scales the measured value by PTRS/PTR before using it in the Petersen Coil directional element and in the various zero-sequence voltage-polarized directional elements.

Table 4.10 Affect of Global Settings VSCONN and PTCONN on Petersen Coil Directional Elements

Relay Function	When VSCONN=VS and PTCONN = WYE	When VSCONN=VS and PTCONN = DELTA	When VSCONN=3VO (PTCONN = WYE or DELTA)
Wattmetric and incremental conductance elements (ORDER setting choice "P").	Use $3V_0$ calculated from V_A, V_B, V_C as polarizing voltage.	ORDER cannot be set to contain P (no zero-sequence voltage source is available)	Use $V_S \cdot$(PTRS/PTR) as $3V_0$ polarizing voltage[a].

[a] The PTRS/PTR adjustment brings the broken-delta $3V_0$ quantity to the same base voltage as the relay settings 59RES, 32WFP, and 32WRP, which are based on the VA, VB, VC voltage base.

E32IV–SELOGIC Control Equation Enable

Refer to *Figure 4.7* and *Figure 4.8*.

SELOGIC control equation setting E32IV must be asserted to logical 1 to enable the zero-sequence voltage-polarized and channel **IN** current-polarized directional elements for directional control of neutral ground and residual ground overcurrent elements.

For most applications, set E32IV directly to logical 1:

E32IV = **1** (numeral 1)

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For situations where zero-sequence source isolation can occur (e.g., by opening a circuit breaker) and result in possible mutual coupling problems for the zero-sequence voltage-polarized and channel IN current-polarized directional elements, SELOGIC control equation setting E32IV should be deasserted to logical 0. In this example, connect a circuit breaker auxiliary contact from the isolating circuit breaker to the SEL-351S:

E32IV = **IN106** (52a connected to optoisolated input **IN106**)

Almost any desired control can be set in SELOGIC control equation setting E32IV.

Ungrounded/High-Impedance Grounded System Considerations for Setting E32IV

On ungrounded/high-impedance grounded systems (when setting ORDER = U), phase-to-phase or unbalanced three-phase faults can cause the ungrounded/high-impedance grounded element to operate on false quantities. To prevent this situation, SELOGIC setting E32IV may be used as follows:

E32IV = **V1GOOD * !32QE**

The V1GOOD Relay Word bit (see *Figure 4.1*) deasserts during a three-phase fault, and the 32QE Relay Word bit (see *Figure 4.6*) asserts during a phase-to-phase fault. If either one of these occur, the E32IV setting evaluates to logical 0, and the ungrounded/high-impedance grounded directional element is blocked (see *Figure 4.8*).

When a switch or breaker closes, the poles can close sequentially (not at the same time), creating a momentary current unbalance condition. To avoid any possible operation of the ungrounded/ high-impedance grounded element for this momentary current unbalance condition, set 3PO (three-pole open condition; see *Figure 5.3*) in SELOGIC setting E32IV as follows:

E32IV = **... + !3PO (= ... + NOT[3PO])**

The 3PO dropout time (setting 3POD) provides the extended blocking (3PO = logical 1; !3PO = logical 0) for this momentary current unbalance condition.

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Directional Control Provided by Torque Control Settings

For most applications, the level direction settings DIR1–DIR4 are used to set overcurrent elements direction forward, reverse, or nondirectional. *Table 4.7* shows the overcurrent elements that are controlled by each level direction setting. Note in *Table 4.7* that all the time-overcurrent elements (51_T elements) are controlled by the DIR1 level direction setting. See *Figure 4.17*, *Figure 4.18*, *Figure 4.23*, and *Figure 4.24*.

In most communications-assisted trip schemes, the levels are set as follows (see *Figure 5.4*):

Level 1 overcurrent elements set direction forward (DIR1 = F)

Level 2 overcurrent elements set direction forward (DIR2 = F)

Level 3 overcurrent elements set direction reverse (DIR3 = R)

Suppose that the Level 1 overcurrent elements should be set as follows:

67P1	direction forward
67G1	direction forward
51P1T	direction forward
51P2T	direction reverse
51N1T	nondirectional
51G1T	direction forward

To accomplish this, the DIR1 setting is turned off, and the corresponding SELOGIC control equation torque control settings for the above overcurrent elements are used to make the elements directional (forward or reverse) or nondirectional. The required settings are:

DIR1 = **N** (turned off; see *Figure 4.17*, *Figure 4.18*, *Figure 4.23*, and *Figure 4.24*)

67P1TC = **32PF** (direction forward; see *Figure 3.3*)

67G1TC = **32GF** (direction forward; see *Figure 3.10*)

51P1TC = **32PF** (direction forward; see *Figure 3.14*)

51P2TC = **32PR** (direction reverse; see *Figure 3.15*)

51N1TC = **1** (nondirectional; see *Figure 3.16*)

51G1TC = **32GF** (direction forward; see *Figure 3.18*)

This is just one example of using SELOGIC control equation torque control settings to make overcurrent elements directional (forward or reverse) or nondirectional. This example shows only Level 1 overcurrent elements (controlled by level direction setting DIR1). The same setting principles apply to the other levels as well. Many variations are possible.

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Section 5
Trip and Target Logic

Trip Logic

The trip logic in *Figure 5.1* provides flexible tripping with SELOGIC® control equation settings:

TRCOMM–Communications-Assisted Trip Conditions. Setting TRCOMM is supervised by communications-assisted trip logic. See *Communications-Assisted Trip Logic—General Overview on page 5.11* for more information on communications-assisted tripping.

DTT–Direct Transfer Trip Conditions. Note in *Figure 5.1* that setting DTT is unsupervised. Any element that asserts in setting DTT will cause Relay Word bit TRIP to assert to logical 1.
Although setting TR is also unsupervised, setting DTT is provided separate from setting TR for target LED purposes. (**COMM** target LED on the front panel illuminates when DTT asserts to logical 1; see **COMM** target LED discussion in *Front-Panel Target LEDs on page 5.32*).
A typical setting for DTT is:

```
DTT = IN106
```

where input **IN106** is connected to the output of direct transfer trip communications equipment.
Setting DTT is also used for Direct Underreaching Transfer Trip (DUTT) schemes.

TRSOTF–Switch-Onto-Fault Trip Conditions. Setting TRSOTF is supervised by the switch-onto-fault condition SOTFE. See *Switch-Onto-Fault (SOTF) Trip Logic on page 5.8* for more information on switch-onto-fault logic.

TR–Other Trip Conditions. Setting TR is the SELOGIC control equation trip setting **most often used** if tripping does not involve communications-assisted (settings TRCOMM and DTT) or switch-onto-fault (setting TRSOTF) trip logic.
Note in *Figure 5.1* that setting TR is unsupervised. Any element that asserts in setting TR will cause Relay Word bit TRIP to assert to logical 1.

ULTR–Unlatch Trip Conditions.

TDURD–Minimum Trip Duration Time. This timer establishes the **minimum** time duration for which the TRIP Relay Word bit asserts. This is rising edge initiated timer. The settable range for this timer is 4–16,000 cycles. See *Figure 5.2*.

More than one trip setting (or all four trip settings TRCOMM, DTT, TRSOTF, and TR) can be set. For example, in a communications-assisted trip scheme, TRCOMM is set with direction forward overreaching Level 2 overcurrent elements, TR is set with direction forward underreaching Level 1 overcurrent

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elements and other time delayed elements (e.g., Level 2 definite-time overcurrent elements), and TRSOTF is set with nondirectional overcurrent elements.

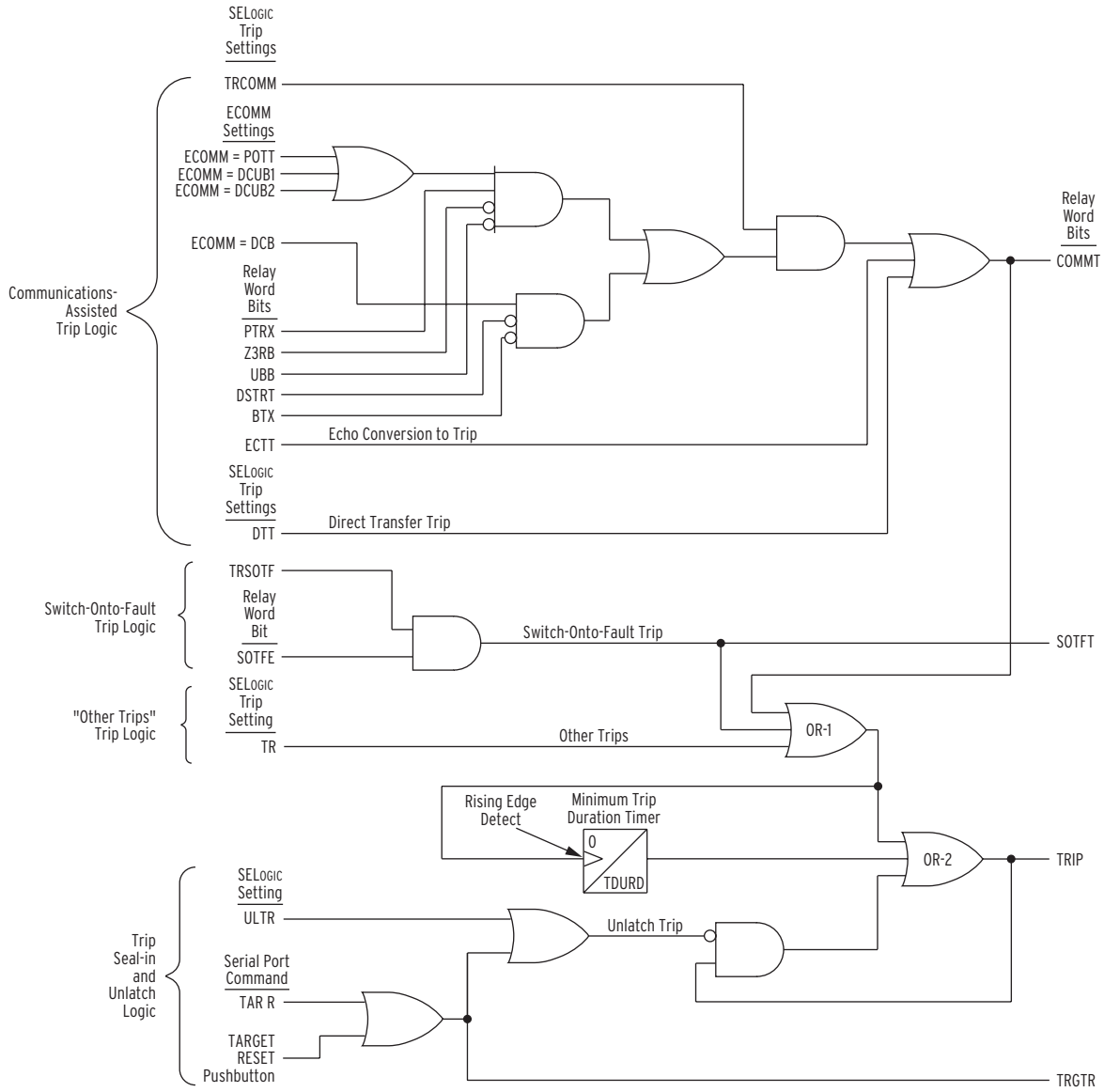


Figure 5.1 Trip Logic

Set Trip

Refer to *Figure 5.1*. All trip conditions:

- Communications-Assisted Trip
- Direct Transfer Trip
- Switch-Onto-Fault Trip
- Other Trips

are combined into OR-1 gate. The output of OR-1 gate asserts Relay Word bit TRIP to logical 1, regardless of other trip logic conditions. It also is routed into the Minimum Trip Duration Timer (setting TDURD).

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As shown in the time line example in *Figure 5.2*, the Minimum Trip Duration Timer (with setting TDURD) outputs a logical 1 for a time duration of "TDURD" cycles any time it sees a **rising edge** on its input (logical 0 to logical 1 transition), if it is not already timing (timer is reset). The TDURD timer ensures that the TRIP Relay Word bit remains asserted at logical 1 for a **minimum** of "TDURD" cycles. If the output of OR-1 gate is logical 1 beyond the TDURD time, Relay Word bit TRIP remains asserted at logical 1 for as long as the output of OR-1 gate remains at logical 1, regardless of other trip logic conditions.

The Minimum Trip Duration Timer can be set no less than 4 cycles.

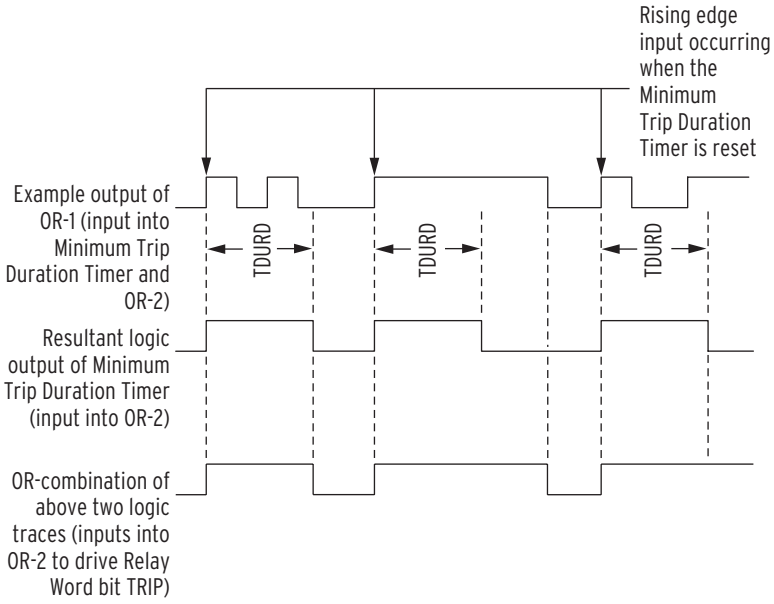


Figure 5.2 Minimum Trip Duration Timer Operation (See Bottom of Figure 5.1)

Unlatch Trip

Once Relay Word bit TRIP is asserted to logical 1, it remains asserted at logical 1 until **all** the following conditions come true:

- Minimum Trip Duration Timer stops timing (logic output of the TDURD timer goes to logical 0)
- Output of OR-1 gate deasserts to logical 0
- One of the following occurs:
  - SELOGIC control equation setting ULTR asserts to logical 1
  - The front-panel **{TARGET RESET}** pushbutton is pressed
  - The **TAR R** (Target Reset) command is executed via the serial port

The front-panel **{TARGET RESET}** pushbutton or the **TAR R** (Target Reset) serial port command are primarily used during testing. Use these to force the TRIP Relay Word bit to logical 0 if test conditions are such that setting ULTR does not assert to logical 1 to automatically deassert the TRIP Relay Word bit instead.

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Other Applications for the Target Reset Function

Refer to the bottom of *Figure 5.1*. Note that the combination of the **{TARGET RESET}** pushbutton and the **TAR R** (Target Reset) serial port command is also available as Relay Word bit TRGTR. See *Figure 5.18* and accompanying text for applications for Relay Word bit TRGTR.

Factory Settings Example (Using Setting TR)

If the "communications-assisted" and "switch-onto-fault" trip logic at the top of *Figure 5.1* can effectively be ignored, the figure becomes a lot smaller. Then SELOGIC control equation trip setting TR is the only input into OR-1 gate and follows into the "seal-in and unlatch" logic for Relay Word bit TRIP.

The factory settings for the trip logic SELOGIC control equation settings are:

TR = 51P1T + 51G1T + 67P1 + PB10 + OC (trip conditions)

ULTR = !(51P1 + 51G1) (unlatch trip conditions)

NOTE: PB10 does not appear in the factory default settings for Model 0351Sxxx5/6/A/B.

The factory setting for the Minimum Trip Duration Timer setting is:

TDURD = 9.00 cycles

See the settings sheets in *Section 9: Setting the Relay* for setting ranges.

Set Trip

In SELOGIC control equation setting

TR = **51P1T + 51G1T + 67P1 + PB10 + OC**:

- Time-overcurrent elements 51P1T (phase) and 51G1T (residual ground) and phase instantaneous overcurrent element 67P1 appear to trip directly (i.e., they are not ANDed with any other elements in SELOGIC control equations trip setting TR). Any "hidden" control of these overcurrent elements is found by inspecting the corresponding SELOGIC control equations torque control settings:

51P1TC = **1** = logical 1; 51P1T is always enabled

51G1TC = **LT1** 51G1T is controlled by the front-panel **{GROUND ENABLED}** operator control—see *Figure 11.8*

67P1TC = **SH0** 67P1 is enabled for first trip (shot = 0) only—see *Table 6.3*

Overcurrent element torque control is explained more fully in the first half of *Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements*.

- Relay Word bit PB10 asserts when the front-panel **{TRIP}** operator control is pressed (see *Figure 11.9*). Relay Word bit OC asserts for execution of the **OPEN** command. See *OPE Command (Open Breaker) on page 10.39* for more information on the **OPEN** command.

  Note that when the front-panel **{TRIP}** operator control is pressed (PB10 asserts) or the **OPEN** command is executed via a serial port (OC asserts), the reclosing relay is driven to lockout:

79DTL = **... + PB10+ OC** SELOGIC control equations drive-to-lockout setting—see *Figure 6.10* and accompanying explanation

NOTE: PB10 does not appear in the TR and 79DTL factory default settings for model 0351Sxxx5/6/A/B (with auxiliary **{TRIP}**/**{CLOSE}** pushbuttons—see Figure 2.5 and Figure 2.6). The auxiliary trip pushbutton eliminates the need for the **{TRIP}** operator control (corresponding to Relay Word bit PB10—see Figure 11.9). The **{TRIP}** operator control is changed to **{AUX 4}** operator control for model 0351Sxxx5/6/A/B.

The auxiliary trip pushbutton on model 0351Sxxx5/6/A/B is electrically separate from the rest of the relay and not part of the trip logic in Figure 5.1. It provides separate tripping capability as shown in Figure 2.31.

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With setting TDURD = 9.00 cycles, once the TRIP Relay Word bit asserts via SELOGIC control equation setting TR, it remains asserted at logical 1 for a **minimum** of 9 cycles.

Unlatch Trip

In SELOGIC control equation setting ULTR = !(51P1 + 51G1):

Both time-overcurrent element pickups 51P1 and 51G1 must be deasserted before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

ULTR = **!(51P1 + 51G1) = NOT(51P1 + 51G1) = NOT(51P1) * NOT(51G1)**

Additional Settings Examples

The factory setting for SELOGIC control equation setting ULTR is a current-based trip unlatch condition. A circuit breaker status unlatch trip condition can be programmed as shown in the following examples.

Unlatch Trip with 52a Circuit Breaker Auxiliary Contact

A 52a circuit breaker auxiliary contact is wired to optoisolated input **IN101**.

52A = **IN101** SELOGIC control equation circuit breaker status setting—see *Optoisolated Inputs on page 7.2*

ULTR = **!IN101**

Input **IN101** has to be de-energized (52a circuit breaker auxiliary contact has to be open) before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

ULTR = **!IN101 = NOT(IN101)**

Unlatch Trip With 52b Circuit Breaker Auxiliary Contact

A 52b circuit breaker auxiliary contact is wired to optoisolated input **IN101**.

52A = **!IN101** SELOGIC control equation circuit breaker status setting—see *Optoisolated Inputs on page 7.2*

ULTR = **IN101**

Input **IN101** must be energized (52b circuit breaker auxiliary contact has to be closed) before the trip logic unlatches and the TRIP Relay Word bit deasserts to logical 0.

Program an Output Contact for Tripping

In the factory settings, the resultant of the trip logic in *Figure 5.1* is routed to output contact **OUT101** with the following SELOGIC control equation setting:

OUT101 = **TRIP**

If more than one **TRIP** output contact is needed, program other output contacts with the TRIP Relay Word bit. Examples of uses for additional **TRIP** output contacts:

- Tripping more than one breaker
- Keying an external breaker failure relay
- Keying communication equipment in a Direct Transfer Trip scheme

See *Output Contacts on page 7.32* for more information on programming output contacts.

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TRIP Used in Other Settings

Besides operating a trip output contact (e.g., OUT101 = TRIP), the TRIP Relay Word bit is used in a number of other factory-default SELOGIC control equations settings:

ULCL = **TRIP + ...** unlatch close—see *Figure 6.3*

79RI = **TRIP** reclose initiate—see *Table 6.4* and following explanation

79DTL = **...*(TRIP + ...) + ...** drive-to-lockout—see *Figure 6.10* and accompanying explanation

79STL = **TRIP** stall open interval timing—see *Table 6.4* and following explanation

LED12 = **TRIP TRIP** target LED—see *Table 5.1*

BKMON = **TRIP** breaker monitor initiation—see *Breaker Monitor on page 8.2*

Change the Trip Settings—Check Other Settings

Any time trip settings are changed/modified (e.g., via SELOGIC control equation trip settings TR), the following SELOGIC control equations should be checked or given consideration for modification:

ULTR (unlatch trip—see Figure 5.1 and following explanation). For example, if lower-set residual ground time-overcurrent element 51G2T is added to the factory-default trip settings (TR = … + 51G2T), consideration should be given to adding its pickup indication (51G2) to the unlatch trip setting [e.g., ULTR = !(… + 51G2)].

79DTL (drive-to-lockout setting—see Figure 6.10 and accompanying explanation). For example, if frequency element 81D1T is added to the factory-default trip settings (TR = … + 81D1T), but no auto-reclosing should occur after an underfrequency load-shedding trip, then frequency element 81D1T should be added to the drive-to-lockout setting (e.g., 79DTL = … + 81D1T).
Note that the factory-default **{TRIP}** operator control (PB10) and serial port **OPEN** command (OC) trip settings (TR = … + PB10 + OC) are already in the factory-default drive-to-lockout setting (79DTL = … + PB10 + OC), except for model 0351S*xxx*5/6/A/B relays, which do not contain PB10 in the factory default settings.

67P1TC-51QTC (torque control for overcurrent elements—see Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements). For example, if residual ground time-overcurrent element 51G2T is added to the factory-default trip settings (TR = … + 51G2T), check its corresponding torque control setting (51G2TC). Should it be enabled all the time (51G2TC = 1)? Should it be controlled by the **{GROUND ENABLED}** operator control (51G2TC = LT1; see *Figure 11.4*)?

LED12-LED21, LED25, LED26 (programmable target LEDs). *Front-Panel Target LEDs on page 5.32* shows the correlation between tripping elements in factory-default SELOGIC control equation trip setting TR and the programmable target LEDs.
For example, if residual ground time-overcurrent element 51G2T is added to the factory-default trip settings (TR = … + 51G2T), it should be added to the 51 trip target LED setting (LED17 = … + 51G2T) and its pickup indication (51G2) should be added to the G fault type target LED setting (LED25 = … + 51G2).
An additional example, if frequency element 81D1T is added to the factory-default trip settings (TR = … + 81D1T), then frequency element 81D1T should be assigned to the dedicated 81 trip target LED setting (LED18 = 81D1T; **LED18** is already set this way in the factory default settings).

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ER (event report trigger conditions–see Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER). For example, if residual ground time-overcurrent element 51G2T is added to the factory-default trip settings (TR = … + 51G2T), consideration should be given to adding its pickup indication (51G2) to the event report trigger conditions setting (ER = … + /51G2). A rising edge operator (/) is added on front of the element (see *Appendix G: Setting SELOGIC Control Equations* for more explanation on rising edge operators).

FAULT (fault indication–see explanation accompanying FAULT setting in SELOGIC Control Equation Settings (Serial Port Command SET L) on page SET.18). For example, if residual ground time-overcurrent element 51G2T is added to the factory-default trip settings (TR = … + 51G2T), consideration should be given to adding its pickup indication (51G2) to the fault indication setting (FAULT = … + 51G2).

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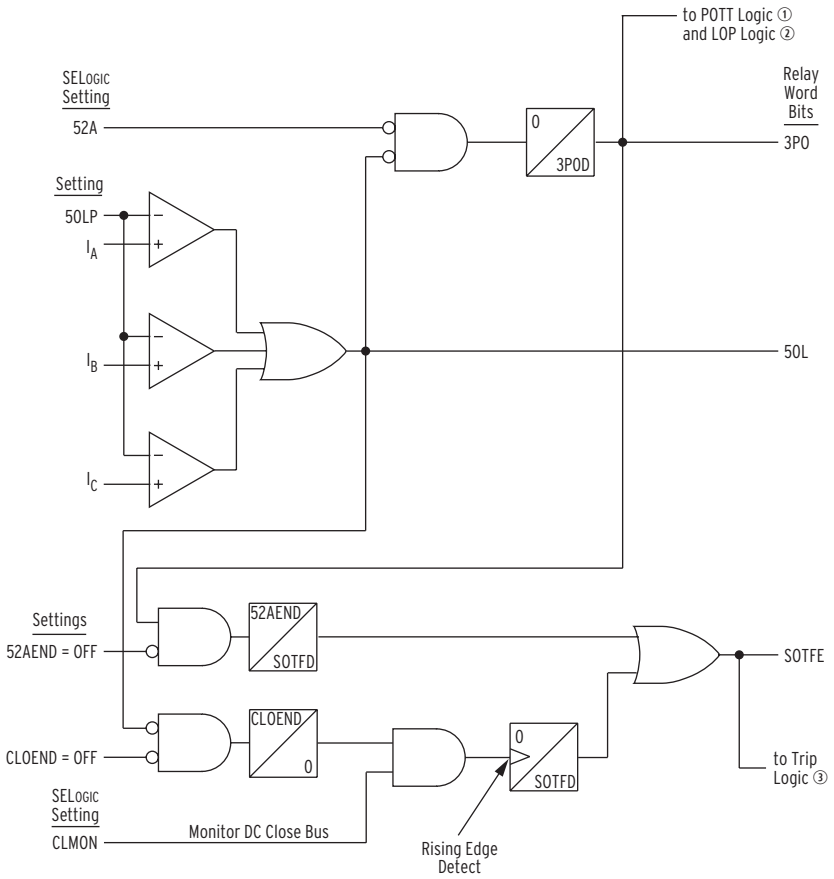
Switch-Onto-Fault (SOTF) Trip Logic

Switch-Onto-Fault (SOTF) trip logic provides a programmable time window for selected elements to trip right after the circuit breaker closes. “Switch-onto-fault” implies that a circuit breaker is closed into an existing fault condition. For example, suppose safety grounds are accidentally left attached to a line after a clearance. If the circuit breaker is closed into such a condition, the resulting fault needs to be cleared right away and reclosing blocked. An instantaneous overcurrent element is usually set to trip in the three-pole open (3PO) logic and the SOTF trip logic.

Refer to the switch-onto-fault trip logic in *Figure 5.1* (middle of figure). The SOTF trip logic permits tripping if **both** the following occur:

- An element asserts in SELOGIC control equation trip setting TRSOTF
- Relay Word bit SOTFE is asserted to logical 1

Relay Word bit SOTFE (the output of the SOTF logic) provides the effective time window for an element in trip setting TRSOTF (e.g., TRSOTF = 50P2) to trip after the circuit breaker closes. *Figure 5.3* and the following discussion describe the three-pole open (3PO) logic and the SOTF logic.



① Figure 5.6, ② Figure 4.1, ③ Figure 5.1

Figure 5.3 Three-Pole Open Logic (Top) and Switch-Onto-Fault Logic (Bottom)

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Three-Pole Open Logic

Three-pole open (3PO) logic is the top half of *Figure 5.3*. It is not affected by enable setting ESOTF (see *Relay Settings (Serial Port Command SET and Front Panel) on page SET.1*).

The open circuit breaker condition is determined from the combination of:

- Circuit breaker status (52A)
- Load current condition (50L)

If the circuit breaker is open (52A = logical 0) **and** current is below phase pickup 50LP (50L = logical 0), then the three-pole open (3PO) condition is true:

3PO = logical 1 (circuit breaker open)

The 3POD dropout time qualifies circuit breaker closure, whether detected by circuit breaker status (52A) or load current level (50L). When the circuit breaker is closed:

3PO = logical 0 (circuit breaker closed)

Determining Three-Pole Open Condition Without Circuit Breaker Auxiliary Contact

If a circuit breaker auxiliary contact is not connected to the SEL-351S Relay, SELOGIC control equation setting 52A is set:

52A = **0** (numeral 0)

With SELOGIC control equation setting 52A continually at logical 0, 3PO logic is controlled solely by load detection element 50L. Phase pickup 50LP is set below load current levels.

When the circuit breaker is open, Relay Word bit 50L drops out (= logical 0) and the 3PO condition asserts:

3PO = logical 1 (circuit breaker open)

When the circuit breaker is closed, Relay Word bit 50L picks up (= logical 0; current above phase pickup 50LP) and the 3PO condition deasserts after the 3POD dropout time:

3PO = logical 0 (circuit breaker closed)

Note that the 3PO condition is also routed to the permissive overreaching transfer trip (POTT) logic (see *Figure 5.6*) and the loss-of-potential (LOP) logic (see *Figure 4.1*).

Circuit Breaker Operated Switch-Onto-Fault Logic

Circuit breaker operated switch-onto-fault logic is enabled by making time setting 52AEND (52AEND ≠ OFF). Time setting 52AEND qualifies the three-pole open (3PO) condition and then asserts Relay Word bit SOTFE:

SOTFE = logical 1

Note that SOTFE is asserted when the circuit breaker is open. This allows elements set in the SELOGIC control equation trip setting TRSOTF to operate if a fault occurs when the circuit breaker is open (see *Figure 5.1*). In such a scenario (e.g., flashover inside the circuit breaker tank), the tripping via setting TRSOTF cannot help in tripping the circuit breaker (the circuit breaker is already open), but can initiate breaker failure protection, if a breaker failure scheme is implemented in the SEL-351S (see output contact **OUT103** example in *Output Contacts on page 7.32*) or externally.

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When the circuit breaker is closed, the 3PO condition deasserts (3PO = logical 0) after the 3POD dropout time (setting 3POD is usually set for no more than a cycle). The SOTF logic output, SOTFE, continues to remain asserted at logical 1 for dropout time SOTFD time.

Close Bus Operated Switch-Onto-Fault Logic

Close bus operated switch-onto-fault logic is enabled by making time setting CLOEND (CLOEND ≠ OFF). Time setting CLOEND qualifies the deassertion of the load detection element 50L (indicating that the circuit breaker is open).

Circuit breaker closure is detected by monitoring the dc close bus. This is accomplished by wiring an optoisolated input on the SEL-351S (e.g., **IN105**) to the dc close bus. When a manual close or automatic reclosure occurs, optoisolated input **IN105** is energized. SELOGIC control equation setting CLMON (close bus monitor) monitors the optoisolated input **IN105**:

```
CLMON = IN105
```

When optoisolated input **IN105** is energized, CLMON asserts to logical 1. At the instant that optoisolated input **IN105** is energized (close bus is energized), the circuit breaker is still open so the output of the CLOEND timer continues to be asserted to logical 1. Thus, the ANDed combination of these conditions latches in the SOTFD timer. The SOTFD timer outputs a logical 1 for a time duration of "SOTFD" cycles any time it sees a **rising edge** on its input (logical 0 to logical 1 transition), if it is not already timing. The SOTF logic output, SOTFE, asserts to logical 1 for SOTFD time.

Switch-Onto-Fault Logic Output (SOTFE)

Relay Word bit SOTFE is the output of the circuit breaker operated SOTF logic or the close bus operated SOTF logic described previously. Time setting SOTFD in each of these logic paths provides the effective time window for the overcurrent elements in SELOGIC control equation trip setting TRSOTF to trip after the circuit breaker closes (see *Figure 5.1*—middle of figure). Time setting SOTFD is usually set around 30 cycles.

A SOTF trip illuminates the **SOTF** front-panel LED.

Switch-Onto-Fault Trip Logic Trip Setting (TRSOTF)

An instantaneous overcurrent element is usually set to trip in the SELOGIC control equation trip setting TRSOTF (e.g., TRSOTF = 50P2).

If the voltage potential for the relay is from the line-side of the circuit breaker, the instantaneous overcurrent element in the SELOGIC control equation trip setting TRSOTF should be nondirectional. When the circuit breaker is open and the line is de-energized, the relay sees zero voltage. If a close-in three-phase fault condition exists on the line (e.g., safety grounds accidentally left attached to the line after a clearance) and then the circuit breaker is closed, the relay continues to see zero voltage. The directional elements have no voltage for reference and cannot operate. In this case, the instantaneous overcurrent element in the SOTF trip logic should be nondirectional.

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Communications-Assisted Trip Logic—General Overview

The SEL-351S includes communications-assisted tripping schemes that provide unit-protection for transmission lines with the help of communications. No external coordination devices are required.

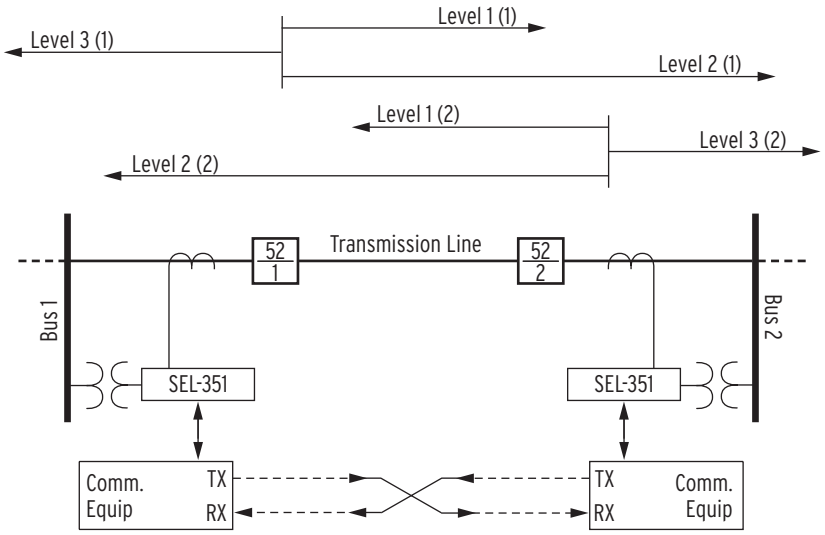


Figure 5.4 Communications-Assisted Tripping Scheme

Refer to *Figure 5.4* and the top half of *Figure 5.1*.

The six available tripping schemes are:

- Direct Transfer Trip (DTT)
- Direct Underreaching Transfer Trip (DUTT)
- Permissive Overreaching Transfer Trip (POTT)
- Permissive Underreaching Transfer Trip (PUTT)
- Directional Comparison Unblocking (DCUB)
- Directional Comparison Blocking (DCB)

Enable Setting ECOMM

The POTT, PUTT, DCUB, and DCB tripping schemes are enabled with enable setting ECOMM. Setting choices are:

ECOMM = **N** no communications-assisted trip scheme enabled

ECOMM = **POTT** POTT or PUTT scheme

ECOMM = **DCUB1** DCUB scheme for two-terminal line (communications from **one** remote terminal)

ECOMM = **DCUB2** DCUB scheme for three-terminal line (communications from **two** remote terminals)

ECOMM = **DCB** DCB scheme

These tripping schemes can all work in two-terminal or three-terminal line applications. The DCUB scheme requires separate settings choices for these applications (ECOMM = DCUB1 or DCUB2) because of unique DCUB logic considerations.

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In most cases, these tripping schemes require (see *Figure 5.4*):

Level 1 underreaching overcurrent elements set direction forward (setting DIR1 = F)

Level 2 overreaching overcurrent elements set direction forward (setting DIR2 = F)

Level 3 overcurrent elements set direction reverse (setting DIR3 = R)

See *Directional Control Settings on page 4.39* for more information on level direction settings DIR1–DIR4.

POTT, PUTT, DCUB, and DCB communications-assisted tripping schemes are explained in subsections that follow.

Trip Setting TRCOMM

The POTT, PUTT, DCUB, and DCB tripping schemes use SELOGIC control equation trip setting TRCOMM for those tripping elements that are supervised by the communications-assisted trip logic (see top half of *Figure 5.1*). Setting TRCOMM is typically set with Level 2 overreaching overcurrent elements (set direction forward):

- 67P2 Level 2 directional phase instantaneous overcurrent element
- 67N2 Level 2 directional neutral ground instantaneous overcurrent element
- 67G2 Level 2 directional residual ground instantaneous overcurrent element
- 67Q2 Level 2 directional negative-sequence instantaneous overcurrent element

The exception is a DCB scheme, where Level 2 overreaching overcurrent elements (set direction forward) with a short delay are used instead:

- 67P2S Level 2 directional phase instantaneous overcurrent element (with delay 67P2SD)
- 67N2S Level 2 directional neutral ground instantaneous overcurrent element (with delay 67N2SD)
- 67G2S Level 2 directional residual ground instantaneous overcurrent element (with delay 67G2SD)
- 67Q2S Level 2 directional negative-sequence instantaneous overcurrent element (with delay 67Q2SD)

The short delays provide necessary carrier coordination delays (waiting for the block trip signal).

Trip Settings TRSOTF and TR

In a communications-assisted trip scheme, the SELOGIC control equation trip settings TRSOTF and TR can also be used, in addition to setting TRCOMM.

Setting TRSOTF can be set as described in preceding subsection *Switch-Onto-Fault (SOTF) Trip Logic on page 5.8*.

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Setting TR is typically set with unsupervised Level 1 underreaching overcurrent elements (set direction forward):

- 67P1 Level 1 directional phase instantaneous overcurrent element
- 67N1 Level 1 directional neutral ground instantaneous overcurrent element
- 67G1 Level 1 directional residual ground instantaneous overcurrent element
- 67Q1 Level 1 directional negative-sequence instantaneous overcurrent element

and other time delayed elements (e.g., Level 2 definite-time overcurrent elements).

Trip Setting DTT

The DTT and DUTT tripping schemes are realized with SELOGIC control equation trip setting DTT, discussed at the beginning of this section.

Use Existing SEL-321 Relay Application Guides for the SEL-351S

The communications-assisted tripping schemes settings in the SEL-351S are very similar to those in the SEL-321. Existing SEL-321 application guides can also be used in setting up these schemes in the SEL-351S. The following application guides are available from SEL:

- AG93-06 *Applying the SEL-321 Relay to Directional Comparison Blocking (DCB) Schemes*
- AG95-29 *Applying the SEL-321 Relay to Permissive Overreaching Transfer Trip (POTT) Schemes*
- AG96-19 *Applying the SEL-321 Relay to Directional Comparison Unblocking (DCUB) Schemes*

The major differences are how the optoisolated input settings and the trip settings are made. The following explanations describe these differences.

Optoisolated Input Settings Differences Between the SEL-321 and the SEL-351S

The SEL-351S does not have optoisolated input settings like the SEL-321. Rather, the optoisolated inputs of the SEL-351S are available because Relay Word bits are used in SELOGIC control equations. The following optoisolated input setting example is for a Permissive Overreaching Transfer Trip (POTT) scheme.

SEL-321	SEL-351S	Function
IN102 = PT	PT1 = IN102	(received permissive trip)

In the above SEL-351S setting example, Relay Word bit IN102 is set in the PT1 SELOGIC control equation. Optoisolated input **IN102** is wired to a communications equipment receiver output contact. Relay Word bit IN102 can also be used in other SELOGIC control equation in the SEL-351S. See *Optoisolated Inputs on page 7.2* for more information on optoisolated inputs.

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Trip Settings Differences Between the SEL-321 and SEL-351S

Some of the SELOGIC control equation trip settings of the SEL-321 and SEL-351S are not operationally different, just labeled differently. The correspondence is:

SEL-321	SEL-351S	Function
MTCS	TRCOMM	(Communications-Assisted Trip Conditions)
MTO	TRSOTF	(Switch-Onto-Fault Trip Conditions)
MTU	TR	(Unconditional or Other Trip Conditions)

The SEL-321 handles trip unlatching with setting TULO. The SEL-351S handles trip unlatching with SELOGIC control equation setting ULTR.

The SEL-321 has single-pole trip logic. The SEL-351S does not have single-pole trip logic.

Using MIRRORED BITS to Implement Communications-Assisted Tripping Schemes

The MIRRORED BITS® relay-to-relay communications protocol is available in SEL-351S-6 and SEL-351S-7, in addition to several other SEL products. MIRRORED BITS implementations have these advantages over traditional communications equipment:

- Less equipment (increases reliability)
- Increased speed (no contact closure delay)
- Better security (through built-in channel monitoring)
- Reduced wiring complexity

The subsections that follow use traditional communications equipment in the examples. If using MIRRORED BITS communications, change some of the SELOGIC control equations to use Transmit MIRRORED BITS instead of output contacts, and Receive MIRRORED BITS instead of optoisolated inputs. Also, MIRRORED BITS communications do not require dc wiring between the relay and communications equipment.

See *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)* for details on configuring a relay port to communicate using MIRRORED BITS.

Several application guides available on the SEL website (www.selic.com) give application examples of MIRRORED BITS in Communications-Assisted Tripping Schemes. Although some of the guides were written for the SEL-321-1 and SEL-311C Distance Relays, these relays are similar to SEL-351S relays, so the guides will still be helpful in designing SEL-351S applications.

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Permissive Overreaching Transfer Trip (POTT) Logic

Enable the POTT logic by setting ECOMM = POTT. The POTT logic in *Figure 5.6* is also enabled for directional comparison unblocking schemes (ECOMM = DCUB1 or ECOMM = DCUB2). The POTT logic performs the following tasks:

- Keys communication equipment to send permissive trip when any element included in the SELOGIC control equation communications-assisted trip equation TRCOMM asserts and the current reversal logic is not asserted
- Prevents keying and tripping by the POTT logic following a current reversal
- Echoes the received permissive signal to the remote terminal
- Prevents channel lockup during echo and test
- Provides a secure means of tripping for weak- and/or zero-infeed line terminals

Use Existing SEL-321 POTT Application Guide for the SEL-351S

Use the existing SEL-321 POTT application guide (AG95-29) to help set up the SEL-351S in a POTT scheme (see preceding subsection *Communications-Assisted Trip Logic—General Overview on page 5.11* for more setting comparison information on the SEL-321/SEL-351S).

External Inputs

See *Optoisolated Inputs on page 7.2* for more information on optoisolated inputs.

PT1–Received Permissive Trip Signal(s)

In two-terminal line POTT applications, a permissive trip signal is received from **one** remote terminal. One optoisolated input on the SEL-351S (e.g., input **IN104**) is driven by a communications equipment receiver output (see *Figure 5.8*). Make SELOGIC control equation setting PT1:

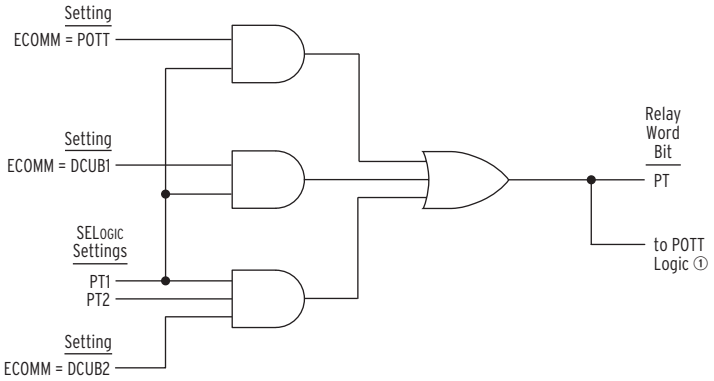
PT1 = **IN104** (two-terminal line application)

In three-terminal line POTT applications, permissive trip signals are received from **two** remote terminals. Two optoisolated inputs on the SEL-351S (e.g., input **IN104** and **IN106**) are driven by communications equipment receiver outputs (see *Figure 5.9*). Make SELOGIC control equation setting PT1 as follows:

PT1 = **IN104 * IN106** (three-terminal line application)

SELOGIC control equation setting PT1 in *Figure 5.5* is routed to control Relay Word bit PT if enable setting ECOMM = POTT. Relay Word bit PT is then an input into the POTT logic in *Figure 5.6* (for echo keying).

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① Figure 5.6.

Figure 5.5 Permissive Input Logic Routing to POTT Logic

Also note that SELOGIC control equation setting PT1 in *Figure 5.7* is routed to control Relay Word bit PTRX if enable setting ECOMM = POTT. Relay Word bit PTRX is the permissive trip receive input into the trip logic in *Figure 5.1*.

Timer Settings

See *Section 9: Setting the Relay* for setting ranges.

Z3RBD–Zone (Level) 3 Reverse Block Delay

Current-reversal guard timer—typically set at five cycles.

EBLKD–Echo Block Delay

Prevents echoing of received PT for settable delay after dropout of local permissive elements in trip setting TRCOMM—typically set at 10 cycles. Set to OFF to defeat EBLKD.

ETDPU–Echo Time Delay Pickup

Sets minimum time requirement for received PT, before echo begins—typically set at two cycles. Set to OFF for no echo.

EDURD–Echo Duration

Limits echo duration, to prevent channel lockup—typically set at 3.5 cycles.

Logic Outputs

The following logic outputs can be tested by assigning them to output contacts. See *Optoisolated Inputs on page 7.2* for more information on output contacts.

Z3RB–Zone (Level) 3 Reverse Block

Current-reversal guard asserted (operates as an input into the trip logic in *Figure 5.1* and the DCUB logic in *Figure 5.10*).

ECTT–Echo Conversion to Trip

PT received, converted to a trip condition for a Weak-Infeed Condition (operates as an input into the trip logic in *Figure 5.1*).

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KEY–Key Permissive Trip

Signals communications equipment to transmit permissive trip. For example, SELOGIC control equation setting OUT105 is set:

OUT105 = **KEY**

Output contact **OUT105** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 5.8*).

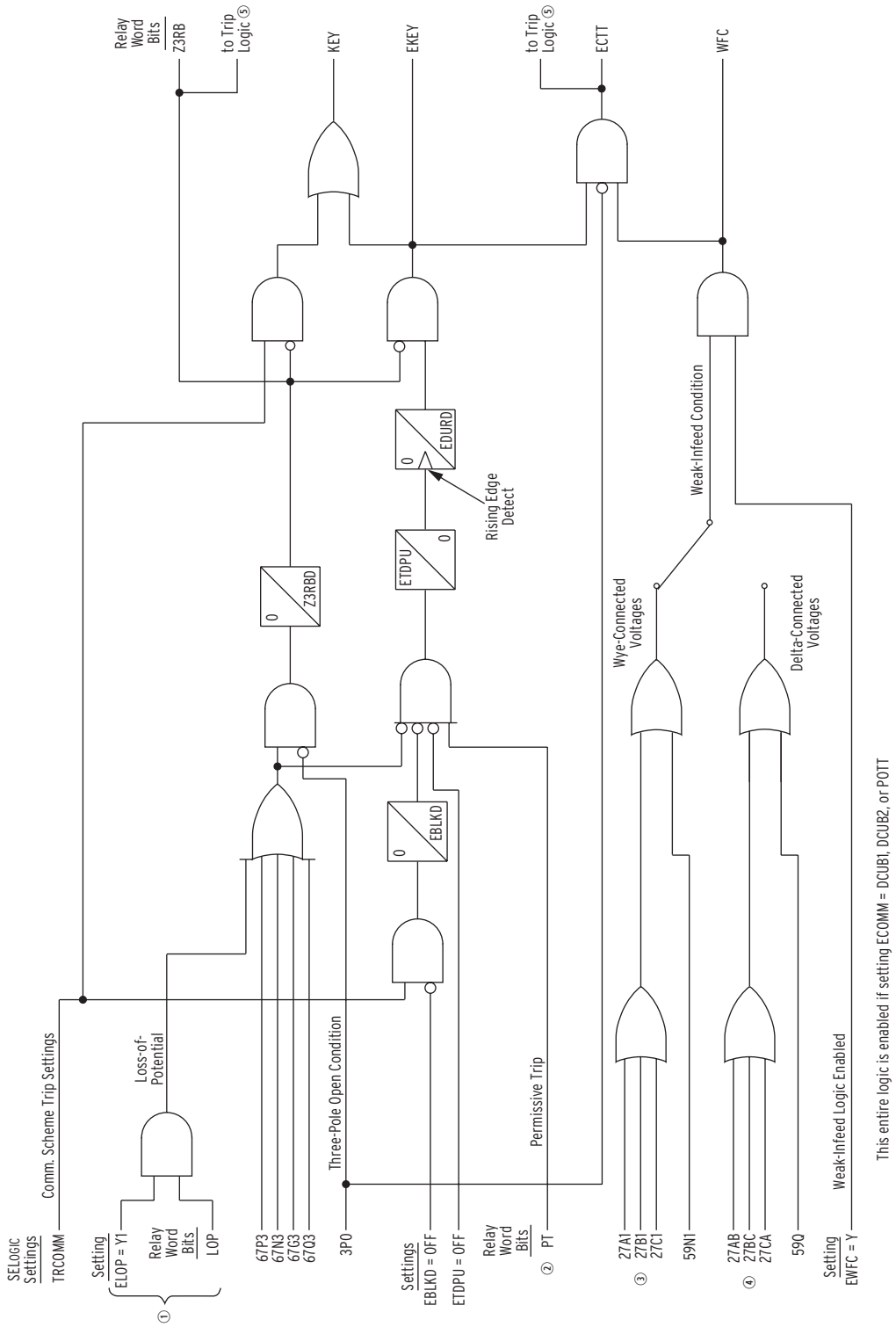
In a three-terminal line scheme, output contact **OUT107** is set the same as OUT105 (see *Figure 5.9*):

OUT107 = **KEY**

EKEY–Echo Key Permissive Trip

Permissive trip signal keyed by Echo logic (used in testing).

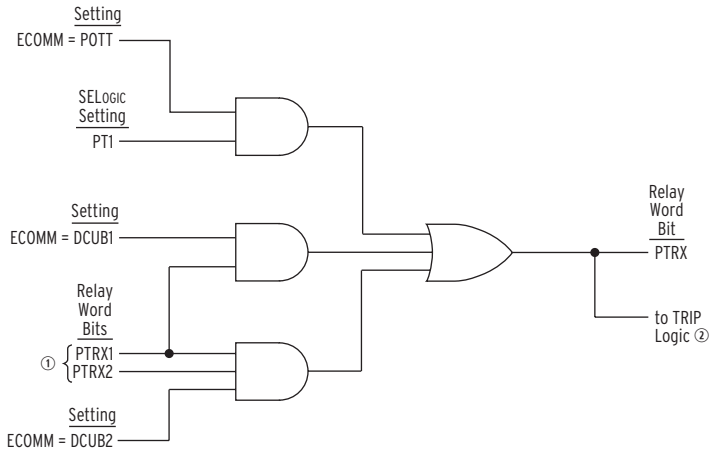
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① Figure 4.1; ② Figure 5.5; ③ Table 3.8; ④ Table 3.10; ⑤ Figure 5.1.

Figure 5.6 POTT Logic

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① Figure 5.10, ② Figure 5.1.

Figure 5.7 Permissive Input Logic Routing to Trip Logic

Variations for Permissive Underreaching Transfer Trip (PUTT) Scheme

Refer to *Figure 5.4* and *Figure 5.6*. In a PUTT scheme, keying is provided by Level 1 underreaching overcurrent elements (set direction forward), instead of with Relay Word bit KEY. This is accomplished by setting output contact **OUT105** with these elements:

- 67P1 Level 1 directional phase instantaneous overcurrent element
- 67N1 Level 1 directional neutral ground instantaneous overcurrent element
- 67G1 Level 1 directional residual ground instantaneous overcurrent element
- 67Q1 Level 1 directional negative-sequence instantaneous overcurrent element

instead of with element KEY (see *Figure 5.8*):

OUT105 = **67P1 + 67N1 + 67G1 + 67Q1**
(**Note**: only use enabled elements)

If echo keying is desired, add the echo key permissive trip logic output, as follows:

OUT105 = **67P1 + 67N1 + 67G1 + 67Q1 + EKEY**

In a three-terminal line scheme, output contact **OUT107** is set the same as **OUT105** (see *Figure 5.9*).

Installation Variations

Figure 5.9 shows output contacts **OUT105** and **OUT107** connected to separate communication equipment, for the two remote terminals. Both output contacts are programmed the same (OUT105 = KEY and OUT107 = KEY).

Depending on the installation, perhaps one output contact (e.g., OUT105 = KEY) could be connected in parallel to both transmitter inputs (**TX**) on the communication equipment in *Figure 5.9*. Then output contact **OUT107** can be used for another function.

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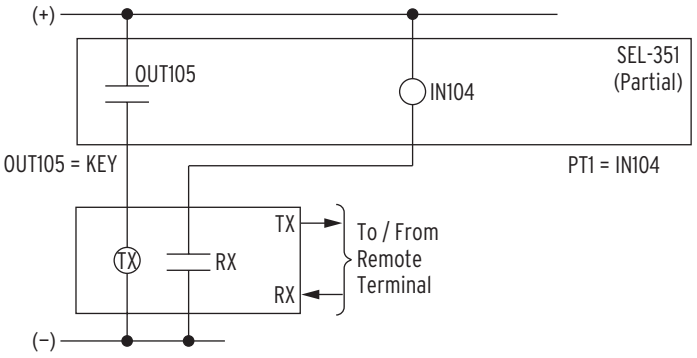


Figure 5.8 SEL-351S Connections to Communications Equipment for a Two-Terminal Line POTT Scheme

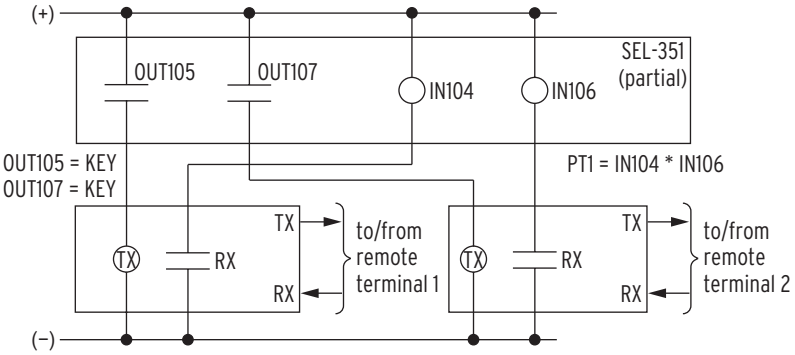


Figure 5.9 SEL-351S Connections to Communications Equipment for a Three-Terminal Line POTT Scheme

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Directional Comparison Unblocking (DCUB) Logic

Enable the DCUB logic by setting ECOMM = DCUB1 or ECOMM = DCUB2. The DCUB logic in *Figure 5.10* is an extension of the POTT logic in *Figure 5.6* Thus, the relay requires **all** the POTT settings and logic, **plus** exclusive DCUB settings and logic. The difference between setting choices DCUB1 and DCUB2 is:

DCUB1 directional comparison unblocking scheme for two-terminal line (communications from **one** remote terminal)

DCUB2 directional comparison unblocking scheme for three-terminal line (communications from **two** remote terminals)

The DCUB logic in *Figure 5.10* takes in the loss-of-guard and permissive trip outputs from the communication receivers (see *Figure 5.12* and *Figure 5.13*) and makes permissive (PTRX1/PTRX2) and unblocking block (UBB1/UBB2) logic output decisions.

DCUB schemes are typically implemented with FSK (frequency shift carrier) or analog microwave as the communications medium.

Use Existing SEL-321 DCUB Application Guide for the SEL-351S

Use the existing SEL-321 DCUB application guide (AG96-19) to help set up the SEL-351S in a DCUB scheme (see preceding subsection *Communications-Assisted Trip Logic—General Overview on page 5.11* for more setting comparison information on the SEL-321/SEL-351S).

External Inputs

See *Optoisolated Inputs on page 7.2* for more information on optoisolated inputs.

PT1, PT2–Received Permissive Trip Signal(s)

In two-terminal line DCUB applications (setting ECOMM = DCUB1), a permissive trip signal is received from **one** remote terminal. One optoisolated input on the SEL-351S (e.g., input **IN104**) is driven by a communications equipment receiver output (see *Figure 5.12*). Make SELOGIC control equation setting PT1:

PT1 = **IN104** (two-terminal line application)

In three-terminal line DCUB applications (setting ECOMM = DCUB2), permissive trip signals are received from **two** remote terminals. Two optoisolated inputs on the SEL-351S (e.g., inputs **IN104** and **IN106**) are driven by communications equipment receiver outputs (see *Figure 5.13*). Make SELOGIC control equation settings PT1 and PT2 as follows:

PT1 = **IN104** (three-terminal line application)

PT2 = **IN106**

SELOGIC control equation settings PT1 and PT2 are routed into the DCUB logic in *Figure 5.10* for “unblocking block” and “permissive trip receive” logic decisions.

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As explained in *Permissive Overreaching Transfer Trip (POTT) Logic on page 5.15*, the SELOGIC control equation settings PT1 and PT2 in *Figure 5.5* are routed in various combinations to control Relay Word bit PT, depending on enable setting ECOMM = DCUB1 or DCUB2. Relay Word bit PT is then an input into the POTT logic in *Figure 5.6* (for echo keying).

LOG1, LOG2–Loss-of-Guard Signal(s)

In two-terminal line DCUB applications (setting ECOMM = DCUB1), a loss-of-guard signal is received from **one** remote terminal. One optoisolated input on the SEL-351S (e.g., input **IN105**) is driven by a communications equipment receiver output (see *Figure 5.12*). Make SELOGIC control equation setting LOG1:

LOG1 = **IN105** (two-terminal line application)

In three-terminal line DCUB applications (setting ECOMM = DCUB2), loss-of-guard signals are received from **two** remote terminals. Two optoisolated inputs on the SEL-351S (e.g., input **IN105** and **IN207**) are driven by communications equipment receiver outputs (see *Figure 5.13*). Make SELOGIC control equation settings LOG1 and LOG2 as follows:

LOG1 = **IN105** (three-terminal line application)

LOG2 = **IN207**

SELOGIC control equation settings LOG1 and LOG2 are routed into the DCUB logic in *Figure 5.10* for "unblocking block" and "permissive trip receive" logic decisions.

Timer Settings

See *Section 9: Setting the Relay* for setting ranges.

GARD1D–Guard-Present Delay

Sets minimum time requirement for reinstating permissive tripping following a loss-of-channel condition—typically set at 10 cycles. Channel 1 and 2 logic use separate timers but have this same delay setting.

UBDURD–DCUB Disable Delay

Prevents tripping by POTT logic after a settable time following a loss-of-channel condition—typically set at 9 cycles (150 ms). Channel 1 and 2 logic use separate timers but have this same delay setting.

UBEND–DCUB Duration Delay

Sets minimum time required to declare a loss-of-channel condition—typically set at 0.5 cycles. Channel 1 and 2 logic use separate timers but have this same delay setting.

Logic Outputs

The following logic outputs can be tested by assigning them to output contacts. See *Optoisolated Inputs on page 7.2* for more information on output contacts.

UBB1, UBB2–Unblocking Block Output(s)

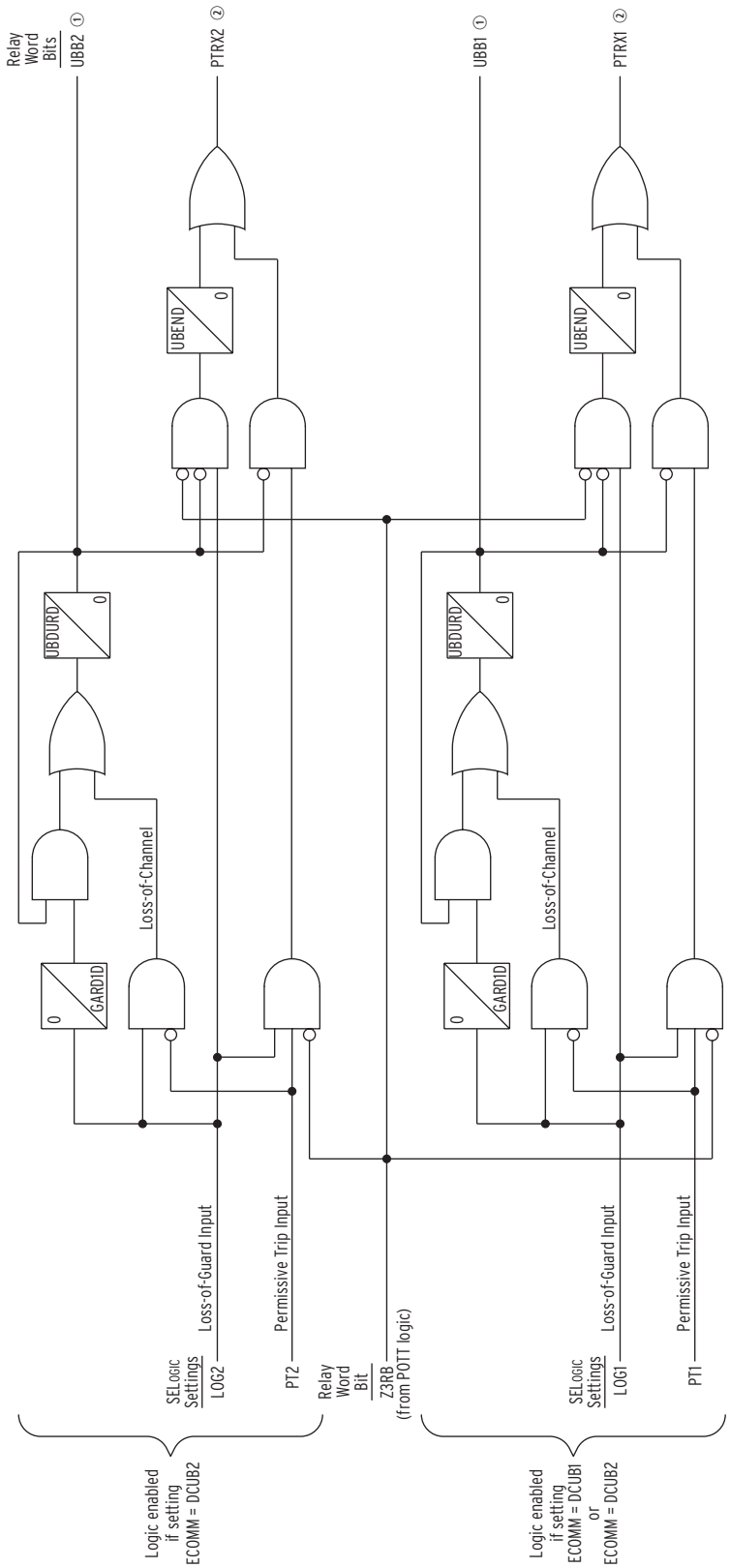
In two-terminal line DCUB applications (setting ECOMM = DCUB1), UBB1 disables tripping if the loss-of-channel condition continues for longer than time UBDURD.

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In three-terminal line DCUB applications (setting ECOMM = DCUB2), UBB1 or UBB2 disable tripping if the loss-of-channel condition (for the respective Channel 1 or 2) continues for longer than time UBDURD.

The UBB1 and UBB2 are routed in various combinations in *Figure 5.11* to control Relay Word bit UBB, depending on enable setting ECOMM = DCUB1 or DCUB2. Relay Word bit UBB is the unblock block input into the trip logic in *Figure 5.1*. When UBB asserts to logical 1, tripping is blocked.

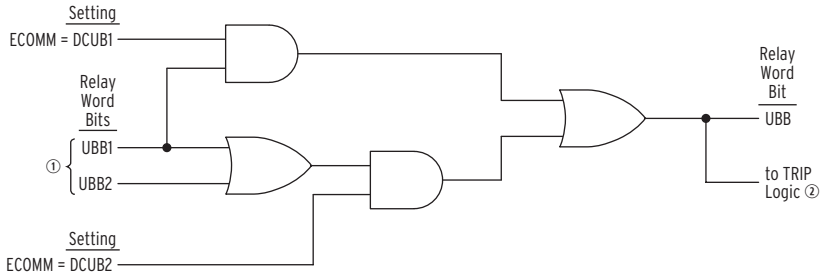
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① Figure 5.11; ② Figure 5.7.

Figure 5.10 DCUB Logic

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① Figure 5.10; ② Figure 5.1.

Figure 5.11 Unblocking Block Logic Routing to Trip Logic

PTRX1, PTRX2–Permissive Trip Receive Outputs

In two-terminal line DCUB applications (setting ECOMM = DCUB1), PTRX1 asserts for loss-of-channel or an actual received permissive trip.

In three-terminal line DCUB applications (setting ECOMM = DCUB2), PTRX1 or PTRX2 assert for loss-of-channel or an actual received permissive trip (for the respective Channel 1 or 2).

The PTRX1/PTRX2 Relay Word bits are then routed in various combinations in *Figure 5.7* to control Relay Word bit PTRX, depending on enable setting ECOMM = DCUB1 or DCUB2. Relay Word bit PTRX is the permissive trip receive input into the trip logic in *Figure 5.1*.

Installation Variations

Figure 5.13 shows output contacts **OUT105** and **OUT107** connected to separate communication equipment, for the two remote terminals. Both output contacts are programmed the same (OUT105 = KEY and OUT107 = KEY).

Depending on the installation, perhaps one output contact (e.g., OUT105 = KEY) could be connected in parallel to both transmitter inputs (**TX**) on the communication equipment in *Figure 5.13*. Then output contact **OUT107** can be used for another function.

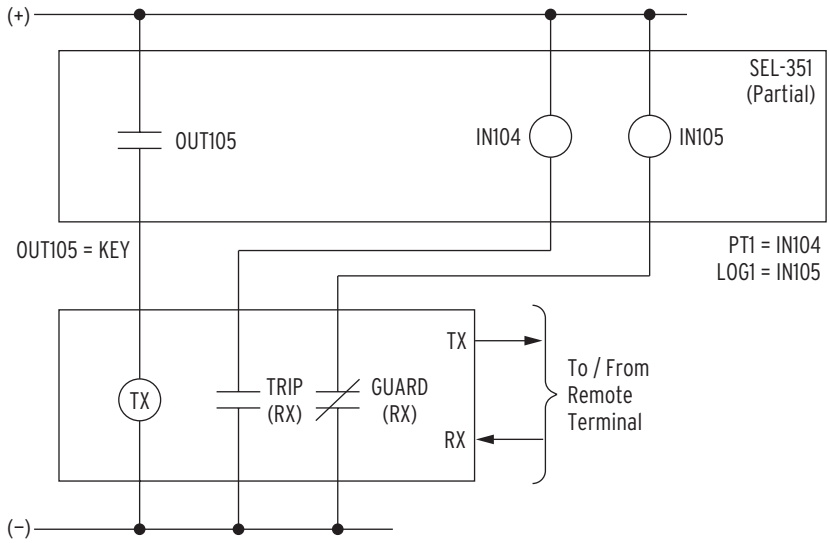


Figure 5.12 SEL-351S Connections to Communications Equipment for a Two-Terminal Line DCUB Scheme (Setting ECOMM = DCUB1)

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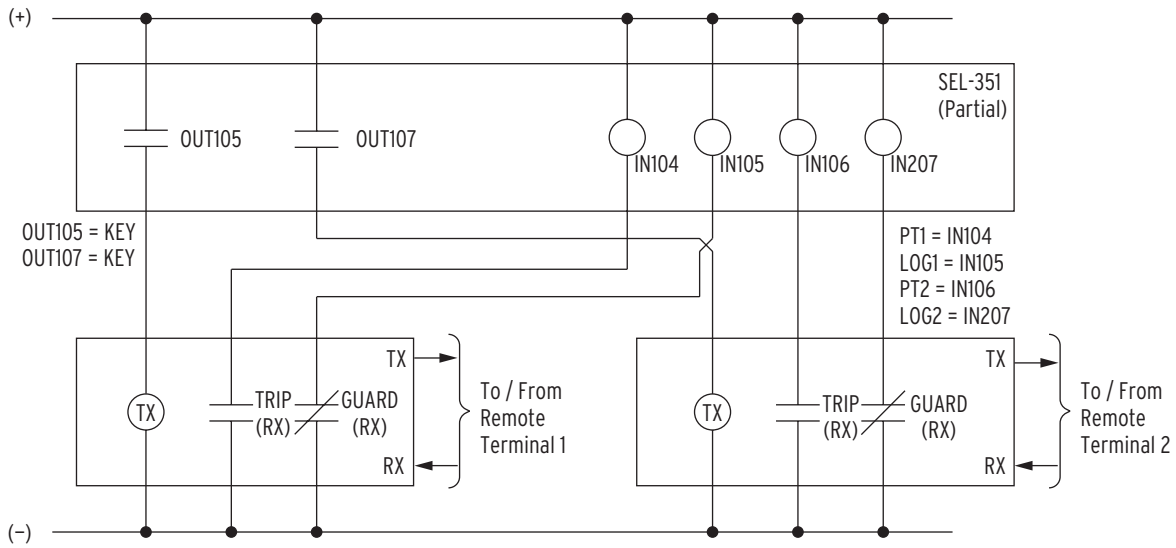


Figure 5.13 SEL-351S Connections to Communications Equipment for a Three-Terminal Line DCUB Scheme (Setting ECOMM = DCUB2)

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Directional Comparison Blocking (DCB) Logic

Enable the DCB logic by setting ECOMM = DCB. The DCB logic in *Figure 5.14* performs the following tasks:

- Provides the individual carrier coordination timers for the Level 2 directional overcurrent elements 67P2S, 67N2S, 67G2S, and 67Q2S. These delays allow time for the block trip signal to arrive from the remote terminal.
- Instantaneously keys the communications equipment to transmit block trip for reverse faults and extends this signal for a settable time following the dropout of all Level 3 directional overcurrent elements 67P3, 67N3, 67G3, and 67Q3.
- Latches the block trip send condition by the directional overcurrent following a close-in zero-voltage three-phase fault where the polarizing memory expires. Latch is removed when the polarizing memory voltage returns or current is removed.
- Extends the received block signal by a settable time.

Use Existing SEL-321 DCB Application Guide for the SEL-351S

Use the existing SEL-321 DCB application guide (AG93-06) to help set up the SEL-351S in a DCB scheme (see preceding subsection *Communications-Assisted Trip Logic—General Overview on page 5.11* for more setting comparison information on the SEL-321/SEL-351S).

External Inputs

See *Optoisolated Inputs on page 7.2* for more information on optoisolated inputs.

BT–Received Block Trip Signal(s)

In two-terminal line DCB applications, a block trip signal is received from **one** remote terminal. One optoisolated input on the SEL-351S (e.g., input **IN104**) is driven by a communications equipment receiver output (see *Figure 5.15*). Make SELOGIC control equation setting BT:

BT = **IN104** (two-terminal line application)

In three-terminal line DCB applications, block trip signals are received from **two** remote terminals. Two optoisolated inputs on the SEL-351S (e.g., input **IN104** and **IN106**) are driven by communications equipment receiver outputs (see *Figure 5.16*). Make SELOGIC control equation setting BT as follows:

BT = **IN104 + IN106** (three-terminal line application)

SELOGIC control equation setting BT is routed through a dropout timer (BTXD) in the DCB logic in *Figure 5.14*. The timer output, Relay Word bit BTX, is routed to the trip logic in *Figure 5.1*.

Timer Settings

See *Section 9: Setting the Relay* for setting ranges.

Z3XPU–Zone (Level) 3 Reverse Pickup Time Delay

Current-reversal guard pickup timer—typically set at one cycle.

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Z3XD–Zone (Level) 3 Reverse Dropout Extension

Current-reversal guard dropout timer—typically set at 5 cycles.

BTXD–Block Trip Receive Extension

Sets reset time of block trip received condition (BTX) after the reset of block trip input BT.

67P2SD, 67N2SD, 67G2SD, 67Q2SD–Level 2 Short Delay

Carrier coordination delays for the output of Level 2 overreaching overcurrent elements 67P2S, 67N2S, 67G2S, and 67Q2S, respectively—typically set at one cycle.

Logic Outputs

The following logic outputs can be tested by assigning them to output contacts. See *Output Contacts on page 7.32* for more information on output contacts.

DSTRT–Directional Carrier Start

Program an output contact for directional carrier start. For example, SELOGIC control equation setting OUT105 is set:

OUT105 = **DSTRT**

Output contact **OUT105** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 5.15*).

In a three-terminal line scheme, output contact **OUT107** is set the same as **OUT105** (see *Figure 5.16*):

OUT107 = **DSTRT**

DSTART includes current reversal guard logic.

NSTRT–Nondirectional Carrier Start

Program an output contact to include nondirectional carrier start, in addition to directional start. For example, SELOGIC control equation setting OUT105 is set:

OUT105 = **DSTRT + NSTRT**

Output contact **OUT105** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 5.15*).

In a three-terminal line scheme, output contact **OUT107** is set the same as **OUT105** (see *Figure 5.16*):

OUT107 = **DSTRT + NSTRT**

STOP–Stop Carrier

Program to an output contact to stop carrier. For example, SELOGIC control equation setting OUT106 is set:

OUT106 = **STOP**

Output contact **OUT106** drives a communications equipment transmitter input in a two-terminal line application (see *Figure 5.15*).

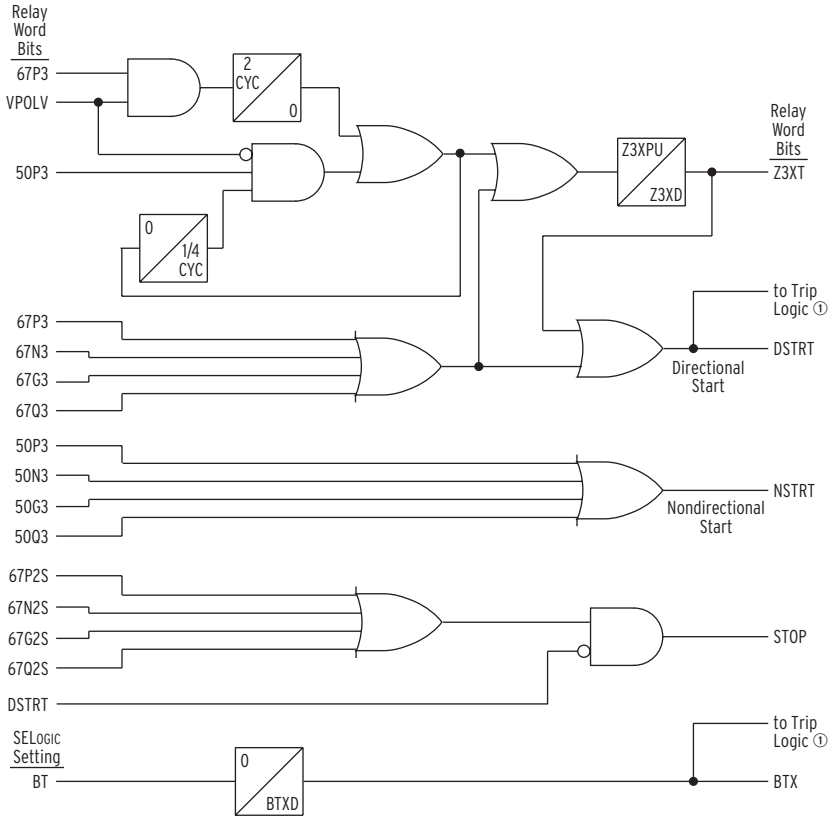
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In a three-terminal line scheme, output contact **OUT208** is set the same as **OUT106** (see *Figure 5.16*):

OUT208 = **STOP**

BTX–Block Trip Extension

The received block trip input (e.g., BT = IN104) is routed through a dropout timer (BTXD) in the DCB logic in *Figure 5.14*. The timer output (BTX) is routed to the trip logic in *Figure 5.1*.



① Figure 5.1.

Figure 5.14 DCB Logic

Installation Variations

Figure 5.16 shows output contacts **OUT105**, **OUT106**, **OUT107**, and **OUT208** connected to separate communication equipment, for the two remote terminals. Both output contact pairs are programmed the same (OUT105 = DSTRT + NSTRT and OUT107 = DSTRT + NSTRT; OUT106 = STOP and OUT208 = STOP).

Depending on the installation, perhaps one output contact (e.g., OUT105 = DSTRT + NSTRT) can be connected in parallel to both START inputs on the communication equipment in *Figure 5.16*. Then output contact **OUT107** can be used for another function.

Depending on the installation, perhaps one output contact (e.g., OUT106 = STOP) can be connected in parallel to both STOP inputs on the communication equipment in *Figure 5.16*. Then output contact **OUT208** can be used for another function.

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Figure 5.16 also shows communication equipment **RX** (receive) output contacts from each remote terminal connected to separate inputs **IN104** and **IN106** on the SEL-351S. The inputs operate as block trip receive inputs for the two remote terminals and are used in the SELOGIC control equation setting:

BT = **IN104 + IN106**

Depending on the installation, perhaps one input (e.g., **IN104**) can be connected in parallel to both communication equipment **RX** (receive) output contacts in *Figure 5.16*. Then setting BT would be programmed as:

BT = **IN104**

and input **IN106** can be used for another function.

In *Figure 5.15* and *Figure 5.16*, the carrier scheme cutout switch contact (85CO) should be closed when the communications equipment is taken out of service so that the BT input of the relay remains asserted. An alternative to asserting the BT input is to change to a setting group where the DCB logic is not enabled.

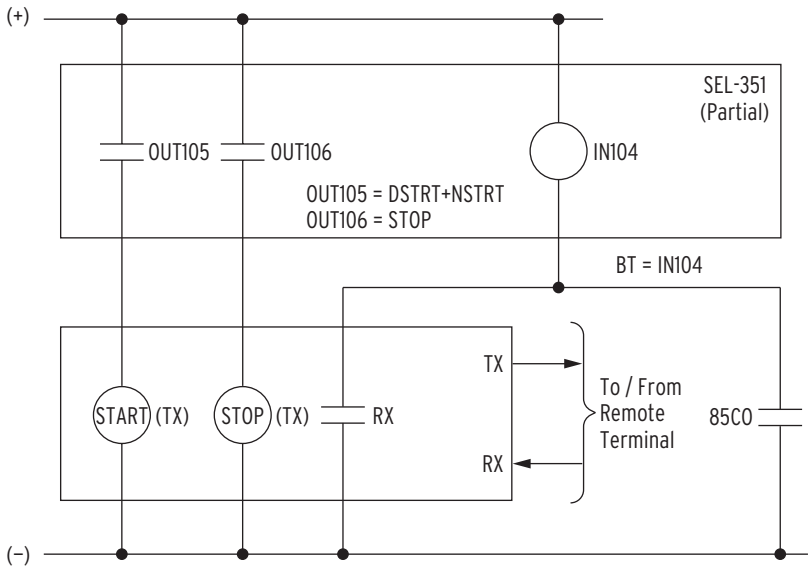


Figure 5.15 SEL-351S Connections to Communications Equipment for a Two-Terminal Line DCB Scheme

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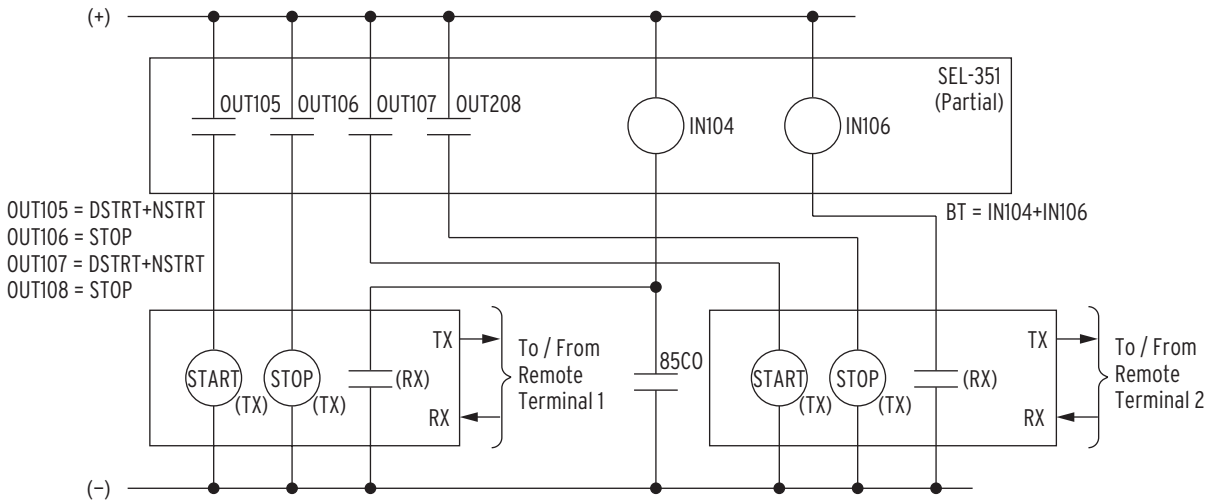


Figure 5.16 SEL-351S Connections to Communications Equipment for a Three-Terminal Line DCB Scheme

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Front-Panel Target LEDs

Refer to *Figure 1.2* and *Figure 2.2–Figure 2.6* for the layout of the front-panel target LEDs. The functions and associated settings for these target LEDs are given in *Table 5.1*.

Table 5.1 SEL-351S Front-Panel Target LED Definitions and Settings

LED Front-Panel Default Label (LED color)	Definition	LED Logic Input (SELOGIC Setting)	Latch In On TRIP? (Global Setting)	LED Logic Output
		(Factory-Default Settings Shown)		
ENABLED (green)	Relay enabled—see subsection *Relay Self-Tests on page 13.9*			TLED11
TRIP (red)	Trip occurred—overcurrent or otherwise	LED12 = TRIP	LED12L = Y	TLED12
INST (red)	Instantaneous trip	LED13 = FAULT*!SV1T	LED13L = Y	TLED13
COMM (red)	Communications-assisted trip	LED14 = COMMT	LED14L = Y	TLED14
SOTF (red)	Switch-onto-fault trip	LED15 = SOTFT	LED15L = Y	TLED15
50 (red)	Inst./Def.-time OC element generated trip	LED16 = 67P1	LED16L = Y	TLED16
51 (red)	Time OC element generated trip	LED17 = 51P1T + 51G1T	LED17L = Y	TLED17
81 (red)	Frequency element generated trip	LED18 = 81D1T	LED18L = Y	TLED18
RESET (green)	Reclosing relay in the reset state	LED19 = 79RS	LED19L = N	TLED19
CYCLE (red)	Reclosing relay in the reclose cycle state	LED20 = 79CY	LED20L = N	TLED20
LOCKOUT (red)	Reclosing relay in the lockout state	LED21 = 79LO	LED21L = N	TLED21
A (red)	Phase A involved in fault		Yes, latch in on trip, but no setting made	TLED22
B (red)	Phase B involved in fault		Yes, latch in on trip, but no setting made	TLED23
C (red)	Phase C involved in fault		Yes, latch in on trip, but no setting made	TLED24
G (red)	Ground involved in fault	LED25 = 51G1	LED25L = Y	TLED25
N (red)	Neutral Ground element generated trip	LED26 = 0	LED26L = Y	TLED26

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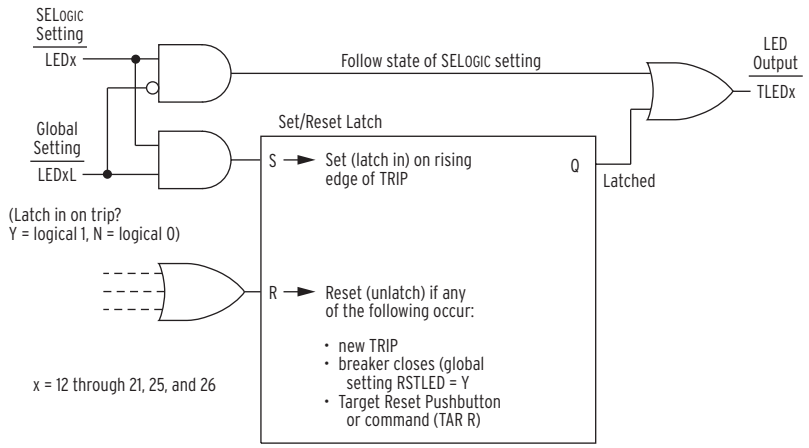


Figure 5.17 Programmable Front-Panel Target LED Logic

Front-Panel Target LED Logic Details

Refer to *Table 5.1* and *Figure 5.17*.

LED12–**LED21** (**TRIP**–**LOCKOUT**), **LED25** (**G**), and **LED26** (**N**) are programmable via the SELOGIC control equation settings and global settings shown in *Table 5.1*. They either latch in on the rising-edge of trip (new assertion of Relay Word bit TRIP—see logic output of *Figure 5.1*) or follow the state of the corresponding SELOGIC control equation setting (illuminated = logical 1; extinguished = logical 0).

LED11 (**ENABLED**) and **LED22**–**LED24** (**A**, **B**, and **C**) do not have settings—they are fixed-function LEDs.

LEDs **A**, **B**, and **C** always latch in on trip, if the corresponding phase is involved with the fault. LEDs **A**, **B**, and **C** reset (unlatch) similar to the other target LEDs set to latch in on trip. SELOGIC control equation FAULT has to be picked up for three-phase fault indication (FAULT = 51P1 + 51G1 in the factory default settings—set with the pickup indicators of the time-overcurrent elements). Additionally, the fault must be present for at least one cycle after the relay trips for reliable targeting. This is most noticeable in relay testing when breaker opening times are not included in the test setup.

SELOGIC control equation setting FAULT also controls other relay functions. See subsection *SELOGIC Control Equation Setting FAULT on page 5.37*.

If neutral channel **IN** is rated 0.2 A nominal and directional control is selected for a Petersen Coil grounded or ungrounded/high-impedance grounded system (see *Table 4.3*), then A, B, and C target logic for ground faults uses Relay Word bits NSA, NSB, and NSC in determining the involved phase for forward faults only.

The LED logic output (TLED11–TLED26) that actually drives the front-panel LEDs is observed via the **TAR 0** and **TAR 1** commands (see *Table 10.6*).

TLED19–TLED26 (**RESET**–**N**) are available as Relay Word bits (see *Table 9.6*, row 51—note the "T" is dropped from the front, so they are listed as LED19–LED26 in row 51). Use Relay Word bits LED22–LED25 (A, B, C, and G) to indicate the type of fault to particular SCADA systems (those requiring an output contact interface; e.g., set OUT103 = LED22, OUT104 = LED23, …).

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Correlation between Trip Target LEDs and Trip Settings

Refer to subsection *Trip Logic on page 5.1* and *Table 5.1*.

The SELOGIC control equation factory-default trip setting is:

TR = **51P1T + 51G1T + 67P1 + PB10 + OC**

NOTE: PB10 does not appear in the TR equation for 0351Sxxx5/6/A/B models.

LED12 (TRIP)

If a trip comes via PB10 (front-panel **{TRIP}** operator control—see *Figure 11.9*) or OC (serial port **OPEN** command—see *OPE Command (Open Breaker) on page 10.39*), no unique LED illuminates, just **LED12** (**TRIP**):

- LED12 = TRIP

LED12 (**TRIP**) illuminates for every trip routed through the trip logic in *Figure 5.1*.

LED13 (INST)

The following SELOGIC control equation settings are involved with **LED13** (**INST**):

- FAULT = 51P1 + 51G1 (the corresponding pickup indicators for time-overcurrent tripping elements 51P1T and 51G1T—see *Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements*)
- SV1 = FAULT (run FAULT through a SV1PU = 3 cycle timer—see *Figure 7.24*)
- LED13 = FAULT*!SV1T (= FAULT * NOT[SV1T])

LED13 (**INST**) illuminates at the rising edge of trip if the time-overcurrent element pickup indicators have been picked up for less than 3 cycles.

SELOGIC control equation setting FAULT also controls other relay functions. See subsection *SELOGIC Control Equation Setting FAULT on page 5.37*.

LED14 (COMM) and LED15 (SOTF)

Refer to the top part of *Figure 5.1*. If overcurrent elements are set in SELOGIC control equations TRCOMM or TRSOTF and a trip results from either associated logic path:

- Relay Word bit COMMT asserts (LED14 = COMMT)
- Relay Word bit SOTFT asserts (LED15 = SOTFT)

then **LED14** (**COMM**) or **LED15** (**SOTF**) illuminates at the rising edge of trip. No overcurrent elements are set in TRCOMM or TRSOTF in the factory-default settings, thus these two target LEDs are always extinguished with factory-default settings.

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LED16 (50) and LED17 (51)

Note that **LED16** (**50**) and **LED17** (**51**) directly contain some of the tripping elements (TR = 51P1T + 51G1T + 67P1 + …), uniquely identifying the trip type when illuminating:

- LED16 = 67P1
- LED17 = 51P1T + 51G1T

LED18 (81)

If frequency element 81D1T is set to trip (e.g., SELOGIC control equation TR = … + 81D1T) and a trip results from 81D1T:

- LED18 = 81D1T

then **LED18** (**81**) illuminates at the rising edge of trip. Frequency element 81D1T is not set to trip in the factory-default settings, thus target **LED18** (**81**) is always extinguished with factory-default settings.

LED25 (G)

Note that **LED25** (**G**) directly contains the pickup indicator of the ground time-overcurrent tripping element (TR = … + 51G1T + …), indicating ground involvement in the fault:

- LED25 = 51G1

LED26 (N)

LED26 (**N**) is used to indicate tripping involving the neutral channel **IN**, especially if it is ordered for sensitive earth fault applications (0.05 A nominal neutral channel). No neutral-ground overcurrent elements are set to trip—neither is **LED26** set in particular:

- LED26 = 0 (= logical 0)

Thus **LED26** (**N**) is always extinguished with factory-default settings:

Change the Trip Settings—Change the Target LED Logic

The last part of the subsection *Trip Logic on page 5.1* discusses checking other settings (including front-panel target LED settings) when changing or modifying trip logic.

Beyond just changing front-panel target LED settings when changing/modifying trip logic, the operation of the programmable front-panel target LEDs can be radically changed, with the flexibility given by the settings in *Table 5.1*. Front panel relabeling would probably be required.

RECLOSING STATE LEDs

If the reclosing relay is turned off (enable setting E79 = N or open interval setting 79OI1 = 0), all the factory-default **RECLOSING STATE** LEDs are extinguished:

- LED19 = 79RS = logical 0
- LED20 = 79CY = logical 0
- LED21 = 79LO = logical 0

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Target Reset/Lamp Test Front-Panel Pushbutton

When the **{TARGET RESET}/{LAMP TEST}** front-panel pushbutton is pressed:

- All front-panel LEDs illuminate for one (1) second.
- All trip latched target LEDs (target LEDs **LED12**–**LED18** and **LED22**–**LED26** in *Table 5.1*) are extinguished (unlatched), unless a trip condition is present, in which case the latched target LEDs reappear in their previous state.

Other Applications for the Target Reset Function

Refer to the bottom of *Figure 5.1*. The combination of the **{TARGET RESET}** pushbutton and the **TAR R** (Target Reset) serial port command is available as Relay Word bit TRGTR. Relay Word bit TRGTR pulses to logical 1 for one processing interval when either the **{TARGET RESET}** pushbutton is pushed or the **TAR R** (Target Reset) serial port command is executed.

Relay Word bit TRGTR can be used to unlatch logic. For example, refer to the breaker failure logic in *Figure 7.26*. If a breaker failure trip occurs (SV7T asserts), the occurrence can be displayed on the front panel with seal-in logic and a rotating default display (also see *Rotating Default Display on page 7.36* and *Section 11: Front-Panel Interface*):

SV8 = (SV8 + SV7T)*!TRGTR

DP3 = SV8

DP3_1 = BREAKER FAILURE

DP3_0 = NA (blank)

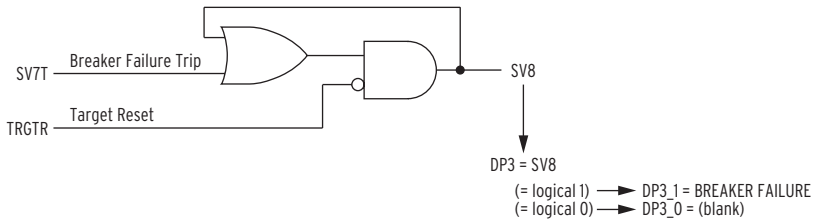


Figure 5.18 Seal-in of Breaker Failure Occurrence for Message Display

If a breaker failure trip has occurred, the momentary assertion of SV7T (breaker failure trip) will cause SV8 in *Figure 5.18* to seal-in. Asserted SV8 in turn asserts DP3, causing the message:



to display in the rotating default display.

This message can be removed from the display rotation by pushing the **{TARGET RESET}** pushbutton (Relay Word bit TRGTR pulses to logical 1, unlatching SV8 and in turn deasserting DP3). Thus, front-panel rotating default displays can be easily reset along with the front-panel targets by pushing the **{TARGET RESET}** pushbutton.

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SELOGIC Control Equation Setting FAULT

SELOGIC control equation setting FAULT has control over or is used in the following:

- Front-panel target LEDs **INST**, **A**, **B**, and **C**. See earlier subsection *Front-Panel Target LEDs on page 5.32*.
- Demand Metering—FAULT is used to suspend demand metering peak recording. See subsection *Demand Metering on page 8.20*.
- Maximum/Minimum Metering—FAULT is used to block Maximum/Minimum metering updating. See subsection *Maximum/Minimum Metering on page 8.30*.
- Voltage Sag, Swell Interruption elements—FAULT is used to suspend the calculation of Vbase. See subsection *Voltage Sag, Swell, and Interruption Elements (Available in Firmware Version 7) on page 3.54*.

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Section 6

Close and Reclose Logic

This section is made up of three topics:

Close Logic on page 6.2. Close Logic describes the final logic that controls the close output contact (e.g., OUT102 = CLOSE). This output contact closes the circuit breaker for automatic reclosures and other close conditions (e.g., manual close initiation via serial port or optoisolated inputs).

If automatic reclosing is not needed, but the SEL-351S Relay is to close the circuit breaker for other close conditions (e.g., manual close initiation via serial port or optoisolated inputs), then this is the only topic that needs to be read (particularly the description of SELOGIC® control equation setting CL).

NOTE: Setting E79 = N defeats the reclosing relay, but does not defeat the ability of the close logic described in the first subsection (Figure 6.1) to close the circuit breaker for other close conditions via SELOGIC control equation setting CL (e.g., manual close initiation via serial port or optoisolated inputs).

Reclose Supervision Logic on page 6.7. Reclose Supervision Logic describes the logic that supervises automatic reclosing when an open-interval time times out—a final condition check right before the close logic asserts the close output contact.

Reclose Logic. Reclose Logic describes all the reclosing relay settings and logic needed for automatic reclosing (besides the final close logic and reclose supervision logic described in the previous subsections).

The reclose enable setting, E79, has setting choices N, 1, 2, 3, 4, C1, C2, C3, and C4. Setting E79 = N defeats the reclosing relay. Setting choices 1 through 4 and C1 through C4 are the number of desired automatic reclosures. Setting choices 1 through 4 have the reclosing relay go to the Lockout state upon Reclose Supervision Failure (refer to *Reclose Supervision Logic*). Setting choices C1 through C4, however, do not have the reclosing relay go to the Lockout state upon Reclose Supervision Failure. Instead, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not true.

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Close Logic

The close logic in *Figure 6.1* provides flexible circuit breaker closing/automatic reclosing with SELOGIC control equation settings:

52A (breaker status—also see *Figure 6.4*)

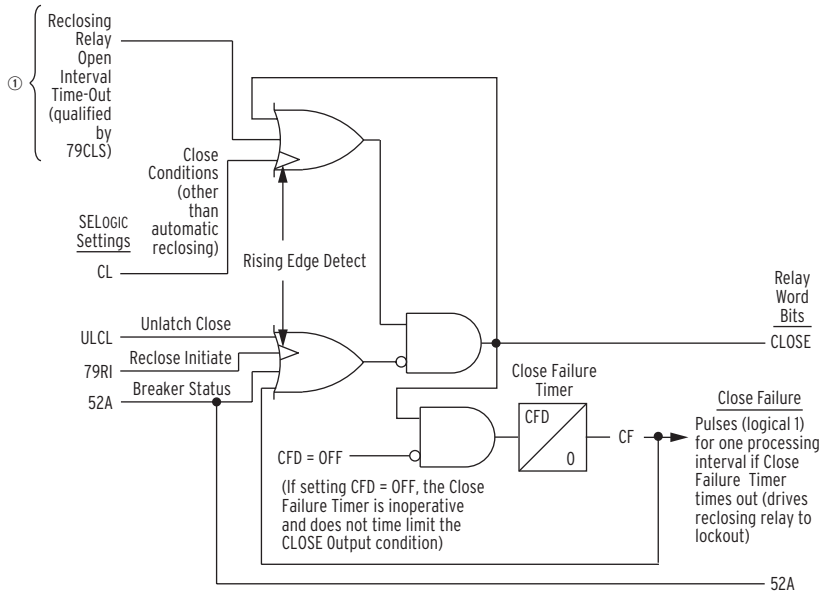
CL (close conditions other than automatic reclosing—also see *Figure 6.2*)

ULCL (unlatch close conditions other than circuit breaker status, close failure, or reclose initiation—also see *Figure 6.3*)

and setting:

CFD (Close Failure Time)

See the settings sheet in *Section 9: Setting the Relay* for setting ranges.



① From Figure 6.5.

Figure 6.1 Close Logic

Set Close

If **all** the following are true:

- The unlatch close condition is not asserted (ULCL = logical 0)
- The circuit breaker is open (52A = logical 0)
- The reclose initiation condition (79RI) is not making a rising edge (logical 0 to logical 1) transition
- And a close failure condition does not exist (Relay Word bit CF = 0)

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Then the CLOSE Relay Word bit can be asserted to logical 1 if either of the following occurs:

- A reclosing relay open-interval times out (qualified by SELOGIC control equation setting 79CLS—see *Figure 6.5*)
- SELOGIC control equation setting CL goes from logical 0 to logical 1 (rising edge transition)

Unlatch Close

If the CLOSE Relay Word bit is asserted at logical 1, it stays asserted at logical 1 until **one** of the following occurs:

- The unlatch close condition asserts (ULCL = logical 1)
- The circuit breaker closes (52A = logical 1)
- The reclose initiation condition (79RI) makes a rising edge (logical 0 to logical 1) transition
- The Close Failure Timer times out (Relay Word bit CF = 1)

The Close Failure Timer is inoperative if setting CFD = OFF.

Factory Settings Example

The factory settings for the close logic SELOGIC control equation settings are:

52A = **IN101**

CL = **(PB9*LT4 + CC)*LT5**

ULCL = **TRIP + !(LT5 + CLOSE) + !(LT4 + CLOSE + CC + 79CY) [= TRIP + NOT(LT5)*NOT(CLOSE) + NOT(LT4)*NOT(CLOSE)*NOT(CC) *NOT(79CY)]**

The factory setting for the Close Failure Timer setting is:

CFD = **60.00 cycles**

See the *SEL-351S Settings Sheets* for setting ranges.

NOTE: PB9*LT4 does not appear in the factory default settings for model 0351Sxxx5/6/A/B.

Set Close

If the Reclosing Relay Open-interval Time-Out logic input at the top of *Figure 6.1* is ignored (reclosing is discussed in detail in a following subsection), then SELOGIC control equation setting CL is the only logic input that can set the CLOSE Relay Word bit.

In SELOGIC control equation setting CL (see *Figure 6.2*), closing means are provided by:

- **{CLOSE}** operator control (local)
- Serial port **CLOSE** command (remote)

Supervision of these local and remote close signals is provided by:

- **{LOCK}** operator control—supervises **{CLOSE}** operator control only
- **{HOT LINE TAG}** operator control—supervises both the **{CLOSE}** operator control and the serial port **CLOSE** command

Other details:

- The **{LOCK}** operator control also supervises other front-panel operator controls (see *Table 11.1*).
- The **{HOT LINE TAG}** operator control also supervises auto-reclosing (see *Table 11.1*).

NOTE: Close logic input PB9*LT4 does not appear in the factory default settings for model 0351Sxxx5/6/A/B (with auxiliary **{TRIP}/{CLOSE}** pushbuttons—see Figure 2.5 and Figure 2.6). The auxiliary close pushbutton eliminates the need for the **{CLOSE}** operator control (corresponding to Relay Word bit PB9—see Figure 11.9). The **{CLOSE}** operator control is changed to **{AUX 3}** operator control for model 0351Sxxx5/6/A/B.

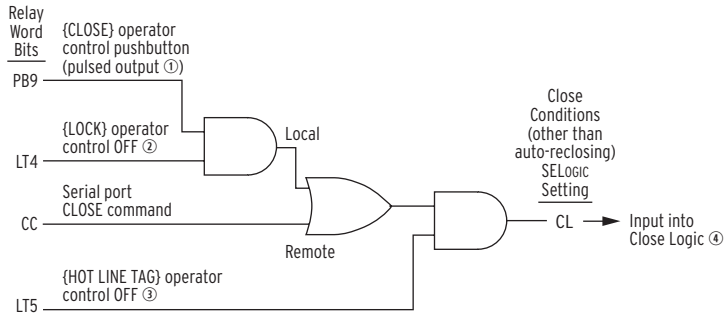
The auxiliary **{CLOSE}** pushbutton on model 0351Sxxx5/6/A/B is electrically separate from the rest of the relay and not part of the close logic in Figure 6.1. It provides separate closing capability as shown in Figure 2.31.

IMPORTANT NOTE:
(Model 0351Sxxx5/6/A/B)
The auxiliary close pushbutton on model 0351Sxxx5/6/A/B is electrically separate from the rest of the relay and not part of the close logic in Figure 6.1. It provides separate closing capability as shown in Figure 2.31. Because of this, the **{HOT LINE TAG}** operator control and **{LOCK}** operator control do not affect the auxiliary **{CLOSE}** pushbutton.

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➤ No “standing close” is possible with the close logic in *Figure 6.2*. The **{CLOSE}** operator control (Relay Word bit PB9) and serial port **CLOSE** command (Relay Word bit CC) pulse for only one processing interval (one quarter cycle) when activated. Also, in *Figure 6.1*, SELOGIC control equation setting CL is rising edge triggered. Thus, if the **{LOCK}** operator control (Relay Word bit LT4) or the **{HOT LINE TAG}** operator control (Relay Word bit LT5) in *Figure 6.2* are turned ON or OFF, no surprise close takes place—there is no standing close condition waiting to get through.

NOTE: A local close via PB9 is removed from the factory default settings for model 0351Sxxx5/6/A/B.



① See Figure 11.12, ② see Figure 11.21, ③ see Figure 11.15, ④ see Figure 6.1.

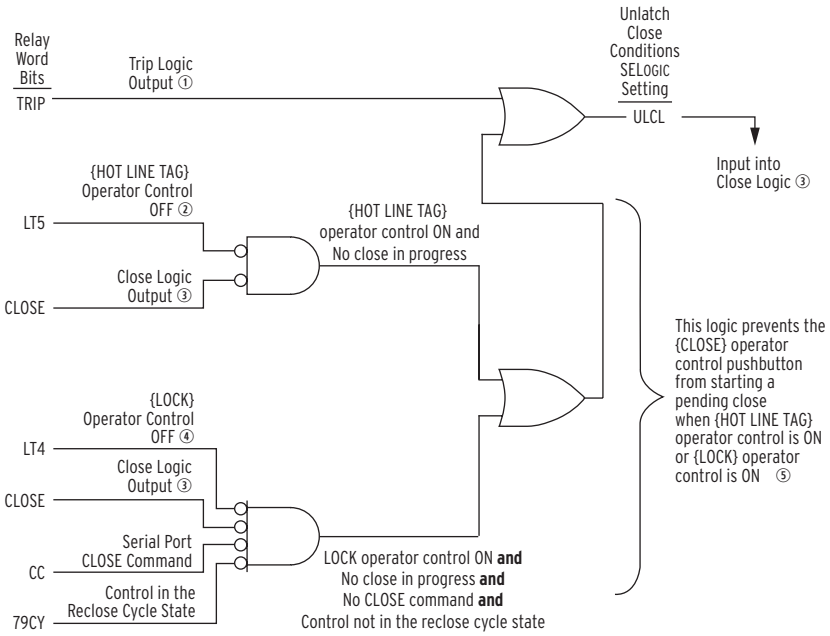
Figure 6.2 Close Conditions—Other Than Auto-Reclosing

Unlatch Close

Figure 6.3 shows the additional means to unlatch the close logic, besides those embedded in *Figure 6.1*. The TRIP Relay Word bit in setting ULCL keeps the TRIP and CLOSE Relay Word bits from being asserted at the same time—TRIP has priority.

The logic in the bottom two-thirds of *Figure 6.3* is primarily made for the scenario where delayed closing occurs via the **{CLOSE}** operator control. When the **{CLOSE}** operator control is set with a time delay (PB9D > 0; see *Figure 11.12*), and is timing toward a pending close, the corresponding **BREAKER CLOSED** LED flashes as a timing indication. Besides unlatching the close signal output, setting ULCL also prevents the **{CLOSE}** operator control from starting to time to a pending close. The **BREAKER CLOSED** LED is kept from flashing by preventing the **{CLOSE}** operator control from starting to time whenever the **{LOCK}** operator control is ON or the **{HOT LINE TAG}** operator control is ON. The logic allows the **CLOSE** command and auto-reclosing to still proceed with the **{LOCK}** operator control ON.

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① See Figure 5.1; ② see Figure 11.15; ③ see Figure 6.1, ④ see Figure 11.21, ⑤ see Figure 11.12.

Figure 6.3 Unlatch Close Conditions

With setting CFD = 60.00 cycles, once the CLOSE Relay Word bit asserts in *Figure 6.1*, it remains asserted at logical 1 no longer than a **maximum** of 60 cycles. If the Close Failure Timer times out, Relay Word bit CF asserts to logical 1, forcing the CLOSE Relay Word bit to logical 0.

Defeat the Close Logic

If SELOGIC control equation circuit breaker auxiliary setting 52A is set with numeral 0 (52A = 0), then the close logic is inoperable. Also, the reclosing relay is defeated (see *Reclosing Relay on page 6.14*).

Circuit Breaker Status

Refer to *Figure 6.4* and to the bottom of *Figure 6.1*. Note that SELOGIC control equation setting 52A (circuit breaker status) is available as Relay Word bit 52A, which makes setting other SELOGIC control equations more convenient. For example, if the following setting is made:

52A = **IN101** 52a auxiliary contact wired to input **IN101**; factory default setting

or

52A = **!IN101** 52b auxiliary contact wired to input **IN101**

then if breaker status is used in other SELOGIC control equations, it can be entered as 52A—the user does not have to enter IN101 (for a 52a) or !IN101 (for a 52b).

52A Used in Many Settings

The following factory-default SELOGIC control equations settings use the resultant 52A Relay Word bit:

79RIS = **52A + 79CY** (reclose initiate—see *Table 6.4* and following explanation)

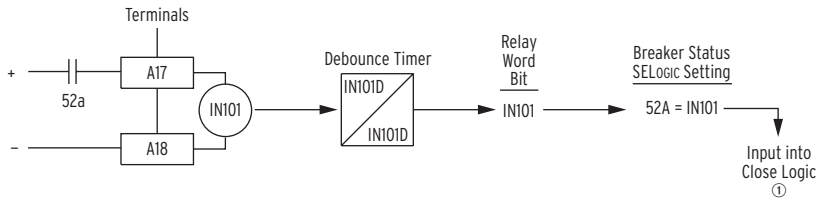
79DTL= **...*(... + !52A) + ...** (drive-to-lockout—see *Figure 6.10* and accompanying explanation)

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LED9 = **52A** (**BREAKER CLOSED** LED—see *Figure 11.9*—model 0351S*xxx*3/4 only)

LED10 = **!52A** (**BREAKER OPEN** LED—see *Figure 11.9*—model 0351S*xxx*3/4 only)

BSYNCH = 52A (block synchronism check elements—see *Figure 3.26*)



① See Figure 6.1.

Figure 6.4 Breaker Status Determination

Program an Output Contact for Closing

In the factory settings, the resultant of the close logic in *Figure 6.1* is routed to output contact **OUT102** with the following SELOGIC control equation:

OUT102 = **CLOSE**

See *Output Contacts on page 7.32* for more information on programming output contacts.

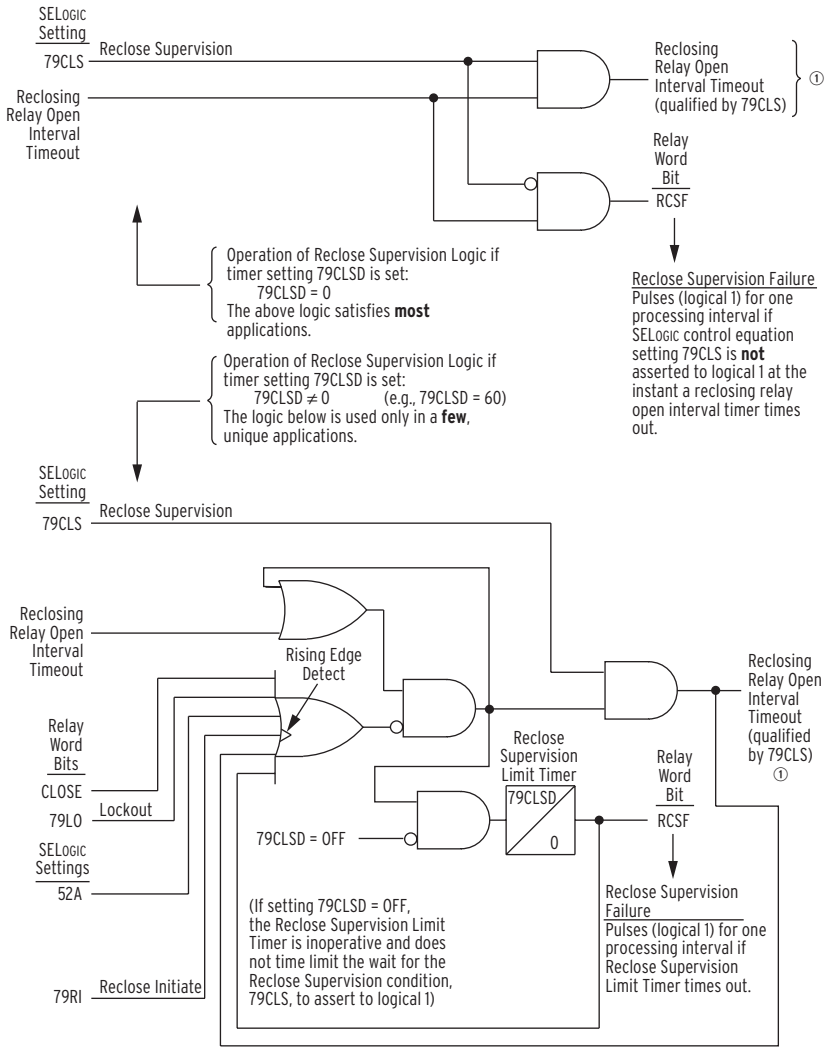
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Reclose Supervision Logic

Note that one of the inputs into the close logic in *Figure 6.1* is:

Reclosing Relay Open-interval Time-Out (qualified by 79CLS)

This input into the close logic in *Figure 6.1* is the indication that a reclosing relay open-interval has timed out (see *Figure 6.9*), a qualifying condition (SELOGIC control equation setting 79CLS) has been met, and thus automatic reclosing of the circuit breaker should proceed by asserting the CLOSE Relay Word bit to logical 1. This input into the close logic in *Figure 6.1* is an output of the reclose supervision logic in the following *Figure 6.5*.



① See Figure 6.1.

Figure 6.5 Reclose Supervision Logic (Following Open-interval Time-Out)

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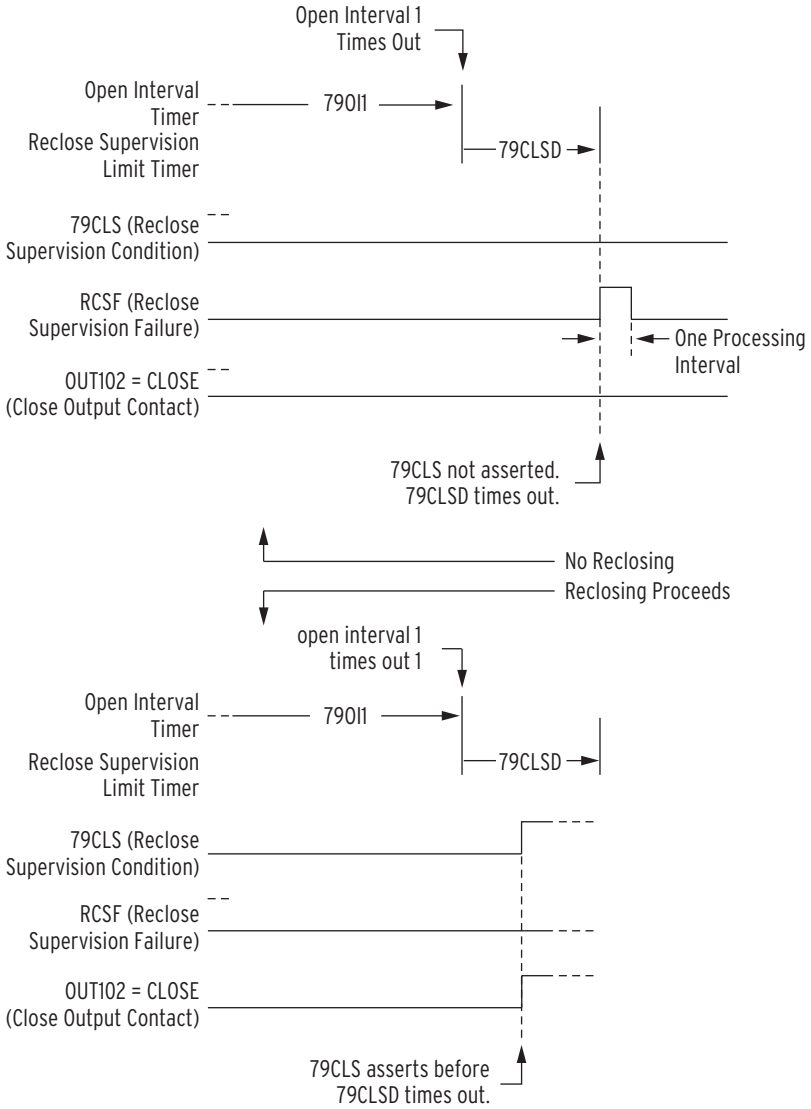


Figure 6.6 Reclose Supervision Limit Timer Operation (Refer to Bottom of Figure 6.5)

Settings and General Operation

Figure 6.5 contains the following SELOGIC control equation setting:

79CLS (reclose supervision conditions—checked after reclosing relay open-interval time-out)

and setting:

79CLSD (Reclose Supervision Limit Time)

See the settings sheets at the end of *Section 9: Setting the Relay* for setting ranges.

For Most Applications (Top of Figure 6.5)

For most applications, the Reclose Supervision Limit Time setting should be set to zero cycles:

79CLSD = **0.00**

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With this setting, the logic in the top of *Figure 6.5* is operative. When an open interval times out, the SELOGIC control equation reclose supervision setting 79CLS is **checked just once**.

If 79CLS is **asserted** to logical 1 at the instant of an open-interval time-out, then the now-qualified open-interval time-out will propagate onto the final close logic in *Figure 6.1* to automatically reclose the circuit breaker.

If 79CLS is **deasserted** to logical 0 at the instant of an open-interval time-out, the following occurs:

- No automatic reclosing takes place.
- Relay Word bit RCSF (Reclose Supervision Failure indication) asserts to logical 1 for one processing interval.
- If setting E79 = 1, 2, 3, or 4, the reclosing relay is driven to Lockout State.
- If setting E79 = C1, C2, C3, or C4, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not true. If the reclosing relay increments to the last shot value (no more open intervals left; see *Figure 6.9* and *Table 6.3*), the reclosing relay is then driven to the Lockout State.

See *Factory Settings Example on page 6.11* and *Additional Settings Example 1 on page 6.11*.

For A Few, Unique Applications (Bottom of Figure 6.5 and Figure 6.6)

For a few unique applications, the Reclose Supervision Limit Time setting is **not** set equal to zero cycles, e.g.:

79CLSD = **60.00**

With this setting, the logic in the bottom of *Figure 6.5* is operative. When an open-interval times out, the SELOGIC control equation reclose supervision setting 79CLS is then **checked for a time window** equal to setting 79CLSD.

If 79CLS **asserts** to logical 1 at any time during this 79CLSD time window, then the now-qualified open-interval time-out will propagate onto the final close logic in *Figure 6.1* to automatically reclose the circuit breaker.

If 79CLS remains **deasserted** to logical 0 during this entire 79CLSD time window, when the time window times out, the following occurs:

- No automatic reclosing takes place.
- Relay Word bit RCSF (Reclose Supervision Failure indication) asserts to logical 1 for one processing interval.
- If setting E79 = 1, 2, 3, or 4, the reclosing relay is driven to Lockout State.
- If setting E79 = C1, C2, C3, or C4, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not true. If the reclosing relay

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increments to the last shot value (no more open intervals left; see *Figure 6.9* and *Table 6.3*), the reclosing relay is then driven to the Lockout State.

The logic in the bottom of *Figure 6.5* is explained in more detail in the following text.

Set Reclose Supervision Logic (Bottom of Figure 6.5)

Refer to the bottom of *Figure 6.5*. If **all** the following are true:

- The close logic output **CLOSE** (also see *Figure 6.1*) is **not** asserted (Relay Word bit CLOSE = logical 0).
- The reclosing relay is **not** in the Lockout State (Relay Word bit 79LO = logical 0).
- The circuit breaker is open (52A = logical 0).
- The reclose initiation condition (79RI) is **not** making a rising edge (logical 0 to logical 1) transition.
- The Reclose Supervision Limit Timer is **not** timed out (Relay Word bit RCSF = logical 0).

then a reclosing relay open-interval time-out seals in *Figure 6.5*. Then, when 79CLS asserts to logical 1, the sealed-in reclosing relay open-interval time-out condition will propagate through *Figure 6.5* and on to the close logic in *Figure 6.1*.

Unlatch Reclose Supervision Logic (Bottom of Figure 6.5)

Refer to the bottom of *Figure 6.5*. If the reclosing relay open-interval time-out condition is sealed in, it stays sealed in until **one** of the following occurs:

- The close logic output **CLOSE** (also see *Figure 6.1*) asserts (Relay Word bit CLOSE = logical 1).
- The reclosing relay goes to the Lockout State (Relay Word bit 79LO = logical 1).
- The circuit breaker closes (52A = logical 1).
- The reclose initiation condition (79RI) makes a rising edge (logical 0 to logical 1) transition.
- SELOGIC control equation setting 79CLS asserts (79CLS = logical 1).
- The Reclose Supervision Limit Timer times out (Relay Word bit RCSF = logical 1 for one processing interval).

The Reclose Supervision Limit Timer is inoperative if setting 79CLSD = OFF. With 79CLSD = OFF, reclose supervision condition 79CLS is not time limited. When an open-interval times out, reclose supervision condition 79CLS is checked indefinitely until one of the other above unlatch conditions comes true.

The unlatching of the sealed-in reclosing relay open-interval time-out condition by the assertion of SELOGIC control equation setting 79CLS indicates successful propagation of a reclosing relay open-interval time-out condition on to the close logic in *Figure 6.1*.

See *Additional Settings Example 2 on page 6.12*.

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Factory Settings Example

Refer to the top of *Figure 6.5*.

The factory setting for the SELOGIC control equation reclose supervision setting is:

79CLS = **1** (numeral 1)

The factory setting for the Reclose Supervision Limit Timer setting is:

79CLSD = **0.00** cycles

Any time a reclosing relay open-interval times out, it propagates immediately through *Figure 6.5* and then on to *Figure 6.1*, because SELOGIC control equation setting 79CLS is always asserted to logical 1. Effectively, there is no special reclose supervision.

Additional Settings Example 1

Refer to the top of *Figure 6.5* and *Figure 6.7*.

SEL-351S relays are installed at both ends of a transmission line in a high-speed reclose scheme. After both circuit breakers open for a transmission line fault, the SEL-351S(1) recloses circuit breaker 52/1 first, followed by the SEL-351S(2) reclosing circuit breaker 52/2, after a synchronism check across circuit breaker 52/2.

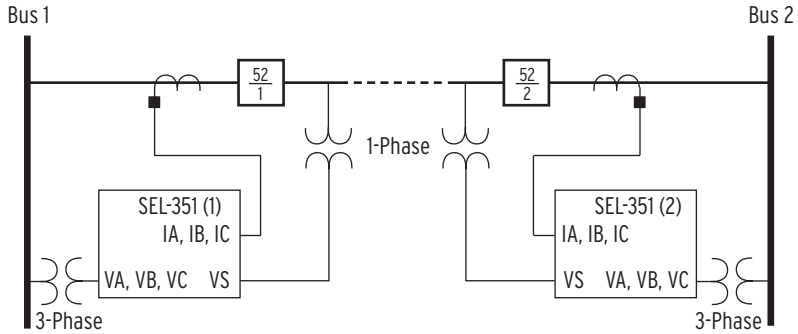


Figure 6.7 SEL-351S Relays Installed at Both Ends of a Transmission Line in a High-Speed Reclose Scheme

SEL-351S(1)

Before allowing circuit breaker 52/1 to be reclosed after an open-interval time-out, the SEL-351S(1) checks that Bus 1 voltage is hot and the transmission line voltage is dead. This requires reclose supervision settings:

79CLSD = **0.00 cycles** (only one check)

79CLS = **3P59 * 27S**

where:

3P59 = all three Bus 1 phase voltages (**VA**, **VB**, and **VC**) are hot

27S = monitored single-phase transmission line voltage (Channel **VS**) is dead

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SEL-351S(2)

The SEL-351S(2) checks that Bus 2 voltage is hot, the transmission line voltage is hot, and in synchronism after the reclosing relay open-interval times out, before allowing circuit breaker 52/2 to be reclosed. This requires reclose supervision settings:

79CLSD = **0.00 cycles** (only one check)

79CLS = **25A1**

where:

25A1 = selected Bus 2 phase voltage (**VA**, **VB**, or **VC**) is in synchronism with monitored single-phase transmission line voltage (Channel **VS**) and both are hot

Other Setting Considerations for SEL-351S(1) and SEL-351S(2)

Refer to *Skip Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively) on page 6.24*.

SELOGIC control equation setting 79STL stalls open-interval timing if it asserts to logical 1. If setting 79STL is deasserted to logical 0, open-interval timing can continue.

The SEL-351S(1) has no intentional open-interval timing stall condition (circuit breaker 52/1 closes first after a transmission line fault):

79STL = **0** (numeral 0)

The SEL-351S(2) starts open-interval timing after circuit breaker 52/1 at the remote end has reenergized the line. The SEL-351S(2) has to see Bus 2 hot, transmission line hot, and in synchronism across open circuit breaker 52/2 for open-interval timing to begin. Thus, SEL-351S(2) open-interval timing is stalled when the transmission line voltage and Bus 2 voltage are **not** in synchronism across open circuit breaker 52/2:

79STL = **!25A1 [=NOT(25A1)]**

A transient synchronism check condition across open circuit breaker 52/2 could possibly occur if circuit breaker 52/1 recloses into a fault on one phase of the transmission line. The other two unfaulted phases would be briefly energized until circuit breaker 52/1 is tripped again. If Channel **VS** of the SEL-351S(2) is connected to one of these briefly energized phases, synchronism check element 25A1 could momentarily assert to logical 1.

So that this possible momentary assertion of synchronism check element 25A1 does not cause any inadvertent reclose of circuit breaker 52/2, make sure the open-interval timers in the SEL-351S(2) are set with some appreciable time greater than the momentary energization time of the faulted transmission line. Or, run the synchronism check element 25A1 through a programmable timer before using it in the preceding 79CLS and 79STL settings for the SEL-351S(2) (see *Figure 7.25* and *Figure 7.26*). Note the built-in 3-cycle qualification of the synchronism check voltages shown in *Figure 3.26*.

Additional Settings Example 2

Refer to subsection *Synchronism Check Elements on page 3.36*. Also refer to *Figure 6.6* and *Figure 6.7*.

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If the synchronizing voltages across open circuit breaker 52/2 are “slipping” with respect to one another, the Reclose Supervision Limit Timer setting 79CLSD should be set greater than zero so there is time for the slipping voltages to come into synchronism. For example:

79CLSD = **60.00 cycles**

79CLS = **25A1**

The status of synchronism check element 25A1 is checked continuously during the 60-cycle window. If the slipping voltages come into synchronism while timer 79CLSD is timing, synchronism check element 25A1 asserts to logical 1 and reclosing proceeds.

In the above referenced subsection *Synchronism Check Elements on page 3.36*, note item 3 under *Synchronism Check Element Outputs on page 3.46*, Voltages V_P and V_S are “Slipping.” Item 3 describes a last attempt for a synchronism check reclose before timer 79CLSD times out (or setting 79CLSD = 0.00 and only one check is made).

- If E79 = 3 (which allows three automatic reclose attempts) and the slipping voltages fail to come into synchronism while timer 79CLSD is timing (resulting in a reclose supervision failure, causing RCSF to assert for one processing interval), then the reclosing relay goes to the Lockout State.
- If E79 = C3 (which allows three automatic reclose attempts) and the slipping voltages fail to come into synchronism while timer 79CLSD is timing (resulting in a reclose supervision failure, causing RCSF to assert for one processing interval), then the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay-going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not true. If the reclosing relay increments to the last shot value (no more open intervals left; see *Figure 6.9* and *Table 6.3*), the reclosing relay is then driven to the Lockout State.

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Reclosing Relay

Note that input:

Reclosing Relay Open-interval Time-Out

in *Figure 6.5* is the logic input that is qualified by SELOGIC control equation setting 79CLS, and then propagated on to the close logic in *Figure 6.1* to automatically reclose a circuit breaker. The explanation that follows in this reclosing relay subsection describes all the reclosing relay settings and logic that eventually result in this open-interval time-out logic input into *Figure 6.5*. Other aspects of the reclosing relay are also explained. Up to four (4) automatic reclosures (shots) are available.

The reclose enable setting, E79, has setting choices N, 1, 2, 3, 4, C1, C2, C3, and C4. Setting E79 = N defeats the reclosing relay. Setting choices 1 through 4 are the number of desired automatic reclosures (see *Open-Interval Timers on page 6.18*). Setting choices 1 through 4 also have the reclosing relay go to the Lockout state upon reclose supervision failure (refer to *Reclose Supervision Logic on page 6.7*).

Setting choice C1–C4 similarly are the number of desired automatic reclosures (C1 for one reclosure, C2 for two reclosures, etc.). Setting choices C1–C4, however, do not have the reclosing relay go to the Lockout state upon reclose supervision failure. Instead, the reclosing relay increments the shot counter and starts timing on the next open interval. This operation emulates a rotating drum timer style reclosing relay—going onto the next open interval time and reclose opportunity if supervising conditions for the present reclose opportunity are not true. If the reclosing relay increments to the last shot value (no more open intervals left; see *Figure 6.9* and *Table 6.3*), the reclosing relay is then driven to the Lockout State.

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Reclosing Relay States and General Operation

Figure 6.8 explains in general the different states of the reclosing relay and its operation.

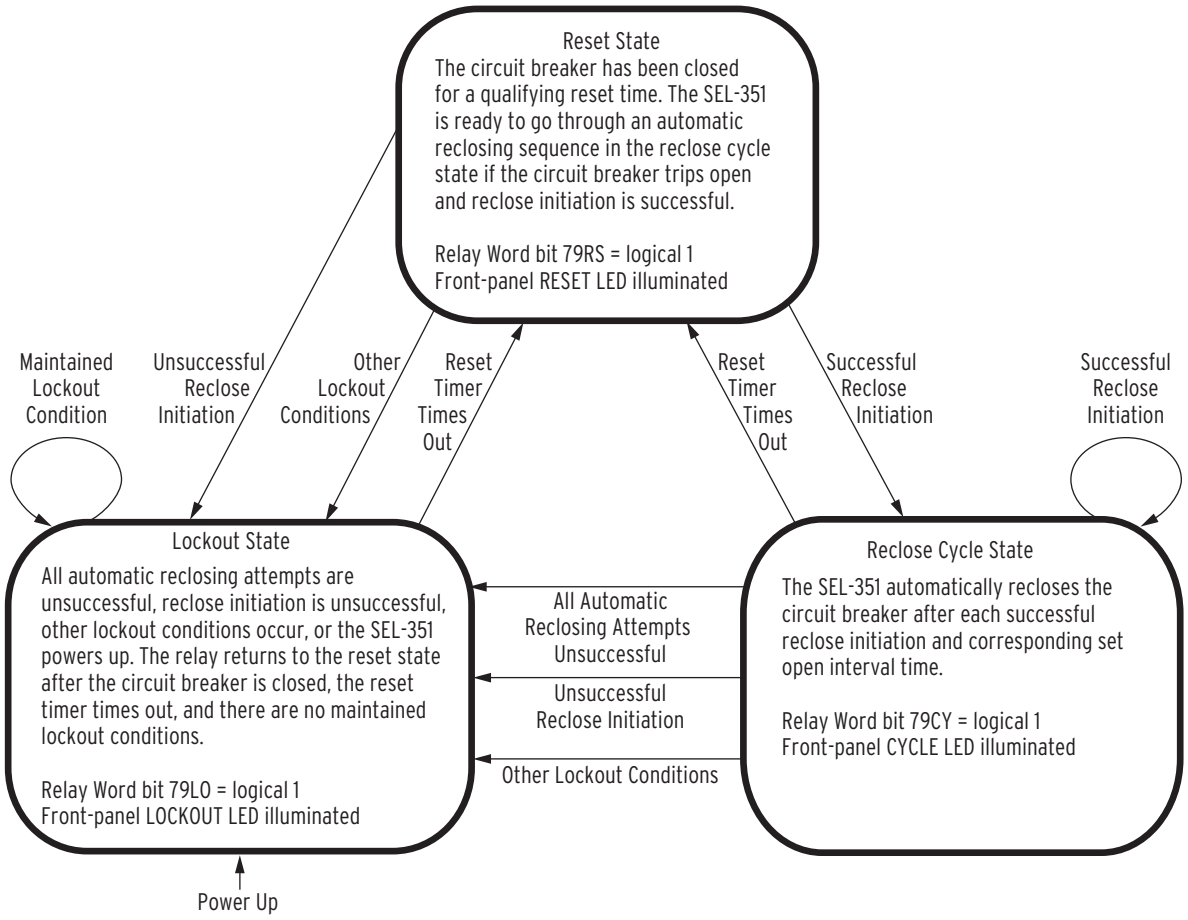


Figure 6.8 Reclosing Relay States and General Operation

Table 6.1 Relay Word Bit and Front-Panel Correspondence to Reclosing Relay States

Reclosing Relay State	Corresponding Relay Word Bit	Corresponding Front-Panel LED
Reset	79RS	RESET
Reclose Cycle	79CY	CYCLE
Lockout	79LO	LOCKOUT

The reclosing relay is in one (and only one) of these states (listed in *Table 6.1*) at any time. When in a given state, the corresponding Relay Word bit asserts to logical 1, and the LED illuminates. Automatic reclosing only takes place when the relay is in the Reclose Cycle State.

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Lockout State

The reclosing relay goes to the Lockout State if any **one** of the following occurs:

- The shot counter is equal to or greater than the last shot at time of reclose initiation (e.g., all automatic reclosing attempts are unsuccessful—see *Figure 6.9*).
- Reclose initiation is unsuccessful because of SELOGIC control equation setting 79RIS [see *Reclose Initiate and Reclose Initiate Supervision Settings (79RI and 79RIS, Respectively) on page 6.21*].
- The circuit breaker opens without reclose initiation (e.g., an external trip).

  If a trip is issued via the front-panel auxiliary trip pushbutton (model 0351S*xxx*5/6/A/B; *Figure 2.5* and *Figure 2.6*) and it is wired similar to *Figure 2.31*, then this trip appears as an external trip to the relay and the relay goes to the lockout state.
- The shot counter is equal to or greater than last shot, and the circuit breaker is open [e.g., the shot counter is driven to last shot with SELOGIC control equation setting 79DLS while open-interval timing is in progress. See *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively) on page 6.23*].
- The close failure timer (setting CFD) times out (see *Figure 6.1*).
- SELOGIC control equation setting 79DTL = logical 1 [see *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively) on page 6.23*].
- The Reclose Supervision Limit Timer (setting 79CLSD) times out (see *Figure 6.2* and top of *Figure 6.3*) and the reclose enable setting, E79, has setting choices 1, 2, 3, or 4.
- A new reclose initiation occurs while the reclosing relay is timing on an open interval (e.g., flashover in the tank while breaker is open).

Reclosing Relay States and Settings/ Setting Group Changes

If individual settings are changed for the active setting group **or** the active setting group is changed, **all** of the following occur:

- The reclosing relay remains in the state it was in before the settings change.
- The shot counter is driven to last shot (last shot corresponding to the new settings; see discussion on last shot that follows).
- The reset timer is loaded with reset time setting 79RSLD (see discussion on reset timing later in this section).

If the relay happened to be in the Reclose Cycle State and was timing on an open-interval before the settings change, the relay would be in the Reclose Cycle State after the settings change, but the relay would immediately go to the Lockout State. This is because the breaker is open, and the relay is at last shot after the settings change, and thus no more automatic reclosures are available.

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If the circuit breaker remains closed through the settings change, the reset timer times out on reset time setting 79RSLD after the settings change and goes to the Reset State (if it is not already in the Reset State), and the shot counter returns to shot = 0. If the relay happens to trip during this reset timing, the relay will immediately go to the Lockout State, because shot = last shot.

Defeat the Reclosing Relay

If **any one** of the following reclosing relay settings are made:

- Reclose enable setting E79 = N
- Open-interval 1 time setting 79OI1 = 0.00

then the reclosing relay is defeated, and no automatic reclosing can occur. These settings are explained later in this section. See also the settings sheets at the end of *Section 9: Setting the Relay*.

If the reclosing relay is defeated, the following also occur:

- All three reclosing relay state Relay Word bits (79RS, 79CY, and 79LO) are forced to logical 0 (see *Table 6.1*).
- All shot counter Relay Word bits (SH0, SH1, SH2, SH3, and SH4) are forced to logical 0 (the shot counter is explained later in this section).
- The front-panel LEDs **RESET**, **CYCLE**, and **LOCKOUT** are all extinguished—a ready indication that the recloser is defeated.

Close Logic Can Still Operate When the Reclosing Relay is Defeated

If the reclosing relay is defeated, the close logic (see *Figure 6.1*) can still operate if SELOGIC control equation circuit breaker status setting 52A is set to something other than numeral 0. Making the setting 52A = 0 defeats the close logic **and** also defeats the reclosing relay.

For example, if 52A = IN101, a 52a circuit breaker auxiliary contact is connected to input **IN101**. If the reclosing relay does not exist, the close logic still operates, allowing closing to take place via SELOGIC control equation setting CL (close conditions, other than automatic reclosing). See *Close Logic on page 6.2* for more discussion on SELOGIC control equation settings 52A and CL. Also see *Optoisolated Inputs on page 7.2* for more discussion on SELOGIC control equation setting 52A.

Reclosing Relay Timer Settings

The open-interval and reset timer factory settings are shown in *Table 6.2*:

Table 6.2 Reclosing Relay Timer Settings and Setting Ranges

Timer Setting (range)	Factory Setting (in cycles)	Definition
79OI1 (0.00–999999 cyc)	300.00	open-interval 1 time
79OI2 (0.00–999999 cyc)	0.00	open-interval 2 time
79OI3 (0.00–999999 cyc)	0.00	open-interval 3 time
79OI4 (0.00–999999 cyc)	0.00	open-interval 4 time
79RSD (0.00–999999 cyc)	1800.00	reset time from reclose cycle state
79RSLD (0.00–999999 cyc)	300.00	reset time from lockout state

The operation of these timers is affected by SELOGIC control equation settings discussed later in this section. Also see the settings sheets at the end of *Section 9: Setting the Relay*.

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Open-Interval Timers

The reclose enable setting, E79, determines the number of open-interval time settings that can be set. For example, if setting E79 = 3, the first three open-interval time settings in *Table 6.2* are made available for setting.

If an open-interval time is set to zero, then that open-interval time is not operable, **and** neither are the open-interval times that follow it.

In the factory settings in *Table 6.2*, the open-interval 2 time setting 79OI2 is the first open-interval time setting set equal to zero:

79OI2 = **0.00 cycles**

Thus, open-interval times 79OI2, 79OI3, and 79OI4 are not operable. In the factory settings, both open-interval times 79OI3 and 79OI4 are set to zero. But if the settings were:

79OI2 = **0.00 cycles**

79OI3 = **900.00 cycles** (set to some value other than zero)

open-interval time 79OI3 would still be inoperative, because a preceding open-interval time is set to zero (i.e., 79OI2 = 0.00).

If open-interval 1 time setting, 79OI1, is set to zero (79OI1 = 0.00 cycles), no open-interval timing takes place, and the reclosing relay is defeated.

The open-interval timers time consecutively; they do not have the same beginning time reference point. In the *Figure 6.9* example, open-interval 1 time setting, 79OI1 = 30, times first. If the subsequent first reclosure is not successful, then open-interval 2 time setting, 79OI2 = 600, starts timing. If the subsequent second reclosure is not successful, the relay goes to the Lockout State. See the example time line in *Figure 6.9*.

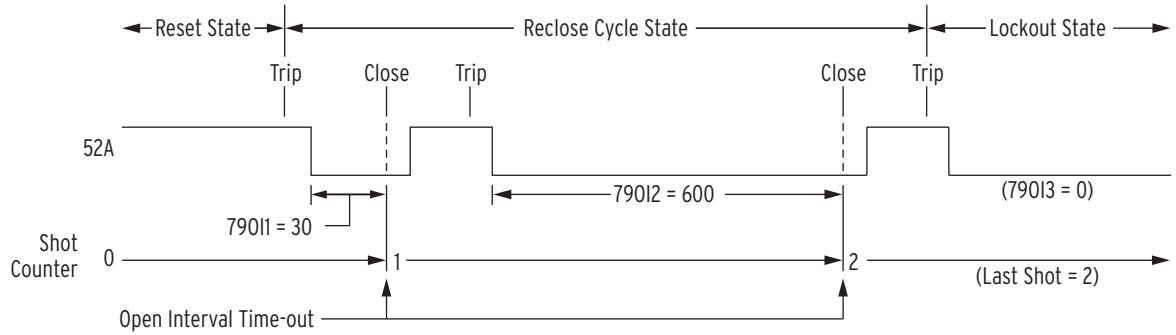


Figure 6.9 Example Reclosing Sequence From Reset to Lockout

SELOGIC control equation setting 79STL (stall open-interval timing) can be set to control open-interval timing [see *Skip Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively) on page 6.24*].

Determination of Number of Reclosures (Last Shot)

The number of reclosures is equal to the number of open-interval time settings that precede the first open-interval time setting set equal to zero. The "last shot" value is also equal to the number of reclosures.

In the *Figure 6.9* example, two set open-interval times precede open-interval 3 time, which is set to zero (79OI3 = 0.00):

79OI1 = **30.00**

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79012 = **600.00**
79013 = **0.00**

For this example:

Number of reclosures (last shot) = 2 = the number of set open-interval times that precede the first open-interval set to zero.

Observe Shot Counter Operation

Observe the reclosing relay shot counter operation, especially during testing, with the front-panel shot counter screen (accessed via the **{OTHER}** pushbutton). See *Functions Unique to the Front-Panel Interface on page 11.6*.

Reset Timer

The reset timer qualifies circuit breaker closure before taking the relay to the Reset State from the Reclose Cycle State or the Lockout State. Circuit breaker status is determined by the SELOGIC control equation setting 52A. (See *Close Logic on page 6.2* for more discussion on SELOGIC control equation setting 52A. Also see *Optoisolated Inputs on page 7.2* for more discussion on SELOGIC control equation setting 52A.)

Setting 79RSD:

Qualifies closures when the relay is in the Reclose Cycle State. These closures are usually automatic reclosures resulting from open-interval time-out.

It is also the reset time used in sequence coordination schemes [see *Sequence Coordination Setting (79SEQ) on page 6.28*].

Setting 79RSLD:

Qualifies closures when the relay is in the Lockout State. These closures are usually manual closures. These manual closures can originate external to the relay, via the **CLOSE** command, or via the SELOGIC control equation setting CL (see *Figure 6.1*).

Setting 79RSLD is also the reset timer used when the relay powers up, has individual settings changed for the active setting group, or the active setting group is changed (see *Reclosing Relay States and Settings/Setting Group Changes on page 6.16*).

Typically, setting 79RSLD is set less than setting 79RSD. Setting 79RSLD emulates reclosing relays with motor-driven timers that have a relatively short reset time from the lockout position to the reset position.

The 79RSD and 79RSLD settings are set independently (setting 79RSLD can even be set greater than setting 79RSD, if desired). SELOGIC control equation setting 79BRS (block reset timing) can be set to control reset timing [see *Block Reset Timing Setting (79BRS) on page 6.27*].

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Monitoring Open-interval and Reset Timing

Open-interval and reset timing can be monitored with the following Relay Word bits:

Relay Word Bits	Definition
OPTMN	Indicates that the open-interval timer is **actively** timing
RSTMN	Indicates that the reset timer is **actively** timing

If the open-interval timer is actively timing, OPTMN asserts to logical 1. When the relay is not timing on an open-interval (e.g., it is in the Reset State or in the Lockout State), OPTMN deasserts to logical 0. The relay can only time on an open-interval when it is in the Reclose Cycle State, but just because the relay is in the Reclose Cycle State does not necessarily mean the relay is timing on an open-interval. The relay only times on an open-interval after successful reclose initiation and no stall conditions are present [see *Skip Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively) on page 6.24*].

If the reset timer is actively timing, RSTMN asserts to logical 1. If the reset timer is not timing, RSTMN deasserts to logical 0. See *Block Reset Timing Setting (79BRS) on page 6.27*.

Reclosing Relay Shot Counter

Refer to *Figure 6.9*.

The shot counter increments for each reclose operation. For example, when the relay is timing on open-interval 1, 79OI1, it is at shot = 0. When the open-interval times out, the shot counter increments to shot = 1 and so forth for the set open-intervals that follow. The shot counter cannot increment beyond the last shot for automatic reclosing [see *Determination of Number of Reclosures (Last Shot) on page 6.18*]. The shot counter resets back to shot = 0 when the reclosing relay returns to the Reset State.

Table 6.3 Shot Counter Correspondence to Relay Word Bits and Open-interval Times

Shot	Corresponding Relay Word Bit	Corresponding Open-Interval
0	SH0	79OI1
1	SH1	79OI2
2	SH2	79OI3
3	SH3	79OI4
4	SH4	

When the shot counter is at a particular shot value (e.g., shot = 2), the corresponding Relay Word bit asserts to logical 1 (e.g., SH2 = logical 1).

The shot counter also increments for sequence coordination operation. The shot counter can increment beyond the last shot for sequence coordination [see *Sequence Coordination Setting (79SEQ) on page 6.28*].

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Reclosing Relay SELOGIC Control Equation Settings Overview

Table 6.4 Reclosing Relay SELOGIC Control Equation Settings

SELOGIC Control Equation Setting	Factory Setting	Definition
79RI	TRIP	Reclose Initiate
79RIS	52A + 79CY	Reclose Initiate Supervision
79DTL	(!LT2 + !LT5)*(TRIP + !52A) + PB10 + OC	Drive-to-Lockout
79DLS	79LO	Drive-to-Last Shot
79SKP	0	Skip Shot
79STL	TRIP	Stall Open-Interval Timing
79BRS	0	Block Reset Timing
79SEQ	0	Sequence Coordination
79CLS	1	Reclose Supervision

NOTE: For model 0351Sxxx5/6/A/B, PB10 does not appear in the 79DTL factory default settings.

The settings in *Table 6.4* are discussed in detail in the remainder of this section.

Reclose Initiate and Reclose Initiate Supervision Settings (79RI and 79RIS, Respectively)

The reclose initiate setting 79RI is a rising-edge detect setting. The reclose initiate supervision setting 79RIS supervises setting 79RI. When setting 79RI senses a rising edge (logical 0 to logical 1 transition), setting 79RIS has to be at logical 1 (79RIS = logical 1) in order for open-interval timing to be initiated.

If 79RIS = logical 0 when setting 79RI senses a rising edge (logical 0 to logical 1 transition), the relay goes to the Lockout State.

Factory Settings Example

With factory settings:

79RI = **TRIP**

79RIS = **52A + 79CY**

the transition of the TRIP Relay Word bit from logical 0 to logical 1 initiates open-interval timing only if the 52A + 79CY Relay Word bit is at logical 1 (52A = logical 1, or 79CY = logical 1). Input **IN101** is assigned as the breaker status input in the factory settings (52A = IN101).

The circuit breaker has to be closed (circuit breaker status 52A = logical 1) at the instant of the first trip of the auto-reclose cycle in order for the SEL-351S to successfully initiate reclosing and start timing on the first open-interval. The SEL-351S is not yet in the reclose cycle state (79CY = logical 0) at the instant of the first trip.

Then for any subsequent trip operations in the auto-reclose cycle, the SEL-351S is in the reclose cycle state (79CY = logical 1) and the SEL-351S successfully initiates reclosing for each trip. Because of factory setting 79RIS = 52A + 79CY, successful reclose initiation in the reclose cycle state (79CY = logical 1) is not dependent on the circuit breaker status (52A). This allows successful reclose initiation for the case of an instantaneous trip, but the circuit breaker status indication is slow—the instantaneous trip (reclose initiation) occurs before the SEL-351S sees the circuit breaker close.

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If a flashover occurs in a circuit breaker tank during an open-interval (circuit breaker open and the SEL-351S calls for a trip), the SEL-351S goes immediately to lockout.

Additional Settings Example

The preceding settings example initiates open-interval timing on rising edge of the TRIP Relay Word bit. The following is an example of reclose initiation on the opening of the circuit breaker.

Presume input **IN101** is connected to a 52a circuit breaker auxiliary contact (52A = IN101).

With setting:

79RI = **!52A**

the transition of the 52A Relay Word bit from logical 1 to logical 0 (breaker opening) initiates open-interval timing. Setting 79RI looks for a logical 0 to logical 1 transition, thus Relay Word bit 52A is inverted in the 79RI setting [!52A = NOT(52A)].

The reclose initiate supervision setting 79RIS supervises setting 79RI. With settings:

79RI = **!52A**

79RIS = **TRIP**

the transition of the 52A Relay Word bit from logical 1 to logical 0 initiates open-interval timing only if the TRIP Relay Word bit is at logical 1 (TRIP = logical 1). Thus, the TRIP Relay Word bit has to be asserted when the circuit breaker opens in order to initiate open-interval timing. With a long enough setting of the Minimum Trip Duration Timer (TDURD), the TRIP Relay Word bit will still be asserted to logical 1 when the circuit breaker opens (see *Figure 5.1* and *Figure 5.2*).

If the TRIP Relay Word bit is at logical 0 (TRIP = logical 0) when the circuit breaker opens (logical 1 to logical 0 transition), the relay goes to the Lockout State. This helps prevent reclose initiation for circuit breaker openings caused by trips external to the relay.

If circuit breaker status indication (52A) is slow, additional setting change ULCL = 0 (unlatch close; refer to *Figure 6.1* and accompanying explanation) may need to be made when 79RI = !52A. ULCL = 0 avoids going to lockout prematurely for an instantaneous trip after an auto-reclose by not turning CLOSE off until the circuit breaker status indication tells the relay that the breaker is closed. The circuit breaker anti-pump circuitry should take care of the TRIP and CLOSE being on together for a short period of time.

Other Settings Considerations

1. In the preceding additional setting example, the reclose initiate setting (79RI) includes input **IN101**, that is connected to a 52a breaker auxiliary contact (52A = IN101).

   79RI = **!52A**

   If a 52b breaker auxiliary contact is connected to input **IN101** (52A = !IN101), the reclose initiate setting (79RI) remains the same.

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2. If no reclose initiate supervision is desired, make the following setting:

   79RIS = **1** (numeral 1)

   Setting 79RIS = logical 1 at all times. Any time a logical 0 to logical 1 transition is detected by setting 79RI, open-interval timing will be initiated (unless prevented by other means).

3. If the following setting is made:

   79RI = **0** (numeral 0)

   reclosing will never take place (reclosing is never initiated). The reclosing relay is effectively inoperative.

4. If the following setting is made:

   79RIS = **0** (numeral 0)

   reclosing will never take place (the reclosing relay goes directly to the lockout state any time reclosing is initiated). The reclosing relay is effectively inoperative.

NOTE: For 0351Sxxx5/6/A/B models, setting combination:
79RI = !52A
79RIS = 1
is not recommended because it allows reclosing when the auxiliary **{TRIP}** pushbutton is pressed. The auxiliary **{TRIP}** pushbutton is electrically separate from the rest of the relay and not part of the trip logic in Figure 5.1. It provides separate tripping capability as shown in Figure 2.31.

Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively)

When 79DTL = logical 1, the reclosing relay goes to the Lockout State (Relay Word bit 79LO = logical 1), and the front-panel **LOCKOUT** LED illuminates.

79DTL has a 60-cycle dropout time. This keeps the drive-to-lockout condition up 60 more cycles after 79DTL has reverted back to 79DTL = logical 0. This is useful for situations where both of the following are true:

- Any of the trip and drive-to-lockout conditions are "pulsed" conditions (e.g., the **OPEN** Command Relay Word bit, OC, asserts for only 1/4 cycle—refer to the following *Factory Settings Example on page 6.25*).
- Reclose initiation is by the breaker contact opening (e.g., 79RI = !52A—refer to *Additional Settings Example 1 on page 6.24* in the preceding setting 79RI [reclose initiation] discussion).

Then the drive-to-lockout condition overlaps reclose initiation and the SEL-351S stays in lockout after the breaker trips open.

When 79DLS = logical 1, the reclosing relay goes to the last shot, if the shot counter is not at a shot value greater than or equal to the calculated last shot (see *Reclosing Relay Shot Counter on page 6.20*).

Factory Settings Example

The drive-to-lockout factory setting is:

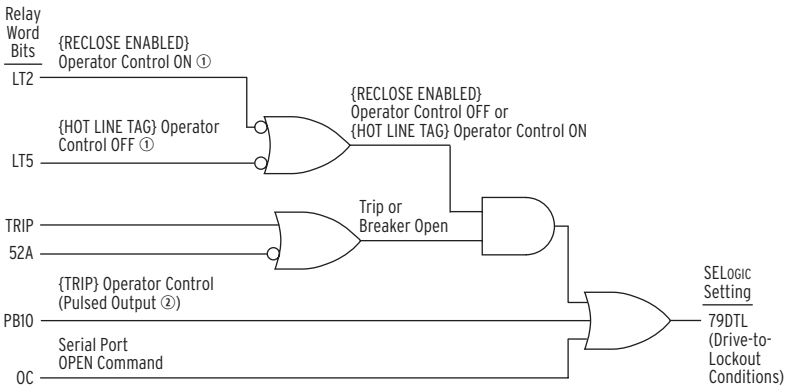
79DTL = **(!LT2 + !LT5)*(TRIP + !52A) + PB10 + OC**

NOTE: PB10 does not appear in the factory default settings for model 0351Sxxx5/6/A/B.

Figure 6.10 shows in more detail the programmed conditions that drive the reclosing relay to lockout:

- If either the **{RECLOSE ENABLED}** operator control is OFF or the **{HOT LINE TAG}** operator control is ON **and** a trip occurs or the breaker opens, the reclosing relay is driven to lockout.
- If the **{TRIP}** operator control is pressed or an **OPEN** command is sent to the serial port, the reclosing relay is driven to lockout. Both these operations are deemed "manual operations," thus no auto-reclosing takes place.

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① See Figure 11.15, ② see Figure 11.13.

Figure 6.10 Factory-Default Drive-to-Lockout Logic

NOTE: PB10 does not appear in the factory default settings for model 0351Sxxx5/6/A/B.

The drive-to-last shot factory setting is:

79DLS = **79LO**

One open-interval is also set in the factory settings, resulting in last shot = 1. Any time the relay is in the lockout state (Relay Word bit 79LO = logical 1), the relay is driven to last shot (if the shot counter is not already at a shot value greater than or equal to shot = 1):

79DLS = **79LO** = logical 1

Additional Settings Example 1

To drive the relay to the Lockout State for fault current above a certain level when tripping (e.g., level of phase instantaneous overcurrent element 50P3), make settings similar to the following:

79DTL = **TRIP * 50P3 + ...**

Additionally, if the reclosing relay should go to the Lockout State for an underfrequency trip, make settings similar to the following:

79DTL = **81D1T + ...**

Other Settings Considerations

If no special drive-to-lockout or drive-to-last shot conditions are desired, make the following settings:

79DTL = **0** (numeral 0)

79DLS = **0** (numeral 0)

With settings 79DTL and 79DLS inoperative, the relay still goes to the Lockout State (and to last shot) if an entire automatic reclose sequence is unsuccessful.

Overall, settings 79DTL or 79DLS are needed to take the relay to the Lockout State (or to last shot) for immediate circumstances.

Skip Shot and Stall Open-Interval Timing Settings (79SKP and 79STL, Respectively)

The skip shot setting 79SKP causes a reclose shot to be skipped. Thus, an open-interval time is skipped, and the next open-interval time is used instead.

If 79SKP = logical 1 at the instant of successful reclose initiation (see preceding discussion on settings 79RI and 79RIS), the relay increments the shot counter to the next shot and then loads the open-interval time

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corresponding to the new shot (see *Table 6.3*). If the new shot is the "last shot," no open-interval timing takes place, and the relay goes to the Lockout State if the circuit breaker is open (see *Lockout State on page 6.16*).

After successful reclose initiation, open-interval timing does not start until allowed by the stall open-interval timing setting 79STL. If 79STL = logical 1, open-interval timing is stalled. If 79STL = logical 0, open-interval timing can proceed.

If an open-interval time has not yet started timing (79STL = logical 1 still), the 79SKP setting is still processed. In such conditions (open-interval timing has not yet started timing), if 79SKP = logical 1, the relay increments the shot counter to the next shot and then loads the open-interval time corresponding to the new shot (see *Table 6.3*). If the new shot turns out to be the "last shot," no open-interval timing takes place, and the relay goes to the Lockout State if the circuit breaker is open (see *Lockout State on page 6.16*).

If the relay is in the middle of timing on an open interval and 79STL changes state to 79STL = logical 1, open-interval timing stops where it is. If 79STL changes state back to 79STL = logical 0, open-interval timing resumes where it left off. Use the OPTMN Relay Word bit to monitor open-interval timing (see *Monitoring Open-interval and Reset Timing on page 6.20*).

Factory Settings Example

The skip shot function is not enabled in the factory settings:

79SKP = **0** (numeral 0)

The stall open-interval timing factory setting is:

79STL = **TRIP**

After successful reclose initiation, open-interval timing does not start as long as the trip condition is present (Relay Word bit TRIP = logical 1). As discussed previously, if an open-interval time has not yet started timing (79STL = logical 1 still), the 79SKP setting is still processed. Once the trip condition goes away (Relay Word bit TRIP = logical 0), open-interval timing can proceed.

Additional Settings Example 1

With skip shot factory setting:

79SKP = **50P2 * SH0**

if shot = 0 (Relay Word bit SH0 = logical 1) **and** phase current is above the phase instantaneous overcurrent element 50P2 threshold (Relay Word bit 50P2 = logical 1), at the instant of successful reclose initiation, the shot counter is incremented from shot = 0 to shot = 1. Then, open-interval 1 time (setting 79OI1) is skipped, and the relay times on the open-interval 2 time (setting 79OI2) instead.

Table 6.5 Example Open-Interval Time Settings

Shot	Corresponding Relay Word Bit	Corresponding Open Interval	Open-Interval Time Setting
0	SH0	79OI1	30 cycles
1	SH1	79OI2	600 cycles

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In *Table 6.5*, note that the open-interval 1 time (setting 79OI1) is a short time, while the following open-interval 2 time (setting 79OI2) is significantly longer. For a high magnitude fault (greater than the phase instantaneous overcurrent element 50P2 threshold), open-interval 1 time is skipped, and open-interval timing proceeds on the following open-interval 2 time.

Once the shot is incremented to shot = 1, Relay Word bit SH0 = logical 0 and then setting 79SKP = logical 0, regardless of Relay Word bit 50P2.

Additional Settings Example 2

If the SEL-351S is used on a feeder with a line-side independent power producer (cogenerator), the utility should not reclose into a line still energized by an islanded generator. To monitor line voltage and block reclosing, connect a line-side single-phase potential transformer to Channel **VS** on the SEL-351S as shown in *Figure 6.11*.

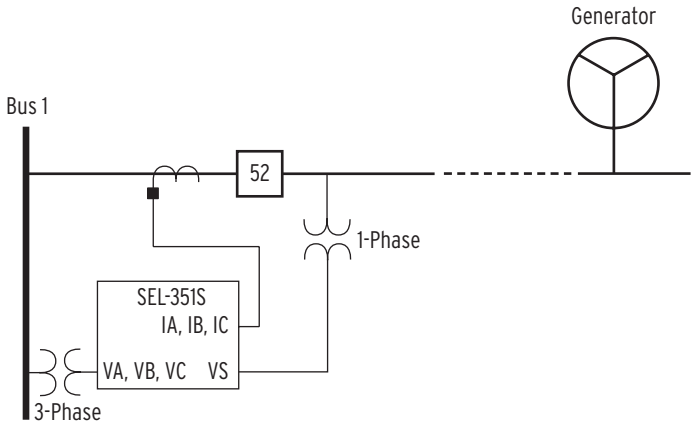


Figure 6.11 Reclose Blocking for Islanded Generator

If the line is energized, channel **VS** overvoltage element 59S1 can be set to assert. Make the following setting:

79STL = **59S1 + ...**

If line voltage is present, Relay Word bit 59S1 asserts, stalling open-interval timing (reclose block). If line voltage is not present, Relay Word bit 59S1 deasserts, allowing open-interval timing to proceed (unless some other set condition stalls open-interval timing).

Additional Settings Example 3

Refer to *Figure 6.7* and accompanying setting example, showing an application for setting 79STL.

Other Settings Considerations

If no special skip shot or stall open-interval timing conditions are desired, make the following settings:

79SKP = **0** (numeral 0)

79STL = **0** (numeral 0)

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Block Reset Timing Setting (79BRS)

The block reset timing setting 79BRS keeps the reset timer from timing. Depending on the reclosing relay state, the reset timer can be loaded with either reset time:

79RSD (Reset Time from Reclose Cycle)

or

79RSLD (Reset Time from Lockout)

Depending on how setting 79BRS is set, none, one, or both of these reset times can be controlled. If the reset timer is timing and then 79BRS asserts to:

79BRS = logical 1

reset timing is stopped and does not begin timing again until 79BRS deasserts to:

79BRS = logical 0

When reset timing starts again, the reset timer is fully loaded. Thus, successful reset timing has to be continuous. Use the RSTMN Relay Word bit to monitor reset timing (see *Monitoring Open-interval and Reset Timing on page 6.20*).

Factory Settings Example

The block reset function is not enabled in the factory settings:

79BRS = **0** (numeral 0)

Additional Settings Example 1

The block reset timing setting is:

79BRS = **(51P1 + 51G1) * 79CY**

Relay Word bit 79CY corresponds to the Reclose Cycle State. The reclosing relay is in one of the three reclosing relay states at any one time (see *Figure 6.8* and *Table 6.1*).

When the relay is in the Reset or Lockout States, Relay Word bit 79CY is deasserted to logical 0. Thus, the 79BRS setting has no effect when the relay is in the Reset or Lockout States. When a circuit breaker is closed from lockout, there could be cold load inrush current that momentarily picks up a time-overcurrent element [e.g., phase time-overcurrent element 51P1T pickup (51P1) asserts momentarily]. But, this assertion of pickup 51P1 has no effect on reset timing because the relay is in the Lockout State (79CY = logical 0). The relay will time immediately on reset time 79RSLD and take the relay from the Lockout State to the Reset State with no additional delay because 79BRS is deasserted to logical 0.

When the relay is in the Reclose Cycle State, Relay Word bit 79CY is asserted to logical 1. Thus, the factory 79BRS setting can function to block reset timing if time-overcurrent pickup 51P1 or 51G1 is picked up while the relay is in the Reclose Cycle State. This helps prevent repetitive “trip-reclose” cycling.

Additional Settings Example 2

If the block reset timing setting is:

79BRS = **51P1 + 51G1**

then reset timing is blocked if time-overcurrent pickup 51P1 or 51G1 is picked up, regardless of the reclosing relay state.

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Sequence Coordination Setting (79SEQ)

The sequence coordination setting 79SEQ keeps the relay in step with a downstream line recloser in a sequence coordination scheme, which prevents overreaching SEL-351S overcurrent elements from tripping for faults beyond the line recloser. This is accomplished by incrementing the shot counter and supervising overcurrent elements with resultant shot counter elements.

In order for the sequence coordination setting 79SEQ to increment the shot counter, **both** the following conditions must be true:

No trip present (Relay Word bit TRIP = logical 0)

Circuit breaker closed (SELOGIC control equation setting 52A = logical 1, effectively)

The sequence coordination setting 79SEQ is usually set with some overcurrent element pickups. If the above two conditions are both true, and a set overcurrent element pickup asserts for at least 1.25 cycles and then deasserts, the shot counter increments by one count. This assertion/deassertion indicates that a downstream device (e.g., line recloser—see *Figure 6.12*) has operated to clear a fault. Incrementing the shot counter keeps the SEL-351S "in step" with the downstream device, as is shown in the following *Additional Settings Example 1 on page 6.28* and *Additional Settings Example 2 on page 6.30*.

Every time a sequence coordination operation occurs, the shot counter is incremented, and the reset timer is loaded up with reset time 79RSD. Sequence coordination can increment the shot counter beyond last shot, but no further than shot = 4. The shot counter returns to shot = 0 after the reset timer times out. Reset timing is subject to SELOGIC control equation setting 79BRS [see *Block Reset Timing Setting (79BRS) on page 6.27*].

Sequence coordination operation does not change the reclosing relay state. For example, if the relay is in the Reset State and there is a sequence coordination operation, it remains in the Reset State.

Factory Settings Example

Sequence coordination is not enabled in the factory settings:

79SEQ = **0**

Additional Settings Example 1

With sequence coordination setting:

79SEQ = **79RS * 51P1**

sequence coordination is operable only when the relay is in the Reset State (79RS = logical 1). Refer to *Figure 6.12* and *Figure 6.13*.

Assume that the line recloser is set to operate twice on the fast curve and then twice on the slow curve. The slow curve is allowed to operate after two fast curve operations because the fast curves are then inoperative for tripping. The SEL-351S phase time-overcurrent element 51PT is coordinated with the line recloser fast curve. The SEL-351S phase time-overcurrent element 51P2T is coordinated with the line recloser slow curve.

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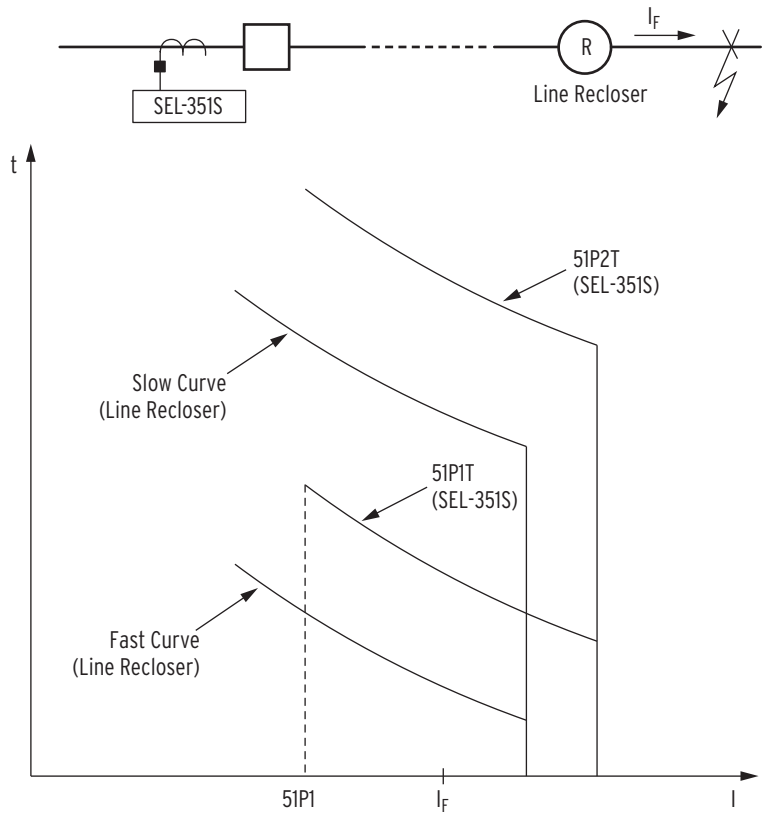
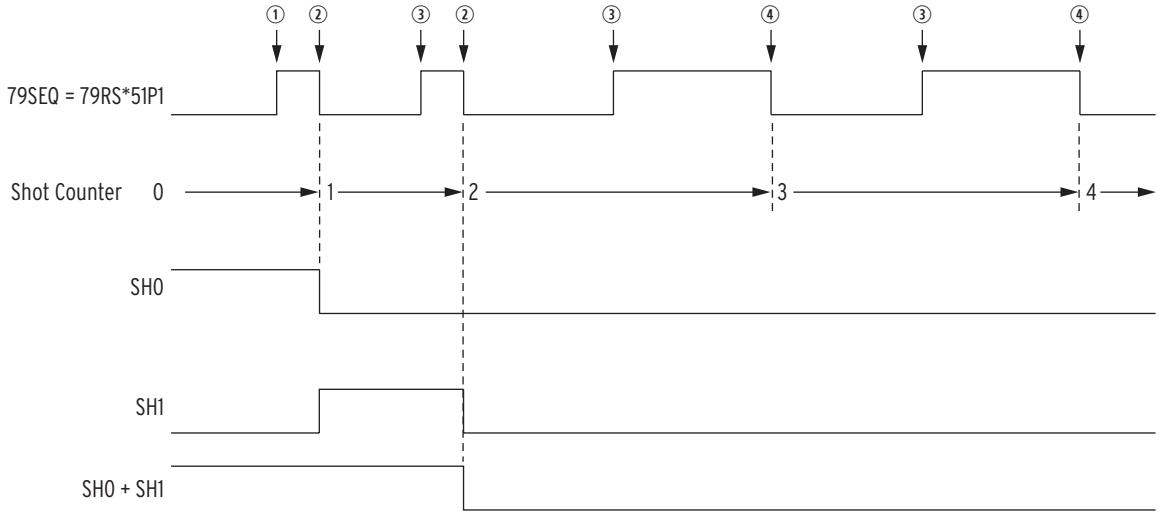


Figure 6.12 Sequence Coordination Between the SEL-351S and a Line Recloser



① Fault occurs beyond line recloser; ② fault cleared by line recloser fast curve; ③ line recloser recloses into fault; ④ fault cleared by line recloser slow curve.

Figure 6.13 Operation of SEL-351S Shot Counter for Sequence Coordination With Line Recloser (Additional Settings Example 1)

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If the SEL-351S is in the Reset State (79RS = logical 1) and then a permanent fault beyond the line recloser occurs (fault current I_F in *Figure 6.12*), the line recloser fast curve operates to clear the fault. The SEL-351S also sees the fault. The phase time-overcurrent pickup 51P1 asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 0 to shot = 1

When the line recloser recloses its circuit breaker, the line recloser fast curve operates again to clear the fault. The SEL-351S also sees the fault again. The phase time-overcurrent pickup 51P1 asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 1 to shot = 2

The line recloser fast curve is now disabled after operating twice. When the line recloser recloses its circuit breaker, the line recloser slow curve operates to clear the fault. The relay does not operate on its faster-set phase time-overcurrent element 51P1T (51P1T is "below" the line recloser slow curve) because the shot counter is now at shot = 2. For this sequence coordination scheme, the SELOGIC control equation trip equation is:

TR = **51P1T * (SH0 + SH1) + 51P2T**

With the shot counter at shot = 2, Relay Word bits SH0 (shot = 0) and SH1 (shot = 1) are both deasserted to logical 0. This keeps the 51P1T phase time-overcurrent element from tripping. The 51P1T phase time-overcurrent element is still operative, and its pickup (51P1) can still assert and then deassert, thus continuing the sequencing of the shot counter to shot = 3, etc. The 51P1T phase time-overcurrent element cannot cause a trip because shot ≥ 2, and SH0 and SH1 both are deasserted to logical 0.

The shot counter returns to shot = 0 after the reset timer (loaded with reset time 79RSD) times out.

NOTE: Sequence coordination can increment the shot counter beyond last shot in this example (last shot = 2 in this factory setting example) but no further than shot = 4.

The following Example 2 limits sequence coordination shot counter incrementing.

Additional Settings Example 2

Review preceding Example 1.

Assume that the line recloser in *Figure 6.12* is set to operate twice on the fast curve and then twice on the slow curve for faults beyond the line recloser.

Assume that the SEL-351S is set to operate once on 51P1T and then twice on 51P2T for faults between the SEL-351S and the line recloser. This results in the following trip setting:

TR = **51P1T * SH0 + 51P2T**

This requires that two open-interval settings be made (see *Table 6.2* and *Figure 6.9*). This corresponds to the last shot being:

last shot = 2

If the sequence coordination setting is:

79SEQ = **79RS * 51P1**

and there is a permanent fault beyond the line recloser, the shot counter of the SEL-351S will increment all the way to shot = 4 (see *Figure 6.13*). If there is a coincident fault **between** the SEL-351S and the line recloser, the SEL-351S will trip and go to the Lockout State. Any time the shot counter is at a value equal to or greater than last shot and the relay trips, it goes to the Lockout State.

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To avoid this problem, make the following sequence coordination setting:

79SEQ = **79RS * 51P1 * SH0**

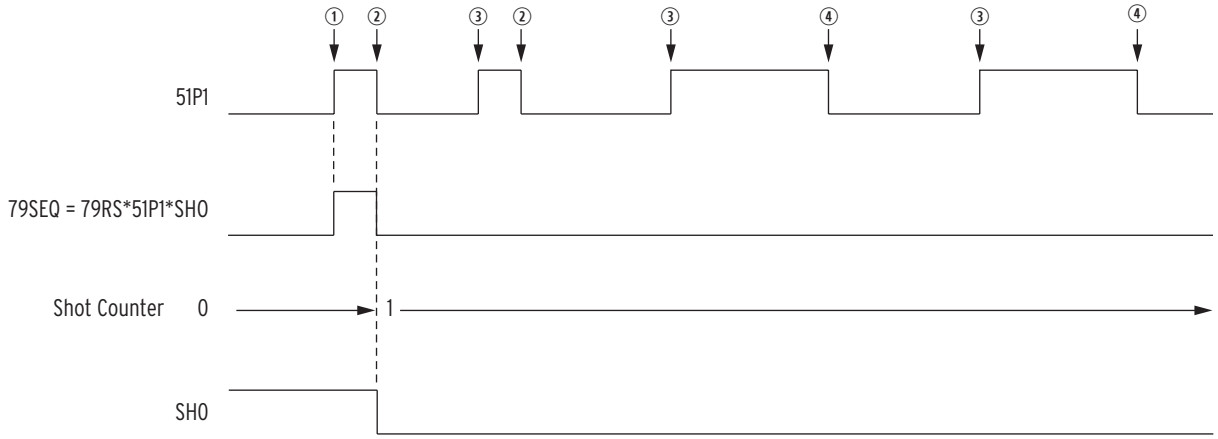
Refer to *Figure 6.14*.

If the SEL-351S is in the Reset State (79RS = logical 0) with the shot counter reset (shot = 0; SH0 = logical 1) and then a permanent fault beyond the line recloser occurs (fault current I_F in *Figure 6.12*), the line recloser fast curve operates to clear the fault. The SEL-351S also sees the fault. The phase time-overcurrent pickup 51P1 asserts and then deasserts without tripping, incrementing the relay shot counter from:

shot = 0 to shot = 1

Now the SEL-351S cannot operate on its faster-set phase time-overcurrent element 51P1T because the shot counter is at shot = 1 (SH0 = logical 0):

TR = **51P1T * SH0 + 51P2T** = 51P1T * (logical 0) + 51P2T = 51P2T



① Fault occurs beyond line recloser; ② fault cleared by line recloser fast curve; ③ line recloser recloses into fault; ④ fault cleared by line recloser slow curve.

Figure 6.14 Operation of SEL-351S Shot Counter for Sequence Coordination With Line Recloser (Additional Settings Example 2)

The line recloser continues to operate for the permanent fault beyond it, but the SEL-351S shot counter does not continue to increment. Sequence coordination setting 79SEQ is effectively disabled by the shot counter incrementing from shot = 0 to shot = 1.

79SEQ = **79RS * 51P1 * SH0** = 79RS * 51P1 * (logical 0) = logical 0

The shot counter stays at shot = 1.

Thus, if there is a coincident fault between the SEL-351S and the line recloser, the SEL-351S will operate on 51P2T and then reclose once, instead of going straight to the Lockout State (shot = 1 < last shot = 2).

As stated earlier, the reset time setting 79RSD takes the shot counter back to shot = 0 after a sequence coordination operation increments the shot counter. Make sure that reset time setting 79RSD is set long enough to maintain the shot counter at shot = 1 as shown in *Figure 6.14*.

Reclose Supervision Setting (79CLS)

See *Reclose Supervision Logic on page 6.7*.

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Section 7

Inputs, Outputs, Timers, and Other Control Logic

This section explains the settings and operation of:

Optoisolated Inputs on page 7.2—**IN101**–**IN106**, **IN201**–**IN208** (extra I/O board)

Local Control Switches on page 7.6—Local bits LB1–LB16

Remote Control Switches on page 7.10—Remote bits RB1–RB16

Latch Control Switches on page 7.12—Latch bits LT1–LT16

Multiple Setting Groups on page 7.19—Group switching settings SS1–SS6

SELOGIC Control Equation Variables/Timers on page 7.28—SV1/SV1T–SV16/SV16T

Output Contacts on page 7.32—**OUT101**–**OUT107** and **ALARM**, **OUT201**–**OUT212** (extra I/O board)

Rotating Default Display on page 7.36—Display points DP1–DP16

The above items are all the logic input/output of the relay. They are combined with the overcurrent, voltage, frequency, and reclosing elements in SELOGIC® control equation settings to realize numerous protection and control schemes.

Relay Word bits and SELOGIC control equation setting examples are used throughout this section. See *Section 9: Setting the Relay* for more information on Relay Word bits and SELOGIC control equation settings. See *Section 10: Serial Port Communications and Commands* for more information on viewing and making SELOGIC control equation settings (commands **SHO L** and **SET L**).

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Optoisolated Inputs

Figure 7.1 and *Figure 7.2* show the resultant Relay Word bits (e.g., Relay Word bits IN101–IN106 in *Figure 7.1*) that follow corresponding optoisolated inputs (e.g., optoisolated inputs **IN101–IN106** in *Figure 7.1*) for the different SEL-351S Relay models. The figures show examples of energized and de-energized optoisolated inputs and corresponding Relay Word bit states. To assert an input, apply rated control voltage to the appropriate terminal pair (see *Figure 1.2*–*Figure 1.4* and *Figure 2.2*–*Figure 2.6*).

Figure 7.1 is used for following discussion/examples. The optoisolated inputs in *Figure 7.2* operate similarly.

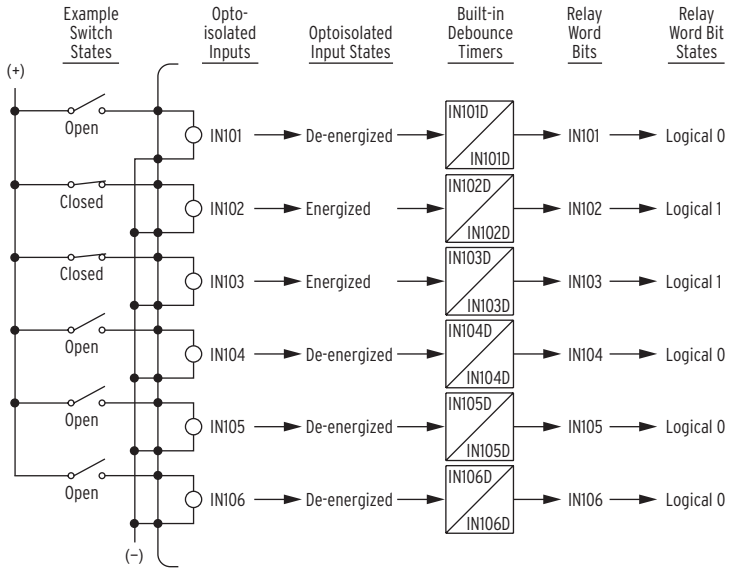


Figure 7.1 Example Operation of Optoisolated Inputs IN101–IN106

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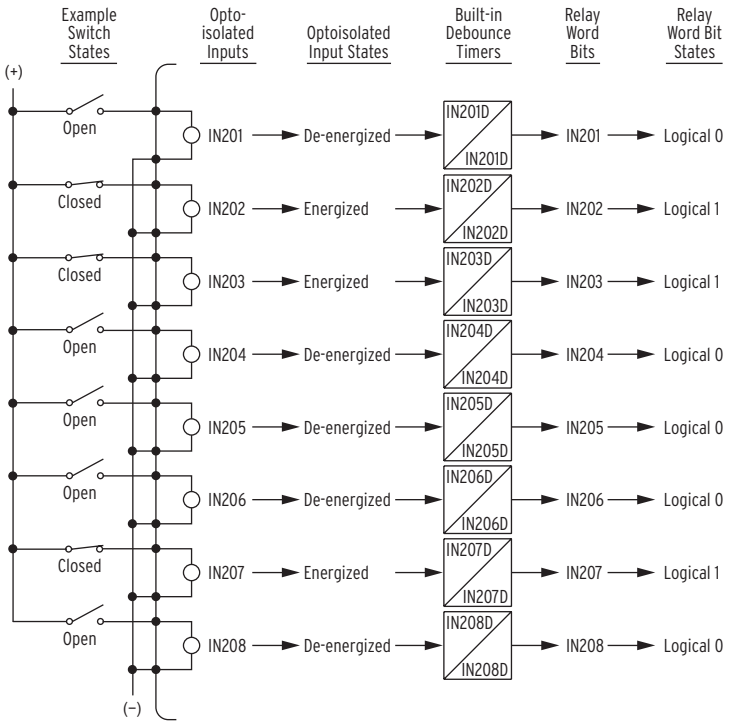


Figure 7.2 Example Operation of Optoisolated Inputs IN201–IN208—Extra I/O Board

Input Debounce Timers

See *Figure 7.1*.

Each input has settable pickup/dropout timers (IN101D–IN106D) for input energization/de-energization debounce. Note that a given time setting (e.g., IN101D = 0.50) is applied to both the pickup and dropout time for the corresponding input.

Time settings IN101D–IN106D are settable from 0.00 to 1.00 cycles, or ac. The relay takes the entered time setting and internally runs the timer at the nearest 1/16-cycle. For example, if setting IN105D = 0.80, internally the timer runs at the nearest 1/16-cycle: 13/16-cycles (13/16 = 0.8125).

The ac setting allows the input to sense ac control signals. The input has a maximum pickup time of 0.75 cycles and a maximum dropout time of 1.25 cycles. The ac setting qualifies the input by not asserting until two successive 1/16 cycle samples are higher than the optoisolated input voltage threshold and not deasserting until sixteen successive 1/16 cycle samples are lower than the optoisolated input voltage threshold.

For **most dc applications**, the input pickup/dropout debounce timers should be set in 1/4-cycle increments. For example, in the **factory default settings**, all the optoisolated input pickup/dropout debounce timers are set at 1/2-cycle (e.g., IN104 = 0.50). See *SHO Command (Show/View Settings) on page 10.27* for a list of the factory default settings.

Only a **few applications** (e.g., communications-assisted tripping schemes) might require input pickup/dropout debounce timers set less than 1/4-cycle [e.g., if setting IN105D = 0.13, internally the timer runs at the nearest 1/16-cycle: 2/16-cycles (2/16 = 0.1250)].

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The relay processing interval is 1/4-cycle, so Relay Word bits IN101–IN106 are updated every 1/4-cycle. The optoisolated input status may have made it through the pickup/dropout debounce timer (for settings less than 1/4-cycle) because these timers run each 1/16-cycle, but Relay Word bits IN101–IN106 are updated every 1/4-cycle.

If more than 1 cycle of debounce is needed, run Relay Word bit IN10*n* (*n* = 1–6) through a SELOGIC control equation variable timer and use the output of the timer for input functions (see *Figure 7.24* and *Figure 7.25*).

Input Functions

There are **no** optoisolated input settings such as:

IN101 =

IN102 =

Optoisolated inputs **IN101**–**IN106** receive their function by how their corresponding Relay Word bits IN101–IN106 are used in SELOGIC control equations.

Settings Examples

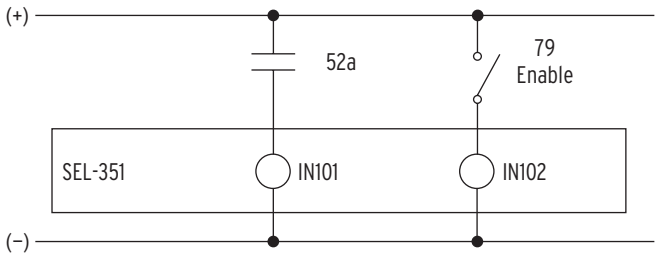


Figure 7.3 Circuit Breaker Auxiliary Contact and Reclose Enable Switch Connected to Optoisolated Inputs IN101 and IN102

The functions for inputs **IN101** and **IN102** are described in the following discussions. Note that *Figure 7.3* corresponds to *Figure 7.29*.

Input IN101

Relay Word bit IN101 is used in the factory settings for the SELOGIC control equation circuit breaker status setting:

52A = **IN101**

Connect input **IN101** to a 52a circuit breaker auxiliary contact.

If a 52b circuit breaker auxiliary contact is connected to input **IN101**, the setting is changed to:

52A = **!IN101** [!IN101 = NOT(IN101)]

See *Close Logic on page 6.2* for more information on SELOGIC control equation setting 52A.

The pickup/dropout timer for input **IN101** (IN101D) is set at:

IN101D = **0.50 cycles**

to provide input energization/de-energization debounce.

Using Relay Word bit IN101 for the circuit breaker status setting 52A does **not** prevent using Relay Word bit IN101 in other SELOGIC control equation settings.

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Input IN102

Relay Word bit IN102 is used in this example for the SELOGIC control equation drive-to-lockout setting:

79DTL = **!IN102 + ...** [=NOT(IN102) + ...]

Connect input **IN102** to a reclose enable switch.

When the reclose enable switch is open, input **IN102** is de-energized and the reclosing relay is driven to lockout:

79DTL = **!IN102 + ...** = NOT(IN102) + ... = NOT(logical 0) +... = logical 1

When the reclose enable switch is closed, input **IN102** is energized and the reclosing relay is enabled, if no other setting condition is driving the reclosing relay to lockout:

79DTL = **!IN102 + ...** = NOT(IN102) + ... = NOT(logical 1) +...
= logical 0 + ...

See *Figure 6.10* and accompanying explanation for more information on SELOGIC control equation setting 79DTL.

The pickup/dropout timer for input **IN102** (IN102D) is set at:

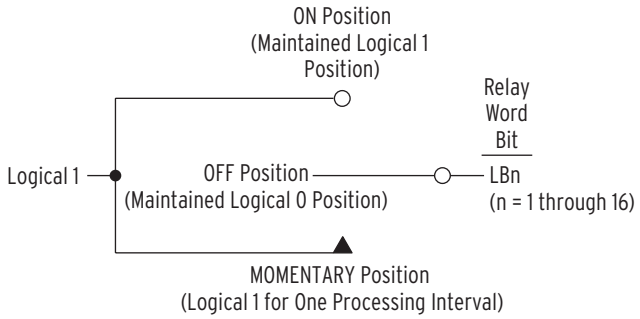
IN102D = **0.50 cycle**

to provide input energization/de-energization debounce.

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Local Control Switches

The local control switch feature of this relay replaces traditional panel-mounted control switches. Operate the sixteen (16) local control switches using the front-panel keyboard/display (see *Section 11: Front-Panel Interface*).



The switch representation in this figure is derived from the standard:

Graphics Symbols for Electrical and Electronics Diagrams IEEE Std 315-1975, CSA Z99-1975, ANSI Y32.2-1975, 4.11 Combination Locking and Nonlocking Switch, Item 4.11.1.

Figure 7.4 Local Control Switches Drive Local Bits LB1-LB16

The output of the local control switch in *Figure 7.4* is a Relay Word bit LB*n* (*n* = 1–16), called a local bit. The local control switch logic in *Figure 7.4* repeats for each local bit LB1–LB16. Use these local bits in SELOGIC control equations. For a given local control switch, the local control switch positions are enabled by making corresponding label settings.

Table 7.1 Correspondence Between Local Control Switch Positions and Label Settings

Switch Position	Label Setting	Setting Definition	Logic State
not applicable	NLB*n*	Name of Local Control Switch	not applicable
ON	SLB*n*	"Set" Local bit LB*n*	logical 1
OFF	CLB*n*	"Clear" Local bit LB*n*	logical 0
MOMENTARY	PLB*n*	"Pulse" Local bit LB*n*	logical 1 for one processing interval

Note the first setting in *Table 7.1* (NLB*n*) is the overall switch name setting. Make each label setting through the serial port using the command **SET T**. View these settings using the serial port command **SHO T** (see *Section 9: Setting the Relay* and *Section 10: Serial Port Communications and Commands*).

Local Control Switch Types

Configure any local control switch as one of the following three switch types:

ON/OFF Switch

Local bit LB*n* is in either the ON (LB*n* = logical 1) or OFF (LB*n* = logical 0) position.

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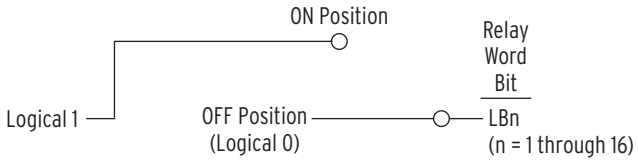


Figure 7.5 Local Control Switch Configured as an ON/OFF Switch

OFF/MOMENTARY Switch

The local bit LB*n* is maintained in the OFF (LB*n* = logical 0) position and pulses to the MOMENTARY (LB*n* = logical 1) position for one processing interval (1/4 cycle).

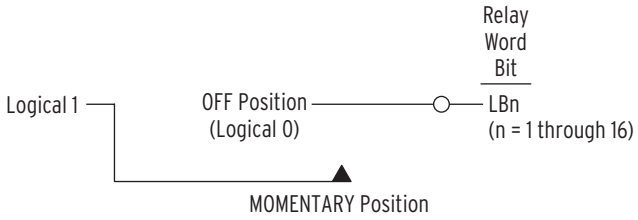


Figure 7.6 Local Control Switch Configured as an OFF/MOMENTARY Switch

ON/OFF/MOMENTARY Switch

The local bit LB*n*:

is in either the ON (LB*n* = logical 1) or OFF (LB*n* = logical 0) position

or

is in the OFF (LB*n* = logical 0) position and pulses to the MOMENTARY (LB*n* = logical 1) position for one processing interval (1/4 cycle).

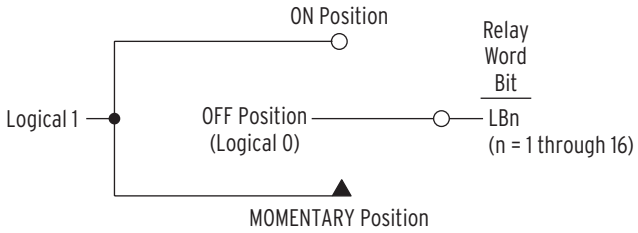


Figure 7.7 Local Control Switch Configured as an ON/OFF/MOMENTARY Switch

Table 7.2 Correspondence Between Local Control Switch Types and Required Label Settings

Local Switch Type	Label NLBn	Label CLBn	Label SLBn	Label PLBn
ON/OFF	X	X	X	
OFF/MOMENTARY	X	X		X
ON/OFF/MOMENTARY	X	X	X	X

Disable local control switches by "nulling out" all the label settings for that switch (see *Section 9: Setting the Relay*). The local bit associated with this disabled local control switch is then fixed at logical 0.

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Settings Examples

Local bits LB3 and LB4 are used in a few example SELOGIC control equation settings for manual trip and close functions. Their corresponding local control switch position labels are set to configure the switches as OFF/MOMENTARY switches:

Local Bit	Label Settings	Function
LB3	NLB3 = MANUAL TRIP	trips breaker and drives reclosing relay to lockout
	CLB3 = RETURN	OFF position (“return” from MOMENTARY position)
	SLB3 =	ON position—not used (left “blank”)
	PLB3 = TRIP	MOMENTARY position
LB4	NLB4 = MANUAL CLOSE	closes breaker, separate from automatic reclosing
	CLB4 = RETURN	OFF position (“return” from MOMENTARY position)
	SLB4 =	ON position—not used (left “blank”)
	PLB4 = CLOSE	MOMENTARY position

Following *Figure 7.8* and *Figure 7.9* show local control switches with example settings.

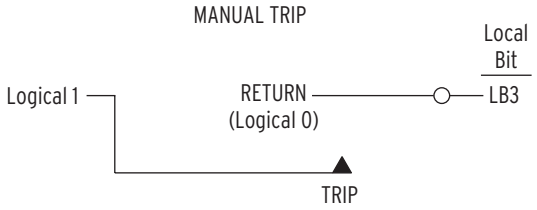


Figure 7.8 Configured Manual Trip Switch Drives Local Bit LB3

Local bit LB3 is set to trip in the following example SELOGIC control equation trip setting (see *Figure 5.1*):

TR = **... + LB3 + ...**

To keep reclosing from being initiated for this trip, set local bit LB3 to drive the reclosing relay to lockout for a manual trip (see *Section 6: Close and Reclose Logic*):

79DTL = **... + LB3**

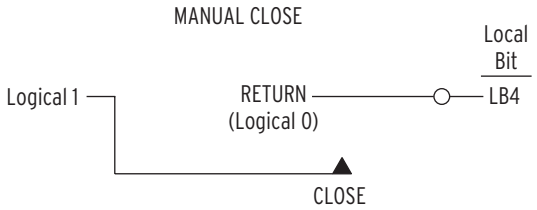


Figure 7.9 Configured Manual Close Switch Drives Local Bit LB4

Local bit LB4 is set to close the circuit breaker in the following example SELOGIC control equation setting:

CL = **LB4**

SELOGIC control equation setting CL is for close conditions, other than automatic reclosing or serial port **CLOSE** command (see *Figure 6.1*).

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Additional Local Control Switch Application Ideas

The preceding settings examples are OFF/MOMENTARY switches. Local control switches configured as ON/OFF switches can be used for such applications as:

- Reclosing relay enable/disable
- Ground relay enable/disable
- Remote control supervision
- Sequence coordination enable/disable

Local control switches can also be configured as ON/OFF/MOMENTARY switches for applications that require such. Local control switches can be applied to almost any control scheme that traditionally requires front-panel switches.

Local Control Switch States Retained

Power Loss

The states of the local bits (Relay Word bits LB1–LB16) are retained if power to the relay is lost and then restored. If a local control switch is in the ON position (corresponding local bit is asserted to logical 1) when power is lost, it comes back in the ON position (corresponding local bit is still asserted to logical 1) when power is restored. If a local control switch is in the OFF position (corresponding local bit is deasserted to logical 0) when power is lost, it comes back in the OFF position (corresponding local bit is still deasserted to logical 0) when power is restored. This feature makes the local bit feature behave the same as a traditional installation with panel-mounted control switches. If power is lost to the panel, the front-panel control switch positions remain unchanged.

If a local bit is routed to a programmable output contact and control power is lost, the state of the local bit is stored in nonvolatile memory but the output contact will go to its de-energized state. When the control power is applied back to the relay, the programmed output contact will go back to the state of the local bit after relay initialization.

Settings Change or Active Setting Group Change

If settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed, the states of the local bits (Relay Word bits LB1–LB16) are retained, much like in the preceding *Power Loss on page 7.15* explanation.

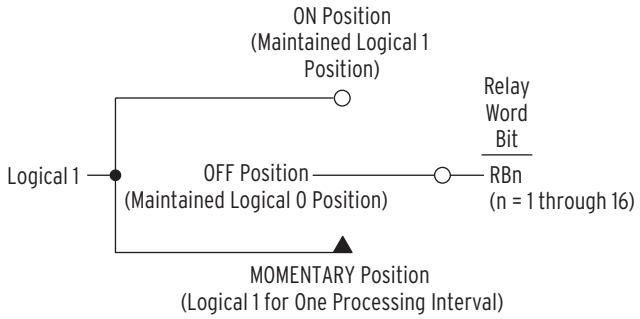
If settings are changed for a setting group other than the active setting group, there is no interruption of the local bits (the relay is not momentarily disabled).

If a local control switch is made inoperable because of a settings change (i.e., the corresponding label settings are nulled), the corresponding local bit is then fixed at logical 0, regardless of the local bit state before the settings change. If a local control switch is made newly operable because of a settings change (i.e., the corresponding label settings are set), the corresponding local bit starts out at logical 0.

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Remote Control Switches

Remote control switches are operated via the serial communications port only (see *CON Command (Control Remote Bit) on page 10.40*).



The switch representation in this figure is derived from the standard:

Graphics Symbols for Electrical and Electronics Diagrams IEEE Std 315-1975, CSA Z99-1975, ANSI Y32.2-1975, 4.11 Combination Locking and Nonlocking Switch, Item 4.11.1.

Figure 7.10 Remote Control Switches Drive Remote Bits RB1–RB16

The outputs of the remote control switches in *Figure 7.10* are Relay Word bits RB*n* (*n* = 1 to 16), called remote bits. Use these remote bits in SELOGIC control equations.

Any given remote control switch can be put in one of the following three positions:

ON (logical 1)

OFF (logical 0)

MOMENTARY (logical 1 for one processing interval)

Remote Bit Application Ideas

With SELOGIC control equations, the remote bits can be used in applications similar to those that local bits are used in (see preceding local control switch discussion).

Also, remote bits can be used much as optoisolated inputs are used in operating latch control switches (see discussion following *Figure 7.15*). Pulse (momentarily operate) the remote bits for this application.

Remote Bit States Not Retained When Power Is Lost

The states of the remote bits (Relay Word bits RB1–RB16) are not retained if power to the relay is lost and then restored. The remote control switches always come back in the OFF position (corresponding remote bit is deasserted to logical 0) when power is restored to the relay.

Remote Bit States Retained When Settings Changed or Active Setting Group Changed

The state of each remote bit (Relay Word bits RB1–RB16) is retained if relay settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed. If a remote control switch is in the ON position (corresponding remote bit is asserted to logical 1) before a setting change or an active setting group change, it comes back in the ON position (corresponding remote bit is still asserted to logical 1) after the change. If a remote control switch is in the OFF position (corresponding

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remote bit is deasserted to logical 0) before a settings change or an active setting group change, it comes back in the OFF position (corresponding remote bit is still deasserted to logical 0) after the change.

If settings are changed for a setting group other than the active setting group, there is no interruption of the remote bits (the relay is not momentarily disabled).

Details on the Remote Control Switch MOMENTARY Position

This subsection describes remote control switch 3, which is also called remote bit 3 (RB3). All of the remote bits RB1–RB16 operate in the same way.

The **CON 3** command and **PRB 3** subcommand places the remote control switch 3 into the MOMENTARY position for one processing interval, regardless of its initial state. Remote control switch 3 is then placed in the OFF position.

If RB3 is initially at logical 0, pulsing it with the **CON 3** command and **PRB 3** subcommand will change RB3 to a logical 1 for one processing interval, and then return it to a logical 0. In this situation, the /RB3 (rising edge operator) will also assert for one processing interval, followed by the \RB3 (falling edge operator) one processing interval later.

If RB3 is initially at logical 1 instead, pulsing it with the **CON 3** command and **PRB 3** subcommand will change RB3 to a logical 0. In this situation, the /RB3 (rising edge operator) will **not** assert, but the \RB3 (falling edge operator) will assert for one processing interval.

See *CON Command (Control Remote Bit) on page 10.40*.

See *Appendix G: Setting SELOGIC Control Equations* for more details on using the rising and falling edge operators in SELOGIC control equations.

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Latch Control Switches

The latch control switch feature of this relay replaces latching relays. Traditional latching relays maintain their output contact state. The SEL-351S latch control switches retain their state even when power to the relay is lost. If the latch control switch is set to a programmable output contact and power to the relay is lost, the state of the latch control switch is stored in nonvolatile memory, but the output contact will go to its de-energized state. When power to the relay is restored, the programmable output contact will go back to the state of the latch control switch after relay initialization.

The state of a traditional latching relay output contact is changed by pulsing the latching relay inputs (see *Figure 7.11*). Pulse the set input to close ("set") the latching relay output contact. Pulse the reset input to open ("reset") the latching relay output contact. Often the external contacts wired to the latching relay inputs are from remote control equipment (e.g., SCADA, RTU).

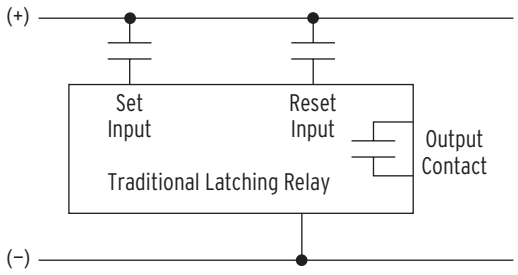


Figure 7.11 Traditional Latching Relay

The sixteen (16) latch control switches in the SEL-351S provide latching relay type functions.

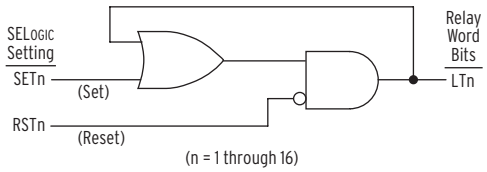


Figure 7.12 Latch Control Switches Drive Latch Bits LT1–LT16

The output of the latch control switch in *Figure 7.12* is a Relay Word bit LT*n* (*n* = 1–16), called a latch bit. The latch control switch logic in *Figure 7.12* repeats for each latch bit LT1–LT16. Use these latch bits in SELOGIC control equations.

These latch control switches each have the following SELOGIC control equation settings:

SET*n* (set latch bit LT*n* to logical 1)

RST*n* (reset latch bit LT*n* to logical 0)

If setting SET*n* asserts to logical 1, latch bit LT*n* asserts to logical 1. If setting RST*n* asserts to logical 1, latch bit LT*n* deasserts to logical 0. If both settings SET*n* and RST*n* assert to logical 1, setting RST*n* has priority and latch bit LT*n* deasserts to logical 0.

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Latch Control Switch Application Ideas

Latch control switches can be used for such applications as:

- Reclosing relay enable/disable
- Ground relay enable/disable
- Sequence coordination enable/disable

Latch control switches can be applied to almost any control scheme. The following is an example of using a latch control switch to enable/disable the reclosing relay in the SEL-351S.

Reclosing Relay Enable/Disable Setting Example

Use a latch control switch to enable/disable the reclosing relay in the SEL-351S. In this example, a SCADA contact is connected to optoisolated input **IN104**. Each pulse of the SCADA contact changes the state of the reclosing relay. The SCADA contact is not maintained, just pulsed to enable/disable the reclosing relay.

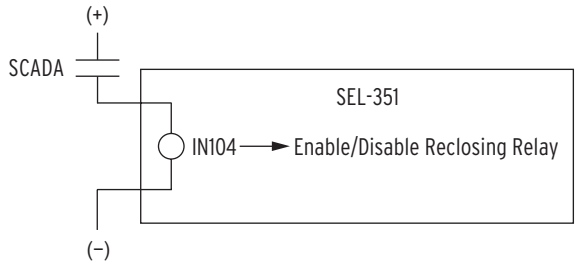


Figure 7.13 SCADA Contact Pulses Input IN104 to Enable/Disable Reclosing Relay

If the reclosing relay is enabled and the SCADA contact is pulsed, the reclosing relay is then disabled. If the SCADA contact is pulsed again, the reclosing relay is enabled again. The control operates in a cyclic manner:

pulse to enable ... pulse to disable ... pulse to enable ... pulse to disable ...

This reclosing relay logic is implemented in the following SELOGIC control equation settings and displayed in *Figure 7.14*.

SET1 = **/IN104*!LT1** [= (rising edge of input **IN104**) **AND** NOT(LT1)]

RST1 = **/IN104*LT1** [= (rising edge of input **IN104**) **AND** LT1]

79DTL = **!LT1** [= NOT(LT1); drive-to-lockout setting]

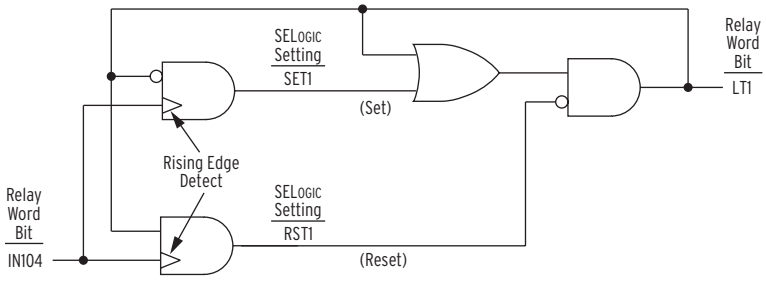


Figure 7.14 Latch Control Switch Controlled by a Single Input to Enable/Disable Reclosing

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Feedback Control

Note in *Figure 7.14* that the latch control switch output (latch bit LT1) is effectively used as feedback for SELOGIC control equation settings SET1 and RST1. The feedback of latch bit LT1 "guides" input **IN104** to the correct latch control switch input.

If latch bit LT1 = logical 0, input **IN104** is routed to setting SET1 (set latch bit LT1):

SET1 = **/IN104*!LT1** = /IN104*NOT(LT1) = /IN104*NOT(logical 0)
= /IN104 = rising edge of input **IN104**

RST1 = **=/IN104*LT1** = /IN104*(logical 0) =logical 0

If latch bit LT1 = logical 1, input **IN104** is routed to setting RST1 (reset latch bit LT1):

SET1 = **=/IN104*!LT1** = /IN104*NOT(LT1) = /IN104*NOT(logical 1)
= /IN104*(logical 0)
= logical 0

RST1 = **=/IN104*LT1** = /IN104*(logical 1)
= /IN104 = rising edge of input **IN104**

Rising Edge Operators

Refer to *Figure 7.14* and *Figure 7.15*.

The rising edge operator in front of Relay Word bit IN104 (/IN104) sees a logical 0 to logical 1 transition as a "rising edge," and /IN104 asserts to logical 1 for one processing interval.

The rising edge operator on input **IN104** is necessary because any single assertion of optoisolated input **IN104** by the SCADA contact will last for at least a few cycles, and each individual assertion of input **IN104** should only change the state of the latch control switch once (e.g., latch bit LT1 changes state from logical 0 to logical 1).

For example in *Figure 7.14*, if:

LT1 = logical 0

input **IN104** is routed to setting SET1 (as discussed previously):

SET1 = **/IN104** = rising edge of input IN104

If input **IN104** is then asserted for a few cycles by the SCADA contact (see Pulse 1 in *Figure 7.15*), SET1 is asserted to logical 1 for one processing interval. This causes latch bit LT1 to change state to:

LT1 = logical 1

the next processing interval.

With latch bit LT1 now at logical 1 for the next processing interval, input **IN104** is routed to setting RST1 (as discussed previously):

RST1 = **/IN104** = rising edge of input **IN104**

This would then appear to enable the "reset" input (setting RST1) the next processing interval. But the "rising edge" condition occurred the preceding processing interval. /IN104 is now at logical 0, so setting RST1 does not assert, even though input **IN104** remains asserted for at least a few cycles by the SCADA contact.

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If the SCADA contact deasserts and then asserts again (new rising edge—see Pulse 2 in *Figure 7.15*), the "reset" input (setting RST1) asserts and latch bit LT1 deasserts back to logical 0 again. Thus each individual assertion of input **IN104** (Pulse 1, Pulse 2, Pulse 3, and Pulse 4 in *Figure 7.15*) changes the state of latch control switch just once.

NOTE: Refer to preceding subsection Optoisolated Inputs on page 7.2 and Figure 7.1. Relay Word bit IN104 shows the state of optoisolated input **IN104 after** the input pickup/dropout debounce timer IN104D. Thus, when using Relay Word bit IN104 in Figure 7.12 and Figure 7.13 and associated SELOGIC control equations, keep in mind any time delay produced by the input pickup/dropout debounce timer IN104D.

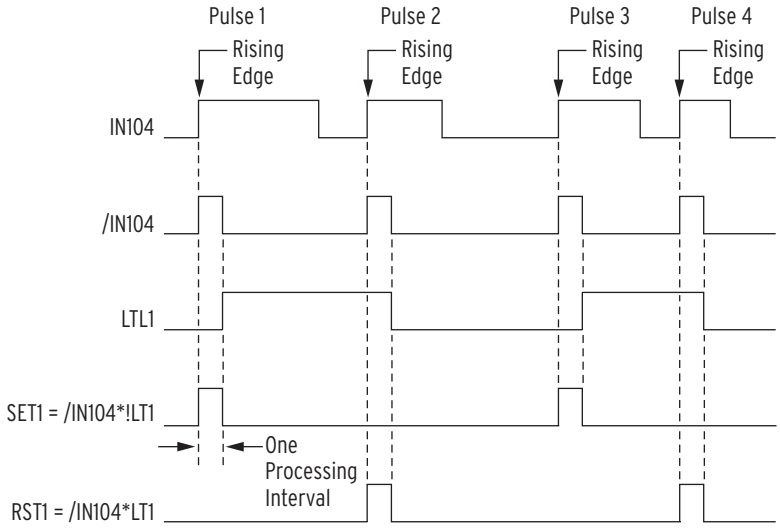


Figure 7.15 Latch Control Switch Operation Time Line

Use a Remote Bit Instead to Enable/Disable the Reclosing Relay

Use a remote bit to enable/disable the reclosing relay, instead of an optoisolated input. For example, substitute remote bit RB1 for optoisolated input **IN104** in the settings accompanying *Figure 7.14*:

SET1 = **/RB1*!LT1**[= (rising edge of remote bit RB1) **AND** NOT(LT1)]

RST1 = **/RB1*LT1**[= (rising edge of remote bit RB1) **AND** LT1]

79DTL = **!LT1**[= NOT(LT1); drive-to-lockout setting]

Pulse remote bit RB1 to enable reclosing, pulse remote bit RB1 to disable reclosing, etc.—much like the operation of optoisolated input **IN104** in the previous example. Remote bits (Relay Word bits RB1–RB16) are operated through the serial port. See *Remote Control Switches on page 7.10* for more information on remote bits.

These are just a few control logic examples—many variations are possible.

Latch Control Switch States Retained

Power Loss

NOTE: If a latch bit is set to a programmable output contact (e.g., OUT103 = LT2) and power to the relay is lost, the state of the latch bit is stored in nonvolatile memory but the output contact will go to its de-energized state. When power to the relay is restored, the programmable output contact will go back to the state of the latch bit after relay initialization.

The states of the latch bits (LT1–LT16) are retained if power to the relay is lost and then restored. If a latch bit is asserted (e.g., LT2 = logical 1) when power is lost, it comes back asserted (LT2 = logical 1) when power is restored. If a latch bit is deasserted (e.g., LT3 = logical 0) when power is lost, it comes back deasserted (LT3 = logical 0) when power is restored. This feature makes the latch bit feature behave the same as traditional latching relays. In a traditional installation, if power is lost to the panel, the latching relay output contact position remains unchanged.

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Settings Change or Active Setting Group Change

If individual settings are changed (for the active setting group or one of the other setting groups) or the active setting group is changed, the states of the latch bits (Relay Word bits LT1–LT16) are retained, much like in the preceding *Power Loss on page 7.26* explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the latch bits (the relay is not momentarily disabled).

If the individual settings change or active setting group change causes a change in SELOGIC control equation settings SET*n* or RST*n* (*n* = 1–16), the retained states of the latch bits can be changed, subject to the newly enabled settings SET*n* or RST*n*.

Reset Latch Bits for Active Setting Group Change

If desired, the latch bits can be reset to logical 0 right after a settings group change, using SELOGIC control equation setting RST*n* (*n* = 1–16). Relay Word bits SG1–SG6 indicate the active setting Group 1–6, respectively (see *Table 7.3*).

For example, when setting Group 4 becomes the active setting group, latch bit LT2 should be reset. Make the following SELOGIC control equation settings in setting Group 4:

SV7 = **SG4**

RST2 = **!SV7T + ...** [= NOT(SV7T) + ...]

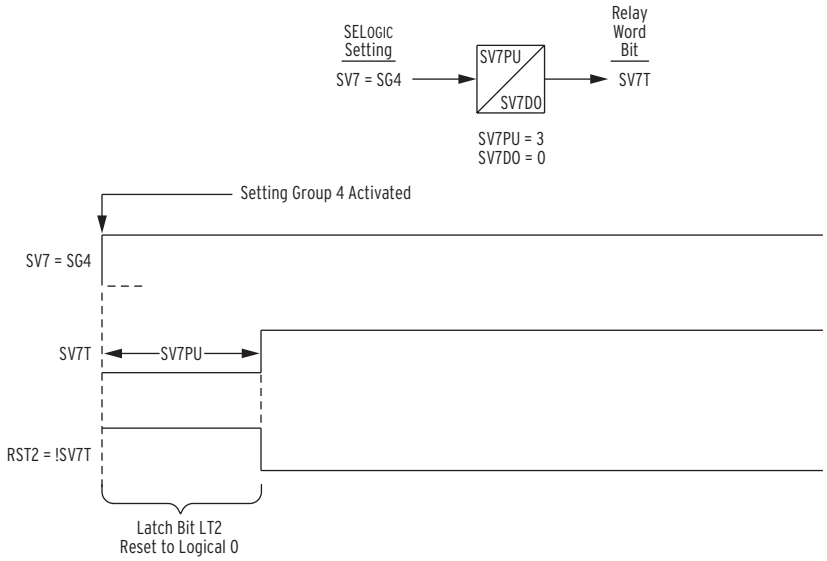


Figure 7.16 Time Line for Reset of Latch Bit LT2 After Active Setting Group Change

In *Figure 7.16*, latch bit LT2 is reset (deasserted to logical 0) when reset setting RST2 asserts to logical 1 for the short time right after setting Group 4 is activated. This logic can be repeated for other latch bits.

Note: Make Latch Control Switch Settings With Care

The latch bit states are stored in nonvolatile memory so they can be retained during power loss, settings change, or active setting group change. The nonvolatile memory is rated for a finite number of "writes" for all cumulative

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latch bit state changes. Exceeding the limit can result in an EEPROM self-test failure. **An average of 70 cumulative latch bit state changes per day can be made for a 25-year relay service life.**

This requires that SELOGIC control equation settings SET*n* and RST*n* for any given latch bit LT*n* (*n* = 1–16; see *Figure 7.12*) be set with care. Settings SET*n* and RST*n* cannot result in continuous cyclical operation of latch bit LT*n*. Use timers to qualify conditions set in settings SET*n* and RST*n*. If any optoisolated inputs IN101–IN106 are used in settings SET*n* and RST*n*, the inputs have their own debounce timer that can help in providing the necessary time qualification (see *Figure 7.1*).

In the preceding reclosing relay enable/disable example application (*Figure 7.14* and *Figure 7.15*), the SCADA contact cannot be asserting/deasserting continuously, thus causing latch bit LT1 to change state continuously. Note that the rising edge operators in the SET1 and RST1 settings keep latch bit LT1 from cyclically operating for any single assertion of the SCADA contact.

Another variation to the example application in *Figure 7.14* and *Figure 7.15* that adds more security is a timer with pickup/dropout times set the same (see *Figure 7.17* and *Figure 7.18*). Suppose that SV6PU and SV6DO are both set to 300 cycles. Then the SV6T timer keeps the state of latch bit LT1 from being able to be changed at a rate faster than once every 300 cycles (5 seconds).

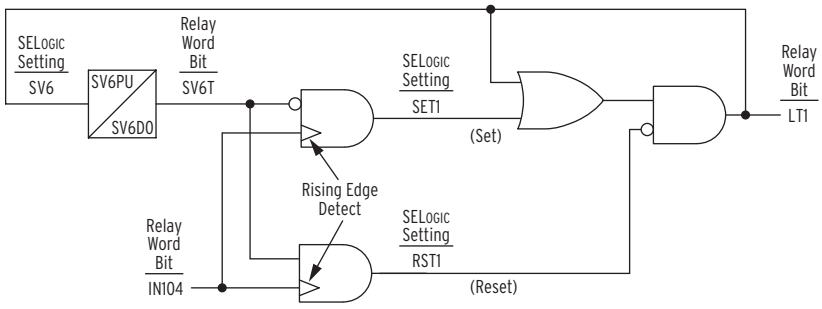


Figure 7.17 Latch Control Switch (With Time Delay Feedback) Controlled by a Single Input to Enable/Disable Reclosing

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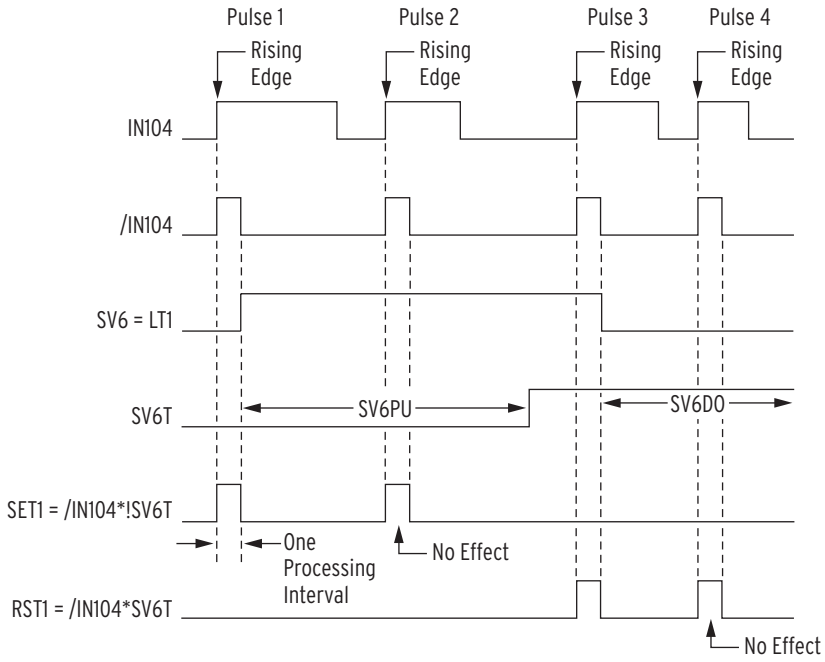


Figure 7.18 Latch Control Switch (With Time Delay Feedback) Operation Time Line

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Multiple Setting Groups

The relay has six (6) independent setting groups. Each setting group has complete relay (overcurrent, reclosing, frequency, etc.) and SELOGIC control equation settings.

Active Setting Group Indication

Only one setting group can be active at a time. Relay Word bits SG1–SG6 indicate the active setting group:

Table 7.3 Definitions for Active Setting Group Indication Relay Word Bits SG1–SG6

Relay Word Bit	Definition
SG1	Indication that setting Group 1 is the active setting group
SG2	Indication that setting Group 2 is the active setting group
SG3	Indication that setting Group 3 is the active setting group
SG4	Indication that setting Group 4 is the active setting group
SG5	Indication that setting Group 5 is the active setting group
SG6	Indication that setting Group 6 is the active setting group

For example, if setting Group 4 is the active setting group, Relay Word bit SG4 asserts to logical 1, and the other Relay Word bits SG1, SG2, SG3, SG5, and SG6 are all deasserted to logical 0.

Selecting the Active Setting Group

The active setting group is selected with:

- SELOGIC control equation settings SS1–SS6.
- The serial port **GROUP** command (see *Section 10: Serial Port Communications and Commands*).
- Or the front-panel **{GROUP}** pushbutton (see *Section 11: Front-Panel Interface*).

SELOGIC control equation settings SS1–SS6 have priority over the serial port **GROUP** command and the front-panel **{GROUP}** pushbutton in selecting the active setting group.

Operation of SELOGIC Control Equation Settings SS1–SS6

Each setting group has its own set of SELOGIC control equation settings SS1–SS6.

Table 7.4 Definitions for Active Setting Group Switching SELOGIC Control Equation Settings SS1–SS6

Setting	Definition
SS1	go to (or remain in) setting Group 1
SS2	go to (or remain in) setting Group 2
SS3	go to (or remain in) setting Group 3
SS4	go to (or remain in) setting Group 4
SS5	go to (or remain in) setting Group 5
SS6	go to (or remain in) setting Group 6

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The operation of these settings is explained with the following example:

Assume the active setting group starts out as setting Group 3. Corresponding Relay Word bit SG3 is asserted to logical 1 as an indication that setting Group 3 is the active setting group (see *Table 7.3*).

With setting Group 3 as the active setting group, setting SS3 has priority. If setting SS3 is asserted to logical 1, setting Group 3 remains the active setting group, regardless of the activity of settings SS1, SS2, SS4, SS5, and SS6. With settings SS1–SS6 all deasserted to logical 0, setting Group 3 still remains the active setting group.

With setting Group 3 as the active setting group, if setting SS3 is deasserted to logical 0 and one of the other settings (e.g., setting SS5) asserts to logical 1, the relay switches from setting Group 3 as the active setting group to another setting group (e.g., setting Group 5) as the active setting group, after qualifying time setting TGR:

> TGR Group Change Delay Setting (settable from 0.00 to 16000.00 cycles)

In this example, TGR qualifies the assertion of setting SS5 before it can change the active setting group.

Operation of Serial Port GROUP Command and Front-Panel {GROUP} Pushbutton

SELOGIC control equation settings SS1–SS6 have priority over the serial port **GROUP** command and the front-panel **{GROUP}** pushbutton in selecting the active setting group. If any **one** of SS1–SS6 asserts to logical 1, neither the serial port **GROUP** command nor the front-panel **{GROUP}** pushbutton can be used to switch the active setting group. But if SS1–SS6 **all** deassert to logical 0, the serial port **GROUP** command or the front-panel **{GROUP}** pushbutton can be used to switch the active setting group.

See *Section 10: Serial Port Communications and Commands* for more information on the serial port **GROUP** command. See *Section 11: Front-Panel Interface* for more information on the front-panel **{GROUP}** pushbutton.

Relay Disabled Momentarily During Active Setting Group Change

The relay is disabled for a **few seconds** while the relay is in the process of changing active setting groups. Relay elements, timers, and logic are reset, unless indicated otherwise in specific logic description [e.g., local bit (LB1–LB16), remote bit (RB1–RB16), and latch bit (LT1–LT16) states are retained during a active setting group change]. The output contacts do not change state until the relay enables in the new settings group and the SELOGIC control equations are processed to determine the output contact status for the new group. For instance, if setting OUT105 = logical 1 in Group 2, and setting OUT105 = logical 1 in Group 3, and the relay is switched from Group 2 to Group 3, OUT105 stays energized before, during, and after the group change. However, if the Group 3 setting was OUT105 = logical 0 instead, then OUT105 remains energized until the relay enables in Group 3, solves the SELOGIC equations, and causes **OUT105** to de-energize. See *Figure 7.27*, and *Figure 7.28* for examples of output contacts in the de-energized state (i.e., corresponding output contact coils de-energized).

Active Setting Group Switching Example 1

Use a single optoisolated input to switch between two setting groups in the SEL-351S. In this example, optoisolated input **IN105** on the relay is connected to a SCADA contact in *Figure 7.19*. Each pulse of the SCADA contact changes the active setting group from one setting group (e.g., setting Group 1) to another (e.g., setting Group 4). The SCADA contact is not maintained, just pulsed to switch from one active setting group to another.

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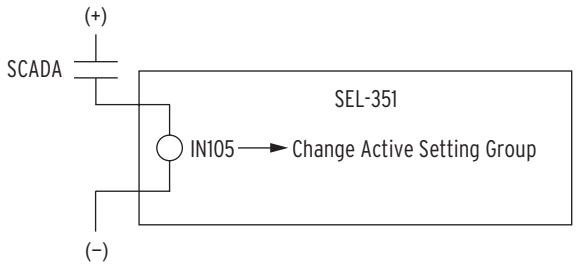


Figure 7.19 SCADA Contact Pulses Input IN105 to Switch Active Setting Group Between Setting Groups 1 and 4

If setting Group 1 is the active setting group and the SCADA contact is pulsed, setting Group 4 becomes the active setting group. If the SCADA contact is pulsed again, setting Group 1 becomes the active setting group again. The setting group control operates in a cyclical manner:

pulse to activate setting Group 4 ... pulse to activate setting Group 1 ...
pulse to activate setting Group 4 ... pulse to activate setting Group 1 ...

This logic is implemented in the SELOGIC control equation settings in *Table 7.5*.

Table 7.5 SELOGIC Control Equation Settings for Switching Active Setting Group Between Setting Groups 1 and 4

Setting Group 1	Setting Group 4
SV8 = SG1	SV8 = SG4
SS1 = 0	SS1 = IN105*SV8T
SS2 = 0	SS2 = 0
SS3 = 0	SS3 = 0
SS4 = IN105*SV8T	SS4 = 0
SS5 = 0	SS5 = 0
SS6 = 0	SS6 = 0

SELOGIC control equation timer input setting SV8 in *Table 7.5* has logic output SV8T, shown in operation in *Figure 7.20* for both setting Groups 1 and 4.

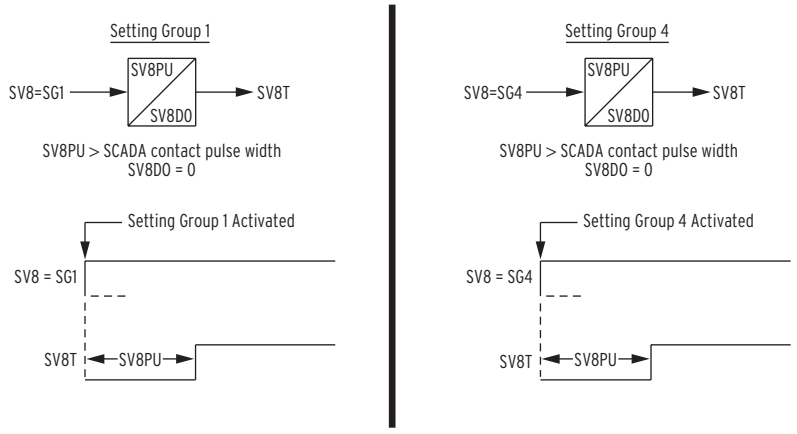


Figure 7.20 SELOGIC Control Equation Variable Timer SV8T Used in Setting Group Switching

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In this example, timer SV8T is used in both setting groups—different timers could have been used with the same operational result. The timers reset during the setting group change, allowing the same timer to be used in both setting groups.

Timer pickup setting SV8PU is set greater than the pulse width of the SCADA contact (*Figure 7.19 on page 7.21*). This allows only one active setting group change (e.g., from setting Group 1 to 4) for each pulse of the SCADA contact (and subsequent assertion of input **IN105**). The function of the SELOGIC control equations in *Table 7.5* becomes more apparent in the following example scenario.

Start Out in Setting Group 1

Refer to *Figure 7.21*.

The relay has been in setting Group 1 for some time, with timer logic output SV8T asserted to logical 1, thus enabling SELOGIC control equation setting SS4 for the assertion of input **IN105**.

Switch to Setting Group 4

Refer to *Figure 7.21*.

The SCADA contact pulses input **IN105**, and the active setting group changes to setting Group 4 after qualifying time setting TGR (perhaps set at a cycle or so to qualify the assertion of setting SS4). Optoisolated input **IN105** also has its own built-in debounce timer (IN105D) available (see *Figure 7.1*).

Note that *Figure 7.21* shows both setting Group 1 and setting Group 4 settings. The setting Group 1 settings (top of *Figure 7.21*) are enabled only when setting Group 1 is the active setting group and likewise for the setting Group 4 settings at the bottom of the figure.

Setting Group 4 is now the active setting group, and Relay Word bit SG4 asserts to logical 1. After the relay has been in setting Group 4 for a time period equal to SV8PU, the timer logic output SV8T asserts to logical 1, thus enabling SELOGIC control equation setting SS1 for a new assertion of input **IN105**.

Note that input **IN105** is still asserted as setting Group 4 is activated. Pickup time SV8PU keeps the continued assertion of input **IN105** from causing the active setting group to revert back again to setting Group 1 for a single assertion of input **IN105**. This keeps the active setting group from being changed at a time interval less than time SV8PU.

Switch Back to Setting Group 1

Refer to *Figure 7.21*.

The SCADA contact pulses input **IN105** a second time, and the active setting group changes back to setting Group 1 after qualifying time setting TGR (perhaps set at a cycle or so to qualify the assertion of setting SS1). Optoisolated input **IN105** also has its own built-in debounce timer (IN105D) available (see *Figure 7.1*).

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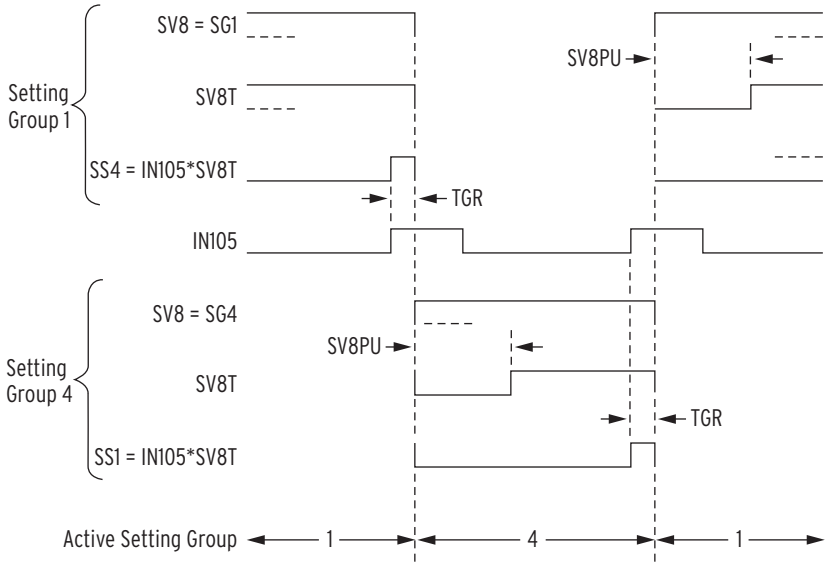


Figure 7.21 Active Setting Group Switching (With Single Input) Time Line

Active Setting Group Switching Example 2

Previous SEL relays (e.g., SEL-321 and SEL-251) have multiple settings groups controlled by the assertion of three optoisolated inputs (e.g., **IN101**, **IN102**, and **IN103**) in different combinations as shown in *Table 7.6*.

Table 7.6 Active Setting Group Switching Input Logic

Input States			Active
IN103	**IN102**	**IN101**	**Setting Group**
0	0	0	Remote
0	0	1	Group 1
0	1	0	Group 2
0	1	1	Group 3
1	0	0	Group 4
1	0	1	Group 5
1	1	0	Group 6

The SEL-351S can be programmed to operate similarly. Use three optoisolated inputs to switch between the six setting groups in the SEL-351S. In this example, optoisolated inputs **IN101**, **IN102**, and **IN103** on the relay are connected to a rotating selector switch in *Figure 7.22*.

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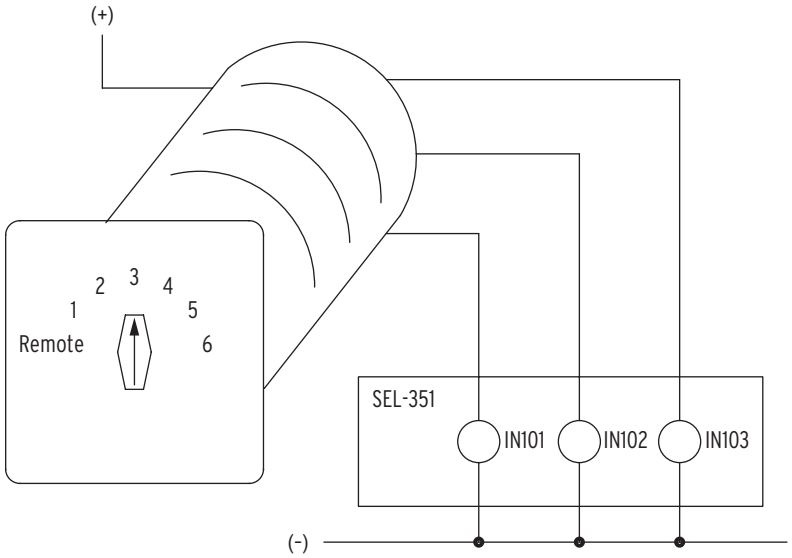


Figure 7.22 Rotating Selector Switch Connected to Inputs IN101, IN102, and IN103 for Active Setting Group Switching

The selector switch has multiple internal contacts arranged to assert inputs **IN101**, **IN102**, and **IN103**, dependent on the switch position. As shown in *Table 7.7*, the selector switch is moved from one position to another, a different setting group is activated. The logic in *Table 7.6* is implemented in the SELOGIC control equation settings in *Table 7.7*.

Table 7.7 SELOGIC Control Equation Settings for Rotating Selector Switch Active Setting Group Switching

SS1 = !IN103 * !IN102 * IN101	= NOT(IN103) * NOT(IN102) * IN101
SS2 = !IN103 * IN102 * !IN101	= NOT(IN103) * IN102 * NOT(IN101)
SS3 = !IN103 * IN102 * IN101	= NOT(IN103) * IN102 * IN101
SS4 = IN103 * !IN102 * !IN101	= IN103 * NOT(IN102) * NOT(IN101)
SS5 = IN103 * !IN102 * IN101	= IN103 * NOT(IN102) * IN101
SS6 = IN103 * IN102 * !IN101	= IN103 * IN102 * NOT(IN101)

The settings in *Table 7.7* are made in each setting Group 1–6.

Selector Switch Starts Out in Position 3

Refer to *Table 7.7* and *Figure 7.23*.

If the selector switch is in position 3 in *Figure 7.22*, setting Group 3 is the active setting group (Relay Word bit SG3 = logical 1). Inputs **IN101** and **IN102** are energized and **IN103** is de-energized:

SS3 = **!IN103 * IN102 * IN101** = NOT(IN103) * IN102 * IN101
= NOT(logical 0) * logical 1 * logical 1 = logical 1

To get from the position 3 to position 5 on the selector switch, the switch passes through the position 4. The switch is only briefly in position 4:

SS4 = **IN103 * !IN102 * !IN101** = IN103 * NOT(IN102) * NOT(IN101)
= logical 1 * NOT(logical 0) * NOT(logical 0) = logical 1

but not long enough to be qualified by time setting TGR in order to change the active setting group to setting Group 4. For such a rotating selector switch application, qualifying time setting TGR is typically set at 180 to 300 cycles.

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Set TGR long enough to allow the selector switch to pass through intermediate positions without changing the active setting group, until the switch rests on the desired setting group position.

Selector Switch Switched to Position 5

Refer to *Figure 7.23*.

If the selector switch is rested on position 5 in *Figure 7.22*, setting Group 5 becomes the active setting group (after qualifying time setting TGR; Relay Word bit SG5 = logical 1). Inputs **IN101** and **IN103** are energized and **IN102** is de-energized:

SS5 = **IN103 * !IN102 * IN101** = IN103 * NOT(IN102) * IN101
= logical 1 * NOT(logical 0) * logical 1 = logical 1

To get from position 5 to position REMOTE on the selector switch, the switch passes through the positions 4, 3, 2, and 1. The switch is only briefly in the these positions, but not long enough to be qualified by time setting TGR in order to change the active setting group to any one of these setting groups.

Selector Switch Now Rests on Position REMOTE

Refer to *Figure 7.23*.

If the selector switch is rested on position REMOTE in *Figure 7.20*, all inputs **IN101**, **IN102**, and **IN103** are de-energized and all settings SS1–SS6 in *Table 7.7* are at logical 0. The last active setting group (Group 5 in this example) remains the active setting group (Relay Word bit SG5 = logical 1).

With settings SS1–SS6 all at logical 0, the serial port **GROUP** command or the front-panel **{GROUP}** pushbutton can be used to switch the active setting group from Group 5, in this example, to another desired setting group.

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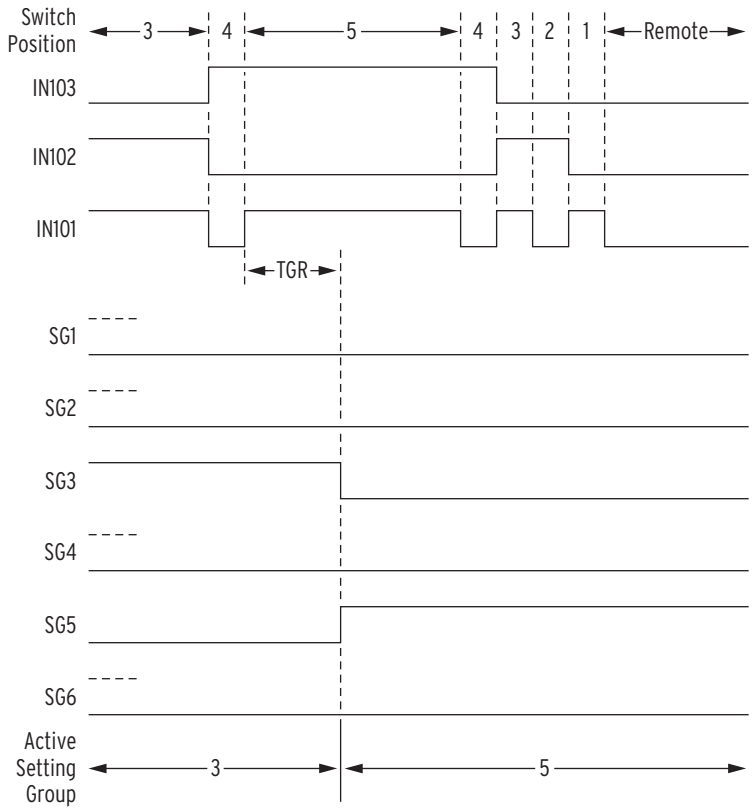


Figure 7.23 Active Setting Group Switching (With Rotating Selector Switch) Time Line

Active Setting Group Retained

Power Loss

The active setting group is retained if power to the relay is lost and then restored. If a particular setting group is active (e.g., setting Group 5) when power is lost, it comes back with the same setting group active when power is restored.

Settings Change

If individual settings are changed (for the active setting group or one of the other setting groups), the active setting group is retained, much like in the preceding *Power Loss on page 7.15* explanation.

If individual settings are changed for a setting group other than the active setting group, there is no interruption of the active setting group (the relay is not momentarily disabled).

If the individual settings change causes a change in one or more SELOGIC control equation settings SS1–SS6, the active setting group can be changed, subject to the newly enabled SS1–SS6 settings.

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Note: Make Active Setting Group Switching Settings With Care

The active setting group is stored in nonvolatile memory so it can be retained during power loss or settings change. The nonvolatile memory is rated for a finite number of "writes" for all setting group changes. Exceeding the limit can result in an EEPROM self-test failure. **An average of one (1) setting group change per day can be made for a 25-year relay service life.**

This requires that SELOGIC control equation settings SS1–SS6 (see *Table 7.4*) be set with care. Settings SS1–SS6 cannot result in continuous cyclical changing of the active setting group. Time setting TGR qualifies settings SS1–SS6 before changing the active setting group. If optoisolated inputs IN101–IN106 are used in settings SS1–SS6, the inputs have their own built-in debounce timer that can help in providing the necessary time qualification (see *Figure 7.1*).

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SELOGIC Control Equation Variables/Timers

Sixteen (16) SELOGIC control equation variables/timers are available. Each SELOGIC control equation variable/timer has a SELOGIC control equation setting input and variable/timer outputs as shown in *Figure 7.24* and *Figure 7.25*.

Timers SV1T–SV6T in *Figure 7.24* have a setting range of a little over 4.5 hours:

0.00–999999.00 cycles in 0.25-cycle increments

Timers SV7T–SV16T in *Figure 7.25* have a setting range of almost 4.5 minutes:

0.00–16000.00 cycles in 0.25-cycle increments

These timer setting ranges apply to both pickup and dropout times (SV*n*PU and SV*n*DO, *n* = 1–16).

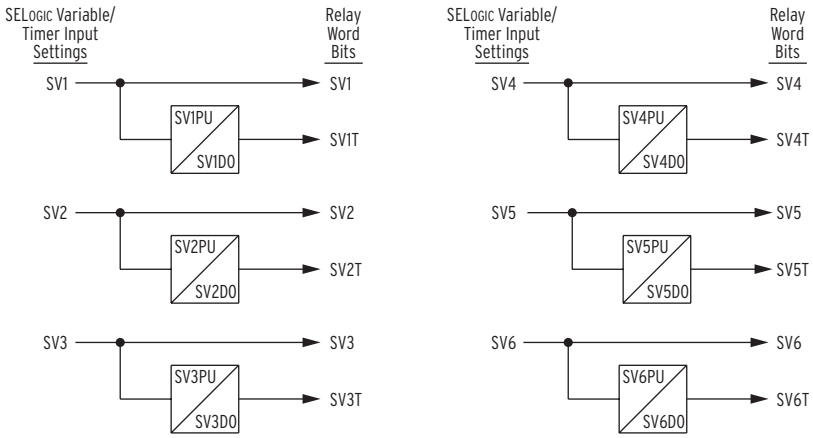


Figure 7.24 SELOGIC Control Equation Variables/Timers SV1/SV1T-SV6/SV6T

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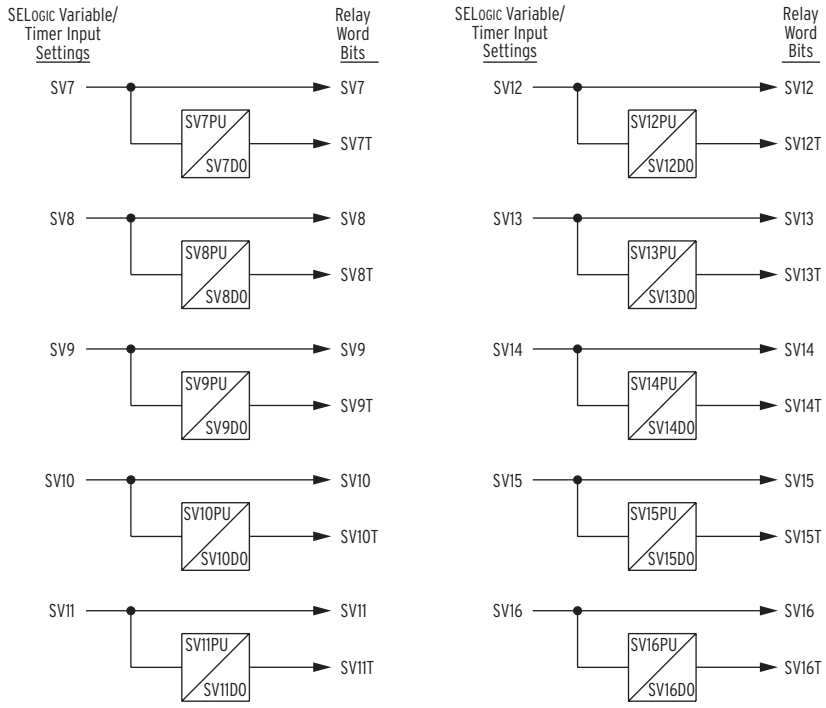


Figure 7.25 SELOGIC Control Equation Variables/Timers SV7/SV7T–SV16/SV16T

Settings Example 1

In the SELOGIC control equation settings, a SELOGIC control equation timer can be used for a simple breaker failure scheme:

SV2 = **TRIP**

The TRIP Relay Word bit is run through a timer for breaker failure timing. Timer pickup setting SV2PU is set to the breaker failure time (SV2PU = 12.00 cycles). Timer dropout setting SV2DO is set for a 2-cycle dropout (SV2DO = 2.00 cycles). The output of the timer (Relay Word bit SV2T) operates output contact **OUT103**.

OUT103 = **SV2T**

Settings Example 2

Another application idea is dedicated breaker failure protection (see *Figure 7.26*):

SV6 = **IN101** (breaker failure initiate)

SV7 = **(SV7 + IN101)*(50P1 + 50N1)**

OUT101 = **SV6T** (retrip)

OUT102 = **SV7T** (breaker failure trip)

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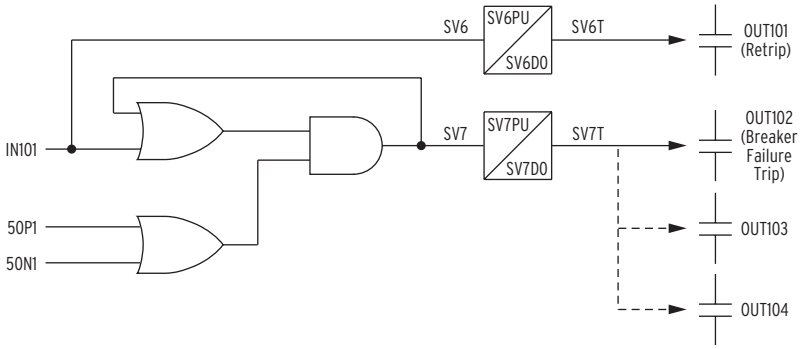


Figure 7.26 Dedicated Breaker Failure Scheme Created With SELOGIC Control Equation Variables/Timers

Note that the above SELOGIC control equation setting SV7 creates a seal-in logic circuit (as shown in *Figure 7.26*) by virtue of SELOGIC control equation setting SV7 being set equal to Relay Word bit SV7 (SELOGIC control equation variable SV7):

SV7 = **(SV7 + IN101)*(50P1 + 50N1)**

Optoisolated input **IN101** functions as a breaker failure initiate input. Phase instantaneous overcurrent element 50P1 and neutral ground instantaneous overcurrent element 50N1 function as fault detectors.

Timer pickup setting SV6PU provides retrip delay, if desired (can be set to zero). Timer dropout setting SV6DO holds the retrip output (output contact **OUT101**) closed for extra time if needed after the breaker failure initiate signal (IN101) goes away.

Timer pickup setting SV7PU provides breaker failure timing. Timer dropout setting SV7DO holds the breaker failure trip output (output contact **OUT102**) closed for extra time if needed after the breaker failure logic unlatches (fault detectors 50P1 and 50N1 dropout).

Note that *Figure 7.26* suggests the option of having output contacts **OUT103** and **OUT104** operate as additional breaker failure trip outputs. This is done by making the following SELOGIC control equation settings:

OUT103 = **SV7T** (breaker failure trip)

OUT104 = **SV7T** (breaker failure trip)

Settings Example 3

The seal-in logic circuit in the dedicated breaker failure scheme in *Figure 7.26* can be removed by changing the SELOGIC control equation setting SV7 to:

SV7 = **IN101*(50P1 + 50N1)**

If the seal-in logic circuit is removed, optoisolated input **IN101** (breaker failure initiate) has to be continually asserted for a breaker failure time-out.

Timers Reset When Power Is Lost, Settings Are Changed, or Active Setting Group Is Changed

If power is lost to the relay, settings are changed (for the active setting group), or the active setting group is changed, the SELOGIC control equation variables/timers are reset. Relay Word bits SV*n* and SV*n*T (*n* = 1–16) are reset to logical 0 and corresponding timer settings SV*n*PU and SV*n*DO load up again after power restoration, settings change, or active setting group switch.

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Preceding *Figure 7.26* shows an effective seal-in logic circuit, created by use of Relay Word bit SV7 (SELOGIC control equation variable SV7) in SELOGIC control equation SV7:

SV7 = **(SV7 + IN101)*(50P1 + 50N1)**

If power is lost to the relay, settings are changed (for the active setting group), or the active setting group is changed, the seal-in logic circuit is "broken" by virtue of Relay Word bit SV7 being reset to logical 0 (assuming input **IN101** is not asserted). Relay Word bit SV7T is also reset to logical 0, and timer settings SV7PU and SV7DO load up again.

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Output Contacts

Figure 7.27 and *Figure 7.28* show the example operation of output contact Relay Word bits (e.g., Relay Word bits OUT101–OUT107 in *Figure 7.27*) due to:

SELOGIC control equation operation (e.g., SELOGIC control equation settings OUT101–OUT107 in *Figure 7.27*)

or

PULSE command execution

The output contact Relay Word bits in turn control the output contacts (e.g., output contacts **OUT101**–**OUT107** in *Figure 7.27*).

Alarm logic/circuitry controls the **ALARM** output contact (see *Figure 7.27*)

Figure 7.27 is used for following discussion/examples. The output contacts in *Figure 7.28* operate similarly.

Factory Settings Example

In the factory SELOGIC control equation settings, two output contacts are used:

OUT101 = **TRIP** (overcurrent tripping/manual tripping; see *Section 5: Trip and Target Logic*)

OUT102 = **CLOSE** (automatic reclosing/manual closing; see *Section 6: Close and Reclose Logic*)

OUT103 = **0** (output contact **OUT103** not used—set equal to zero)

•

•

•

OUT107 = **0** (output contact **OUT107** not used—set equal to zero)

Operation of Output Contacts for Different Output Contact Types

Output Contacts OUT101 -OUT107

Refer to *Figure 7.27*.

The execution of the serial port command **PULSE *n*** (*n* = OUT101–OUT107) asserts the corresponding Relay Word bit (OUT101–OUT107) to logical 1. The assertion of SELOGIC control equation setting OUT*m* (*m* = 101–107) to logical 1 also asserts the corresponding Relay Word bit OUT*m* (*m* = 101–107) to logical 1.

The assertion of Relay Word bit OUT*m* (*m* = 101–107) to logical 1 causes the energization of the corresponding output contact OUT*m* coil. Depending on the contact type (a or b), the output contact closes or opens as demonstrated in *Figure 7.27*. An “a” type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A “b” type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

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Notice that *Figure 7.27* shows all four possible combinations of output contact coil states (energized or de-energized) and output contact types (a or b). See *Output Contact Jumpers on page 2.44* for output contact type options.

Output contact pickup time is less than 5 ms.

Output contact dropout time is less than 8 ms, typical.

ALARM Output Contact

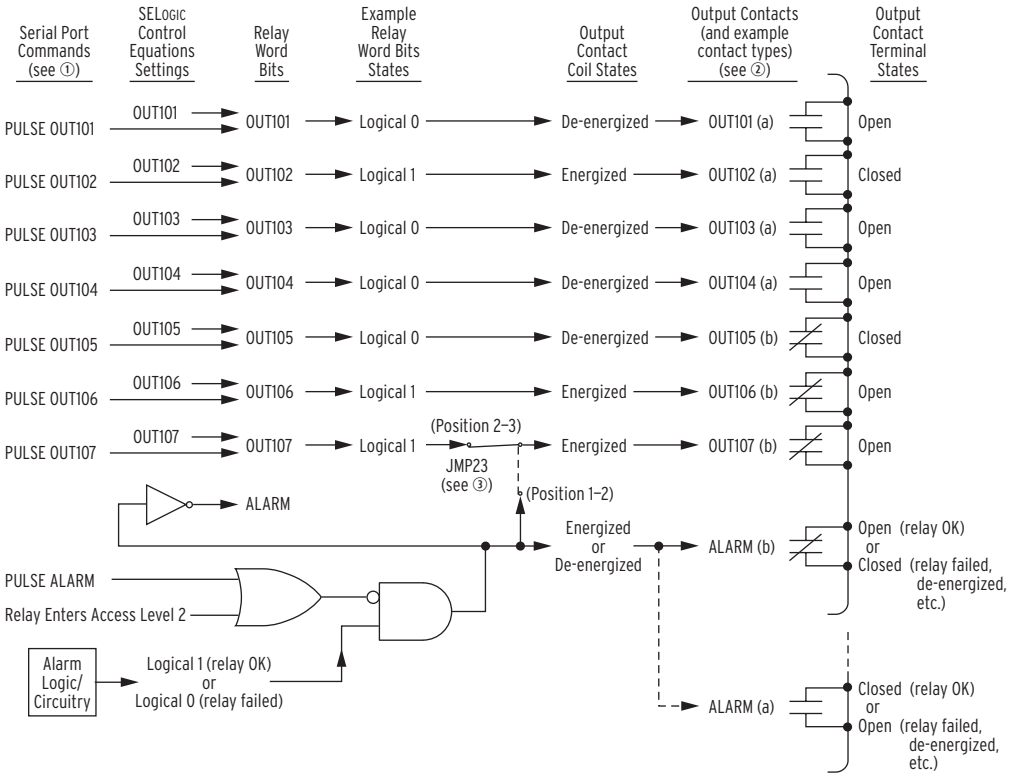
Refer to *Figure 7.27* and *Relay Self-Tests on page 13.9*. When the relay is operational, the **ALARM** output contact coil is energized. The alarm logic/circuitry keeps the **ALARM** output contact coil energized. Depending on the **ALARM** output contact type (a or b), the **ALARM** output contact closes or opens as demonstrated in *Figure 7.27*. An "a" type output contact is open when the output contact coil is de-energized and closed when the output contact coil is energized. A "b" type output contact is closed when the output contact coil is de-energized and open when the output contact coil is energized.

To verify **ALARM** output contact mechanical integrity, execute the serial port command **PULSE ALARM**. Execution of this command momentarily de-energizes the **ALARM** output contact coil.

The Relay Word bit ALARM is deasserted to logical 0 when the relay is operational. When the serial port command **PULSE ALARM** is executed, the ALARM Relay Word bit momentarily asserts to logical 1. Also, when the relay enters Access Level 2, the ALARM Relay Word bit momentarily asserts to logical 1 (and the **ALARM** output contact coil is de-energized momentarily).

Notice that *Figure 7.27* shows all possible combinations of **ALARM** output contact coil states (energized or de-energized) and output contact types (a or b). See *Output Contact Jumpers on page 2.44* for output contact type options.

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① The **PULSE** command is also available via the front panel (**{CNTRL}** pushbutton, "output contact testing" option). Execution of the **PULSE** command results in a logical 1 input into the above logic (one-second default pulse width).

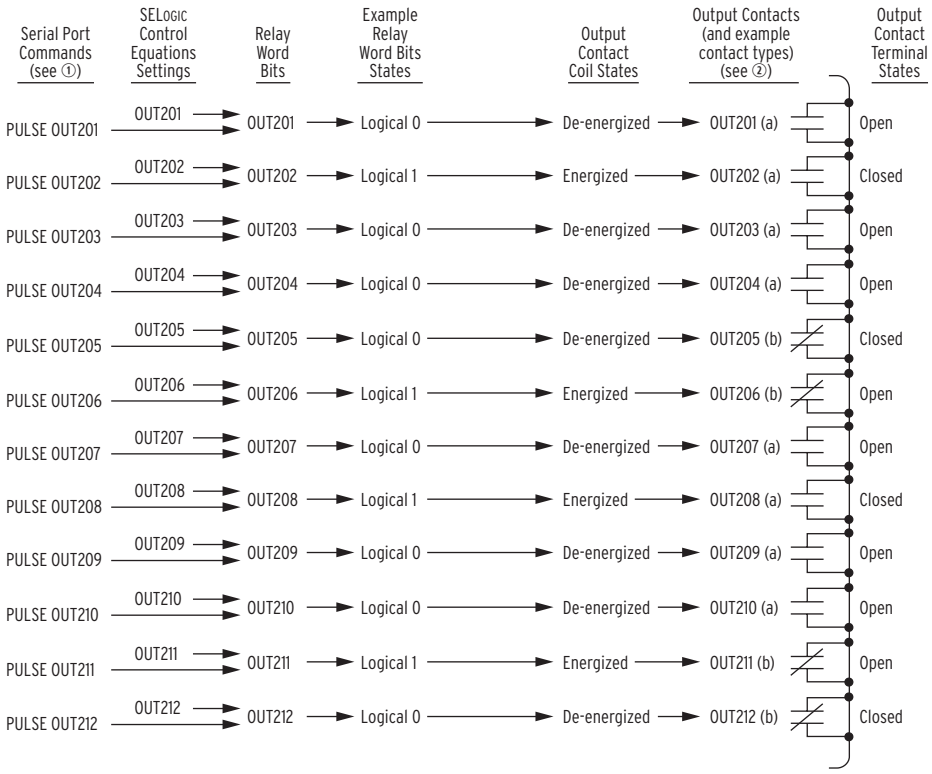
② Output contacts **OUT101–ALARM** are configurable as "a" or "b" type output contacts. See Figure 2.32 and Table 2.3 for more information on selecting output contact type.

③ Main board jumper JMP23 allows output contact **OUT107** to operate as: regular output contact **OUT107** (JMP23 in position 2–3); an extra Alarm output contact (JMP23 in position 1–2).

See Figure 2.32 and Table 2.4 for more information on jumper JMP23.

Figure 7.27 Logic Flow for Example Output Contact Operation

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① The **PULS**E command is also available via the front panel (**{CNTRL}** pushbutton, "output contact testing" option). Execution of the **PULSE** command results in a logical 1 input into the above logic (one-second default pulse width).

② Output contacts **OUT209–OUT212** are configurable as "a" or "b" type output contacts on plug-in connector versions. All 12 outputs are configurable on screw-terminal block versions. See Figure 2.33, Figure 2.34, and Table 2.3 for more information on selecting output contact type.

Figure 7.28 Logic Flow for Example Output Contact Operation—Extra I/O Board

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Rotating Default Display

The rotating default display on the relay front-panel replaces indicating panel lights. Traditional indicating panel lights are turned on and off by circuit breaker auxiliary contacts, front-panel switches, SCADA contacts, etc. They indicate such conditions as:

circuit breaker open/closed

reclosing relay enabled/disabled

Traditional Indicating Panel Lights

Figure 7.29 shows traditional indicating panel lights wired in parallel with SEL-351S optoisolated inputs. Input **IN101** provides circuit breaker status to the relay, and input **IN102** enables/disables reclosing in the relay via the following SELOGIC control equation settings:

52A = **IN101**

79DTL = **!IN102** [= NOT(IN102); drive-to-lockout setting]

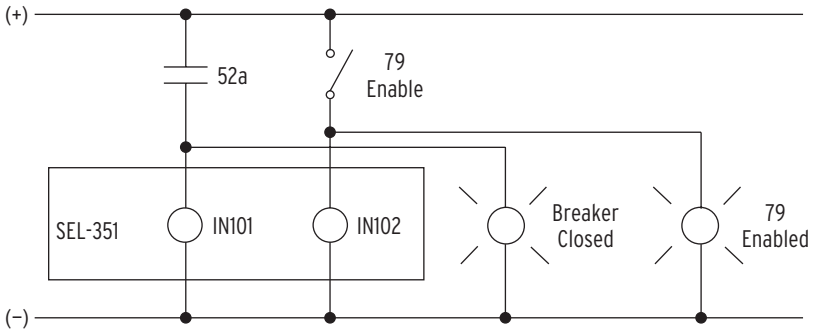


Figure 7.29 Traditional Panel Light Installations

Note that *Figure 7.29* corresponds to *Figure 7.3* (settings examples).

Reclosing Relay Status Indication

In *Figure 7.29*, the **79 ENABLED** panel light illuminates when the "79 Enable" switch is closed. When the "79 Enable" switch is open, the **79 ENABLED** panel light extinguishes, and it is understood that the reclosing relay is disabled.

Circuit Breaker Status Indication

In *Figure 7.29*, the **BREAKER CLOSED** panel light illuminates when the 52a circuit breaker auxiliary contact is closed. When the 52a circuit breaker auxiliary contact is open, the **BREAKER CLOSED** panel light extinguishes, and it is understood that the breaker is open.

Traditional Indicating Panel Lights Replaced With Rotating Default Display

The indicating panel lights are not needed if the rotating default display feature in the SEL-351S is used. *Figure 7.30* shows the elimination of the indicating panel lights by using the rotating default display.

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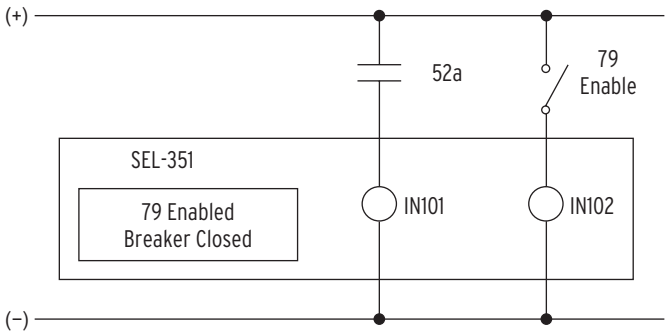


Figure 7.30 Rotating Default Display Replaces Traditional Panel Light Installations

There are sixteen (16) of these default displays available in the SEL-351S. Each default display has two complementary screens (e.g., **BREAKER CLOSED** and **BREAKER OPEN**) available.

General Operation of Rotating Default Display Settings

SELOGIC control equation display point setting DP*n* (*n* = 1–16) controls the display of corresponding, complementary text settings:

DP*n*_1 (displayed when DP*n* = logical 1)

DP*n*_0 (displayed when DP*n* = logical 0)

Make each text setting through the serial port using the command **SET T**. View these text settings using the serial port command **SHO T** (see *Section 9: Setting the Relay* and *Section 10: Serial Port Communications and Commands*). These text settings are displayed on the SEL-351S front-panel display on a time-variable rotation using Global Setting SCROLD (see *Rotating Default Display on page 11.12* for more specific operation information).

The following settings examples use optoisolated inputs **IN101** and **IN102** in the display points settings. Local bits (LB1–LB16), latch bits (LT1–LT16), remote bits (RB1–RB16), setting group indicators (SG1–SG6), and any other combination of Relay Word bits in a SELOGIC control equation setting can also be used in display point settings DP*n*.

Settings Examples

These example settings provide the replacement solution shown in *Figure 7.30* for the traditional indicating panel lights in *Figure 7.29*.

Reclosing Relay Status Indication

Make SELOGIC control equation display point setting DP1:

DP1 = **IN102**

Make corresponding, complementary text settings:

DP1_1 = **79 ENABLED**

DP1_0 = **79 DISABLED**

Display point setting DP1 controls the display of the text settings.

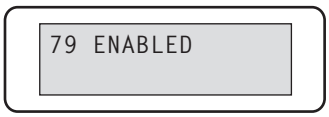
Reclosing Relay Enabled

In *Figure 7.30*, optoisolated input **IN102** is energized to enable the reclosing relay, resulting in:

DP1 = **IN102** = logical 1

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This results in the display of corresponding text setting DP1_1 on the front-panel display:

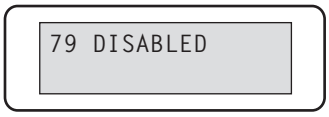


Reclosing Relay Disabled

In *Figure 7.30*, optoisolated input **IN102** is de-energized to disable the reclosing relay, resulting in:

DP1 = **IN102** = logical 0

This results in the display of corresponding text setting DP1_0 on the front-panel display:



Circuit Breaker Status Indication

Make SELOGIC control equation display point setting DP2:

52A = **IN101**

DP2 = **52A**

Make corresponding, complementary text settings:

DP2_1 = **BREAKER CLOSED**

DP2_0 = **BREAKER OPEN**

Display point setting DP2 controls the display of the text settings.

Circuit Breaker Closed

In *Figure 7.30*, optoisolated input **IN101** is energized when the 52a circuit breaker auxiliary contact is closed, resulting in:

52A = **IN101** = logical 1

DP2 = **52A** = logical 1

This results in the display of corresponding text setting DP2_1 on the front-panel display:



Circuit Breaker Open

In *Figure 7.30*, optoisolated input **IN101** is de-energized when the 52a circuit breaker auxiliary contact is open, resulting in:

52A = **IN101** = logical 0

DP2 = **52A** = logical 0

This results in the display of corresponding text setting DP2_0 on the front-panel display:

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Additional Settings Examples

Display Only One Message

To display just one screen, but not its complement, set only one of the text settings. For example, to display just the "breaker closed" condition, but not the "breaker open" condition, make the following settings:

52A = **IN101**

DP2 = **52A** (52a circuit breaker auxiliary contact connected to input **IN101**—see *Figure 7.30*)

DP2_1 = **BREAKER CLOSED** (displays when DP2 = logical 1)

DP2_0 = (blank)

Circuit Breaker Closed

In *Figure 7.30*, optoisolated input **IN101** is energized when the 52a circuit breaker auxiliary contact is closed, resulting in:

52A = **IN101** = logical 1

DP2 = **52A** = logical 1

This results in the display of corresponding text setting DP2_1 on the front-panel display:



Circuit Breaker Open

In *Figure 7.30*, optoisolated input **IN101** is de-energized when the 52a circuit breaker auxiliary contact is open, resulting in:

52A = I **N101** = logical 0

DP2 = **52A** = logical 0

Corresponding text setting DP2_0 is not set (it is "blank"), so no message is displayed on the front-panel display.

Continually Display a Message

To continually display a message in the rotation, set the SELOGIC control equation display point setting directly to 0 (logical 0) or 1 (logical 1) and the corresponding text setting. For example, if an SEL-351S is protecting a 12 kV distribution feeder, labeled "Feeder 1204," the feeder name can be continually displayed with the following settings

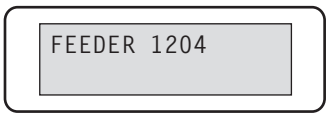
DP5 = **1** (set directly to logical 1)

DP5_1 = **FEEDER 1204** (displays when DP5 = logical 1)

DP5_0 = ("blank")

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This results in the continual display of text setting DP5_1 on the front-panel display:



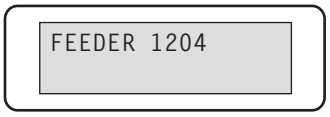
This can also be realized with the following settings:

DP5 = **0** (set directly to logical 0)

DP5_1 = ("blank")

DP5_0 = **FEEDER 1204** (displays when DP5 = logical 0)

This results in the continual display of text setting DP5_0 on the front-panel display:



Active Setting Group Switching Considerations

The SELOGIC control equation display point settings DP*n* (*n* = 1–16) are available separately in each setting group. The corresponding text settings DP*n*_1 and DP*n*_0 are made only once and used in all setting groups.

Refer to *Figure 7.30* and the following example setting group switching discussion.

Setting Group 1 Is the Active Setting Group

When setting Group 1 is the active setting group, optoisolated input **IN102** operates as a reclose enable/disable switch with the following settings:

SELOGIC control equation settings:

79DTL = **!IN102 + ...** [= NOT(IN102) + ...; drive-to-lockout setting]

DP1 = **IN102**

Text settings:

DP1_1 = **79 ENABLED** (displayed when DP1 = logical 1)

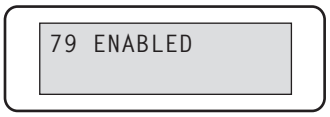
DP1_0 = **79 DISABLED** (displayed when DP1 = logical 0)

Reclosing Relay Enabled

In *Figure 7.30*, optoisolated input **IN102** is energized to enable the reclosing relay, resulting in:

DP1 = **IN102** = logical 1

This results in the display of corresponding text setting DP1_1 on the front-panel display:



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Reclosing Relay Disabled

In *Figure 7.30*, optoisolated input **IN102** is de-energized to disable the reclosing relay, resulting in:

DP1 = **IN102** = logical 0

This results in the display of corresponding text setting DP1_0 on the front-panel display:



Now the active setting group is switched from setting Group 1 to 4.

Switch to Setting Group 4 as the Active Setting Group

When setting Group 4 is the active setting group, the reclosing relay is always disabled and optoisolated input **IN102** has no control over the reclosing relay. The text settings cannot be changed (they are used in all setting groups), but the SELOGIC control equation settings can be changed:

SELOGIC control equation settings:

79DTL = **1** (set directly to logical 1—reclosing relay permanently "driven-to-lockout")

DP1 = **0** (set directly to logical 0)

Text settings (remain the same for all setting groups):

DP1_1 = **79 ENABLED** (displayed when DP1 = logical 1)

DP1_0 = **79 DISABLED** (displayed when DP1 = logical 0)

Because SELOGIC control equation display point setting DP1 is always at logical 0, the corresponding text setting DP1_0 continually displays in the rotating default displays:



Additional Rotating Default Display Example

See *Figure 5.18* and accompanying text in *Section 5: Trip and Target Logic* for an example of resetting a rotating default display with the **{TARGET RESET}** pushbutton.

Displaying Values (other than user-entered text) on the Rotating Default Display

Table 7.8–*Table 7.11* list all the available values (other than the user-entered text values, discussed previously) that rotate on the default display, subject to the number of available display points. These available values cover metering (*Table 7.8*), breaker wear monitor (*Table 7.9*), and time-overcurrent element pickups (*Table 7.10* and *Table 7.11*).

In general, any of these values can be selected for the rotating default display with a leading two-character sequence:

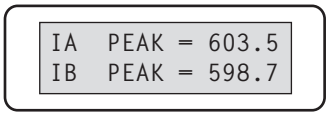
"::" (double colon)

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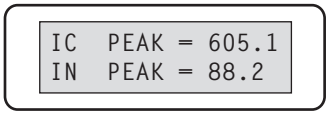
followed by the mnemonic text setting. For example, to display peak demand currents (*Table 7.8*) for currents **IA**, **IB**, **IC**, and **IN**, make the following text (**SET T** command) and logic (**SET L** command) settings:

SET T	SET L
DP1_0 = ::IAPK	DP1 = 0
DP2_0 = ::IBPK	DP2 = 0
DP3_0 = ::ICPK	DP3 = 0
DP4_0 = ::INPK	DP4 = 0

Logic settings DP1–DP4 are permanently set to logical 0 in this example. This causes the corresponding DP*n*_0 value to permanently rotate in the display (the mnemonics in the DP*n*_0 settings indicate the value displayed, per *Table 7.8*):



then,



Rotating Default Display on page 11.12 explains pictorially which display setting is displayed (DP*n*_0 or DP*n*_1), depending on the logic state (logical 0 or 1) of corresponding logic setting DP*n*.

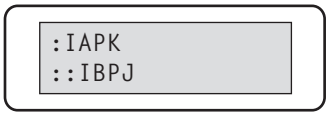
Values Displayed for Incorrect Settings

If the display point setting does not match the correct format (using the leading two-character sequence "::" followed by the correct mnemonic), the relay will display the setting text string as it was actually entered, without substituting the display value. For example:

SET T		SET L
DP1_0 = :IAPK	(missing ":")	DP1 = 0
DP2_0 = ::IBPJ	(misspelled mnemonic)	DP2 = 0

Again, logic settings DP1 and DP2 are permanently set to logical 0. This causes the corresponding DP*n*_0 value to permanently rotate in the display. With the DP*n*_0 setting problems just discussed, the relay displays the setting text string as it was actually entered, without substituting the intended display value from *Table 7.8*:

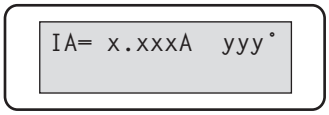
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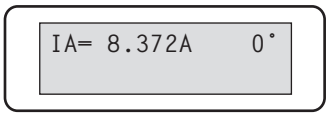
Extra Details for Displaying Metering Values on the Rotating Default Display

Table 7.8 lists all the available metering values that rotate on the default display, subject to the number of available display points. These values correspond to the primary metering values available via the **METER** command (**MET** [Instantaneous], **MET X** [Extended Instantaneous], **MET D** [Demand], and **MET E** [Energy]; see *Section 10* for serial port commands).

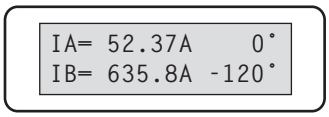
Note in *Table 7.8* that many of the magnitude values are listed with three digits behind the decimal point. For example, the first value in *Table 7.8* is shown generically as in this example:



Magnitudes less than 10 display with three digits behind the decimal point:



Magnitudes greater than or equal to 10 display with two or fewer digits behind the decimal point:



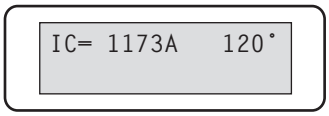


Table 7.8 Mnemonic Settings for Metering on the Rotating Default Display (Sheet 1 of 4)

Mnemonic	Display																Description
IA		I	A	=	x	x	.	x	x	x	A		y	y	y	°	IA input current
IB		I	B	=	x	x	.	x	x	x	A		y	y	y	°	IB input current
IC		I	C	=	x	x	.	x	x	x	A		y	y	y	°	IC input current
IN		I	N	=	x	x	.	x	x	x	A		y	y	y	°	IN input current
VA[a]		V	A	=	x	.	x	x	x	k	V		y	y	y	°	VA input voltage
VB[a]		V	B	=	x	.	x	x	x	k	V		y	y	y	°	VB input voltage
VC[a]		V	C	=	x	.	x	x	x	k	V		y	y	y	°	VC input voltage
VS		V	S	=	x	.	x	x	x	k	V		y	y	y	°	VS input voltage
IG		I	G	=	x	x	.	x	x	x	A		y	y	y	°	IG=IA+IB+IC (residual current)
3IO	3	I	0	=	x	x	.	x	x	x	A		y	y	y	°	3I0=IG (zero-sequence current)

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Table 7.8 Mnemonic Settings for Metering on the Rotating Default Display (Sheet 2 of 4)

Mnemonic	Display																Description
I1		I	1	=	x	x	.	x	x	x	A		y	y	y	°	positive-sequence current I1
3I2	3	I	2	=	x	x	.	x	x	x	A		y	y	y	°	negative-sequence current 3I2
3V0[a]	3	V	0	=	x	.	x	x	x	k	V		y	y	y	°	zero-sequence voltage
V1		V	1	=	x	.	x	x	x	k	V		y	y	y	°	positive-sequence voltage V1
V2		V	2	=	x	.	x	x	x	k	V		y	y	y	°	negative-sequence voltage V2
MWA[a]				M	W			A	=		x	x	.	x	x	x	A-phase megawatts
MWB[a]				M	W			B	=		x	x	.	x	x	x	B-phase megawatts
MWC[a]				M	W			C	=		x	x	.	x	x	x	C-phase megawatts
MW3				M	W		3	P	=		x	x	.	x	x	x	three-phase megawatts
MVARA[a]		M	V	A	R			A	=		x	x	.	x	x	x	A-phase megavars
MVARB[a]		M	V	A	R			B	=		x	x	.	x	x	x	B-phase megavars
MVARC[a]		M	V	A	R			C	=		x	x	.	x	x	x	C-phase megavars
MVAR3		M	V	A	R		3	P	=		x	x	.	x	x	x	three-phase megavars
PFA[a]	P	F			A	=		x	.	x	x		L	E	A	D	A-phase power factor
PFB[a]	P	F			B	=		x	.	x	x		L	A	G		B-phase power factor
PFC[a]	P	F			C	=		x	.	x	x		L	A	G		C-phase power factor
PF3	P	F		3	P	=		x	.	x	x		L	E	A	D	three-phase power factor
FREQ	F	R	Q	=	x	x	.	x									system frequency from VA or V1
VAB	V	A	B	=	x	.	x	x	x	k	V		y	y	y	°	VAB input voltage
VBC	V	B	C	=	x	.	x	x	x	k	V		y	y	y	°	VBC input voltage
VCA	V	C	A	=	x	.	x	x	x	k	V	_	y	y	y	°	VCA input voltage
IADEM		I	A		D	E	M		=		x	x	.	x	x	x	IA demand current
IAPK		I	A		P	E	A	K	=		x	x	.	x	x	x	IA peak demand current
IBDEM		I	B		D	E	M		=		x	x	.	x	x	x	IB demand current
IBPK		I	B		P	E	A	K	=		x	x	.	x	x	x	IB peak demand current
ICDEM		I	C		D	E	M		=		x	x	.	x	x	x	IC demand current
ICPK		I	C		P	E	A	K	=		x	x	.	x	x	x	IC peak demand current
INDEM		I	N		D	E	M		=		x	x	.	x	x	x	IN demand current
INPK		I	N		P	E	A	K	=		x	x	.	x	x	x	IN peak demand current
IGDEM		I	G		D	E	M		=		x	x	.	x	x	x	IG demand current
IGPK		I	G		P	E	A	K	=		x	x	.	x	x	x	IG peak demand current
3I2DEM	3	I	2		D	E	M		=		x	x	.	x	x	x	3I2 demand current
3I2PK	3	I	2		P	E	A	K	=		x	x	.	x	x	x	3I2 peak demand current
MWADI[a]	M	W	A		I	N		D	E	M	=	x	.	x	x	x	A-phase demand megawatts in
MWAPI[a]	M	W	A		I	N		P	K		=	x	.	x	x	x	A-phase peak demand megawatts in
MWBDI[a]	M	W	B		I	N		D	E	M	=	x	.	x	x	x	B-phase demand megawatts in
MWBPI[a]	M	W	B		I	N		P	K		=	x	.	x	x	x	B-phase peak demand megawatts in
MWCDI[a]	M	W	C		I	N		D	E	M	=	x	.	x	x	x	C-phase demand megawatts in
MWCPI[a]	M	W	C		I	N		P	K		=	x	.	x	x	x	C-phase peak demand megawatts in

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Table 7.8 Mnemonic Settings for Metering on the Rotating Default Display (Sheet 3 of 4)

Mnemonic	Display																Description
MW3DI	M	W	3		I	N		D	E	M	=	x	.	x	x	x	three-phase demand megawatts in
MW3PI	M	W	3		I	N		P	K		=	x	.	x	x	x	three-phase peak demand megawatts in
MVRADI[a]	M	V	R	A		I		D	E	M	=	x	.	x	x	x	A-phase demand megavars in
MVRAPI[a]	M	V	R	A		I		P	K		=	x	.	x	x	x	A-phase peak demand megavars in
MVRBDI[a]	M	V	R	B		I		D	E	M	=	x	.	x	x	x	B-phase demand megavars in
MVRBPI[a]	M	V	R	B		I		P	K		=	x	.	x	x	x	B-phase peak demand megavars in
MVRCDI[a]	M	V	R	C		I		D	E	M	=	x	.	x	x	x	C-phase demand megavars in
MVRCPI[a]	M	V	R	C		I		P	K		=	x	.	x	x	x	C-phase peak demand megavars in
MVR3DI	M	V	R	3		I		D	E	M	=	x	.	x	x	x	three-phase demand megavars in
MVR3PI	M	V	R	3		I		P	K		=	x	.	x	x	x	three-phase peak demand megavars in
MWADO[a]	M	W	A			O		D	E	M	=	x	.	x	x	x	A-phase demand megawatts out
MWAPO[a]	M	W	A			O		P	K		=	x	.	x	x	x	A-phase peak demand megawatts out
MWBDO[a]	M	W	B			O		D	E	M	=	x	.	x	x	x	B-phase demand megawatts out
MWBPO[a]	M	W	B			O		P	K		=	x	.	x	x	x	B-phase peak demand megawatts out
MWCDO[a]	M	W	C			O		D	E	M	=	x	.	x	x	x	C-phase demand megawatts out
MWCPO[a]	M	W	C			O		P	K		=	x	.	x	x	x	C-phase peak demand megawatts out
MW3DO	M	W	3			O		D	E	M	=	x	.	x	x	x	three-phase demand megawatts out
MW3PO	M	W	3			O		P	K		=	x	.	x	x	x	three-phase peak demand megawatts out
MVRADO[a]	M	V	R	A		O		D	E	M	=	x	.	x	x	x	A-phase demand megavars out
MVRAPO[a]	M	V	R	A		O		P	K		=	x	.	x	x	x	A-phase peak demand megavars out
MVRBDO[a]	M	V	R	B		O		D	E	M	=	x	.	x	x	x	B-phase demand megavars out
MVRBPO[a]	M	V	R	B		O		P	K		=	x	.	x	x	x	B-phase peak demand megavars out
MVRCDO[a]	M	V	R	C		O		D	E	M	=	x	.	x	x	x	C-phase demand megavars out
MVRCPO[a]	M	V	R	C		O		P	K		=	x	.	x	x	x	C-phase peak demand megavars out
MVR3DO	M	V	R	3		O		D	E	M	=	x	.	x	x	x	three-phase demand megavars out
MVR3PO	M	V	R	3		O		P	K		=	x	.	x	x	x	three-phase peak demand megavars out
MWHAI[a]	M	W	h		A			I	N	=	x	x	.	x	x	x	A-phase megawatt-hours in
MWHAO[a]	M	W	h		A		O	U	T	=	x	x	.	x	x	x	A-phase megawatt-hours out
MWHBI[a]	M	W	h		B			I	N	=	x	x	.	x	x	x	B-phase megawatt-hours in
MWHBO[a]	M	W	h		B		O	U	T	=	x	x	.	x	x	x	B-phase megawatt-hours out
MWHCI[a]	M	W	h		C			I	N	=	x	x	.	x	x	x	C-phase megawatt-hours in
MWHCO[a]	M	W	h		C		O	U	T	=	x	x	.	x	x	x	C-phase megawatt-hours out
MWH3I	M	W	h		3			I	N	=	x	x	.	x	x	x	three-phase megawatt-hours in
MWH3O	M	W	h		3		O	U	T	=	x	x	.	x	x	x	three-phase megawatt-hours out
MVRHAI[a]	M	V	A	R	h		A		I	=	x	x	.	x	x	x	A-phase megavar-hours in
MVRHAO[a]	M	V	A	R	h		A		O	=	x	x	.	x	x	x	A-phase megavar-hours out
MVRHBI[a]	M	V	A	R	h		B		I	=	x	x	.	x	x	x	B-phase megavar-hours in
MVRHBO[a]	M	V	A	R	h		B		O	=	x	x	.	x	x	x	B-phase megavar-hours out

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Table 7.8 Mnemonic Settings for Metering on the Rotating Default Display (Sheet 4 of 4)

Mnemonic	Display																Description
MVRHCI[a]	M	V	A	R	h		C		I	=	x	x	.	x	x	x	C-phase megavar-hours in
MVRHCO[a]	M	V	A	R	h		C		O	=	x	x	.	x	x	x	C-phase megavar-hours out
MVRH3I	M	V	A	R	h		3		I	=	x	x	.	x	x	x	three-phase megavar-hours in
MVRH3O	M	V	A	R	h		3		O	=	x	x	.	x	x	x	three-phase megavar-hours out

[a] Delta-connected relays do not respond to VA, VB, VC, 3V0, MWA, MWB, MWC, MVARA, MVARB, MVARC, PFA, PFB, PFC, MWADI, MWAPI, MWBDI, MWBPI, MWCDI, MWCPI, MVRADI, MVRAPI, MVRBDI, MVRBPI, MVRCDI, MVRCPI, MWADO, MWAPO, MWBDO, MWBPO, MWCDO, MWCPO, MVRAPO, MVRADO, MVRBPO, MVRBDO, MVRCPO, MVRCDO, MWHAI, MWHAO, MWHBI, MWHBO, MWHCI, MWHCO, MVRHAI, MVRHAO, MVRHBI, MVRHBO, MVRHCI, MVRHCO display point settings.

For example: in a delta-connected relay (PTCONN=DELTA), if the following is entered:

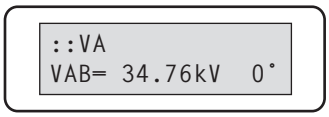
DP1_0 = ::VA

DP2_0 = ::VAB

DP1 = 0

DP2 = 0

Then the front-panel displays:



in sequence with any other defined display points and the default screens.

Extra Details for Displaying Breaker Wear Monitor Quantities on the Rotating Default Display

Table 7.9 lists all the available breaker wear monitor values that rotate on the default display, subject to the number of available display points. Refer to *Section 8: Breaker Monitor, Metering, and Load Profile Functions* for more information about the breaker monitor function.

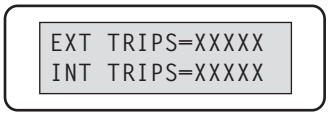
This example demonstrates use of the rotating display to show breaker wear monitor quantities automatically on the rotating default display. This example will set the EXTTR, INTTR, INTIA, EXTIA, and WEARA to display in the rotating default display.

Set the following:

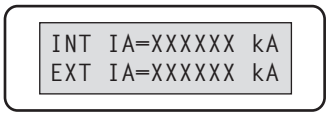
SET T	SET L
DP1_0 = ::EXTTR	DP1 = 0
DP2_0 = ::INTTR	DP2 = 0
DP3_0 = ::INTIA	DP3 = 0
DP4_0 = ::EXTIA	DP4 = 0
DP5_0 = ::WEARA	DP5 = 0

Setting DP*n* = 0 and using the DP*n*_0 in the text settings allows the setting to permanently rotate in the display. The DP*n* logic equation can be set to control the text display-turning it on and off under certain conditions. With the relay set as shown previously, the LCD will show the following:

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then,



and then,

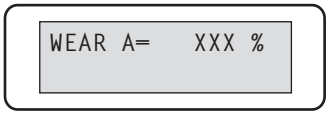


Table 7.9 Mnemonic Settings for Breaker Wear Monitor Values on the Rotating Default Display

Mnemonic	Display																Description
BRKDAT	R	S	T		D	A	T	:	m	m	/	d	d	/	y	y	last reset date
BRKTIM	R	S	T		T	I	M	:	h	h	:	m	m	:	s	s	last reset time
INTTR	I	N	T		T	R	I	P	S	=		x	x	x	x	x	internal trip count
OPSCTR	O	P	S		C	N	T	R	=			x	x	x	x	x	internal and external trip count
INTIA	I	N	T		I	A	=		x	x	x	x	x		k	A	internal trip Σ IA
INTIB	I	N	T		I	B	=		x	x	x	x	x		k	A	internal trip Σ IB
INTIC	I	N	T		I	C	=		x	x	x	x	x		k	A	internal trip Σ IC
EXTTR	E	X	T		T	R	I	P	S	=		x	x	x	x	x	external trip count
EXTIA	E	X	T		I	A	=		x	x	x	x	x		k	A	external trip Σ IA
EXTIB	E	X	T		I	B	=		x	x	x	x	x		k	A	external trip Σ IB
EXTIC	E	X	T		I	C	=		x	x	x	x	x		k	A	external trip Σ IC
WEARA	W	E	A	R		A	=					y	y	y		%	A phase wear monitor
WEARB	W	E	A	R		B	=					y	y	y		%	B phase wear monitor
WEARC	W	E	A	R		C	=					y	y	y		%	C phase wear monitor

Extra Details for Displaying Time-Overcurrent Elements on the Rotating Default Display

The LCD can display the pickup settings for the time-overcurrent elements in primary units via a special character sequence in the display points equations. As with the previously described display points, the operator does not need to press any buttons to see this information.

To program a display point to show the pickup setting of a time-overcurrent element, first enter the two-character sequence "::" (double colon) followed by the name of the desired time-overcurrent element pickup setting (e.g., 51P1P, 51P2P, 51N1P, 51N2P, 51G1P, 51G2P, or 51QP).

For example, with the settings 51P1P = 6.00 A, and CTR = 120, setting DP1_0 =::51P1P will display **720.00 A pri**.

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The relay calculates the value to display by multiplying the 51PP setting (6.00 A secondary) by the CTR setting (120), arriving at 720.00 A primary. The relay displays the display point DP1_0 because the factory default SELOGIC control equation DP1 = 0 (logical 0).

The calculations for the remaining time-overcurrent elements are similar, except for 51N1P and 51N2P, which are multiplied by the CTRN setting.

If the display point setting does not match the correct format, the relay will display the setting text string as it was actually entered, without substituting the time-overcurrent element setting value.

Table 7.10 lists all the available Time-Overcurrent Elements that rotate on the default display, subject to the number of available display points.

Displaying Time-Overcurrent Elements Example

This example demonstrates use of the rotating display to show time-overcurrent elements in primary units. This example will set the 51P1P and 51N1P to display in the rotating default display.

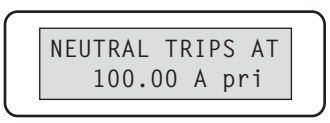
Set the following:

SET	SET T	SET L
CTR = 100	DP1_0 = PHASE TRIPS AT	DP1 = 0
CTRN = 100	DP2_0 = ::51P1P	DP2 = 0
E51P = 1	DP3_0 = NEUTRAL TRIPS AT	DP3 = 0
E51N = 1	DP4_0 = ::51N1P	DP4 = 0
51P1P = 5		
51N1P = 1		

Setting DP*n* = 0 and using the DP*n*_0 in the text settings allows the setting to permanently rotate in the display. The DP*n* logic equation can be set to control the text display—turning it on and off under certain conditions. With the relay set as shown above, the LCD will show the following:



then,



With the control string set on the even display points “DP2, DP4, DP6, …” and the description set on the odd display points “DP1, DP3, …,” each screen the relay scrolls through will have a description with the value below it.

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Table 7.10 Mnemonic Settings for Time-Overcurrent (TOC) Element Pickups on the Rotating Default Display

Mnemonic	Display																Description
51P1P	x	x	x	x	x	x	x	.	x	x		A		p	r	i	pickup for phase TOC element 51P1T
51P2P	x	x	x	x	x	x	x	.	x	x		A		p	r	i	pickup for phase TOC element 51P2T
51N1P	x	x	x	x	x	x	x	.	x	x		A		p	r	i	pickup for neutral ground TOC element 51N1T
51N2P	x	x	x	x	x	x	x	.	x	x		A		p	r	i	pickup for neutral ground TOC element 51N2T
51G1P	x	x	x	x	x	x	x	.	x	x		A		p	r	i	pickup for residual ground TOC element 51G1T
51G2P	x	x	x	x	x	x	x	.	x	x		A		p	r	i	pickup for residual ground TOC element 51G2T
51QP	x	x	x	x	x	x	x	.	x	x		A		p	r	i	pickup for negative-sequence TOC element 51QT

Additional Format for Displaying Time-Overcurrent Elements on the Rotating Default Display

To set the description and the control string of time-overcurrent element on one display point, use the following **SET T** format:

DPi_j = XXX;;[;]ABCDE;YYY

where:

- i is a display point number from 1 to 16
- j is either 1 or 0 (logical 1 or logical 0)
- XXX is an optional pre-label consisting of any characters that you wish to add for labeling the setting value.
- [;] signifies an optional ";" for the ";;;" control string to make more characters available for labeling purposes
  The label character count is the sum of the characters used in the pre- and post-labels. (For example, three characters at the beginning and three characters at the end of the string equal six total characters used for labeling.)
- ABCDE is a relay setting variable from *Table 7.11*.
- YYY is an optional post-label, preceded by a single semicolon (;) character. If no trailing semicolon and label text are added, the relay does not display a post-setting label. Refer to *Table 7.11* to determine the maximum characters allowed for use in pre-/post-label text.

Table 7.11 Mnemonic Settings for Time-Overcurrent (TOC) Element Pickups Using the Same-Line-Label Format on the Rotating Default Display (Sheet 1 of 2)

SET T Setting Variable	Displays Relay Setting Value	Display Format/ Resolution	Maximum Label Characters
;;51P1P	51P1P	xxxxxxx.xx	6
;;51P2P	51P2P	xxxxxxx.xx	6
;;51G1P	51G1P	xxxxxxx.xx	6
;;51G2P	51G2P	xxxxxxx.xx	6
;;51QP	51QP	xxxxxxx.xx	6
;;51N1P	51N1P	xxxxxxx.xx	6
;;51N2P	51N2P	xxxxxxx.xx	6
;;;000	51P1P	xxxxxxx	9
;;;001	51P2P	xxxxxxx	9
;;;002	51G1P	xxxxxxx	9
;;;003	51G2P	xxxxxxx	9
;;;004	51QP	xxxxxxx	9

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Table 7.11 Mnemonic Settings for Time-Overcurrent (TOC) Element Pickups Using the Same-Line-Label Format on the Rotating Default Display (Sheet 2 of 2)

SET T Setting Variable	Displays Relay Setting Value	Display Format/ Resolution	Maximum Label Characters
;;;005	51N1P	xxxxxxx	9
;;;006	51N2P	xxxxxxx	9

Examples with ";; ;" control strings:

SET L DP1 = IN101

SET L DP2 = IN101

SET T DP1_1 = PTO=;;51P1P;Ap

The pre- and post-label characters for DP1_1, are "P", "T", "O", "=", "A", "p", a total of 6 characters. The relay setting to be displayed is 51P1P, as indicated after the control string ";;". The relay converts lowercase "p" to uppercase when the setting is saved.

SET T DP1_0 = NEUTRP;;51N1P;

The pre-label characters for DP1_0, are "N", "E", "U", "T", "R", "P", a total of 6 characters. The relay setting to be displayed is 51N1P, as indicated after the control string ";;"

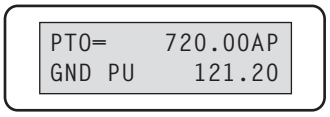
SET T DP2_1 = GND PU;;51G1P;B1

The characters for DP2_1, consist of six pre characters "G", "N", "D", " ", "P", "U", and two post characters "B", "1". The maximum number of label characters is six, so the "B1" will be ignored. The relay setting to be displayed is 51G1P, as indicated after the control string ";;"

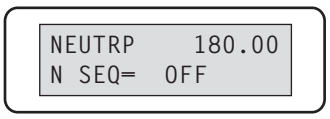
SET T DP2_0 = N SEQ=;;51QP;A

The characters for DP2_0, consist of six pre characters "N", " ", "S", "E", "Q", "=" and one post character "A". The "A" will be ignored. The relay setting to be displayed is 51QP, as indicated after the control string ";;"

When IN101 = 1, the following will display on the front-panel display (assuming 51PP= 720 A primary, and 51GP = 121.2 A primary):



When IN101 = 0, the following will display on the front-panel display (assuming 51NP= 180 A primary, and 51QP = OFF):



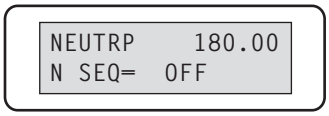
If the pre-label is longer than six characters, the string is processed as if there were only six pre-characters.

To illustrate this, continuing from the above example:

SET T DP1_0 = NEUTRP=;;51N1P;A

with IN101 deasserted, will display:

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The addition of the "=" sign caused the number of pre-characters to exceed 6, so the processing logic stops there, and will display the first six characters followed by the setting values. The post character(s), "A" in this case, are ignored.

Examples With ";;; ;" Control Strings:

Use the ";;;" control string to decrease the display resolution, and make more characters available for labeling purposes. Use the table above to determine the appropriate numerical setting variable. The following setting example allows nine characters of label text:

SET L DP1 = **IN101**

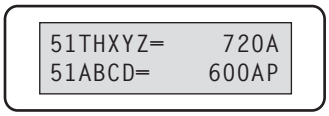
SET L DP2 = **IN101**

SET T DP1_0 = **51THXYZ=;;;000;A**

(The pre-label characters are: "5, 1, T, H, X, Y, Z, =". The post-label character is "A". The total number of label characters is 9.)

SET T DP2_0 = **51ABCD=;;;001;AP**

When IN101 = 0, the following will display on the front-panel display (assuming 51P1P = 720 A primary, and 51P2P = 600 A primary):



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Section 8

Breaker Monitor, Metering, and Load Profile Functions

Introduction

The SEL-351S Relay monitoring functions include:

- *Breaker Monitor on page 8.2*
- *Station DC Battery Monitor on page 8.15*

In addition to instantaneous metering, the SEL-351S metering functions include:

- *Demand Metering on page 8.20*
- *Energy Metering on page 8.29*
- *Maximum/Minimum Metering on page 8.30*
- *Small Signal Cutoff for Metering on page 8.32*
- *Synchrophasor Metering on page 8.33*

The SEL-351S offers a particular reporting feature: *Load Profile Report (Available in Firmware Versions 6 and 7) on page 8.34*.

This section explains these functions in detail.

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Breaker Monitor

The breaker monitor in the SEL-351S helps in scheduling circuit breaker maintenance. The breaker monitor is enabled with the enable setting:

EBMON = **Y**

The breaker monitor settings in *Table 8.2* are available via the **SET G** and **SET L** commands (see *Table 9.1* and also *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25*). Also refer to *BRE Command (Breaker Monitor Data) on page 10.15* and *BRE n Command (Preload/Reset Breaker Wear) on page 10.37*.

The breaker monitor is set with breaker maintenance information provided by circuit breaker manufacturers. This breaker maintenance information lists the number of close/open operations that are permitted for a given current interruption level. The following is an example of breaker maintenance information for a 25 kV circuit breaker.

Table 8.1 Breaker Maintenance Information for a 25 kV Circuit Breaker

Current Interruption Level (kA)	Permissible Number of Close/Open Operations[a]
0.00–1.20	10,000
2.00	3,700
3.00	1,500
5.00	400
8.00	150
10.00	85
20.00	12

[a] The action of a circuit breaker closing and then later opening is counted as one close/open operation.

The breaker maintenance information in *Table 8.1* is plotted in *Figure 8.1*.

Connect the plotted points in *Figure 8.1* for a breaker maintenance curve. To estimate this breaker maintenance curve in the SEL-351S breaker monitor, three set points are entered:

Set Point 1 — **maximum** number of close/open operations with corresponding current interruption level.

Set Point 2 — number of close/open operations that correspond to some **midpoint** current interruption level.

Set Point 3 — number of close/open operations that correspond to the **maximum** current interruption level.

These three points are entered with the settings in *Table 8.2*.

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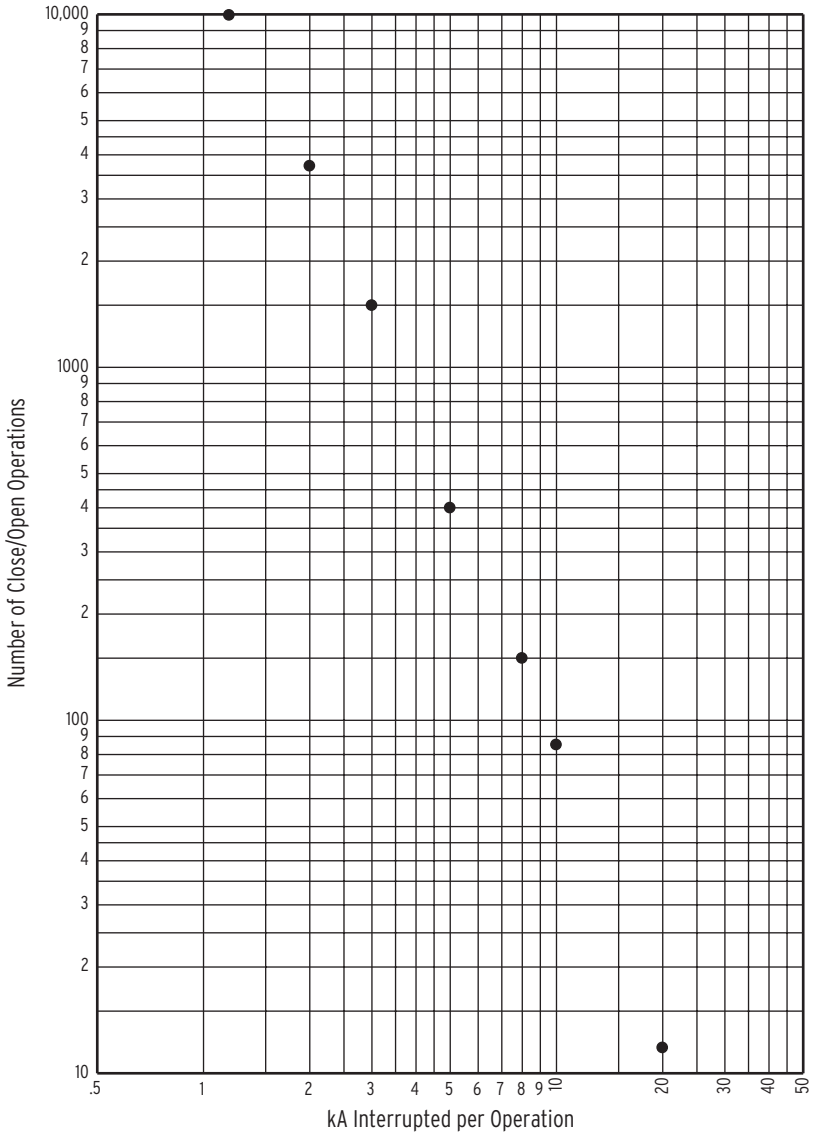


Figure 8.1 Plotted Breaker Maintenance Points for a 25 kV Circuit Breaker

Breaker Monitor Setting Example

Table 8.2 Breaker Monitor Settings and Settings Ranges

Setting	Definition	Range
COSP1	Close/Open set point 1—maximum	0–65000 close/open operations
COSP2	Close/Open set point 2—middle	0–65000 close/open operations
COSP3	Close/Open set point 3—minimum	0–65000 close/open operations
KASP1	kA Interrupted set point 1—minimum	0.00–999.00 kA in 0.01 kA steps
KASP2	kA Interrupted set point 2—middle	0.00–999.00 kA in 0.01 kA steps
KASP3	kA Interrupted set point 3—maximum	0.00–999.00 kA in 0.01 kA steps
BKMON	SELOGIC® control equation breaker monitor initiation setting	Relay Word bits referenced in *Table 9.6*

Setting notes:

- COSP1 must be set greater than COSP2.
- COSP2 must be set greater than or equal to COSP3.

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- KASP1 must be set less than KASP2.
- If COSP2 is set the same as COSP3, then KASP2 must be set the same as KASP3.
- KASP3 must be set at least five times (but no more than 100 times) the KASP1 setting value.

The following settings are made from the breaker maintenance information in *Table 8.1* and *Figure 8.1*:

COSP1 = **10000**
COSP2 = **150**
COSP3 = **12**
KASP1 = **1.20**
KASP2 = **8.00**
KASP3 = **20.00**

Figure 8.2 shows the resultant breaker maintenance curve.

Breaker Maintenance Curve Details

In *Figure 8.2*, note that set points KASP1, COSP1 and KASP3, COSP3 are set with breaker maintenance information from the two extremes in *Table 8.1* and *Figure 8.1*.

In this example, set point KASP2, COSP2 happens to be from an in-between breaker maintenance point in the breaker maintenance information in *Table 8.1* and *Figure 8.1*, but it does not have to be. Set point KASP2, COSP2 should be set to provide the best "curve-fit" with the plotted breaker maintenance points in *Figure 8.1*.

Each phase (A, B, and C) has its own breaker maintenance curve (like that in *Figure 8.2*), because the separate circuit breaker interrupting contacts for phases A, B, and C do not necessarily interrupt the same magnitude current (depending on fault type and loading).

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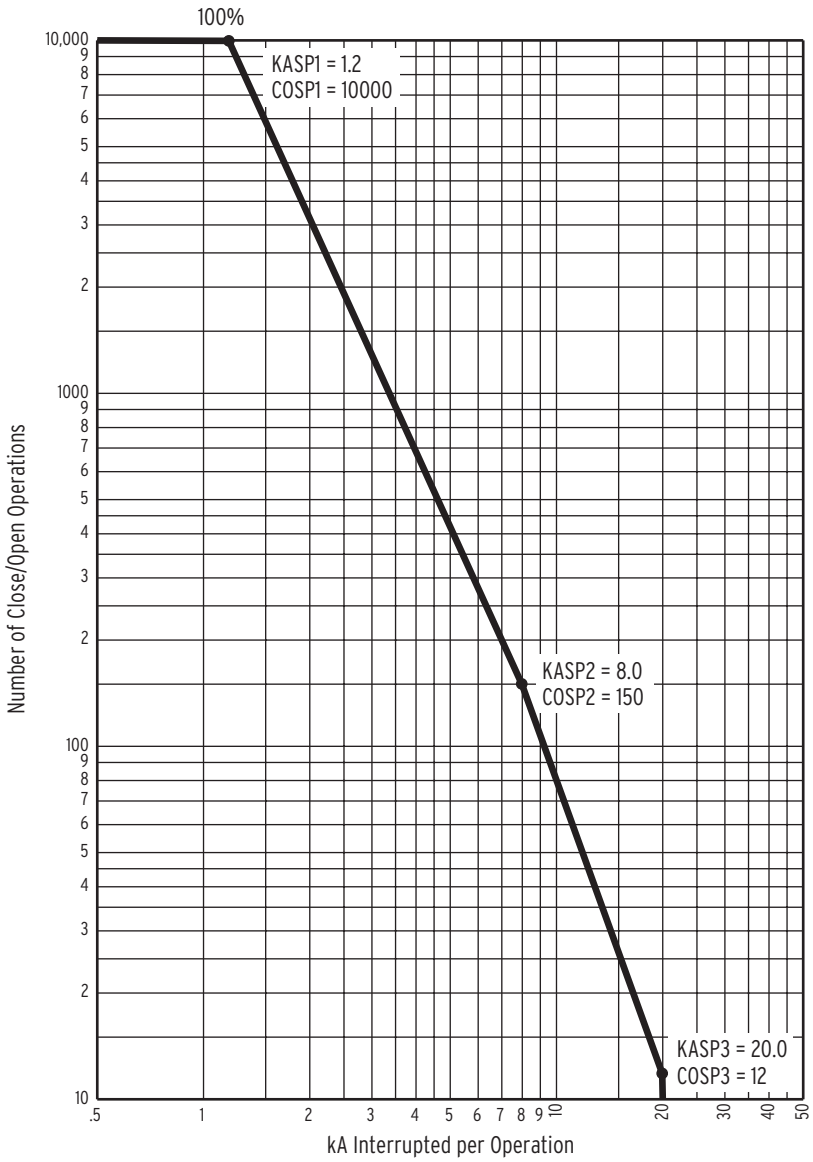


Figure 8.2 SEL-351S Breaker Maintenance Curve for a 25 kV Circuit Breaker

In *Figure 8.2*, note that the breaker maintenance curve levels off horizontally above set point KASP1, COSP1. This is the close/open operation limit of the circuit breaker (COSP1 = 10000), regardless of interrupted current value.

Also, note that the breaker maintenance curve falls vertically below set point KASP3, COSP3. This is the maximum interrupted current limit of the circuit breaker (KASP3 = 20.0 kA). If the interrupted current is greater than setting KASP3, the interrupted current is accumulated as a current value equal to setting KASP3.

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Operation of SELOGIC Control Equation Breaker Monitor Initiation Setting BKMON

The SELOGIC control equation breaker monitor initiation setting BKMON in *Table 8.2* determines when the breaker monitor reads in current values (Phases A, B, and C) for the breaker maintenance curve (see *Figure 8.2*) and the breaker monitor accumulated currents/trips [see *BRE Command (Breaker Monitor Data) on page 10.15*].

The BKMON setting looks for a rising edge (logical 0 to logical 1 transition) as the indication to read in current values. The acquired current values are then applied to the breaker maintenance curve and the breaker monitor accumulated currents/trips (see references in previous paragraph).

In the factory default settings, the SELOGIC control equation breaker monitor initiation setting is set:

BKMON = **TRIP** (TRIP is the logic output of *Figure 5.1*)

Refer to *Figure 8.3*. When BKMON asserts (Relay Word bit TRIP goes from logical 0 to logical 1), the breaker monitor reads in the current values and applies them to the breaker monitor maintenance curve and the breaker monitor accumulated currents/trips.

As detailed in *Figure 8.3*, the breaker monitor actually reads in the current values 1.5 cycles after the assertion of BKMON. This helps especially if an instantaneous trip occurs. The instantaneous element trips when the fault current reaches its pickup setting level. The fault current may still be "climbing" to its full value, at which it levels off. The 1.5-cycle delay on reading in the current values allows time for the fault current to level off.

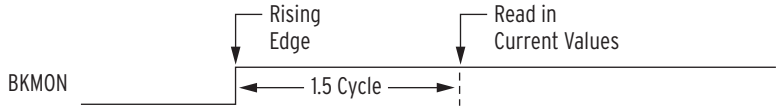


Figure 8.3 Operation of SELOGIC Control Equation Breaker Monitor Initiation Setting

See *Figure 8.8* and accompanying text for more information on setting BKMON. The operation of the breaker monitor maintenance curve, when new current values are read in, is explained in the following example.

Breaker Monitor Operation Example

As stated earlier, each phase (A, B, and C) has its own breaker maintenance curve. For this example, presume that the interrupted current values occur on a single phase in *Figure 8.4*–*Figure 8.7*. Also, presume that the circuit breaker interrupting contacts have no wear at first (brand new or recent maintenance performed).

Note in the following four figures (*Figure 8.4*–*Figure 8.7*) that the interrupted current in a given figure is the same magnitude for all the interruptions (e.g., in *Figure 8.5*, 2.5 kA is interrupted 290 times). This is not realistic, but helps in demonstrating the operation of the breaker maintenance curve and how it integrates for varying current levels.

0 Percent to 10 Percent Breaker Wear

Refer to *Figure 8.4*. 7.0 kA is interrupted 20 times (20 close/open operations = 20 – 0), pushing the breaker maintenance curve from the 0 percent wear level to the 10 percent wear level.

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Compare the 100 percent and 10 percent curves and note that for a given current value, the 10 percent curve has only 1/10 of the close/open operations of the 100 percent curve.

10 Percent to 25 Percent Breaker Wear

Refer to *Figure 8.5*. The current value changes from 7.0 kA to 2.5 kA. 2.5 kA is interrupted 290 times (290 close/open operations = 480 – 190), pushing the breaker maintenance curve from the 10 percent wear level to the 25 percent wear level.

Compare the 100 percent and 25 percent curves and note that for a given current value, the 25 percent curve has only 1/4 of the close/open operations of the 100 percent curve.

25 Percent to 50 Percent Breaker Wear

Refer to *Figure 8.6*. The current value changes from 2.5 kA to 12.0 kA. 12.0 kA is interrupted 11 times (11 close/open operations = 24 – 13), pushing the breaker maintenance curve from the 25 percent wear level to the 50 percent wear level.

Compare the 100 percent and 50 percent curves and note that for a given current value, the 50 percent curve has only 1/2 of the close/open operations of the 100 percent curve.

50 Percent to 100 Percent Breaker Wear

Refer to *Figure 8.7*. The current value changes from 12.0 kA to 1.5 kA. 1.5 kA is interrupted 3000 times (3000 close/open operations = 6000 – 3000), pushing the breaker maintenance curve from the 50 percent wear level to the 100 percent wear level.

When the breaker maintenance curve reaches 100 percent for a particular phase, the percentage wear remains at 100 percent (even if additional current is interrupted), until reset by the **BRE R** command (see *View or Reset Breaker Monitor Information on page 8.12*). But the current and trip counts continue to be accumulated, until reset by the **BRE R** command.

Additionally, logic outputs assert for alarm or other control applications—see the following discussion.

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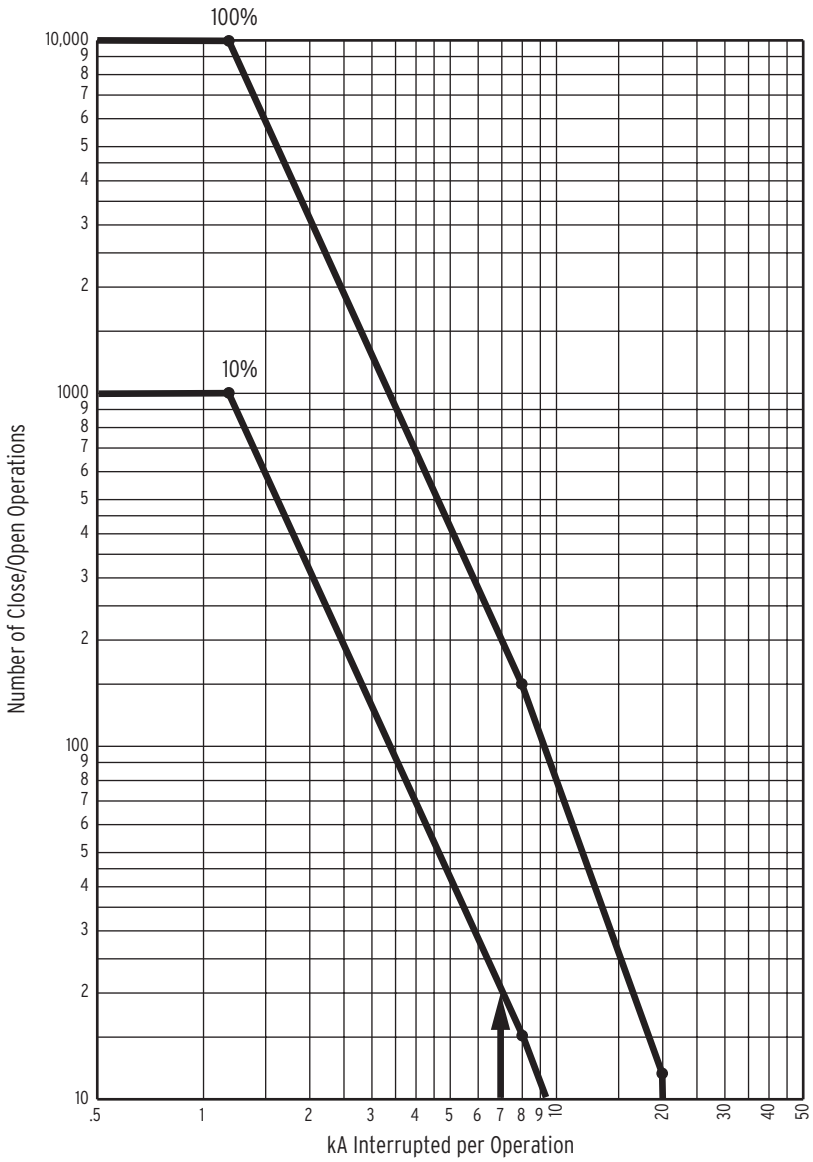


Figure 8.4 Breaker Monitor Accumulates 10 Percent Wear

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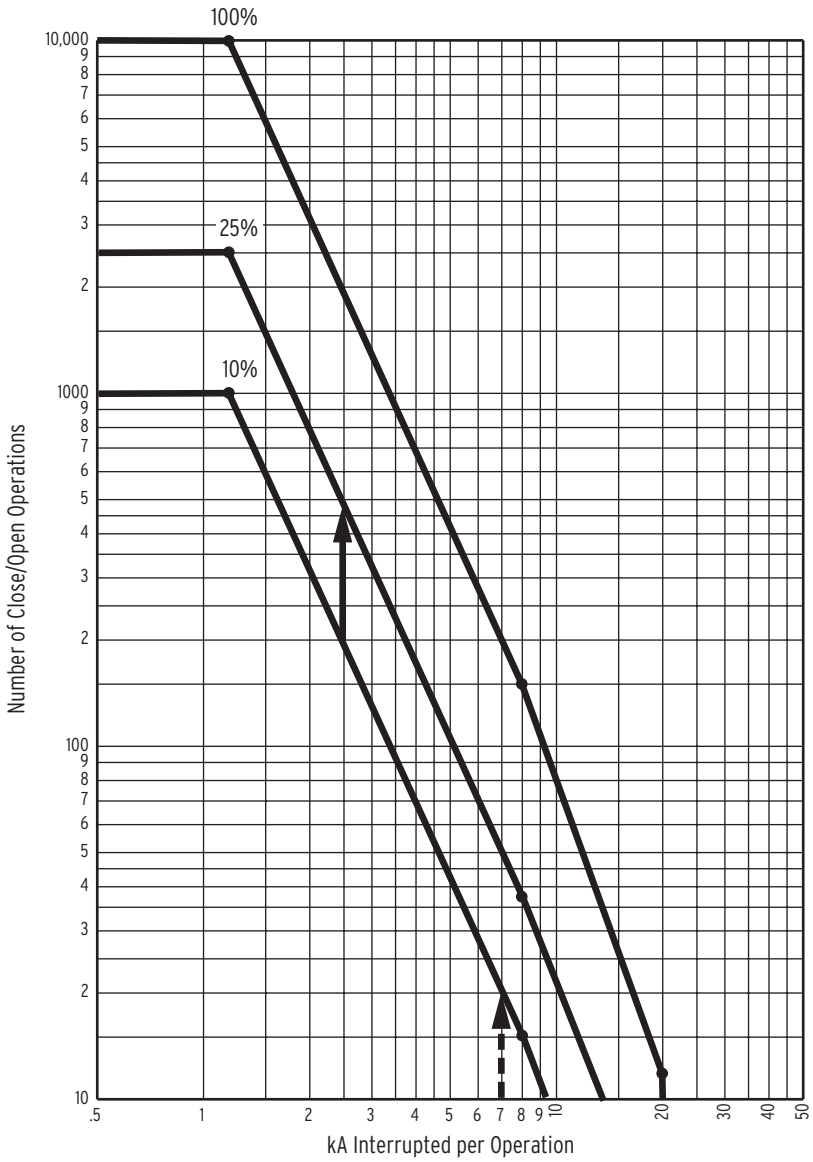


Figure 8.5 Breaker Monitor Accumulates 25 Percent Wear

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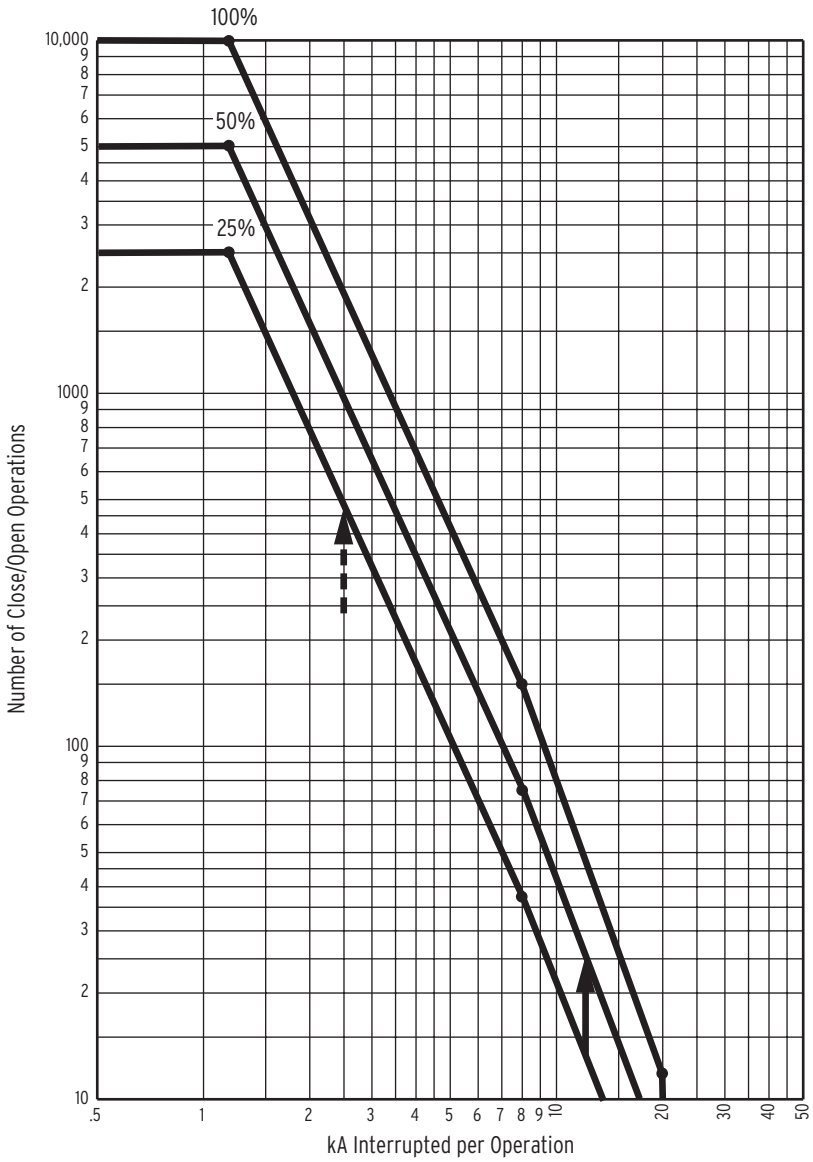


Figure 8.6 Breaker Monitor Accumulates 50 Percent Wear

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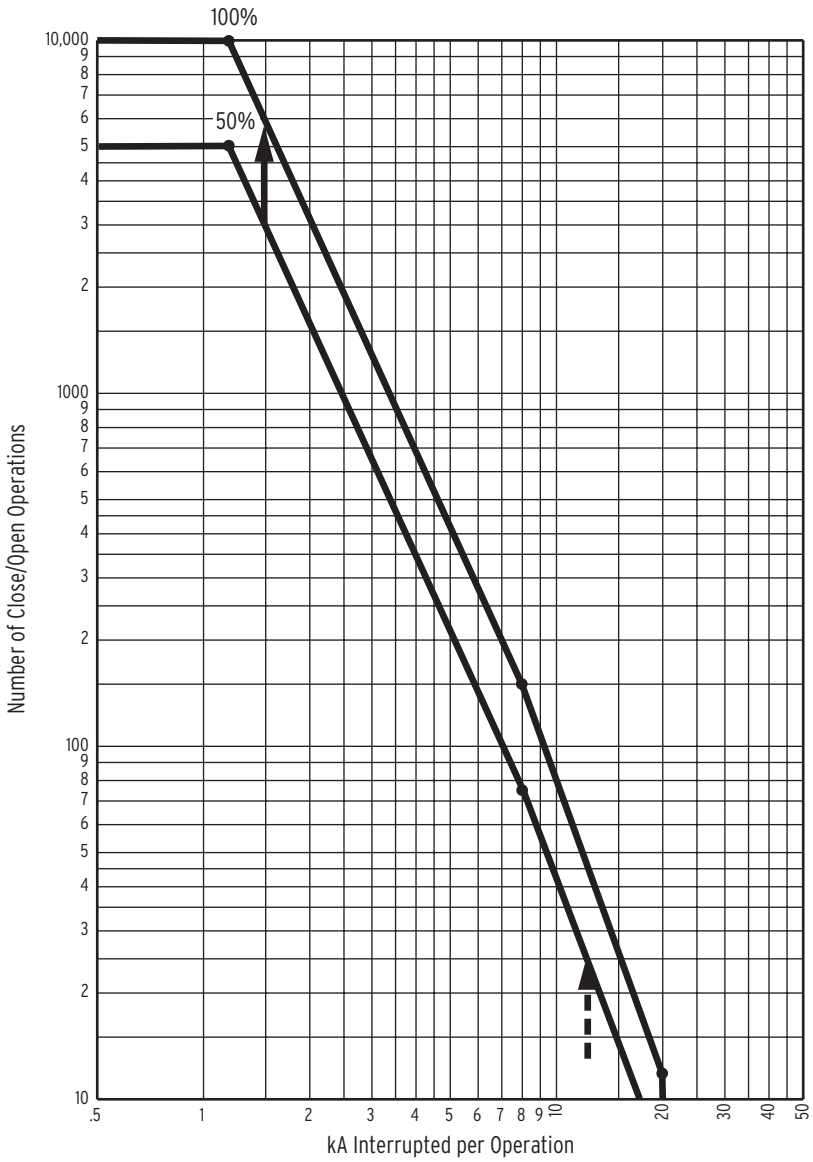


Figure 8.7 Breaker Monitor Accumulates 100 Percent Wear

Breaker Monitor Output

When the breaker maintenance curve for a particular phase (A, B, or C) reaches the 100 percent wear level (see *Figure 8.7*), a corresponding Relay Word bit (BCWA, BCWB, or BCWC) asserts.

Relay Word Bits	Definition
BCWA	Phase A breaker contact wear has reached the 100 percent wear level
BCWB	Phase B breaker contact wear has reached the 100 percent wear level
BCWC	Phase C breaker contact wear has reached the 100 percent wear level
BCW	BCWA + BCWB + BCWC

Example Applications

These logic outputs can be used to alarm:

OUT105 = **BCW**

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or drive the relay to lockout the next time the relay trips:

79DTL = **TRIP*BCW**

View or Reset Breaker Monitor Information

Accumulated breaker wear/operations data is retained if the relay loses power or the breaker monitor is disabled (setting EBMON = N). The accumulated data can only be reset if the **BRE R** command is executed (see the following discussion on the **BRE R** command).

Via Serial Port

See *BRE Command (Breaker Monitor Data) on page 10.15*. The **BRE** command displays the following information:

- Accumulated number of relay initiated trips
- Accumulated interrupted current from relay initiated trips
- Accumulated number of externally initiated trips
- Accumulated interrupted current from externally initiated trips
- Percent circuit breaker contact wear for each phase
- Date when the preceding items were last reset (via the **BRE R** command)

See *BRE n Command (Preload/Reset Breaker Wear) on page 10.37*. The **BRE W** command allows the trip counters, accumulated values, and percent breaker wear to be preloaded for each individual phase.

The **BRE R** command resets the accumulated values and the percent wear for all three phases. For example, if breaker contact wear has reached the 100 percent wear level for A-phase, the corresponding Relay Word bit BCWA asserts (BCWA = logical 1). Execution of the **BRE R** command resets the wear levels for all three phases back to 0 percent and consequently causes Relay Word bit BCWA to deassert (BCWA = logical 0).

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **BRE** and **BRE R** are also available via the front-panel {OTHER} pushbutton. See *Figure 11.3*.

Determination of Relay Initiated Trips and Externally Initiated Trips

See *BRE Command (Breaker Monitor Data) on page 10.15*. Note in the **BRE** command response that the accumulated number of trips and accumulated interrupted current are separated into two groups of data: that generated by **relay initiated trips** (Rly Trips) and that generated by **externally initiated trips** (Ext Trips). The categorization of this data is determined by the status of the TRIP Relay Word bit when the SELOGIC control equation breaker monitor initiation setting BKMON operates.

Refer to *Figure 8.3* and accompanying explanation. If BKMON newly asserts (logical 0 to logical 1 transition), the relay reads in the current values (Phases A, B, and C). Now the decision has to be made: where is this current and trip count information accumulated? Under **relay initiated trips or externally initiated trips**?

To make this determination, the status of the TRIP Relay Word bit is checked at the instant BKMON newly asserts (TRIP is the logic output of *Figure 5.1 on page 5.2*). If TRIP is asserted (TRIP = logical 1), the current and trip count

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information is accumulated under **relay initiated trips** (Rly Trips). If TRIP is deasserted (TRIP = logical 0), the current and trip count information is accumulated under **externally initiated trips** (Ext Trips).

Regardless of whether the current and trip count information is accumulated under relay initiated trips or externally initiated trips, this same information is routed to the breaker maintenance curve for continued breaker wear integration (see *Figure 8.3*–*Figure 8.7*).

Relay initiated trips (Rly Trips) are also referred to as **internally initiated trips** (Int Trips) in the course of this manual; the terms are interchangeable.

Factory Default Setting Example

As discussed previously, the SELOGIC control equation breaker monitor initiation factory default setting is:

BKMON = **TRIP**

Thus, any new assertion of BKMON will be deemed a relay trip, and the current and trip count information is accumulated under **relay initiated trips** (Rly Trips).

Additional Example

Refer to *Figure 8.8*. Output contact **OUT101** is set to provide tripping:

OUT101 = **TRIP**

Note that optoisolated input **IN106** monitors the trip bus. If the trip bus is energized by output contact **OUT101**, an external control switch, or some other external trip, then **IN106** is asserted.

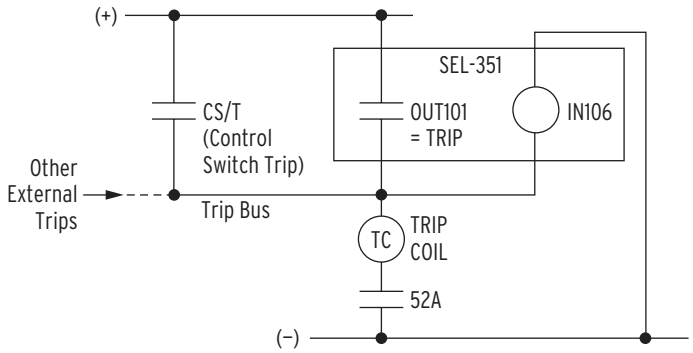


Figure 8.8 Input IN106 Connected to Trip Bus for Breaker Monitor Initiation

If the SELOGIC control equation breaker monitor initiation setting is set:

BKMON = **IN106**

then the SEL-351S breaker monitor sees all trips.

If output contact **OUT101** asserts, energizing the trip bus, the breaker monitor will deem it a **relay initiated trip**. This is because when BKMON is newly asserted (input **IN106** energized), the TRIP Relay Word bit is asserted. Thus, the current and trip count information is accumulated under **relay initiated trips** (Rly Trips).

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If the control switch trip (or some other external trip) asserts, energizing the trip bus, the breaker monitor will deem it an **externally initiated trip**. This is because when BKMON is newly asserted (input IN106 energized), the TRIP Relay Word bit is deasserted. Thus, the current and trip count information is accumulated under **externally initiated trips** (Ext Trips).

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Station DC Battery Monitor

The station dc battery monitor in the SEL-351S can alarm for under- or overvoltage dc battery conditions and give a view of how much the station dc battery voltage dips when tripping, closing, and other dc control functions take place. The monitor measures the station dc battery voltage applied to the rear-panel terminals labeled **POWER** (see *Figure 2.2*–*Figure 2.6*). The station dc battery monitor settings (DCLOP and DCHIP) are available via the **SET G** command (see *Table 9.1* and also *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25*).

DC Under- and Overvoltage Elements

Refer to *Figure 8.9*. The station dc battery monitor compares the measured station battery voltage (Vdc) to the undervoltage (low) and overvoltage (high) pickups DCLOP and DCHIP. The setting range for pickup settings DCLOP and DCHIP is:

20 to 300 Vdc, 1 Vdc increments

This range allows the SEL-351S to monitor nominal battery voltages of 24, 48, 110, 125, 220, and 250 V. When testing the pickup settings DCLOP and DCHIP, **do not** operate the SEL-351S outside of its power supply limits. See *Specifications*: *General on page 1.10* for the various power supply specifications. The power supply rating is located on the serial number sticker on the relay rear panel.

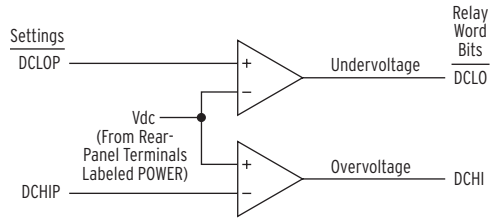


Figure 8.9 DC Under- and Overvoltage Elements

Logic outputs DCLO and DCHI in *Figure 8.9* operate as follows:

DCLO = 1 (logical 1), if $V_{dc} \leq$ pickup setting DCLOP
= 0 (logical 0), if $V_{dc} >$ pickup setting DCLOP

DCHI = 1 (logical 1), if $V_{dc} \geq$ pickup setting DCHIP
= 0 (logical 0), if $V_{dc} <$ pickup setting DCHIP

Create Desired Logic for DC Under- and Overvoltage Alarming

Pickup settings DCLOP and DCHIP are set independently. Thus, they can be set:

DCLOP < DCHIP or DCLOP > DCHIP

Figure 8.10 shows the resultant dc voltage elements that can be created with SELOGIC control equations for these two setting cases. In these two examples, the resultant dc voltage elements are time-qualified by timer SV4T and then routed to output contact **OUT106** for alarm purposes.

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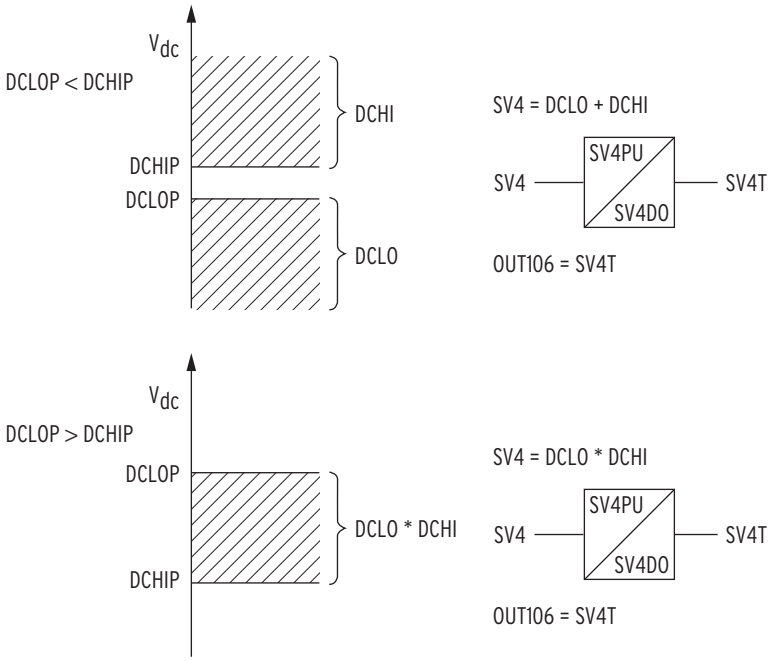


Figure 8.10 Create DC Voltage Elements with SELOGIC Control Equations

DCLO < DCHI (Top of Figure 8.10)

Output contact **OUT106** asserts when:

$$V_{dc} \leq DCLOP \text{ or } V_{dc} \geq DCHIP$$

Pickup settings DCLOP and DCHIP are set such that output contact **OUT106** asserts when dc battery voltage goes below or above allowable limits.

If the relay loses power entirely (V_{dc} = 0 Vdc)

$$V_{dc} = < DCLOP$$

then output contact **OUT106** should logically assert (according to top of *Figure 8.10*), but cannot because of the total loss of power (all output contacts deassert on total loss of power). Thus, the resultant dc voltage element at the bottom of *Figure 8.10* would probably be a better choice—see following discussion.

DCLO > DCHI (Bottom of Figure 8.10)

Output contact **OUT106** asserts when:

$$DCHIP \leq V_{dc} \leq DCLOP$$

Pickup settings DCLOP and DCHIP are set such that output contact **OUT106** asserts when dc battery voltage stays between allowable limits.

If the relay loses power entirely (V_{dc} = 0 Vdc)

$$V_{dc} = < DCHIP$$

then output contact **OUT106** should logically deassert (according to bottom of *Figure 8.10*), and this is surely what happens for a total loss of power (all output contacts deassert on total loss of power).

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Output Contact Type Considerations (“a” or “b”)

Refer to *Output Contacts on page 7.32* (especially Note 2 in *Figure 7.27*). Consider the output contact type (“a” or “b”) needed for output contact **OUT106** in the bottom of *Figure 8.10* (dc voltage alarm example).

If SELOGIC control equation setting OUT106 is asserted (OUT106 = SV4T = logical 1; dc voltage OK), the state of output contact **OUT106** (according to contact type) is:

closed (“a” type output contact)

open (“b” type output contact)

If SELOGIC control equation setting OUT106 is deasserted (OUT106 = SV4T = logical 0; dc voltage **not** OK), the state of output contact **OUT106** (according to contact type) is:

open (“a” type output contact)

closed (“b” type output contact)

If the relay loses power entirely, all output contacts deassert, and the state of output contact **OUT106** (according to contact type) is:

open (“a” type output contact)

closed (“b” type output contact)

Additional Application

Other than alarming, the dc voltage elements can be used to disable reclosing.

For example, if the station dc batteries have a problem and the station dc battery voltage is declining, drive the reclosing relay to lockout:

79DTL **= !SV4T + ...** [= NOT(SV4T) + ...]

Timer output SV4T is from the bottom of *Figure 8.10*. When dc voltage falls below pickup DCHIP, timer output SV4T drops out (= logical 0), driving the relay to lockout:

79DTL = **!SV4T + ...** = NOT(SV4T) + ... = NOT(logical 0) + ... = logical 1

Circuit breaker tripping and closing requires station dc battery energy. If the station dc batteries are having a problem and the station dc battery voltage is declining, the relay should not reclose after a trip—there might not be enough dc battery energy to trip a second time after a reclose.

View Station DC Battery Voltage

Via Serial Port

See *MET Command (Metering Data)*, *MET k—Instantaneous Metering on page 10.20*. The **MET** command displays the station dc battery voltage (labeled VDC).

Via Front Panel

The information available via the previously discussed **MET** serial port command is also available via the front-panel **{OTHER}** pushbutton. See *Figure 11.3*.

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Analyze Station DC Battery Voltage

See *Standard 15/30-Cycle Event Reports on page 12.2*. The station dc battery voltage is displayed in column Vdc in the example event report in *Figure 12.3*. Changes in station dc battery voltage for an event (e.g., circuit breaker tripping) can be observed. Use the **EVE** command to retrieve event reports as discussed in *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

Station DC Battery Voltage Dips During Circuit Breaker Tripping

Event reports are automatically generated when the TRIP Relay Word bit asserts (TRIP is the logic output of *Figure 5.1 on page 5.2*). For example, output contact **OUT101** is set to trip:

OUT101 = **TRIP**

Anytime output contact **OUT101** closes and energizes the circuit breaker trip coil, any dip in station dc battery voltage can be observed in column Vdc in the event report.

To generate an event report for external trips, make connections similar to *Figure 8.8* and program optoisolated input **IN106** (monitoring the trip bus) in the SELOGIC control equation event report generation setting:

e.g., ER = **/IN106 + ...**

Anytime the trip bus is energized, any dip in station dc battery voltage can be observed in column Vdc in the event report.

Station DC Battery Voltage Dips During Circuit Breaker Closing

To generate an event report when the SEL-351S closes the circuit breaker, make the SELOGIC control equation event report generation setting:

ER = **/OUT102 + ...**

In this example, output contact **OUT102** is set to close:

OUT102 = **CLOSE** (CLOSE is the logic output of *Figure 6.1*)

Anytime output contact **OUT102** closes and energizes the circuit breaker close coil, any dip in station dc battery voltage can be observed in column Vdc in the event report.

This event report generation setting (ER = /OUT102 + ...) might be made just as a **testing** setting. Generate several event reports when doing circuit breaker close testing and observe the "signature" of the station dc battery voltage in column Vdc in the event reports.

Station DC Battery Voltage Dips Anytime

To generate an event report anytime there is a station dc battery voltage dip, set the dc voltage element directly in the SELOGIC control equation event report generation setting:

ER = **\SV4T + ...**

Timer output SV4T is an example dc voltage element from the bottom of *Figure 8.10*. Anytime dc voltage falls below pickup DCHIP, timer output SV4T drops out (logical 1 to logical 0 transition), creating a falling-edge condition that generates an event report.

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Also, the Sequential Event Recorder (SER) report can be used to time-tag station dc battery voltage dips [see *Sequential Events Recorder (SER) Report on page 12.25*].

Operation of Station DC Battery Monitor When AC Voltage is Powering the Relay

If the SEL-351S has a power supply that can be powered by ac voltage, when powering the relay with ac voltage, the dc voltage elements in *Figure 8.9* see the **average** of the sampled ac voltage powering the relay, which is very near zero volts (as displayed in column Vdc in event reports). Thus, pickup settings DCLOP and DCHIP should be set off (DCLOP = OFF, DCHIP = OFF). They are of no real use.

If a "raw" event report is displayed (with the **EVE R** command), column Vdc will display the sampled ac voltage waveform, rather than the average.

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Demand Metering

The SEL-351S offers the choice between two types of demand metering, settable with the enable setting:

EDEM = **THM** (Thermal Demand Meter)

or

EDEM = **ROL** (Rolling Demand Meter)

The demand metering settings (in *Table 8.3*) are available via the **SET** command (see *Table 9.1* and also *Relay Settings (Serial Port Command SET and Front Panel) on page SET.1*). Also refer to *MET Command (Metering Data) on page 10.20*).

The SEL-351S provides demand and peak demand metering for the following values:

Currents

$I_{A,B,C,N}$	Input currents (A primary)
I_G	Residual ground current (A primary; IG = 3I0 = IA + IB + IC)
$3I_2$	Negative-sequence current (A primary)

Power

$MW_{A,B,C}$	Single-phase megawatts (wye-connected voltages only)
$MVAR_{A,B,C}$	Single-phase megavars (wye-connected voltages only)
MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars

Depending on enable setting EDEM, these demand and peak demand values are thermal demand or rolling demand values. The differences between thermal and rolling demand metering are explained in the following discussion.

Comparison of Thermal and Rolling Demand Meters

The example in *Figure 8.11* shows the response of thermal and rolling demand meters to a step current input. The current input is at a magnitude of zero and then suddenly goes to an instantaneous level of 1.0 per unit (a “step”).

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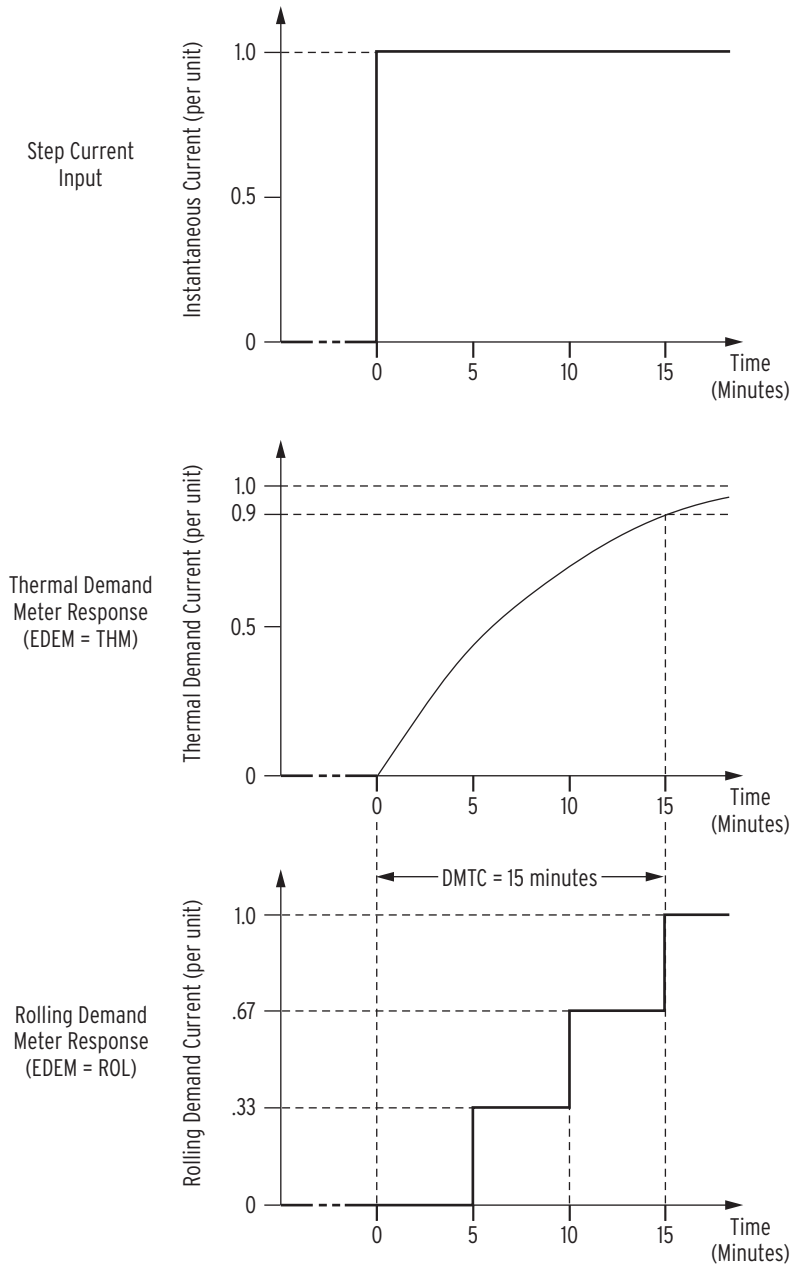


Figure 8.11 Response of Thermal and Rolling Demand Meters to a Step Input (Setting DMTC = 15 Minutes)

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Thermal Demand Meter Response (EDEM = THM)

The response of the thermal demand meter in *Figure 8.11* (middle) to the step current input (top) is analogous to the series RC circuit in *Figure 8.12*.

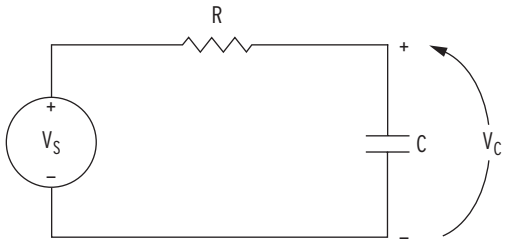


Figure 8.12 Voltage V_S Applied to Series RC Circuit

In the analogy:

Voltage V_S in *Figure 8.12* corresponds to the step current input in *Figure 8.11* (top).

Voltage V_C across the capacitor in *Figure 8.12* corresponds to the response of the thermal demand meter in *Figure 8.11* (middle).

If voltage V_S in *Figure 8.12* has been at zero (V_S = 0.0 per unit) for some time, voltage V_C across the capacitor in *Figure 8.12* is also at zero (V_C = 0.0 per unit). If voltage V_S is suddenly stepped up to some constant value (V_S = 1.0 per unit), voltage V_C across the capacitor starts to rise toward the 1.0 per unit value. This voltage rise across the capacitor is analogous to the response of the thermal demand meter in *Figure 8.11* (middle) to the step current input (top).

In general, as voltage V_C across the capacitor in *Figure 8.12* cannot change instantaneously, the thermal demand meter response is not immediate either for the increasing or decreasing applied instantaneous current. The thermal demand meter response time is based on the demand meter time constant setting DMTC (see *Table 8.3*). Note in *Figure 8.11*, the thermal demand meter response (middle) is at 90 percent (0.9 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC = 15 minutes, referenced to when the step current input is first applied.

The SEL-351S updates thermal demand values approximately every two seconds.

Rolling Demand Meter Response (EDEM = ROL)

The response of the rolling demand meter in *Figure 8.11* (bottom) to the step current input (top) is calculated with a sliding time-window arithmetic average calculation. The width of the sliding time window is equal to the demand meter time constant setting DMTC (see *Table 8.3*). Note in *Figure 8.11*, the rolling demand meter response (bottom) is at 100 percent (1.0 per unit) of full applied value (1.0 per unit) after a time period equal to setting DMTC = 15 minutes, referenced to when the step current input is first applied.

The rolling demand meter integrates the applied signal (e.g., step current) input in five-minute intervals. The integration is performed approximately every two seconds. The average value for an integrated five-minute interval is derived and stored as a five-minute total. The rolling demand meter then averages a number of the five-minute totals to produce the rolling demand meter response. In the *Figure 8.11* example, the rolling demand meter

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averages the three latest five-minute totals because setting DMTC = 15 (15/5 = 3). The rolling demand meter response is updated every five minutes, after a new five-minute total is calculated.

The following is a step-by-step calculation of the rolling demand response example in *Figure 8.11* (bottom).

Time = 0 Minutes

Presume that the instantaneous current has been at zero for quite some time before "Time = 0 minutes" (or the demand meters were reset). The three 5-minute intervals in the sliding time-window at "Time = 0 minutes" each integrate into the following 5-minute totals:

5-Minute Totals	Corresponding 5-Minute Interval
0.0 per unit	–15 to –10 minutes
0.0 per unit	–10 to –5 minutes
0.0 per unit	–5 to 0 minutes
0.0 per unit	

Rolling demand meter response at "Time = 0 minutes" = 0.0/3 = 0.0 per unit

Time = 5 Minutes

The three 5-minute intervals in the sliding time-window at "Time = 5 minutes" each integrate into the following five-minute totals:

5-Minute Totals	Corresponding 5-Minute Interval
0.0 per unit	–10 to –5 minutes
0.0 per unit	–5 to 0 minutes
1.0 per unit	0 to 5 minutes
1.0 per unit	

Rolling demand meter response at "Time = 5 minutes" = 1.0/3 = 0.33 per unit

Time = 10 Minutes

The three 5-minute intervals in the sliding time-window at "Time = 10 minutes" each integrate into the following 5-minute totals:

5-Minute Totals	Corresponding 5-Minute Interval
0.0 per unit	–5 to 0 minutes
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
2.0 per unit	

Rolling demand meter response at "Time = 10 minutes" = 2.0/3 = 0.67 per unit

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Time = 15 Minutes

The three 5-minute intervals in the sliding time-window at "Time = 15 minutes" each integrate into the following five-minute totals:

5-Minute Totals	Corresponding 5-Minute Interval
1.0 per unit	0 to 5 minutes
1.0 per unit	5 to 10 minutes
1.0 per unit	10 to 15 minutes
3.0 per unit	

Rolling demand meter response at "Time = 15 minutes" = 3.0/3 = 1.0 per unit

Demand Meter Settings

NOTE: Changing setting EDEM or DMTC resets the demand meter values to zero. This also applies to changing the active setting group, and setting EDEM or DMTC is different in the new active setting group. Demand current pickup settings PDEMP, NDEMP, GDEMP, and QDEMP can be changed without affecting the demand meters.

The examples in this section discuss demand current, but MW and MVAR demand values are also available, as stated at the beginning of this subsection.

Table 8.3 Demand Meter Settings and Settings Range

Setting	Definition	Range
EDEM	Demand meter type	THM = thermal ROL = rolling
DMTC	Demand meter time constant	5, 10, 15, 30, or 60 minutes
PDEMP	Phase demand current pickup	OFF 0.50–16.00 A {5 A nominal} 0.10–3.20 A {1 A nominal} Additional ranges for NDEMP: 0.005–0.640 A {0.2 A nominal channel IN current input} 0.005–0.160 A {0.05 A nominal channel IN current input}
NDEMP	Neutral ground demand current pickup	
GDEMP	Residual ground demand current pickup	
QDEMP	Negative-sequence demand current pickup	

The demand current pickup settings in *Table 8.3* are applied to demand current meter outputs as shown in *Figure 8.13*. For example, when residual ground demand current $I_{G(DEM)}$ goes above corresponding demand pickup GDEMP, Relay Word bit GDEM asserts to logical 1. Use these demand current logic outputs (PDEM, NDEM, GDEM, and QDEM) to alarm for high loading or unbalance conditions. Use in other schemes such as the following example.

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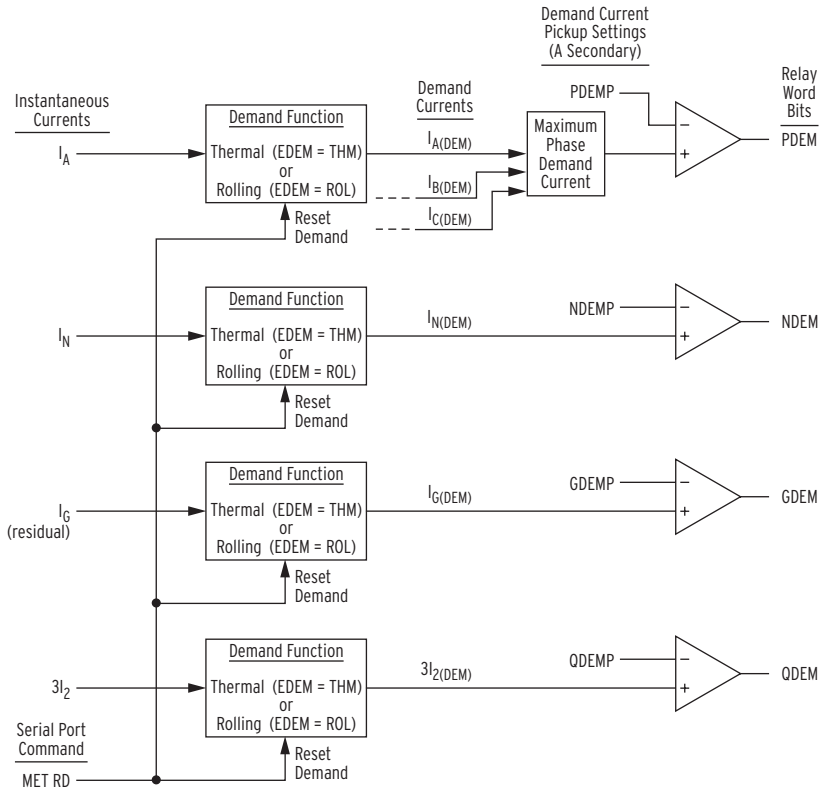


Figure 8.13 Demand Current Logic Outputs

Demand Current Logic Output Application—Raise Pickup for Unbalance Current

During times of high loading, the residual ground overcurrent elements can see relatively high unbalance current I_G ($I_G = 3I_0$). To avoid tripping on unbalance current I_G, use Relay Word bit GDEM to detect the residual ground (unbalance) demand current $I_{G(DEM)}$ and effectively raise the pickup of the residual ground time-overcurrent element 51G1T. This is accomplished with the following settings from *Table 8.3*, pertinent residual ground overcurrent element settings, and SELOGIC control equation torque control setting 51G1TC:

EDEM = **THM**
DMTC = **5**
GDEMP = **1.0**
51G1P = **1.50**
50G5P = **2.30**
51G1TC = **!GDEM + GDEM*50G5**

Refer to *Figure 8.13*, *Figure 8.14*, and *Figure 3.18*.

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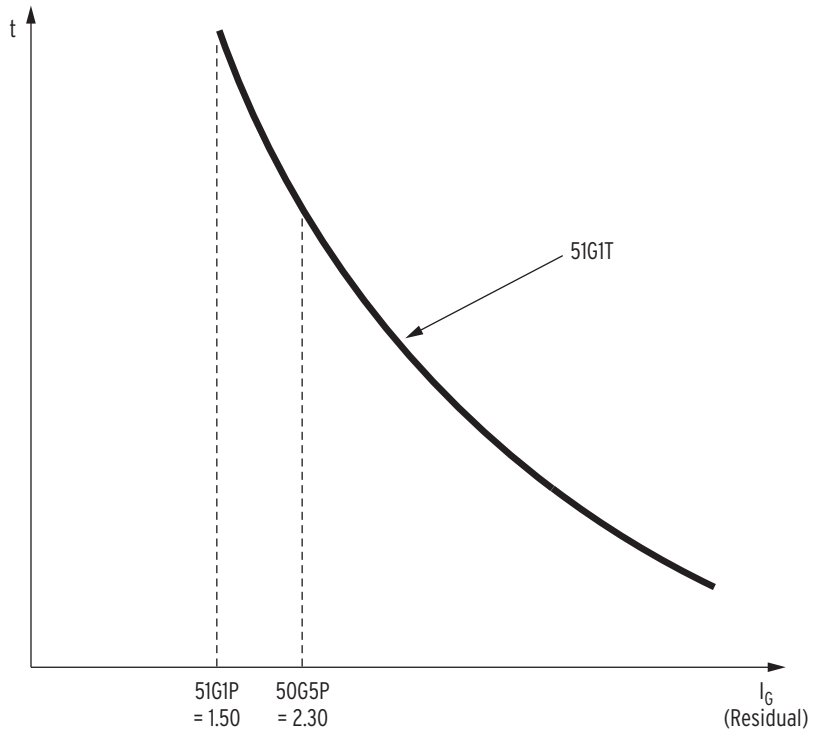


Figure 8.14 Raise Pickup of Residual Ground Time-Overcurrent Element for Unbalance Current

Residual Ground Demand Current Below Pickup GDEMP

When unbalance current I_G is low, unbalance demand current $I_{G(DEM)}$ is below corresponding demand pickup GDEMP = 1.00 A secondary, and Relay Word bit GDEM is deasserted to logical 0. This results in SELOGIC control equation torque control setting 51G1TC being in the state:

51G1TC = **= !GDEM + GDEM*50G5** = NOT(GDEM) + GDEM*50G5
= NOT(logical 0) + (logical 0)*50G5 = logical 1

Thus, the residual ground time-overcurrent element 51G1T operates on its standard pickup:

51G1P = **1.50 A secondary**

If a ground fault occurs, the residual ground time-overcurrent element 51G1T operates with the sensitivity provided by pickup 51G1P = 1.50 A secondary. The thermal demand meter, even with setting DMTC = 5 minutes, does not respond fast enough to the ground fault to make a change to the effective residual ground time-overcurrent element pickup—it remains at 1.50 A secondary. Demand meters respond to more "slow moving" general trends.

Residual Ground Demand Current Goes Above Pickup GDEMP

When unbalance current I_G increases, unbalance demand current $I_{G(DEM)}$ follows, going above corresponding demand pickup GDEMP = 1.00 A secondary, and Relay Word bit GDEM asserts to logical 1. This results in SELOGIC control equation torque control setting 51GTC being in the state:

51G1TC = **= !GDEM + GDEM*50G5** = NOT(GDEM) + GDEM*50G5
= NOT(logical 1) + (logical 1)*50G5 = logical 0 + 50G5
= 50G5

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Thus, the residual ground time-overcurrent element 51G1T operates with an effective, less-sensitive pickup:

50G5P = **2.30 A secondary**

The reduced sensitivity keeps the residual ground time-overcurrent element 51G1T from tripping on higher unbalance current I_G.

Residual Ground Demand Current Goes Below Pickup GDEMP Again

When unbalance current I_G decreases again, unbalance demand current $I_{G(DEM)}$ follows, going below corresponding demand pickup GDEMP = 1.00 A secondary, and Relay Word bit GDEM deasserts to logical 0. This results in SELOGIC control equation torque control setting 51G1TC being in the state:

51G1TC = **!GDEM + GDEM*50G5** = NOT(GDEM) + GDEM*50G5
= NOT(logical 0) + (logical 0)*50G5 = logical 1

Thus, the residual ground time-overcurrent element 51G1T operates on its standard pickup again:

51G1P = **1.50 A secondary**

View or Reset Demand Metering Information

Via Serial Port

See *MET Command (Metering Data)*, *MET D—Demand Metering on page 10.23*. The **MET D** command displays demand and peak demand metering for the following values:

Currents

$I_{A,B,C,N}$	Input currents (A primary)
I_G	Residual ground current (A primary; IG = 3I0 = IA + IB + IC)
$3I_2$	Negative-sequence current (A primary)

Power

$MW_{A,B,C}$	Single-phase megawatts (wye-connected voltages only)
$MVAR_{A,B,C}$	Single-phase megavars (wye-connected voltages only)
MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars

The **MET RD** command resets the demand metering values. The **MET RP** command resets the peak demand metering values.

If setting EDEM = ROL, after resetting the demand values, there may be a delay of up to two times the DMTC setting before the demand values are updated.

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET D**, **MET RD**, and **MET RP** are also available via the front-panel METER pushbutton. See *Figure 11.2*.

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Demand Metering Updating and Storage

The SEL-351S updates demand values approximately every two seconds.

The relay stores peak demand values to nonvolatile storage once per day (it overwrites the previous stored value if it is exceeded). Should the relay lose control power, it will restore the peak demand values saved by the relay at 23:50 hours on the previous day.

Demand metering peak recording is momentarily suspended when SELOGIC control equation setting FAULT is asserted (= logical 1). See the explanation for the FAULT setting in the following subsection *Maximum/Minimum Metering on page 8.30*.

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Energy Metering

View or Reset Energy Metering Information

Via Serial Port

See *MET Command (Metering Data)*, *MET E—Energy Metering on page 10.24*. The **MET E** command displays accumulated single- and three-phase megawatt and megavar hours. The **MET RE** command resets the accumulated single- and three-phase megawatt and megavar hours.

(Single-phase quantities only available when Global Setting PTCONN = WYE.)

Via Front Panel

The information and reset functions available via the previously discussed serial port commands **MET E** and **MET RE** are also available via the front-panel **{METER}** pushbutton. See *Figure 11.2*.

Energy Metering Updating and Storage

The SEL-351S updates energy values approximately every two seconds.

The relay stores energy values to nonvolatile storage once per day (it overwrites the previous stored value). Should the relay lose control power, it will restore the energy values saved by the relay at 23:50 hours on the previous day.

Accumulated energy metering values function like those in an electromechanical energy meter. When the energy meter reaches 99999 MWh or 99999 MVARh, it starts over at zero. In firmware versions released prior to November 2002, the SEL 351S relay energy meter registered dollar signs ($$) after reaching the upper metering limit.

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Maximum/Minimum Metering

View or Reset Maximum/Minimum Metering Information

Via Serial Port

See *MET M—Maximum/Minimum Metering on page 10.25*. The **MET M** command displays maximum/minimum metering for the following values:

Currents

$I_{A,B,C,N}$	Input currents (A primary)
I_G	Residual ground current (A primary; IG = 3I0)

Voltages

$V_{A,B,C}$	Input voltages (kV primary, wye-connected voltage only)
$V_{AB,BC,CA}$	Input voltages (kV primary, delta-connected voltage only)
V_S	Input voltages (kV primary)

Power

MW_{3P}	Three-phase megawatts
$MVAR_{3P}$	Three-phase megavars

The **MET RM** command resets the maximum/minimum metering values.

The power maximum and minimum values can be negative or positive, indicating the range of power flow that has occurred since the last **MET RM** reset command. These functions simulate analog meter drag-hands, with the maximum value representing the upper drag-hand and the minimum value representing the lower drag-hand.

Table 8.4 shows the values that the relay would record for various power flow directions (either MW3P or MVAR3P).

NOTE: Previous firmware releases treated the positive and negative power values differently. See Appendix A: Firmware and Manual Versions for a list of previous firmware releases.

Table 8.4 Operation of Maximum/Minimum Metering With Directional Power Quantities

If Power Varies		Recorded MAX	Recorded MIN
From:	To:		
9.7	16.2	16.2	9.7
–4.2	1.4	1.4	–4.2
–25.3	–17.4	–17.4	–25.3
–6.2	27.4	27.4	–6.2

(For simplicity, the date and time stamps are not shown here.)

Via Front Panel

The metering and reset functions available via serial port commands **MET M** and **MET RM** are also available via the front-panel **{METER}** pushbutton. See *Figure 11.2*.

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Maximum/Minimum Metering Update and Storage

The maximum/minimum metering function is intended to reflect normal load variations rather than fault conditions or outages. Therefore, the SEL-351S updates maximum/minimum values only if SELOGIC control equation setting FAULT is deasserted (= logical 0) and has been deasserted for at least 3600 cycles.

[The factory default setting is set with time-overcurrent element pickups:

FAULT = **51P1 + 51G1**

If there is a fault, 51P1 or 51G1 asserts and blocks updating of maximum/minimum metering values.]

In addition to FAULT being deasserted for at least 3600 cycles, the following conditions must also be met:

- For wye-connected voltage values $V_{A,B,C,S}$, or delta-connected voltage values $V_{AB,BC,CA,S}$, the voltage is above the threshold:
  25.0 V secondary
- For current values $I_{A,B,C,N}$ the current is above the corresponding threshold:
  0.05 A secondary {5 A nominal current inputs}
  0.01 A secondary {1 A nominal current inputs}
  2.0 mA secondary {0.2 A nominal channel **IN** current input}
  0.5 mA secondary {0.05 A nominal channel **IN** current input}
- For the residual current value I_G:
  All three phase currents $I_{A,B,C}$ are above threshold.
- For power values MW_{3P} and $MVAR_{3P}$:
  All three phase currents $I_{A,B,C}$ are above threshold and all three voltages $V_{A,B,C}$ (or $V_{AB,BC,CA}$) are above threshold.
- The metering value is above the previous maximum or below the previous minimum for approximately four seconds.

The SEL-351S stores maximum/minimum values to nonvolatile storage once per day and overwrites the previous stored value if that is exceeded. If the relay loses control power, it will restore the maximum/minimum values saved at 23:50 hours on the previous day.

NOTE: SELOGIC control equation setting FAULT also controls other relay functions; see subsection SELOGIC Control Equation Setting FAULT on page 5.37.

NOTE: The values used by the maximum/minimum metering are the same values used by the regular **MET** command (serial port or instantaneous, front panel), which are eight-cycle averaged values. The maximum/minimum metering function updates every two seconds (approximately). These values should be relatively immune to transient conditions.

In previous firmware releases, the maximum/minimum metering values were based on high-speed protection voltage values. Because these values could update after being above the previous maximum or below the previous minimum for only two cycles, the maximum/minimum recorder occasionally responded to transient conditions. See Appendix A: Firmware and Manual Versions for a list of previous firmware releases.

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Small Signal Cutoff for Metering

The relay applies a threshold to the voltage and current metering quantities to force a reading to zero when the measurement is near zero. *Table 8.5* lists the thresholds for nominal current and voltage values. These thresholds are above the noise level for analog measurement by a digital system.

Without these thresholds, if a bus is deenergized or a circuit breaker is open, noise-level values would cause erroneous energy accumulation.

These thresholds affect the metering functions for power and energy on a per-phase basis. For example, if a load-side single-phase disconnect is open on C-phase, the relay will force the IC metering value to 0.00, and the resulting power and energy values for C-phase will be 0.00. In this example, the A-phase and B-phase values are still calculated, provided the current and voltage exceed the threshold values.

Table 8.5 Metering Thresholds (Secondary Units)

Current Channels:	Nominal Current Input Rating			
	5 A	1 A	0.2 A	0.05 A
IA, IB, IC	0.05 A	0.01 A	N/A	N/A
IN	0.05 A	0.01 A	0.002 A	0.0005 A
Voltage Channels:	**All Models**			
VA, VB, VC, VS	0.1 V			

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Synchrophasor Metering

View Synchrophasor Metering Information Via Serial Port

See *MET Command (Metering Data) on page 10.20*. The **MET PM** command displays the synchrophasor measurements. For more information, see *View Synchrophasors by Using the MET PM Command on page L.12*.

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Load Profile Report (Available in Firmware Versions 6 and 7)

At the interval given by load profile acquisition rate setting LDAR, the relay adds a record to the load profile buffer. This record contains the time stamp, the present value of each of the analog quantities listed in the load profile list setting LDLIST and a checksum. These settings are made and reviewed with the **SET R** and **SHO R** serial port commands, respectively. Setting LDAR can be set to any of the following values: 5, 10, 15, 30, and 60 minutes. Setting LDLIST may contain any of the following labels shown below.

Label	Quantity Recorded
IA, IB, IC, IN	Phase and neutral current magnitudes
VA, VB, VC	Phase voltage magnitudes (wye connected only)
VAB, VBC, VCA	Phase-to-phase voltage magnitudes
VS	Sync (or broken delta) voltage magnitude
IG, I1, 3I2, V1, V2	Sequence current and voltage magnitudes
3V0	Zero-sequence voltage magnitude (wye connected only)
VDC	Battery voltage
FREQ	Phase frequency
MWA, MWB, MWC	Phase megawatts (wye connected only)
MW3	Three-phase megawatts
MVARA, MVARB, MVARC	Phase megaVARs (wye connected only)
MVAR3	Three-phase megaVARs
PFA, PFB, PFC	Phase power factor (wye connected only)
PF3	Three-phase power factor
LDPFA, LDPFB, LDPFC	Phase power factor lead/lag status (0 = lag, 1 = lead) (wye connected only)
LDPF3	Three-phase power factor lead/lag status (0 = lag, 1 = lead)
IADEM, IBDEM, ICDEM, INDEM, IGDEM, 3I2DEM	Demand ammeter quantities
MWADI, MWBDI, MWCDI	Phase demand megaWATTs in (wye connected only)
MW3DI	Three-phase demand megaWATTs in
MWADO, MWBDO, MWCDO	Phase demand megaWATTs out (wye connected only)
MW3DO	Three-phase demand megaWATTs out
MVRADI, MVRBDI, MVRCDI	Phase demand megaVARs in (wye connected only)
MVR3DI	Three-phase demand megaVARs in
MVRADO, MVRBDO, MVRCDO	Phase demand megaVARs out (wye connected only)
MVR3DO	Three-phase demand megaVARs out
MWHAI, MWHBI, MWHCI	Phase megaWATT hours in (wye connected only)
MWH3I	Three-phase megaWATT hours in
MWHAO, MWHBO, MWHCO	Phase megaWATT hours out (wye connected only)

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Label	Quantity Recorded
MWH3O	Three-phase megaWATT hours out
MVRHAI, MVRHBI, MVRHCI	Phase megaVAR hours in (wye connected only)
MVRH3I	Three-phase megaVAR hours in
MVRHAO, MVRHBO, MVRHCO	Phase megaVAR hours out (wye connected only)
MVRH3O	Three-phase megaVAR hours out

Labels are entered into the setting as either comma or space delimited, but are displayed as comma delimited. Load profiling is disabled if the LDLIST setting is empty (i.e., set to NA or 0), which is displayed as LDLIST = 0. The load buffer is stored in nonvolatile memory and the acquisition is synchronized to the time of day, with a resolution of ±5 seconds. Changing the LDAR setting may result in up to two acquisition intervals before resynchronization occurs. If LDAR setting is increased, the next acquisition time does not have a complete interval; therefore, no record is saved until the second acquisition time, which is a complete cycle. When the buffer fills up, newer records overwrite older records. The relay is able to store at least 13 days of data at a LDAR of five minutes, if all 15 values are used. If less than 15 values are specified, the relay will be able to store more days of data before data over-write occurs. Likewise, if the interval is set longer, the relay will be able to store more days of data before data over-write occurs.

The load profile report is retrieved via the **LDP** command, which has the following format:

LDP [**a**] [**b**]

If the command is entered without parameters (i.e., **LDP**), the relay displays all records in the load buffer. If the command is entered with a single numeric parameter [a] (i.e., **LDP 10**), the relay displays the most recent [a] records in the buffer. If the command is entered with two numeric parameters [a] [b] (i.e., **LDP 10 20**), the relay displays load buffer records [a] through [b]. If the command is entered with a single data parameter [a] (i.e., **LDP 7/7/96**), the relay displays all load buffer records for the specified date. If the command is entered with two date parameters [a] [b] (i.e., **LDP 7/7/96 8/8/96**), the relay displays all load records occurring from date [a] through date [b] inclusive.

Example LDP Serial Port Commands	Format
LDP	If LDP is entered with no numbers following it, all available rows are displayed. They display with the oldest row at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
LDP 17	If LDP is entered with a single number following it (17 in this example), the first 17 rows are displayed, if they exist. They display with the oldest row (row 17) at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.

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Example LDP Serial Port Commands	Format
LDP 10 33	If LDP is entered with two numbers following it (10 and 33 in this example; 10 < 33), all the rows between (and including) rows 10 and 33 are displayed, if they exist. They display with the oldest row (row 33) at the beginning (top) of the report and the latest row (row 10) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
LDP 47 22	If LDP is entered with two numbers following it (47 and 22 in this example; 47 > 22), all the rows between (and including) rows 47 and 22 are displayed, if they exist. They display with the newest row (row 22) at the beginning (top) of the report and the oldest row (row 47) at the end (bottom) of the report. **Reverse** chronological progression through the report is down the page and in ascending row number.
LDP 3/30/97	If LDP is entered with one date following it (date 3/30/97 in this example), all the rows on that date are displayed, if they exist. They display with the oldest row at the beginning (top) of the report and the latest row at the end (bottom) of the report, for the given date. Chronological progression through the report is down the page and in descending row number.
LDP 2/17/97 3/23/97	If LDP is entered with two dates following it (date 2/17/97 chronologically **precedes** date 3/23/97 in this example), all the rows between (and including) dates 2/17/97 and 3/23/97 are displayed, if they exist. They display with the oldest row (date 2/17/97) at the beginning (top) of the report and the latest row (date 3/23/97) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
LDP 3/16/97 1/5/97	If LDP is entered with two dates following it (date 3/16/97 chronologically **follows** date 1/5/97 in this example), all the rows between (and including) dates 1/5/97 and 3/16/97 are displayed, if they exist. They display with the latest row (date 3/16/97) at the beginning (top) of the report and the oldest row (date 1/5/97) at the end (bottom) of the report. **Reverse** chronological progression through the report is down the page and in ascending row number.

The date entries in the above example **LDP** commands are dependent on the Date Format setting DATE_F. If setting DATE_F = MDY, then the dates are entered as in the above examples (Month/Day/Year). If setting DATE_F = YMD, then the dates are entered Year/Month/Day.

The load profile output has the following format:

```
=>LDP 7/23/96<Enter>

<STX>
FEEDER 1                    Date: mm/dd/yy    Time: hh:mm:ss.sss
STATION A

FID=SEL-351S-6-R100-V0-Z001001-D199908xx     CID=xxxx

#     DATE     TIME     label1    label2    label3    label4    ... labeln
512   07/23/96 07:00:35 xxxxx.xxx xxxxx.xxx xxxxx.xxx xxxxx.xxx ... xxxxx.xxx
511   07/23/96 08:00:15 xxxxx.xxx xxxxx.xxx xxxxx.xxx xxxxx.xxx ... xxxxx.xxx
510   07/23/96 09:00:01 xxxxx.xxx xxxxx.xxx xxxxx.xxx xxxxx.xxx ... xxxxx.xxx
<ETX>
=>
```

If the requested load profile report rows do not exist, the relay responds:

```
No Load Profile Data
```


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Determining the Size of the Load Profile Buffer

The **LDP D** command displays maximum number of days of data the relay may acquire with the present settings, before data overwrite will occur.

```
=>LDP D <Enter>

There is room for a total of 45 days of data in the load profile buffer,
with room for 21 days of data remaining.
```

Clearing the Load Profile Buffer

Clear the load profile report from nonvolatile memory with the **LDP C** command as shown in the following example:

```
=>LDP C <Enter>

Clear the load profile buffer
Are you sure (Y/N) ? Y <Enter>
Clearing Complete
```

Changing the LDLIST setting will also result in the buffer being cleared.

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Section 9
Setting the Relay

Introduction

Change or view settings with the **SET** and **SHOWSET** serial port commands and the front-panel {SET} pushbutton. *Table 9.1* lists the serial port **SET** commands.

Table 9.1 Serial Port SET Commands

Command	Settings Type	Description	Settings Sheets[a]
SET *n*	Relay	Overcurrent and voltage elements, reclosing relay, timers, etc., for settings Group *n* (*n* = 1, 2, 3, 4, 5, 6).	1–17
SET L *n*	Logic	SELOGIC® control equations for settings Group *n* (*n* = 1, 2, 3, 4, 5, 6).	18–24
SET G	Global	Battery and breaker monitors, optoisolated input debounce timers, synchrophasors, etc.	25–28
SET R	SER	Sequential Events Recorder (SER) trigger conditions and Load Profile Recorder (LDP) settings. (LDP available only in firmware versions 6 and 7).	29–30
SET T	Text	Front-panel default display and local control text.	31–34
SET P *n*	Port	Serial port settings for Serial Port *n* (*n* = 1, 2, 3, or F).	35

[a] Located at end of this section

View settings with the respective serial port **SHOWSET** commands (**SHO**, **SHO L**, **SHO G** , **SHO R**, **SHO T**, **SHO P**). See *SHO Command (Show/View Settings) on page 10.27*.

In Some Applications, Make Global Settings (SET G) First

Make Global Settings (on *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25*) before making other relay settings for applications that require delta-connected PTs, or applications requiring an external zero-sequence voltage source to be connected to the relay. Changing Global Settings PTCONN or VSCONN automatically resets many of the remaining relay settings to default values. For example, any settings previously entered for the Group Settings (SET; SET 1–SET 6), Logic Settings (SET L; SET L 1–SET L 6), and Report Settings (SET R) will be lost and will need to be re-entered. The relay will provide two confirmation prompts prior to accepting a change to either PTCONN or VSCONN. See *Delta-Connected Voltages (Global Setting PTCONN = DELTA) on page 2.19* and *Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20*.

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Applications that use wye-connected PTs and have no external zero-sequence voltage source connection do not require changes in the PTCONN and VSCONN settings, so are not affected by the order of setting entry.

Using the ACSELERATOR® QuickSet™ SEL-5030 software to make settings changes handles these details automatically.

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Settings Changes via the Front Panel

The relay front-panel **{SET}** pushbutton provides access to the Relay, Global, and Port settings only. Thus, the corresponding Relay, Global, and Port settings sheets that follow in this section can also be used when making these settings via the front panel. Refer to *Figure 11.3* for information on front-panel communications.

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Settings Changes via the Serial Port

See *Section 10: Serial Port Communications and Commands* for information on serial port communications and relay access levels. The **SET** commands in *Table 9.1* operate at Access Level 2 (screen prompt: =>>). To change a specific setting, enter the command:

SET *n m* s TERSE

where:

n = L, G, R, T, or P (parameter *n* is not entered for the relay settings).

m = group (1....6) or port (1....3). The relay selects the active group or port if *m* is not specified.

s = the name of the specific setting you wish to jump to and begin setting. If *s* is not entered, the relay starts at the first setting.

TERSE = instructs the relay to skip the **SHOWSET** display after the last setting. Use this parameter to speed up the **SET** command. If you wish to review the settings before saving, do not use the TERSE option.

When you issue the **SET** command, the relay presents a list of settings, one at a time. Enter a new setting, or press **<Enter>** to accept the existing setting. Editing keystrokes are shown in *Table 9.2*.

Table 9.2 Set Command Editing Keystrokes

Press Key(s)	Results
<Enter>	Retains setting and moves to the next setting.
^ <Enter>	Returns to previous setting.
< <Enter>	Returns to previous setting section.
> <Enter>	Moves to next setting section.
END <Enter>	Exits editing session, then prompts you to save the settings.
<Ctrl + X>	Aborts editing session without saving changes.

The relay checks each entry to ensure that it is within the setting range. If it is not, an `Out of Range` message is generated, and the relay prompts for the setting again.

When all the settings are entered, the relay displays the new settings and prompts for approval to enable them. Answer **Y <Enter>** to enable the new settings. If changes are made to Global, SER, or Text settings (see *Table 9.1*), the relay is disabled while it saves the new settings. If changes are made to the Relay or Logic settings for the active setting group (see *Table 9.1*), the relay is disabled while it saves the new settings. The **ALARM** contact closes momentarily (for b contact, opens for an a; see *Figure 7.27*) and the **ENABLED** LED extinguishes (see *Table 5.1*) while the relay is disabled. The relay is disabled for about one second. If Logic Settings are changed for the active group, the relay can be disabled for up to 15 seconds.

If changes are made to the Relay or Logic Settings for a setting group other than the active setting group (see *Table 9.1*), the relay is not disabled while it saves the new settings. The **ALARM** contact closes momentarily (for b contact, opens for an a; see *Figure 7.27*), but the **ENABLED** LED remains on (see *Table 5.1*) while the new settings are saved.

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Time-Overcurrent Curves

The following information describes the curve timing for the curve and time dial settings made for the time-overcurrent elements (see *Figure 3.14*–*Figure 3.20*). The time-overcurrent relay curves in *Figure 9.1*–*Figure 9.10* conform to IEEE C37.112-1996 IEEE Standard Inverse-Time Characteristic Equations for Overcurrent Relays.

where:

t_p = operating time in seconds
t_r = electromechanical induction-disk emulation reset time in seconds (if you select electromechanical reset setting)
TD = time-dial setting
M = applied multiples of pickup current [for operating time (t_p), M>1; for reset time (t_r), M≤1]

Table 9.3 Equations Associated with U.S. Curves

Curve Type	Operating Time	Reset Time	Figure
U1 (Moderately Inverse)	$t_p = TD \bullet \left(0.0226 + \frac{0.0104}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{1.08}{1 - M^2}\right)$	*Figure 9.1*
U2 (Inverse)	$t_p = TD \bullet \left(0.180 + \frac{5.95}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{5.95}{1 - M^2}\right)$	*Figure 9.2*
U3 (Very Inverse)	$t_p = TD \bullet \left(0.0963 + \frac{3.88}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{3.88}{1 - M^2}\right)$	*Figure 9.3*
U4 (Extremely Inverse)[a]	$t_p = TD \bullet \left(0.0352 + \frac{5.67}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{5.67}{1 - M^2}\right)$	*Figure 9.4*
U5 (Short-Time Inverse)	$t_p = TD \bullet \left(0.00262 + \frac{0.00342}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{0.323}{1 - M^2}\right)$	*Figure 9.5*

[a] U.S. Curve U4 differs slightly from the SEL-351R Recloser Control and SEL-351 Relay family U4 curves.

Table 9.4 Equations Associated with IEC Curves (Sheet 1 of 2)

Curve Type	Operating Time	Reset Time	Figure
C1 (Standard Inverse)	$t_p = TD \bullet \left(\frac{0.14}{M^{0.02} - 1}\right)$	$t_r = TD \bullet \left(\frac{13.5}{1 - M^2}\right)$	*Figure 9.6*
C2 (Very Inverse)	$t_p = TD \bullet \left(\frac{13.5}{M - 1}\right)$	$t_r = TD \bullet \left(\frac{47.3}{1 - M^2}\right)$	*Figure 9.7*
C3 (Extremely Inverse)	$t_p = TD \bullet \left(\frac{80}{M^2 - 1}\right)$	$t_r = TD \bullet \left(\frac{80}{1 - M^2}\right)$	*Figure 9.8*

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Table 9.4 Equations Associated with IEC Curves (Sheet 2 of 2)

Curve Type	Operating Time	Reset Time	Figure
C4 (Long-Time Inverse)	$t_p = TD \bullet \left(\frac{120}{M - 1}\right)$	$t_r = TD \bullet \left(\frac{120}{1 - M}\right)$	*Figure 9.9*
C5 (Short-Time Inverse)	$t_p = TD \bullet \left(\frac{0.05}{M^{0.04} - 1}\right)$	$t_r = TD \bullet \left(\frac{4.85}{1 - M^2}\right)$	*Figure 9.10*

Recloser Curves

Traditional recloser curves are available for the time-overcurrent elements (see *Figure 3.14–Figure 3.20*). The recloser curves in *Figure 9.11–Figure 9.20* can be specified with either the older electronic recloser control designation or the newer micro-processor-based recloser control designation (see *Table 9.5*). For example, a given recloser curve has the following two designations:

Older electronic recloser control designation: A

Newer microprocessor-based recloser control designation: 101

Recloser curve A and curve 101 are the same curve—use either designation in making curve settings in the SEL-351S Relay.

The recloser curves have a time-dial setting range of 0.10 to 2.00, as is available in traditional microprocessor-based recloser controls. In traditional microprocessor-based recloser controls, the time-dial setting is often referred to as a "vertical multiplier" setting instead.

The recloser curves in *Figure 9.11–Figure 9.20* are shown with an effective time-dial setting of 1.00.

NOTE: The electromechanical reset setting is not available with recloser curves. It is only available with traditional electromechanical time-overcurrent relay curves (U1–U5 and C1–C5). See Table 3.2–Table 3.6 for further information.

Table 9.5 Recloser Curve Designations

Recloser Curve Cross Reference—Old to New					
Old	**New**	**Old**	**New**	**Old**	**New**
A	101	P	115	7	152
B	117	R	105	8	113
C	133	T	161	8PLUS	111
D	116	V	137	9	131
E	132	W	138	KG	165
F	163	Y	120	11	141
G	121	Z	134	13	142
H	122	1	102	14	119
J	164	2	135	15	112
KP	162	3	140	16	139
L	107	4	106	17	103
M	118	5	114	18	151
N	104	6	136		

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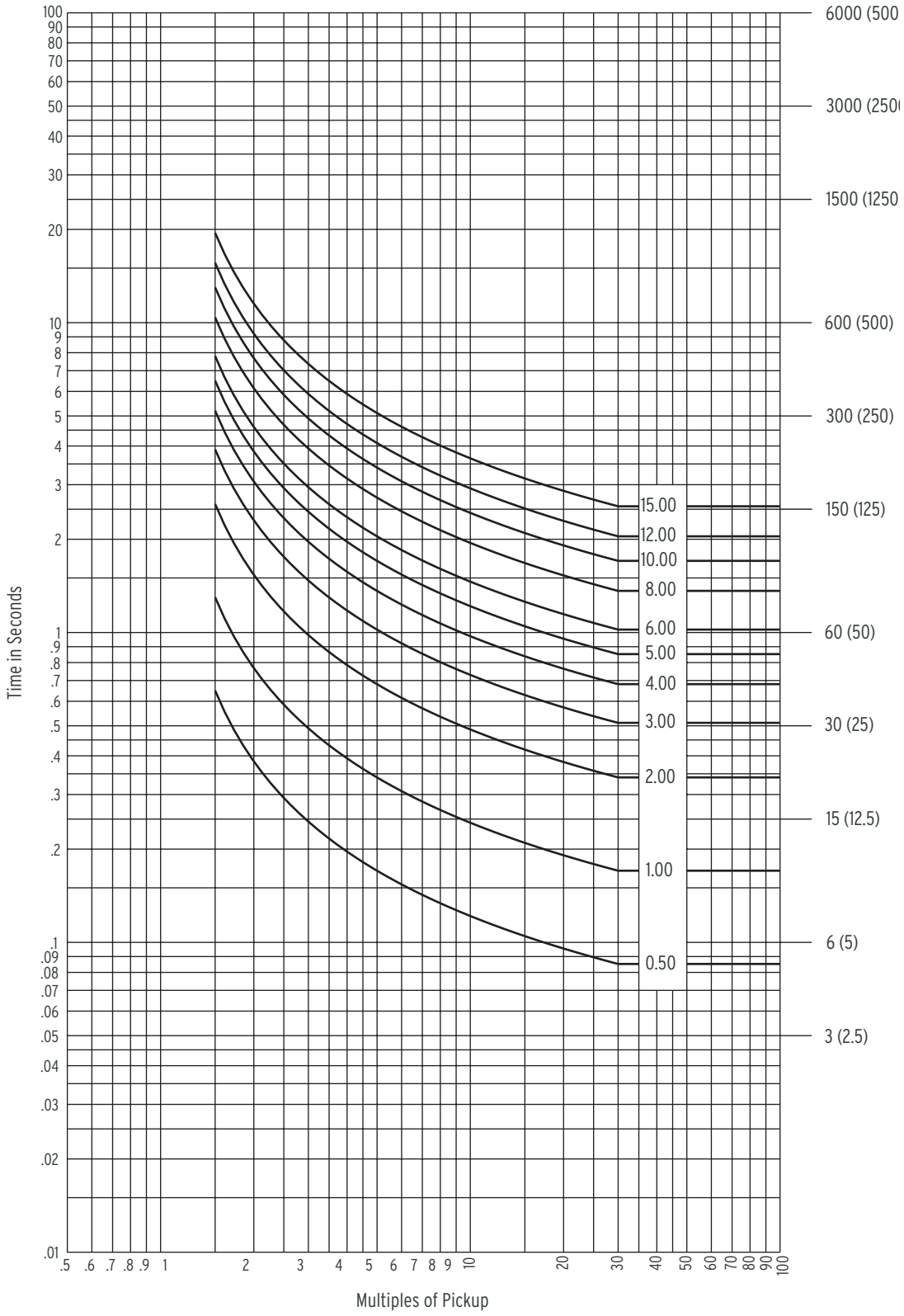


Figure 9.1 U.S. Moderately Inverse Curve: U1

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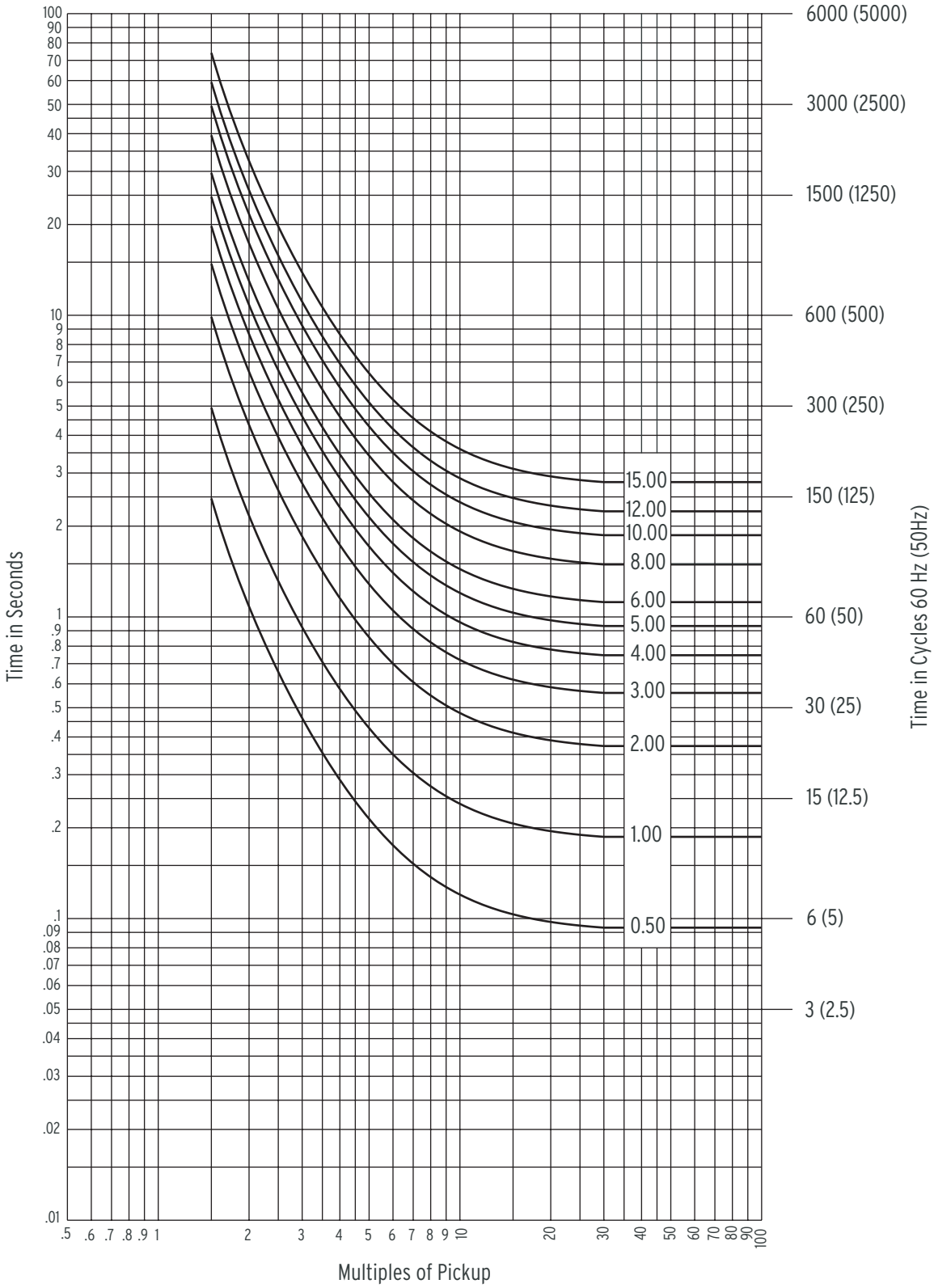


Figure 9.2 U.S. Inverse Curve: U2

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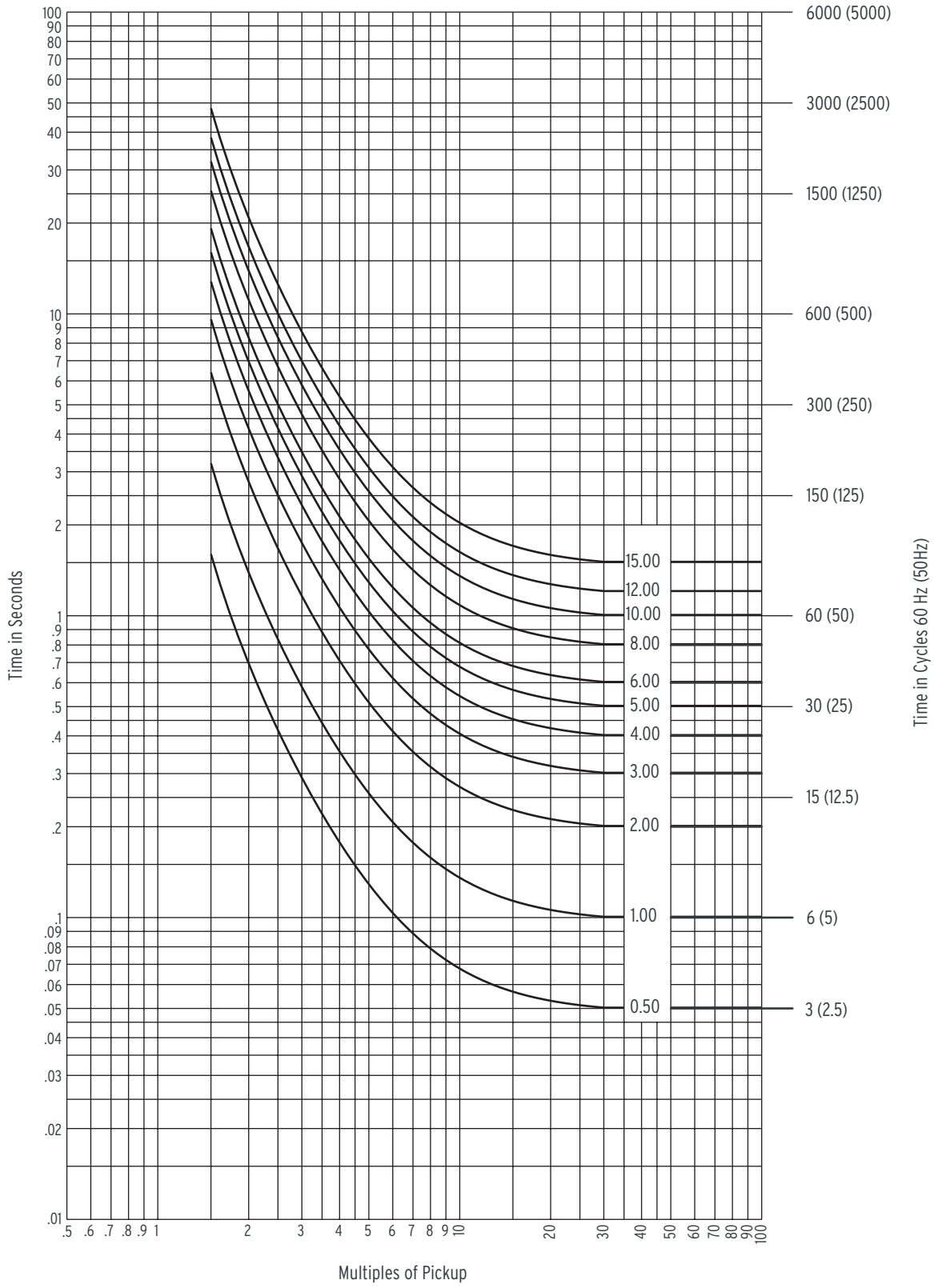


Figure 9.3 U.S. Very Inverse Curve: U3

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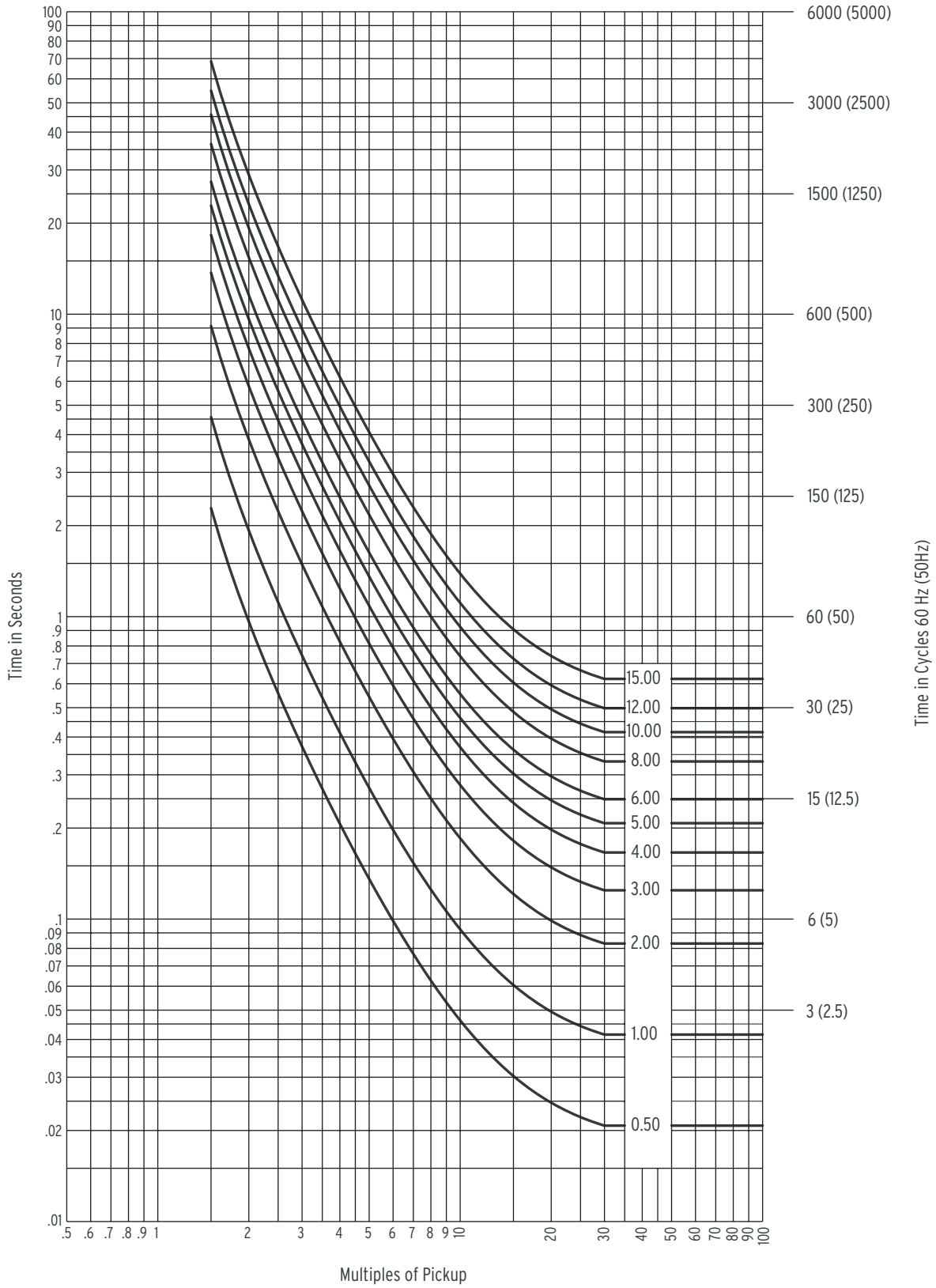


Figure 9.4 U.S. Extremely Inverse Curve: U4

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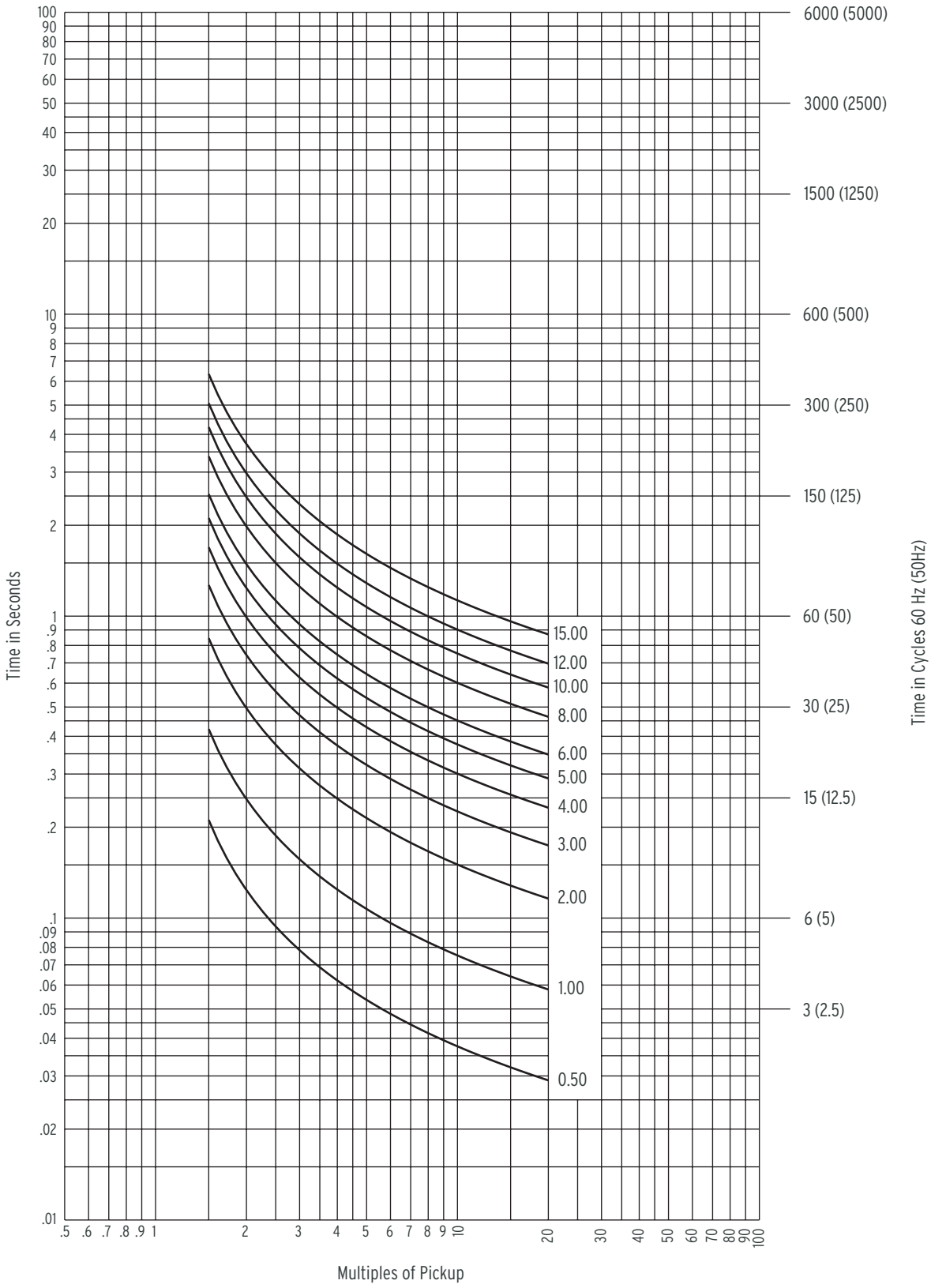


Figure 9.5 U.S. Short-Time Inverse Curve: U5

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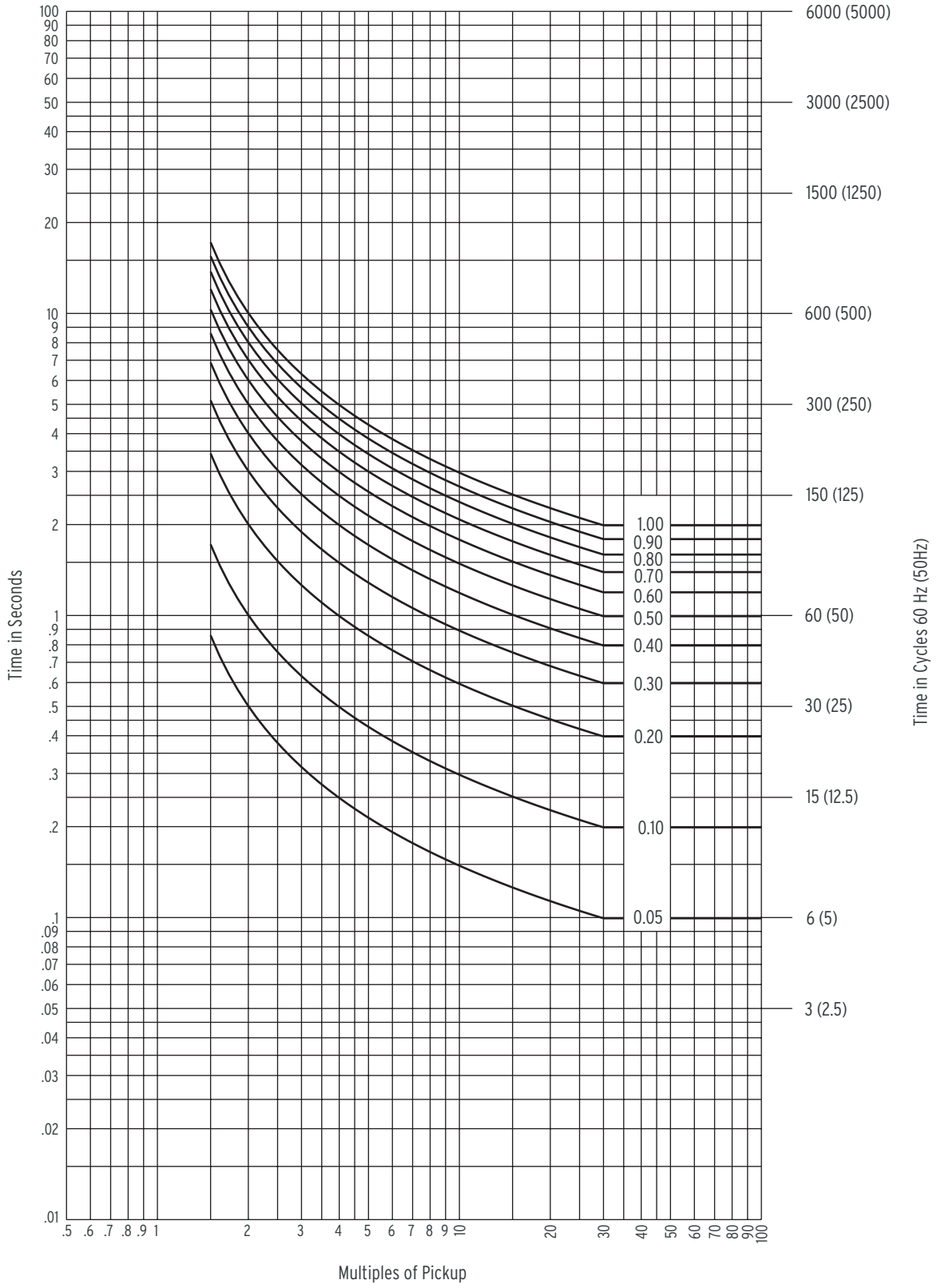


Figure 9.6 I.E.C. Class A Curve (Standard Inverse): C1

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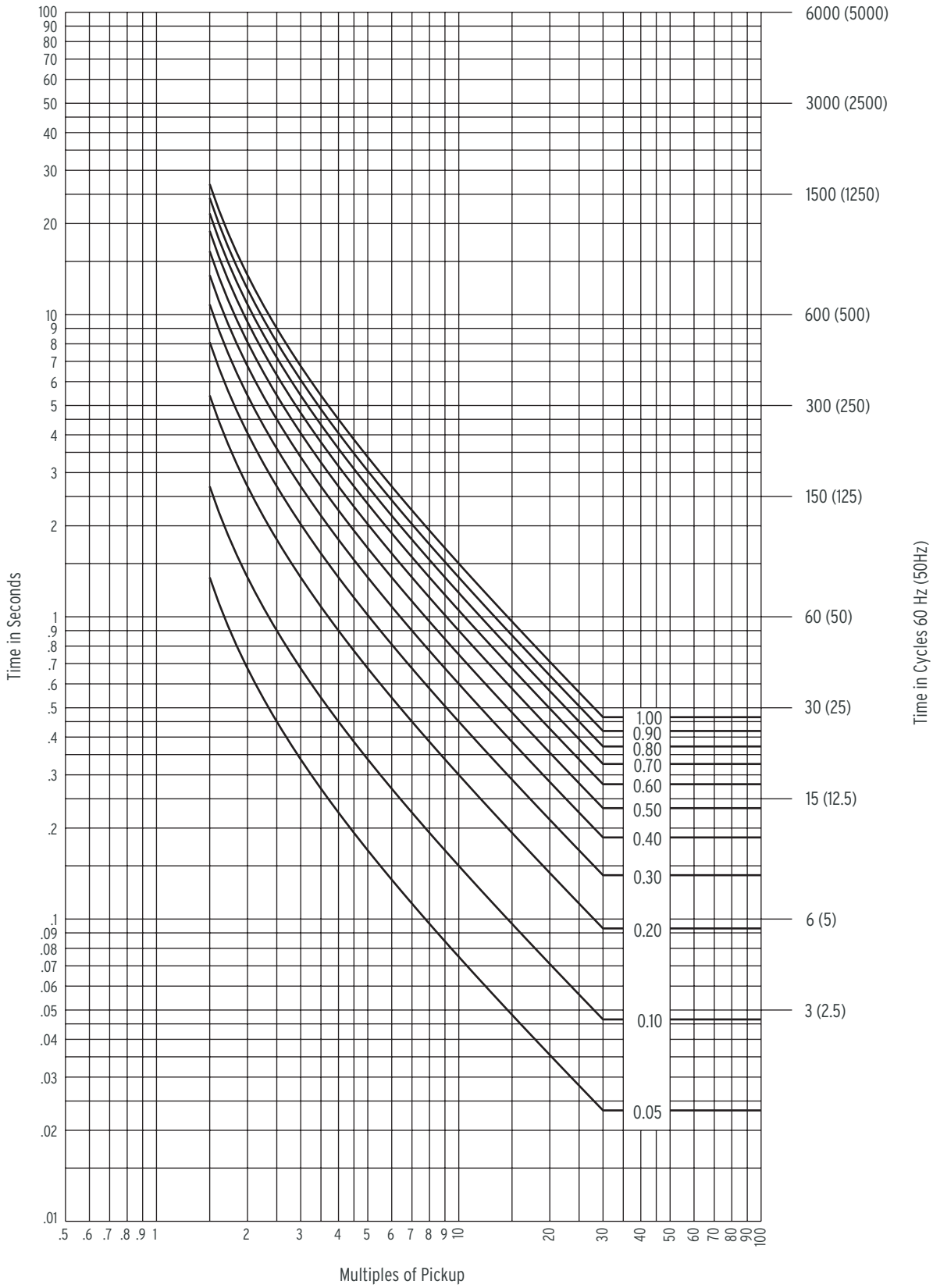


Figure 9.7 I.E.C. Class B Curve (Very Inverse): C2

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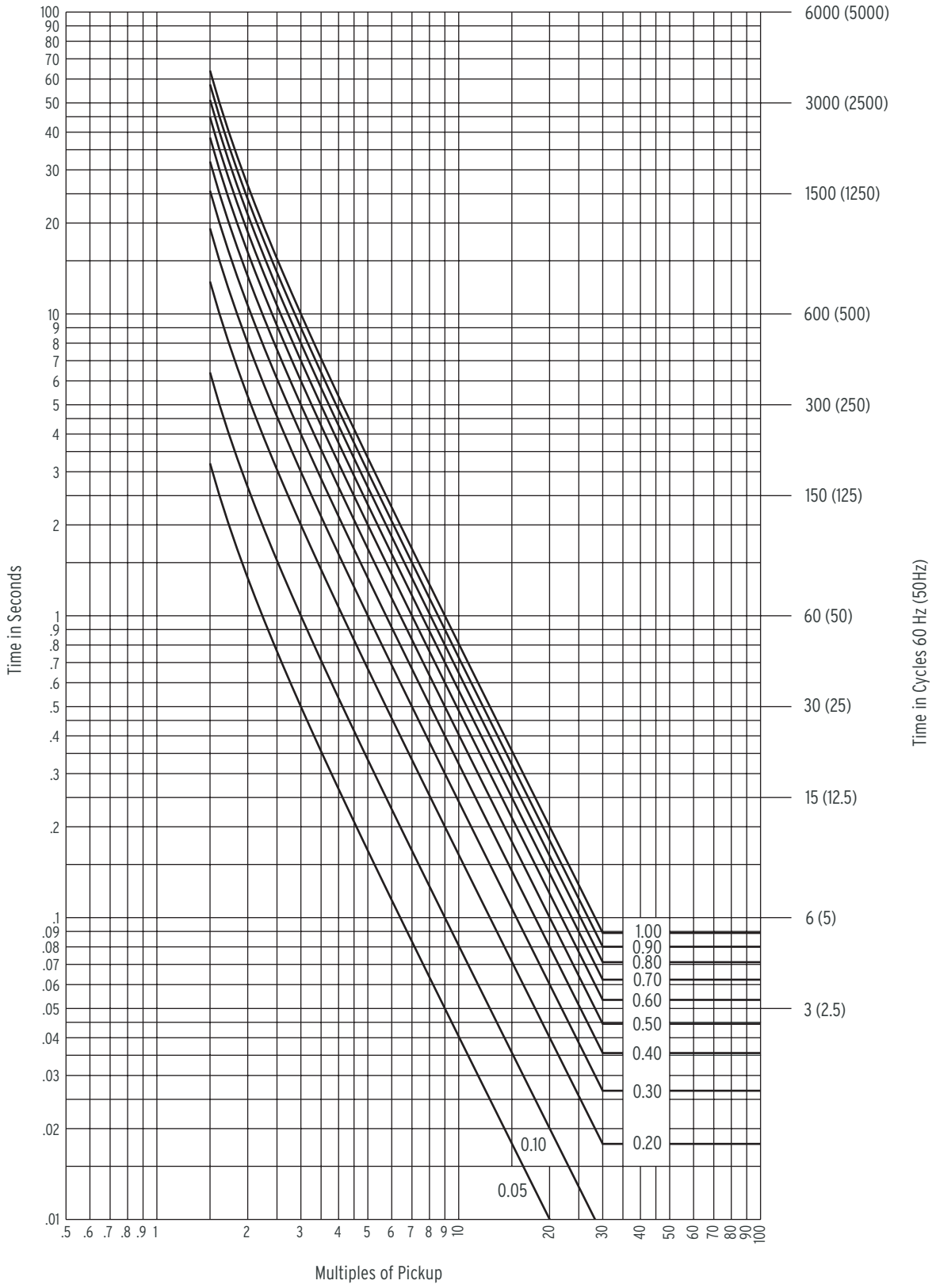


Figure 9.8 I.E.C. Class C Curve (Extremely Inverse): C3

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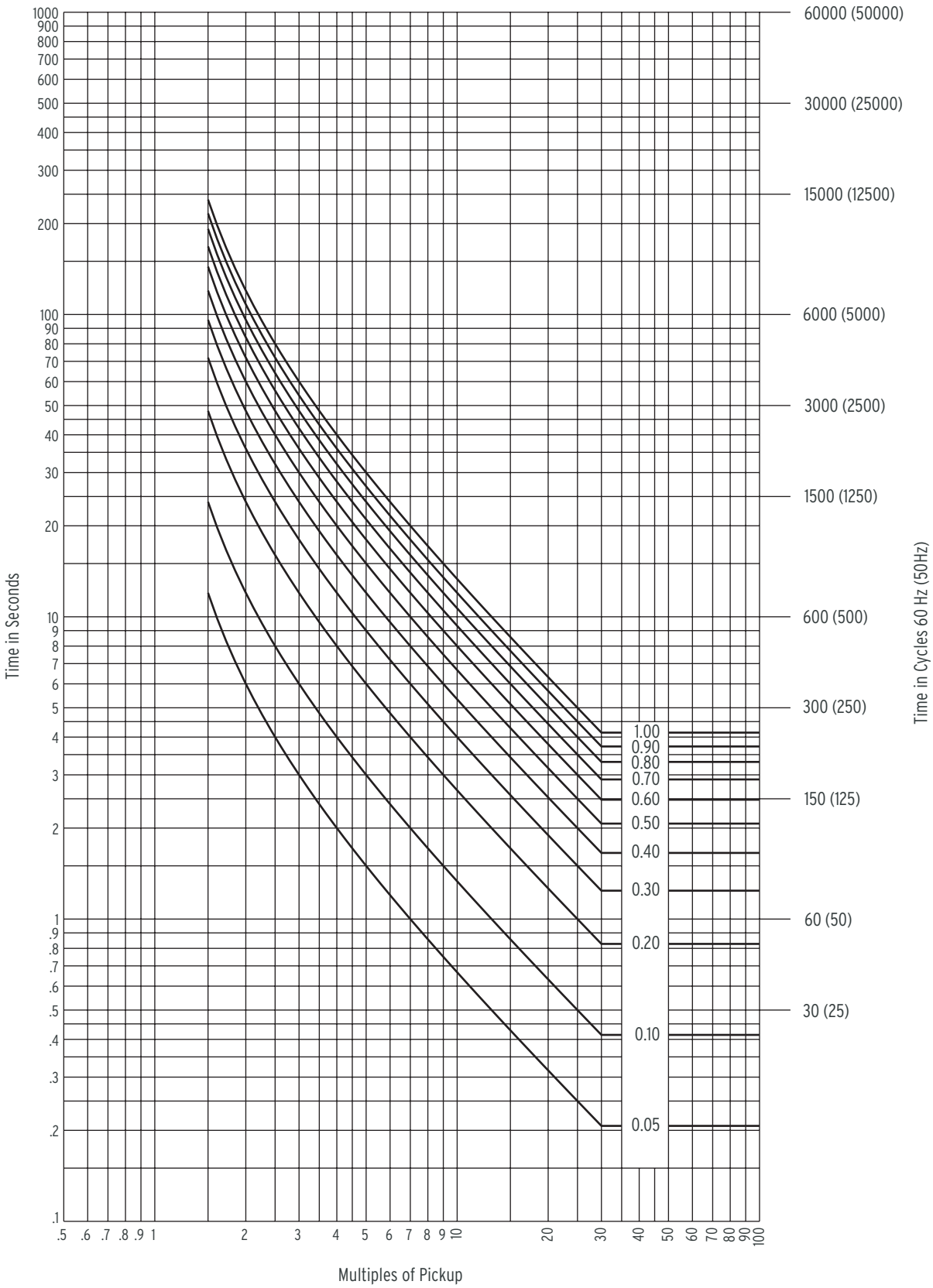


Figure 9.9 I.E.C. Long-Time Inverse Curve: C4

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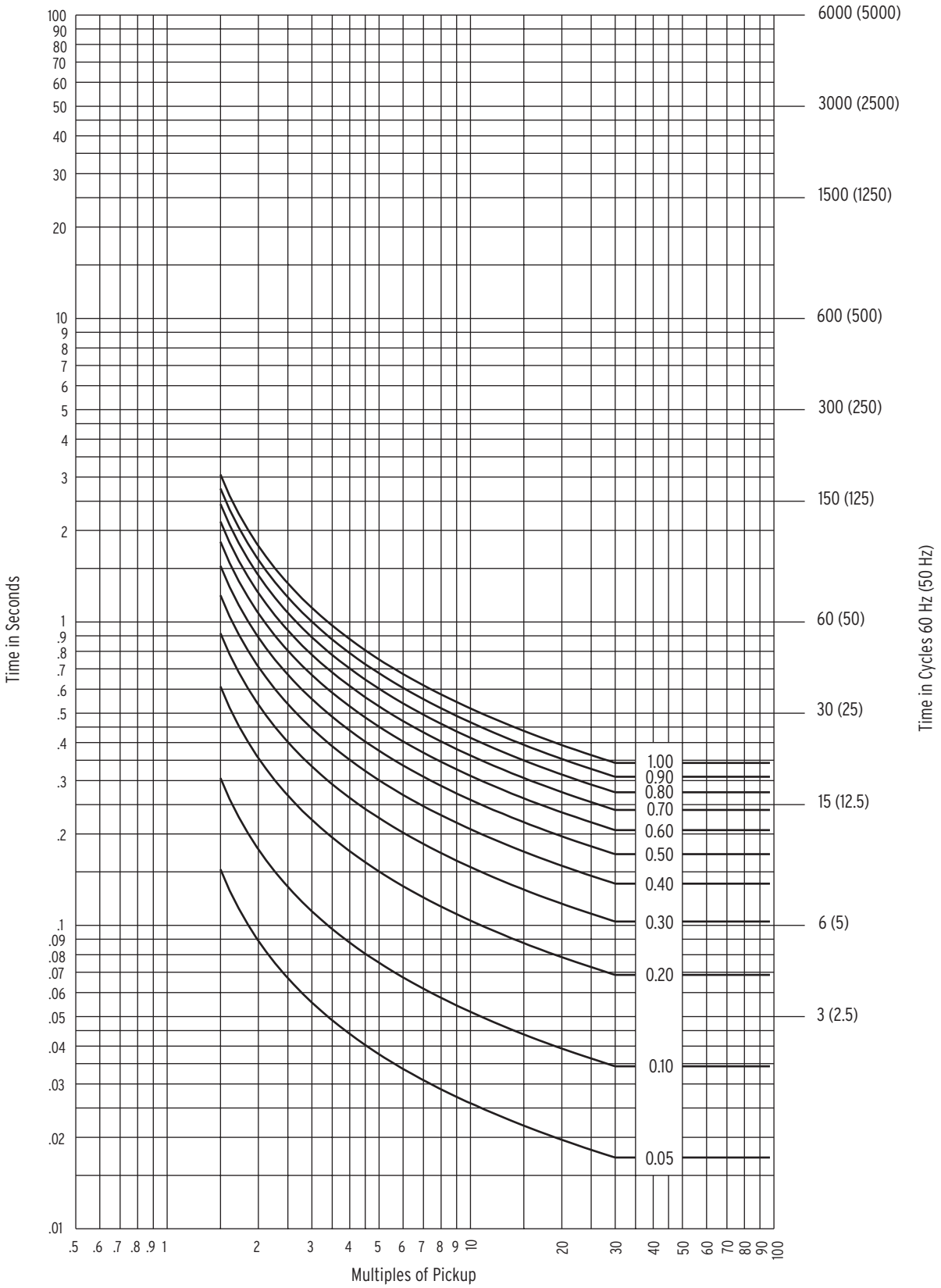


Figure 9.10 I.E.C. Short-Time Inverse Curve: C5

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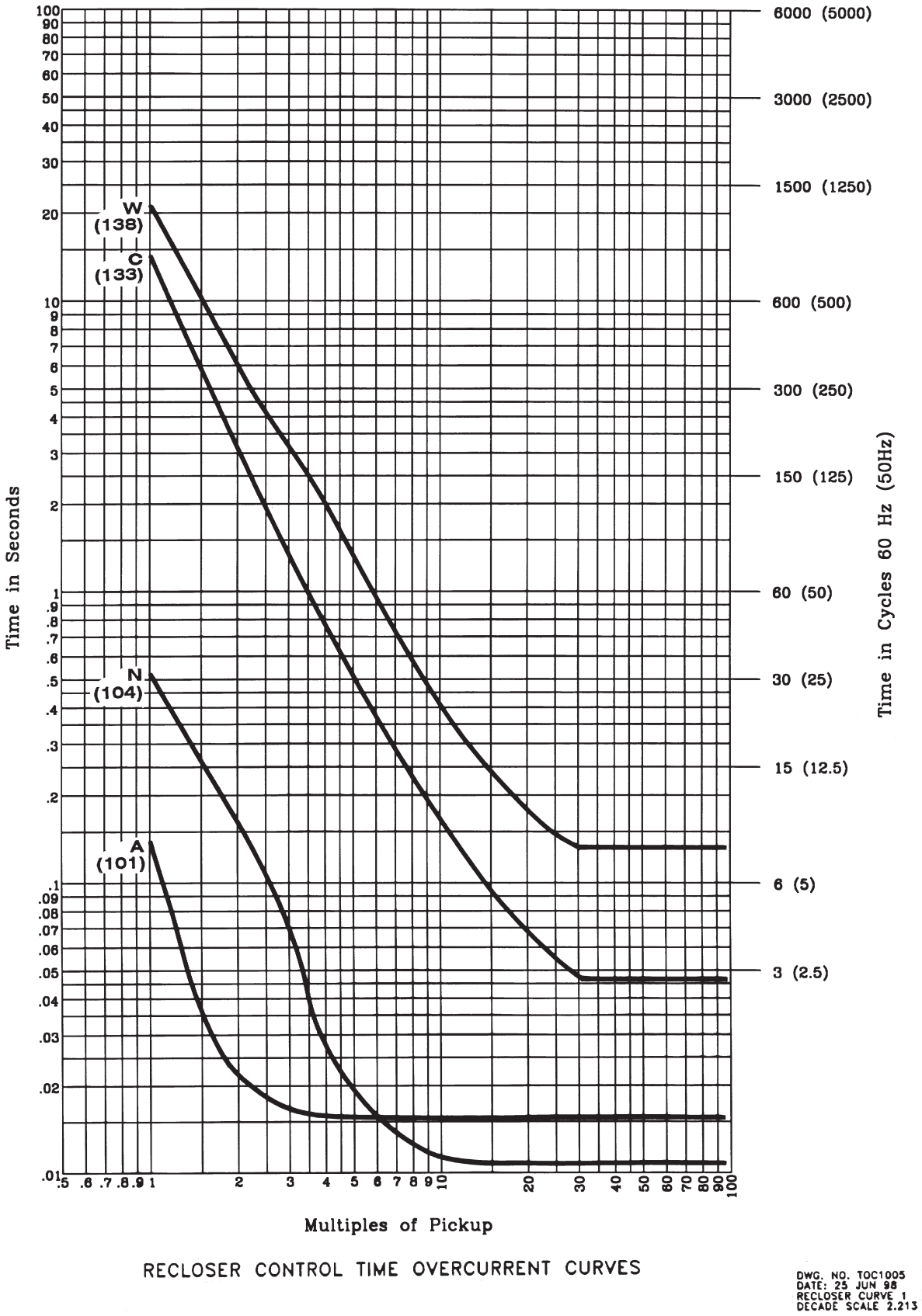


Figure 9.11 Recloser Control Response Curves A, C, N, and W

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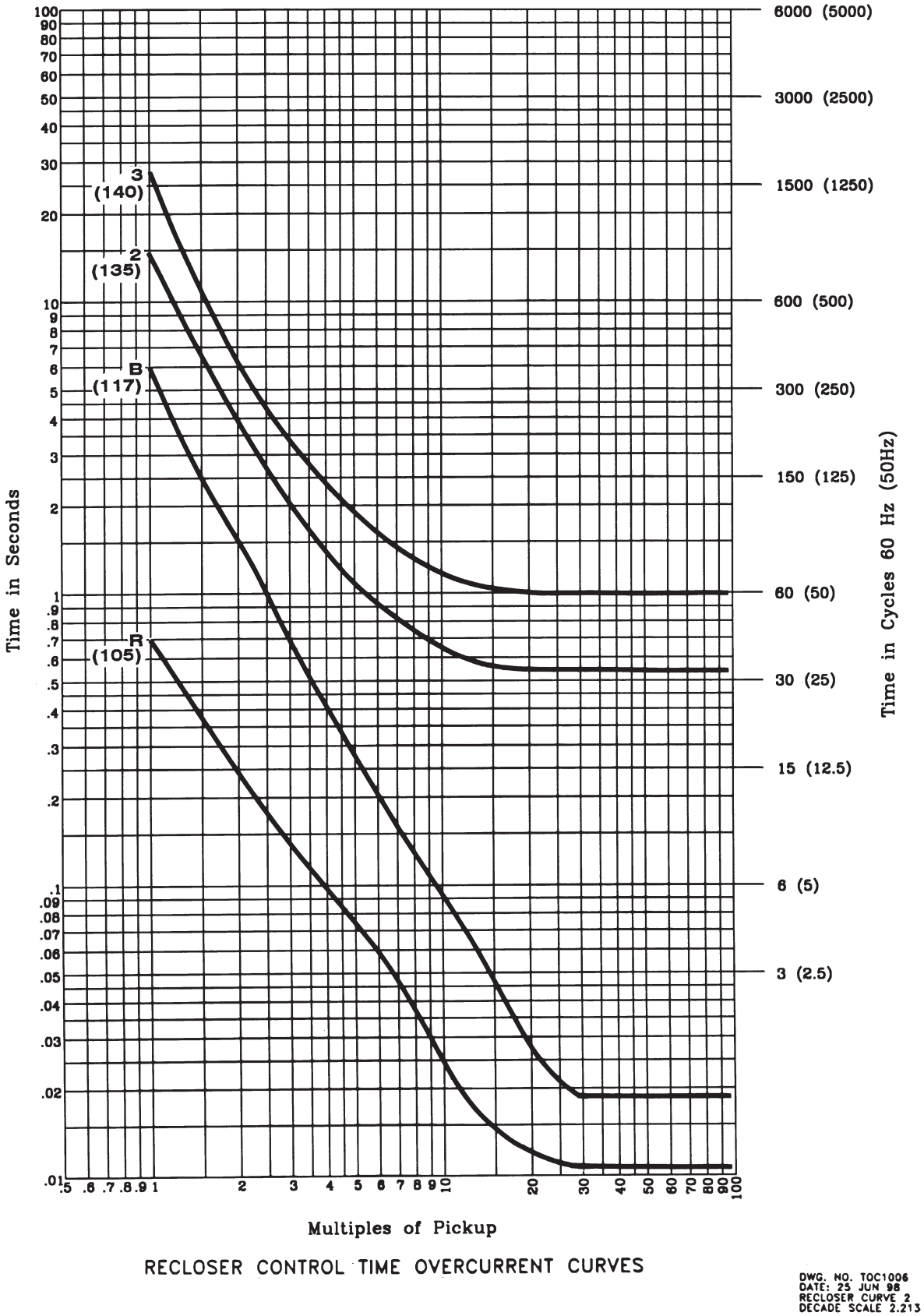


Figure 9.12 Recloser Control Response Curves B, R, 2, and 3

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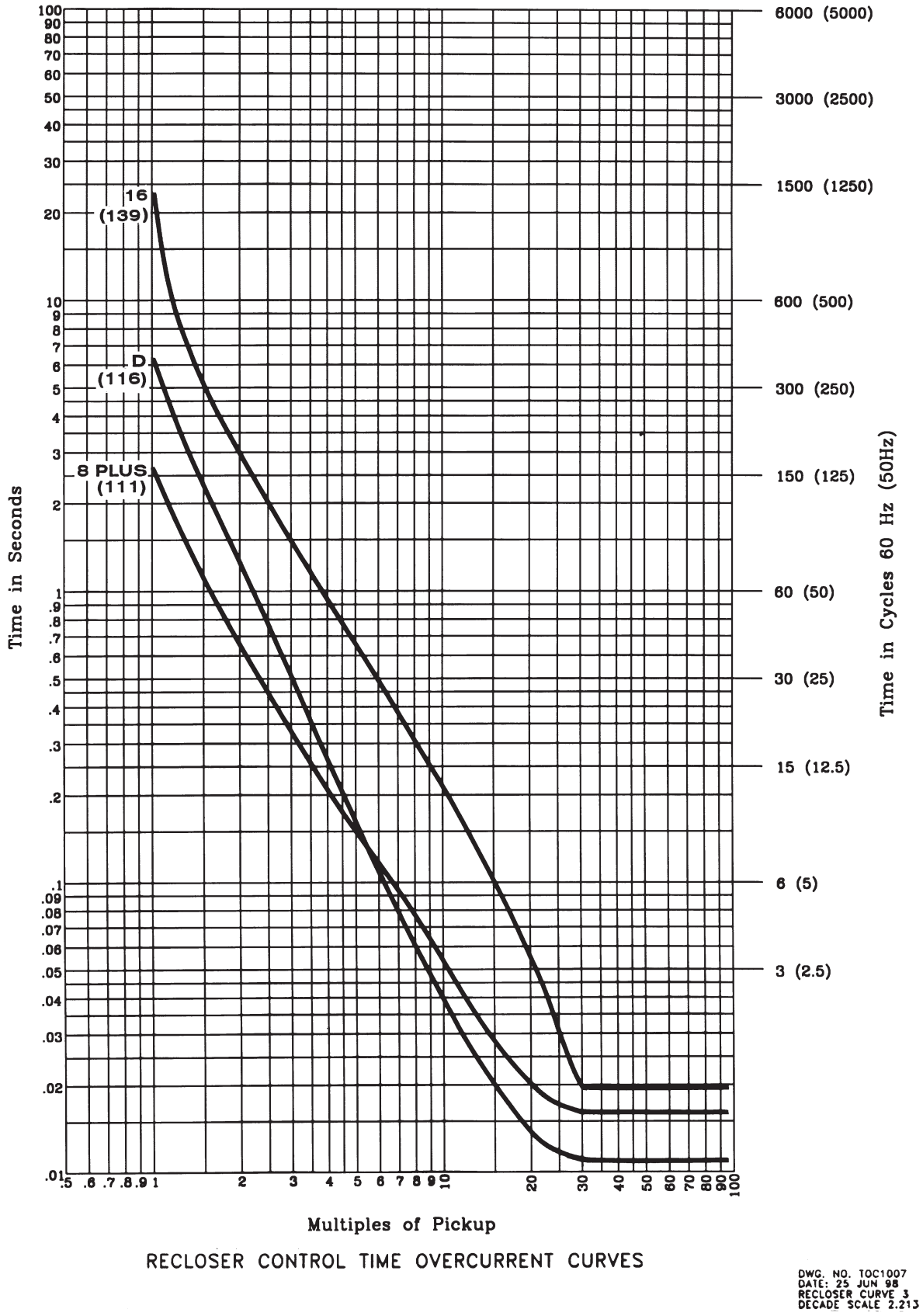


Figure 9.13 Recloser Control Response Curves D, 8PLUS, and 16

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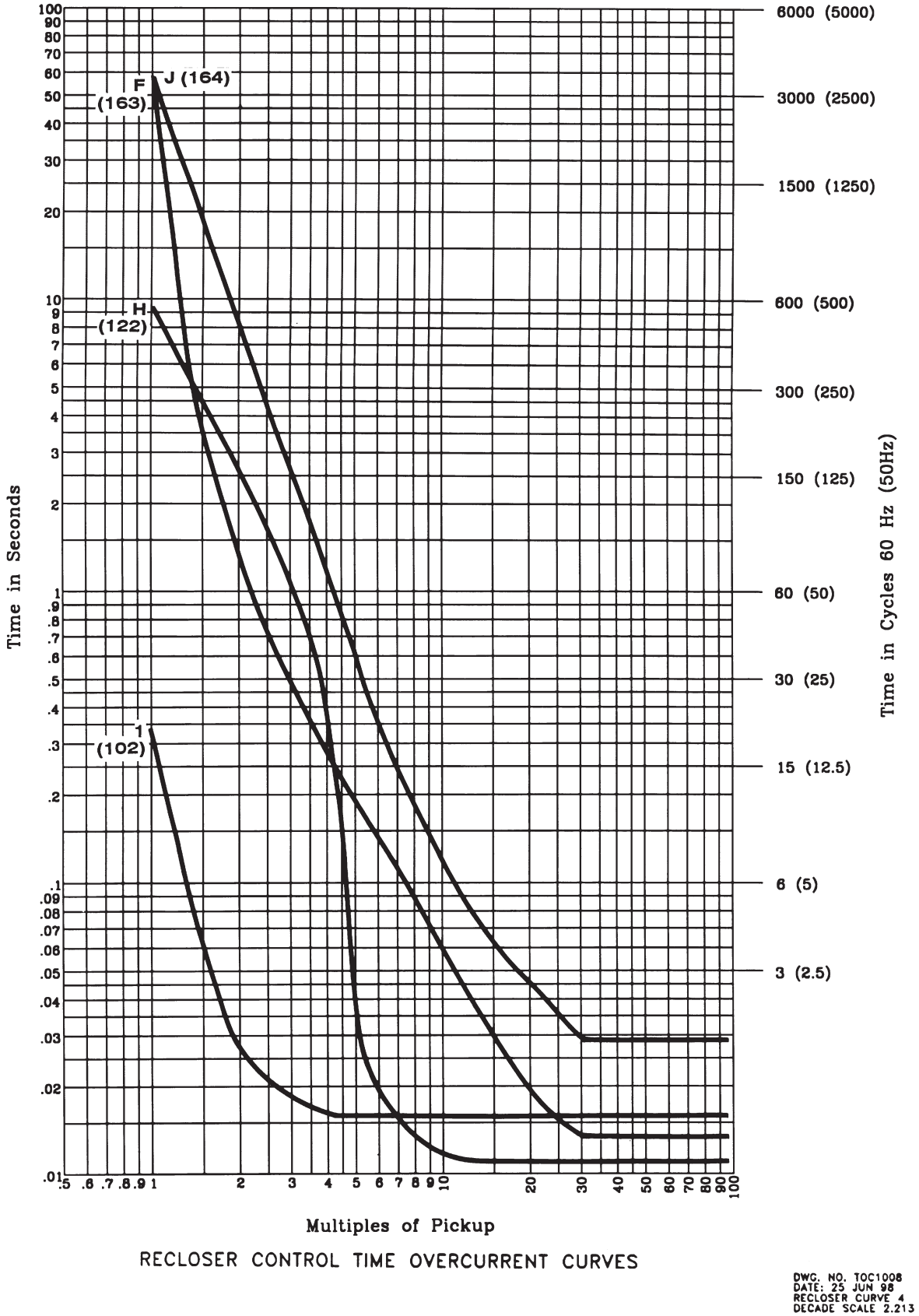


Figure 9.14 Recloser Control Response Curves F, H, J, and 1

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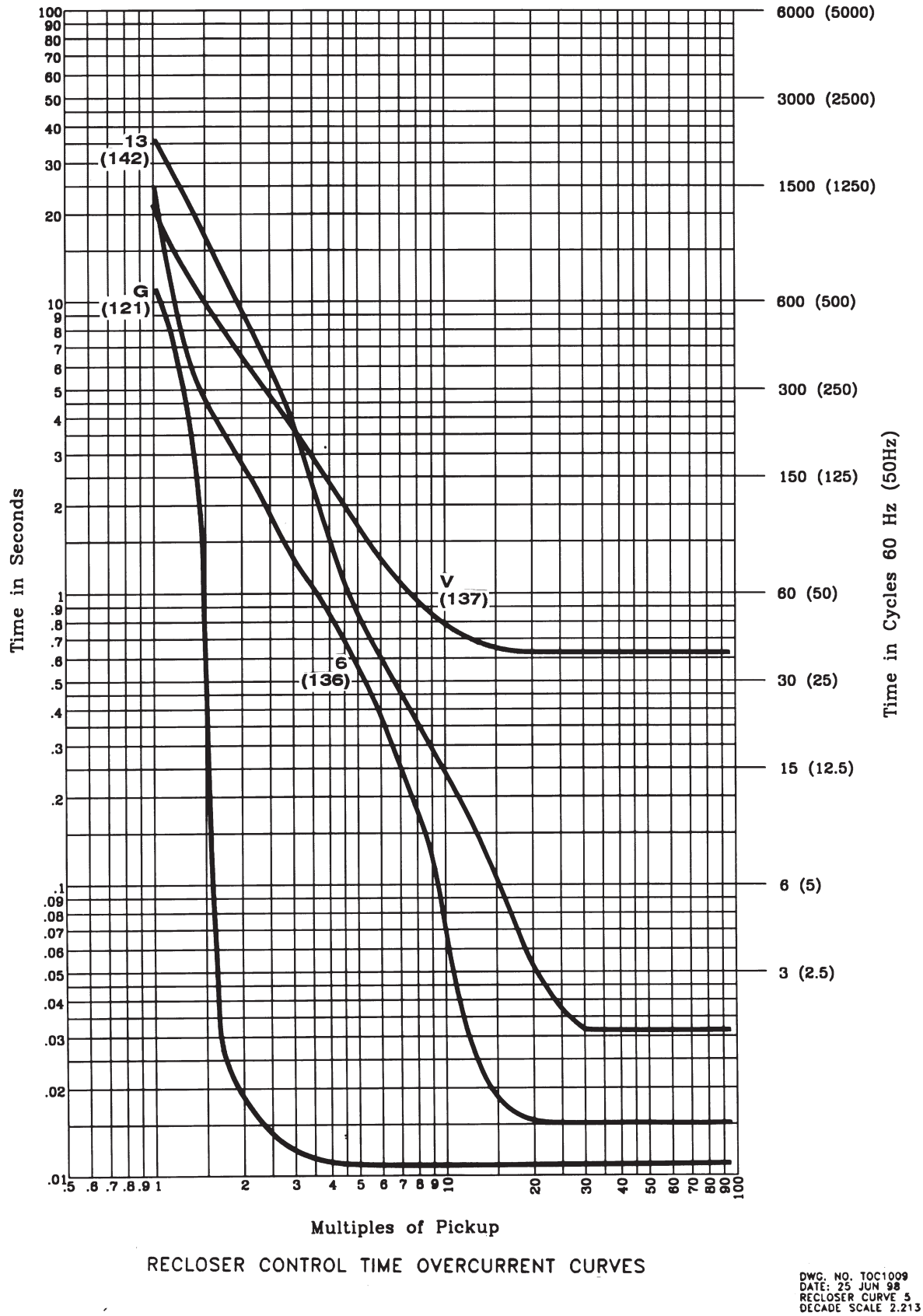


Figure 9.15 Recloser Control Response Curves G, V, 6, and 13

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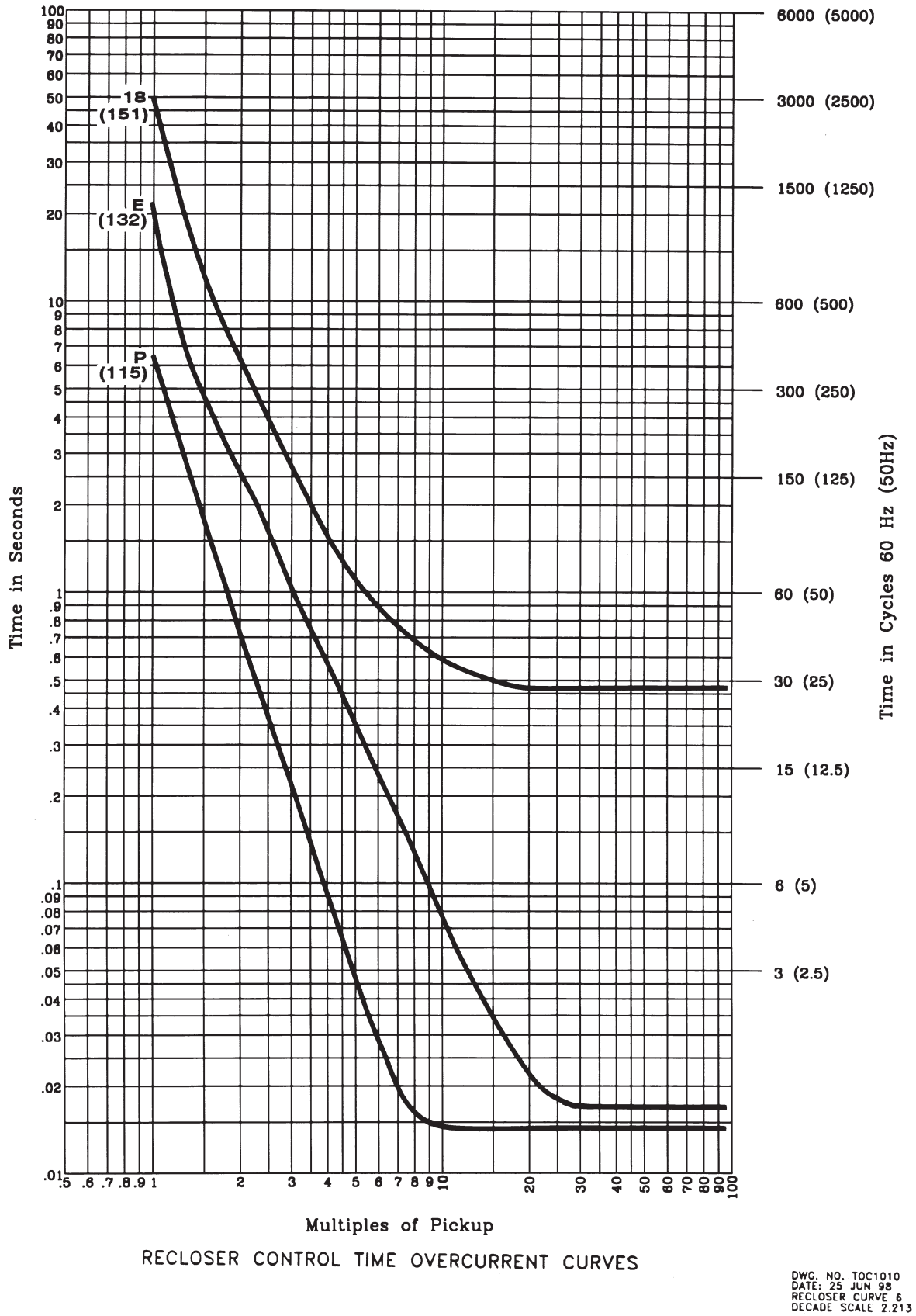


Figure 9.16 Recloser Control Response Curves E, P, and 18

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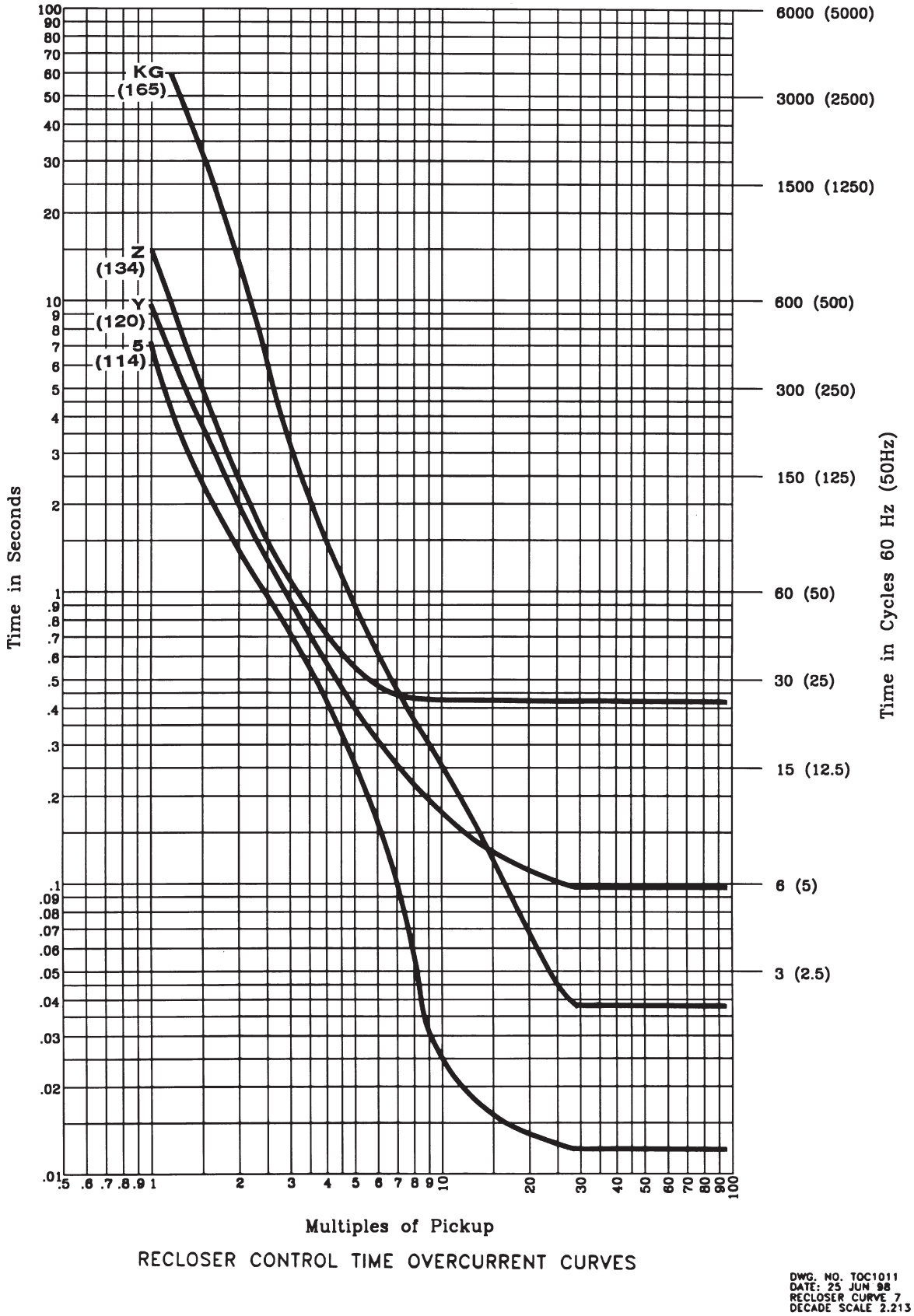


Figure 9.17 Recloser Control Response Curves KG, Y, Z, and 5

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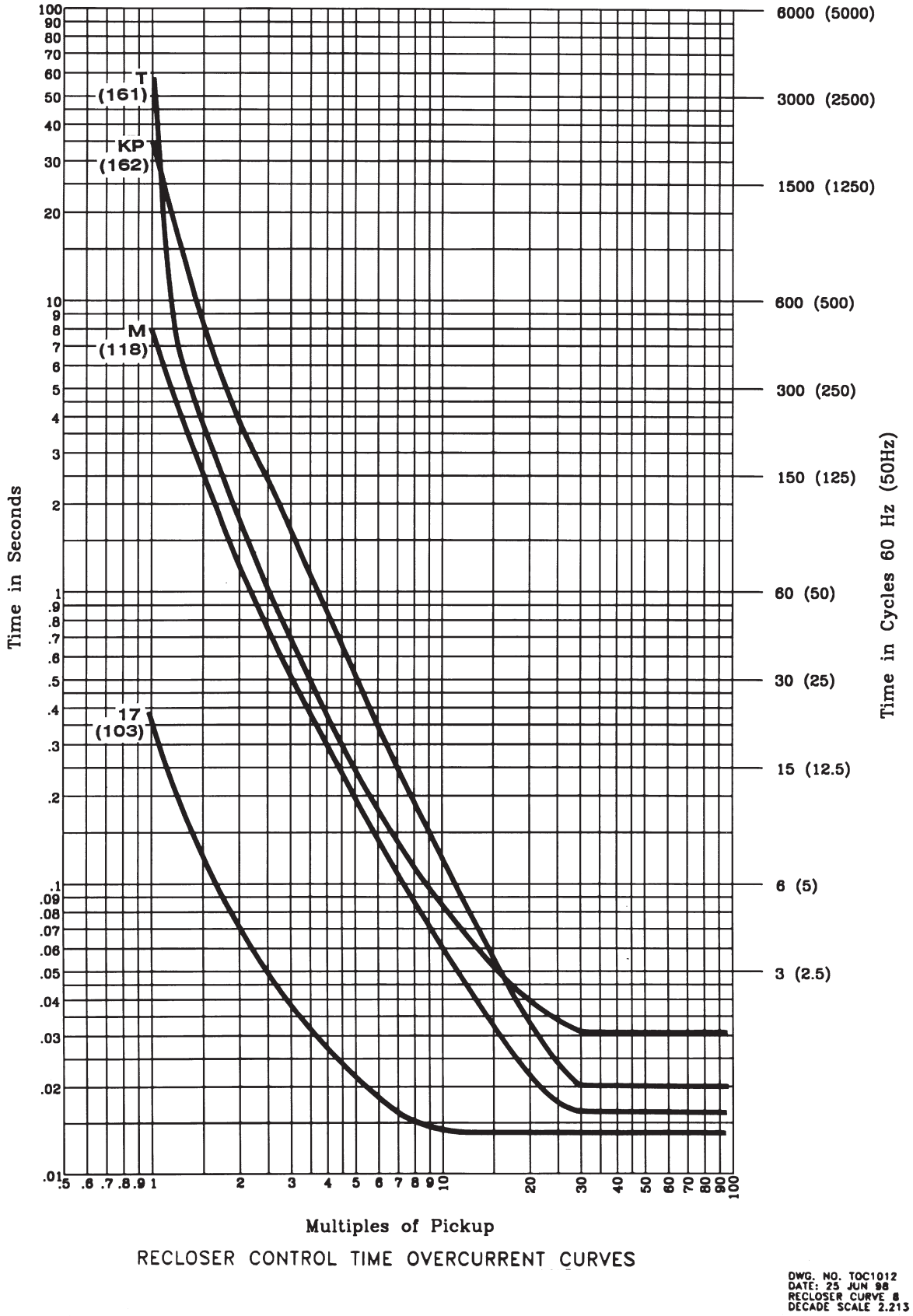


Figure 9.18 Recloser Control Response Curves KP, M, T, and 17

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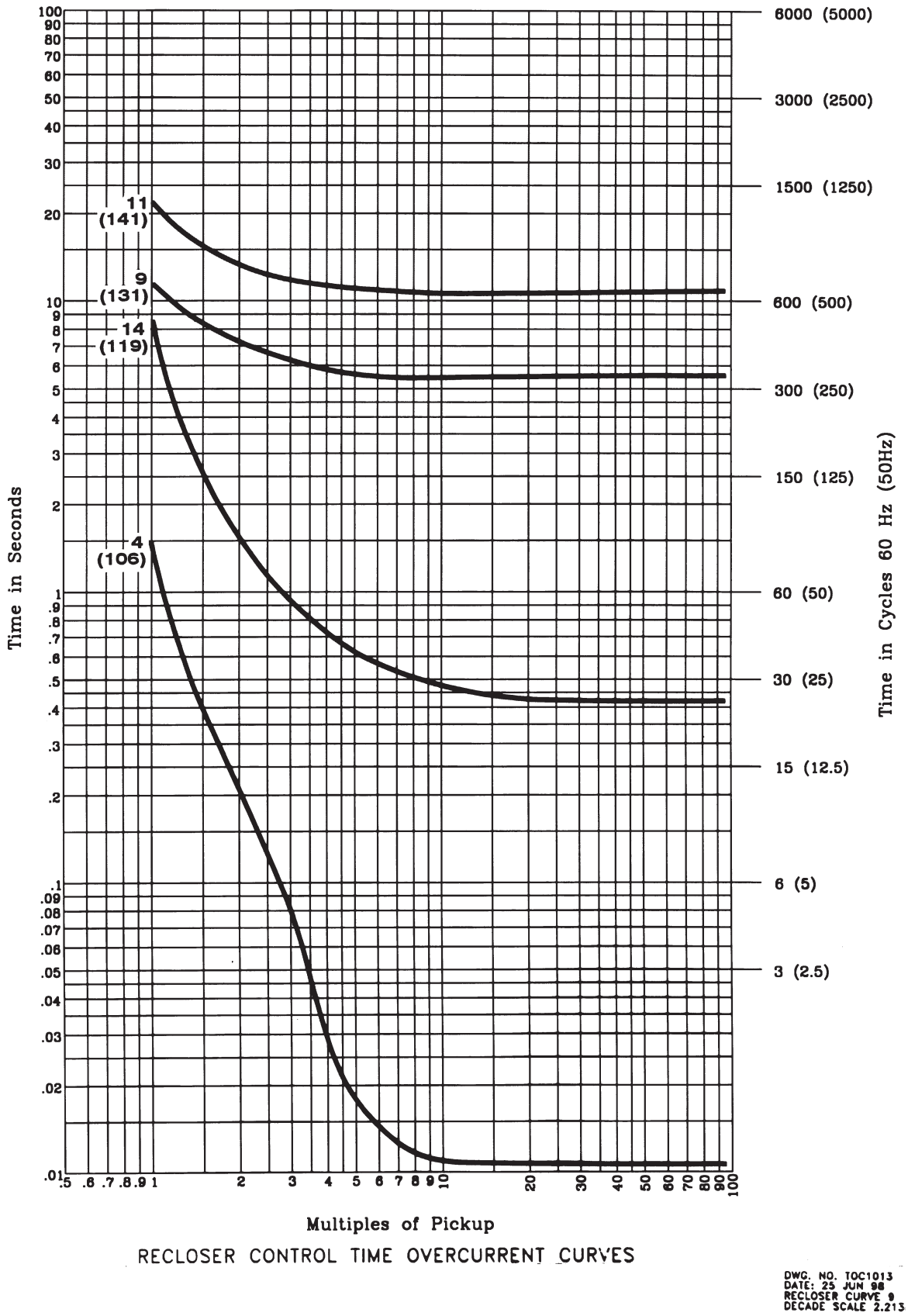


Figure 9.19 Recloser Control Response Curves 4, 9, 11, and 14

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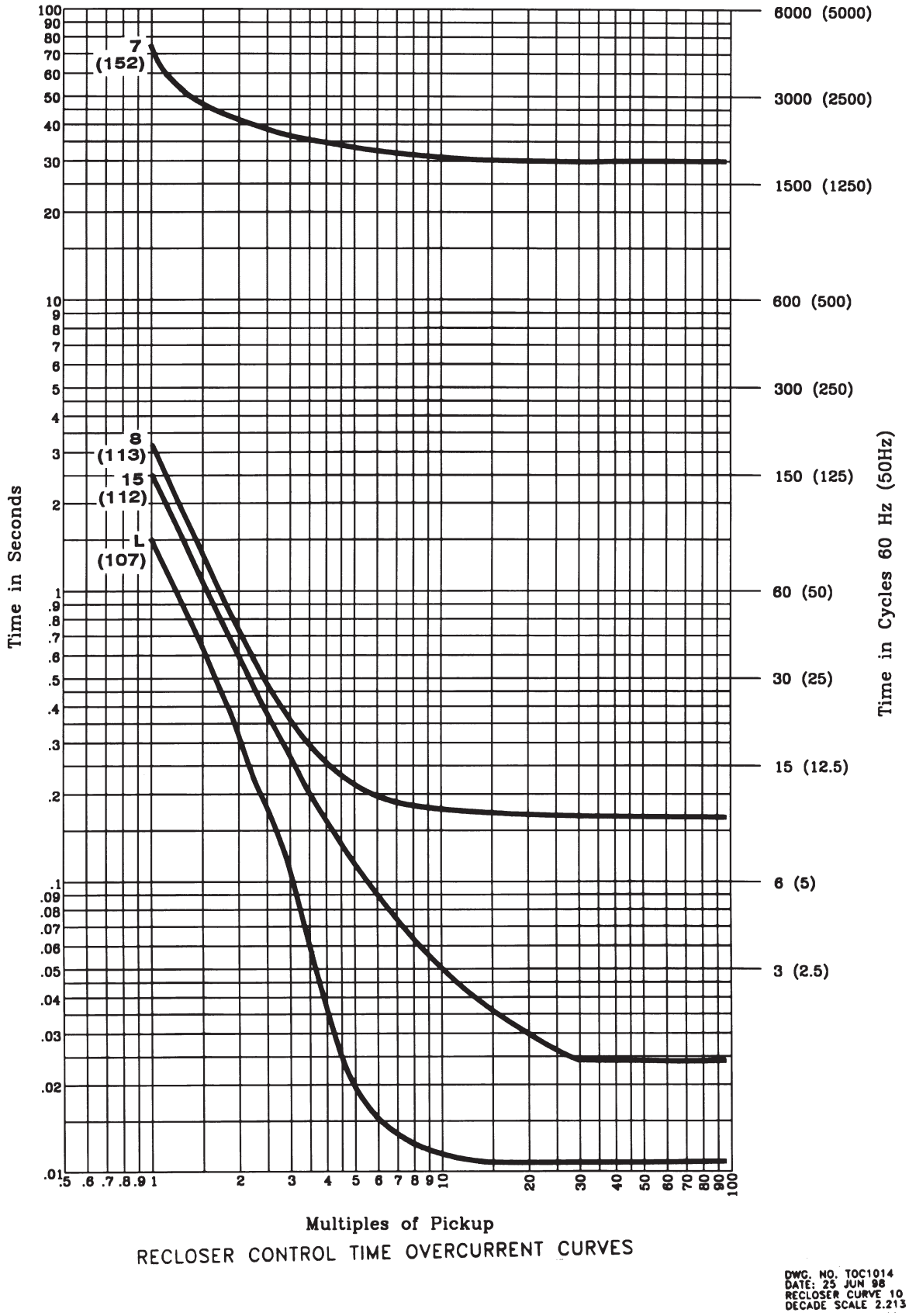


Figure 9.20 Recloser Control Response Curves L, 7, 8, and 15

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Relay Word Bits (Used in SELOGIC Control Equations)

Relay Word bits are used in SELOGIC control equation settings. Numerous SELOGIC control equation settings examples are given in *Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements* through *Section 8: Breaker Monitor, Metering, and Load Profile Functions*. SELOGIC control equation settings can also be **set directly** to 1 (logical 1) or 0 (logical 0). *Appendix G: Setting SELOGIC Control Equations* gives SELOGIC control equation details, examples, and limitations.

The Relay Word bit row numbers correspond to the row numbers used in the **TAR** command [see *TAR Command (Display Relay Element Status) on page 10.34*]. Rows 0 and 1 are reserved for the display of the two front-panel target LED rows (See *Table 10.6*).

Table 9.6 SEL-351S Relay Word Bits (Sheet 1 of 3)

Row	Relay Word Bits							
2	50A1	50B1	50C1	50A2	50B2	50C2	50A3	50B3
3	50C3	50A4	50B4	50C4	50AB1	50BC1	50CA1	50AB2
4	50BC2	50CA2	50AB3	50BC3	50CA3	50AB4	50BC4	50CA4
5	50A	50B	50C	51P1	51P1T	51P1R	51N1	51N1T
6	51N1R	51G1	51G1T	51G1R	51P2	51P2T	51P2R	51N2
7	51N2T	51N2R	51G2	51G2T	51G2R	51Q	51QT	51QR
8	50P1	50P2	50P3	50P4	50N1	50N2	50N3	50N4
9	67P1	67P2	67P3	67P4	67N1	67N2	67N3	67N4
10	67P1T	67P2T	67P3T	67P4T	67N1T	67N2T	67N3T	67N4T
11	50G1	50G2	50G3	50G4	50Q1	50Q2	50Q3	50Q4
12	67G1	67G2	67G3	67G4	67Q1	67Q2	67Q3	67Q4
13	67G1T	67G2T	67G3T	67G4T	67Q1T	67Q2T	67Q3T	67Q4T
14	50P5	50P6	50N5	50N6	50G5	50G6	50Q5	50Q6
15	50QF	50QR	50GF	50GR	32VE	32QGE	32IE	32QE
16	F32P	R32P	F32Q	R32Q	F32QG	R32QG	F32V	R32V
17	F32I	R32I	32PF	32PR	32QF	32QR	32GF	32GR
18	27A1	27B1	27C1	27A2	27B2	27C2	59A1	59B1
19	59C1	59A2	59B2	59C2	27AB	27BC	27CA	59AB
20	59BC	59CA	59N1	59N2	59Q	59V1	27S	59S1
21	59S2	59VP	59VS	SF	25A1	25A2	3P27	3P59
22	81D1	81D2	81D3	81D4	81D5	81D6	27B81	50L
23	81D1T	81D2T	81D3T	81D4T	81D5T	81D6T	VPOLV	LOP
24	SFAST	SSLOW	IN106	IN105	IN104	IN103	IN102	IN101[a]
25	LB1	LB2	LB3	LB4	LB5	LB6	LB7	LB8
26	LB9	LB10	LB11	LB12	LB13	LB14	LB15	LB16
27	RB1	RB2	RB3	RB4	RB5	RB6	RB7	RB8
28	RB9	RB10	RB11	RB12	RB13	RB14	RB15	RB16
29	LT1	LT2	LT3	LT4	LT5	LT6	LT7	LT8
30	LT9	LT10	LT11	LT12	LT13	LT14	LT15	LT16

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Table 9.6 SEL-351S Relay Word Bits (Sheet 2 of 3)

Row	Relay Word Bits							
31	SV1	SV2	SV3	SV4	SV1T	SV2T	SV3T	SV4T
32	SV5	SV6	SV7	SV8	SV5T	SV6T	SV7T	SV8T
33	SV9	SV10	SV11	SV12	SV9T	SV10T	SV11T	SV12T
34	SV13	SV14	SV15	SV16	SV13T	SV14T	SV15T	SV16T
35	79RS	79CY	79LO	SH0	SH1	SH2	SH3	SH4
36	CLOSE	CF	RCSF	OPTMN	RSTMN	FSA	FSB	FSC
37	LED9	50P32	LED10	59VA	TRGTR	52A	PB10	PB9
38	SG1	SG2	SG3	SG4	SG5	SG6	ZLOUT	ZLIN
39	ZLOAD	BCWA	BCWB	BCWC	COMMT	FAULT	SOTFT	BCW
40	ALARM	OUT107	OUT106	OUT105	OUT104	OUT103	OUT102	OUT101[b]
41	3PO	SOTFE	Z3RB	KEY	EKEY	ECTT	WFC	PT
42	PTRX2	PTRX	PTRX1	UBB1	UBB2	UBB	Z3XT	DSTRT
43	NSTRT	STOP	BTX	TRIP	OC	CC	DCHI	DCLO
44	67P2S	67N2S	67G2S	67Q2S	PDEM	NDEM	GDEM	QDEM
45	OUT201	OUT202	OUT203	OUT204	OUT205	OUT206	OUT207	OUT208[b,c]
46	OUT209	OUT210	OUT211	OUT212[3]	*	*	*	*
47	IN208	IN207	IN206	IN205	IN204	IN203	IN202	IN201[a,c]
48	*	*	*	*	*	*	*	*
49	PB1	PB2	PB3	PB4	PB5	PB6	PB7	PB8
50	LED1	LED2	LED3	LED4	LED5	LED6	LED7	LED8
51	LED19	LED20	LED21	LED22	LED23	LED24	LED25	LED26
52	RMB8A	RMB7A	RMB6A	RMB5A	RMB4A	RMB3A	RMB2A	RMB1A[d]
53	TMB8A	TMB7A	TMB6A	TMB5A	TMB4A	TMB3A	TMB2A	TMB1A
54	RMB8B	RMB7B	RMB6B	RMB5B	RMB4B	RMB3B	RMB2B	RMB1B
55	TMB8B	TMB7B	TMB6B	TMB5B	TMB4B	TMB3B	TMB2B	TMB1B
56	LBOKB	CBADB	RBADB	ROKB	LBOKA	CBADA	RBADA	ROKA
57	PWRA1	PWRB1	PWRC1	PWRA2	PWRB2	PWRC2	INTC	INT3P[e]
58	PWRA3	PWRB3	PWRC3	PWRA4	PWRB4	PWRC4	INTA	INTB
59	SAGA	SAGB	SAGC	SAG3P	SWA	SWB	SWC	SW3P
60	SAGAB	SAGBC	SAGCA	SWAB	SWBC	SWCA	TSOK	TIRIG
61	3PWR1	3PWR2	3PWR3	3PWR4	INTAB	INTBC	INTCA	DELTA

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Table 9.6 SEL-351S Relay Word Bits (Sheet 3 of 3)

Row	Relay Word Bits							
62	27AB2	27BC2	27CA2	59AB2	59BC2	59CA2	59Q2	3V0
63	V1GOOD	*	*	V0GAIN	INMET	ICMET	IBMET	IAMET
64	GNDSW[f]	50NF[f]	50NR[f]	32NE[f]	F32N[f]	R32N[f]	32NF	32NR
65	PMDOK	F32W[f]	R32W[f]	F32C[f]	R32C[f]	NSA[f]	NSB[f]	NSC[f]

* Not used.

[a] See Figure 7.1 for more information on the operation of optoisolated inputs IN101–IN106. See Figure 7.2 for more information on the operation of optoisolated inputs IN201–IN208.
[b] All output contacts can be "a" or "b" type contacts. See Figure 2.32 and Figure 7.27 for more information on the operation of output contacts OUT101–ALARM. See Figure 2.33, Figure 2.34, and Figure 7.28 for more information on the operation of output contacts OUT201–OUT212.
[c] OUT201–OUT212 and IN201–IN208 only available when the optional I/O board is present.
[d] MIRRORED BITS® elements only valid in Firmware Versions 6 or 7 (rows 52–56).
[e] Power Elements and Sag/Swell/Interruption elements only valid in Firmware Version 7 (rows 57–61), except for the DELTA Relay Word bit in Row 61, which is always available.
[f] Indicated Relay Word bits are only valid in Relays with 0.2 A nominal neutral channel (rows 64–65).

Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 1 of 19)

Row	Bit	Definition	Primary Application
2	50A1	Level 1 A-phase instantaneous overcurrent element (A-phase current above pickup setting 50P1P; see *Figure 3.1*)	Tripping, Control
	50B1	Level 1 B-phase instantaneous overcurrent element (B-phase current above pickup setting 50P1P; see *Figure 3.1*)	
	50C1	Level 1 C-phase instantaneous overcurrent element (C-phase current above pickup setting 50P1P; see *Figure 3.1*)	
	50A2	Level 2 A-phase instantaneous overcurrent element (A-phase current above pickup setting 50P2P; see *Figure 3.1*)	
	50B2	Level 2 B-phase instantaneous overcurrent element (B-phase current above pickup setting 50P2P; see *Figure 3.1*)	
	50C2	Level 2 C-phase instantaneous overcurrent element (C-phase current above pickup setting 50P2P; see *Figure 3.1*)	
	50A3	Level 3 A-phase instantaneous overcurrent element (A-phase current above pickup setting 50P3P; see *Figure 3.1*)	
	50B3	Level 3 B-phase instantaneous overcurrent element (B-phase current above pickup setting 50P3P; see *Figure 3.1*)	
3	50C3	Level 3 C-phase instantaneous overcurrent element (C-phase current above pickup setting 50P3P; see *Figure 3.1*)	
	50A4	Level 4 A-phase instantaneous overcurrent element (A-phase current above pickup setting 50P4P; see *Figure 3.1*)	
	50B4	Level 4 B-phase instantaneous overcurrent element (B-phase current above pickup setting 50P4P; see *Figure 3.1*)	
	50C4	Level 4 C-phase instantaneous overcurrent element (C-phase current above pickup setting 50P4P; see *Figure 3.1*)	
	50AB1	Level 1 AB-phase-to-phase instantaneous overcurrent element (AB-phase-to-phase current above pickup setting 50PP1P; see *Figure 3.7*)	
	50BC1	Level 1 BC-phase-to-phase instantaneous overcurrent element (BC-phase-to-phase current above pickup setting 50PP1P; see *Figure 3.7*)	
	50CA1	Level 1 CA-phase-to-phase instantaneous overcurrent element (CA-phase-to-phase current above pickup setting 50PP1P; see *Figure 3.7*)	
	50AB2	Level 2 AB-phase-to-phase instantaneous overcurrent element (AB-phase-to-phase current above pickup setting 50PP2P; see *Figure 3.7*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 2 of 19)

Row	Bit	Definition	Primary Application
4	50BC2	Level 2 BC-phase-to-phase instantaneous overcurrent element (BC-phase-to-phase current above pickup setting 50PP2P; see *Figure 3.7*)	
	50CA2	Level 2 CA-phase-to-phase instantaneous overcurrent element (CA-phase-to-phase current above pickup setting 50PP2P; see *Figure 3.7*)	
	50AB3	Level 3 AB-phase-to-phase instantaneous overcurrent element (AB-phase-to-phase current above pickup setting 50PP3P; see *Figure 3.7*)	
	50BC3	Level 3 BC-phase-to-phase instantaneous overcurrent element (BC-phase-to-phase current above pickup setting 50PP3P; see *Figure 3.7*)	
	50CA3	Level 3 CA-phase-to-phase instantaneous overcurrent element (CA-phase-to-phase current above pickup setting 50PP3P; see *Figure 3.7*)	
	50AB4	Level 4 AB-phase-to-phase instantaneous overcurrent element (AB-phase-to-phase current above pickup setting 50PP4P; see *Figure 3.7*)	
	50BC4	Level 4 BC-phase-to-phase instantaneous overcurrent element (BC-phase-to-phase current above pickup setting 50PP4P; see *Figure 3.7*)	
	50CA4	Level 4 CA-phase-to-phase instantaneous overcurrent element (CA-phase-to-phase current above pickup setting 50PP4P; see *Figure 3.7*)	
5	50A	= 50A1 + 50A2 + 50A3 + 50A4 (see *Figure 3.4*)	
	50B	= 50B1 + 50B2 + 50B3 + 50B4 (see *Figure 3.4*)	
	50C	= 50C1 + 50C2 + 50C3 + 50C4 (see *Figure 3.4*)	
	51P1	Maximum phase current above pickup setting 51P1P for phase time-overcurrent element 51P1T (see *Figure 3.14*)	Testing, Control
	51P1T	Phase time-overcurrent element 51P1T timed out (see *Figure 3.14*)	Tripping
	51P1R	Phase time-overcurrent element 51P1T reset (see *Figure 3.14*)	Testing
	51N1	Neutral ground current (channel IN) above pickup setting 51N1P for neutral ground time-overcurrent element 51N1T (see *Figure 3.16*)	Testing, Control
	51N1T	Neutral ground time-overcurrent element 51N1T timed out (see *Figure 3.16*)	Tripping
6	51N1R	Neutral ground time-overcurrent element 51N1T reset (see *Figure 3.16*)	Testing
	51G1	Residual ground current above pickup setting 51G1P for residual ground time-overcurrent element 51G1T (see *Figure 3.18*)	Testing, Control
	51G1T	Residual ground time-overcurrent element 51G1T timed out (see *Figure 3.18*)	Tripping
	51G1R	Residual ground time-overcurrent element 51G1T reset (see *Figure 3.18*)	Testing
	51P2	Maximum phase current above pickup setting 51P2P for phase time-overcurrent element 51P2T (see *Figure 3.15*)	Testing, Control
	51P2T	Phase time-overcurrent element 51P2T timed out (see *Figure 3.15*)	Tripping
	51P2R	Phase time-overcurrent element 51P2T reset (see *Figure 3.15*)	Testing
	51N2	Neutral ground current (channel IN) above pickup setting 51N2P for neutral ground time-overcurrent element 51N2T (see *Figure 3.17*)	Testing, Control

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 3 of 19)

Row	Bit	Definition	Primary Application
7	51N2T	Neutral ground time-overcurrent element 51N2T timed out (see *Figure 3.17*)	Tripping
	51N2R	Neutral ground time-overcurrent element 51N2T reset (see *Figure 3.17*)	Testing
	51G2	Residual ground current above pickup setting 51G2P for residual ground time-overcurrent element 51G2T (see *Figure 3.19*)	Testing, Control
	51G2T	Residual ground time-overcurrent element 51G2T timed out (see *Figure 3.19*)	Tripping
	51G2R	Residual ground time-overcurrent element 51G2T reset (see *Figure 3.19*)	Testing
	51Q[a]	Negative-sequence current above pickup setting 51QP for negative-sequence time-overcurrent element 51QT (see *Figure 3.20*)	Testing, Control
	51QT[a]	Negative-sequence time-overcurrent element 51QT timed out (see *Figure 3.20*)	Tripping
	51QR	Negative-sequence time-overcurrent element 51QT reset (see *Figure 3.20*)	Testing
8	50P1	Level 1 phase instantaneous overcurrent element (= 50A1 + 50B1 + 50C1; see *Figure 3.1*)	Tripping, Testing, Control
	50P2	Level 2 phase instantaneous overcurrent element (= 50A2 + 50B2 + 50C2; see *Figure 3.1*)	
	50P3	Level 3 phase instantaneous overcurrent element (= 50A3 + 50B3 + 50C3; see *Figure 3.1*)	
	50P4	Level 4 phase instantaneous overcurrent element (= 50A4 + 50B4 + 50C4; see *Figure 3.1*)	
	50N1	Level 1 neutral ground instantaneous overcurrent element [neutral ground current (channel IN) above pickup setting 50N1P; see *Figure 3.8*]	
	50N2	Level 2 neutral ground instantaneous overcurrent element [neutral ground current (channel IN) above pickup setting 50N2P; see *Figure 3.8*]	
	50N3	Level 3 neutral ground instantaneous overcurrent element [neutral ground current (channel IN) above pickup setting 50N3P; see *Figure 3.8*]	
	50N4	Level 4 neutral ground instantaneous overcurrent element [neutral ground current (channel IN) above pickup setting 50N4P; see *Figure 3.8*]	
9	67P1	Level 1 phase instantaneous overcurrent element (derived from 50P1; see *Figure 3.3*)	
	67P2	Level 2 phase instantaneous overcurrent element (derived from 50P2; see *Figure 3.3*)	
	67P3	Level 3 phase instantaneous overcurrent element (derived from 50P3; see *Figure 3.3*)	
	67P4	Level 4 phase instantaneous overcurrent element (derived from 50P4; see *Figure 3.3*)	
	67N1	Level 1 neutral ground instantaneous overcurrent element (derived from 50N1; see *Figure 3.8*)	
	67N2	Level 2 neutral ground instantaneous overcurrent element (derived from 50N2; see *Figure 3.8*)	
	67N3	Level 3 neutral ground instantaneous overcurrent element (derived from 50N3; see *Figure 3.8*)	
	67N4	Level 4 neutral ground instantaneous overcurrent element (derived from 50N4; see *Figure 3.8*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 4 of 19)

Row	Bit	Definition	Primary Application
10	67P1T	Level 1 phase definite-time overcurrent element 67P1T timed out (derived from 67P1; see *Figure 3.3*)	Tripping
	67P2T	Level 2 phase definite-time overcurrent element 67P2T timed out (derived from 67P2; see *Figure 3.3*)	
	67P3T	Level 3 phase definite-time overcurrent element 67P3T timed out (derived from 67P3; see *Figure 3.3*)	
	67P4T	Level 4 phase definite-time overcurrent element 67P4T timed out (derived from 67P4; see *Figure 3.3*	
	67N1T	Level 1 neutral ground definite-time overcurrent element 67NIT timed out (derived from 67N1; see *Figure 3.8*)	
	67N2T	Level 2 neutral ground definite-time overcurrent element 67N2T timed out (derived from 67N2; see *Figure 3.8*)	
	67N3T	Level 3 neutral ground definite-time overcurrent element 67N3T timed out (derived from 67N3; see *Figure 3.8*)	
	67N4T	Level 4 neutral ground definite-time overcurrent element 67N4T timed out (derived from 67N4; see *Figure 3.8*)	
11	50G1	Level 1 residual ground instantaneous overcurrent element (residual ground current above pickup setting 50G1P; see *Figure 3.10*)	Tripping, Testing, Control
	50G2	Level 2 residual ground instantaneous overcurrent element (residual ground current above pickup setting 50G2P; see *Figure 3.10*)	
	50G3	Level 3 residual ground instantaneous overcurrent element (residual ground current above pickup setting 50G3P; see *Figure 3.10*)	
	50G4	Level 4 residual ground instantaneous overcurrent element (residual ground current above pickup setting 50G4P; see *Figure 3.10*)	
	50Q1[a]	Level 1 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q1P; see *Figure 3.12*)	Testing, Control
	50Q2[a]	Level 2 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q2P; see *Figure 3.12*)	
	50Q3[a]	Level 3 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q3P; see *Figure 3.12*)	
	50Q4[a]	Level 4 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q4P; see *Figure 3.12*)	
12	67G1	Level 1 residual ground instantaneous overcurrent element (derived from 50G1; see *Figure 3.10*)	Tripping, Testing, Control
	67G2	Level 2 residual ground instantaneous overcurrent element (derived from 50G2; see *Figure 3.10*)	
	67G3	Level 3 residual ground instantaneous overcurrent element (derived from 50G3; see *Figure 3.10*)	
	67G4	Level 4 residual ground instantaneous overcurrent element (derived from 50G4; see *Figure 3.10*)	
	67Q1[a]	Level 1 negative-sequence instantaneous overcurrent element (derived from 50Q1; see *Figure 3.12*)	Testing, Control
	67Q2[a]	Level 2 negative-sequence instantaneous overcurrent element (derived from 50Q2; see *Figure 3.12*)	
	67Q3[a]	Level 3 negative-sequence instantaneous overcurrent element (derived from 50Q3; see *Figure 3.12*)	
	67Q4[a]	Level 4 negative-sequence instantaneous overcurrent element (derived from 50Q4; see *Figure 3.12*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 5 of 19)

Row	Bit	Definition	Primary Application
13	67G1T	Level 1 residual ground definite-time overcurrent element 67G1T timed out (derived from 67G1; see *Figure 3.10*)	Tripping
	67G2T	Level 2 residual ground definite-time overcurrent element 67G2T timed out (derived from 67G2; see *Figure 3.10*)	
	67G3T	Level 3 residual ground definite-time overcurrent element 67G3T timed out (derived from 67G3; see *Figure 3.10*)	
	67G4T	Level 4 residual ground definite-time overcurrent element 67G4T timed out (derived from 67G4; see *Figure 3.10*)	
	67Q1T[a]	Level 1 negative-sequence definite-time overcurrent element 67Q1T timed out (derived from 67Q1; see *Figure 3.12*)	
	67Q2T[a]	Level 2 negative-sequence definite-time overcurrent element 67Q2T timed out (derived from 67Q2; see *Figure 3.12*)	
	67Q3T[a]	Level 3 negative-sequence definite-time overcurrent element 67Q3T timed out (derived from 67Q3; see *Figure 3.12*)	
	67Q4T[a]	Level 4 negative-sequence definite-time overcurrent element 67Q4T timed out (derived from 67Q4; see *Figure 3.12*)	
14	50P5	Level 5 phase instantaneous overcurrent element (maximum phase current above pickup setting 50P5P; see *Figure 3.2*)	Tripping, Control
	50P6	Level 6 phase instantaneous overcurrent element (maximum phase current above pickup setting 50P6P; see *Figure 3.2*)	
	50N5	Level 5 neutral ground instantaneous overcurrent element [neutral ground current (channel IN) above pickup setting 50N5P; see *Figure 3.9*]	
	50N6	Level 6 neutral ground instantaneous overcurrent element [neutral ground current (channel IN) above pickup setting 50N6P; see *Figure 3.9*]	
	50G5	Level 5 residual ground instantaneous overcurrent element (residual ground current above pickup setting 50G5P; see *Figure 3.11*)	
	50G6	Level 6 residual ground instantaneous overcurrent element (residual ground current above pickup setting 50G6P; see *Figure 3.11*)	
	50Q5[a]	Level 5 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q5P; see *Figure 3.13*)	Control
	50Q6[a]	Level 6 negative-sequence instantaneous overcurrent element (negative-sequence current above pickup setting 50Q6P; see *Figure 3.13*)	
15	50QF	Forward direction negative-sequence overcurrent threshold exceeded (see *Figure 4.4*, *Figure 4.6*, and *Figure 4.19*)	Testing
	50QR	Reverse direction negative-sequence overcurrent threshold exceeded (see *Figure 4.4*, *Figure 4.6*, and *Figure 4.19*)	
	50GF	Forward direction residual ground overcurrent threshold exceeded (see *Figure 4.4* and *Figure 4.7*)	
	50GR	Reverse direction residual ground overcurrent threshold exceeded (see *Figure 4.4* and *Figure 4.7*)	
	32VE	Internal enable for zero-sequence voltage-polarized directional element (see *Figure 4.4* and *Figure 4.7*)	
	32QGE	Internal enable for negative-sequence voltage-polarized directional element (for ground; see *Figure 4.4* and *Figure 4.6*)	
	32IE	Internal enable for channel IN current-polarized directional element (see *Figure 4.4* and *Figure 4.7*)	
	32QE	Internal enable for negative-sequence voltage-polarized directional element (see *Figure 4.4*, and *Figure 4.19*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 6 of 19)

Row	Bit	Definition	Primary Application
16	F32P	Forward positive-sequence voltage-polarized directional element (see *Figure 4.19* and *Figure 4.21*)	Testing, Special directional control schemes
	R32P	Reverse positive-sequence voltage-polarized directional element (see *Figure 4.19* and *Figure 4.21*)	
	F32Q	Forward negative-sequence voltage-polarized directional element (see *Figure 4.19* and *Figure 4.20*)	
	R32Q	Reverse negative-sequence voltage-polarized directional element (see *Figure 4.19* and *Figure 4.20*)	
	F32QG	Forward negative-sequence voltage-polarized directional element (for ground; see *Figure 4.4* and *Figure 4.9*)	
	R32QG	Reverse negative-sequence voltage-polarized directional element (for ground; see *Figure 4.4* and *Figure 4.9*)	
	F32V	Forward zero-sequence voltage-polarized directional element (see *Figure 4.4* and *Figure 4.10*)	
	R32V	Reverse zero-sequence voltage-polarized directional element (see *Figure 4.4* and *Figure 4.10*)	
17	F32I	Forward channel IN current-polarized directional element (see *Figure 4.4* and *Figure 4.11*)	
	R32I	Reverse channel IN current-polarized directional element (see *Figure 4.4* and *Figure 4.11*)	
	32PF	Forward directional control routed to phase overcurrent elements (see *Figure 4.19* and *Figure 4.22*)	
	32PR	Reverse directional control routed to phase overcurrent elements (see *Figure 4.19* and *Figure 4.22*)	
	32QF	Forward directional control routed to negative-sequence overcurrent elements (see *Figure 4.19* and *Figure 4.22*)	
	32QR	Reverse directional control routed to negative-sequence overcurrent elements (see *Figure 4.19* and *Figure 4.22*)	
	32GF	Forward directional control routed to residual ground overcurrent elements (see *Figure 4.4* and *Figure 4.15*)	
	32GR	Reverse directional control routed to residual ground overcurrent elements (see *Figure 4.4* and *Figure 4.15*)	
18	27A1	A-phase instantaneous undervoltage element (A-phase voltage below pickup setting 27P1P; see *Figure 3.21*)	Control
	27B1	B-phase instantaneous undervoltage element (B-phase voltage below pickup setting 27P1P; see *Figure 3.21*)	
	27C1	C-phase instantaneous undervoltage element (C-phase voltage below pickup setting 27P1P; see *Figure 3.21*)	
	27A2	A-phase instantaneous undervoltage element (A-phase voltage below pickup setting 27P2P; see *Figure 3.21*)	
	27B2	B-phase instantaneous undervoltage element (B-phase voltage below pickup setting 27P2P; see *Figure 3.21*)	
	27C2	C-phase instantaneous undervoltage element (C-phase voltage below pickup setting 27P2P; see *Figure 3.21*)	
	59A1	A-phase instantaneous overvoltage element (A-phase voltage above pickup setting 59P1P; see *Figure 3.21*)	
	59B1	B-phase instantaneous overvoltage element (B-phase voltage above pickup setting 59P1P; see *Figure 3.21*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 7 of 19)

Row	Bit	Definition	Primary Application
19	59C1	C-phase instantaneous overvoltage element (C-phase voltage above pickup setting 59P1P; see *Figure 3.21*)	
	59A2	A-phase instantaneous overvoltage element (A-phase voltage above pickup setting 59P2P; see *Figure 3.21*)	
	59B2	B-phase instantaneous overvoltage element (B-phase voltage above pickup setting 59P2P; see *Figure 3.21*)	
	59C2	C-phase instantaneous overvoltage element (C-phase voltage above pickup setting 59P2P; see *Figure 3.21*)	
	27AB	AB-phase-to-phase instantaneous undervoltage element (AB-phase-to-phase voltage below pickup setting 27PP; see *Figure 3.22* and *Figure 3.23*)	
	27BC	BC-phase-to-phase instantaneous undervoltage element (BC-phase-to-phase voltage below pickup setting 27PP; see *Figure 3.22* and *Figure 3.23*)	
	27CA	CA-phase-to-phase instantaneous undervoltage element (CA-phase-to-phase voltage below pickup setting 27PP; see *Figure 3.22* and *Figure 3.23*)	
	59AB	AB-phase-to-phase instantaneous overvoltage element (AB-phase-to-phase voltage above pickup setting 59PP; see *Figure 3.22* and *Figure 3.23*)	
20	59BC	BC-phase-to-phase instantaneous overvoltage element (BC-phase-to-phase voltage above pickup setting 59PP; see *Figure 3.22* and *Figure 3.23*)	
	59CA	CA-phase-to-phase instantaneous overvoltage element (CA-phase-to-phase voltage above pickup setting 59PP; see *Figure 3.22* and *Figure 3.23*)	
	59N1	Zero-sequence instantaneous overvoltage element (zero-sequence voltage above pickup setting 59N1P; see *Figure 3.22*)	
	59N2	Zero-sequence instantaneous overvoltage element (zero-sequence voltage above pickup setting 59N2P; see *Figure 3.22*)	
	59Q	Negative-sequence instantaneous overvoltage element (negative-sequence voltage above pickup setting 59QP; see *Figure 3.22* and *Figure 3.24*)	
	59V1	Positive-sequence instantaneous overvoltage element (positive-sequence voltage above pickup setting 59V1P; see *Figure 3.22* and *Figure 3.24*)	
	27S	Channel **VS** instantaneous undervoltage element (channel **VS** voltage below pickup setting 27SP; see *Figure 3.25*)	
	59S1	Channel **VS** instantaneous overvoltage element (channel **VS** voltage above pickup setting 59S1P; see *Figure 3.25*)	
21	59S2	Channel **VS** instantaneous overvoltage element (channel **VS** voltage above pickup setting 59S2P; see *Figure 3.25*)	
	59VP	Phase voltage window element (selected phase voltage [VP] between threshold settings 25VLO and 25VHI; see *Figure 3.26*)	Testing
	59VS	Channel **VS** voltage window element (channel **VS** voltage between threshold settings 25VLO and 25VHI; see *Figure 3.26*)	
	SF	Slip frequency is between voltages VP and VS, and less than setting 25SF (see *Figure 3.26*)	
	25A1	Synchronism check element (see *Figure 3.27*)	Control
	25A2	Synchronism check element (see *Figure 3.27*)	
	3P27	= 27A1 * 27B1 * 27C1 (see *Figure 3.21* and *Figure 3.23*)	
	3P59	= 59A1 * 59B1 * 59C1 (see *Figure 3.21* and *Figure 3.23*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 8 of 19)

Row	Bit	Definition	Primary Application
22	81D1	Level 1 instantaneous frequency element (with corresponding pickup setting 81D1P; see *Figure 3.31*)	Testing
	81D2	Level 2 instantaneous frequency element (with corresponding pickup setting 81D2P; see *Figure 3.31*)	
	81D3	Level 3 instantaneous frequency element (with corresponding pickup setting 81D3P; see *Figure 3.31*)	
	81D4	Level 4 instantaneous frequency element (with corresponding pickup setting 81D4P; see *Figure 3.31*)	
	81D5	Level 5 instantaneous frequency element (with corresponding pickup setting 81D5P; see *Figure 3.31*)	
	81D6	Level 6 instantaneous frequency element (with corresponding pickup setting 81D6P; see *Figure 3.31*)	
	27B81	Undervoltage element for frequency element blocking (any phase voltage below pickup setting 27B81P; see *Figure 3.29*, and *Figure 3.30*)	
	50L	Phase instantaneous overcurrent element for load detection (maximum phase current above pickup setting 50LP; see *Figure 5.3*)	
23	81D1T	Level 1 definite-time frequency element 81D1T timed out (derived from 81D1; see *Figure 3.31*)	Tripping, Control
	81D2T	Level 2 definite-time frequency element 81D2T timed out (derived from 81D2; see *Figure 3.31*)	
	81D3T	Level 3 definite-time frequency element 81D3T timed out (derived from 81D3; see *Figure 3.31*)	
	81D4T	Level 4 definite-time frequency element 81D4T timed out (derived from 81D4; see *Figure 3.31*)	
	81D5T	Level 5 definite-time frequency element 81D5T timed out (derived from 81D5; see *Figure 3.31*)	
	81D6T	Level 6 definite-time frequency element 81D6T timed out (derived from 81D6; see *Figure 3.31*)	
	VPOLV	Positive-sequence polarization voltage valid (see *Figure 4.21*)	Testing
	LOP	Loss-of-potential (see *Figure 4.1*)	Testing, Special directional control schemes
24	SFAST	$f_P > f_S$ (frequency V_P > frequency V_S; see *Figure 3.26*)	Special control schemes
	SSLOW	$f_P \leq f_S$ (frequency $V_P \leq$ frequency V_S; see *Figure 3.26*)	
	IN106	Optoisolated input **IN106** asserted (see *Figure 7.1*)	Circuit breaker status, Control via optoisolated inputs
	IN105	Optoisolated input **IN105** asserted (see *Figure 7.1*)	
	IN104	Optoisolated input **IN104** asserted (see *Figure 7.1*)	
	IN103	Optoisolated input **IN103** asserted (see *Figure 7.1*)	
	IN102	Optoisolated input **IN102** asserted (see *Figure 7.1*)	
	IN101	Optoisolated input **IN101** asserted (see *Figure 7.1*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 9 of 19)

Row	Bit	Definition	Primary Application
25	LB1	Local Bit 1 asserted (see *Figure 7.4*)	Control via front panel—replacing traditional panel-mounted control switches
	LB2	Local Bit 2 asserted (see *Figure 7.4*)	
	LB3	Local Bit 3 asserted (see *Figure 7.4*)	
	LB4	Local Bit 4 asserted (see *Figure 7.4*)	
	LB5	Local Bit 5 asserted (see *Figure 7.4*)	
	LB6	Local Bit 6 asserted (see *Figure 7.4*)	
	LB7	Local Bit 7 asserted (see *Figure 7.4*)	
	LB8	Local Bit 8 asserted (see *Figure 7.4*)	
26	LB9	Local Bit 9 asserted (see *Figure 7.4*)	Control via front panel—replacing traditional panel-mounted control switches
	LB10	Local Bit 10 asserted (see *Figure 7.4*)	
	LB11	Local Bit 11 asserted (see *Figure 7.4*)	
	LB12	Local Bit 12 asserted (see *Figure 7.4*)	
	LB13	Local Bit 13 asserted (see *Figure 7.4*)	
	LB14	Local Bit 14 asserted (see *Figure 7.4*)	
	LB15	Local Bit 15 asserted (see *Figure 7.4*)	
	LB16	Local Bit 16 asserted (see *Figure 7.4*)	
27	RB1	Remote Bit 1 asserted (see *Figure 7.10*)	Control via serial port
	RB2	Remote Bit 2 asserted (see *Figure 7.10*)	
	RB3	Remote Bit 3 asserted (see *Figure 7.10*)	
	RB4	Remote Bit 4 asserted (see *Figure 7.10*)	
	RB5	Remote Bit 5 asserted (see *Figure 7.10*)	
	RB6	Remote Bit 6 asserted (see *Figure 7.10*)	
	RB7	Remote Bit 7 asserted (see *Figure 7.10*)	
	RB8	Remote Bit 8 asserted (see *Figure 7.10*)	
28	RB9	Remote Bit 9 asserted (see *Figure 7.10*)	Control via serial port
	RB10	Remote Bit 10 asserted (see *Figure 7.10*)	
	RB11	Remote Bit 11 asserted (see *Figure 7.10*)	
	RB12	Remote Bit 12 asserted (see *Figure 7.10*)	
	RB13	Remote Bit 13 asserted (see *Figure 7.10*)	
	RB14	Remote Bit 14 asserted (see *Figure 7.10*)	
	RB15	Remote Bit 15 asserted (see *Figure 7.10*)	
	RB16	Remote Bit 16 asserted (see *Figure 7.10*)	
29	LT1	Latch Bit 1 asserted (see *Figure 7.12*)	Control—replacing traditional latching relays
	LT2	Latch Bit 2 asserted (see *Figure 7.12*)	
	LT3	Latch Bit 3 asserted (see *Figure 7.12*)	
	LT4	Latch Bit 4 asserted (see *Figure 7.12*)	
	LT5	Latch Bit 5 asserted (see *Figure 7.12*)	
	LT6	Latch Bit 6 asserted (see *Figure 7.12*)	
	LT7	Latch Bit 7 asserted (see *Figure 7.12*)	
	LT8	Latch Bit 8 asserted (see *Figure 7.12*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 10 of 19)

Row	Bit	Definition	Primary Application
30	LT9	Latch Bit 9 asserted (see *Figure 7.12*)	Control—replacing traditional latching relays
	LT10	Latch Bit 10 asserted (see *Figure 7.12*)	
	LT11	Latch Bit 11 asserted (see *Figure 7.12*)	
	LT12	Latch Bit 12 asserted (see *Figure 7.12*)	
	LT13	Latch Bit 13 asserted (see *Figure 7.12*)	
	LT14	Latch Bit 14 asserted (see *Figure 7.12*)	
	LT15	Latch Bit 15 asserted (see *Figure 7.12*)	
	LT16	Latch Bit 16 asserted (see *Figure 7.12*)	
31	SV1	SELOGIC control equation variable timer input SV1 asserted (see *Figure 7.24*)	Testing, Seal-in functions, etc. (see *Figure 7.27*)
	SV2	SELOGIC control equation variable timer input SV2 asserted (see *Figure 7.24*)	
	SV3	SELOGIC control equation variable timer input SV3 asserted (see *Figure 7.24*)	
	SV4	SELOGIC control equation variable timer input SV4 asserted (see *Figure 7.24*)	
	SV1T	SELOGIC control equation variable timer output SV1T asserted (see *Figure 7.24*)	Control
	SV2T	SELOGIC control equation variable timer output SV2T asserted (see *Figure 7.24*)	
	SV3T	SELOGIC control equation variable timer output SV3T asserted (see *Figure 7.24*)	
	SV4T	SELOGIC control equation variable timer output SV4T asserted (see *Figure 7.24*)	
32	SV5	SELOGIC control equation variable timer input SV5 asserted (see *Figure 7.24*)	Testing, Seal-in functions, etc. (see *Figure 7.27*)
	SV6	SELOGIC control equation variable timer input SV6 asserted (see *Figure 7.24*)	
	SV7	SELOGIC control equation variable timer input SV7 asserted (see *Figure 7.25*)	
	SV8	SELOGIC control equation variable timer input SV8 asserted (see *Figure 7.25*)	
	SV5T	SELOGIC control equation variable timer output SV5T asserted (see *Figure 7.24*)	Control
	SV6T	SELOGIC control equation variable timer output SV6T asserted (see *Figure 7.24*)	
	SV7T	SELOGIC control equation variable timer output SV7T asserted (see *Figure 7.25*)	
	SV8T	SELOGIC control equation variable timer output SV8T asserted (see *Figure 7.25*)	
33	SV9	SELOGIC control equation variable timer input SV9 asserted (see *Figure 7.25*)	Testing, Seal-in functions, etc. (see *Figure 7.27*)
	SV10	SELOGIC control equation variable timer input SV10 asserted (see *Figure 7.25*)	
	SV11	SELOGIC control equation variable timer input SV11 asserted (see *Figure 7.25*)	
	SV12	SELOGIC control equation variable timer input SV12 asserted (see *Figure 7.25*)	
	SV9T	SELOGIC control equation variable timer output SV9T asserted (see *Figure 7.25*)	Control
	SV10T	SELOGIC control equation variable timer output SV10T asserted (see *Figure 7.25*)	
	SV11T	SELOGIC control equation variable timer output SV11T asserted (see *Figure 7.25*)	
	SV12T	SELOGIC control equation variable timer output SV12T asserted (see *Figure 7.25*)	
34	SV13	SELOGIC control equation variable timer input SV13 asserted (see *Figure 7.25*)	Testing, Seal-in functions, etc. (see *Figure 7.27*)
	SV14	SELOGIC control equation variable timer input SV14 asserted (see *Figure 7.25*)	
	SV15	SELOGIC control equation variable timer input SV15 asserted (see *Figure 7.25*)	
	SV16	SELOGIC control equation variable timer input SV16 asserted (see *Figure 7.25*)	
	SV13T	SELOGIC control equation variable timer output SV13T asserted (see *Figure 7.25*)	Control
	SV14T	SELOGIC control equation variable timer output SV14T asserted (see *Figure 7.25*)	
	SV15T	SELOGIC control equation variable timer output SV15T asserted (see *Figure 7.25*)	
	SV16T	SELOGIC control equation variable timer output SV16T asserted (see *Figure 7.25*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 11 of 19)

Row	Bit	Definition	Primary Application
35	79RS	Reclosing relay in the Reset State (see *Figure 6.8* and *Table 6.1*)	
	79CY	Reclosing relay in the Reclose Cycle State (see *Figure 6.8* and *Table 6.1*)	
	79LO	Reclosing relay in the Lockout State (see *Figure 6.8* and *Table 6.1*)	
	SH0	Reclosing relay shot counter = 0 (see *Table 6.3*)	
	SH1	Reclosing relay shot counter = 1 (see *Table 6.3*)	
	SH2	Reclosing relay shot counter = 2 (see *Table 6.3*)	
	SH3	Reclosing relay shot counter = 3 (see *Table 6.3*)	
	SH4	Reclosing relay shot counter = 4 (see *Table 6.3*)	
36	CLOSE	Close logic output asserted (see *Figure 6.1*)	Output contact assignment
	CF	Close Failure condition (asserts for 1/4 cycle; see *Figure 6.1*)	Indication
	RCSF	Reclose supervision failure (asserts for 1/4 cycle; see *Figure 6.5*)	
	OPTMN	Open interval timer is timing (see *Reclosing Relay on page 6.14*)	Testing
	RSTMN	Reset timer is timing (see *Reclosing Relay on page 6.14*)	
	FSA	A-phase fault identification logic output used in A-phase targeting (see *Front-Panel Target LED Logic Details on page 5.33*)	Control
	FSB	B-phase fault identification logic output used in B-phase targeting (see *Front-Panel Target LED Logic Details on page 5.33*)	
	FSC	C-phase fault identification logic output used in C-phase targeting (see *Front-Panel Target LED Logic Details on page 5.33*)	
37	LED9	**BREAKER CLOSED** LED/**AUX 3** (see *Figure 11.9*)	Indication
	50P32	Three-phase overcurrent threshold exceeded (see *Figure 4.21*)	Testing
	LED10	**BREAKER OPEN** LED/**AUX 4** (see *Figure 11.9*)	Indication
	59VA	Channel **VA** voltage window element (channel **VA** voltage between threshold settings 25VLO and 25VHI; see *Figure 3.26*)	Testing
	TRGTR	Target Reset. TRGTR pulses to logical 1 for one processing interval when either the **{TARGET RESET}** pushbutton is pushed or the **TAR R** (Target Reset) serial port command is executed (see *Figure 5.1* and *Figure 5.18*)	Control
	52A	Circuit breaker status (asserts to logical 1 when circuit breaker is closed; see *Figure 6.4*)	Indication
	PB10	**{TRIP/AUX 4}** pushbutton output (see *Figure 11.9*)	Control
	PB9	**{CLOSE/AUX 3}** pushbutton output (see *Figure 11.9*)	
38	SG1	Setting Group 1 active (see *Table 7.3*)	Indication
	SG2	Setting Group 2 active (see *Table 7.3*)	
	SG3	Setting Group 3 active (see *Table 7.3*)	
	SG4	Setting Group 4 active (see *Table 7.3*)	
	SG5	Setting Group 5 active (see *Table 7.3*)	
	SG6	Setting Group 6 active (see *Table 7.3*)	
	ZLOUT	Load encroachment “load out” element (see *Figure 4.2*)	Special phase overcurrent element control
	ZLIN	Load encroachment “load in” element (see *Figure 4.2*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 12 of 19)

Row	Bit	Definition	Primary Application
39	ZLOAD	= ZLOUT + ZLIN (see *Figure 4.2*)	Special phase overcurrent element control
	BCWA	A-phase breaker contact wear has reached 100% wear level (see *Breaker Monitor on page 8.2*)	Indication
	BCWB	B-phase breaker contact wear has reached 100% wear level (see *Breaker Monitor on page 8.2*)	
	BCWC	C-phase breaker contact wear has reached 100% wear level (see *Breaker Monitor on page 8.2*)	
	COMMT	Communications-assisted trip (see *Figure 5.1*; used in *Table 5.1*)	
	FAULT	Output of SELOGIC control equation FAULT (see explanation accompanying FAULT setting in *SELOGIC Control Equation Settings (Serial Port Command SET L) on page SET.18*)	
	SOTFT	Switch-onto-fault trip (see *Figure 5.3*; used in *Table 5.1*)	
	BCW	= BCWA + BCWB + BCWC	
40	ALARM	**ALARM** output contact indicating that relay failed or **PULSE ALARM** command executed (see *Figure 7.27*)	
	OUT107	Output contact **OUT107** asserted (see *Figure 7.27*)	
	OUT106	Output contact **OUT106** asserted (see *Figure 7.27*)	
	OUT105	Output contact **OUT105** asserted (see *Figure 7.27*)	
	OUT104	Output contact **OUT104** asserted (see *Figure 7.27*)	
	OUT103	Output contact **OUT103** asserted (see *Figure 7.27*)	
	OUT102	Output contact **OUT102** asserted (see *Figure 7.27*)	
	OUT101	Output contact **OUT101** asserted (see *Figure 7.27*)	
41	3PO	Three pole open condition (see *Figure 5.3*)	Testing
	SOTFE	Switch-onto-fault condition (see *Figure 5.3*)	
	Z3RB	Zone (level) 3 reverse block (see *Figure 5.6*)	
	KEY	Key permissive trip signal start (see *Figure 5.6*)	
	EKEY	Echo key (see *Figure 5.6*)	
	ECTT	Echo conversion to trip condition (see *Figure 5.6*)	
	WFC	Weak infeed condition (see *Figure 5.6*)	
	PT	Permissive trip signal to POTT logic (see *Figure 5.5*)	
42	PTRX2	Permissive trip 2 signal from DCUB logic (see *Figure 5.10*)	
	PTRX	Permissive trip signal to Trip logic (see *Figure 5.7*)	
	PTRX1	Permissive trip 1 signal from DCUB logic (see *Figure 5.10*)	
	UBB1	Unblocking block 1 from DCUB logic (see *Figure 5.10*)	
	UBB2	Unblocking block 2 from DCUB logic (see *Figure 5.10*)	
	UBB	Unblocking block to Trip logic (see *Figure 5.11*)	
	Z3XT	Logic output from zone (level) 3 extension timer (see *Figure 5.14*)	
	DSTRT	Directional carrier start (see *Figure 5.14*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 13 of 19)

Row	Bit	Definition	Primary Application
43	NSTRT	Nondirectional carrier start (see *Figure 5.14*)	
	STOP	Carrier stop (see *Figure 5.14*)	
	BTX	Block trip input extension (see *Figure 5.14*)	
	TRIP	Trip logic output asserted (see *Figure 5.1*)	Output contact assignment
	OC	Asserts 1/4 cycle for **OPEN** Command execution	Testing
	CC	Asserts 1/4 cycle for **CLOSE** Command execution	
	DCHI	Station dc battery instantaneous overvoltage element (see *Figure 8.9*)	Indication
	DCLO	Station dc battery instantaneous undervoltage element (see *Figure 8.9*)	
44	67P2S	Level 2 directional phase definite-time (short delay) overcurrent element 67P2S timed out (derived from 67P2; see *Figure 3.3* and *Figure 5.14*)	Tripping in DCB schemes
	67N2S	Level 2 directional neutral ground definite-time (short delay) overcurrent element 67N2S timed out (derived from 67N2; see *Figure 3.8* and *Figure 5.14*)	
	67G2S	Level 2 directional residual ground definite-time (short delay) overcurrent element 67G2S timed out (derived from 67G2; see *Figure 3.10* and *Figure 5.14*)	
	67Q2S	Level 2 directional negative-sequence definite-time (short delay) overcurrent element 67Q2S timed out (derived from 67Q2; see *Figure 3.12* and *Figure 5.14*)	
	PDEM	Phase demand current above pickup setting PDEMP (see *Figure 8.13*)	Indication
	NDEM	Neutral ground demand current above pickup setting NDEMP (see *Figure 8.13*)	
	GDEM	Residual ground demand current above pickup setting GDEMP (see *Figure 8.13*)	
	QDEM	Negative-sequence demand current above pickup setting QDEMP (see *Figure 8.13*)	
45	OUT201	Output contact **OUT201** asserted (see *Figure 7.28*)	(only operable if extra I/O board installed)
	OUT202	Output contact **OUT202** asserted (see *Figure 7.28*)	
	OUT203	Output contact **OUT203** asserted (see *Figure 7.28*)	
	OUT204	Output contact **OUT204** asserted (see *Figure 7.28*)	
	OUT205	Output contact **OUT205** asserted (see *Figure 7.28*)	
	OUT206	Output contact **OUT206** asserted (see *Figure 7.28*)	
	OUT207	Output contact **OUT207** asserted (see *Figure 7.28*)	
	OUT208	Output contact **OUT208** asserted (see *Figure 7.28*)	
46	OUT209	Output contact **OUT209** asserted (see *Figure 7.28*)	
	OUT210	Output contact **OUT210** asserted (see *Figure 7.28*)	
	OUT211	Output contact **OUT211** asserted (see *Figure 7.28*)	
	OUT212	Output contact **OUT212** asserted (see *Figure 7.28*)	
	*		
	*		
	*		
	*		

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 14 of 19)

Row	Bit	Definition	Primary Application
47	IN208	Optoisolated input **IN208** asserted (see *Figure 7.2*)	Circuit breaker status, Control via optoisolated inputs (only operable if extra I/O board installed)
	IN207	Optoisolated input **IN207** asserted (see *Figure 7.2*)	
	IN206	Optoisolated input **IN206** asserted (see *Figure 7.2*)	
	IN205	Optoisolated input **IN205** asserted (see *Figure 7.2*)	
	IN204	Optoisolated input **IN204** asserted (see *Figure 7.2*)	
	IN203	Optoisolated input **IN203** asserted (see *Figure 7.2*)	
	IN202	Optoisolated input **IN202** asserted (see *Figure 7.2*)	
	IN201	Optoisolated input **IN201** asserted (see *Figure 7.2*)	
48	*		
	*		
	*		
	*		
	*		
	*		
	*		
	*		
49	PB1	**{GROUND ENABLED}** pushbutton output (see *Figure 11.8*)	Control
	PB2	**{RECLOSE ENABLED}** pushbutton output (see *Figure 11.8*)	
	PB3	**{REMOTE ENABLED}** pushbutton output (see *Figure 11.8*)	
	PB4	**{ALTERNATE SETTINGS}** pushbutton output (see *Figure 11.8*)	
	PB5	**{LOCK}** pushbutton output (see *Figure 11.8*)	
	PB6	**{HOT LINE TAG}** pushbutton output (see *Figure 11.9*)	
	PB7	**{AUX 1}** pushbutton output (see *Figure 11.9*)	
	PB8	**{AUX 2}** pushbutton output (see *Figure 11.9*)	
50	LED1	**GROUND ENABLED** LED (see *Figure 11.8*)	Indication
	LED2	**RECLOSE ENABLED** LED (see *Figure 11.8*)	
	LED3	**REMOTE ENABLED** LED (see *Figure 11.8*)	
	LED4	**ALTERNATE SETTINGS** LED (see *Figure 11.8*)	
	LED5	**LOCK** LED (see *Figure 11.8*)	
	LED6	**HOT LINE TAG** LED (see *Figure 11.9*)	
	LED7	**AUX 1** LED (see *Figure 11.9*)	
	LED8	**AUX 2** LED (see *Figure 11.9*)	
51[b]	LED19	**RESET** state LED	
	LED20	Reclose **CYCLE** state LED	
	LED21	**LOCKOUT** state LED	
	LED22	**A**-phase fault-type LED	
	LED23	**B**-phase fault-type LED	
	LED24	**C**-phase fault-type LED	
	LED25	**GROUND** involvement fault-type LED	
	LED26	Sensitive earth fault overcurrent element trip LED[b] See **Note** at the end of this table.	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 15 of 19)

Row	Bit	Definition	Primary Application
52	RMB8A	Channel A, received bit 8 (see *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*)	(only operable in Firmware Versions 6, 7)
	RMB7A	Channel A, received bit 7	
	RMB6A	Channel A, received bit 6	
	RMB5A	Channel A, received bit 5	
	RMB4A	Channel A, received bit 4	
	RMB3A	Channel A, received bit 3	
	RMB2A	Channel A, received bit 2	
	RMB1A	Channel A, received bit 1	
53	TMB8A	Channel A, transmit bit 8 (see *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*)	
	TMB7A	Channel A, transmit bit 7	
	TMB6A	Channel A, transmit bit 6	
	TMB5A	Channel A, transmit bit 5	
	TMB4A	Channel A, transmit bit 4	
	TMB3A	Channel A, transmit bit 3	
	TMB2A	Channel A, transmit bit 2	
	TMB1A	Channel A, transmit bit 1	
54	RMB8B	Channel B, received bit 8 (see *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*)	
	RMB7B	Channel B, received bit 7	
	RMB6B	Channel B, received bit 6	
	RMB5B	Channel B, received bit 5	
	RMB4B	Channel B, received bit 4	
	RMB3B	Channel B, received bit 3	
	RMB2B	Channel B, received bit 2	
	RMB1B	Channel B, received bit 1	
55	TMB8B	Channel B, transmit bit 8 (see *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*)	
	TMB7B	Channel B, transmit bit 7	
	TMB6B	Channel B, transmit bit 6	
	TMB5B	Channel B, transmit bit 5	
	TMB4B	Channel B, transmit bit 4	
	TMB3B	Channel B, transmit bit 3	
	TMB2B	Channel B, transmit bit 2	
	TMB1B	Channel B, transmit bit 1	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 16 of 19)

Row	Bit	Definition	Primary Application
56	LBOKB	Channel B, looped back ok (see *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*)	
	CBADB	Channel B, channel unavailability over threshold	
	RBADB	Channel B, outage duration over threshold	
	ROKB	Channel B, received data ok	
	LBOKA	Channel A, looped back ok	
	CBADA	Channel A, channel unavailability over threshold	
	RBADA	Channel A, outage duration over threshold	
	ROKA	Channel A, received data ok	
57	PWRA1	Level 1 A-phase power element (see *Figure 3.36*)	Tripping, Control (only operable in Firmware Version 7)
	PWRB1	Level 1 B-phase power element	
	PWRC1	Level 1 C-phase power element	
	PWRA2	Level 2 A-phase power element	
	PWRB2	Level 2 B-phase power element	
	PWRC2	Level 2 C-phase power element	
	INTC	C-phase interruption element (see *Figure 3.34*)	Sag/Swell/Int reporting (only operable in Firmware Version 7)
	INT3P	3-phase interruption element	
58	PWRA3	Level 3 A-phase power element (see *Figure 3.36*)	Tripping, Control (only operable in Firmware Version 7)
	PWRB3	Level 3 B-phase power element	
	PWRC3	Level 3 C-phase power element	
	PWRA4	Level 4 A-phase power element	
	PWRB4	Level 4 B-phase power element	
	PWRC4	Level 4 C-phase power element	
	INTA	A-phase voltage interruption element	Sag/Swell/Int reporting (only operable in Firmware Version 7)
	INTB	B-phase voltage interruption element	
59	SAGA	A-phase voltage sag element (see *Figure 3.32*)	
	SAGB	B-phase voltage sag element	
	SAGC	C-phase voltage sag element	
	SAG3P	3-phase voltage sag element	
	SWA	A-phase voltage swell element (see *Figure 3.33*)	
	SWB	B-phase voltage swell element	
	SWC	C-phase voltage swell element	
	SW3P	3-phase voltage swell element	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 17 of 19)

Row	Bit	Definition	Primary Application
60	SAGAB	Phase-to-phase AB voltage sag element (see *Figure 3.32*)	Sag/Swell/Int reporting (only operable in Firmware Version 7)
	SAGBC	Phase-to-phase BC voltage sag element	
	SAGCA	Phase-to-phase CA voltage sag element	
	SWAB	Phase-to-phase AB voltage swell element (see *Figure 3.33*)	
	SWBC	Phase-to-phase BC voltage swell element	
	SWCA	Phase-to-phase CA voltage swell element	
	TSOK	Time synchronization OK (see *Synchrophasor Relay Word Bits on page L.11*)	Synchrophasors
	TIRIG	Relay Time is based on IRIG-B time source (see *Synchrophasor Relay Word Bits on page L.11*)	
61	3PWR1	Level 1 three-phase power element (see *Figure 3.37*)	Tripping, Control (only operable in Firmware Version 7)
	3PWR2	Level 2 three-phase power element	
	3PWR3	Level 3 three-phase power element	
	3PWR4	Level 4 three-phase power element	
	INTAB	Phase-to-phase AB voltage interruption element (see *Figure 3.34*)	Sag/ Swell/Int Reporting (only operable in Firmware Version 7)
	INTBC	Phase-to-phase BC voltage interruption element	
	INTCA	Phase-to-phase CA voltage interruption element	
	DELTA	Delta configuration element (asserts when global setting PTCONN = DELTA; see *Figure 9.21*)	Indication
62	27AB2	AB-phase-to-phase instantaneous undervoltage element (AB-phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.23*)	Control
	27BC2	BC-phase-to-phase instantaneous undervoltage element (BC-phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.23*)	
	27CA2	CA-phase-to-phase instantaneous undervoltage element (CA-phase-to-phase voltage below pickup setting 27PP2P; see *Figure 3.23*)	
	59AB2	AB-phase-to-phase instantaneous overvoltage element (AB-phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.23*)	
	59BC2	BC-phase-to-phase instantaneous overvoltage element (BC-phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.23*)	
	59CA2	CA-phase-to-phase instantaneous overvoltage element (CA-phase-to-phase voltage above pickup setting 59PP2P; see *Figure 3.23*)	
	59Q2	Negative-sequence instantaneous overvoltage element (negative-sequence voltage above pickup setting 59Q2P; see *Figure 3.24*)	
	3V0	3V0 configuration element (asserts when global setting VSCONN = 3V0; see *Figure 9.21*)	Indication

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 18 of 19)

Row	Bit	Definition	Primary Application
63	V1GOOD	Positive-sequence overvoltage element (positive-sequence voltage greater than setting VNOM • 0.75 (wye-connected) or VNOM • 0.43 (delta-connected); see *Figure 4.1*)	Testing
	*		
	*		
	V0GAIN	V0 based on gained data	
	INMET	Channel IN high-gain mode active (asserts at threshold just below current channel nominal rating)	Event Report
	ICMET	Channel IC high-gain mode active (asserts at threshold just below current channel nominal rating)	
	IBMET	Channel IB high-gain mode active (asserts at threshold just below current channel nominal rating)	
	IAMET	Channel IA high-gain mode active (asserts at threshold just below current channel nominal rating)	
64	GNDSW	Directional element for low-impedance grounded or ungrounded/high-impedance grounded systems is operating on neutral channel (IN) current I_N; if GNDSW = logical 0, then directional element is running off of residual ground current I_G instead (see internal enables discussion, following *Table 4.4*)	Testing
	50NF	Forward direction neutral ground overcurrent threshold exceeded (see *Figure 4.8*)	
	50NR	Reverse direction neutral ground overcurrent threshold exceeded (see *Figure 4.8*)	
	32NE	Internal enable for directional elements for low-impedance grounded, Petersen Coil grounded, or ungrounded/high-impedance grounded systems (see *Figure 4.8*)	
	F32N	Forward directional element for low-impedance grounded, Petersen Coil grounded (wattmetric element only—see F32W), or ungrounded/high-impedance grounded systems (depending on ORDER setting—see *Table 4.3*)	Testing, Special directional control schemes
	R32N	Reverse directional element for low-impedance grounded, Petersen Coil grounded (wattmetric element only—see R32W), or ungrounded/high-impedance grounded systems (depending on ORDER setting—see *Table 4.3*)	
	32NF	Forward directional control routed to neutral ground overcurrent elements (see *Figure 4.16*)	
	32NR	Reverse directional control routed to neutral ground overcurrent elements (see *Figure 4.16*)	

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Table 9.7 Relay Word Bit Definitions for SEL-351S (Sheet 19 of 19)

Row	Bit	Definition	Primary Application
65	PMDOK	Phasor measurement data OK (see *Synchrophasor Relay Word Bits on page L.11*)	Synchrophasors
	F32W	Forward directional output for Petersen Coil Wattmetric element (an input to F32N logic)	Control, Indication
	R32W	Reverse directional output for Petersen Coil Wattmetric element (an input to R32N logic)	
	F32C	Forward directional element for Petersen Coil Incremental Conductance Element	
	R32C	Reverse directional element for Petersen Coil Incremental Conductance Element	
	NSA	A-phase forward-fault identification logic output used in fault-type target logic for Petersen Coil grounded and ungrounded/high-impedance grounded systems (see *Front-Panel Target LEDs on page 5.32*)	
	NSB	B-phase forward-fault identification logic output used in fault-type target logic for Petersen Coil grounded and ungrounded/high-impedance grounded systems (see *Front-Panel Target LEDs on page 5.32*)	
	NSC	C-phase forward-fault identification logic output used in fault-type target logic for Petersen Coil grounded and ungrounded/high-impedance grounded systems (see *Front-Panel Target LEDs on page 5.32*)	

* Not used.

[a] **IMPORTANT:** See Appendix F: Setting Negative-Sequence Overcurrent Elements for special instructions on setting negative-sequence overcurrent elements.

[b] **NOTE: The Relay Word bits in Row 51 of the Relay Word (LED19–LED26) correspond exactly to the LED logic output in the right-hand column of Table 5.1 (TLED–TLED26, respectively). They are just labeled differently. TLED19–TLED26 are available only through the TAR command (see Table 10.6) and cannot be used in SELOGIC control equations. However Relay Word bits LED19–LED26 can be used in SELOGIC control equations.**
Relay Word bits LED19–LED26 have labels similar to the SELOGIC control equation settings in the middle column in Table 5.1 (LED19–LED21, LED25, LED26). The LEDx SELOGIC control equation settings are logic inputs (see Figure 5.17). If logic input LEDx is asserted to logical 1 and corresponding Global Setting LEDxL = Y, then corresponding LED output TLEDx latches in (asserts to logical 1) when a trip condition occurs. Thus, Relay Word bit LEDx also asserts to logical 1, because it corresponds exactly to LED logic output TLDx. SELOGIC control equation LEDx (a logic input) eventually deasserts to logical 0 when the trip condition goes away, but Relay Word bit LEDx (a logic output) remains asserted to logical 1.

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Settings Explanations

Note that most of the settings in the settings sheets that follow include references for additional information. The following explanations are for settings that do not have reference information anywhere else in the instruction manual.

Identifier Labels

Refer to *Relay Settings (Serial Port Command SET and Front Panel) on page SET.1*.

The SEL-351S has two identifier labels: the Relay Identifier (RID) and the Terminal Identifier (TID). The Relay Identifier is typically used to identify the relay or the type of protection scheme. Typical Terminal Identifiers include an abbreviation of the substation name and line terminal.

The relay tags each report (event report, meter report, etc.) with the Relay Identifier and Terminal Identifier. This allows you to distinguish the report as one generated for a specific breaker and substation.

RID and TID settings may include the following characters: 0–9, A–Z, -, /, ., space. These two settings cannot be made via the front-panel interface.

Current Transformer Ratios

Refer to *Relay Settings (Serial Port Command SET and Front Panel)*.

Phase and neutral current transformer ratios are set independently. If neutral channel IN is connected residually with IA, IB, and IC, then set CTR and CTRN the same. Relay settings CTR and CTRN are used in relay event reports and metering functions to scale secondary current quantities into primary values.

For directional control on low-impedance grounded, Petersen Coil grounded, and ungrounded/ high-impedance grounded systems, neutral channel IN is usually connected to a core-balance current transformer that encompasses the three phases (see *Figure 2.25*–*Figure 2.28*). This type of current transformer typically has a lower ratio than the phase current transformers, which allows for more sensitivity in ground fault detection. Core-balance current transformers are also used for non-directional sensitive earth fault (SEF) protection (see *Figure 2.23*).

CT Sizing

Sizing a CT to avoid saturation for the maximum asymmetrical fault is ideal, but not always possible. This requires a CT ANSI voltage classification greater than (1 + X/R) times the burden voltage for the maximum symmetrical fault current, where X/R is the reactance-to-resistance ratio of the primary system.

Use caution when selecting CTs for saturation conditions in firmware revisions released prior to November 2002 (see *Appendix A: Firmware and Manual Versions*). If you apply the SEL-351S in high fault current situations, such as in power plant auxiliary buses with as much as 40000 A of line-to-line fault current, current transformers used with the SEL-351S should meet the following criterion:

$$262.5 \geq \left(\frac{X}{R} + 1\right) \bullet I_f \bullet Z_b$$

Equation 9.1

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where:

I_f is the maximum fault current in per unit of CT rating
Z_b is the CT burden in per unit of standard burden
X/R is the X/R ratio of the primary fault circuit

This ensures a two-cycle trip of an instantaneous element set at 80 A. The following examples show how the criterion is used.

Example 1: Maximum Fault Current with an 80 A Instantaneous Setting

Maximum fault current in terms of primary CT and ANSI voltage rating, burden in ohms, and X/R ratio is:

$$I_{MAX} = \frac{262.5}{\left(1 + \frac{X}{R}\right)} \bullet \frac{ANSI}{100 \bullet Z_B} \bullet CT_{RATING}$$

Equation 9.2

Equation 9.2 is an actual-value equation derived from *Equation 9.1* above where:

I_{MAX} is the maximum primary fault current for line-to-line fault
CT_{RATING} is the CT primary rating in amperes
Z_B is the total CT secondary burden in ohms
ANSI is the ANSI voltage classification of CTs

An SEL-351S phase instantaneous overcurrent element is to be set at 80 amps. The relay will be used with a C400, 400:5 current transformer with a 0.50 Ω ohm total burden. The X/R ratio is 20. Determine the maximum fault current for dependable operation.

The burden is primarily from the CT windings and external leads to the SEL-351S (the SEL-351S has a negligible burden):

300 feet full-circuit run of #10 AWG (1.0 Ω /1000-ft)	0.30
CT winding of 80 turns at 0.0025 Ω/turn + 0.2	+ 0.20
Total burden	0.50 Ω

$$I_{MAX} = \frac{262.5}{\left(1 + \frac{X}{R}\right)} \bullet \frac{ANSI}{100 \bullet Z_B} \bullet CT_{RATING}$$

$$= \frac{262.5}{(1 + 20)} \bullet \frac{400}{100 \bullet 0.50\ \Omega} \bullet 400 = 40000\ A$$

Example 2: Minimum CT Rating with an 80 A Instantaneous Setting

CT rating in terms of maximum fault current, X/R ratio, ANSI rating, and burden is:

$$CT_{RATING} = \frac{\left(1 + \frac{X}{R}\right)}{262.5} \bullet \frac{100}{ANSI} \bullet I_{MAX} \bullet Z_B$$

Equation 9.3

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With an 80 amp instantaneous setting, what is the minimum CT rating that can be used when the maximum fault current is 40000 amps, X/R = 20, and the burden is 0.50 Ω ohms?

$$CT_{RATING} = \frac{\left(1 + \frac{X}{R}\right)}{262.5} \bullet \frac{100}{ANSI} \bullet I_{MAX} \bullet Z_B$$
$$= \frac{(1 + 20)}{262.5} \bullet \frac{100}{400} \bullet 40000 \bullet 0.50 = 400 \text{ A}$$

Example 3: Determine Whether the Following Application Meets the Above Criteria

CTs used	400:5 A, class C400
Instantaneous element pickup setting	80 A secondary
Maximum current for a line-to-line fault	40000 A primary
X/R ratio	20
Total CT secondary burden	0.50 Ω ohm

Apply *Equation 9.1* to verify if the CTs meet the required criteria.

$$\left(\frac{X}{R} + 1\right) \bullet I_f \bullet Z_b = (20 + 1) \bullet \frac{40000}{400} \bullet \frac{0.50\ \Omega}{4} = 262.5$$

The calculation shows that the 400:5 (class C400) CT meets the criteria in *Equation 9.1*.

Settings for Voltage Input Configuration

SEL-351S relays with firmware version R107 or lower can only accept wye-connected PTs to the voltage inputs, and can only use voltage input **VS** as a synchronism check voltage/auxiliary voltage input. Beginning with firmware revision R108, these relays have two new global settings, PTCONN and VSCONN; and a new Group Setting: VNOM.

Refer to *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25*.

PTCONN = WYE is the factory default value. PTCONN = DELTA, if selected, allows an open-delta PT connection. See *Delta-Connected Voltages (Global Setting PTCONN = DELTA) on page 2.19* for connection details. When PTCONN = DELTA, the relay presents some different group settings, and there is a change in some relay element availability, as compared to PTCONN = WYE. Comparing *Table 9.8* with *Table 9.9* shows some of these changes. This Instruction Manual explains these and other differences in relation to each affected element or setting. To indicate the state of PTCONN in SELOGIC control equations, Relay Word bit DELTA operates as shown in *Figure 9.21*.

Refer to *Global Settings (Serial Port Command SET G and Front Panel)*.

VSCONN = VS is the factory default value, which leaves voltage input **VS** in its traditional role of voltage input for the synchronism check elements. See *Synchronism Check Elements on page 3.36*. VSCONN = 3V0, if selected, allows an external $3V_0$ zero-sequence voltage source to be connected to relay voltage input **VS**. See *Broken-Delta VS Connection (Global Setting VSCONN = 3V0) on page 2.20*. When VSCONN = 3V0, the measured value from relay

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voltage input **VS-NS** is used in certain relay elements, as shown in *Table 9.8* and *Table 9.9*. When VSCONN = 3V0, some relay elements are unavailable or cannot be selected. This Instruction Manual explains these differences in relation to each affected element or setting. To indicate the state of VSCONN in SELOGIC control equations, Relay Word bit 3V0 operates as shown in *Figure 9.21*.

Refer to *Relay Settings (Serial Port Command SET and Front Panel) on page SET.1*.

VNOM = 67.00 V secondary (when PTCONN = WYE) or 116.05 V secondary (when PTCONN = DELTA) is the factory default value. See *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings on page 9.53* for details on using VNOM with numeric setting values.
VNOM = OFF, if selected, causes several relay elements and functions to be disabled or nonselectable, as shown in *Table 9.10*. The relay interprets setting VNOM = OFF as indicating that valid three-phase voltages are **not** connected to relay terminals **VA**, **VB**, **VC**, and **N**. See *Figure 2.30* for an example application that uses VNOM = OFF. This selection is intended to allow the remaining relay features to be used with just one phase voltage connected, without any of the sequence-voltage-based elements misoperating because of erroneous quantities.

Table 9.8 Main Relay Functions That Change With VSCONN, When PTCONN = WYE

Relay Function	When VSCONN=VS	When VSCONN=3VO
Zero-sequence voltage-polarized ground directional elements (ORDER setting choices “V”, “S”, and “U”)	Uses $3V_0$ calculated from V_A, V_B, V_C.	Uses V_S·(PTRS/PTR) as $3V_0$[a].
Wattmetric and incremental conductance elements (ORDER setting choice “P”).	Uses $3V_0$ calculated from V_A, V_B, V_C	Uses V_S·(PTRS/PTR) as $3V_0$[a].
Synchronism check elements	Available	Not available
Three-phase power elements (EPWR = 3P1–3P4). See *Power Elements (Available in Firmware Version 7) on page 3.59*.	No difference Uses a three-phase power formula, including $3V_0$ calculated from V_A, V_B, V_C.	
Three-phase power metering (MW3P, MVAR3P, etc.)	No difference Uses the sum of the single-phase power calculations from V_A, V_B, V_C, I_A, I_B, I_C (primary values).	
Quantity “3V0” in Metering, Fast Meter, Load Profile Recorder (LDP), and Distributed Network Protocol (DNP).	No difference Uses $3V_0$ calculated from V_A, V_B, V_C (primary value).	
Quantity “VS” in Metering, Fast Meter, Load Profile, and DNP.	No difference Uses V_S as VS (primary value).	

[a] The PTRS/PTR adjustment brings the broken-delta $3V_0$ quantity to the same base voltage as the relay impedance settings, which are based on the V_A, V_B, V_C voltage base.

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Table 9.9 Main Relay Functions That Change With VSCONN, When PTCONN = DELTA

Relay Function	When VSCONN=VS	When VSCONN=3VO
Zero-sequence voltage-polarized ground directional elements (ORDER setting choices "V", "S", and "U")	Not available	Uses VS·(PTRS/PTR) as $3V_0$[a].
Wattmetric and incremental conductance elements (ORDER setting choice "P")	Not available	Uses VS·(PTRS/PTR) as $3V_0$[a].
Synchronism check elements	Available	Not available
Three-phase power elements (EPWR = 3P1–3P4). See *Power Elements (Available in Firmware Version 7) on page 3.59*.	Uses a three-phase power formula, without $3V_0$[b].	Uses a three-phase power formula, including VS·(PTRS/PTR) as $3V_0$[c].
Three-phase power metering (MW3P, MVAR3P, etc.)	Uses a three-phase power formula, without $3V_0$ (primary value)[b].	Uses a three-phase power formula, including VS as $3V_0$ (primary value).
Quantity "3V0" in Metering, Fast Meter, Load Profile Recorder (LDP), and Distributed Network Protocol (DNP)	No difference "3V0" is not shown or not available in **METER** command and LDP. Fast Meter and DNP return 3V0 = 0.00 kV	
Quantity "VS" in Metering, Fast Meter, Load Profile, and DNP	No difference Uses V_S as VS (primary value)	

[a] The PTRS/PTR adjustment brings the broken-delta $3V_0$ quantity to the same base voltage as the relay impedance settings, which are based on the V_A, V_B, V_C voltage base.
[b] The three-phase power formula requires a $3V_0$ quantity to correct for any unbalanced conditions. In both cases noted in this table, the metering or power element accuracy will be reduced in conditions of system unbalance.
[c] The PTRS/PTR adjustment brings the broken-delta $3V_0$ quantity to the same base voltage as the relay phase voltages.

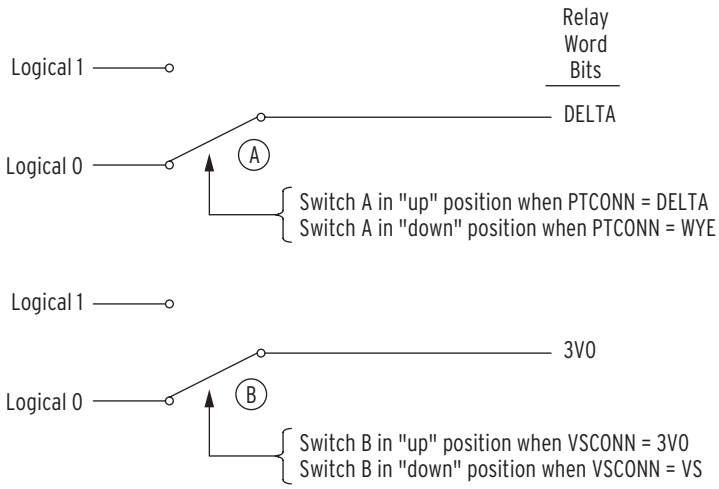


Figure 9.21 Operation of DELTA and 3VO Relay Word Bits

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Table 9.10 Main Relay Functions That Change With VNOM = OFF

Relay Function	When VNOM = Numeric Value	When VNOM = OFF
Undervoltage block for frequency elements: 27B81	Requires all three voltages V_A, V_B, V_C (when PTCONN = WYE) or V_{AB}, V_{BC}, V_{CA} (when PTCONN = DELTA) to be greater than setting 27B81P in order to deassert	Requires one voltage V_A (when PTCONN = WYE) or V_{AB} (when PTCONN = DELTA) to be greater than setting 27B81P in order to deassert
Load encroachment logic (enable setting ELOAD)	Available	Not available (can only set ELOAD = N)
Negative-sequence and positive-sequence voltage polarized directional elements	Available	32QE is disabled, F32P/R32P disabled, ground directional element ORDER setting choice "Q" not selectable
Phase and negative-sequence element directional control (*Figure 4.23*–*Figure 4.24*)	Available	Not available (defaults to "non-directional" in levels DIR1–DIR4)
Loss-of-Potential Logic (enable setting ELOP)	Available	Not available (can only set ELOP = N); Output Relay Word bits disabled (LOP = logical 0, V1GOOD = logical 0)

Potential Transformer Ratios and PT Nominal Secondary Voltage Settings

Refer to *Relay Settings (Serial Port Command SET and Front Panel) on page SET.1*.

Relay setting PTR is the overall potential ratio from the primary system to the relay phase voltage inputs **VA-VB-VC-N**. For example, on a 12.5 kV phase-to-phase primary system with wye-connected 7200:120 V PTs, the correct PTR setting is 60. For the same 12.5 kV system connected through 12470:115 V PTs in an open-delta configuration (Global Setting PTCONN = DELTA, and the relay wired as shown in *Figure 2.29*), the correct PTR setting is 108.44

Relay setting PTRS is the overall potential ratio from the synchronizing or broken-delta voltage source to the relay **VS-NS** voltage inputs. For example, in a synchronism check application (global setting VSCONN = VS), with phase-to-ground voltage connected from a 12.5 kV phase-to-phase primary system through a 7200:120 V PT, the correct PTRS setting is 60.

In an application that uses a broken-delta PT connection to create a $3V_0$ zero-sequence voltage signal (global setting VSCONN = 3V0, and the relay **VS–NS** terminals wired as shown in *Figure 2.28*), the step-down transformer, if present, must also be included in the overall PTRS ratio calculation. For example, if there are three PTs connected wye (primary)/broken delta (secondary) with ratios of 7200:120, and a 400:250 step-down instrumentation transformer in the circuit, the correct PTRS setting is 60 • 1.6 = 96.00.

Settings PTR and PTRS are used in event report and **METER** commands so that power system values can be reported in primary units.

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Settings PTR and PTRS are also used when global setting VSCONN = 3V0, to scale the measured **VS** voltage into the same voltage base as voltage inputs **VA-VB-VC-N** for certain functions, as shown in *Table 9.8* and *Table 9.9*. If no PTs are connected to voltage inputs **VA-VB-VC-N**, make setting PTR the same value as setting PTRS.

The ratio of the PTRS and PTR settings (PTRS/PTR) must be less than 1000 and greater than 0.001 when VSCONN = 3V0.

Relay setting VNOM is the nominal secondary voltage connected to voltage inputs **VA-VB-VC-N**. For wye-connected PTs, VNOM is a phase-to-neutral secondary voltage value. For open-delta connected PTs, VNOM is a phase-to-phase secondary voltage value.

For example, for a 10 kV (phase-to-phase) system with wye-connected PTs rated 7200:120 V (PTR = 60), the setting for VNOM would be 10000 V/(√3 • 60) = 96.22 V. For a 12.5 kV (phase-to-phase) system with open-delta connected PTs rated 14000:115 V (PTR = 121.74), the setting for VNOM would be 12500 V/121.74 = 102.68 V.

In the loss-of-potential logic (see *Figure 4.1* and accompanying text), setting VNOM scales certain voltage thresholds for voltage measurement comparisons. In *Table 9.10*, a setting of VNOM = OFF is shown to disable/turn-off a number of features. Effectively, setting VNOM = OFF signifies that a full three-phase voltage source is not connected to voltage inputs **VA-VB-VC-N**. Even with VNOM = OFF, voltage can still be connected to voltage inputs **VA-VB-VC-N** (e.g., single-phase voltage connected to voltage input **VA-N**), as discussed in the top of *Table 9.10* (for the undervoltage block for frequency elements) and demonstrated in *Figure 2.30*.

Line Settings

Refer to *Relay Settings (Serial Port Command SET and Front Panel) on page SET.1* and *Directional Elements (See Directional Control Settings on page 4.39) on page SET.8*.

Line impedance settings Z1MAG, Z1ANG, Z0MAG, and Z0ANG are used in the fault locator (see *Fault Location on page 12.5*) and in automatically making directional element settings Z2F, Z2R, Z0F, and Z0R (see *Settings Made Automatically on page 4.39*). A corresponding line length setting (LL) is also used in the fault locator.

If the protected line belongs to a hybrid power system, such as shown in *Figure 9.22*, then for proper directional decision, Z0ANG ≠ Z0MTA and E32 ≠ AUTO. Z0MTA must be set to compensate for the neutral ground resistor and is used in the Best Choice Ground Directional Logic™ to make proper forward and reverse fault determination. Z0ANG must be set to the Line Angle for correct fault location for forward faults.

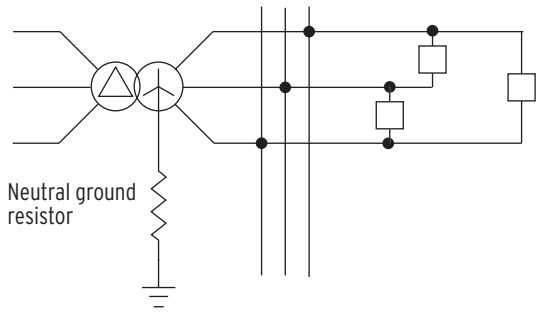


Figure 9.22 Hybrid Power System With Neutral Ground Resistor

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The line impedance settings Z1MAG, Z1ANG, Z0MAG, and Z0ANG are set in Ω secondary. Line impedance (Ω primary) is converted to Ω secondary:

Ω primary • (CTR/PTR) = Ω secondary

where:

CTR = phase (**IA**, **IB**, **IC**) current transformer ratio
PTR = phase (**VA**, **VB**, **VC**) potential transformer ratio

The zero-sequence line impedance setting Z0MAG is automatically scaled by the relay for use with neutral channel **IN** for directional control on low-impedance grounded systems. See Z0F and Z0R settings explanation in the latter part of *Section 4: Loss-of-Potential, Load Encroachment, and Directional Element Logic*.

Line length setting LL is unitless and corresponds to the line impedance settings. For example, if a particular line length is 15 miles, enter the line impedance values (Ω secondary) and then enter the corresponding line length:

LL = **15.00** (miles)

If this length of line is measured in kilometers rather than miles, then enter:

LL = **24.14** (kilometers)

Delta-Connected PTs (PTCONN = DELTA)

NOTE: If global setting VSCONN = 3V0, settings Z0SMAG and Z0SANG are not required, regardless of the PTCONN setting.

Additional zero-sequence source impedance settings Z0SMAG (magnitude, Ω secondary) and Z0SANG (angle, degrees) are required so that zero-sequence voltage can be derived for fault locating.

Enable Settings

Refer to *Relay Settings (Serial Port Command SET and Front Panel) on page SET.1* and *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25*.

The enable settings in *Relay Settings (Serial Port Command SET and Front Panel)* (E50P–EDEM) control the settings that follow, through *Voltage Sag/Swell/Interrupt (Available in Firmware Version 7; see Figure 3.32–Figure 3.34) on page SET.17*. Enable setting EBMON in *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25* controls the settings that immediately follow it. This helps limit the number of settings that need to be made.

Each setting subgroup in *Phase Inst./Def.-Time Overcurrent Elements (See Figure 3.1, Figure 3.2, and Figure 3.3) on page SET.3* through *Voltage Sag/Swell/Interrupt (Available in Firmware Version 7; see Figure 3.32–Figure 3.34)* has a reference back to the controlling enable setting. For example, the phase time-overcurrent element settings in *Phase Time-Overcurrent Element (See Figure 3.14 and Figure 3.15) on page SET.6* (settings 51P1P–51P2MR) are controlled by enable setting E51P.

Other System Parameters

Refer to *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25*.

The global settings NFREQ and PHROT allow you to configure the SEL-351S to your specific system.

Set NFREQ equal to your nominal power system frequency, either 50 Hz or 60 Hz.

Set PHROT equal to your power system phase rotation, either ABC or ACB.

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Set DATE_F to format the date displayed in relay reports and the front-panel display. Set DATE_F to MDY to display dates in Month/Day/Year format; set DATE_F to YMD to display dates in Year/Month/Day format.

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Settings Sheets

The settings sheets that follow include the definition and input range for each setting in the relay. Refer to *Relay Element Pickup Ranges and Accuracies* in *Introduction and Specifications on page 1.10* for information on 5 A nominal and 1 A nominal ordering options (and additional 0.2 A nominal and 0.05 A nominal options for neutral channel **IN**) and how they influence overcurrent element setting ranges.

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SEL-351S Settings Sheets

Relay Settings (Serial Port Command SET and Front Panel)

To avoid lost settings, enter Global settings first if Global Settings PTCONN or VSCONN are going to be changed. Refer to In Some Applications, Make Global Settings (SET G) First on page 9.1.

Identifier Labels

Relay Identifier (30 characters) (0–9, A–Z, -, /, ., space)

RID = _____

Terminal Identifier (30 characters) (0–9, A–Z, -, /, ., space)

TID = _____

Current and Potential Transformer Ratios (See Settings Explanations on page 9.48)

Phase (IA, IB, IC) Current Transformer Ratio (1–6000)	**CTR**	= _____
Neutral (IN) Current Transformer Ratio (1–10000)	**CTRN**	= _____
Phase (VA, VB, VC; wye-connected) or Phase-to-Phase (VAB, VBC, VCA; delta-connected) Potential Transformer Ratio (1.00–10000.00)	**PTR**	= _____
Synchronism Voltage (VS) Potential Transformer Ratio (1.00–10000.00)	**PTRS**	= _____
PT Nominal Voltage (line-to-neutral {wye-connected} or line-to-line {delta-connected}) (OFF, 25.00–300.00 V secondary)	**VNOM**	= _____

Line Settings (See Settings Explanations on page 9.48)

Positive-sequence line impedance magnitude (0.10–510.00 Ω secondary {5 A nom.}) (0.50–2550.00 Ω secondary {1 A nom.})	**Z1MAG**	= _____
Positive-sequence line impedance angle (50.00–90.00 degrees)	**Z1ANG**	= _____
Zero-sequence line impedance magnitude (0.10–510.00 Ω secondary {5 A nom.}) (0.50–2550.00 Ω secondary {1 A nom.})	**Z0MAG**	= _____
Zero-sequence line impedance angle (50.00–90.00 degrees)	**Z0ANG**	= _____

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NOTE: Make settings Z0SMAG and Z0SANG when Global Settings PTCONN = DELTA and VSCONN = VS

Zero-sequence source impedance magnitude (delta-connected voltages) (0.10–510.00 Ω secondary {5 A nom.}) (0.50–2550.00 Ω secondary {1 A nom.})	**Z0SMAG**	= _____
Zero-sequence source impedance angle (delta-connected voltages) (0.00–90.00 degrees)	**Z0SANG**	= _____
Line length (0.10–999.00, unitless)	**LL**	= _____

Instantaneous/Definite-Time Overcurrent Enable Settings

Phase element levels (N, 1–6) (see *Figure 3.1*, *Figure 3.2*, *Figure 3.3*, and *Figure 3.7*)	**E50P**	= _____
Neutral ground element levels-channel IN (N, 1–6) (see *Figure 3.8* and *Figure 3.9*)	**E50N**	= _____
Residual ground element levels (N, 1–6) (see *Figure 3.10* and *Figure 3.11*)	**E50G**	= _____
Negative-sequence element levels (N, 1–6) (see *Figure 3.12* and *Figure 3.13*)	**E50Q**	= _____

Time-Overcurrent Enable Settings

Phase elements (N, 1, 2) (see *Table 3.1* and *Figure 3.14* and *Figure 3.15*)	**E51P**	= _____
Neutral ground elements-channel IN (N, 1, 2) (see *Figure 3.16* and *Figure 3.17*)	**E51N**	= _____
Residual ground elements (N, 1, 2) (see *Figure 3.18* and *Figure 3.19*)	**E51G**	= _____
Negative-sequence elements (Y, N) (see *Figure 3.20*)	**E51Q**	= _____

Other Enable Settings

NOTE: When VNOM = OFF, and the relay has a 0.2 or 0.05 A nominal neutral rating, and Global Setting VSCONN = VS, setting E32 can only be set to "N")

Directional control (Y, AUTO, N) (see *Directional Control Settings on page 4.39*)	**E32**	= _____

NOTE: When VNOM = OFF, setting ELOAD can only be set to "N"

Load encroachment (Y, N) (see *Figure 4.2*)	**ELOAD**	= _____
Switch-onto-fault (Y, N) (see *Figure 5.3*)	**ESOTF**	= _____
Voltage elements (Y, N) (see *Figure 3.21–Figure 3.25*)	**EVOLT**	= _____

NOTE: When Global Setting VSCONN = 3V0, setting E25 can only be set to "N")

Synchronism check (Y, N) (see *Figure 3.26* and *Figure 3.27*)	**E25**	= _____

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NOTE: When setting VNOM = OFF, setting EFLOC can only be set to "N"

Fault location (Y, N) (see *Fault Location on page 12.5*)	**EFLOC**	= _____

NOTE: When setting VNOM = OFF, setting ELOP can only be set to "N"

Loss-of-potential (Y, Y1, N) (see *Figure 4.1*)	**ELOP**	= _____
Communications-assisted trip scheme (N, DCB, POTT, DCUB1, DCUB2) (see *Communications-Assisted Trip Logic—General Overview on page 5.11*)	**ECOMM**	= _____
Frequency elements (N, 1–6) (see *Figure 3.31*)	**E81**	= _____
Reclosures (N, 1– 4, C1–C4) (see *Reclosing Relay on page 6.14*)	**E79**	= _____
SELOGIC® Control Equation Variable Timers (N, 1–16) (see *Figure 7.24* and *Figure 7.25*)	**ESV**	= _____
Demand Metering (THM = Thermal, ROL = Rolling) (see *Figure 8.13*)	**EDEM**	= _____
Power element levels (N, 1–4, 3P1–3P4) (only available in Firmware Version 7) (setting choices 1–4 only available when global setting PTCONN = WYE)	**EPWR**	= _____
Voltage Sag/Swell/Interruption (Y, N) (only available in Firmware Version 7) (see *Figure 3.32*, *Figure 3.33*, and *Figure 3.34*)	**ESSI**	= _____

Phase Inst./Def.-Time Overcurrent Elements (See Figure 3.1, Figure 3.2, and Figure 3.3)

NOTE: Number of phase element pickup settings dependent on preceding enable setting E50P = 1-6

Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50P1P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50P2P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50P3P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50P4P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50P5P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50P6P**	= _____

Phase Definite-Time Overcurrent Elements (See Figure 3.3)

NOTE: Number of phase element time delay settings dependent on preceding enable setting E50P = 1-6; all four time delay settings are enabled if E50P ≥ 4

Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67P1D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67P2D**	= _____

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Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67P3D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67P4D**	= _____

Phase-to-Phase Instantaneous Overcurrent Elements (See Figure 3.7)

NOTE: Number of phase-to-phase element pickup settings dependent on preceding enable setting E50P = 1-6; all four pickup settings are enabled if E50P ≥ 4

Pickup (OFF, 1.00–170.00 A {5 A nom.}, 0.20–34.00 A {1 A nom.})	**50PP1P**	= _____
Pickup (OFF, 1.00–170.00 A {5 A nom.}, 0.20–34.00 A {1 A nom.})	**50PP2P**	= _____
Pickup (OFF, 1.00–170.00 A {5 A nom.}, 0.20–34.00 A {1 A nom.})	**50PP3P**	= _____
Pickup (OFF, 1.00–170.00 A {5 A nom.}, 0.20–34.00 A {1 A nom.})	**50PP4P**	= _____

Neutral Ground Inst./Def.-Time Overcurrent Elements—Channel IN (See Figure 3.8 and Figure 3.9)

NOTE: Number of neutral ground element pickup settings dependent on preceding enable setting E50N = 1-6

Pickup (OFF, 0.250–100.000 A {5 A nom.}, 0.050–20.000 A {1 A nom.}, 0.005–2.500 A {0.2 A nom}, 0.005–1.500 A {0.05 A nom.})	**50N1P**	= _____
Pickup (OFF, 0.250–100.000 A {5 A nom.}, 0.050–20.000 A {1 A nom.}, 0.005–2.500 A {0.2 A nom}, 0.005–1.500 A {0.05 A nom.})	**50N2P**	= _____
Pickup (OFF, 0.250–100.000 A {5 A nom.}, 0.050–20.000 A {1 A nom.}, 0.005–2.500 A {0.2 A nom}, 0.005–1.500 A {0.05 A nom.})	**50N3P**	= _____
Pickup (OFF, 0.250–100.000 A {5 A nom.}, 0.050–20.000 A {1 A nom.}, 0.005–2.500 A {0.2 A nom}, 0.005–1.500 A {0.05 A nom.})	**50N4P**	= _____
Pickup (OFF, 0.250–100.000 A {5 A nom.}, 0.050–20.000 A {1 A nom.}, 0.005–2.500 A {0.2 A nom}, 0.005–1.500 A {0.05 A nom.})	**50N5P**	= _____
Pickup (OFF, 0.250–100.000 A {5 A nom.}, 0.050–20.000 A {1 A nom.}, 0.005–2.500 A {0.2 A nom}, 0.005–1.500 A {0.05 A nom.})	**50N6P**	= _____

Neutral Ground Definite-Time Overcurrent Elements (See Figure 3.8)

NOTE: Number of neutral ground element time delay settings dependent on preceding enable setting E50N = 1-6; all four time delay settings are enabled if E50N ≥ 4

Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67N1D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67N2D**	= _____

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Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67N3D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67N4D**	= _____

Residual Ground Inst./Def.-Time Overcurrent Elements (See Figure 3.10 and Figure 3.11)

NOTE: Number of residual ground element pickup settings dependent on preceding enable setting E50G = 1-6.

NOTE: 50G1P-50G6P setting step size 0.010 A {5 A nom.}, 0.002 A {1 A nom.}

Pickup (OFF, 0.050–100.000 A {5 A nom.}, 0.010–20.000 A {1 A nom.})	**50G1P**	= _____
Pickup (OFF, 0.050–100.000 A {5 A nom.}, 0.010–20.000 A {1 A nom.})	**50G2P**	= _____
Pickup (OFF, 0.050–100.000 A {5 A nom.}, 0.010–20.000 A {1 A nom.})	**50G3P**	= _____
Pickup (OFF, 0.050–100.000 A {5 A nom.}, 0.010–20.000 A {1 A nom.})	**50G4P**	= _____
Pickup (OFF, 0.050–100.000 A {5 A nom.}, 0.010–20.000 A {1 A nom.})	**50G5P**	= _____
Pickup (OFF, 0.050–100.000 A {5 A nom.}, 0.010–20.000 A {1 A nom.})	**50G6P**	= _____

Residual Ground Definite-Time Overcurrent Elements (See Figure 3.10)

NOTE: Number of residual ground element time delay settings dependent on preceding enable setting E50G = 1-6; all four time delay settings are enabled if E50G ≥ 4

Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67G1D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67G2D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67G3D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67G4D**	= _____

Negative-Sequence Inst./Def.-Time Overcurrent Elements (See Figure 3.12 and Figure 3.13)

IMPORTANT: See Appendix F: Setting Negative-Sequence Overcurrent Elements for information on setting negative-sequence overcurrent elements.

NOTE: Number of negative-sequence element time delay settings dependent on preceding enable setting E50Q = 1-6

Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50Q1P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50Q2P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50Q3P**	= _____

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Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50Q4P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50Q5P**	= _____
Pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.})	**50Q6P**	= _____

Negative-Sequence Definite-Time Overcurrent Elements (See Figure 3.12)

IMPORTANT: See Appendix F: Setting Negative-Sequence Overcurrent Elements for information on setting negative-sequence overcurrent elements.

NOTE: Number of negative-sequence element time delay settings dependent on preceding enable setting E50Q = 1-6; all four time delay settings are enabled if E50Q ≥ 4

Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67Q1D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67Q2D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67Q3D**	= _____
Time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**67Q4D**	= _____

Phase Time-Overcurrent Element (See Figure 3.14 and Figure 3.15)

NOTE: Make the following settings if preceding enable setting E51P = 1 or 2

Pickup (OFF, 0.25–16.00 A {5 A nom.}, 0.05–3.20 A {1 A nom.})	**51P1P**	= _____
Curve (U1–U5, C1–C5, recloser curves; see *Figure 9.1–Figure 9.20*)	**51P1C**	= _____
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, 0.10–2.00 for recloser curves)	**51P1TD**	= _____
Electromechanical Reset (Y, N; applicable only to curves U1–U5, C1–C5)	**51P1RS**	= _____
Constant time adder (0.00–60.00 cyc.)	**51P1CT**	= _____
Minimum Response (0.00–60.00 cyc.)	**51P1MR**	= _____

NOTE: Make the following settings if preceding enable setting E51P = 2

Pickup (OFF, 0.25–16.00 A {5 A nom.}, 0.05–3.20 A {1 A nom.})	**51P2P**	= _____
Curve (U1–U5, C1–C5, recloser curves; see *Figure 9.1–Figure 9.20*)	**51P2C**	= _____
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, 0.10–2.00 for recloser curves)	**51P2TD**	= _____
Electromechanical Reset (Y, N; applicable only to curves U1–U5, C1–C5)	**51P2RS**	= _____
Constant time adder (0.00–60.00 cyc.)	**51P2CT**	= _____
Minimum Response (0.00–60.00 cyc.)	**51P2MR**	= _____

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Neutral Ground Time-Overcurrent Elements—Channel IN (See Figure 3.16 and Figure 3.17)

NOTE: Make the following settings if preceding enable setting E51N = 1 or 2

Pickup (OFF, 0.500–16.000 A {5 A nom.}, 0.100–3.200 A {1 A nom.}, 0.005–0.640 A {0.2 A nom.}, 0.005–0.160 A {0.05 A nom.})	**51N1P**	= _____
Curve (U1–U5, C1–C5, recloser curves; see *Figure 9.1–Figure 9.20*)	**51N1C**	= _____
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, 0.10–2.00 for recloser curves)	**51N1TD**	= _____
Electromechanical Reset (Y, N; applicable only to curves U1–U5, C1–C5)	**51N1RS**	= _____
Constant time adder (0.00–60.00 cyc.)	**51N1CT**	= _____
Minimum Response (0.00–60.00 cyc.)	**51N1MR**	= _____

NOTE: Make the following settings if preceding enable setting E51N = 2

Pickup (OFF, 0.500–16.000 A {5 A nom.}, 0.100–3.200 A {1 A nom.}, 0.005–0.640 A {0.2 A nom.}, 0.005–0.160 A {0.05 A nom.})	**51N2P**	= _____
Curve (U1–U5, C1–C5, recloser curves; see *Figure 9.1–Figure 9.20*)	**51N2C**	= _____
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, 0.10–2.00 for recloser curves)	**51N2TD**	= _____
Electromechanical Reset (Y, N; applicable only to curves U1–U5, C1–C5)	**51N2RS**	= _____
Constant time adder (0.00–60.00 cyc.)	**51N2CT**	= _____
Minimum Response (0.00–60.00 cyc.)	**51N2MR**	= _____

Residual Ground Time-Overcurrent Elements (See Figure 3.18 and Figure 3.19)

NOTE: Make the following settings if preceding enable setting E51G = 1 or 2

Pickup (OFF, 0.10–16.00 A {5 A nom.}, 0.02–3.20 A {1 A nom})	**51G1P**	= _____
Curve (U1–U5, C1–C5, recloser curves; see *Figure 9.1–Figure 9.20*)	**51G1C**	= _____
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, 0.10–2.00 for recloser curves)	**51G1TD**	= _____
Electromechanical Reset (Y, N; applicable only to curves U1–U5, C1–C5)	**51G1RS**	= _____
Constant time adder (0.00–60.00 cyc.)	**51G1CT**	= _____
Minimum Response (0.00–60.00 cyc.)	**51G1MR**	= _____

NOTE: Make the following settings if preceding enable setting E51G = 2

Pickup (OFF, 0.10–16.00 A {5 A nom.}, 0.02–3.20 A {1 A nom})	**51G2P**	= _____

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Curve (U1–U5, C1–C5, recloser curves; see *Figure 9.1–Figure 9.20*)	**51G2C**	= _____
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, 0.10–2.00 for recloser curves)	**51G2TD**	= _____
Electromechanical Reset (Y, N; applicable only to curves U1–U5, C1–C5)	**51G2RS**	= _____
Constant time adder (0.00–60.00 cyc.)	**51G2CT**	= _____
Minimum Response (0.00–60.00 cyc.)	**51G2MR**	= _____

Negative-Sequence Time-Overcurrent Element (See Figure 3.20)

IMPORTANT: See Appendix F: Setting Negative-Sequence Overcurrent Elements for information on setting negative-sequence overcurrent elements.

NOTE: Make the following settings if preceding enable setting E51Q = Y

Pickup (OFF, 0.25–16.00 A {5 A nom.}, 0.05–3.20 A {1 A nom.})	**51QP**	= _____
Curve (U1–U5, C1–C5, recloser curves; see *Figure 9.1–Figure 9.20*)	**51QC**	= _____
Time-Dial (0.50–15.00 for curves U1–U5, 0.05–1.00 for curves C1–C5, 0.10–2.00 for recloser curves)	**51QTD**	= _____
Electromechanical Reset (Y, N; applicable only to curves U1–U5, C1–C5)	**51QRS**	= _____
Constant time adder (0.00–60.00 cyc.)	**51QCT**	= _____
Minimum Response (0.00–60.00 cyc.)	**51QMR**	= _____

Load-Encroachment Elements (See Figure 4.2)

NOTE: Make the following settings if preceding enable setting ELOAD = Y

Forward load impedance (0.10–128.00 Ω secondary {5 A nom.}) (0.50–640.00 Ω secondary {1 A nom.})	**ZLF**	= _____
Reverse load impedance (0.10–128.00 Ω secondary {5 A nom.}) (0.50–640.00 Ω secondary {1 A nom.})	**ZLR**	= _____
Positive forward load angle (–90.00° to +90.00°)	**PLAF**	= _____
Negative forward load angle (–90.00° to +90.00°)	**NLAF**	= _____
Positive reverse load angle (+90.00° to +270.00°)	**PLAR**	= _____
Negative reverse load angle (+90.00° to +270.00°)	**NLAR**	= _____

Directional Elements (See Directional Control Settings on page 4.39)

NOTE: Make settings DIR1–DIR4 and ORDER if preceding enable setting E32 = Y or AUTO

Level 1 direction: Forward, Reverse, None (F, R, N)	**DIR1**	= _____
Level 2 direction: Forward, Reverse, None (F, R, N)	**DIR2**	= _____

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Level 3 direction: Forward, Reverse, None (F, R, N)	**DIR3**	= _____
Level 4 direction: Forward, Reverse, None (F, R, N)	**DIR4**	= _____
Ground directional element priority: combination of Q, V, I, P, S, U, or OFF	**ORDER**	= _____

NOTE: If neutral channel **IN** is rated 0.05 A or 0.20 A nominal, then setting option "I" is not available for setting ORDER.

Setting options "P", "S", and "U" are only available if neutral channel **IN** is rated 0.2 A nominal, and either Global Setting PTCONN = WYE, or Global Setting VSCONN = 3V0.

Setting option "V" is only available if Global Setting PTCONN = WYE, or Global Setting VSCONN = 3V0.

When setting VNOM = OFF, and Global Setting VSCONN = VS, setting ORDER cannot contain "V", "S", "P", or "U".

When setting VNOM = OFF, setting ORDER cannot contain Q.

See Table 4.4 for permissible setting combinations for setting ORDER.)

NOTE: Make setting 50P32P if preceding enable settings E32 = Y or AUTO and ELOAD = N

Phase directional element 3-phase current pickup (0.50–10.00 A {5 A nom.}, 0.10–2.00 A {1 A nom.})	**50P32P**	= _____

NOTE: Make settings Z2F, Z2R, 50QFP, 50QRP, a2 and k2 if preceding enable setting E32 = Y. If E32 = AUTO, these settings are made automatically.

Forward directional Z2 threshold (–128.00–128.00 Ω secondary {5 A nom.}) (–640.00–640.00 Ω secondary {1 A nom.})	**Z2F**	= _____
Reverse directional Z2 threshold (–128.00–128.00 Ω secondary {5 A nom.}) (–640.00–640.00 Ω secondary) {1 A nom.}	**Z2R**	= _____
Forward directional negative-sequence current pickup (0.25–5.00 A {5 A nom.}, 0.05–1.00 A {1 A nom.})	**50QFP**	= _____
Reverse directional negative-sequence current pickup (0.25–5.00 A {5 A nom.}, 0.05–1.00 A {1 A nom.})	**50QRP**	= _____
Positive-sequence current restraint factor, I2/I1 (0.02–0.50, unitless)	**a2**	= _____
Zero-sequence current restraint factor, I2/I0 (0.10–1.20, unitless)	**k2**	= _____

NOTE: Make settings 50GFP, 50GRP, and a0 if preceding enable setting E32 = Y and preceding setting ORDER contains V or I. If E32 = AUTO and ORDER contains V or I, these settings are made automatically.

Forward directional residual ground pickup (0.05–5.00 A {5 A nom.}, 0.01–1.00 A {1 A nom.})	**50GFP**	= _____
Reverse directional residual ground pickup (0.05–5.00 A {5 A nom.}, 0.01–1.00 A {1 A nom.})	**50GRP**	= _____
Positive-sequence current restraint factor, I0/I1 (0.02–0.50, unitless)	**a0**	= _____

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NOTE: Make settings Z0F and Z0R if preceding enable setting E32 = Y and preceding setting ORDER contains V or S. If E32 = AUTO and ORDER contains V or S, these settings are made automatically.

Forward directional Z0 threshold (–128.00–128.00 Ω secondary {5 A nom.}) (–640.00–640.00 Ω secondary {1 A nom.})	**Z0F**	= _____
Reverse directional Z0 threshold (–128.00–128.00 Ω secondary {5 A nom}) (–640.00–640.00 Ω secondary {5 A nom})	**Z0R**	= _____

NOTE: Make setting Z0MTA if [E32 = Y] **and** [ORDER contains V or S].

Zero-Sequence Maximum Torque Angle (–90 to –5.00 degrees and 5.00 to 90 degrees)	**Z0MTA**	= _____

NOTE: Make settings 50NFP, 50NRP, and a0N if [E32 = Y or AUTO] **and** [ORDER contains U or S].

Forward Directional IN Pickup (0.005–5.000 A)	**50NFP**	= _____
Reverse Directional IN Pickup (0.005–5.000 A)	**50NRP**	= _____
Positive-Sequence Restraint Factor, IN/I1 (0.001–0.500, unitless)	**a0N**	= _____

Wattmetric Element Settings (Petersen Coil Grounded System; see Directional Control Settings on page 4.39)

NOTE: Make settings 59RES, 32WFP, 32WRP, and 32WD if [E32 = Y or AUTO] **and** [ORDER contains P]

Wattmetric 3V0 Overvoltage Pickup (1.00–430.00 V secondary)	**59RES**	= _____
Forward Wattmetric Pickup, (0.001–150 W secondary)	**32WFP**	= _____
Reverse Wattmetric Pickup, (0.001–150 W secondary)	**32WRP**	= _____
Wattmetric Delay (30.00–999999.00 cycles)	**32WD**	= _____

Voltage Elements (See Figure 3.21–Figure 3.25)

NOTE: Make the following settings if preceding enable setting EVOLT =Y and Global Setting PTCONN = WYE

Phase undervoltage pickup (OFF, 0.00–300.00 V secondary)	**27P1P**	= _____
Phase undervoltage pickup (OFF, 0.00–300.00 V secondary)	**27P2P**	= _____
Phase overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59P1P**	= _____
Phase overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59P2P**	= _____
Zero-sequence (3V0) overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59N1P**	= _____
Zero-sequence (3V0) overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59N2P**	= _____
Negative-sequence (V2) overvoltage pickup (OFF, 0.00–200.00 V secondary)	**59QP**	= _____

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Positive-sequence (V1) overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59V1P**	= _____
Channel **VS** undervoltage pickup (OFF, 0.00–300.00 V secondary)	**27SP**	= _____
Channel **VS** overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59S1P**	= _____
Channel **VS** overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59S2P**	= _____
Phase-to-phase undervoltage pickup (OFF, 0.00–520.00 V secondary)	**27PP**	= _____
Phase-to-phase overvoltage pickup (OFF, 0.00–520.00 V secondary)	**59PP**	= _____

NOTE: Make the following settings if preceding enable setting EVOLT = Y **and** Global Setting PTCONN = DELTA

Negative-sequence (V2) overvoltage pickup (OFF, 0.00–120.00 V secondary)	**59QP**	= _____
Negative-sequence (V2) overvoltage pickup (OFF, 0.00–120.00 V secondary)	**59Q2P**	= _____
Positive-sequence (V1) overvoltage pickup (OFF, 0.00–170.00 V secondary)	**59V1P**	= _____
Channel **VS** undervoltage pickup (OFF, 0.00–300.00 V secondary)	**27SP**	= _____
Channel **VS** overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59S1P**	= _____
Channel **VS** overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59S2P**	= _____
Phase-to-phase undervoltage pickup (OFF, 0.00–300.00 V secondary)	**27PP**	= _____
Phase-to-phase undervoltage pickup (OFF, 0.00–300.00 V secondary)	**27PP2P**	= _____
Phase-to-phase overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59PP**	= _____
Phase-to-phase overvoltage pickup (OFF, 0.00–300.00 V secondary)	**59PP2P**	= _____

Synchronism Check Elements (See Figure 3.26 and Figure 3.27)

NOTE: Make the following settings if preceding enable setting E25 = Y

Voltage window–low threshold (0.00–300.00 V secondary)	**25VLO**	= _____
Voltage window–high threshold (0.00–300.00 V secondary)	**25VHI**	= _____
Maximum slip frequency (0.005–0.500 Hz)	**25SF**	= _____
Maximum angle 1 (0.00°–80.00°)	**25ANG1**	= _____
Maximum angle 2 (0.00°–80.00°)	**25ANG2**	= _____

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Synchronizing phase (Global Setting PTCONN=WYE: VA, VB, VC or 0° to 330° in 30° steps; degree option is for **VS** not in phase with **VA**, **VB**, or **VC**—set with respect to **VS** constantly lagging **VA**) (Global Setting PTCONN=DELTA: VAB, VBC, VCA or 0° to 330° in 30° steps; degree option is for **VS** not in phase with VAB, VBC, or VCA—set with respect to **VS** constantly lagging VAB)	**SYNCP**	= _____
Breaker close time for angle compensation (0.00–60.00 cycles in 0.25-cycle steps)	**TCLOSD**	= _____

Frequency Element (See Figure 3.29–Figure 3.31)

NOTE: Make the following settings if preceding enable setting E81 = 1-6

Phase undervoltage block (25.00–300.00 V secondary)	**27B81P**	= _____
Level 1 pickup (OFF, 40.10–65.00 Hz)	**81D1P**	= _____
Level 1 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D1D**	= _____
Level 2 pickup (OFF, 40.10–65.00 Hz)	**81D2P**	= _____
Level 2 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D2D**	= _____
Level 3 pickup (OFF, 40.10–65.00 Hz)	**81D3P**	= _____
Level 3 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D3D**	= _____
Level 4 pickup (OFF, 40.10–65.00 Hz)	**81D4P**	= _____
Level 4 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D4D**	= _____
Level 5 pickup (OFF, 40.10–65.00 Hz)	**81D5P**	= _____
Level 5 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D5D**	= _____
Level 6 pickup (OFF, 40.10–65.00 Hz)	**81D6P**	= _____
Level 6 time delay (2.00–16000.00 cycles in 0.25-cycle steps)	**81D6D**	= _____

Reclosing Relay (See Table 6.2 and Table 6.3)

NOTE: Make the following settings if preceding enable setting E79 = 1-4

Open interval 1 time (0.00–999999.00 cycles in 0.25-cycle steps)	**79OI1**	= _____
Open interval 2 time (0.00–999999.00 cycles in 0.25-cycle steps)	**79OI2**	= _____
Open interval 3 time (0.00–999999.00 cycles in 0.25-cycle steps)	**79OI3**	= _____
Open interval 4 time (0.00–999999.00 cycles in 0.25-cycle steps)	**79OI4**	= _____
Reset time from reclose cycle (0.00–999999.00 cycles in 0.25-cycle steps)	**79RSD**	= _____

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Reset time from lockout (0.00–999999.00 cycles in 0.25-cycle steps)	**79RSLD**	= _____
Reclose supervision time limit (OFF, 0.00–999999.00 cycles in 0.25-cycle steps) (set 79CLSD = 0.00 for most applications; see *Figure 6.5*)	**79CLSD**	= _____

Switch-Onto-Fault (See Figure 5.3)

NOTE: Make the following settings if preceding enable setting ESOTF = Y

Close enable time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**CLOEND**	= _____
52 A enable time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**52AEND**	= _____
SOTF duration (0.50–16000.00 cycles in 0.25-cycle steps)	**SOTFD**	= _____

POTT Trip Scheme Settings (Also Used in DCUB Trip Schemes) (See Figure 5.6)

NOTE: Make the following settings if preceding enable setting ECOMM = POTT, DCUB1, or DCUB2

Zone (level) 3 reverse block time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**Z3RBD**	= _____
Echo block time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**EBLKD**	= _____
Echo time delay pickup (OFF, 0.00–16000.00 cycles in 0.25-cycle steps)	**ETDPU**	= _____
Echo duration time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**EDURD**	= _____
Weak-infeed enable (Y, N)	**EWFC**	= _____

Additional DCUB Trip Scheme Settings (See Figure 5.10)

NOTE: Make the following settings if preceding enable setting ECOMM = DCUB1 or DCUB2

Guard present security time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**GARD1D**	= _____
DCUB disabling time delay (0.25–16000.00 cycles in 0.25-cycle steps)	**UBDURD**	= _____
DCUB duration time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**UBEND**	= _____

DCB Trip Scheme Settings (See Figure 5.14)

NOTE: Make the following settings if preceding enable setting ECOMM = DCB

Zone (level) 3 reverse pickup time delay (0.00–16000.00 cycles in 0.25-cycle steps)	**Z3XPU**	= _____
Zone (level) 3 reverse dropout extension (0.00–16000.00 cycles in 0.25-cycle steps)	**Z3XD**	= _____
Block trip receive extension (0.00–16000.00 cycles in 0.25-cycle steps)	**BTXD**	= _____

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Level 2 phase short delay (0.00–60.00 cycles in 0.25-cycle steps)	**67P2SD**	= _____
Level 2 neutral ground short delay (0.00–60.00 cycles in 0.25-cycle steps)	**67N2SD**	= _____
Level 2 residual ground short delay (0.00–60.00 cycles in 0.25-cycle steps)	**67G2SD**	= _____
Level 2 negative-sequence short delay (0.00–60.00 cycles in 0.25-cycle steps)	**67Q2SD**	= _____

Demand Metering Settings (See Figure 8.11 and Figure 8.13)

NOTE: Make the following settings, whether preceding enable setting EDEM = THM or ROL.

Time constant (5, 10, 15, 30, 60 minutes)	**DMTC**	= _____
Phase pickup (OFF, 0.50–16.00 A {5 A nom.}, 0.10–3.20 A {1 A nom.})	**PDEMP**	= _____
Neutral ground pickup-channel IN (OFF, 0.500–16.000 A {5 A nom.}, 0.100–3.200 A {1 A nom.},0.005–0.640 A {0.2 A nom.}, 0.005–0.160 A {0.05 A nom.})	**NDEMP**	= _____
Residual ground pickup (OFF, 0.10–16.00 A {5 A nom.}, 0.02–3.20 A {1 A nom.})	**GDEMP**	= _____
Negative-sequence pickup (OFF, 0.50–16.00 A {5 A nom.}, 0.10–3.20 A {1 A nom.})	**QDEMP**	= _____

Other Settings

NOTE: Make the following settings—they have no controlling enable setting.

Minimum trip duration time (4.00–16000.00 cycles in 0.25-cycle steps) (see *Figure 5.1*)	**TDURD**	= _____
Close failure time delay (OFF, 0.00–16000.00 cycles in 0.25-cycle steps) (see *Figure 6.1*)	**CFD**	= _____
Three-pole open time delay (0.00–60.00 cycles in 0.25-cycle steps) (usually set for no more than a few cycles; see *Figure 5.3*)	**3POD**	= _____
Load detection phase pickup (OFF, 0.25–100.00 A {5 A nom.}, 0.05–20.00 A {1 A nom.}) (see *Figure 5.3*)	**50LP**	= _____

SELOGIC Control Equation Variable Timers (See Figure 7.24 and Figure 7.25)

NOTE: Number of timer pickup/dropout settings dependent on preceding enable setting ESV = 1-16.

SV1 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV1PU**	= _____
SV1 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV1DO**	= _____
SV2 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV2PU**	= _____
SV2 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV2DO**	= _____
SV3 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV3PU**	= _____
SV3 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV3DO**	= _____

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SV4 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV4PU**	= _____
SV4 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV4DO**	= _____
SV5 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV5PU**	= _____
SV5 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV5DO**	= _____
SV6 Pickup Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV6PU**	= _____
SV6 Dropout Time (0.00–999999.00 cycles in 0.25-cycle steps)	**SV6DO**	= _____
SV7 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV7PU**	= _____
SV7 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV7DO**	= _____
SV8 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV8PU**	= _____
SV8 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV8DO**	= _____
SV9 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV9PU**	= _____
SV9 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV9DO**	= _____
SV10 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV10PU**	= _____
SV10 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV10DO**	= _____
SV11 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV11PU**	= _____
SV11 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV11DO**	= _____
SV12 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV12PU**	= _____
SV12 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV12DO**	= _____
SV13 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV13PU**	= _____
SV13 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV13DO**	= _____
SV14 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV14PU**	= _____
SV14 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV14DO**	= _____
SV15 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV15PU**	= _____
SV15 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV15DO**	= _____
SV16 Pickup Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV16PU**	= _____
SV16 Dropout Time (0.00–16000.00 cycles in 0.25-cycle steps)	**SV16DO**	= _____

Power Elements (Available in Firmware Version 7; See Figure 3.36 and Figure 3.37)

NOTE: Number of power element settings dependent on preceding enable setting EPWR = 1–4, 3P1–3P4.

NOTE: Make setting PWR1P if EPWR = 1–4.

Per Phase Power Element Pickup (OFF, 0.33–13000.00 VA secondary per phase {5 A nom}) (OFF, 0.07–2600.00 VA secondary per phase {1 A nom})	**PWR1P**	= _____

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NOTE: Make setting 3PWR1P if EPWR = 3P1-3P4).

Three-Phase Power Element Pickup (OFF, 1.00–39000.00 VA secondary three-phase {5 A nom}) (OFF, 0.20–7800.00 VA secondary three-phase {1 A nom})	**3PWR1P**	= _____
Pwr Ele. Type (+WATTS, –WATTS, +VARS, –VARS)	**PWR1T**	= _____
Pwr Ele. Time Delay (0.00–16000.00 cyc.)	**PWR1D**	= _____

NOTE: Make setting PWR2P if EPWR = 2-4.

Per Phase Power Element Pickup (OFF, 0.33–13000.00 VA secondary per phase {5 A nom}) (OFF, 0.07–2600.00 VA secondary per phase {1 A nom})	**PWR2P**	= _____

NOTE: Make setting 3PWR2P if EPWR = 3P2-3P4.

Three-Phase Power Element Pickup (OFF, 1.00–39000.00 VA secondary three-phase {5 A nom}) (OFF, 0.20–7800.00 VA secondary three-phase {1 A nom})	**3PWR2P**	= _____
Pwr Ele. Type (+WATTS, –WATTS, +VARS, –VARS)	**PWR2T**	= _____
Pwr Ele. Time Delay (0.00–16000.00 cyc.)	**PWR2D**	= _____

NOTE: Make setting PWR3P if EPWR = 3-4.

Per Phase Power Element Pickup (OFF, 0.33–13000.00 VA secondary per phase {5 A nom}) (OFF, 0.07–2600.00 VA secondary per phase {1 A nom})	**PWR3P**	= _____

NOTE: Make setting 3PWR3P if EPWR = 3P3-3P4.

Three-Phase Power Element Pickup (OFF, 1.00–39000.00 VA secondary three-phase {5 A nom}) (OFF, 0.20–7800.00 VA secondary three-phase {1 A nom})	**3PWR3P**	= _____
Pwr Ele. Type (+WATTS, –WATTS, +VARS, –VARS)	**PWR3T**	= _____
Pwr Ele. Time Delay (0.00–16000.00 cyc.)	**PWR3D**	= _____

NOTE: Make setting PWR4P if EPWR = 4.

Per Phase Power Element Pickup (OFF, 0.33–13000.00 VA secondary per phase {5 A nom}) (OFF, 0.07–2600.00 VA secondary per phase {1 A nom})	**PWR4P**	= _____

NOTE: Make setting 3PWR4P if EPWR = 3P4.

Three-Phase Power Element Pickup (OFF, 1.00–39000.00 VA secondary three-phase {5 A nom}) (OFF, 0.20–7800.00 VA secondary three-phase {1 A nom})	**3PWR4P**	= _____
Pwr Ele. Type (+WATTS, –WATTS, +VARS, –VARS)	**PWR4T**	= _____
Pwr Ele. Time Delay (0.00–16000.00 cyc.)	**PWR4D**	= _____

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Voltage Sag/Swell/Interrupt (Available in Firmware Version 7; see Figure 3.32–Figure 3.34)

NOTE: Make the following settings if preceding enable setting ESSI=Y

Percent Phase Interruption Pickup {Global Setting PTCONN = WYE} or Percent Line-to-Line Interruption Pickup {Global Setting PTCONN = DELTA} (OFF, 5.00–95.00; cannot be set higher than VSAG)	**VINT**	= _____
Percent Phase Voltage Sag Pickup {Global Setting PTCONN = WYE} or Percent Line-to-Line Voltage Sag Pickup {Global Setting PTCONN = DELTA} (OFF, 10.00–95.00)	**VSAG**	= _____
Percent Phase Voltage Swell Pickup {Global Setting PTCONN = WYE} or Percent Line-to-Line Voltage Swell Pickup {Global Setting PTCONN = DELTA} (OFF; 105.00–180.00)	**VSWELL**	= _____

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SELOGIC Control Equation Settings (Serial Port Command SET L)

SELOGIC control equation settings consist of Relay Word bits (see Table 9.6) and SELOGIC control equation operators * (AND), + (OR), ! (NOT), / (rising edge), \ (falling edge), and ( ) (parentheses). Numerous SELOGIC control equation settings examples are given in Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements–Section 8: Breaker Monitor, Metering, and Load Profile Functions. SELOGIC control equation settings can also be set directly to 1 (logical 1) or 0 (logical 0). Appendix G: Setting SELOGIC Control Equations gives SELOGIC control equation details, examples, and limitations.

Trip Logic Equations (See Figure 5.1)

Other trip conditions	**TR**	= _____
Communications-assisted trip conditions	**TRCOMM**	= _____
Switch-onto-fault trip conditions	**TRSOTF**	= _____
Direct transfer trip conditions	**DTT**	= _____
Unlatch trip conditions	**ULTR**	= _____

Communications-Assisted Trip Scheme Input Equations

Permissive trip 1 (used for ECOMM = POTT, DCUB1, or DCUB2; see *Figure 5.5*, *Figure 5.7*, and *Figure 5.10*	**PT1**	= _____
Loss-of-guard 1 (used for ECOMM = DCUB1 or DCUB2; see *Figure 5.10*)	**LOG1**	= _____
Permissive trip 2 (used for ECOMM = DCUB2; see *Figure 5.5* and *Figure 5.10*)	**PT2**	= _____
Loss of guard 2 (used for ECOMM = DCUB2; see *Figure 5.10*)	**LOG2**	= _____
Block trip (used for ECOMM = DCB; see *Figure 5.14*)	**BT**	= _____

Close Logic Equations (See Figure 6.1)

Circuit breaker status (used in *Figure 5.3*, also)	**52A**	= _____
Close conditions (other than automatic reclosing or **CLOSE** command)	**CL**	= _____
Unlatch close conditions	**ULCL**	= _____

Reclosing Relay Equations (See Reclosing Relay on page 6.14)

Reclose initiate	**79RI**	= _____
Reclose initiate supervision	**79RIS**	= _____
Drive-to-lockout	**79DTL**	= _____
Drive-to-last shot	**79DLS**	= _____
Skip shot	**79SKP**	= _____

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Stall open interval timing	**79STL**	=
Block reset timing	**79BRS**	=
Sequence coordination	**79SEQ**	=
Reclose supervision (see *Figure 6.5*)	**79CLS**	=

Latch Bits Set/Reset Equations (See Figure 7.12)

Set Latch Bit LT1	**SET1**	=
Reset Latch Bit LT1	**RST1**	=
Set Latch Bit LT2	**SET2**	=
Reset Latch Bit LT2	**RST2**	=
Set Latch Bit LT3	**SET3**	=
Reset Latch Bit LT3	**RST3**	=
Set Latch Bit LT4	**SET4**	=
Reset Latch Bit LT4	**RST4**	=
Set Latch Bit LT5	**SET5**	=
Reset Latch Bit LT5	**RST5**	=
Set Latch Bit LT6	**SET6**	=
Reset latch Bit LT6	**RST6**	=
Set Latch Bit LT7	**SET7**	=
Reset Latch Bit LT7	**RST7**	=
Set Latch Bit LT8	**SET8**	=
Reset Latch Bit LT8	**RST8**	=
Set Latch Bit LT9	**SET9**	=
Reset Latch Bit LT9	**RST9**	=
Set Latch Bit LT10	**SET10**	=
Reset Latch Bit LT10	**RST10**	=
Set Latch Bit LT11	**SET11**	=
Reset Latch Bit LT11	**RST11**	=
Set Latch Bit LT12	**SET12**	=
Reset Latch Bit LT12	**RST12**	=
Set Latch Bit LT13	**SET13**	=
Reset Latch Bit LT13	**RST13**	=
Set Latch Bit LT14	**SET14**	=

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Reset latch Bit LT14	**RST14**	=
Set Latch Bit LT15	**SET15**	=
Reset Latch Bit LT15	**RST15**	=
Set Latch Bit LT16	**SET16**	=
Reset Latch Bit LT16	**RST16**	=

Torque Control Equations for Inst./Def.-Time Overcurrent Elements

NOTE: Torque control equation settings cannot be set directly to logical 0.

Level 1 phase (see *Figure 3.3*)	**67P1TC**	=
Level 2 phase (see *Figure 3.3*)	**67P2TC**	=
Level 3 phase (see *Figure 3.3*)	**67P3TC**	=
Level 4 phase (see *Figure 3.3*)	**67P4TC**	=
Level 1 neutral ground (see *Figure 3.8*)	**67N1TC**	=
Level 2 neutral ground (see *Figure 3.8*)	**67N2TC**	=
Level 3 neutral ground (see *Figure 3.8*)	**67N3TC**	=
Level 4 neutral ground (see *Figure 3.8*)	**67N4TC**	=
Level 1 residual ground (see *Figure 3.10*)	**67G1TC**	=
Level 2 residual ground (see *Figure 3.10*)	**67G2TC**	=
Level 3 residual ground (see *Figure 3.10*)	**67G3TC**	=
Level 4 residual ground (see *Figure 3.10*)	**67G4TC**	=
Level 1 negative-sequence (see *Figure 3.12*)	**67Q1TC**	=
Level 2 negative-sequence (see *Figure 3.12*)	**67Q2TC**	=
Level 3 negative-sequence (see *Figure 3.12*)	**67Q3TC**	=
Level 4 negative-sequence (see *Figure 3.12*)	**67Q4TC**	=

Torque Control Equations for Time-Overcurrent Elements

NOTE: torque control equation settings cannot be set directly to logical 0.

Phase (see *Figure 3.14*)	**51P1TC**	=
Neutral Ground (see *Figure 3.16*)	**51N1TC**	=
Residual Ground (see *Figure 3.18*)	**51G1TC**	=
Phase (see *Figure 3.15*)	**51P2TC**	=
Neutral Ground (see *Figure 3.17*)	**51N2TC**	=
Residual Ground (see *Figure 3.19*)	**51G2TC**	=
Negative-Sequence (see *Figure 3.20*)	**51QTC**	=

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SELOGIC Control Equation Variable Timer Input Equations (See Figure 7.24 and Figure 7.25)

SELOGIC Control Equation Variable SV1	**SV1**	=
SELOGIC Control Equation Variable SV2	**SV2**	=
SELOGIC Control Equation Variable SV3	**SV3**	=
SELOGIC Control Equation Variable SV4	**SV4**	=
SELOGIC Control Equation Variable SV5	**SV5**	=
SELOGIC Control Equation Variable SV6	**SV6**	=
SELOGIC Control Equation Variable SV7	**SV7**	=
SELOGIC Control Equation Variable SV8	**SV8**	=
SELOGIC Control Equation Variable SV9	**SV9**	=
SELOGIC Control Equation Variable SV10	**SV10**	=
SELOGIC Control Equation Variable SV11	**SV11**	=
SELOGIC Control Equation Variable SV12	**SV12**	=
SELOGIC Control Equation Variable SV13	**SV13**	=
SELOGIC Control Equation Variable SV14	**SV14**	=
SELOGIC Control Equation Variable SV15	**SV15**	=
SELOGIC Control Equation Variable SV16	**SV16**	=

Output Contact Equations (See Figure 7.27)

Output Contact OUT101	**OUT101**	=
Output Contact OUT102	**OUT102**	=
Output Contact OUT103	**OUT103**	=
Output Contact OUT104	**OUT104**	=
Output Contact OUT105	**OUT105**	=
Output Contact OUT106	**OUT106**	=
Output Contact OUT107	**OUT107**	=

Output Contact Equations–Extra I/O Board (See Figure 7.28)

Output Contact OUT201	**OUT201**	=
Output Contact OUT202	**OUT202**	=
Output Contact OUT203	**OUT203**	=
Output Contact OUT204	**OUT204**	=

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Output Contact OUT205	**OUT205**	=
Output Contact OUT206	**OUT206**	=
Output Contact OUT207	**OUT207**	=
Output Contact OUT208	**OUT208**	=
Output Contact OUT209	**OUT209**	=
Output Contact OUT210	**OUT210**	=
Output Contact OUT211	**OUT211**	=
Output Contact OUT212	**OUT212**	=

Target and Operator Control LED Equations (see Table 5.1, and Figure 11.8 and Figure 11.9)

LED1 (GROUND ENABLED)	**LED1**	=
LED2 (RECLOSE ENABLED)	**LED2**	=
LED3 (REMOTE ENABLED)	**LED3**	=
LED4 (ALTERNATE SETTINGS)	**LED4**	=
LED5 (LOCK)	**LED5**	=
LED6 (HOT LINE TAG)	**LED6**	=
LED7 (AUX 1)	**LED7**	=
LED8 (AUX 2)	**LED8**	=
LED9 (BREAKER CLOSED/AUX 3)	**LED9**	=
LED10 (BREAKER OPEN/AUX 4)	**LED10**	=
LED12 (TRIP)	**LED12**	=
LED13 (INST)	**LED13**	=
LED14 (COMM)	**LED14**	=
LED15 (SOTF)	**LED15**	=
LED16 (50)	**LED16**	=
LED17 (51)	**LED17**	=
LED18 (81)	**LED18**	=
LED19 (RESET)	**LED19**	=
LED20 (CYCLE)	**LED20**	=
LED21 (LOCKOUT)	**LED21**	=
LED25 (G)	**LED25**	=
LED26 (N)	**LED26**	=

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Display Point Equations (See Rotating Default Display on page 7.36 and Rotating Default Display on page 11.12)

Display Point DP1	**DP1**	= _____
Display Point DP2	**DP2**	= _____
Display Point DP3	**DP3**	= _____
Display Point DP4	**DP4**	= _____
Display Point DP5	**DP5**	= _____
Display Point DP6	**DP6**	= _____
Display Point DP7	**DP7**	= _____
Display Point DP8	**DP8**	= _____
Display Point DP9	**DP9**	= _____
Display Point DP10	**DP10**	= _____
Display Point DP11	**DP11**	= _____
Display Point DP12	**DP12**	= _____
Display Point DP13	**DP13**	= _____
Display Point DP14	**DP14**	= _____
Display Point DP15	**DP15**	= _____
Display Point DP16	**DP16**	= _____

Setting Group Selection Equations (See Table 7.4)

Select Setting Group 1	**SS1**	= _____
Select Setting Group 2	**SS2**	= _____
Select Setting Group 3	**SS3**	= _____
Select Setting Group 4	**SS4**	= _____
Select Setting Group 5	**SS5**	= _____
Select Setting Group 6	**SS6**	= _____

Other Equations

Event report trigger conditions (see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*)	**ER**	= _____
Fault indication [used in INST, A, B, and C target logic and other relay functions, see subsection *SELOGIC Control Equation Setting FAULT on page 5.37*]	**FAULT**	= _____
Block synchronism check elements (see *Figure 3.26*)	**BSYNCH**	= _____
Close bus monitor (see *Figure 5.3*)	**CLMON**	= _____

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Breaker monitor initiation (see *Figure 8.3*)	**BKMON**	=
Enable for zero-sequence voltage-polarized and channel IN current-polarized directional elements (see *Figure 4.7*)	**E32IV**	=

MIRRORED BITS® Transmit Equations (Available in Firmware Versions 6 and 7; see Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7))

Channel A, transmit bit 1	**TMB1A**	=
Channel A, transmit bit 2	**TMB2A**	=
Channel A, transmit bit 3	**TMB3A**	=
Channel A, transmit bit 4	**TMB4A**	=
Channel A, transmit bit 5	**TMB5A**	=
Channel A, transmit bit 6	**TMB6A**	=
Channel A, transmit bit 7	**TMB7A**	=
Channel A, transmit bit 8	**TMB8A**	=
Channel B, transmit bit 1	**TMB1B**	=
Channel B, transmit bit 2	**TMB2B**	=
Channel B, transmit bit 3	**TMB3B**	=
Channel B, transmit bit 4	**TMB4B**	=
Channel B, transmit bit 5	**TMB5B**	=
Channel B, transmit bit 6	**TMB6B**	=
Channel B, transmit bit 7	**TMB7B**	=
Channel B, transmit bit 8	**TMB8B**	=

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Global Settings (Serial Port Command SET G and Front Panel)

To avoid lost settings, enter global settings first if Global Settings PTCONN or VSCONN are going to be changed. Refer to In Some Applications, Make Global Settings (SET G) First on page 9.1.

Voltage Input Configuration (See Settings for Voltage Input Configuration on page 9.50)

NOTE: Changing the setting value of PTCONN or VSCONN will cause the relay to display the following message:

```
WARNING!  The PTCONN or VSCONN setting was changed, which will cause
the Group, Logic, and Report settings to be reset to default values.
Save Changes(Y/N)? Y <Enter>
Are you sure (Y/N)? _
```

Phase Potential Transformer Connection (DELTA,WYE)	**PTCONN**	= _____
VS Channel Input (VS, 3V0)	**VSCONN**	= _____

Settings Group Change Delay (See Multiple Setting Groups on page 7.19)

Group change delay (0.00–16000.00 cycles in 0.25-cycle steps)	**TGR**	= _____

Power System Configuration and Date Format (See Settings Explanations on page 9.48)

Nominal frequency (50 Hz, 60 Hz)	**NFREQ**	= _____
Phase rotation (ABC, ACB)	**PHROT**	= _____
Date format (MDY, YMD)	**DATE_F**	= _____

Front-Panel Display Operation (See Section 11: Front-Panel Interface)

Front-panel display time-out (should be OFF, 1–30 minutes in 1-minute steps)	**FP_TO**	= _____

NOTE: If FP_TO = OFF, no time-out occurs and display remains on last display screen (e.g., continually display metering)

Display update rate (1–60 seconds)	**SCROLD**	= _____
Front-panel neutral/ground display (OFF, IN, IG)	**FPNGD**	= _____

Event Report Parameters (See Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER)

Length of event report (15, 30 cycles)	**LER**	= _____
Length of prefault in event report (1 to LER-1 cycles in 1-cycle steps)	**PRE**	= _____

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Station DC Battery Monitor (See Figure 8.9 and Figure 8.10)

DC battery instantaneous undervoltage pickup (OFF, 20–300 Vdc)	**DCLOP**	= _____
DC battery instantaneous overvoltage pickup (OFF, 20–300 Vdc)	**DCHIP**	= _____

Optoisolated Input Timers (See Figure 7.1)

Input IN101 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN101D**	= _____
Input IN102 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN102D**	= _____
Input IN103 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN103D**	= _____
Input IN104 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN104D**	= _____
Input IN105 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN105D**	= _____
Input IN106 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN106D**	= _____

Optoisolated Input Timers-Extra I/O Board (See Figure 7.2)

Input IN201 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN201D**	= _____
Input IN202 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN202D**	= _____
Input IN203 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN203D**	= _____
Input IN204 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN204D**	= _____
Input IN205 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN205D**	= _____
Input IN206 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN206D**	= _____
Input IN207 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN207D**	= _____
Input IN208 debounce time (AC, 0.00–1.00 cycles in 0.25-cycle steps)	**IN208D**	= _____

Breaker Monitor Settings (See Breaker Monitor on page 8.2)

Breaker monitor enable (Y, N)	**EBMON**	= _____

NOTE: Make the following settings if preceding enable setting EBMON = Y

Close/Open set point 1-max. (0–65000 operations)	**COSP1**	= _____
Close/Open set point 2-mid. (0–65000 operations)	**COSP2**	= _____

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Close/Open set point 3-min. (0–65000 operations)	**COSP3**	= _____
kA Interrupted set point 1-min. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP1**	= _____
kA Interrupted set point 2-mid. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP2**	= _____
kA Interrupted set point 3-max. (0.00–999.00 kA primary in 0.01 kA steps)	**KASP3**	= _____

NOTES:

- ➤ COSP1 must be set greater than COSP2.
- ➤ COSP2 must be set greater than or equal to COSP3.
- ➤ KASP1 must be set less than KASP2.
- ➤ If COSP2 is set the same as COSP3, then KASP2 must be set the same as KASP3.
- ➤ KASP3 must be set at least 5 times (but no more than 100 times) the KASP1 setting value.

Synchronized Phasor Settings (see Appendix L: SEL Synchrophasors)

Synchronized Phasor Measurement (Y, N)	**EPMU**	= _____

(Make the following settings if preceding enable setting EPMU = Y.)

PMU Hardware ID	**PMID**	= _____
Phasor Data Set, Voltages (V1, ALL)	**PHDATAV**	= _____
Voltage Angle Comp. Factor (–179.99 to +180 degrees)	**VCOMP**	= _____
Phasor Data Set, Currents (ALL, NA)	**PHDATAI**	= _____
Current Angle Comp. Factor (–179.99 to +180 degrees)	**ICOMP**	= _____
Time Source Type (IRIG, IEEE)	**TS_TYPE**	= _____

NOTE: EPMU is not available if global setting PTCONN = DELTA.

Trip Latch LEDs Settings (See Table 5.1)

Trip Latch LED 12 (Y,N)	**LED12L**	= _____
Trip Latch LED 13 (Y,N)	**LED13L**	= _____
Trip Latch LED 14 (Y,N)	**LED14L**	= _____
Trip Latch LED 15 (Y,N)	**LED15L**	= _____
Trip Latch LED 16 (Y,N)	**LED16L**	= _____
Trip Latch LED 17 (Y,N)	**LED17L**	= _____
Trip Latch LED 18 (Y,N)	**LED18L**	= _____
Trip Latch LED 19 (Y,N)	**LED19L**	= _____
Trip Latch LED 20 (Y,N)	**LED20L**	= _____
Trip Latch LED 21 (Y,N)	**LED21L**	= _____

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Trip Latch LED 25 (Y,N)	**LED25L**	= _____
Trip Latch LED 26 (Y,N)	**LED26L**	= _____
Reset trip-latched LEDs when breaker closes (Y,Y1,N,N1) The numeral "1" appended to setting options "Y1" and "N1" disables the embedded 3-second qualifying time delay on the **{LOCK}** operator control (the **{LOCK}** operator control effectively operates as the other operator controls, with no time delay).	**RSTLED**	= _____

Operator Control Time Delays (See Figure 11.12 and Figure 11.13)

{CLOSE/AUX 3} operator control time delay (0.00–3600.00 cycles in 0.25-cycle steps)	**PB9D**	= _____
{TRIP/AUX 4} operator control time delay (0.00–3600.00 cycles in 0.25-cycle steps)	**PB10D**	= _____

For **{AUX 3}** and **{AUX 4}** in model 0351S*xxx*5/6/A/B, corresponding time delay settings should be left at factory defaults, PB9D = 0 cycles and PB10D = 0 cycles, respectively (no time delay).

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Sequential Events Recorder and Load Profile Settings (Serial Port Command SET R)

Sequential Events Recorder settings are comprised of three trigger lists. Each trigger list can include up to 24 Relay Word bits (see Table 9.6) delimited by commas. Enter NA to remove a list of these Relay Word bit settings. See Sequential Events Recorder (SER) Report on page 12.25.

SER Trigger List 1	**SER1**	= _____
SER Trigger List 2	**SER2**	= _____
SER Trigger List 3	**SER3**	= _____

Load Profile settings are only available in Firmware Versions 6 and 7. See Load Profile Report (Available in Firmware Versions 6 and 7) on page 8.34.

Load profile list (15 elements max., enter NA to null)	**LDLIST**	= _____
Load profile acquisition rate (5,10,15,30,60 min)	**LDAR**	= _____

LDLIST may contain any of the following elements (delimit with spaces or commas):

Element	Quantity Recorded
IA, IB, IC, IN	Phase and neutral current magnitudes
VA, VB, VC	Phase voltage magnitudes (wye-connected only)
VAB, VBC, VCA	Phase-to-phase voltage magnitudes
VS	Sync (or broken delta) voltage magnitude
IG, I1, 3I2, V1, V2	Sequence current and voltage magnitudes
3V0	Zero-sequence voltage magnitude (wye-connected only)
VDC	Battery voltage
FREQ	Phase frequency
MWA, MWB, MWC	Phase megawatts (wye-connected only)
MW3	Three-phase megawatts
MVARA, MVARB, MVARC	Phase megaVARs (wye-connected only)
MVAR3	Three-phase megaVARs
PFA, PFB, PFC	Phase power factor (wye-connected only)
PF3	Three-phase power factor
LDPFA, LDPFB, LDPFC	Phase power factor lead/lag status (0 = lag, 1 = lead) (wye-connected only)
LDPF3	Three-phase power factor lead/lag status (0 = lag, 1 = lead)
IADEM, IBDEM, ICDEM, INDEM, IGDEM, 3I2DEM	Demand ammeter quantities
MWADI, MWBDI, MWCDI	Phase demand megaWATTs in (wye-connected only)
MW3DI	Three-phase demand megaWATTs in
MWADO, MWBDO, MWCDO	Phase demand megaWATTs out (wye-connected only)
MW3DO	Three-phase demand megaWATTs out
MVRADI, MVRBDI, MVRCDI	Phase demand megaVARs in (wye-connected only)
MVR3DI	Three-phase demand megaVARs in
MVRADO, MVRBDO, MVRCDO	Phase demand megaVARs out (wye-connected only)
MVR3DO	Three-phase demand megaVARs out
MWHAI, MWHBI, MWHCI	Phase megaWATT hours in (wye-connected only)

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Element	Quantity Recorded
MWH3I	Three-phase megaWATT hours in
MWHAO, MWHBO, MWHCO	Phase megaWATT hours out (wye-connected only)
MWH3O	Three-phase megaWATT hours out
MVRHAI, MVRHBI, MVRHCI	Phase megaVAR hours in (wye-connected only)
MVRH3I	Three-phase megaVAR hours in
MVRHAO, MVRHBO, MVRHCO	Phase megaVAR hours out (wye-connected only)
MVRH3O	Three-phase megaVAR hours out

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Text Label Settings (Serial Port Command SET T)

NOTE: Enter the following characters: 0–9, A–Z, -, /, ., space for each text label setting, subject to the specified character limit. Enter NA to null a label.

Local Bit Labels (See Table 7.1 and Table 7.2)

Local Bit LB1 Name (14 characters)	**NLB1**	=
Clear Local Bit LB1 Label (7 characters)	**CLB1**	=
Set Local Bit LB1 Label (7 characters)	**SLB1**	=
Pulse Local Bit LB1 Label (7 characters)	**PLB1**	=
Local Bit LB2 Name (14 characters)	**NLB2**	=
Clear Local Bit LB2 Label (7 characters)	**CLB2**	=
Set Local Bit LB2 Label (7 characters)	**SLB2**	=
Pulse Local Bit LB2 Label (7 characters)	**PLB2**	=
Local Bit LB3 Name (14 characters)	**NLB3**	=
Clear Local Bit LB3 Label (7 characters)	**CLB3**	=
Set Local Bit LB3 Label (7 characters)	**SLB3**	=
Pulse Local Bit LB3 Label (7 characters)	**PLB3**	=
Local Bit LB4 Name (14 characters)	**NLB4**	=
Clear Local Bit LB4 Label (7 characters)	**CLB4**	=
Set Local Bit LB4 Label (7 characters)	**SLB4**	=
Pulse Local Bit LB4 Label (7 characters)	**PLB4**	=
Local Bit LB5 Name (14 characters)	**NLB5**	=
Clear Local Bit LB5 Label (7 characters)	**CLB5**	=
Set Local Bit LB5 Label (7 characters)	**SLB5**	=
Pulse Local Bit LB5 Label (7 characters)	**PLB5**	=
Local Bit LB6 Name (14 characters)	**NLB6**	=
Clear Local Bit LB6 Label (7 characters)	**CLB6**	=
Set Local Bit LB6 Label (7 characters)	**SLB6**	=
Pulse Local Bit LB6 Label (7 characters)	**PLB6**	=
Local Bit LB7 Name (14 characters)	**NLB7**	=
Clear Local Bit LB7 Label (7 characters)	**CLB7**	=
Set Local Bit LB7 Label (7 characters)	**SLB7**	=
Pulse Local Bit LB7 Label (7 characters)	**PLB7**	=
Local Bit LB8 Name (14 characters)	**NLB8**	=
Clear Local Bit LB8 Label (7 characters)	**CLB8**	=

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Set Local Bit LB8 Label (7 characters)	**SLB8**	=
Pulse Local Bit LB8 Label (7 characters)	**PLB8**	=
Local Bit LB9 Name (14 characters)	**NLB9**	=
Clear Local Bit LB9 Label (7 characters)	**CLB9**	=
Set Local Bit LB9 Label (7 characters)	**SLB9**	=
Pulse Local Bit LB9 Label (7 characters)	**PLB9**	=
Local Bit LB10 Name (14 characters)	**NLB10**	=
Clear Local Bit LB10 Label (7 characters)	**CLB10**	=
Set Local Bit LB10 Label (7 characters)	**SLB10**	=
Pulse Local Bit LB10 Label (7 characters)	**PLB10**	=
Local Bit LB11 Name (14 characters)	**NLB11**	=
Clear Local Bit LB11 Label (7 characters)	**CLB11**	=
Set Local Bit LB11 Label (7 characters)	**SLB11**	=
Pulse Local Bit LB11 Label (7 characters)	**PLB11**	=
Local Bit LB12 Name (14 characters)	**NLB12**	=
Clear Local Bit LB12 Label (7 characters)	**CLB12**	=
Set Local Bit LB12 Label (7 characters)	**SLB12**	=
Pulse Local Bit LB12 Label (7 characters)	**PLB12**	=
Local Bit LB13 Name (14 characters)	**NLB13**	=
Clear Local Bit LB13 Label (7 characters)	**CLB13**	=
Set Local Bit LB13 Label (7 characters)	**SLB13**	=
Pulse Local Bit LB13 Label (7 characters)	**PLB13**	=
Local Bit LB14 Name (14 characters)	**NLB14**	=
Clear Local Bit LB14 Label (7 characters)	**CLB14**	=
Set Local Bit LB14 Label (7 characters)	**SLB14**	=
Pulse Local Bit LB14 Label (7 characters)	**PLB14**	=
Local Bit LB15 Name (14 characters)	**NLB15**	=
Clear Local Bit LB15 Label (7 characters)	**CLB15**	=
Set Local Bit LB15 Label (7 characters)	**SLB15**	=
Pulse Local Bit LB15 Label (7 characters)	**PLB15**	=
Local Bit LB16 Name (14 characters)	**NLB16**	=
Clear Local Bit LB16 Label (7 characters)	**CLB16**	=
Set Local Bit LB16 Label (7 characters)	**SLB16**	=
Pulse Local Bit LB16 Label (7 characters)	**PLB16**	=

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Display Point Labels (See Rotating Default Display on page 7.36 and Rotating Default Display on page 11.12)

Display if DP1 = logical 1 (16 characters)	**DP1_1**	= _____
Display if DP1 = logical 0 (16 characters)	**DP1_0**	= _____
Display if DP2 = logical 1 (16 characters)	**DP2_1**	= _____
Display if DP2 = logical 0 (16 characters)	**DP2_0**	= _____
Display if DP3 = logical 1 (16 characters)	**DP3_1**	= _____
Display if DP3 = logical 0 (16 characters)	**DP3_0**	= _____
Display if DP4 = logical 1 (16 characters)	**DP4_1**	= _____
Display if DP4 = logical 0 (16 characters)	**DP4_0**	= _____
Display if DP5 = logical 1 (16 characters)	**DP5_1**	= _____
Display if DP5 = logical 0 (16 characters)	**DP5_0**	= _____
Display if DP6 = logical 1 (16 characters)	**DP6_1**	= _____
Display if DP6 = logical 0 (16 characters)	**DP6_0**	= _____
Display if DP7 = logical 1 (16 characters)	**DP7_1**	= _____
Display if DP7 = logical 0 (16 characters)	**DP7_0**	= _____
Display if DP8 = logical 1 (16 characters)	**DP8_1**	= _____
Display if DP8 = logical 0 (16 characters)	**DP8_0**	= _____
Display if DP9 = logical 1 (16 characters)	**DP9_1**	= _____
Display if DP9 = logical 0 (16 characters)	**DP9_0**	= _____
Display if DP10 = logical 1 (16 characters)	**DP10_1**	= _____
Display if DP10 = logical 0 (16 characters)	**DP10_0**	= _____
Display if DP11 = logical 1 (16 characters)	**DP11_1**	= _____
Display if DP11 = logical 0 (16 characters)	**DP11_0**	= _____
Display if DP12 = logical 1 (16 characters)	**DP12_1**	= _____
Display if DP12 = logical 0 (16 characters)	**DP12_0**	= _____
Display if DP13 = logical 1 (16 characters)	**DP13_1**	= _____
Display if DP13 = logical 0 (16 characters)	**DP13_0**	= _____
Display if DP14 = logical 1 (16 characters)	**DP14_1**	= _____
Display if DP14 = logical 0 (16 characters)	**DP14_0**	= _____
Display if DP15 = logical 1 (16 characters)	**DP15_1**	= _____
Display if DP15 = logical 0 (16 characters)	**DP15_0**	= _____

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Display if DP16 = logical 1 (16 characters)	**DP16_1**	= _____
Display if DP16 = logical 0 (16 characters)	**DP16_0**	= _____

Reclosing Relay Labels (See Functions Unique to the Front-Panel Interface on page 11.6)

Reclosing Relay Last Shot Label (14 char.)	**79LL**	= _____
Reclosing Relay Shot Counter Label (14 char.)	**79SL**	= _____

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Port Settings (Serial Port Command SET P and Front Panel)

Protocol Settings (See Below)

Protocol (SEL, LMD, DNP, DNPE, MBA, MBB, MB8A, MB8B)	**PROTO**	=

Protocol Settings Set PROTO = SEL for standard SEL ASCII protocol. For SEL Distributed Port Switch Protocol (LMD), set PROTO = LMD. Refer to Appendix C: SEL Distributed Port Switch Protocol for details on the LMD protocol. For Distributed Network Protocol (DNP), set PROTO = DNP or DNPE. Refer to Appendix H: Distributed Network Protocol for details on DNP protocol. For MIRRORED BITS, set PROTO = MBA,MBB, MB8A, or MB8B. Refer to Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7) for details on MIRRORED BITS.

The following settings are used if PROTO = LMD.

LMD Prefix (@, #, $, %, &)	**PREFIX**	=
LMD Address (01–99)	**ADDR**	=
LMD Settling Time (0–30 seconds)	**SETTLE**	=

Communications Settings

Baud Rate (300, 1200, 2400, 4800, 9600, 19200, 38400) (38400 is not available on Port 1)	**SPEED**	=
Data Bits (6, 7, 8)	**BITS**	=
Parity (O, E, N) {Odd, Even, None}	**PARITY**	=
Stop Bits (1, 2)	**STOP**	=

Other Port Settings (See Below)

Time-out (0–30 minutes)	**T_OUT**	=
Send Auto Messages to Port (Y, N, DTA)	**AUTO**	=
Enable Hardware Handshaking (Y, N, MBT)	**RTSCTS**	=
Fast Operate Enable (Y, N)	**FASTOP**	=

Other Port Settings Set T_OUT to the number of minutes of serial port inactivity for an automatic log out. Set T_OUT = 0 for no port time out.

Set AUTO = Y to allow automatic messages at the serial port. Set AUTO = DTA to use the serial port with an SEL-DTA2 Display/Transducer Adapter.

Set RTSCTS = Y to enable hardware handshaking. With RTSCTS = Y, the relay will not send characters until the CTS input is asserted. Also, if the relay is unable to receive characters, it deasserts the RTS line. Setting RTSCTS is not applicable to serial Port 1 (EIA-485) or A port configured for SEL Distributed Port Switch Protocol.

Setting RTSCTS=MBT is only available at 9600 baud (SPEED selection). In this mode, the relay deasserts the RTS line and does not monitor the CTS line. This selection is normally used with MIRRORED BITS, PROTO=MBA or MBB. See Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7) for more detail.

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Set FASTOP = Y to enable binary Fast Operate messages at the serial port. Set FASTOP = N to block binary Fast Operate messages. Refer to Appendix D: Configuration, Fast Meter, and Fast Operate Commands for the description of the SEL-351S Relay Fast Operate commands.

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Section 10
Serial Port Communications and Commands

Introduction

The SEL-351S Relay comes equipped with the following serial ports:

- Serial Port 1, EIA-485 (rear panel; see *Table 10.2*)
- Serial Port 2, EIA-232 (rear panel; see *Table 10.1*)
- Serial Port 3, EIA-232 (rear panel; see *Table 10.1*)
- Serial Port F, EIA-232 (front panel; see *Table 10.1*)

Connect the serial port to a computer serial port for local communications or to a modem for remote communications. Other devices useful for communications include:

- SEL-PRTU
- SEL-2032, SEL-2030, and SEL-2020 Communications Processors
- SEL-2505 Remote I/O Module
- SEL-2100 Logic Processor
- SEL-DTA2 Display Transducer Adapter

You can use a variety of terminal emulation programs on your personal compute to communicate with the relay.

For the best display, use VT-100 terminal emulation or the closest variation.

The default settings for all serial ports are:

Baud Rate = 2400
Data Bits = 8
Parity = N
Stop Bits = 1

To change the port settings, use the **SET P** command (see *Section 9: Setting the Relay*) or the front-panel **{SET}** pushbutton.

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Port Connector and Communications Cables

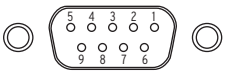


Figure 10.1 DB-9 Connector Pinout for EIA-232 Serial Ports

IRIG-B

Demodulated IRIG-B time code can be input into Serial Port 1 or Serial Port 2 (pin functions +IRIG-B and –IRIG-B, see *Table 10.1* and *Table 10.2*). This is handled adeptly by connecting Serial Port 2 of the SEL-351S to an SEL-2032 with Cable C273A (see cable diagrams that follow in this section).

If demodulated IRIG-B time code is input into Serial Port 1, it should not be input into Serial Port 2 and vice versa.

Table 10.1 Pinout Functions for EIA-232 Serial Ports 2, 3, and F

Pin	Port 2	Port 3	Port F
1	N/C or +5 Vdc[a]	N/C or +5 Vdc[a]	N/C
2	RXD	RXD	RXD
3	TXD	TXD	TXD
4	+IRIG-B	N/C	N/C
5, 9	GND	GND	GND
6	–IRIG-B	N/C	N/C
7	RTS	RTS	RTS
8	CTS	CTS	CTS

[a] See EIA-232 Serial Port Voltage Jumpers on page 2.46.

Table 10.2 Terminal Functions for EIA-485 Serial Port 1

Terminal	Function
1	+TX
2	–TX
3	+RX
4	–RX
5	SHIELD
6	N/C
7	+IRIG-B
8	–IRIG-B

Relay Word Bit TIRIG

TIRIG asserts when the relay time is based on an IRIG-B time source. In the event that the relay is not synchronized to a connected IRIG-B time source (TIRIG = logical 0), the troubleshooting steps detailed in the **IRI** command discussion should be used.

Relay Word Bit TSOK

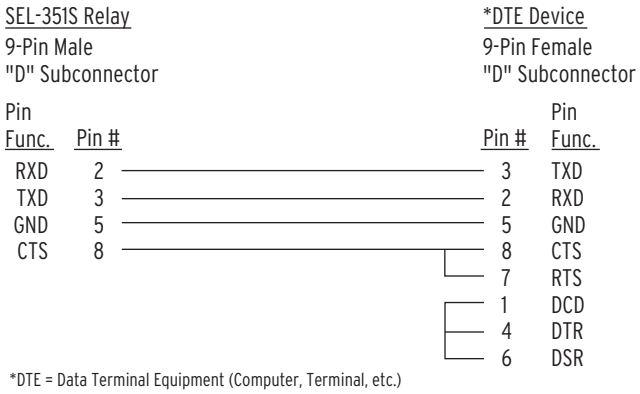
TSOK asserts to indicate that the IRIG-B time source is of sufficient accuracy for synchrophasor measurement. See *Appendix L: SEL Synchrophasors* for more information regarding the SEL Fast Message Synchrophasor Protocol.

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The following cable diagrams show several types of EIA-232 serial communications cables that connect the SEL-351S to other devices. These and other cables are available from SEL. Contact the factory for more information.

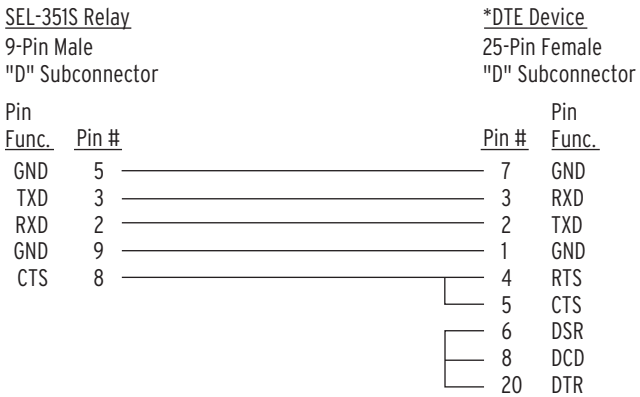
SEL-351S to Computer

Cable SEL-C234A



*DTE = Data Terminal Equipment (Computer, Terminal, etc.)

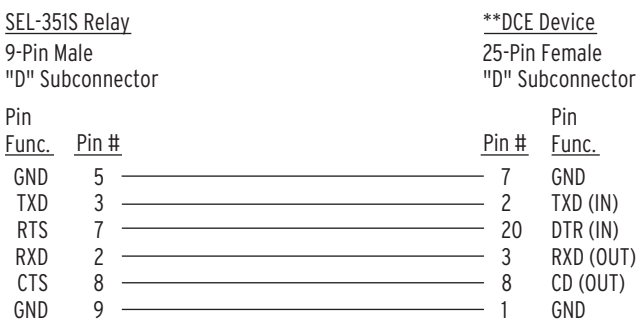
Cable SEL-C227A



*DTE = Data Terminal Equipment (Computer, Terminal, etc.)

SEL-351S to Modem

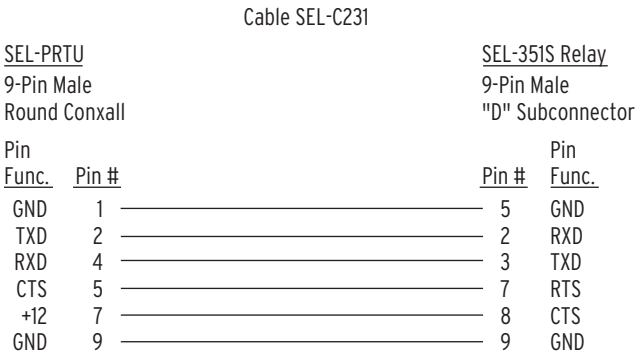
Cable SEL-C222



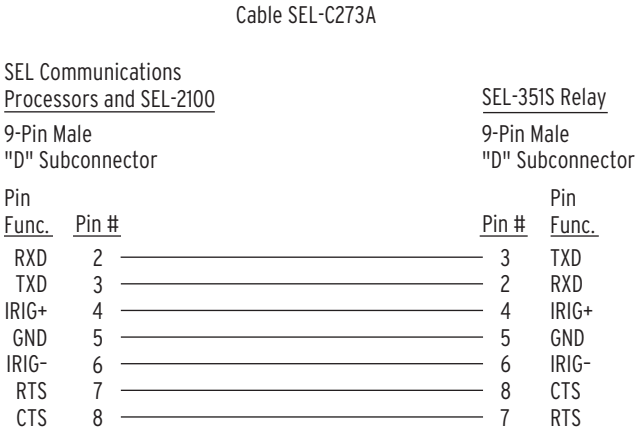
**DCE = Data Communications Equipment (Modem, etc.)

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SEL-351S to SEL-PRTU



SEL-351S to SEL-2032, SEL-2030, SEL-2020 or to SEL-2100



SEL-351S to SEL-DTA2

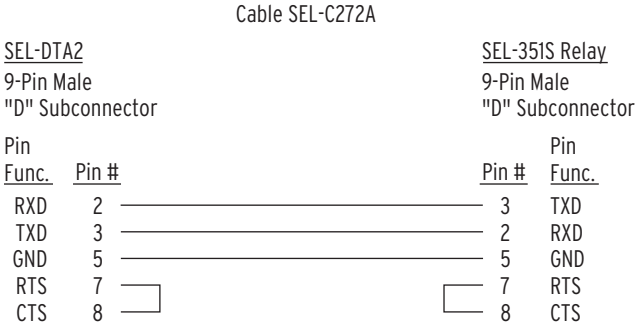


Table 10.3 Serial Communications Port Pin/Terminal Function Definitions
(Sheet 1 of 2)

Pin Function	Definition
N/C	No Connection
+5 Vdc (0.5 A limit)	5 Vdc Power Connection
RXD, RX	Receive Data
TXD, TX	Transmit Data
IRIG-B	IRIG-B Time-Code Input
GND	Ground
SHIELD	Shielded Ground
RTS	Request To Send
CTS	Clear To Send
DCD	Data Carrier Detect

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Table 10.3 Serial Communications Port Pin/Terminal Function Definitions
(Sheet 2 of 2)

Pin Function	Definition
DTR	Data Terminal Ready
DSR	Data Set Ready

For long-distance communications up to 500 meters and for electrical isolation of communications ports, use the SEL-2800 family of Fiber-Optic Transceivers. Contact SEL for more details on these devices.

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Communications Protocol

Hardware Protocol

All EIA-232 serial ports support RTS/CTS hardware handshaking. RTS/CTS handshaking is not supported on the EIA-485 Serial Port 1.

To enable hardware handshaking, use the **SET P** command (or front-panel **{SET}** pushbutton) to set RTSCTS = Y. Disable hardware handshaking by setting RTSCTS = N.

If RTSCTS = N, the relay permanently asserts the RTS line.

If RTSCTS = Y, the relay deasserts RTS when it is unable to receive characters.

If RTSCTS = Y, the relay does not send characters until the CTS input is asserted.

Software Protocols

The SEL-351S provides standard SEL protocols:

- SEL ASCII
- SEL Distributed Port Switch Protocol (LMD)
- SEL Fast Meter
- SEL Compressed ASCII
- SEL Fast SER

In addition, the relay provides MIRRORED BITS® communications and Distributed Network Protocol (DNP3) as an ordering option. The relay activates protocols on a per-port basis. The SEL-351S is compatible with the SEL-DTA2 Display/Transducer Adapter. See *Port Settings (Serial Port Command SET P and Front Panel) on page SET.35*.

To select SEL ASCII protocol, set the port PROTO setting to SEL. To select SEL Distributed Port Switch Protocol (LMD), set PROTO = LMD. To select DNP protocol, set PROTO = DNP.

SEL Fast Meter and SEL Compressed ASCII commands are active when PROTO is set to either SEL or LMD. The commands are not active when PROTO is set to DNP or MIRRORED BITS.

SEL ASCII Protocol

SEL ASCII protocol is designed for manual and automatic communications.

1. All commands received by the relay must be of the form:

   <command><CR> or <command><CRLF>

   A command transmitted to the relay should consist of the command followed by either a CR (carriage return) or a CRLF (carriage return and line feed). You may truncate commands to the first three characters. For example, **EVENT 1 <Enter>** would become **EVE 1 <Enter>**. Upper- and lowercase characters may be used without distinction, except in passwords.

NOTE: The **<Enter>** key on most keyboards is configured to send the ASCII character 13 (^M) for a carriage return. This manual instructs you to press the **<Enter>** key after commands, which should send the proper ASCII code to the relay.

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2. The relay transmits all messages in the following format:

   <STX><MESSAGE LINE 1><CRLF>

   <MESSAGE LINE 2><CRLF>

   -
   -
   -

   <LAST MESSAGE LINE><CRLF>< ETX>

   Each message begins with the start-of-transmission character (ASCII 02) and ends with the end-of-transmission character (ASCII 03). Each line of the message ends with a carriage return and line feed.

3. The relay implements XON/XOFF flow control.

   The relay transmits XON (ASCII hex 11) and asserts the RTS output (if hardware handshaking enabled) when the relay input buffer drops below 25 percent full.

   The relay transmits XOFF (ASCII hex 13) when the buffer is over 75 percent full. If hardware handshaking is enabled, the relay deasserts the RTS output when the buffer is approximately 95 percent full. Automatic transmission sources should monitor for the XOFF character so they do not overwrite the buffer. Transmission should terminate at the end of the message in progress when XOFF is received and may resume when the relay sends XON.

4. You can use the XON/XOFF protocol to control the relay during data transmission. When the relay receives XOFF during transmission, it pauses until it receives an XON character. If there is no message in progress when the relay receives XOFF, it blocks transmission of any message presented to its buffer. Messages will be accepted after the relay receives XON.

   The CAN character (ASCII hex 18) aborts a pending transmission. This is useful in terminating an unwanted transmission.

   Control characters can be sent from most keyboards with the following keystrokes:

   XON: **<Ctrl + Q>** (hold down the Ctrl key and press Q)
   XOFF: **<Ctrl + S>** (hold down the Ctrl key and press S)
   CAN: **<Ctrl + X>** (hold down the Ctrl key and press X)

SEL Distributed Port Switch Protocol (LMD)

The SEL Distributed Port Switch Protocol (LMD) permits multiple SEL relays to share a common communications channel. The protocol is selected by setting the port setting PROTO = LMD. See *Appendix C: SEL Distributed Port Switch Protocol* for more information.

SEL Fast Meter Protocol

SEL Fast Meter protocol supports binary messages to transfer metering and control messages. The protocol is described in *Appendix D: Configuration, Fast Meter, and Fast Operate Commands*.

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SEL Compressed ASCII Protocol

SEL Compressed ASCII protocol provides compressed versions of some of the relay ASCII commands. The protocol is described in *Appendix E: Compressed ASCII Commands*.

SEL Fast Sequential Events Recorder (SER) Protocol

SEL Fast Sequential Events Recorder (SER) Protocol, also known as SEL Unsolicited Sequential Events Recorder, provides SER events to an automated data collection system. SEL Fast SER Protocol is available on any serial port. The protocol is described in *Appendix J: SEL-351S Fast SER Protocol*.

Distributed Network Protocol (DNP3)

The relay provides Distributed Network Protocol (DNP3) slave support. DNP is an optional protocol and is described in *Appendix H: Distributed Network Protocol*.

MIRRORED BITS Communications

The SEL-351S supports MIRRORED BITS relay-to-relay communications on two ports simultaneously (available in firmware versions 6 and 7 only, see *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*).

SEL Fast Message Synchrophasor Protocol

SEL Fast Message Synchrophasor protocol are generally Fast Messages that transport measured synchrophasor information. The protocol is described in *Appendix L: SEL Synchrophasors*.

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Serial Port Automatic Messages

When the serial port AUTO setting is Y, the relay sends automatic messages to indicate specific conditions. The automatic messages are described in *Table 10.4*.

When the serial port AUTO setting is DTA, the SEL-351S is compatible with the SEL-DTA2 on that port. The **MET** and **MET D** command responses are modified to comply with the DTA2 data format for that port.

Table 10.4 Serial Port Automatic Messages

Condition	Description
Power Up	The relay sends a message containing the present date and time, Relay and Terminal Identifiers, and the Access Level 0 prompt when the relay is turned on.
Event Trigger	The relay sends an event summary each time an event report is triggered. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.
Group Switch	The relay displays the active settings group after a group switch occurs. See *GRO Command (Display Active Setting Group Number) on page 10.17*.
Self-Test Warning or Failure	The relay sends a status report each time a self-test warning or failure condition is detected. See *STA Command (Relay Self-Test Status) on page 10.32*.

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Serial Port Access Levels

Commands can be issued to the relay via the serial port to view metering values, change relay settings, etc. The available serial port commands are listed in *Table 10.5*. The commands can be accessed only from the corresponding access level as shown in *Table 10.5*. The access levels are:

- Access Level 0 (the lowest access level)
- Access Level 1
- Access Level B
- Access Level 2 (the highest access level)

Access Level 0

Once serial port communications are established with the relay, the relay sends the following prompt:

```
=
```

This is referred to as Access Level 0. The only command that is available at Access Level 0 is the **ACC** command (see *Table 10.5*). Enter the **ACC** command at the Access Level 0 prompt:

```
=ACC <Enter>
```

The **ACC** command takes the relay to Access Level 1 [see *ACC, BAC, and 2AC Commands (Go to Access Level 1, B, or 2) on page 10.14* for more detail].

Access Level 1

When the relay is in Access Level 1, the relay sends the following prompt:

```
=>
```

Commands **2AC** through **TRI** in *Table 10.5* are available from Access Level 1. For example, enter the **MET** command at the Access Level 1 prompt to view metering data:

```
=>MET <Enter>
```

The **2AC** command allows the relay to go to Access Level 2 [see *ACC, BAC, and 2AC Commands (Go to Access Level 1, B, or 2)* for more detail]. Enter the **2AC** command at the Access Level 1 prompt:

```
=>2AC <Enter>
```


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The **BAC** command allows the relay to go to Access Level B [see *ACC, BAC, and 2AC Commands (Go to Access Level 1, B, or 2) on page 10.14* for more detail]. Enter the **BAC** command at the Access Level 1 prompt:

```
=>BAC <Enter>
```

Access Level B

When the relay is in Access Level B, the relay sends the prompt:

```
==>
```

Commands **BRE *n*** through **PUL** in *Table 10.5* are available from Access Level B. For example, enter the **CLO** command at the Access Level B prompt to close the circuit breaker:

```
==>CLO <Enter>
```

While in Access Level B, any of the Access Level 1 commands are also available (commands **2AC** through **TRI** in *Table 10.5*).

The **2AC** command allows the relay to go to Access Level 2 [see *ACC, BAC, and 2AC Commands (Go to Access Level 1, B, or 2)* for more detail]. Enter the **2AC** command at the Access Level B prompt:

```
==>2AC <Enter>
```

Access Level 2

When the relay is in Access Level 2, the relay sends the prompt:

```
=>>
```

Commands **CON** through **VER** in *Table 10.5* are available from Access Level 2. For example, enter the **SET** command at the Access Level 2 prompt to make relay settings:

```
=>>SET <Enter>
```

While in Access Level 2, any of the Access Level 1 and Access Level B commands are also available (commands **BAC** through **PUL** in *Table 10.5*).

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Command Summary

Table 10.5 alphabetically lists the serial port commands within a given access level. Much of the information available from the serial port commands is also available via the front-panel pushbuttons. The correspondence between the serial port commands and the front-panel pushbuttons is also given in *Table 10.5*. See *Section 11: Front-Panel Interface* for more information on the front-panel pushbuttons.

The serial port commands at the different access levels offer varying levels of control:

- The Access Level 1 commands primarily allow the user to look at information only (settings, metering, etc.), not change it.
- The Access Level B commands primarily allow the user to operate output contacts or change the active setting group.
- The Access Level 2 commands primarily allow the user to change relay settings.

Again, a higher access level can access the serial port commands in a lower access level. The commands are shown in uppercase letters, but they can also be entered with lowercase letters.

Table 10.5 Serial Port Command Summary (Sheet 1 of 2)

Access Level	Prompt	Serial Port Command	Command Description	Corresponding Front-Panel Pushbutton
0	=	**ACC**	Go to Access Level 1	
1	=>	**BAC**	Go to Access Level B	
1	=>	**2AC**	Go to Access Level 2	
1	=>	**BRE**	Breaker monitor data	{OTHER}
1	=>	**COM**	MIRRORED BITS communications statistics	
1	=>	**DAT**	View/change date	{OTHER}
1	=>	**EVE**	Event reports	
1	=>	**GRO**	Display active setting group number	{GROUP}
1	=>	**HIS**	Event summaries/histories	{EVENTS}
1	=>	**IRI**	Synchronize to IRIG-B	
1	=>	**LDP**	Load profile report	
1	=>	**MET**	Metering data	{METER}
1	=>	**QUI**	Quit access level	
1	=>	**SER**	Sequential Events Recorder	
1	=>	**SHO**	Show/view settings	{SET}
1	=>	**SSI**	Voltage Sag/Swell/Interruption Report	
1	=>	**STA**	Relay self-test status	{STATUS}
1	=>	**TAR**	Display relay element status	{OTHER}
1	=>	**TIM**	View/change time	{OTHER}

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Table 10.5 Serial Port Command Summary (Sheet 2 of 2)

Access Level	Prompt	Serial Port Command	Command Description	Corresponding Front-Panel Pushbutton
1	=>	**TRI**	Trigger an event report	
B	==>	**BRE *n***	Preload/reset breaker wear	{OTHER}
B	==>	**CLO**	Close breaker	
B	==>	**GRO *n***	Change active setting group	{GROUP}
B	==>	**OPE**	Open breaker	
B	==>	**PUL**	Pulse output contact	{CNTRL}
2	=>>	**CON**	Control remote bit	
2	=>>	**COP**	Copy setting group	
2	=>>	**LOO**	Loopback	
2	=>>	**PAS**	Change passwords	{SET}
2	=>>	**SET**	Change settings	{SET}
2	=>>	**VER**	Show relay configuration and firmware version	{SET}

The relay responds with `Invalid Access Level` if a command is entered from an access level lower than the specified access level for the command. The relay responds:

```
Invalid Command
```

to commands not listed above or entered incorrectly.

Many of the command responses display the following header at the beginning:

```
FEEDER 1                        Date: 03/05/97    Time: 17:03:26.484
STATION A
```

The definitions are:

`FEEDER 1`: This is the RID setting (the relay is shipped with the default setting RID = FEEDER 1; see *Identifier Labels on page 9.48*).

`STATION A`: This is the TID setting (the relay is shipped with the default setting TID = STATION A; see *Identifier Labels*).

`Date`: This is the date the command response was given [except for relay response to the **EVE** command (Event), where it is the date the event occurred]. You can modify the date display format (Month/Day/Year or Year/Month/Day) by changing the DATE_F relay setting.

`Time`: This is the time the command response was given (except for relay response to the **EVE** command, where it is the time the event occurred).

The serial port command explanations that follow in *Command Explanations on page 10.14* are in the same order as the commands listed in *Table 10.5*.

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Command Explanations

Access Level 0 Commands

ACC, BAC, and 2AC Commands (Go to Access Level 1, B, or 2)

The **ACC**, **BAC**, and **2AC** commands provide entry to the multiple access levels. Different commands are available at the different access levels as shown in *Table 10.5*. Commands **ACC**, **BAC**, and **2AC** are explained together because they operate similarly.

ACC moves from Access Level 0 to Access Level 1.

BAC moves from Access Level 1 to Access Level B.

2AC moves from Access Level 1 or B to Access Level 2

Password Requirements

Passwords are required if the main board Password jumper is **not** in place (Password jumper = OFF). Passwords are not required if the main board Password jumper is in place (Password jumper = ON). Refer to *Table 2.6* and *Table 2.7* for Password jumper information. See *PAS Command (Change Passwords) on page 10.42* for the list of default passwords and for more information on changing passwords.

Access Level Attempt (Password Required)

Assume the following conditions: Password jumper = OFF (not in place), Access Level = 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the Password jumper is not in place, the relay asks for the Access Level 1 password to be entered:

```
Password: ?
```

The relay is shipped with the default Access Level 1 password shown in the table under *PAS Command (Change Passwords)*. At the prompt above, enter the default password and press the **<Enter>** key. The relay responds:

```
FEEDER 1                          Date: 03/05/97    Time: 08:31:10.361
STATION A

Level 1
=>
```

The => prompt indicates the relay is now in Access Level 1.

If the entered password is incorrect, the relay asks for the password again (`Password: ?`). The relay will ask up to three times. If the requested password is incorrectly entered three times, the relay closes the **ALARM** contact for one second and displays an invalid access message.

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Access Level Attempt (Password Not Required)

Assume the following conditions: Password jumper = ON (in place), Access Level = 0.

At the Access Level 0 prompt, enter the **ACC** command:

```
=ACC <Enter>
```

Because the Password jumper is in place, the relay does not ask for a password; it goes directly to Access Level 1. The relay responds:

```
FEEDER 1                          Date: 03/05/97    Time: 08:31:10.361
STATION A

Level 1
=>
```

The => prompt indicates the relay is now in Access Level 1.

The above two examples demonstrate how to go from Access Level 0 to Access Level 1. The procedure to go from Access Level 1 to Access Level B, Access Level 1 to Access Level 2, or Access Level B to Access Level 2 is much the same, with command **BAC** or **2AC** entered at the access level screen prompt. The relay closes the **ALARM** contact for one second after a successful Level B or Level 2 access. If access is denied, the **ALARM** contact closes for one second.

Access Level 1 Commands

BRE Command (Breaker Monitor Data)

Use the **BRE** command to view the breaker monitor report.

```
=>BRE <Enter>

FEEDER 1                          Date: 02/02/97    Time: 08:40:14.802
STATION A

Rly Trips=      9
 IA=       40.7 IB=       41.4 IC=       53.8 kA

Ext Trips=      3
 IA=        0.8 IB=        0.9 IC=        1.1 kA

Percent wear: A=   4 B=   4 C=   6

LAST RESET 12/27/96 15:32:59
=>
```

See *BRE n Command (Preload/Reset Breaker Wear) on page 10.37* and *Breaker Monitor on page 8.2* for further details on the breaker monitor.

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COMM Command (Communication Data–Available in Firmware Versions 6 and 7)

The **COMM** command displays integral relay-to-relay (MIRRORED BITS) communications data. For more information on MIRRORED BITS communications, see *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*. To get a summary report, enter the command with the channel parameter (**A** or **B**).

```
=>COMM A <Enter>

FEEDER 1                          Date: 04/20/98    Time: 18:36:11.748
STATION A
FID=SEL-351S-5-R100-V0-Z001001-D199908xx       CID=xxxx
Summary for Mirrored Bits channel A

For 04/20/01 18:36:09.279 to 04/20/01 18:36:11.746

    Total failures      1                   Last error  Relay Disabled
    Relay Disabled      1
    Data error          0                   Longest Failure     2.458 sec.
    Re-Sync             0
    Underrun            0                   Unavailability  0.996200
    Overrun             0
    Parity error        0
    Framing error       0                   Loopback     0
=>
```

If only one MIRRORED BITS port is enabled, the channel specifier may be omitted. Use the **L** parameter to get a summary report, followed by a listing of the COMM records.

```
=>COMM L <Enter>

FEEDER 1                          Date: 02/20/98    Time: 18:37:36.125
STATION A

FID=SEL-351S-5-R100-V0-Z001001-D199908xx       CID=xxxx
Summary for Mirrored Bits channel A

For 02/05/98 17:18:12.993 to 02/20/98 18:37:36.123

    Total failures      4                   Last error  Relay Disabled
    Relay Disabled      2
    Data error          0                   Longest Failure     2.835 sec.
    Re-Sync             0
    Underrun            1                   Unavailability  0.000003
    Overrun             0
    Parity error        1
    Framing error       0                   Loopback     0

    Failure                Recovery

#   Date     Time          Date     Time          Duration  Cause
1   02/20/98 18:36:09.279  02/20/98 18:37:36.114     2.835  Relay Disabled
2   02/14/98 13:18:09.236  02/14/98 13:18:09.736     0.499  Parity error
3   02/08/98 11:43:35.547  02/08/98 11:43:35.637     0.089  Underrun
4   02/05/98 17:18:12.993  02/05/98 17:18:13.115     0.121  Relay Disabled

=>
```

There may be up to 255 records in the extended report.

1. To limit the number of COMM records displayed in the report to the 10 most recent records, type **COMM 10 L <Enter>**.
2. To select lines 10–20 of the COMM records for display in the report, type **COMM 10 20 L <Enter>**.
3. To reverse the order of the COMM records in the report, supply a range of row numbers, with the larger number first, i.e., **COMM 40 10 L <Enter>**.

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4. To display all the COMM records that started on a particular day, supply that date as a parameter, i.e., **COMM 2/8/98 L <Enter>**.
5. To display all the COMM records that started between a range of dates, supply both dates as parameters, i.e., **COMM 2/21/98 2/7/98 L <Enter>**.
6. Reversing the order of the dates will reverse the order of the records in the report.
7. To receive a summary report for a subset of the records, use one of the above methods while omitting the **L** parameter.
8. To clear the COMM records, type **COMM C <Enter>**. The prompting message: `Are you sure (Y/N) ?` is displayed.
    a. Typing **N <Enter>** aborts the clearing operation with the message `Canceled`.
    b. If both MIRRORED BITS channels are enabled, omitting the channel specifier in the clear command will cause both channels to be cleared.

DAT Command (View/Change Date)

DAT displays the date stored by the internal calendar/clock. If the date format setting DATE_F is set to MDY, the date is displayed as month/day/year. If the date format setting DATE_F is set to YMD, the date is displayed as year/month/day.

NOTE: After setting the date, allow at least 60 seconds before powering down the relay or the new setting may be lost.

To set the date:

Step 1. Type **DATE mm/dd/yy <Enter>** if the DATE_F setting is MDY.

Step 2. If the DATE_F is set to YMD, enter **DATE yy/mm/dd <Enter>**.

To set the date to June 1, 1997, enter:

```
=>DATE 6/1/98 <Enter>

6/1/98
=>
```

You can separate the month, day, and year parameters with spaces, commas, slashes, colons, and semicolons.

EVE Command (Event Reports)

Use the **EVE** command to view event reports. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER* for further details on retrieving event reports.

GRO Command (Display Active Setting Group Number)

Use the **GRO** command to display the active settings group number. See *GRO n Command (Change Active Setting Group) on page 10.38* and *Multiple Setting Groups on page 7.19* for further details on settings groups.

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HIS Command (Event Summaries/History)

HIS *x* displays event summaries or allows you to clear event summaries (and corresponding event reports) from nonvolatile memory.

If no parameters are specified with the **HIS** command:

```
=HIS <Enter>
```

the relay displays the most recent event summaries in reverse chronological order.

If ***x*** is a number (1–29):

```
=HIS x <Enter>
```

the relay displays the ***x*** most recent event summaries. The maximum number of available event summaries is a function of the LER (length of event report) setting.

If ***x*** is "C" or "c", the relay clears the event summaries and all corresponding event reports from nonvolatile memory.

The event summaries include the date and time the event was triggered, the type of event, the fault location, the maximum phase current in the event, the power system frequency, the number of the active setting group, the reclose shot count, and the front-panel targets.

To display the relay event summaries, enter the following command:

```
=>HIS <Enter>

FEEDER 1                          Date: 02/01/97    Time: 08:40:16.740
STATION A

#     DATE      TIME     EVENT   LOCAT  CURR  FREQ GRP SHOT TARGETS

1  02/01/97 08:33:00.365 TRIG  $$$$$$$     1 60.00  3    2   10000000   10000000
2  01/31/97 20:32:58.361 ER    $$$$$$$   231 60.00  2    2   10000000   10000000
3  01/29/97 07:30:11.055 AG T     9.65  2279 60.00  3    2   11100100   01010010

=>
```

The fault locator has influence over information in the EVENT and LOCAT columns. If the fault locator is enabled (enable setting EFLOC = Y), the fault locator will attempt to run if the event report is generated by a trip (assertion of TRIP Relay Word bit) or other programmable event report trigger condition (SELOGIC® control equation setting ER).

If the fault locator runs successfully, the location is listed in the LOCAT column, and the event type is listed in the EVENT column:

- AG for A-phase to ground faults
- BG for B-phase to ground faults
- CG for C-phase to ground faults
- AB for A–B phase-to-phase faults
- BC for B–C phase-to-phase faults
- CA for C–A phase-to-phase faults
- ABG for A–B phase-to-phase to ground faults

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BCG	for B–C phase-to-phase to ground faults
CAG	for C–A phase-to-phase to ground faults
ABC	for three-phase faults
A	for A-phase faults (Petersen Coil or Ungrounded/High-Impedance Grounded Systems only)
B	for B-phase faults (Petersen Coil or Ungrounded/High-Impedance Grounded Systems only)
C	for C-phase faults (Petersen Coil or Ungrounded/High-Impedance Grounded Systems only)

If a trip occurs in the same event report, a T is appended to the event type (e.g., AG T).

If the fault locator does not run successfully, $$$$$$$ is listed in the LOCAT column. If the fault locator is disabled (enable setting EFLOC = N), the LOCAT column is left blank. For either of these cases where the fault locator does not run, the event type listed in the EVENT column is one of the following:

TRIP	event report generated by assertion of Relay Word bit TRIP
ER	event report generated by assertion of SELOGIC control equation event report trigger condition setting ER
PULSE	event report generated by execution of the **PUL** (Pulse) command
TRIG	event report generated by execution of the **TRI** (Trigger) command

The TARGETS column displays the front panel target LED status during the event in binary format. The top row of target LEDs are shown first and the bottom row of LEDs are shown next under the TARGETS column. A 1 indicates the LED was illuminated during the event and a 0 the LED was extinguished.

For example, 11100100 01010010 under the TARGETS column is interpreted as follows (first four digits):

1 → **ENABLED** LED illuminated

1 → **TRIP** LED illuminated

1 → **INST** LED illuminated

0 → **COMM** LED extinguished

For more information on front-panel target LEDs, see *Section 5: Trip and Target Logic*. For more information on event reports, see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

IRI Command (Synchronize to IRIG-B Time Code)

IRI directs the relay to read the demodulated IRIG-B time code at the serial port input.

To force the relay to synchronize to IRIG-B, enter the following command:

```
=>IRI <Enter>
```


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If the relay successfully synchronizes to IRIG, it sends the following header and access level prompt:

```
FEEDER 1                          Date: 03/05/97    Time: 10:15:09.609
STATION A

=>
```

If no IRIG-B code is present at the serial port input or if the code cannot be read successfully, the relay responds:

```
IRIG-B DATA ERROR

=>
```

If an IRIG-B signal is present, the relay synchronizes its internal clock with IRIG-B. It is not necessary to issue the **IRI** command to synchronize the relay clock with IRIG-B. Use the **IRI** command to determine if the relay is properly reading the IRIG-B signal.

LDP Command (Load Profile Report–Available in Firmware Versions 6 and 7)

Use the **LDP** command to view the Load Profile report. For more information on Load Profile reports, see *Section 8: Breaker Monitor, Metering, and Load Profile Functions*.

MET Command (Metering Data)

NOTE: If the serial port AUTO setting is DTA, the SEL-351S response for **MET**, **MET X**, and **MET D** will be formatted differently on that serial port than shown below.

The **MET** commands provide access to the relay metering data. Metered quantities include phase voltages and currents, sequence component voltages and currents, power, frequency, substation battery voltage, energy, demand, and maximum/minimum logging of selected quantities. To make the extensive amount of meter information manageable, the relay divides the displayed information into five groups: Instantaneous, Demand, Energy, Maximum/Minimum, and Synchrophasors.

MET k–Instantaneous Metering

The **MET k** command displays instantaneous magnitudes (and angles if applicable) of the following quantities:

Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
Voltages	$V_{A,B,C,S}$	Wye-connected voltage inputs (kV primary)
	$V_{AB,BC,CA,S}$	Delta-connected voltage inputs (kV primary)
Power	$MW_{A,B,C}$	Single-phase megawatts (wye-connected voltage inputs only)
	MW_{3P}	Three-phase megawatts
	$MVAR_{A,B,C}$	Single-phase megavars (wye-connected voltage inputs only)
	$MVAR_{3P}$	Three-phase megavars

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Power Factor	$PF_{A,B,C}$	Single-phase power factor; leading or lagging (wye-connected voltage inputs only)
	PF_{3P}	Three-phase power factor; leading or lagging
Sequence	I_1, $3I_2$, $3I_0$	Positive-, negative-, and zero-sequence currents (A primary)
	V_1, V_2	Positive- and negative-sequence voltages (kV primary)
	$3V_0$	Zero-sequence voltage (kV primary, wye-connected voltage inputs only)
Frequency	FREQ (Hz)	Instantaneous power system frequency (measured on voltage channel **VA** or from voltage V1)
Station DC	VDC (V)	Voltage at **POWER** terminals (input into station battery monitor)

The angles are referenced to voltage V_A {wye-connected} or V_{AB} {delta-connected} if the reference voltage is greater than 13 V secondary; otherwise, the angles are referenced to A-phase current. The angles range from –179.99 to 180.00 degrees.

To view instantaneous metering values, enter the command:

```
=>MET k <Enter>
```

where *k* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. If *k* is not specified, the meter report is displayed once. The output from an SEL-351S with wye-connected voltage inputs is shown:

```
=>MET <Enter>

FEEDER 1                          Date: 02/01/97    Time: 15:00:52.615
STATION A

                  A         B         C         N         G
I MAG (A)      195.146   192.614   198.090     0.302     4.880
I ANG (DEG)     -8.03   -128.02    111.89     52.98     81.22

                  A         B         C         S
V MAG (KV)     11.691    11.686    11.669    11.695
V ANG (DEG)     0.00   -119.79    120.15     0.05

                  A         B         C        3P
MW              2.259     2.228     2.288     6.774
MVAR            0.319     0.322     0.332     0.973
PF              0.990     0.990     0.990     0.990
                LAG       LAG       LAG       LAG

                 I1       3I2       3I0        V1        V2       3V0
MAG            195.283     4.630     4.880    11.682     0.007     0.056
ANG   (DEG)     -8.06   -103.93     81.22     0.12    -80.25    -65.83

FREQ (Hz)      60.00              VDC (V)      129.5
=>
```

NOTE: See Small Signal Cutoff for Metering on page 8.32 for metering behavior with small signals.

MET X k—Extended Instantaneous Metering

The **MET X *k*** command displays the same data as the **MET *k*** command with the addition of calculated phase-to-phase voltage quantities Vab, Vbc, Vca, and the Vbase quantity used by the Voltage Sag/Swell/Interruption Recorder.

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Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
Voltages	$V_{A,B,C,S}$	Phase-to-neutral voltage inputs (kV primary) (wye-connected)
	$V_{AB,BC,CA,S}$	Phase-to-phase voltages (kV primary) (delta-connected)
	$V_{AB,BC,CA}$	Calculated phase-to-phase voltages (kV primary) (wye-connected)
	Vbase	Demand average value based on V1, subject to the operating logic of the SSI Elements (see *Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements*) when setting ESSI=Y in the active setting group. Vbase only registers a value after valid three-phase voltage signals have been present since the last Vbase initializing. The Vbase quantity is used in the SEL-351S-7 relay model. Vbase is always shown as 0.00 kV in SEL-351S-5, -6 relay models.
Power	$MW_{A,B,C}$	Single-phase megawatts (wye-connected voltage inputs only)
	MW_{3P}	Three-phase megawatts
	$MVAR_{A,B,C}$	Single-phase megavars (wye-connected voltage inputs only)
	$MVAR_{3P}$	Three-phase megavars
Power Factor	$PF_{A,B,C}$	Single-phase power factor; leading or lagging (wye-connected voltage inputs only)
	PF_{3P}	Three-phase power factor; leading or lagging
Sequence	I_1, $3I_2$, $3I_0$	Positive-, negative-, and zero-sequence currents (A primary)
	V_1, V_2	Positive- and negative-sequence voltages (kV primary)
	$3V_0$	Zero-sequence voltage (kV primary) (wye-connected voltage inputs only)
Frequency	FREQ (Hz)	Instantaneous power system frequency (measured on voltage channel **VA** or from voltage V1)
Station DC	VDC (V)	Voltage at **POWER** terminals (input into station battery monitor)

The angles are referenced to voltage V_A {wye-connected} or V_{AB} {delta-connected} if the reference voltage is greater than 13 V secondary; otherwise, the angles are referenced to A-phase current. The angles range from –179.99 to 180.00 degrees.

To view instantaneous metering values, enter the command:

```
=>MET X k <Enter>
```


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where *k* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. If *k* is not specified, the meter report is displayed once. The output from an SEL-351S with wye-connected voltage inputs is shown:

NOTE: See Small Signal Cutoff for Metering on page 8.32 for metering behavior with small signals.

```
=>MET X <Enter>

FEEDER 12                          Date: 12/12/00    Time: 11:31:22.626
SUB B
                    A         B         C         N         G
I MAG (A)        30.302    36.558    29.254     7.454     7.526
I ANG (DEG)      -2.02   -121.88    119.60   -115.20   -117.52

                    A         B         C         S
V MAG (KV)       14.761    14.636    14.880    15.235
V ANG (DEG)       0.00   -119.95    120.94     29.93

                   AB        BC        CA        Vbase
V MAG (KV)       25.452    25.448    25.790    14.759
V ANG (DEG)      29.89     -89.23    150.34

                    A         B         C         3P
MW                  0.447     0.535     0.435     1.417
MVAR                0.016     0.018     0.010     0.044
PF                  0.999     0.999     1.000     1.000
                    LAG       LAG       LAG       LAG

                   I1        3I2       3I0        V1        V2        3V0
MAG              32.036     6.196     7.526    14.759     0.131     0.212
ANG   (DEG)      -1.47    106.38   -117.52      0.33    -59.08    157.40

FREQ (Hz)       60.00                VDC (V)      125.6

=>
```

MET D—Demand Metering

The **MET D** command displays the demand and peak demand values of the following quantities:

Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
	$3I_2$	Negative-sequence current (A primary)
Power	$MW_{A,B,C}$	Single-phase megawatts (wye-connected voltage inputs only)
	MW_{3P}	Three-phase megawatts
	$MVAR_{A,B,C}$	Single-phase megavars (wye-connected voltage inputs only)
	$MVAR_{3P}$	Three-phase megavars
Reset Time	Demand, Peak	Last time the demands and peak demands were reset

To view demand metering values, enter the command:

```
=>MET D <Enter>
```


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The output from an SEL-351S with wye-connected voltage inputs is shown:

```
=>MET D <Enter>

FEEDER 1                          Date: 02/01/97    Time: 15:08:05.615
STATION A
            IA        IB        IC        IN        IG        3I2
DEMAND     188.6     186.6     191.8       0.2       4.5       4.7
PEAK       188.6     186.6     191.8       0.3       4.5       4.7
              MWA       MWB       MWC      MW3P     MVARA     MVARB     MVARC    MVAR3P
DEMAND IN     0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
PEAK IN       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
DEMAND OUT    2.2       2.2       2.2       6.6       0.3       0.3       0.3       0.9
PEAK OUT      3.1       3.1       3.1       9.3       0.4       0.4       0.4       1.2
LAST DEMAND RESET 01/27/97 15:31:51.238   LAST PEAK RESET 01/27/97 15:31:56.239

=>
```

NOTE: See Small Signal Cutoff for Metering on page 8.32 for metering behavior with small signals.

Reset the accumulated demand values using the **MET RD** command. Reset the peak demand values using the **MET RP** command. For more information on demand metering, see *Demand Metering on page 8.20*.

MET E—Energy Metering

The **MET E** command displays the following quantities:

Energy	$MWh_{A,B,C}$	Single-phase megawatt hours (in and out; wye-connected voltage inputs only)
	MWh_{3P}	Three-phase megawatt hours (in and out)
	$MVARh_{A,B,C}$	Single-phase megavar hours (in and out; wye-connected voltage inputs only)
	$MVARh_{3P}$	Three-phase megavar hours (in and out)
Reset Time		Last time the energy meter was reset

To view energy metering values, enter the command:

```
=>MET E <Enter>
```

The output from an SEL-351S with wye-connected voltage inputs is shown:

```
=>MET E <Enter>

FEEDER 1                          Date: 02/01/97    Time: 15:11:24.056
STATION A
        MWhA      MWhB      MWhC     MWh3P    MVARhA    MVARhB    MVARhC   MVARh3P
IN       0.0       0.0       0.0       0.0       0.0       0.0       0.0       0.0
OUT     36.0      36.6      36.7     109.2       5.1       5.2       5.3      15.6
LAST RESET 01/31/97 23:31:28.864

=>
```

NOTE: See Small Signal Cutoff for Metering on page 8.32 for metering behavior with small signals.

Reset the energy values using the **MET RE** command. For more information on energy metering, see *Energy Metering on page 8.29*.

Accumulated energy metering values function like those in an electromechanical energy meter. When the energy meter reaches 99999 MWh or 99999 MVARh, it starts over at zero. In firmware versions released prior to November 2002, the SEL-351S energy meter registered dollar signs ($$) after reaching the upper metering limit.

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MET M—Maximum/Minimum Metering

The **MET M** command displays the maximum and minimum values of the following quantities:

Currents	$I_{A,B,C,N}$	Input currents (A primary)
	I_G	Residual ground current (A primary; $I_G = 3I_0 = I_A + I_B + I_C$)
Voltages	$V_{A,B,C,S}$	Wye-connected voltage inputs (kV primary)
	$V_{AB,BC,CA,S}$	Delta-connected voltage inputs (kV primary)
Power	MW_{3P}	Three-phase megawatts
	$MVAR_{3P}$	Three-phase megavars
Reset Time		Last time the maximum/minimum meter was reset

To view maximum/minimum metering values, enter the command:

```
=>MET M <Enter>
```

The output from an SEL-351S with wye-connected voltage inputs is shown:

```
=>MET M <Enter>

FEEDER 1                          Date: 02/01/97    Time: 15:16:00.239
STATION A
           Max    Date      Time             Min    Date      Time
IA(A)      196.8  02/01/97  15:00:42.574      30.0  02/01/97  14:51:02.391
IB(A)      195.0  02/01/97  15:05:19.558      31.8  02/01/97  14:50:55.536
IC(A)      200.4  02/01/97  15:00:42.578      52.2  02/01/97  14:51:02.332
IN(A)       42.6  02/01/97  14:51:02.328      42.6  02/01/97  14:51:02.328
IG(A)       42.0  02/01/97  14:50:55.294      42.0  02/01/97  14:50:55.294
VA(kV)      11.7  02/01/97  15:01:01.576       3.4  02/01/97  15:00:42.545
VB(kV)      11.7  02/01/97  15:00:42.937       2.4  02/01/97  15:00:42.541
VC(kV)      11.7  02/01/97  15:00:42.578       3.1  02/01/97  15:00:42.545
VS(kV)      11.7  02/01/97  15:01:01.576       3.4  02/01/97  15:00:42.545
MW3P         6.9  02/01/97  15:00:44.095       0.4  02/01/97  15:00:42.545
MVAR3P       1.0  02/01/97  15:00:42.578       0.1  02/01/97  15:00:42.545
LAST RESET 01/27/97 15:31:41.237
=>
```

Reset the maximum/minimum values using the **MET RM** command. All values will display RESET until new maximum/minimum values are recorded. For more information on maximum/minimum metering, see *Maximum/Minimum Metering on page 8.30*.

MET PM—Synchrophasor Metering

The **MET PM** command (available when TSOK = logical 1 and EPMU = Y) displays the synchrophasor measurements. For more information, see *View Synchrophasors by Using the MET PM Command on page L.12*.

To view synchrophasor metering values, enter the command:

```
=>MET PM [time] [k] <Enter>
```

where *time* is an optional parameter to specify the exact time to display the synchrophasor measurements and *k* is an optional parameter to specify the number of times (1–32767) to repeat the meter display. If *time* is not specified, the meter report is displayed at the current time. If *k* is not specified, the meter

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report is displayed once. The *time* and *k* parameters cannot be used simultaneously. The time should be input in 24-hour format (i.e., 15:11:00.000). If fractional seconds are input, they will be truncated. If the TSOK Relay Word bit is not set when at the specified trigger time, the relay responds:

```
Aborted: Relay word bit TSOK is not set.

=>
```

When valid time parameters are entered, the relay responds:

```
Synchronized Phasor Measurement Data Will be Displayed at hh:mm:ss.000

=>
```

One **MET PM [*time*]** command may be pending on a single port at any one time. If a **MET PM [*time*]** command is entered while another command is pending, the old request will be cancelled and the new request will be pending. **MET PM** commands entered without the time parameter will not affect any pending **MET PM [*time*]** commands.

The output from an SEL-351S is shown:

```
=>MET PM<Enter>

                                  Date: 03/31/2007    Time: 15:51:00.000
Time Quality   Maximum time synchronization error:    0.000 (ms)  TSOK = 1


Synchrophasors
                     Phase Voltages             Pos. Sequence Voltage
                  VA         VB         VC                 V1
MAG (kV)          11.691     11.686     11.669             11.682
ANG (DEG)        129.896     10.262   -111.764            129.485

                     Phase Currents             Pos. Sequence Current
                  IA         IB         IC                 I1
MAG (A)          195.146    192.614    198.090            198.283
ANG (DEG)        114.930     -2.786   -120.238            117.338

FREQ (Hz) 60.029

Digitals

SV3     SV4     SV5     SV6     SV7     SV8     SV9     SV10
 0       0       0       0       0       0       0       0
SV11    SV12    SV13    SV14    SV15    SV16
 0       0       0       0       0       0

=>
```

QUI Command (Quit Access Level)

The **QUI** command returns the relay to Access Level 0.

To return to Access Level 0, enter the command:

```
=>QUI <Enter>
```


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The relay sets the port access level to 0 and responds:

```
FEEDER 1                          Date: 03/05/97    Time: 08:55:33.986
STATION A

=
```

The = prompt indicates the relay is back in Access Level 0.

The **QUI** command terminates the SEL Distributed Port Switch Protocol (LMD) connection if it is established [see *Appendix C: SEL Distributed Port Switch Protocol* for more information].

SER Command (Sequential Events Recorder Report)

Use the **SER** command to view the Sequential Events Recorder report. For more information on SER reports, see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

SHO Command (Show/View Settings)

Use the **SHO** command to view relay settings, SELOGIC control equations, Global Settings, Serial Port settings, Sequential Events Recorder (SER) settings, and Text Label settings. Below are the **SHO** command options.

SHO *n* Show relay settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.

SHO L *n* Show SELOGIC control equation settings. *n* specifies the setting group (1, 2, 3, 4, 5, or 6); *n* defaults to the active setting group if not listed.

SHO G Show Global settings.

SHO P *n* Show Serial Port settings. *n* specifies the port (1, 2, 3, or F); *n* defaults to the active port if not listed.

SHO R Show Sequential Events Recorder (SER) and Load Profile Recorder (LDP) settings. (LDP only available in firmware versions 6 and 7).

SHO T Show Text Label settings.

You may append a setting name to each of the commands to specify the first setting to display (e.g., **SHO 1 E50P** displays the setting Group 1 relay settings starting with setting E50P). The default is the first setting.

The **SHO** commands display only the enabled settings. To display all settings, including disabled/hidden settings, append an **A** to the **SHO** command (e.g., **SHO 1 A**).

Below are sample **SHO** commands for the SEL-351S, showing the **factory default settings** (only model 0351S*xxx*3 firmware version 7; see *Table 1.2*). The factory default settings for the other SEL-351S models are similar.

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```
=>SHO <Enter>

Group 1
Group Settings:

RID   =FEEDER 1                        TID   =STATION A
CTR   = 120      CTRN  = 120
PTR   = 180.00   PTRS  = 180.00   VNOM  = 67.00
Z1MAG = 2.14     Z1ANG = 68.86    Z0MAG = 6.38     Z0ANG = 72.47
LL    = 4.84
E50P  = 1        E50N  = N        E50G  = N        E50Q  = N
E51P  = 1        E51N  = N        E51G  = 1        E51Q  = N
E32   = N        ELOAD = N        ESOTF = N        EVOLT = N
E25   = N        EFLOC = Y        ELOP  = N        ECOMM = N
E81   = N        E79   = 1        ESV   = 1        EDEM  = THM
EPWR  = N        ESSI  = N
50P1P = 15.00
67P1D = 0.00
50PP1P= OFF
51P1P = 6.00     51P1C = U3       51P1TD= 3.00     51P1RS= N
51P1CT= 0.00     51P1MR= 0.00
51G1P = 1.50     51G1C = U3       51G1TD= 1.50     51G1RS= N

Press RETURN to continue
51G1CT= 0.00     51G1MR= 0.00
79OI1 = 300.00
79RSD = 1800.00  79RSLD= 300.00   79CLSD= 0.00
DMTC  = 5
PDEMP = 5.00     NDEMP = 1.500    GDEMP = 1.50     QDEMP = 1.50
TDURD = 9.00     CFD   = 60.00    3POD  = 1.50     50LP  = 0.25
SV1PU = 3.00     SV1DO = 0.00

=>
```

```
=>SHO L <Enter>

SELogic group 1

SELogic Control Equations:
TR    =51P1T + 51G1T + 67P1 + PB10 + OC
TRCOMM=0
TRSOTF=0
DTT   =0
ULTR  =!(51P1 + 51G1)
PT1   =0
LOG1  =0
PT2   =0
LOG2  =0
BT    =0
52A   =IN101
CL    =(PB9 * LT4 + CC) * LT5
ULCL  =TRIP + !(LT5 + CLOSE) + !(LT4 + CLOSE + CC + 79CY)
79RI  =TRIP
79RIS =52A + 79CY
79DTL =(!LT2 + !LT5) * (TRIP + !52A) + PB10 + OC
79DLS =79LO

Press RETURN to continue
79SKP =0
79STL =TRIP
79BRS =0
79SEQ =0
79CLS =1
SET1  =!LT1 * PB1 * LT4
RST1  =LT1 * PB1 * LT4
SET2  =!LT2 * LT5 * PB2 * LT4
RST2  =LT2 * PB2 * LT4 + !LT5 + !(79RS + 79CY + 79LO)
SET3  =!LT3 * PB3 * LT4
RST3  =LT3 * PB3 * LT4
SET4  =!LT4 * PB5
RST4  =LT4 * PB5
SET5  =!LT5 * PB6 * LT4
RST5  =LT5 * PB6 * LT4
SET6  =!LT6 * PB7 * LT4
RST6  =LT6 * PB7 * LT4
SET7  =!LT7 * PB8 * LT4
RST7  =LT7 * PB8 * LT4
SET8  =0
```

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```
Press RETURN to continue
RST8  =0
SET9  =0
RST9  =0
SET10 =0
RST10 =0
SET11 =0
RST11 =0
SET12 =0
RST12 =0
SET13 =0
RST13 =0
SET14 =0
RST14 =0
SET15 =0
RST15 =0
SET16 =0
RST16 =0
67P1TC=SHO
67P2TC=1
67P3TC=1

Press RETURN to continue
67P4TC=1
67N1TC=1
67N2TC=1
67N3TC=1
67N4TC=1
67G1TC=1
67G2TC=1
67G3TC=1
67G4TC=1
67Q1TC=1
67Q2TC=1
67Q3TC=1
67Q4TC=1
51P1TC=1
51N1TC=1
51G1TC=LT1
51P2TC=1
51N2TC=1
51G2TC=1
51QTC =1

Press RETURN to continue
SV1   =FAULT
SV2   =0
SV3   =0
SV4   =0
SV5   =0
SV6   =0
SV7   =0
SV8   =0
SV9   =0
SV10  =0
SV11  =0
SV12  =0
SV13  =0
SV14  =0
SV15  =0
SV16  =0

OUT101=TRIP
OUT102=CLOSE
OUT103=0
OUT104=0
```

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```
Press RETURN to continue
OUT105=0
OUT106=0
OUT107=0
OUT201=0
OUT202=0
OUT203=0
OUT204=0
OUT205=0
OUT206=0
OUT207=0
OUT208=0
OUT209=0
OUT210=0
OUT211=0
OUT212=0
LED1  =LT1
LED2  =LT2
LED3  =0
LED4  =!SG1
LED5  =!LT4

Press RETURN to continue
LED6  =!LT5
LED7  =0
LED8  =0
LED9  =52A
LED10 =!52A
LED12 =TRIP
LED13 =FAULT * !SV1T
LED14 =COMMT
LED15 =SOTFT
LED16 =67P1
LED17 =51P1T + 51G1T
LED18 =81D1T
LED19 =79RS
LED20 =79CY
LED21 =79LO
LED25 =51G1
LED26 =0
DP1   =0
DP2   =0
DP3   =0

Press RETURN to continue
DP4   =0
DP5   =0
DP6   =0
DP7   =0
DP8   =0
DP9   =0
DP10  =0
DP11  =0
DP12  =0
DP13  =0
DP14  =0
DP15  =0
DP16  =0
SS1   =!SG1 * PB4 * LT4
SS2   =SG1 * PB4 * LT4
SS3   =0
SS4   =0
SS5   =0
SS6   =0
ER    =/51P1 + /51G1

Press RETURN to continue
FAULT =51P1 + 51G1
BSYNCH=52A
CLMON =0
BKMON =TRIP
E32IV =1
TMB1A =0
TMB2A =0
TMB3A =0
TMB4A =0
TMB5A =0
TMB6A =0
```

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```
                                                        (Continued from previous page)
TMB7A =0
TMB8A =0
TMB1B =0
TMB2B =0
TMB3B =0
TMB4B =0
TMB5B =0
TMB6B =0
TMB7B =0

Press RETURN to continue
TMB8B =0
=>
```

=>SHO G <Enter>

```
Global Settings:
PTCONN= WYE       VSCONN= VS       TGR   = 0.00
NFREQ = 60        PHROT = ABC      DATE_F= MDY
FP_TO = 15        SCROLD= 2        FPNGD = IG
LER   = 15        PRE   = 4        DCLOP = OFF      DCHIP = OFF
IN101D= 0.50      IN102D= 0.50     IN103D= 0.50     IN104D= 0.50
IN105D= 0.50      IN106D= 0.50
IN201D= 0.50      IN202D= 0.50     IN203D= 0.50     IN204D= 0.50
IN205D= 0.50      IN206D= 0.50     IN207D= 0.50     IN208D= 0.50

EBMON = Y         COSP1 = 10000    COSP2 = 150      COSP3 = 12
KASP1 = 1.20      KASP2 = 8.00     KASP3 = 20.00
LED12L= Y         LED13L= Y        LED14L= Y        LED15L= Y
LED16L= Y         LED17L= Y        LED18L= Y        LED19L= N
LED20L= N         LED21L= N        LED25L= Y        LED26L= Y
RSTLED= Y
PB9D  = 0.00      PB10D = 0.00
EPMU  = N
=>
```

=>SHO P <Enter>

```
Port F

PROTO = SEL
SPEED = 2400      BITS  = 8        PARITY= N        STOP  = 1
T_OUT = 15        AUTO  = N        RTSCTS= N        FASTOP= N

=>
```

=>SHO R <Enter>

```
Sequential Events Recorder trigger lists:
SER1  =TRIP,51P1T,51G1T,67P1,PB10,OC
SER2  =CLOSE,52A,CF,79RS,79CY,79LO,SH0,SH1,SH2,SH3,SH4,PB9,CC
SER3  =0

Load Profile settings:
LDLIST=0
LDAR  = 15

=>
```


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```
=>SHO T <Enter>

Text Labels:
NLB1  =               CLB1  =        SLB1  =        PLB1  =
NLB2  =               CLB2  =        SLB2  =        PLB2  =
NLB3  =               CLB3  =        SLB3  =        PLB3  =
NLB4  =               CLB4  =        SLB4  =        PLB4  =
NLB5  =               CLB5  =        SLB5  =        PLB5  =
NLB6  =               CLB6  =        SLB6  =        PLB6  =
NLB7  =               CLB7  =        SLB7  =        PLB7  =
NLB8  =               CLB8  =        SLB8  =        PLB8  =
NLB9  =               CLB9  =        SLB9  =        PLB9  =
NLB10 =               CLB10 =        SLB10 =        PLB10 =
NLB11 =               CLB11 =        SLB11 =        PLB11 =
NLB12 =               CLB12 =        SLB12 =        PLB12 =
NLB13 =               CLB13 =        SLB13 =        PLB13 =
NLB14 =               CLB14 =        SLB14 =        PLB14 =
NLB15 =               CLB15 =        SLB15 =        PLB15 =
NLB16 =               CLB16 =        SLB16 =        PLB16 =
DP1_1 =                 DP1_0 =

Press RETURN to continue
DP2_1 =                 DP2_0 =
DP3_1 =                 DP3_0 =
DP4_1 =                 DP4_0 =
DP5_1 =                 DP5_0 =
DP6_1 =                 DP6_0 =
DP7_1 =                 DP7_0 =
DP8_1 =                 DP8_0 =
DP9_1 =                 DP9_0 =
DP10_1=                 DP10_0=
DP11_1=                 DP11_0=
DP12_1=                 DP12_0=
DP13_1=                 DP13_0=
DP14_1=                 DP14_0=
DP15_1=                 DP15_0=
DP16_1=                 DP16_0=
79LL  =SET RECLOSURES 79SL  =RECLOSE COUNT

=>
```

SSI Command (Voltage Sag/Swell/Interruption Report–Available in Firmware Version 7)

Use the **SSI** command to view the voltage Sag, Swell, and Interruption report. For more information on SSI reports, see *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

STA Command (Relay Self-Test Status)

The **STA** command displays the status report, showing the relay self-test information.

To view a status report, enter the command:

```
=>STA n <Enter>
```

where *n* is an optional parameter to specify the number of times (1–32767) to repeat the status display. If *n* is not specified, the status report is displayed once. A sample output of an SEL-351S is shown:

```
=>STA <Enter>

FEEDER 1                          Date: 02/01/97    Time: 12:21:48.226
STATION A
FID=SEL-351S-5-R100-V0-Z001001-D199908xx       CID=xxxx
```

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```
SELF TESTS

W=Warn    F=Fail
       IA      IB      IC      IN      VA      VB      VC      VS      MOF
OS     -5     -19      -9     -16       3       9      -6      15       3

       +5V_PS  +5V_REG -5V_REG +12V_PS -12V_PS +15V_PS -15V_PS
PS      4.92    5.06   -4.95    12.03  -12.07   14.92  -14.82

       TEMP    RAM     ROM     A/D     CR_RAM  EEPROM  IO_BRD
        26.8   OK      OK      OK      OK      OK      OK

Relay Enabled
```

STA Command Row and Column Definitions

FID	FID is the firmware identifier string. It identifies the firmware revision.
CID	CID is the firmware checksum identifier.
OS	OS = Offset; displays measured dc offset voltages in millivolts for the current and voltage channels. The MOF (master) status is the dc offset in the A/D circuit when a grounded input is selected.
PS	PS = Power Supply; displays power supply voltages in Vdc for the power supply outputs.
TEMP	Displays the internal relay temperature in degrees Celsius.
RAM, ROM, CR_RAM (critical RAM), and EEPROM	These tests verify the relay memory components. The columns display OK if memory is functioning properly; the columns display FAIL if the memory area has failed.
A/D	Analog to Digital convert status.
IO_BRD	Extra I/O board status.
W or F	W (Warning) or F (Failure) is appended to the values to indicate an out-of-tolerance condition.

The relay latches all self-test warnings and failures in order to capture transient out-of-tolerance conditions. To reset the self-test statuses, use the **STA C** command from Access Level 2:

```
=>>STA C <Enter>
```

The relay responds:

```
Reboot the relay and clear status
Are you sure (Y/N) ?
```

If you select “N” or “n”, the relay displays:

```
Canceled
```

and aborts the command.

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If you select "Y", the relay displays:

```
Rebooting the relay
```

The relay then restarts (just like powering down, then powering up relay), and all diagnostics are rerun before the relay is enabled.

Refer to *Table 13.1* for self-test thresholds and corrective actions.

TAR Command (Display Relay Element Status)

The **TAR** command displays the status of front-panel target LEDs or relay elements, whether they are asserted or deasserted. The elements are represented as Relay Word bits and are listed in rows of eight, called Relay Word rows. The first two rows correspond to *Table 10.6*. The remaining rows correspond to the Relay Word as described in *Table 9.6*.

A Relay Word bit is either at a logical 1 (asserted) or a logical 0 (deasserted). Relay Word bits are used in SELOGIC control equations. See *Appendix G: Setting SELOGIC Control Equations*.

The **TAR** command does not remap the front-panel target LEDs, as is done in some previous SEL relays. But the execution of the equivalent **TAR** command via the front-panel display does remap the bottom row of the front-panel target LEDs (see *Figure 11.3*, pushbutton **{OTHER}**).

The **TAR** command options are:

TAR *n k* or **TAR ROW *n k***	Shows Relay Word row number *n* (0–65). *k* is an optional parameter to specify the number of times (1–32767) to repeat the Relay Word row display. If *k* is not specified, the Relay Word row is displayed once. Adding **ROW** to the command displays the Relay Word Row number at the start of each line.
TAR *name k* or **TAR ROW *name k***	Shows Relay Word row containing Relay Word bit name (e.g., TAR 50C displays Relay Word Row 5). Valid names are shown in *Table 10.6*, in *Table 9.6*, and in *Table 9.7*. *k* is an optional parameter to specify the number of times (1–32767) to repeat the Relay Word row display. If *k* is not specified, the Relay Word row is displayed once. Adding **ROW** to the command displays the Relay Word Row number at the start of each line.
TAR LIST or **TAR ROW LIST**	Shows all the Relay Word bits in all of the rows. Adding **ROW** to the command displays the Relay Word Row number at the start of each line.
TAR R	Clears front-panel tripping target LEDs **TRIP**, **INST**, **COMM**, **SOTF**, **50**, **51**, **81**, **A**, **B**, **C**, **G**, and **N**. Unlatches the trip logic for testing purposes (see *Figure 5.1*). Shows Relay Word Row 0.

NOTE: The **TAR R** command cannot reset the latched Targets if a TRIP condition is present.

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Table 10.6 SEL-351S Word and Its Correspondence to TAR Command

TAR 0 (Front-Panel LEDs)	TLED11 (ENABLED)	TLED12 (TRIP)	TLED13 (INST)	TLED14 (COMM)	TLED15 (SOTF)	TLED16 (50)	TLED17 (51)	TLED18 (81)
TAR 1 (Front-Panel LEDs)	TLED19 (RESET)	TLED20 (CYCLE)	TLED21 (LOCKOUT)	TLED22 (A)	TLED23 (B)	TLED24 (C)	TLED25 (G)	TLED26 (N)

Command **TAR SH1 10** is executed in the following example:

```
=>TAR SH1 10 <Enter>

79RS   79CY   79LO   SH0    SH1    SH2    SH3    SH4
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0

79RS   79CY   79LO   SH0    SH1    SH2    SH3    SH4
0      0      1      0      1      0      0      0
0      0      1      0      1      0      0      0

=>
```

Note that Relay Word row containing the SH1 bit is repeated 10 times. In this example, the reclosing relay is in the Lockout State (79LO = logical 1), and the shot is at shot = 1 (SH1 = logical 1). Command **TAR 35** will report the same data since the SH1 bit is in Row 35 of the Relay Word.

Command **TAR ROW LIST** is executed in the following example (SEL-351S with 0.2 A nominal neutral channel):

```
=>TAR ROW LIST <Enter>

Row    TLED11 TLED12 TLED13 TLED14 TLED15 TLED16 TLED17 TLED18
0      1      0      0      0      0      0      0      0

Row    TLED19 TLED20 TLED21 TLED22 TLED23 TLED24 TLED25 TLED26
1      0      0      1      0      0      0      0      0

Row    50A1   50B1   50C1   50A2   50B2   50C2   50A3   50B3
2      0      0      0      0      0      0      0      0

Row    50C3   50A4   50B4   50C4   50AB1  50BC1  50CA1  50AB2
3      0      0      0      0      0      0      0      0

Row    50BC2  50CA2  50AB3  50BC3  50CA3  50AB4  50BC4  50CA4
4      0      0      0      0      0      0      0      0

   .
   .    (57 rows not shown)
   .

Row    27AB2  27BC2  27CA2  59AB2  59BC2  59CA2  59Q2   3V0
62     0      0      0      0      0      0      0      0

Row    V1GOOD *      *      VOGAIN INMET  ICMET  IBMET  IAMET
63     0      0      0      1      1      1      1      1

Row    GNDSW  50NF   50NR   32NE   F32N   R32N   32NF   32NR
64     1      0      0      0      0      0      0      0

Row    PMDOK  F32W   R32W   F32C   R32C   NSA    NSB    NSC
65     0      0      0      0      0      0      0      0

=>
```


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TIM Command (View/Change Time)

TIM displays the relay clock.

NOTE: After setting the date, allow at least 60 seconds before powering down the relay or the new setting may be lost.

Step 1. To set the clock, type **TIM**.

Step 2. Type the desired setting.

Step 3. Press **<Enter>**.

Step 4. Separate the hours, minutes, and seconds with colons, semicolons, spaces, commas, or slashes.

To set the clock to 23:30:00, enter:

```
=>TIM 23:30:00 <Enter>
23:30:00
=>
```

TRI Command (Trigger Event Report)

Issue the **TRI** command to generate an event report:

```
=>TRI [time] <Enter>
```

where *time* is an optional parameter to specify the exact time to trigger an event. If *time* is not specified, the event is triggered at the current time. The *time* should be input in 24-hour format (i.e., 15:11:00). If fractional seconds are input, they will be truncated.

When valid time parameters are entered, the relay responds:

```
An event will trigger at hh:mm:ss

=>
```

One **TRI [*time*]** command may be pending on a single port at any one time. If a **TRI [*time*]** command is entered while another command is pending, the old request will be cancelled and the new request will be pending. **TRI** commands entered without the time parameter will not effect any pending **TRI [*time*]** commands. A **TRI STA** command may be used if a **TRI [*time*]** command is pending.

The following shows the output from an SEL-351S:

```
Triggered

=>
```

If the serial port AUTO setting = Y, the relay sends the summary event report:

```
FEEDER 1                          Date: 02/02/97    Time: 12:57:01.737
STATION A

Event: TRIG  Location: $$$$$$$  Shot: 2  Frequency:  60.00
Targets:
Currents (A Pri), ABCNGQ:    235   236   237     0     2     0
=>
```


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See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER* for more information on event reports.

Access Level B Commands

BRE n Command (Preload/Reset Breaker Wear)

Use the **BRE W** command to preload breaker monitor data.

```
==> BRE W <Enter>

Breaker Wear Preload

Relay (or Internal) Trip Counter (0-65000)    =     0      ? 14 <Enter>
Internal Current (0.0-999999 kA)      IA      = 0.0        ? 32.4 <Enter>
                                      IB      = 0.0        ? 18.6 <Enter>
                                      IC      = 0.0        ? 22.6 <Enter>

External Trip Counter (0-65000)               =     0      ? 2 <Enter>
External Current (0.0-999999 kA)      IA      = 0.0        ? 0.8 <Enter>
                                      IB      = 0.0        ? 0.6 <Enter>
                                      IC      = 0.0        ? 0.7 <Enter>

Percent Wear (0-100%)                 A-phase =   0        ? 22 <Enter>
                                      B-phase =   0        ? 28 <Enter>
                                      C-phase =   0        ? 25 <Enter>


Last Reset                            Date    = 03/26/02   ? 11/12/00
                                      Time    = 13:57:42   ? 09:25:14
Save Changes(Y/N)? Y <Enter>

FEEDER 1                          Date: 03/26/02    Time: 16:14:32.655
STATION A

Rly Trips=    14

 IA=     32.4 IB=     18.6 IC=     27.6 kA

Ext Trips=     2
 IA=      0.8 IB=      0.6 IC=      0.7 kA

Percent wear: A= 22 B= 28 C= 25

LAST RESET 11/12/00 09:25:14
==>
```

The **BRE W** command only saves new settings after the `Save Changes (Y/N)?` message. If a data entry error is made using the **BRE W** command, the values echoed after the `Invalid format, changes not saved` message are the previous **BRE** values, unchanged by the aborted **BRE W** attempt.

```
==> BRE W <Enter>

Breaker Wear Preload

Relay (or Internal) Trip Counter (0-65000)    =     6      ? 14 <Enter>
Internal Current (0.0-999999 kA)      IA      = 124.5      ? 32.4 <Enter>
                                      IB      = 9.2        ? 18.6 <Enter>
                                      IC      = 84.8       ? 22.6 <Enter>

External Trip Counter (0-65000)               =     3      ? -22 <Enter>

Invalid format, changes not saved

FEEDER 1                          Date: 03/26/02    Time: 16:14:32.655
STATION A

Rly Trips=     6
 IA=    124.5 IB=      9.2 IC=     84.8 kA

Ext Trips=     3
 IA=      0.3 IB=      0.8 IC=      1.5 kA

Percent wear: A= 17 B=  3 C=  7

LAST RESET 03/26/02 13:57:42
==>
```


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Use the **BRE R** command to reset the breaker monitor:

```
==>BRE R <Enter>

Reset Trip Counters and Accumulated Currents/Wear
Are you sure (Y/N) ? Y <Enter>

FEEDER 1                          Date: 02/03/01    Time: 05:41:07.289
STATION A

Rly Trips=      0
 IA=      0.0 IB=      0.0 IC=      0.0 kA

Ext Trips=      0
 IA=      0.0 IB=      0.0 IC=      0.0 kA

Percent wear: A=   0 B=   0 C=   0

LAST RESET 02/03/01 05:41:07
```

See *Breaker Monitor on page 8.2* for further details on the breaker monitor.

CLO Command (Close Breaker)

The **CLO** (**CLOSE**) command asserts Relay Word bit CC for 1/4 cycle when it is executed. Relay Word bit CC can then be programmed into the CL SELOGIC control equation to assert the CLOSE Relay Word bit (see *Figure 6.2*), which in turn asserts an output contact (e.g., OUT102 = CLOSE) to close a circuit breaker. See *Figure 6.1*.

To issue the **CLO** command, enter the following:

```
==>CLO <Enter>

Close Breaker  (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

Typing **N <Enter>** after either of the above prompts will abort the command.

The **CLO** command is supervised by the main board Breaker jumper (see *Table 2.6* and *Table 2.7*). If the Breaker jumper is not in place (Breaker jumper = OFF), the relay does not execute the **CLO** command and responds:

```
Aborted: No Breaker Jumper
```

GRO n Command (Change Active Setting Group)

The **GRO *n*** command changes the active setting group to setting Group *n*. To change to settings Group 2, enter the following:

```
==>GRO 2 <Enter>

Change to Group 2
Are you sure (Y/N) ? Y <Enter>
Active Group = 2
==>
```

The relay switches to Group 2 and pulses the **ALARM** contact. If the serial port AUTO setting = Y, the relay sends the group switch report:

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```
==>

FEEDER 1                          Date: 02/02/97    Time: 09:40:34.611
STATION A

Active Group = 2
==>
```

If any of the SELOGIC control equations settings SS1 through SS6 are asserted to logical 1, the active setting group may not be change with the **GRO** command—SELOGIC control equations settings SS1 through SS6 have priority over the **GRO** command in active setting group control.

For example, assume setting Group 1 is the active setting group and the SS1 setting is asserted to logical 1 (e.g., SS1 = IN101 and optoisolated input IN101 is asserted). An attempt to change to setting Group 2 with the **GRO 2** command will not be accepted:

```
==>GRO 2 <Enter>

No group change (see manual)
Active Group = 1
==>
```

For more information on setting group selection, see *Multiple Setting Groups on page 7.19*.

OPE Command (Open Breaker)

The **OPE** (OPEN) command asserts Relay Word bit OC for 1/4 cycle when it is executed. Relay Word bit OC can then be programmed into the TR SELOGIC control equation to assert the TRIP Relay Word bit, which in turn asserts an output contact (e.g., OUT101 = TRIP) to trip a circuit breaker. See *Figure 5.1* and bottom part of *Figure 6.10*.

To issue the **OPE** command, enter the following:

```
==>OPE <Enter>

Open Breaker  (Y/N) ? Y <Enter>
Are you sure (Y/N) ? Y <Enter>
==>
```

Typing **N <Enter>** after either of the above prompts will abort the command.

The **OPE** command is supervised by the main board Breaker jumper (see *Table 2.6* and *Table 2.7*). If the Breaker jumper is not in place (Breaker jumper = OFF), the relay does not execute the **OPE** command and responds:

```
Aborted: No Breaker Jumper
```

PUL Command (Pulse Output Contact)

The **PUL** command allows you to pulse any of the output contacts for a specified length of time. The command format is:

PUL *x y*

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where:

x is the output name (e.g., **OUT101**, **OUT107**, **ALARM**, **OUT211**—see *Figure 7.28–Figure 7.30*).

y is the pulse duration (1–30) in seconds. If ***y*** is not specified, the pulse duration defaults to one second.

To pulse **OUT101** for five seconds:

```
==>PUL OUT101 5 <Enter>

Are you sure (Y/N) ? Y <Enter>
==>
```

If the response to the `Are you sure (Y/N) ?` prompt is "N" or "n", the command is aborted.

The **PUL** command is supervised by the main board Breaker jumper (see *Table 2.6* and *Table 2.7*). If the Breaker is not in place (Breaker jumper = OFF), the relay does not execute the **PUL** command and responds:

```
Aborted:  No Breaker Jumper
```

The relay generates an event report if any of the **OUT101**–**OUT107** contacts are pulsed. The **PULSE** command is primarily used for testing purposes.

Access Level 2 Commands

CON Command (Control Remote Bit)

The **CON** command is a two-step command that allows you to control Relay Word bits RB1–RB16 (see Rows 27 and 28 in *Table 9.6*).

Step 1. At the Access Level 2 prompt, type:

a. CON

b. a space

c. the number of the remote bit you wish to control (1–16)

Step 2. Press the **<Enter>** key on your computer.

The relay responds by repeating your command followed by a colon.

Step 3. At the colon, type the Control subcommand you wish to perform (see *Table 10.7*).

The following example shows the steps necessary to pulse Remote Bit 5 (RB5):

```
=>>CON 5 <Enter>

CONTROL RB5: PRB 5 <Enter>
=>>
```

You must enter the same remote bit number in both steps in the command. If the bit numbers do not match, the relay responds

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```
Invalid Command
```

Table 10.7 SEL-351S Control Subcommand

Subcommand	Description
SRB *n*	Set Remote Bit *n* (“ON” position)
CRB *n*	Clear Remote Bit *n* (“OFF” position)
PRB *n*	Pulse Remote Bit *n* for 1/4 cycle (“MOMENTARY” position)

See *Remote Control Switches on page 7.10* for more information.

COP m n Command (Copy Setting Group)

Copy relay and SELOGIC control equation settings from setting Group *m* to setting Group *n* with the **COP *m n*** command. Setting group numbers range from 1 to 6. After entering settings into one setting group with the **SET** and **SET L** commands, copy them to the other groups with the **COP** command. Use the **SET** and **SET L** commands to modify the copied settings. The relay disables for a few seconds and the **ALARM** output pulses if you copy settings into the active group. This is similar to a Group Change (see *Section 7: Inputs, Outputs, Timers, and Other Control Logic*).

For example, to copy settings from Group 1 to Group 3 issue the following command:

```
=>>COP 1 3 <Enter>

Copy 1 to 3
Are you sure (Y/N) ? Y <Enter>

Please wait...
Settings copied
=>>
```

LOO Command (Loop Back–Available in Firmware Versions 6 and 7)

The **LOO** (LOOP) command is used for testing the MIRRORED BITS communications channel. For more information on MIRRORED BITS, see *Appendix I: MIRRORED BITS Communications (In Firmware Versions 6 and 7)*. With the transmitter of the communications channel physically looped back to the receiver, the MIRRORED BITS addressing will be wrong and ROK will be deasserted. The **LOO** command tells the MIRRORED BITS software to temporarily expect to see its own data looped back as its input. In this mode, LBOK will assert if error-free data is received.

The **LOO** command with just the channel specifier, enables looped back mode on that channel for five minutes, while the inputs are forced to the default values.

```
=>>LOO A <Enter>

Loopback will be enabled on Mirrored Bits channel A for the next 5 minutes.
The RMB values will be forced to default values while loopback is enabled
Are you sure (Y/N) ?
=>>
```


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If only one MIRRORED BITS port is enabled, the channel specifier may be omitted. To enable looped back mode for other than the default five minutes, enter the desired number of minutes (1–5000) as a command parameter. To allow the looped back data to modify the RMB values, include the **DATA** parameter.

```
=>>LOO 10 DATA <Enter>

Loopback will be enabled on Mirrored Bits channel A for the next 10 minutes.
The RMB values will be allowed to change while loopback is enabled.
Are you sure (Y/N) ? N <Enter>
Canceled.
=>>
```

To disable looped back mode before the selected number of minutes, re-issue the **LOOP** command with the **R** parameter. If both MIRRORED BITS channels are enabled, omitting the channel specifier in the disable command, will cause both channels to be disabled.

```
=>>LOO R <Enter>

loopback is disabled on both channels.
=>>
```

PAS Command (Change Passwords)

The relay is shipped with factory default passwords for Access Levels 1, B, and 2. These passwords are shown in *Table 10.8*.

⚠WARNING

This device is shipped with default passwords. Default passwords should be changed to private passwords at installation. Failure to change each default password to a private password may allow unauthorized access. SEL shall not be responsible for any damage resulting from unauthorized access.

Table 10.8 Factory Default Passwords for Access Levels 1, B, and 2

Access Level	Factory Default Password
1	OTTER
B	EDITH
2	TAIL

The **PAS**sword command allows you to change existing passwords at Access Level 2. To change passwords, enter **PAS *x***, where ***x*** is the access level whose password is being changed. The relay will prompt for the old password, new password, and a confirmation of the new password.

To change the password for Access Level 1, enter the following:

```
=>>PAS 1 <Enter>

Old Password: *********

New Password: ******
Confirm New Password: ******

Password Changed
=>>
```

Similarly, **PAS B** and **PAS 2** can be used to change the Level B and Level 2 passwords, respectively.

The new password will not echo on the screen, and passwords cannot be viewed from the device. Record the new password in a safe place for future reference.

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If the passwords are lost or you wish to operate the relay without password protection, put the main board password jumper in place (Password jumper = ON). Refer to *Table 2.6* and *Table 2.7* for password jumper information. While the password protection is disabled by setting the main board password jumper in place (Password jumper = ON), lost or forgotten passwords can be assigned a new password, by using the **PAS *x*** command at Access Level 2. The relay will prompt for a new password and a confirmation of the new password.

If you wish to disable password protection for a specific access level [even if the password jumper is not in place (Password jumper = OFF)], simply set the password to DISABLE. For example, to disable password protection for level 1, enter **PAS 1**. When the relay prompts for the new password and a confirmation of the new password, enter **DISABLE**. The relay will respond with `Password Disabled`.

Passwords may include up to 12 characters. See *Table 10.9* for valid characters. Upper- and lowercase letters are treated as different characters. Strong passwords consist of 12 characters, with at least one special character or digit and mixed-case sensitivity, but do not form a name, date, acronym, or word. Passwords formed in this manner are less susceptible to password guessing and automated attacks. Examples of valid, distinct strong passwords include:

Ot3579A24.68 Ih2d&s4u-Iwg .351s.Nt9g-t

Table 10.9 Valid Password Characters

Alpha	ABCDEFGHIJKLMNOPQRSTUVWXYZ abcdefghijklmnopqrstuvwxyz
Numeric	0123456789
Special	! " # $ % & ' ( ) * , - . / : ; < = > ? @ [\ ] ^ _ ` { | } ~

The relay shall issue a weak password warning if the new password does not include at least one special character, number, lowercase letter, and uppercase letter.

```
=>>PAS 1 <Enter>

Old Password: *********

New Password: ******
Confirm New Password: ******

Password Changed
=>>

CAUTION:  This password can be strengthened.  Strong passwords do not include a name,
     date, acronym, or word.  They consist of the maximum allowable characters, with
     at least one special character, number, lower-case letter, and upper-case letter.
     A change in password is recommended.

=>>
```

SET Command (Change Settings)

The **SET** command allows the user to view or change the relay settings—see *Table 9.1*.

VER Command (Show Relay Configuration and Firmware Version)

The **VER** command provides relay configuration and information such as nominal current input ratings.

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An example printout of the **VER** command for an SEL-351S follows:

```
=>>VER <Enter>

Partnumber: 0351S71H345B4XX

Mainboard: 0311
Appearance: Horizontal, Conventional
Data FLASH Size:  1024 KBytes
Analog Input Voltage (PT): 300 Vac, Wye or Delta connected
Analog Input Current (CT): 5 Amp Phase, 0.20 Amp Neutral
Extended Relay Features:
  Voltage Sag/Swell/Interruption Elements
  Power Elements
  Mirrored Bits
  Load Profile
  Directional Sensitive Neutral Channel
  Enhanced Integration Bits & Fast SER
SELboot checksum 09CC OK
FID=SEL-351S-7-R1xx-V0-Zxxxxxx-D2002xxxx

SELboot-35R-R101

If above information is unexpected,
contact SEL for assistance
=>>
```


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SEL-351S Relay
Command Summary

SEL-351S Relay Commands (Sheet 1 of 3)

Command	Description
2AC	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
ACC	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
BAC	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts the user for the Access Level B password.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE *n*	Enter **BRE W** to preload breaker wear. Enter **BRE R** to reset breaker monitor data.
CLO	Close circuit breaker (assert Relay Word bit CC).
COM[a] *p*	Show communications summary report (COM report) on MIRRORED BITS® channel *p* (where *p* = A or B) using all failure records in the channel calculations.
COM[a] *p n*	Show a COM report for MIRRORED BITS channel *p* using the latest *n* failure records (*n* = 1–512, where 1 is the most recent entry).
COM[a] *p m n*	Show COM report for MIRRORED BITS channel *p* using failure records *m*–*n* (*m* = 1–512).
COM[a] *p d1*	Show COM report for MIRRORED BITS channel *p* using failures recorded on date *d1* (see **DAT** command for date format).
COM[a] *p d1 d2*	Show COM report for MIRRORED BITS BITS channel *p* using failures recorded between dates *d1* and *d2* inclusive.
COM[a] . . . L	For all **COM** commands, L causes the specified COM report records to be listed after the summary.
COM[a] *p* C	Clears communications records for MIRRORED BITS channel *p* (or both channels if *p* is not specified, **COM C** command).
CON *n*	Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1–16). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following: **SRB *n*** set Remote Bit *n* (assert RB*n*). **CRB *n*** clear Remote Bit *n* (deassert RB*n*). **PRB *n*** pulse Remote Bit *n* (assert RB*n* for 1/4 cycle).
COP *m n*	Copy relay and logic settings from group *m* to group *n* (*m* and *n* are numbers 1–6).
DAT	Show date.
DAT mm/dd/yy	Enter date in this manner if global Date Format setting, DATE_F, is set to MDY.
DAT yy/mm/dd	Enter date in this manner if global Date Format setting, DATE_F, is set to YMD.
EVE *n*	Show event report *n* with 4 samples per cycle (*n* = 1 to highest numbered event report, where 1 is the most recent report: see **HIS** command). If *n* is omitted (**EVE** command), most recent report is displayed.
EVE *n* R	Show event report *n* in raw (unfiltered) format with 16 samples-per-cycle resolution.
EVE *n* C	Show event report *n* in compressed ASCII format for use with the SEL-5601 Analytic Assistant.
EVE *n* A	Show event report *n* with analog section only.
EVE *n* D	Show event report *n* with digital section only.
EVE *n* M	Show event report *n* with communications section only.
EVE *n* S*x*	Show event report *n* with *x* samples per cycle (*x* = 4 or 16).
EVE *n* L	Show event report *n* with 16 samples per cycle (similar to **EVE *n* S16**).

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SEL-351S Relay Commands (Sheet 2 of 3)

Command	Description
EVE *n* L*y*	Show first *y* cycles of event report *n* (*y* = 1 to global setting LER).
EVE *n* V	Show event report *n* with variable scaling for analog values.
EVE *n* P	Show event report *n* with synchrophasor-level accuracy time adjustment.
GRO	Display active group number.
GRO *n*	Change active group to group *n* (*n* = 1–6).
HIS *n*	Show brief summary of *n* latest event reports, where 1 is the most recent entry. If *n* is not specified, (**HIS** command) all event summaries are displayed.
HIS C	Clear all event reports from nonvolatile memory.
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
LDP[a]	Show entire Load Profile (LDP) report.
LDP[a] *n*	Show latest *n* rows in the LDP report (*n* = 1 to several thousand, where 1 is the most recent entry).
LDP[a] *m n*	Show rows *m*–*n* in the LDP report (*m* = 1 to several thousand).
LDP[a] *d1*	Show all rows in the LDP report recorded on the specified date (see **DAT** command for date format).
LDP[a] *d1 d2*	Show all rows in the LDP report recorded between dates *d1* and *d2*, inclusive.
LDP[a] D	Display the number of days of LDP storage capacity before data overwrite will occur.
LDP[a] C	Clears the LDP report from nonvolatile memory.
LOO[a] *p t*	Set MIRRORED BITS port *p* to loopback (*p* = A or B). The received MIRRORED BITS elements are forced to default values during the loopback test; *t* specifies the loopback duration in minutes (*t* = 1–5000, default is 5).
LOO[a] *p* DATA	Set MIRRORED BITS port *p* to loopback. DATA allows the received MIRRORED BITS elements to change during the loopback test.
MET *k*	Display instantaneous metering data. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET X *k*	Display same as **MET** command with phase-to-phase voltages and Vbase. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET D	Display demand and peak demand data. Select **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Select **MET RE** to reset.
MET M	Display maximum/minimum metering data. Select **MET RM** to reset.
MET PM [*time*] [*k*]	Display synchrophasor measurements (available when TSOK = logical 1). Enter *time* to display the synchrophasor for an exact specified time, in 24-hour format. Enter *k* for repeat count.
OPE	Open circuit breaker (assert Relay Word bit OC).
PAS 1	Change Access Level 1 password.
PAS B	Change Access Level B password.
PAS 2	Change Access Level 2 password. Entering DISABLE as the password disables the password requirement for the specified access level.
PUL *n k*	Pulse output contact *n* (where *n* is one of ALARM, OUT101–OUT107, OUT201–OUT212) for *k* seconds. Specify parameter *n*; *k* = 1–30 seconds; if not specified, default is 1.
QUI	Quit. Returns to Access Level 0. Terminates SEL Distributed Port Switch Protocol (LMD) connection.
SER	Show entire Sequential Events Recorder (SER) report.
SER *n*	Show latest *n* rows in the SER report (*n* = 1–512, where 1 is the most recent entry).
SER *m n*	Show rows *m*–*n* in the SER report (*m* = 1–512).
SER *d1*	Show all rows in the SER report recorded on the specified date (see **DAT** command for date format).
SER *d1 d2*	Show all rows in the SER report recorded between dates *d1* and *d2*, inclusive.
SER C	Clears SER report from nonvolatile memory.

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SEL-351S Relay Commands (Sheet 3 of 3)

Command	Description
SET *n*	Change relay settings (overcurrent, reclosing, timers, etc.) for group *n* (*n* = 1–6, if not specified, default is active setting group).
SET *n* L	Change SELOGIC® control equation settings for group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SET G	Change global settings.
SET R	Change SER and LDP Recorder[a] settings.
SET T	Change text label settings.
SET P *p*	Change serial port *p* settings, (*p* = 1, 2, 3, or F; if not specified, default is active port).
SET . . . *name*	For all **SET** commands, jump ahead to specific setting by entering setting name.
SET . . . TERSE	For all **SET** commands, TERSE disables the automatic **SHO** command after settings entry.
SHO *n*	Show relay settings (overcurrent, reclosing, timers, etc.) for group *n* (*n* = 1–6, if not specified, default is active setting group).
SHO *n* L	Show SELOGIC control equation settings for group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SHO G	Show global settings.
SHO R	Show SER and LDP Recorder[a] settings.
SHO T	Show text label settings.
SHO P *p*	Show serial port *p* settings, (*p* = 1, 2, 3, or F; if not specified, default is active port).
SHO . . . *name*	For all **SHO** commands, jump ahead to specific setting by entering setting name.
SSI[b]	Show entire Voltage Sag/Swell/Interruption (SSI) report.
SSI[b] *n*	Show latest *n* rows in SSI report (*n* = 1 to several thousand, where 1 is the most recent entry).
SSI[b] *m n*	Show rows *m*–*n* in SSI report (*m* = 1 to several thousand).
SSI[b] *d1*	Show all rows in SSI report recorded on the specified date (see **DAT** command for date format).
SSI[b] *d1 d2*	Show all rows in SSI report recorded between dates *d1* and *d2*, inclusive.
SSI[b] C	Clears SSI report from nonvolatile memory.
SSI[b] R	Resets Vbase element. See Vbase initialization.
SSI[b] T	Trigger the SSI recorder.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots the relay.
TAR R	Reset front-panel tripping targets.
TAR *n k*	Display Relay Word row. If *n* = 0–59, display row *n*. If *n* is an element name (e.g., 50A1), display row containing element *n*. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
TAR LIST	Shows all the Relay Words in all of the rows.
TAR ROW. . .	Shows the Relay Word row number at the start of each line, with other selected **TARGET** commands as described above, such as *n*, *name*, *k*, and LIST.
TIM	Show or set time (24-hour time). Show current relay time by entering **TIM**. Set the current time by entering **TIM** followed by the time of day (e.g., set time 22:47:36 by entering **TIM 22:47:36**).
TRI [*time*]	Trigger an event report. Enter *time* to trigger an event at an exact specified time, in 24-hour format.
VER	Show relay configuration and firmware version.

[a] Available in firmware versions 6 and 7.
[b] Available in firmware version 7.

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Key Stroke Commands

Key Stroke	Description	Key Stroke When Using SET Command	Description
Ctrl + Q	Send **XON** command to restart communications port output previously halted by XOFF.	**<Enter>**	Retains setting and moves on to next setting.
Ctrl + S	Send **XOFF** command to pause communications port output.	**^<Enter>**	Returns to previous setting.
Ctrl + X	Send **CANCEL** command to abort current command and return to current access level prompt.	**<<Enter>**	Returns to previous setting section.
		><Enter>	Skips to next setting section.
		END <Enter>	Exits setting editing session, then prompts user to save settings.
		Ctrl + X	Aborts setting editing session without saving changes.

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Section 11
Front-Panel Interface

Introduction

This section describes how to get information, make settings, and execute control operations from the SEL-351S Relay front panel. It also describes the default displays.

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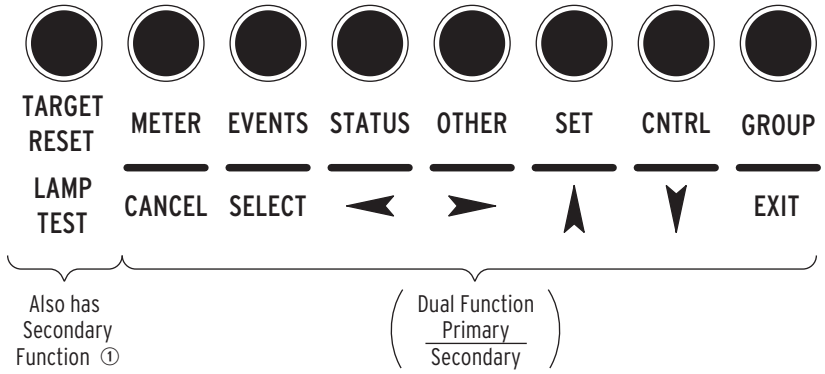
Front-Panel Pushbutton Operation

Overview

Note in *Figure 11.1* that most of the pushbuttons have dual functions (primary/secondary).

A primary function is selected first (e.g., **{METER}** pushbutton).

After a primary function is selected, the pushbuttons then revert to operating on their secondary functions (**{CANCEL}**, **{SELECT}**, left/right arrows, up/down arrows, **{EXIT}**). For example, after the **{METER}** pushbutton is pressed, the up/down arrows are used to scroll through the front-panel metering screens. The primary functions are activated again when the present selected function (metering) is exited (press **{EXIT}** pushbutton) or the display goes back to the default display after no front-panel activity for a settable time period (see global setting FP_TO in *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25*; relay shipped with FP_TO = 15 minutes).



① From Figure 11.4.

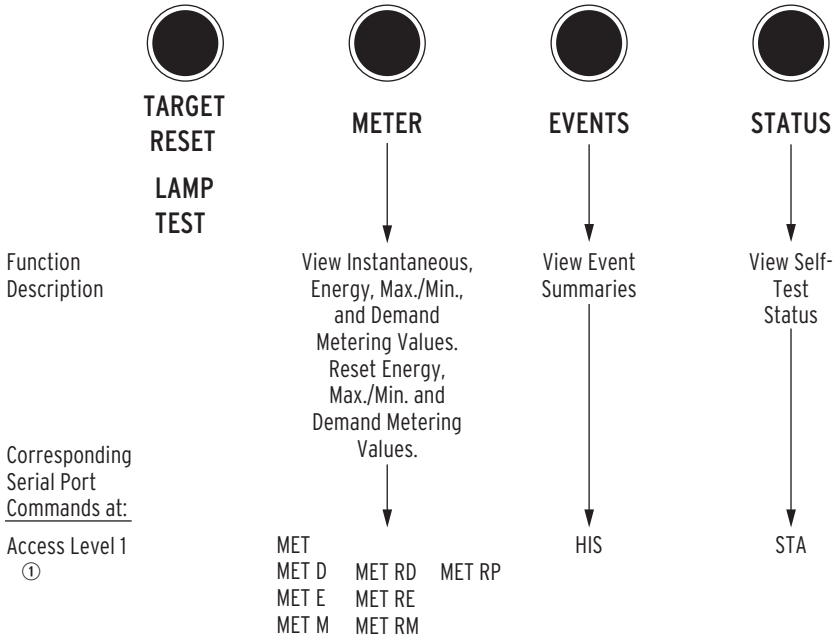
Figure 11.1 SEL-351S Front-Panel Pushbuttons–Overview

Primary Functions

Note in *Figure 11.2* and *Figure 11.1* that the front-panel pushbutton primary functions correspond to serial port commands—both retrieve the same information or perform the same function. To get more detail on the information provided by the front-panel pushbutton primary functions, refer to the corresponding serial port commands in *Table 10.5*. For example, to get more information on the metering values available via the front-panel **{METER}** pushbutton, refer to the *MET Command (Metering Data) on page 10.20*.

Some of the front-panel primary functions do **not** have serial port command equivalents. These are discussed in *Functions Unique to the Front-Panel Interface on page 11.6*.

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① Front-panel pushbutton functions that correspond to Access Level 1 serial port commands do not require the entry of the Access Level 1 password through the front panel.

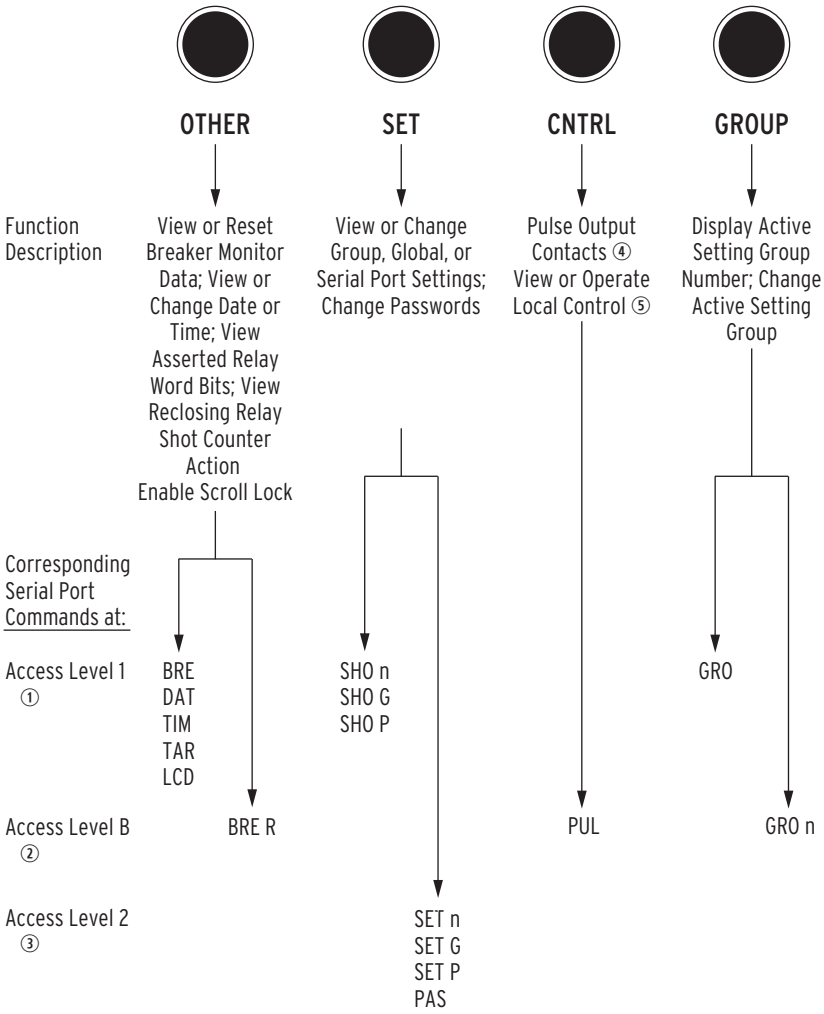
Figure 11.2 SEL-351S Front-Panel Pushbuttons—Primary Functions

Front-Panel Password Security

Refer to the comments at the bottom of *Figure 11.3* concerning Access Level B and Access Level 2 passwords. See *PAS Command (Change Passwords) on page 10.42* for the list of default passwords and for more information on changing passwords.

To enter the Access Level B and Access Level 2 passwords from the front panel (if required), use the left/right arrow pushbuttons to underscore a password digit position. Use the up/down arrow pushbuttons to then change the digit. Press the **{SELECT}** pushbutton once the correct Access Level B or Access Level 2 password is ready to enter.

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① Front-panel pushbutton functions that correspond to Access Level 1 serial port commands do not require the entry of the Access Level 1 password through the front panel.

② Front-panel pushbutton functions that correspond to Access Level B serial port commands **do** require the entry of the Access Level B or Access Level 2 passwords through the front panel **if** the main board Password jumper is not in place (see Table 2.5 and Table 2.6).

③ Front-panel pushbutton functions that correspond to Access Level 2 serial port commands **do** require the entry of the Access Level 2 password through the front panel **if** the main board Password jumper is not in place (see Table 2.5 and Table 2.6).

④ Output contacts are pulsed for only one second from the front panel.

⑤ Local control is **not** available through the serial port and does **not** require the entry of a password.

Figure 11.3 SEL-351S Front-Panel Pushbuttons—Primary Functions (continued)

Secondary Functions

After a primary function is selected (see *Figure 11.2* and *Figure 11.3*), the pushbuttons then revert to operating on their secondary functions (see *Figure 11.4*).

Step 1. Use the left/right arrows to underscore a desired function.

Step 2. Press the **{SELECT}** pushbutton to select the function.

Step 3. Use left/right arrows to underscore a desired setting digit.

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Step 4. Use the up/down arrows to change the digit.

Step 5. After the setting changes are complete, press the **{SELECT}** pushbutton to select/enable the setting.

Step 6. Press the **{CANCEL}** pushbutton to abort a setting change procedure and return to the previous display.

Step 7. Press the **{EXIT}** pushbutton to return to the default display and have the primary pushbutton functions activated again (see *Figure 11.2* and *Figure 11.3*).

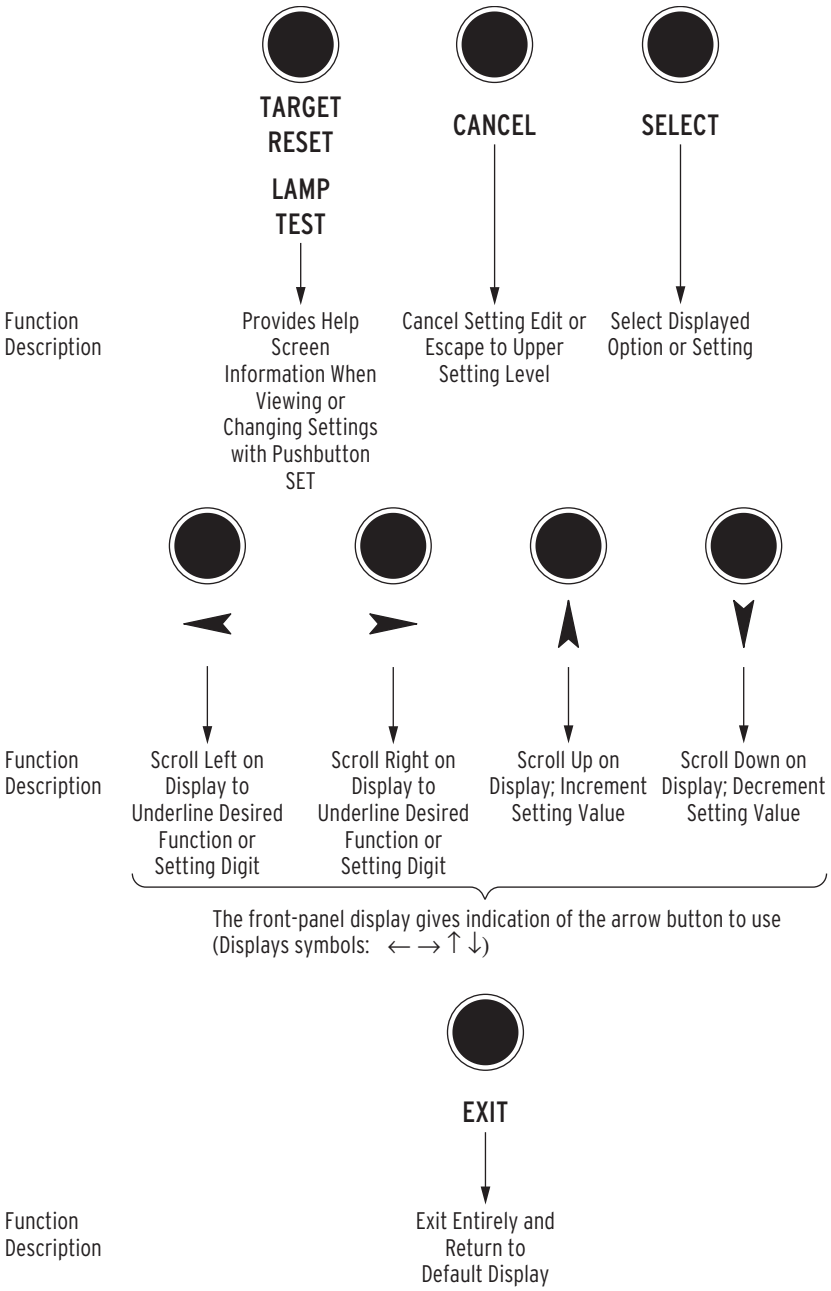


Figure 11.4 SEL-351S Front-Panel Pushbuttons—Secondary Functions

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Functions Unique to the Front-Panel Interface

Three front-panel primary functions do **not** have serial port command equivalents. These are:

- Reclosing relay shot counter screen (accessed via the **{OTHER}** pushbutton)
- Local control (accessed via the **{CNTRL}** pushbutton)
- Modified rotating display with scroll lock control (accessed via the **{OTHER}** pushbutton)

Reclosing Relay Shot Counter Screen

Use this screen to see the progression of the shot counter during reclosing relay testing.

Access the reclosing relay shot counter screen via the **{OTHER}** pushbutton. The following screen appears:

```
DATE   TIME  79
TAR BRK_MON LCD
```

Scroll right with the right arrow button and select function 79. Upon selecting function 79, the following screen appears (shown here with example settings):

```
SET RECLOSURES=2
RECLOSE COUNT =0
```

or

```
SET RECLOSURES=2
RECLOSE COUNT =2
```

If the reclosing relay does not exist (see *Reclosing Relay on page 6.14*), the following screen appears:

```
No Reclosing set
```

The corresponding text label settings (shown with factory default settings) are:

79LL = **SET RECLOSURES** (Last Shot Label–limited to 14 characters)

79SL = **RECLOSE COUNT** (Shot Counter Label–limited to 14 characters)

These text label settings are set with the **SET T** command or viewed with the **SHO T** command via the serial port [see *Section 9: Setting the Relay* and *SHO Command (Show/View Settings) on page 10.27*].

The top numeral in the above example screen (SET RECLOSURES=2) corresponds to the "last shot" value, which is a function of the number of set open intervals. There are two set open intervals in these example settings, thus two reclosures (shots) are possible in a reclose sequence.

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The bottom numeral in the above example screen [RECLOSE COUNT = 0 (or = 2)] corresponds to the "present shot" value. If the breaker is closed and the reclosing relay is reset (**RS** LED on front panel is illuminated), RECLOSE COUNT = 0. If the breaker is open and the reclosing relay is locked out after a reclose sequence (**LO** LED on front panel is illuminated), RECLOSE COUNT = 2.

Reclosing Relay Shot Counter Screen Operation (With Example Settings)

With the breaker closed and the reclosing relay in the reset state (front-panel **RS** LED illuminated), the reclosing relay shot counter screen appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =0
```

The relay trips the breaker open, and the reclosing relay goes to the reclose cycle state (front-panel **CY** LED illuminates). The reclosing relay shot counter screen still appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =0
```

The first open interval (e.g., 79OI1 = 30) times out, the shot counter increments from 0 to 1, and the relay recloses the breaker. The reclosing relay shot counter screen shows the incremented shot counter:

```
SET RECLOSURES=2
RECLOSE COUNT =1
```

The relay trips the breaker open again. The reclosing relay shot counter screen still appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =1
```

The second open interval (e.g., 79OI2 = 600) times out, the shot counter increments from 1 to 2, and the relay recloses the breaker. The reclosing relay shot counter screen shows the incremented shot counter:

```
SET RECLOSURES=2
RECLOSE COUNT =2
```

If the relay trips the breaker open again, the reclosing relay goes to the lockout state (front-panel LO LED illuminates). The reclosing relay shot counter screen still appears as:

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```
SET RECLOSURES=2
RECLOSE COUNT =2
```

If the breaker is closed, the reclosing relay reset timer times out (e.g., 79RSLD = 300), the relay goes to the reset state (front-panel **LO** LED extinguishes and **RS** LED illuminates), and the shot counter returns to 0. The reclosing relay shot counter screen appears as:

```
SET RECLOSURES=2
RECLOSE COUNT =0
```

Local Control

Use local control to enable/disable schemes, trip/close breakers, etc., via the front panel.

In more specific terms, local control asserts (sets to logical 1) or deasserts (sets to logical 0) what are called local bits LB1–LB16. These local bits are available as Relay Word bits and are used in SELOGIC® control equations (see Rows 25 and 26 in *Table 9.6*).

Local control can emulate the following switch types in *Figure 11.5*–*Figure 11.7*.

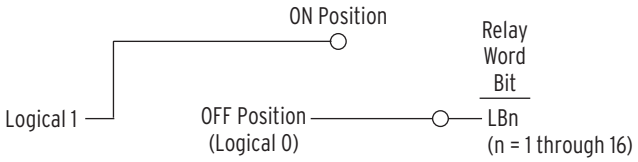


Figure 11.5 Local Control Switch Configured as an ON/OFF Switch

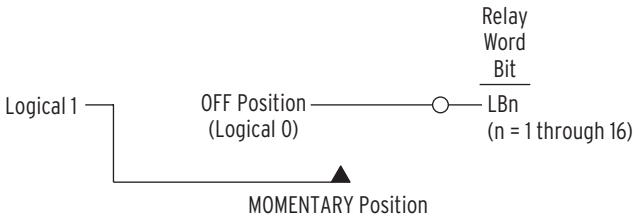


Figure 11.6 Local Control Switch Configured as an OFF/MOMENTARY Switch

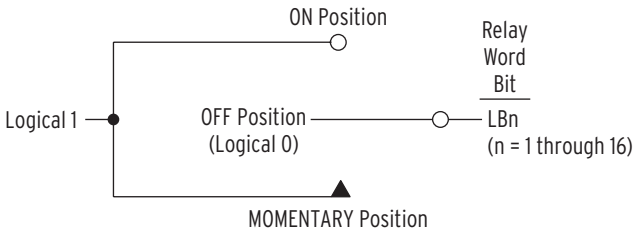


Figure 11.7 Local Control Switch Configured as an ON/OFF/MOMENTARY Switch

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Local control switches are created by making corresponding switch position label settings. These text label settings are set with the **SET T** command or viewed with the **SHO T** command via the serial port [see *Section 9: Setting the Relay* and *SHO Command (Show/View Settings) on page 10.27*]. See *Local Control Switches on page 7.6* for more information on local control.

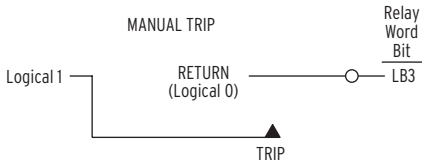
View Local Control (Example Settings)

Access local control via the **{CNTRL}** pushbutton. If local control switches exist (i.e., corresponding switch position label settings were made), the following message displays with the rotating default display messages.

```
Press CNTRL for
Extra Control
```

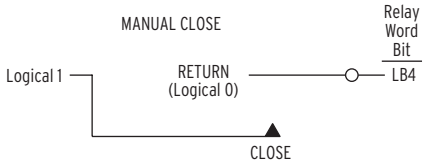
Press the **{CNTRL}** pushbutton, and the first set local control switch displays (shown here with example settings):

```
MANUAL TRIP 1←→
Position: RETURN
```



Press the right arrow pushbutton, and scroll to the next example local control switch:

```
MANUAL CLOSE 1←→
Position: RETURN
```



The `MANUAL TRIP: RETURN/TRIP` and `MANUAL CLOSE: RETURN/CLOSE` switches are both OFF/MOMENTARY switches (see *Figure 11.6*).

There are no more local control switches in the example settings. Press the right arrow pushbutton, and scroll to the `Output Contact` testing function:

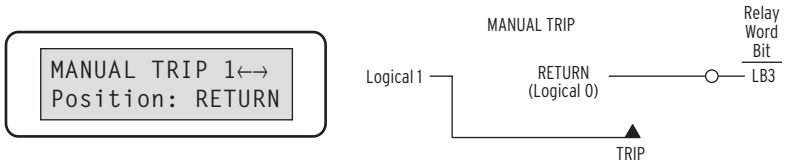
```
Output Contact←→
Testing
```

This front-panel function provides the same function as the serial port **PUL** command (see *Figure 11.3*).

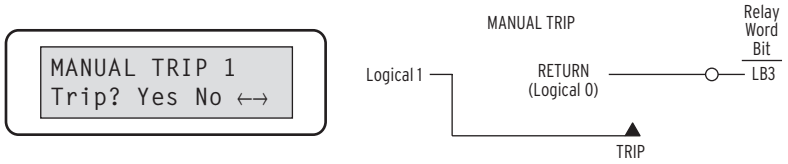
Operate Local Control (With Example Settings)

Press the right arrow pushbutton, and scroll back to the first set local control switch in the example settings:

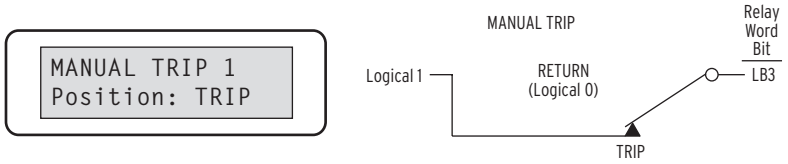
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Press the **{SELECT}** pushbutton, and the operate option for the displayed local control switch displays:



Scroll left with the left arrow button and then select `Yes`. The display then shows the new local control switch position:



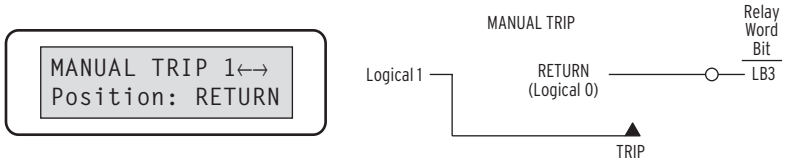
Because this is an OFF/MOMENTARY type switch, the `MANUAL TRIP` switch returns to the `RETURN` position after momentarily being in the `TRIP` position. Technically, the `MANUAL TRIP` switch (being an OFF/MOMENTARY type switch) is in the:

> `TRIP` position for one processing interval (1/4 cycle; long enough to assert the corresponding local bit LB3 to logical 1).

and then returns to the:

> `RETURN` position (local bit LB3 deasserts to logical 0 again).

On the display, the `MANUAL TRIP` switch is shown to be in the `TRIP` position for two seconds (long enough to be seen), and then it returns to the `RETURN` position:



The `MANUAL CLOSE` switch is an OFF/MOMENTARY type switch, like the `MANUAL TRIP` switch, and operates similarly.

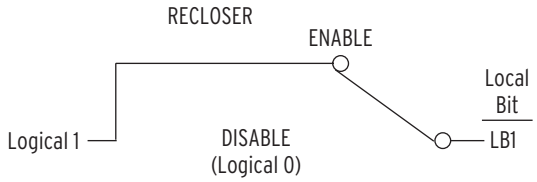
See *Local Control Switches on page 7.6* for details on how local bit outputs LB3 and LB4 can be set in SELOGIC control equation settings to respectively trip and close a circuit breaker.

Local Control State Retained When Relay De-Energized

Local bit states are stored in nonvolatile memory, so when power to the relay is turned off, the local bit states are retained.

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For example, suppose the local control switch with local bit output LB1 is configured as an ON/OFF type switch (see *Figure 11.5*). Additionally, suppose it is used to enable/disable reclosing. If local bit LB1 is at logical 1, reclosing is enabled:



If power to the relay is turned off and then turned on again, local bit LB1 remains at logical 1, and reclosing is still enabled. This is akin to a traditional panel, where enabling/disabling of reclosing and other functions is accomplished by panel-mounted switches. If dc control voltage to the panel is lost and then restored again, the switch positions are still in place. If the reclosing switch is in the enable position (switch closed) before the power outage, it will be in the same position after the outage when power is restored.

EXAMPLE 11.1 Reclose Enable/Disable Function

As an example setting, the reclose enable/disable function is provided by optoisolated input **IN102** with the following SELOGIC control equation drive-to-lockout setting:

79DTL = **!IN102 + LB3** [=NOT(IN102) + LB3]

Local bit LB3 is the output of the previously discussed local control switch configured as a manual trip switch. The relay is driven to lockout for any manual trip via LB3.

When input **IN102** is energized (IN102 = logical 1), reclosing is enabled (not driven-to-lockout):

79DTL = **!IN102 + ...** = !(logical 1) + ... = NOT(logical 1) + ... = logical 0 + ...

If local bit LB1 is substituted for input **IN102** to provide the reclose enable/disable function, the SELOGIC control equation drive-to-lockout setting is set as follows:

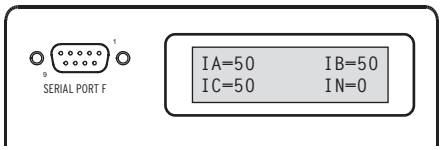
79DTL = **!LB1 + LB3** [=NOT(LB1) + LB3]

See *Drive-to-Lockout and Drive-to-Last Shot Settings (79DTL and 79DLS, Respectively) on page 6.23* for more information on setting 79DTL.

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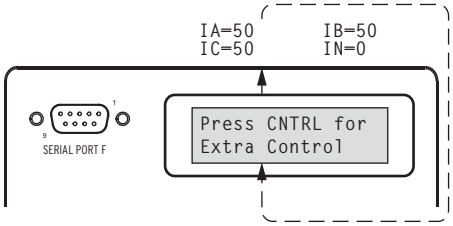
Rotating Default Display

The channel **IA**, **IB**, **IC**, and **IN** current values (in A primary) display continually if no local control is operational (i.e., no corresponding switch position label settings were made) and no display point labels are enabled for display.

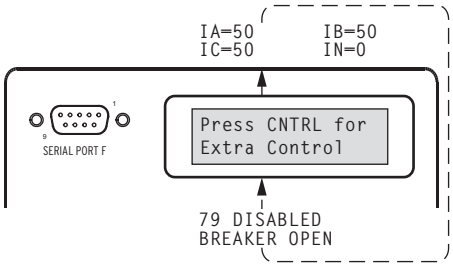


Global setting FPNGD determines whether `IN` (current channel **IN**) or `IG` (residual ground current) displays in the lower right-hand corner, or whether the lower right-hand corner is blank.

The `Press CNTRL for Extra Control` message displays in rotation with the default metering screen if at least one local control switch is operational. It is a reminder of how to access the local control function. See the preceding discussion in this section and *Latch Control Switches on page 7.12* for more information on local control.



If display point labels (e.g., `79 DISABLED` and `BREAKER OPEN`) are enabled for display, they also enter into the display rotation.



Global setting SCROLD determines how long each message is displayed, settable from 1 to 60 seconds.

The following table and figures demonstrate the correspondence between changing display point states (e.g., DP1 and DP2) and enabled display point labels (DP1_1/DP1_0 and DP2_1/DP2_0, respectively).

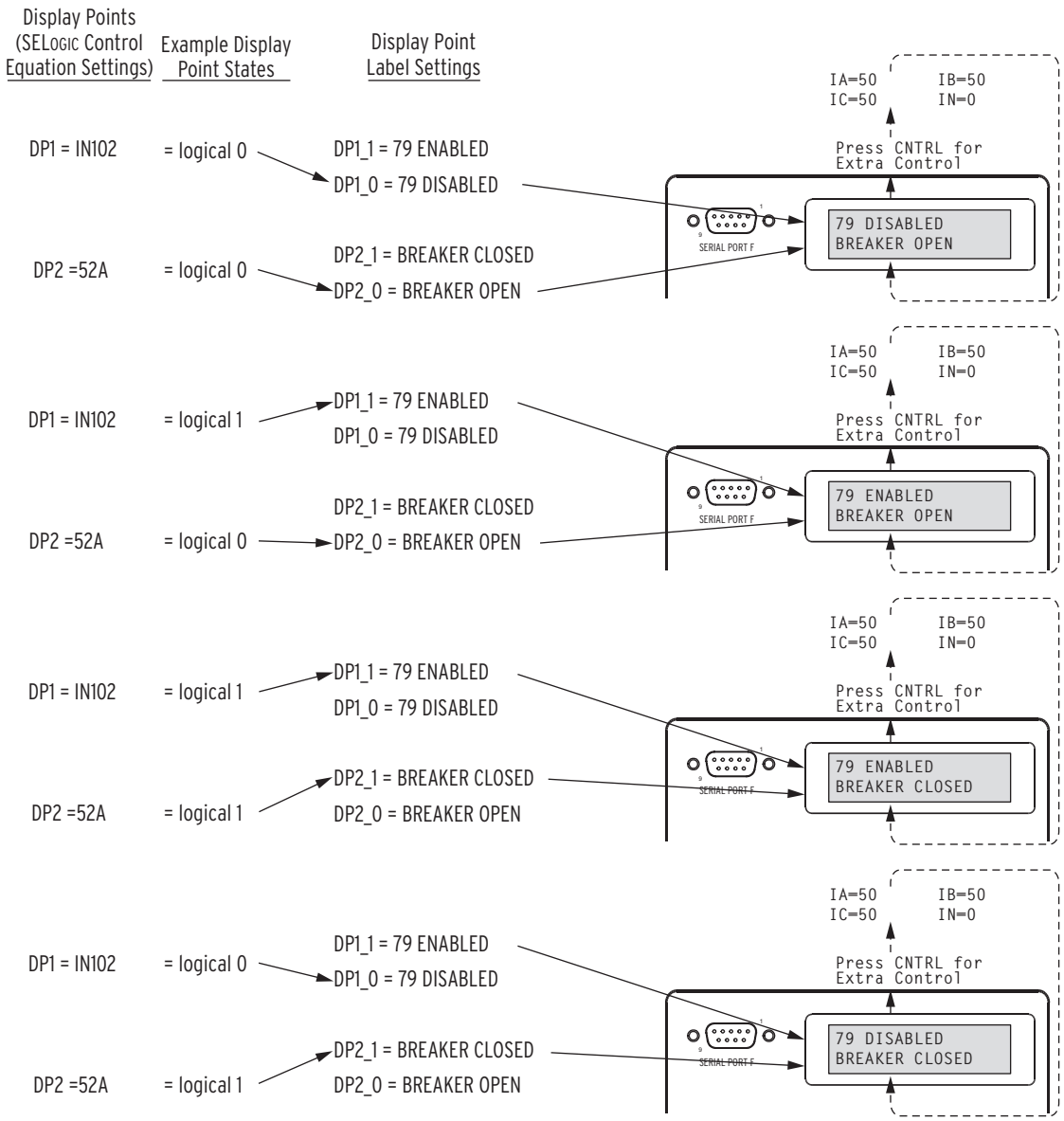
The display point example settings are:

DP1 = **IN102** (optoisolated input **IN102**)

DP2 = **52A** (breaker status)

Optoisolated input **IN102** is used as a recloser enable/disable in this example. See *Optoisolated Inputs on page 7.2*.

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In the preceding example, only two display points (DP1 and DP2) and their corresponding display point labels are set. If additional display points and corresponding display point labels are set, the additional enabled display point labels join the rotation (display time = SCROLD) on the front-panel display. The SCROLD setting is made with the **SET G** command and reviewed with the **SHO G** command.

Display point label settings are set with the **SET T** command or viewed with the **SHO T** command via the serial port [see *Section 9: Setting the Relay* and *SHO Command (Show/View Settings) on page 10.27*].

For more detailed information on the logic behind the rotating default display, see *Rotating Default Display on page 7.36*.

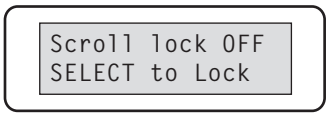
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Scroll Lock Control of Front-Panel LCD

The rotating default display can be locked on a single screen. (See *Rotating Default Display*). Access the scroll lock control with the **{OTHER}** pushbutton.

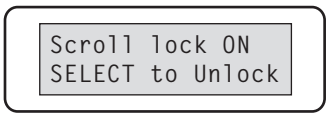


Select `LCD` for Scroll Lock Control mode. The rotating display will then appear, and the scroll mode reminder screen will appear every eight seconds for one second as a reminder that the display is in Scroll Lock Control mode.



Stop Scrolling (Lock)

When in the Scroll Lock Control mode, press the **{SELECT}** key to stop display rotation. Scrolling can be stopped on any of the display point screens, or on the current-meter display screen. While rotation is stopped, the active display is updated continuously so that current or display point changes can be seen. If no button is pressed for eight seconds, the reminder message will appear for one second, followed by the active screen.



Restart Scrolling (Unlock)

The **{SELECT}** key unlocks the LCD and resumes the rotating display.

Single Step

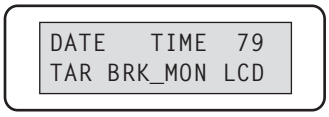
From the Scroll Locked state, single-step through the display screens, by pressing the **{SELECT}** key twice. Wait for the first press to display the next screen as the active display, then press the **{SELECT}** key a second time to freeze scrolling.

Exit

Press the **{EXIT}** key to leave Scroll Lock Control and return the rotating display to normal operation.

Cancel

Press the **{CANCEL}** key to return to the **{OTHER}** menu.

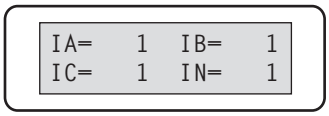


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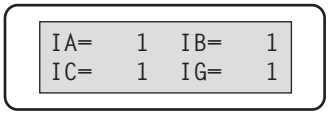
Front-Panel Neutral/ Ground Current Display

Global setting FPNGD (Front-Panel Neutral/Ground Display) selects whether IG, IN, or neither is displayed on the front-panel rotating display. Setting choices are:

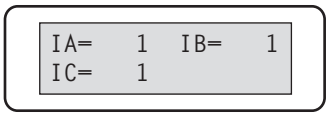
FPNGD = **IN**



FPNGD = **IG**



FPNGD = **OFF**



Additional Rotating Default Display Example

See *Figure 5.18* and accompanying text for an example of resetting a rotating default display with the **{TARGET RESET}** pushbutton.

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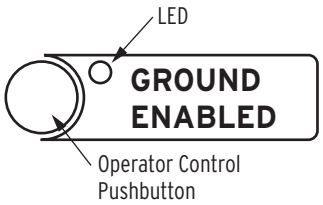
Operator Controls

NOTE: The functions described in Table 11.1 are based on the factory default settings and operator control labels.

NOTE: On some models, the operator-control labels can be user-configured. See User-Configurable Label Option for the Front Panel on page 2.9.

Refer to *Figure 1.2*, *Figure 2.2*, *Figure 2.3*, *Figure 2.4*, *Figure 2.5*, and *Figure 2.6* for the layout of the front-panel operator controls. Except for the {LOCK} operator control pushbutton, all the following operator control pushbuttons should be **pressed momentarily** to execute their function.

Table 11.1 SEL-351S Front-Panel Operator Control Functions (Sheet 1 of 3)

Press the {GROUND ENABLED} operator control pushbutton to enable/disable ground overcurrent element tripping. Corresponding LED illuminates to indicate the enabled state. See the discussion surrounding *Figure 11.4* on making ground overcurrent element torque control settings changes to allow the {GROUND ENABLED} operator control to enable/disable newly set ground overcurrent elements.	
Press the {RECLOSE ENABLED} operator control pushbutton to enable/disable auto reclosing. Corresponding LED illuminates to indicate the enabled state. The {RECLOSE ENABLED} operator control is overridden by the operation of the {HOT LINE TAG} operator control in the following scenario: Initial state: {RECLOSE ENABLED} "on" or "off" and {HOT LINE TAG} "off." Action: Press {HOT LINE TAG} operator control pushbutton. Result: {RECLOSE ENABLED} "off" and {HOT LINE TAG} "on." The {RECLOSE ENABLED} operator control is now nonfunctional (remains "off"). {RECLOSE ENABLED} cannot be turned "on" again, until {HOT LINE TAG} is turned "off." Once {HOT LINE TAG} is "off," the {RECLOSE ENABLED} operator control is then functional, but remains "off" until the {RECLOSE ENABLED} operator control pushbutton is pressed again.	
Press the {REMOTE ENABLED} operator control pushbutton to enable/disable remote control. Corresponding LED illuminates to indicate the enabled state. **NOTE**: The {REMOTE ENABLED} operator control is not operable with the factory settings. See *Figure 11.17* for information and ideas on how to program this control.	
Press the {ALTERNATE SETTINGS} operator control pushbutton to switch the active setting group between the main setting group (Setting Group 1) and the alternate setting group (Setting Group 2). Corresponding LED illuminates to indicate that the alternate setting group is active.	

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Table 11.1 SEL-351S Front-Panel Operator Control Functions (Sheet 2 of 3)

Continually press the **{LOCK}** operator control pushbutton for three (3) seconds to engage/disengage the lock function. While this pushbutton is pressed, the corresponding LED flashes on and off, indicating a pending engagement or disengagement of the lock function. The LED illuminates constantly to indicate the engaged state. While the lock function is engaged, the following operator controls are "locked in position" (assuming factory default settings):

{GROUND ENABLED}
{RECLOSE ENABLED}
{REMOTE ENABLED}
{ALTERNATE SETTINGS}
{HOT LINE TAG}
{AUX 1}
{AUX 2}

While "locked in position," these operator controls cannot change state if pressed—their corresponding LEDs remain in the same state. When the lock function is engaged, the **{CLOSE}** operator control cannot close the breaker, but the **{TRIP}** operator control can still trip the breaker.

Important Note: (Model 0351S*xxx*5/6/A/B) The auxiliary close pushbutton on model 0351S*xxx*5/6/A/B is electrically separate from the rest of the relay and not part of the close logic in *Figure 6.1*. It provides separate closing capability as shown in *Figure 2.31*. Because of this, the **{HOT LINE TAG}** operator control and **{LOCK}** operator control do not affect the auxiliary close pushbutton.



Press the **{HOT LINE TAG}** operator control pushbutton to enable/disable the hot line tag function. Corresponding LED illuminates to indicate the enabled state.

While the hot line tag function is enabled, no closing or auto reclosing can take place via the control (e.g., the **{CLOSE}** operator control is inoperative). The **{HOT LINE TAG}** operator overrides the **{RECLOSE ENABLED}** operator control (see previous **{RECLOSE ENABLED}** operator control description).

Important Note: (Model 0351S*xxx*5/6/A/B) The auxiliary close pushbutton on model 0351S*xxx*5/6/A/B is electrically separate from the rest of the relay and not part of the close logic in *Figure 6.1*. It provides separate closing capability as shown in *Figure 2.31*. Because of this, the **{HOT LINE TAG}** operator control and **{LOCK}** operator control do not affect the auxiliary close pushbutton.



Press the **{AUX 1}** operator control pushbutton to enable/disable user-programmed auxiliary control. Corresponding LED can be programmed to illuminate during the enabled state.

NOTE: The **{AUX 1}** operator control does not perform any function with the factory settings.



Press the **{AUX 2}** operator control pushbutton to enable/disable user-programmed auxiliary control. Corresponding LED can be programmed to illuminate during the enabled state.

NOTE: The **{AUX 2}** operator control does not perform any function with the factory settings.



Press the **{CLOSE}** operator control pushbutton to close the breaker. Corresponding **BREAKER CLOSED** LED illuminates to indicate the breaker is closed.

Option: Set a delay, so the operator can press the **{CLOSE}** operator control pushbutton and then move a safe distance away from the breaker before the SEL-351S issues a close (the **{CLOSE}** operator control comes with no set delay in the factory settings). With a set delay, press the **{CLOSE}** operator control pushbutton momentarily, and notice that the corresponding **BREAKER CLOSED** LED flashes on and off during the delay time, indicating a pending close. Abort the pending close by pressing the **{CLOSE}** operator control pushbutton again or by pressing the **{TRIP}** operator control pushbutton. This delay setting for the **{CLOSE}** operator control is PB9D (range: 0 to 3600 cycles; factory-set at 0 cycles—no delay). The delay is set via the **SET G** command. See *Figure 11.10* for more information.



(Model 0351Sxxx3)

Or



(Model 0351Sxxx4)

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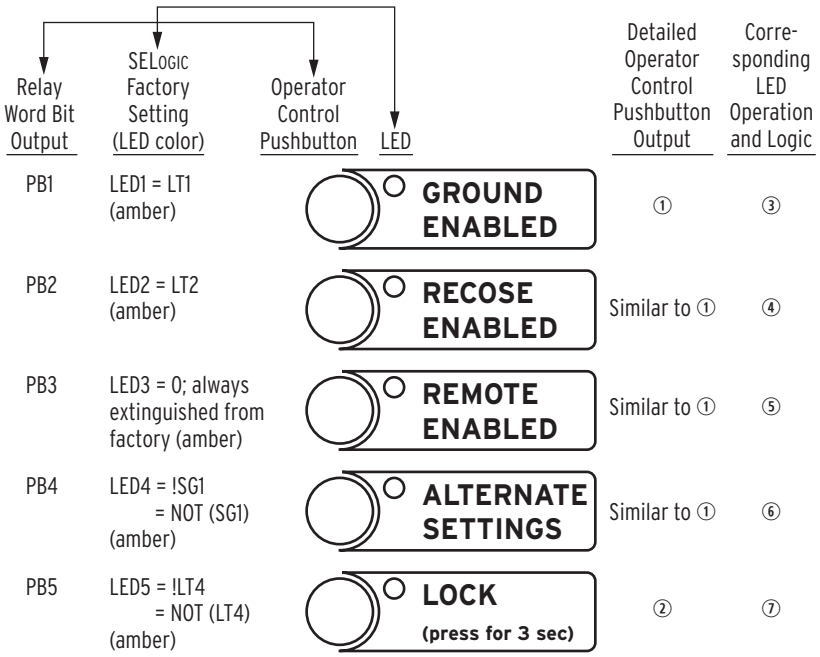
Table 11.1 SEL-351S Front-Panel Operator Control Functions (Sheet 3 of 3)

In model 0351S*xxx*5/6/A/B, the ninth operator control is labeled **{AUX 3}**, instead of **{CLOSE/BREAKER CLOSED}** (as in relay model 0351S*xxx*3/4). In model 0351S*xxx*5/6/A/B, the auxiliary **{CLOSE}** pushbutton is normally wired to the close bus to perform breaker closing directly, thus eliminating any need for a **{CLOSE}** operator control (see *Figure 2.5*, *Figure 2.6*, and *Figure 2.31*). The **{AUX 3}** operator control and corresponding LED do not perform any function with the factory default settings. Program the **{AUX 3}** operator control to achieve almost any type of control (e.g., program to enable/disable a user-designed scheme). **NOTE**: The time-delay setting for the **{AUX 3}** 3 operator control (global setting PB9D) should be left set to the factory default of PB9D = 0 cycles (no time delay). If PB9D > 0 cycles, the operation of corresponding Relay Word bit PB9 will be supervised by SELOGIC setting ULCL—see *Figure 11.10*. If ULCL is asserted (logical 1), this operator will be effectively disabled.	 (Model 0351Sxxx5/6/A/B)
Press the **{TRIP}** operator control pushbutton to trip the breaker (and take the control to the lockout state). Corresponding **BREAKER OPEN** LED illuminates to indicate the breaker is open. **Option:** Set a delay, so the operator can press the **{TRIP}** operator control pushbutton and then move a safe distance away from the breaker before the SEL-351S issues a trip (the **{TRIP}** operator control comes with no set delay in the factory settings). With a set delay, press the **{TRIP}** operator control pushbutton momentarily and notice the corresponding **BREAKER OPEN** LED flashes on and off during the delay time, indicating a pending trip. Abort the pending trip by pressing the **{TRIP}** operator control pushbutton again or by pressing the **{CLOSE}** operator control pushbutton. This delay setting for the **{TRIP}** operator control is PB10D (range: 0 to 3600 cycles; factory-set at 0 cycles—no delay). The delay is set via the **SET G** command. See *Figure 11.13* for more information.	 (Model 0351Sxxx3)
Or	 (Model 0351Sxxx4)
In model 0351S*xxx*5/6/A/B, the tenth operator control is labeled **{AUX 4}**, instead of **{TRIP/BREAKER OPEN}** (as in relay model 0351S*xxx*3/4). In model 0351S*xxx*5/6/A/B, the auxiliary **{TRIP}** pushbutton is normally wired to the trip bus to perform breaker tripping directly, thus eliminating any need for a **{TRIP}** operator control (see *Figure 2.5*, *Figure 2.6*, and *Figure 2.31*). The **{AUX 4}** operator control and corresponding LED do not perform any function with the factory default settings. Program the **{AUX 4}** operator control to achieve almost any type of control (e.g., program to enable/disable a user-designed scheme). **NOTE**: The time-delay setting for the **{AUX 4}** operator control (global setting PB10D) should be left set to the factory default of PB10D = 0 cycles (no time delay).	 (Model 0351Sxxx5/6/A/B)

The operator controls are programmable. See *Figure 11.8* and *Figure 11.9*. Relay Word bits PB1–PB10 are the outputs of operator-control pushbuttons **{GROUND ENABLED}**–**{TRIP}**, respectively.

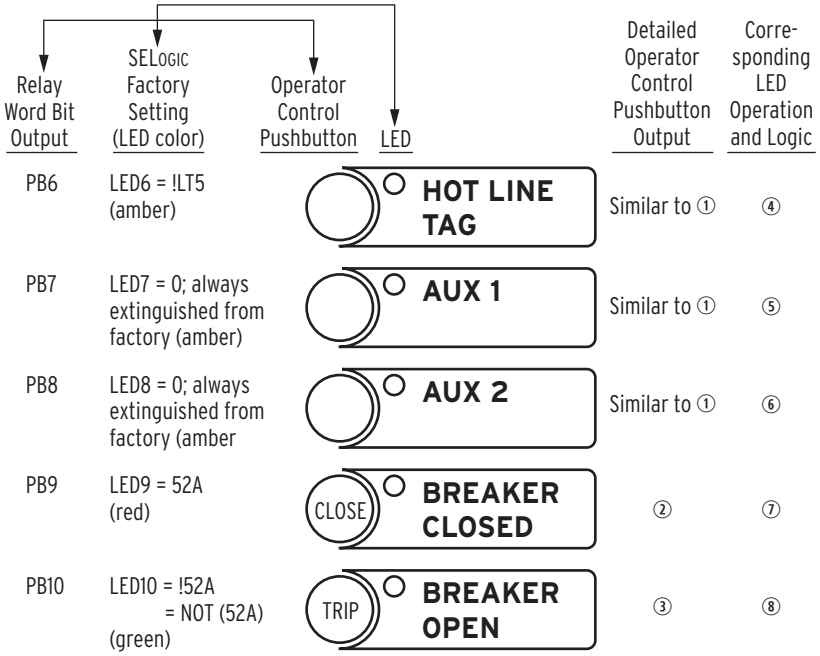
The corresponding LEDs (**LED1**–**LED10**, respectively) are programmed independently. This allows great flexibility, especially in indicating status for a function that is controlled both locally and remotely.

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① See Figure 11.10; ② see Figure 11.11; ③ see Figure 11.14; ④ see Figure 11.15; ⑤ see Figure 11.16; ⑥ see Figure 11.20; ⑦ see Figure 11.21.

Figure 11.8 Operator Controls–{GROUND ENABLED}–{LOCK}



① See Figure 11.10; ② see Figure 11.12; ③ see Figure 11.13; ④ see Figure 11.15; ⑤ see Figure 11.18; ⑥ see Figure 11.19; ⑦ see Figure 6.2; ⑧ see Figure 5.1.

Figure 11.9 Operator Controls–{HOT LINE TAG} through {TRIP} (Model 0351Sxxx3)

NOTE: The bottom two operator controls in Figure 11.9 (for model 0351S*xxx*3) are different for model 0351S*xxx*5/6/A/B (see the latter part of Table 11.1 for a comparison). The **{AUX 3}** and **{AUX 4}** operator controls and corresponding LEDs for model 0351S*xxx*5/6/A/B in Table 11.1 do not perform any function with the factory default settings (corresponding LED settings are set LED9 = 0 and LED10 = 0).

Detailed Operator Control Pushbutton Output

Figure 11.8 and *Figure 11.9* list corresponding figures that detail operator control pushbutton output and corresponding LED operation and logic operation. Note that the pushbutton output (e.g., Relay Word bit PB1 for the **{GROUND ENABLED}** operator control pushbutton) corresponds number-wise to the LED setting (e.g., SELOGIC setting LED1 for the **GROUND ENABLED** LED).

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{GROUND ENABLED} Operator Control Pushbutton Output

Figure 11.10 describes the **{GROUND ENABLED}** operator control pushbutton output. Every time the **{GROUND ENABLED}** operator control pushbutton is pressed momentarily, Relay Word bit PB1 asserts to logical 1 immediately for one processing interval.

The corresponding **GROUND ENABLED** LED (controlled by SELOGIC setting LED1) is independent of the **{GROUND ENABLED}** operator control pushbutton.

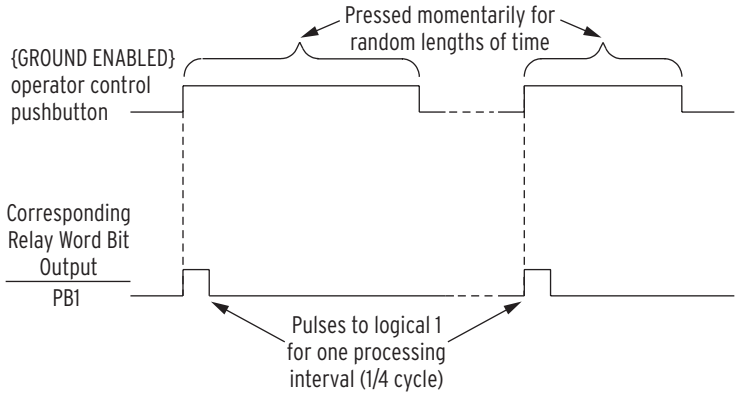


Figure 11.8 and Figure 11.9 list other operator control pushbuttons that operate similarly to the above detailed **{GROUND ENABLED}** operator control pushbutton and corresponding Relay Word bit PB1.

Figure 11.10 {GROUND ENABLED} Operator Control Pushbutton Output

Other Operator Control Pushbutton Outputs Operate Similarly to {GROUND ENABLED}

The following operator control pushbutton outputs operate similarly to the **{GROUND ENABLED}** operator control pushbutton output described in *Figure 11.10* (corresponding Relay Word bits PB2, PB3, PB4, PB6, PB7, and PB8 assert to logical 1 immediately for one processing interval when the operator control pushbutton is pressed momentarily):

{RECLOSE ENABLED} (PB2) **{HOT LINE TAG}** (PB6)

{REMOTE ENABLED} (PB3) **{AUX 1}** (PB7)

{ALTERNATE SETTINGS} (PB4) **{AUX 2}** (PB8)

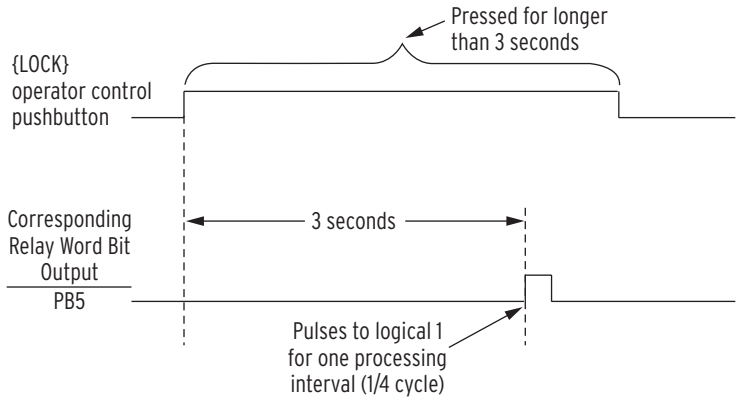
{LOCK} Operator Control Pushbutton Output

NOTE: The three-second delay described in Figure 11.11 can be defeated via setting (see global setting RSTLED in Global Settings (Serial Port Command SET G and Front Panel) on page SET.25). If the three-second delay is defeated, the **{LOCK}** operator control operates similar to Figure 11.10.

Figure 11.11 describes the output of the unique **{LOCK}** operator control pushbutton. Note the need to press the **{LOCK}** operator control pushbutton continually for three seconds until Relay Word bit PB5 asserts to logical 1 for one processing interval.

The corresponding **LOCK** LED (controlled by SELOGIC setting LED5) is independent of the **{LOCK}** operator control pushbutton, unless the **{LOCK}** operator control pushbutton is pressed for the three seconds (and the LED flashes), as described in *Figure 11.11*.

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The corresponding **LOCK** operator control LED flashes during this three-second timing period while the **{LOCK}** operator control pushbutton is pressed. This flashing indicates a pending pulsing of Relay Word bit PB5, regardless of the setting of corresponding SELOGIC control equation setting LED5.

If the **{LOCK}** operator control pushbutton is released before three seconds, the corresponding LED stops flashing and Relay Word bit PB5 is not pulsed. The LED returns to its regular operation, per SELOGIC control equation setting LED5 (see Figure 11.21.

Figure 11.11 {LOCK} Operator Control Pushbutton Output

{TRIP} and {CLOSE} Operator Control Pushbutton Outputs (0351S*xxx*3/4 Models Only)

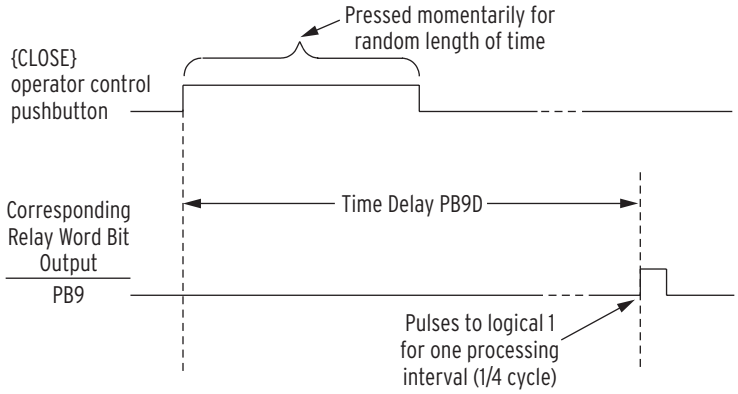
Figure 11.12 and *Figure 11.13* describe the operation of the **{CLOSE}** and **{TRIP}** operator control pushbutton outputs, respectively. On the 0351S*xxx*4 model, the words CLOSE and TRIP do not appear on the pushbuttons—see *Table 11.1*. The discussion that follows will still refer to the pushbuttons by these names, because the factory logic settings are the same as those for the 0351S*xxx*3 model.

Note the programmable time delays (PB9D and PB10D, respectively),whereby the operator control can be pressed momentarily and the corresponding Relay Word bit (PB9 or PB10) asserts to logical 1 for one processing interval after the time delay. Also note the interlocking between the **{CLOSE}** and **{TRIP}** pushbuttons as described in *Figure 11.12* and *Figure 11.13*, whereby a pending close can be turned off by pressing the **{TRIP}** pushbutton and a pending trip can be turned off by pressing the **{CLOSE}** pushbutton.

The corresponding **BREAKER CLOSED** and **BREAKER OPEN** LEDs (controlled by SELOGIC settings LED9 and LED10, respectively) are independent of the **{CLOSE}** and **{TRIP}** operator control pushbuttons, unless the **{CLOSE}** or **{TRIP}** operator control pushbutton is pressed and a pending close or trip results (and LED flashes), as described in *Figure 11.12* and *Figure 11.13*.

{CLOSE} and **{TRIP}** operator control outputs (Relay Word bits PB9 and PB10) are routed into close logic (see *Figure 6.2*) and trip logic (see *Figure 5.1*), respectively.

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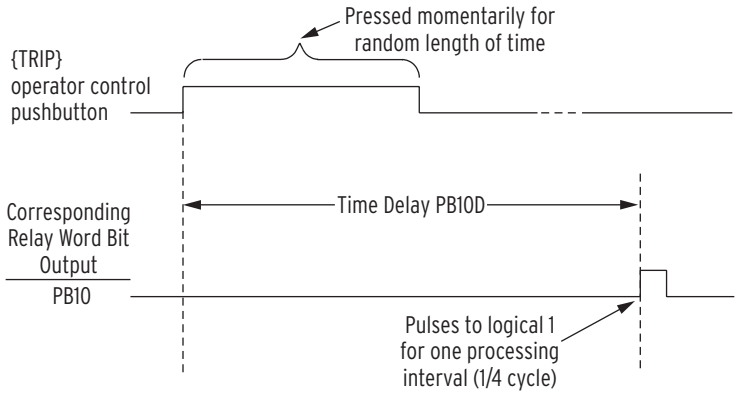
The corresponding **BREAKER CLOSED** LED flashes during the timing of time delay PB8D. This flashing indicates a pending pulsing of Relay Word bit PB9, regardless of the setting of corresponding SELOGIC control equation setting LED9.

If the **{CLOSE}** operator control pushbutton is pressed again (or the **{TRIP}** operator control pushbutton is pressed) while PB9D is timing, the **BREAKER CLOSED** LED stops flashing, PB9D stops timing, and Relay Word bit PB9 is not pulsed. The pending close operation is aborted. The **BREAKER CLOSED** LED returns to its regular operation, per SELOGIC control equation setting LED9 (see Figure 11.9).

If time delay setting PB9D is set PB9D >0, then the assertion of SELOGIC setting ULCL (unlatch close) to logical 1 also aborts pending closes and prevents the **{CLOSE}** operator control pushbutton from starting a pending close in the first place. See Figure 6.3.

If time delay setting PB9D is set PB9D = 0 (no time delay), then Relay Word bit PB9 functions in a manner similar to Figure 11.10.

Figure 11.12 {CLOSE} Operator Control Pushbutton Output



The corresponding **BREAKER OPEN** LED flashes during the timing of time delay PB10D. This flashing indicates a pending pulsing of Relay Word bit PB10, regardless of the setting of corresponding SELOGIC control equation setting LED10.

If the **{TRIP}** operator control pushbutton is pressed again (or the **{CLOSE}** operator control pushbutton is pressed) while PB10D is timing, the **BREAKER OPEN** LED stops flashing, PB10D stops timing, and Relay Word bit PB10 is not pulsed. The pending trip operation is aborted. The **BREAKER OPEN** LED returns to its regular operation, per SELOGIC control equation setting LED10 (see Figure 11.9).

If time delay setting PB10D is set PB10D = 0 (no time delay), then Relay Word bit PB10 functions in a manner similar to Figure 11.10.

Figure 11.13 {TRIP} Operator Control Pushbutton Output

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{AUX 3} and {AUX 4} Operator Control Pushbutton Outputs (0351S*xxx*5/6/A/B Models Only)

See the latter part of *Table 11.1*, comparing the following operator controls, per model type:

Model 0351S*xxx*3/4	Model 0351S*xxx*5/6/A/B
{CLOSE/BREAKER CLOSED}	{AUX 3}
{TRIP/BREAKER OPEN} (see also *Figure 2.2*–*Figure 2.4*)	{AUX 4} (see also *Figure 2.5* and *Figure 2.6*)

These operator controls, regardless of the model, operate identically at the operator control level described in *{TRIP} and {CLOSE} Operator Control Pushbutton Outputs (0351Sxxx3/4 Models Only) on page 11.21* (e.g., the detailed descriptions in *Figure 11.12* and *Figure 11.13* also apply to **{AUX 3}** and **{AUX 4}**, respectively). The only differences are the apparent front-panel labeling and where the resultant operator control Relay Word bit outputs (PB9 and PB10, respectively) are programmed in SELOGIC control equations settings by the user.

For **{AUX 3}** and **{AUX 4}** in model 0351S*xxx*5/6/A/B, corresponding time-delay settings should be left at factory defaults PB9D = 0 cycles and PB10D = 0 cycles, respectively (no time delay). Then, the auxiliary operator control Relay Word bit outputs (PB9 and PB10) operate like the operator control output described in *Figure 11.10*.

Corresponding Operator Control LEDs and Logic

The operator control logic makes extensive use of the programmable latch control switches (LT1–LT7; see *Latch Control Switches on page 7.12*). The factory settings for these latch control switches are listed under *SHO Command (Show/View Settings) on page 10.27* (SELOGIC control equation settings SET*x* and RST*x*; *x* = 1–7). The programmable operator control LED settings are also found in the same subsection (SELOGIC control equation settings **LED1**–**LED10**).

{GROUND ENABLED} Operator Control

Figure 11.14 describes the logic driven by the **{GROUND ENABLED}** operator control pushbutton (pulsed output PB1) and operation of the corresponding LED. Note that the **{LOCK}** operator control logic supervises the **{GROUND ENABLED}** operator control. The **{LOCK}** operator control has to be OFF (LT4 = logical 1) in order for the **{GROUND ENABLED}** operator control to effectively function—so that Relay Word bit PB1 can propagate on to latch LT1.

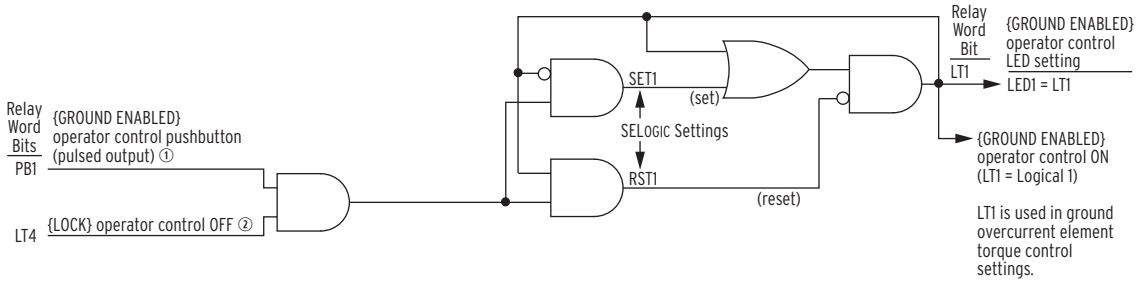
Latch LT1 is set up as a flip-flop with one effective logic input:

- Momentarily press the **{GROUND ENABLED}** operator control pushbutton and LT1 sets to logical 1
- Momentarily press the **{GROUND ENABLED}** operator control pushbutton again and LT1 resets to logical 0

All latches (LT1–LT16) are nonvolatile (retain their state if the SEL-351S is powered down and then powered up again). The latch output (Relay Word bit LT1) propagates to the following logic:

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- Drives the corresponding **{GROUND ENABLED}** operator control LED (SELOGIC setting LED1 = LT1) to indicate that ground overcurrent tripping is enabled (LED is illuminated) or disabled (LED is extinguished).
- Drives the 51G1T residual-ground overcurrent element torque control equation (51G1TC = LT1) to enable or disable this factory-set element (TR = … + 51G1T + …).



① See Figure 11.10; ② see Figure 11.21.

Figure 11.14 {GROUND ENABLED} Operator Control LED and Logic

If other ground overcurrent elements are set to trip (e.g., TR = … + 67G1T), consideration should be given to having these elements also controlled by the **{GROUND ENABLED}** operator control (e.g., 67G1TC = LT1). The last part of *Trip Logic on page 5.1* discusses checking other settings (including overcurrent element torque control settings) when changing or modifying trip logic.

{RECLOSE ENABLED} and {HOT LINE TAG} Operator Controls

As shown in *Figure 11.15*, the **{RECLOSE ENABLED}** and **{HOT LINE TAG}** operator controls have interlocking logic, as explained in *Table 11.1*. Additionally, if the reclosing relay is turned off (enable setting E79 = N or open interval setting 79OI1 = 0), then reclosing is defeated as shown at the bottom of *Figure 11.15* (all the reclosing states [79RS, 79CY, and 79LO] go to logical 0).

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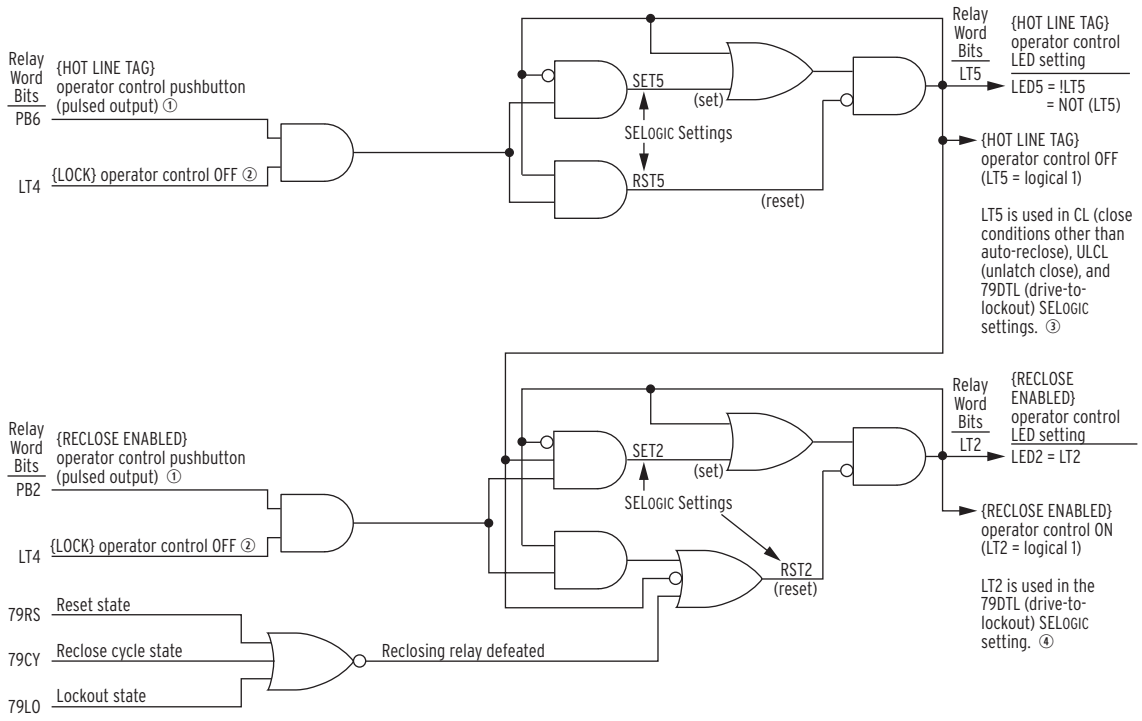


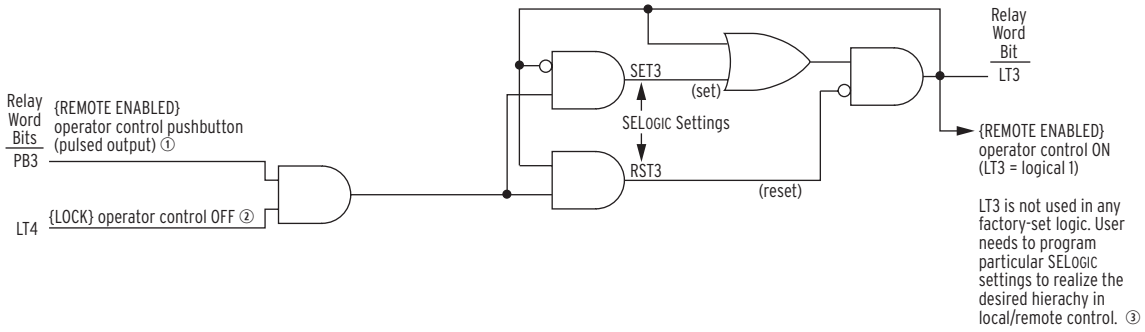
Figure 11.15 {RECLOSE ENABLED} and {HOT LINE TAG ENABLED} Operator Control Logic

① See Figure 11.10; ② see Figure 11.21; ③ see Figure 6.2, Figure 6.3, and Figure 6.10; ④ see Figure 6.10.

{REMOTE ENABLED} Operator Control

IMPORTANT NOTE: (Model 0351S*xxx*5/6/A/B) The auxiliary close pushbutton on model 0351S*xxx*5/6/A/B is electrically separate from the rest of the relay and not part of the close logic in Figure 6.1. It provides separate closing capability as shown in Figure 2.31. Because of this, the **{HOT LINE TAG}** operator control and **{LOCK}** operator control do not affect the auxiliary close pushbutton.

As stated in *Figure 11.16* (**{REMOTE ENABLED}**), latch LT3 is not used in any of the factory-set logic. Each press of the **{REMOTE ENABLED}** operator control pushbutton toggles latch LT3 from LT3 = logical 0 to LT3 = logical 1 and vice versa, but LT3 is not used in any of the factory-set logic. Thus the **{REMOTE ENABLED}** operator control is not functional from the factory (corresponding LED is extinguished all the time, too; SELOGIC setting LED3 = 0, see *Figure 11.8*).



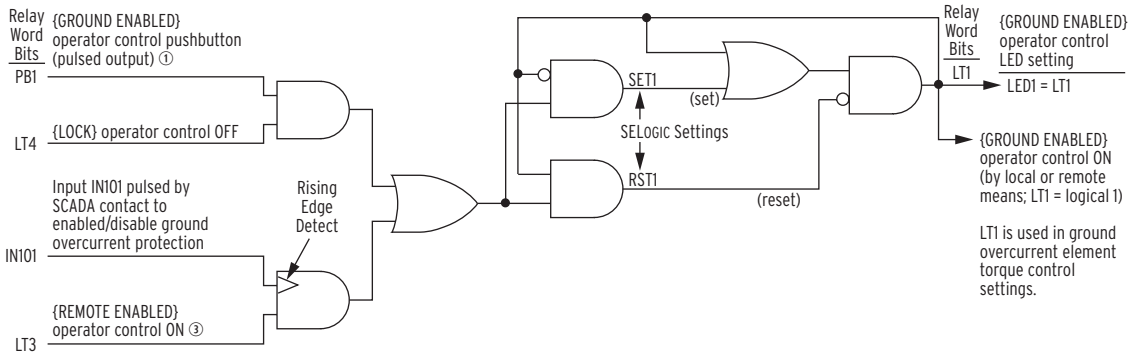
① See Figure 11.10; ② see Figure 11.21; ③ see Figure 11.17.

Figure 11.16 {REMOTE ENABLED} Operator Control Logic

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Example Application for the {REMOTE ENABLED} Operator Control

To use the **{REMOTE ENABLED}** operator control, change the corresponding LED setting to LED3 = LT3 (to monitor the output of latch LT3) and assign LT3 to a supervising role in logic. For example, *Figure 11.17* is a logic modification to *Figure 11.14* (**{GROUND ENABLED}** operator control). Latch LT1 can be set/reset locally (with **{GROUND ENABLED}** operator control pushbutton) or remotely (with input **IN101**). Note that the remote control (IN101) is supervised by Relay Word bit LT3 (**{REMOTE ENABLED}** operator control). Likewise, the local control (**{GROUND ENABLED}** operator control) is supervised by Relay Word bit LT4 (**{LOCK}** operator control). This is just one example—many variations are possible.

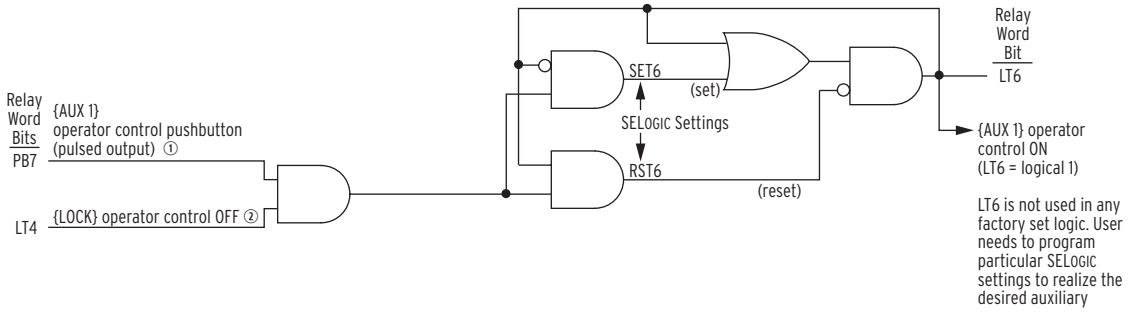


① See Figure 11.10; ② see Figure 11.21; ③ see Figure 11.16.

Figure 11.17 Example {REMOTE ENABLED} Operator Control Application (Supervising Remote Control of Ground Overcurrent Elements)

{AUX 1} and {AUX 2} Operator Controls

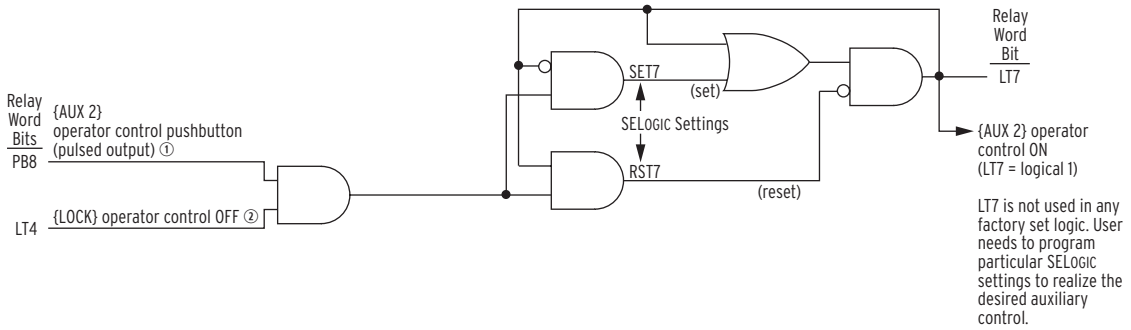
As stated in *Figure 11.18* (**{AUX 1}**) and *Figure 11.19* (**{AUX 2}**), latches LT6 and LT7 are not used in any of the factory-set logic. Each press of the **{AUX 1}** operator control pushbutton toggles latch LT6 from LT6 = logical 0 to LT6 = logical 1 and vice versa, but LT6 is not used in any of the factory-set logic. Thus the **{AUX 1}** operator control is not functional from the factory (corresponding LED is extinguished all the time, too; SELOGIC setting LED7 = 0, see *Figure 11.9*). The **{AUX 2}** operator control operates similarly.



① See Figure 11.10; ② see Figure 11.21.

Figure 11.18 {AUX 1} Operator Control Logic

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① See Figure 11.10; ② see Figure 11.21.

Figure 11.19 {AUX 2} Operator Control Logic

{AUX 3} and {AUX 4} Operator Controls (0351S*xxx*5/6/A/B Models Only)

The **{AUX 3}** and **{AUX 4}** operator controls and corresponding LEDs do not perform any function with the factory default settings. The Relay Word bit outputs for the **{AUX 3}** and **{AUX 4}** operator controls (PB9 and PB10, respectively) are not programmed to any logic, with factory default settings (as contrasted to **{AUX 1}** and **{AUX 2}** operator controls in *Figure 11.18* and *Figure 11.19*, respectively). Corresponding LED settings for **{AUX 3}** and **{AUX 4}** operator controls are set LED9 = 0 and LED10 = 0, respectively (the **AUX 3** and **AUX 4** LEDs are always extinguished).

{ALTERNATE SETTINGS} Operator Control

Figure 11.20 describes the logic driven by the **{ALTERNATE SETTINGS}** operator control pushbutton (pulsed output PB4) and operation of the corresponding LED. Note that the **{LOCK}** operator control logic supervises the **{ALTERNATE SETTINGS}** operator control. The **{LOCK}** operator control has to be OFF (LT4 = logical 1) in order for the **{ALTERNATE SETTINGS}** operator control to effectively function, and so that Relay Word bit PB4 can propagate on to:

- "select setting group" SELOGIC settings SS1 and SS2
- **{ALTERNATE SETTINGS}** operator control LED setting LED4

Relay Word bit SG1 = logical 1 indicates that settings group 1 is the active setting group. Relay Word bit SG1 routes the **{ALTERNATE SETTINGS}** operator control pushbutton output PB4 to:

- SELOGIC setting SS1 (go to setting group 1) when SG1 = logical 0 (setting group 1 is **not** presently the active setting group)
- SELOGIC setting SS2 (go to setting group 2) when SG1 = logical 1 (setting group 1 is presently the active setting group)

Each time the **{ALTERNATE SETTINGS}** operator control pushbutton is momentarily pressed, the active setting group switches between:

- Setting group 2 as the active setting group (**ALTERNATE SETTINGS** operator control LED illuminates)
- And setting group 1 as the active setting group (**ALTERNATE SETTINGS** operator control LED extinguishes)

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Neither SELOGIC setting SS1 nor SS2 has to be maintained at logical 1 in order for the active setting group to remain at setting group 1 or setting group 2, respectively. See *Multiple Setting Groups on page 7.19*.

The active setting group designation is nonvolatile (retained if the SEL-351S is powered down and then powered up again, i.e., returns to the same active setting group).

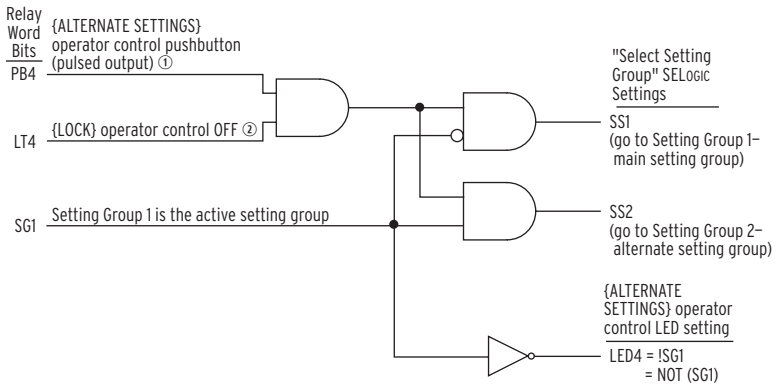


Figure 11.20 {ALTERNATE SETTINGS} Operator Control LED and Logic

① See Figure 11.10; ② see Figure 11.21.

{LOCK} Operator Control

Figure 11.21 describes the logic driven by the **{LOCK}** operator control pushbutton (pulsed output PB5) and operation of the corresponding LED. Relay Word bit PB5 propagates to latch LT4.

Latch LT4 is set up as a flip-flop:

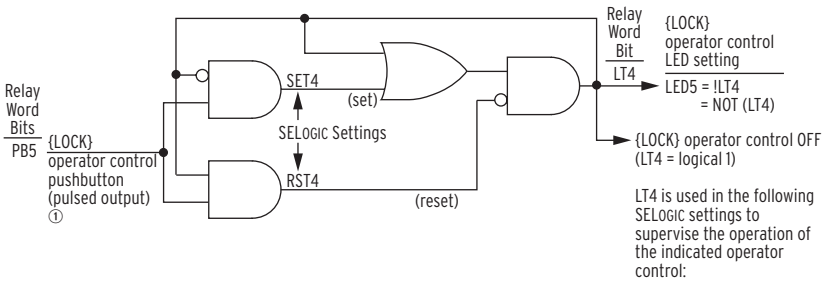
- Press the **{LOCK}** operator control pushbutton (for three seconds as described in *Figure 11.11*—see Note 1) and LT4 sets to logical 1
- Press the **{LOCK}** operator control pushbutton (for three seconds as described in *Figure 11.11*—see Note 1) again and LT4 resets to logical 0

NOTE: The "press for three seconds" requirement on the fifth operator control pushbutton (PB5) can be disabled via global setting RSTLED– see Global Settings (Serial Port Command SET G and Front Panel) on page SET.25.

All latches (LT1–LT16) are nonvolatile (retain their state if the SEL-351S is powered down and then powered up again). The latch output (Relay Word bit LT4) propagates to the following logic:

- Drives the corresponding **{LOCK}** operator control LED [SELOGIC setting LED5 = !LT4 = NOT(LT4)] to indicate that **{LOCK}** is ON (LED is illuminated; LT4 = logical 0) or OFF (LED is extinguished; LT4 = logical 1).
- Supervises most of the other operator controls as listed at the bottom of *Figure 11.21*.

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Operator Control	SELOGIC Settings	Logic Application
{GROUND ENABLED}	SET1, RST1	②
{RECLOSE ENABLED}	SET2, RST2	③
{REMOTE ENABLED}	SET3, RST3	④
{ALTERNATE SETTINGS}	SS1, SS2	⑤
{HOT LINE TAG}	SET5, RST5	③
{AUX 1}	SET6, RST6	⑥
{AUX 2}	SET7, RST7	⑦
{CLOSE}	CL	⑧

Figure 11.21 {LOCK} Operator Control LED and Logic

① See Figure 11.11; ② see Figure 11.14; ③ see Figure 11.15; ④ see Figure 11.16; ⑤ see Figure 11.20; ⑥ see Figure 11.18; ⑦ see Figure 11.19; ⑧ see Figure 6.2.

IMPORTANT NOTE: (Model 0351Sxxx5/6/A/B) The auxiliary close pushbutton on model 0351Sxxx5/6/A/B is electrically separate from the rest of the relay and not part of the close logic in Figure 6.1. It provides separate closing capability as shown in Figure 2.31. Because of this, the **{HOT LINE TAG}** operator control and **{LOCK}** operator control do not affect the auxiliary close pushbutton.

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Section 12

Standard Event Reports, Sag/Swell/Interruption Report, and SER

Introduction

The SEL-351S Relay offers two styles of event reports:

- Standard 15/30-cycle event reports
- Sequential events recorder (SER) report

Resolution: 1 ms

Accuracy: +1/4 cycle

The event reports contain date, time, current, voltage, frequency, relay element, optoisolated input, output contact, and fault location information.

The relay generates (triggers) standard 15/30-cycle event reports by fixed and programmable conditions. These reports show information for 15 or 30 continuous cycles which depends on the LER setting (see the following subsection). The relay stores the most recent event report data in nonvolatile memory. Twenty-three 15-cycle or eleven 30-cycle reports are maintained; if more reports are triggered, the latest event report overwrites the oldest event report. See *Figure 12.3* for an example standard 15-cycle event report.

The relay adds lines in the SER report for a change of state of a programmable condition. The SER lists date and time-stamped lines of information each time a programmed condition changes state. The relay stores the latest 512 lines of the SER report in nonvolatile memory. If the report fills up, newer rows overwrite the oldest rows in the report. See *Figure 12.7* for an example SER report.

The SEL-351S-7 offers an additional style of event report:

- Sag/Swell/Interruption (SSI) report

The SSI report (available in Firmware Version 7) records date, time, current, voltage, and Voltage Sag/Swell/Interruption (VSSI) element status during voltage disturbances, as determined by programmable settings, VINT, VSAG, and VSWELL. When the relay is recording a disturbance, entries are automatically added to the SSI report at one of four rates: once per quarter-cycle, once per cycle, once per 64-cycles, or once per day. The most recent 3,855 SSI entries are always available from nonvolatile memory, and up to 3,855 older entries may also be available. See *Figure 12.8* for an example SSI report.

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Standard 15/30-Cycle Event Reports

NOTE: Figure 12.3 is on multiple pages.

See *Figure 12.3* for an example event report.

Event Report Length (Settings LER and PRE)

The SEL-351S provides user-programmable event report length and prefault length. Event report length is either 15 or 30 cycles. Prefault length ranges from 1 to 29 cycles. Prefault length is the first part of the event report that precedes the event report triggering point.

Set the event report length with the LER setting. Set the prefault length with the PRE setting. See the **SET G** command in *Table 9.1* and *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25* for instructions on setting the LER and PRE settings.

Changing the LER setting will erase all events stored in nonvolatile memory. Changing the PRE setting has no effect on the nonvolatile reports.

Standard Event Report Triggering

The relay triggers (generates) a standard event report when any of the following occur:

- Relay Word bit TRIP asserts
- Programmable SELOGIC® control equation setting ER asserts to logical 1
- **TRI** (Trigger Event Reports) serial port command executed
- Output contacts **OUT101**–**OUT107** pulsed via the serial port or front-panel **PUL** (Pulse Output Contact) command

Relay Word Bit TRIP

Refer to *Figure 5.1*. If Relay Word bit TRIP asserts to logical 1, an event report is automatically generated. Thus, any condition that causes a trip does **not** have to be entered in SELOGIC control equation setting ER.

For example, SELOGIC control equation trip setting TR is unsupervised. Any trip condition that asserts in setting TR causes the TRIP Relay Word bit to assert immediately. The factory setting for trip setting TR is:

TR = **51P1T + 51G1T + 67P1 + PB10 + OC**

NOTE: PB10 does not appear in the factory default settings for Model 0351S*xxx*5/6/A/B.

If any of the individual conditions 51P1T, 51G1T, 67P1, PB10, or OC assert, Relay Word bit TRIP asserts, and an event report is automatically generated. Thus, these conditions do **not** have to be entered in SELOGIC control equation setting ER.

Relay Word bit TRIP (in *Figure 5.1*) is usually assigned to an output contact for tripping a circuit breaker (e.g., SELOGIC control equation setting OUT101 = TRIP).

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Programmable SELOGIC Control Equation Setting ER

The programmable SELOGIC control equation event report trigger setting ER is set to trigger standard event reports for conditions other than trip conditions. When setting ER sees a logical 0 to logical 1 transition, it generates an event report (if the SEL-351S is not already generating a report that encompasses the new transition). The factory setting is:

ER = **/51P1 + /51G1**

The elements in this example setting are:

- 51P1 Maximum phase current above pickup setting 51P1P for phase time-overcurrent element 51P1T (see *Figure 3.14*).
- 51G1 Residual ground current above pickup setting 51G1P for residual ground time-overcurrent element 51G1T (see *Figure 3.18*).

Note the rising edge operator / in front of each of these elements. See *Appendix G: Setting SELOGIC Control Equations* for more information on rising edge operators and SELOGIC control equations in general.

Rising edge operators are especially useful in generating an event report at fault inception and then generating another later if a breaker failure condition occurs. For example, at the inception of a ground fault, pickup indicator 51G1 asserts and an event report is generated:

ER = **... + /51G1 + ... = logical 1** (for one processing interval)

Even though the 51G1 pickup indicator will remain asserted for the duration of the ground fault, the rising edge operator / in front of 51G1 (/51G1) causes setting ER to be asserted for only one processing interval.

Falling edge operators \ are also used to generate event reports. See *Figure G.2* for more information on falling edge operators.

TRI (Trigger Event Report) and PUL (Pulse Output Contact) Commands

The sole function of the **TRI** serial port command is to generate standard event reports, primarily for testing purposes.

The **PUL** command asserts the output contacts for testing purposes or for remote control. If output contact **OUT101**–**OUT107** asserts via the **PUL** command, the relay triggers a standard event report. The **PUL** command is available at the serial port and the relay front-panel **{CNTRL}** pushbutton.

See *Section 10: Serial Port Communications and Commands* and *Figure 11.3* for more information on the **TRI** (Trigger Event Report) and **PUL** (Pulse Output Contact) commands.

Standard Event Report Summary

Each time the relay generates a standard event report, it also generates a corresponding event summary (see *Figure 12.1*). Event summaries contain the following information:

- Relay and terminal identifiers (settings RID and TID)
- Date and time when the event was triggered
- Event type
- Fault location
- Recloser shot count at the trigger time

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- System frequency at the front of the event report
- Front-panel fault targets at the time of trip
- Phase (**IA**, **IB**, **IC**), neutral ground (**IN**), calculated residual ground ($I_G = 3I_0$), and negative-sequence ($3I_2$) current magnitudes in amps primary measured at the largest phase current magnitude in the triggered event report

The Event Report Summary shows the magnitude of the maximum phase current calculated by the cosine filter or bipolar peak detector. When the relay uses the bipolar peak detector value, the relay displays `pk` as shown in the Event Summary portion of *Example Standard 15-Cycle Event Report on page 12.28* (for more information on the cosine filter and bipolar peak detector, see *CT Saturation Protection on page 1.3*).

NOTE: Figure 12.3 is on multiple pages.

The relay includes the event summary in the standard event report. The identifiers, date, and time information is at the top of the standard event report, and the other information follows at the end. See *Figure 12.3*.

The example event summary in *Figure 12.1* corresponds to the full-length standard 15-cycle event report in *Figure 12.3*.

```
FEEDER 1                          Date: 07/12/99    Time: 09:28:31.721
STATION A

Event: AG T  Location:    2.36  Shot: 0  Frequency:  60.01
Targets: 11100100    01010010
Currents (A Pri), ABCNGQ:   2752 pk   209   209     0  2689  2689
```

Figure 12.1 Example Event Summary

The relay sends event summaries to all serial ports with setting AUTO = Y each time an event triggers.

The latest event summaries are stored in nonvolatile memory and are accessed by the **HIS** (Event Summaries/History) command.

Event Type

The `Event:` field shows the event type. The possible event types and their descriptions are shown in the table below. Note the correspondence to the preceding event report triggering conditions (see *Standard Event Report Triggering on page 12.2*).

Table 12.1 Event Types (Sheet 1 of 2)

Event Type	Description
AG, BG, CG	Single phase-to-ground faults. Appends T if TRIP asserted.
A, B, C	Single phase-to-ground faults (Petersen Coil and ungrounded/ high-impedance grounded systems only). Appends T if TRIP asserted.
ABC	Three-phase faults. Appends T if TRIP asserted.
AB, BC, CA	Phase-to-phase faults. Appends T if TRIP asserted.
ABG, BCG, CAG	Phase-to-phase-to-ground faults. Appends T if TRIP asserted.
TRIP	Assertion of Relay Word bit TRIP (fault locator could not operate successfully to determine the phase involvement, so just TRIP is displayed).
ER	SELOGIC control equation setting ER. Phase involvement is indeterminate.

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Table 12.1 Event Types (Sheet 2 of 2)

Event Type	Description
TRIG	Execution of **TRIGGER** command.
PULSE	Execution of **PULSE** command.

The event type designations AG–CAG in *Table 12.1* are only entered in the Event: field if the fault locator operates successfully. If the fault locator does not operate successfully, just TRIP or ER is displayed.

Fault Location

NOTE: The fault locator will not operate properly unless three-phase voltages are connected.

NOTE: The fault locator is most accurate when the fault currents last longer than two cycles.

NOTE: The fault locator will not operate for phase-to-ground faults on Petersen Coil or ungrounded/high-impedance grounded systems.

The relay reports the fault location if the EFLOC setting = Y and the fault locator operates successfully after an event report is generated. If the fault locator does not operate successfully, $$$$$$ is listed in the field. If EFLOC = N, the field is blank. Fault location is based upon the line impedance settings Z1MAG, Z1ANG, Z0MAG, and Z0ANG; source impedance settings Z0SMAG and Z0SANG; and corresponding line length setting LL. See the **SET** command in *Table 9.1* and corresponding *Global Settings (Serial Port Command SET G and Front Panel) on page SET.25* for information on the line parameter settings.

The fault locator algorithm uses the overcurrent elements 50P1–50P4, 50N1–50N4, 50G1–50G4, 67Q1–67Q4, 51P1, 51P2, 51N1, 51N2, 51G1, 51G2, and 51Q as fault detectors. If any of these elements are set to low pickup values for use as load indicators, they may be asserted during non-fault conditions. In this situation, even though these elements are not being used for tripping the relay, they may still affect the operation of the fault locator, because the start of the disturbance may be unclear. If load detectors are required in your application, use the highest-numbered instantaneous overcurrent elements 50P5, 50P6, 50N5, 50N6, 50G5, 50G6, 50Q5, or 50Q6, because these are not used by the fault locator algorithm.

Targets

The relay reports the targets at the rising edge of TRIP. The targets are displayed in binary format. See *Front-Panel Target LEDs on page 5.32*.

Currents

The Currents (A pri), ABCNGQ: field shows the currents present in the event report row containing the maximum phase current. The listed currents are:

Phase (A = channel **IA**, B = channel **IB**, C = channel **IC**)
Neutral ground (N = channel **IN**)
Calculated residual (($I_G = 3I_0$; calculated from channels **IA**, **IB**, and **IC**)
Negative-sequence (Q = $3I_2$; calculated from channels **IA**, **IB**, and **IC**)

Retrieving Full-Length Standard Event Reports

The latest event reports are stored in nonvolatile memory. Each event report includes four sections:

- Current, voltage, station battery, frequency, contact outputs, optoisolated inputs
- Protection and control elements
- Event summary
- Group, SELOGIC control equations, and global settings

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Use the **EVE** command to retrieve the reports. There are several options to customize the report format. The general command format is:

EVE [***n*** **S*x*** **L*y*** **L R A D V C M P**]

where:

n	Event number (1–number of events stored). Defaults to 1 if not listed, where 1 is the most recent event.
S*x*	Display *x* samples per cycle (4 or 16); defaults to 4 if not listed.
L*y*	Display *y* cycles of data (1–LER). Defaults to LER value if not listed. Unfiltered reports (R parameter) display an extra cycle of data.
L	Display 16 samples per cycle; same as the S16 parameter.
R	Specifies the unfiltered (raw) event report. Defaults to 16 samples per cycle unless overridden with the S*x* parameter.
A	Specifies that only the analog section of the event is displayed (current, voltage, station battery, frequency, contact outputs, optoisolator inputs).
D	Specifies that only the digital section (Protection and Control Elements) of the event is displayed.
V	Specifies variable scaling for analog values.
C	Display the report in Compressed ASCII format.
M	Specifies only the Communication element section of the event is displayed.
P	Precise to synchrophasor level accuracy for signal content at nominal frequency. This option is available when TSOK = logical 1. The P option implies R as only raw analog data is available with this accuracy. When M or D are specified with P, then the P option is ignored since it only pertains to analog data.

Below are example **EVE** commands.

Serial Port Command	Description
EVE	Display the most recent event report at 1/4-cycle resolution.
EVE 2	Display the second event report at 1/4-cycle resolution.
EVE S16 L10	Display 10 cycles of the most recent report at 1/16-cycle resolution.
EVE C 2	Display the second report in Compressed ASCII format at 1/4-cycle resolution.
EVE L	Display most recent report at 1/16-cycle resolution.
EVE R	Display most recent report at 1/16-cycle resolution; analog and digital data are unfiltered (raw).
EVE 2 D L10	Display 10 cycles of the protection and control elements section of the second event report at 1/4-cycle resolution.
EVE 2 A R S4 V	Display the unfiltered analog section of the second event report at 1/4-cycle resolution, with variable scaling of the analog values.

If an event report is requested that does not exist, the relay responds:

```
Invalid Event
```


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Synchrophasor-Level Accuracy in Event Reports

The SEL-351S provides the option to display event report data aligned to a high-accuracy time source by adding the P parameter. The header indicates the availability of a high-accuracy time source by displaying the status of Relay Word bit TSOK. The `Time:` value in the header includes three additional digits. These represent 100 µs, 10 µs, and 1 µs. The 1 µs digit is always displayed as zero. The `Time:` value contains the time stamp of the analog value associated with the trigger point. Furthermore, the `FREQ` column in the analog section of the report is replaced by a `DT` column. DT means "Difference Time." It represents the difference time in units of microseconds from another row. The trigger point shall have a DT value of 0000 because the trigger time corresponds to the time displayed in the event report header. The DT value for rows preceding the trigger point is referenced to the following row (so they increment backwards in time). The DT value for rows following the trigger point is referenced to the previous row (so they increment forward in time). If TSOK = logical 0, this event report display option is not available.

Figure 12.2 shows how an event report is modified with the P parameter.

```
 =>>EVE P<Enter>

FEEDER 1     Date: 03/15/2007 Time: 11:31:14.889770
STATION A     TSOK = 1

FID=SEL-351S-5-R400-V0-Z008006-D20070117             CID=xxxx
                                                                 Out  In
      Currents (Amps Pri)        Voltages (kV Pri)                1357 135
    IA    IB    IC    IP    IG     VA     VB     VC     VS Vdc   DT  246A 246

[0]
   130   781  -941    -8   -30   76.8   54.9 -131.2   -0.0  23  1043 .... ...
  -317   963  -701   -10   -54   31.5   93.9 -127.1   -0.0  23  1041 .... ...
  -607   979  -393    -8   -21  -20.8  123.1 -100.8   -0.0  23  1046 .... ...
  -896   828    17    -9   -51  -68.0  131.3  -65.8    0.0  23  1040 .... ...
  -996   594   372   -10   -29 -106.5  119.4  -11.5    0.0  23  1040 .... ...
  -956   201   712    -9   -43 -127.6   91.9   33.9    0.0  23  1044 .... ...
  -802  -146   907    -8   -41 -129.9   45.9   84.2    0.0  23  1043 .... ...
  -459  -553   979    -9   -33 -112.7   -1.4  113.5   -0.0  23  1040 .... ...
.
.
.

[4]
   158   763  -953   -10   -31   79.8   51.5 -130.8   -0.0  23  1040 .... ...
  -291   955  -724   -11   -60   34.9   91.3 -128.0   -0.0  23  1039 .... ...
  -585   982  -419    -8   -21  -17.2  121.8 -103.1    0.0  23  1043 .... ...
  -884   843   -12    -9   -52  -64.8  131.3  -68.9    0.0  23  1041 .... ...
  -991   617   347    -8   -27 -104.3  120.9  -15.1   -0.0  23  1043 .... ...
  -963   230   692    -7   -41 -126.7   94.5   30.3    0.0  23  1042 .... ...
  -819  -118   896    -9   -40 -130.4   49.2   81.5    0.0  23  1044 .... ...
  -482  -528   980    -9   -30 -114.6    2.4  111.6    0.0  23  1046 .... ...
  -170  -790   912    -8   -48  -80.4  -51.2  130.3    0.0  23  1039 .... ...
   279  -985   683    -9   -23  -35.5  -91.2  127.6    0.0  23  1040 .... ...
   574 -1012   380   -10   -58   16.6 -121.8  102.8   -0.0  23  1041 .... ...
   872  -875   -29   -11   -32   64.2 -131.4   68.9   -0.0  23  1043 .... ...
   981  -650  -383    -9   -51  103.6 -121.2   15.3    0.0  23  1042 .... ...
   955  -263  -731   -10   -40  126.3  -95.0  -30.3   -0.0  23  1041 .... ...
   811    85  -936    -9   -40  130.2  -49.7  -81.6   -0.0  23  1046 .... ...
   476   497 -1022   -10   -49  114.6   -3.0 -111.9   -0.0  23  0000>.... ...

[5]
   165   759  -956   -10   -32   80.6   50.6 -130.7   -0.0  23  1040 .... ...
  -283   955  -726   -10   -54   35.8   90.7 -128.2   -0.0  23  1043 .... ...
  -580   982  -424    -9   -22  -16.5  121.5 -103.6    0.0  23  1038 .... ...
  -881   847   -17    -9   -51  -64.0  131.3  -69.7   -0.0  23  1043 .... ...
.
.
.
=>>
```

Figure 12.2 Example Synchrophasor-Level Precise Event Report 1/16-Cycle Resolution

Compressed ASCII Event Reports

The SEL-351S provides compressed ASCII event reports to facilitate event report storage and display. The SEL-2032, SEL-2030, and SEL-2020 Communications Processors and the SEL-5601 Analytic Assistant software

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NOTE: Compressed ASCII Event Reports contain all of the Relay Word bits. Regular, uncompressed event reports only contain a subset of the Relay Word bits.

take advantage of the Compressed ASCII format. Use the **EVE C** command or **CEVENT** command to display Compressed ASCII event reports. See the **CEVENT** command discussion in *Appendix E: Compressed ASCII Commands* for further information.

Filtered and Unfiltered Event Reports

The SEL-351S samples the basic power system measurands (ac voltage, ac current, station battery, and optoisolated inputs) 16 times per power system cycle. The relay filters the measurands to remove transient signals. The relay operates on the filtered values and reports them in the event report.

To view the raw inputs to the relay, select the unfiltered event report (e.g., **EVE R**). Use the unfiltered event reports to observe:

- Power system harmonics on channels **IA**, **IB**, **IC**, **IN**, **VA**, **VB**, **VC**, **VS**
- Decaying dc offset during fault conditions on **IA**, **IB**, **IC**
- Optoisolated input contact bounce on channels **IN101**–**IN106**
- Transients on the station dc battery channel Vdc (power input terminals **Z25** and **Z26**)

The filters for ac current and voltage and station battery are fixed. You can adjust the optoisolated input debounce via debounce settings (see *Figure 7.1*).

Raw event reports display one extra cycle of data at the beginning of the report.

Unfiltered Event Reports With PTCONN = DELTA

When global setting PTCONN = DELTA, the raw event report voltage columns reflect the signals applied to relay terminals **VA-N**, **VB-N**, **VC-N**, even though the relay is configured for an open-delta PT connection (see *Figure 2.29*). If the relay is properly wired, the value shown in column VB should be at or near 0 kV, because input terminal **VB** is tied to terminal **N**. Column VA should reflect power system voltage V_{AB}, and column VC should reflect power system voltage V_{CB} (or $-V_{BC}$).

Clearing Standard Event Report Buffer

The **HIS C** command clears the event summaries and corresponding standard event reports from nonvolatile memory. See *Section 10: Serial Port Communications and Commands* for more information on the **HIS** (Event Summaries/History) command.

Standard Event Report Column Definitions

NOTE: Figure 12.3 is on multiple pages.

Refer to the example event report in *Figure 12.3* to view event report columns. This example event report displays rows of information each 1/4 cycle and was retrieved with the **EVE** command.

The columns contain ac current, ac voltage, station dc battery voltage, frequency, output, input, and protection and control element information.

Current, Voltage, and Frequency Columns

Table 12.2 summarizes the event report current, voltage, and frequency columns.

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Table 12.2 Standard Event Report Current, Voltage, and Frequency Columns

Column Heading	Definition
IA	Current measured by channel **IA** (primary A)
IB	Current measured by channel **IB** (primary A)
IC	Current measured by channel **IC** (primary A)
IN	Current measured by channel **IN** (primary A)
IG	Calculated residual current IG = $3I_0$ = IA + IB + IC (primary A)
VA	Voltage measured by channel **VA** (primary kV, PTCONN = WYE)[a]
VB	Voltage measured by channel **VB** (primary kV, PTCONN = WYE)[a]
VC	Voltage measured by channel **VC** (primary kV, PTCONN = WYE)[a]
VAB	Power system phase-to-phase voltage V_{AB} (primary kV, PTCONN = DELTA)[b]
VBC	Power system phase-to-phase voltage V_{BC} (primary kV, PTCONN = DELTA)[b]
VCA	Power system phase-to-phase voltage V_{CA} (primary kV, PTCONN = DELTA)[b]
VS	Voltage measured by channel **VS** (primary kV)
Vdc	Voltage measured at power input terminals **Z15** and **Z16** (Vdc)
Freq[c]	Frequency of channel **VA** (or V_1 if V_A is not present) (Hz)
DT[d]	Difference time referenced to previous row (microseconds)

[a] Also for global setting PTCONN = DELTA when viewing unfiltered (raw) event reports.
[b] When global setting PTCONN = DELTA, and relay terminals VA, VB, VC, and N are properly wired as shown in Figure 2.29, the filtered event report voltage values are determined as follows:
– VAB reflects the measured value from relay terminals VA-N.
– VBC reflects the measured value from relay terminals VC-N rotated by 180° ($V_{BC} = -V_{CB}$).
– VCA reflects the value derived from the subtraction of the measured value from relay terminals VA-N from the measured value from relay terminals VC-N ($V_{CA} = V_{CB} - V_{AB}$).
[c] Not available with P parameter.
[d] Only available with P parameter.

Note that the ac values change from plus to minus (–) values in *Figure 12.3*, indicating the sinusoidal nature of the waveforms.

Other figures help in understanding the information available in the event report current columns:

- *Figure 12.5*: shows how event report current column data relates to the actual sampled current waveform and RMS current values.
- *Figure 12.6*: shows how event report current column data can be converted to phasor RMS current values.

Variable Scaling for Analog Values

The following example shows the difference between two cycles of the analog values of an event report without variable scaling (command **EVE**) and with variable scaling (command **EVE V**). Variable scaling event reports display data for currents less than 10 A with 2 decimal places and data for voltages less than 10 kV with 3 decimal places.

Example without variable scaling (**EVE**), wye-connected:

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```
=>>EVE <Enter>

.
.
.

                                                                  Out  In
Currents (Amps Pri)            Voltages (kV Pri)                  1357 135
    IA    IB    IC    IN    IG     VA     VB     VC     VS Vdc Freq  246A 246
[1]
   181  -103   -92   -14   -14   14.8   -7.5   -7.5   13.8 125 60.00 .45. ...
     1   158  -161    -3    -3   -0.0   13.2  -13.0   -8.0 125 60.00 .45. ...
  -181   102    93    14    14  -14.8    7.4    7.6  -13.7 125 60.00 .45. ...
     1  -159   161     3     3    0.1  -13.3   13.0    8.1 125 60.00 .45. ...
[2]
   181  -100   -94   -14   -14   14.8   -7.3   -7.7   13.7 125 60.01 .45. ...
    -2   159  -160    -3    -3   -0.2   13.3  -12.9   -8.2 125 60.01 .45. ...
  -181    99    95    14    14  -14.8    7.2    7.8  -13.6 125 60.01 .45. ...
     3  -160   159     3     3    0.3  -13.4   12.9    8.2 125 60.01 .45. ...
     :
```

NOTE: The "V" option has no effect for compressed event reports (**EVE C**) because the analog values automatically have variable scaling. Variable scaling for compressed data displays both currents less than 10 A and voltages less than 10 kV with 3 decimal places.

Example with variable scaling (**EVE V**), wye-connected:

```
=>>EVE V <Enter>

.
.
.

                                                                        Out  In
      Currents (Amps Pri)                Voltages (kV Pri)              1357 135
    IA    IB    IC    IN    IG     VA      VB      VC     VS Vdc Freq  246A 246
[1]
   181  -103   -92   -14   -14   14.8  -7.477  -7.547   13.8 123 60.00 .45. ...
  0.58   158  -161 -2.81 -2.96 -0.036    13.2   -13.0 -7.956 123 60.00 .45. ...
  -181   102    93    14    14  -14.8   7.375   7.644  -13.7 123 60.00 .45. ...
  0.73  -159   161  2.71  2.73  0.145   -13.3    13.0  8.057 123 60.00 .45. ...
[2]
   181  -100   -94   -14   -14   14.8  -7.282  -7.736   13.7 123 60.01 .45. ...
 -1.97   159  -160 -2.62 -2.57 -0.250    13.3   -12.9 -8.154 123 60.01 .45. ...
  -181    99    95    14    14  -14.8   7.190   7.822  -13.6 123 60.01 .45. ...
  3.14  -160   159  2.52  2.54  0.347   -13.4    12.9  8.243 123 60.01 .45. ...
     :
```

Output, Input, and Protection, and Control Columns

Table 12.3 summarizes the event report output, input, protection and control columns. See *Table 9.6* for more information on Relay Word bits shown in *Table 12.3*.

Some of the column definitions are different for wye-connected PT applications (global setting PTCONN = WYE) and delta-connected PT applications (global setting PTCONN = DELTA). These differences are noted in *Table 12.3*. *Figure 12.3* shows a wye-connected example event report, and *Figure 12.4* shows a delta-connected example event report.

NOTE: The event report does not show the output contacts (**OUT201–OUT212**) or optoisolated inputs (**IN201–IN208**) for the extra I/O board.

Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 1 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
All columns		•	Element/input/output not picked up or not asserted, unless otherwise stated.
[a]Out 12	OUT101, OUT102	1	Output contact **OUT101** asserted.
		2	Output contact **OUT102** asserted.
		b	Both **OUT101** and **OUT102** asserted.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 2 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
[a]Out 34	OUT103, OUT104	3	Output contact **OUT103** asserted.
		4	Output contact **OUT104** asserted.
		b	Both **OUT103** and **OUT104** asserted.
[a]Out 56	OUT105, OUT106	5	Output contact **OUT105** asserted.
		6	Output contact **OUT106** asserted.
		b	Both **OUT105** and **OUT106** asserted.
[a]Out 7A	OUT107, ALARM	7	Output contact **OUT107** asserted.
		A	Output contact **ALARM** asserted.
		b	Both **OUT107** and **ALARM** asserted.
In 12	IN101, IN102	1	Optoisolated input **IN101** asserted.
		2	Optoisolated input **IN102** asserted.
		b	Both **IN101** and **IN102** asserted.
In 34	IN103, IN104	3	Optoisolated input **IN103** asserted.
		4	Optoisolated input **IN104** asserted.
		b	Both **IN103** and **IN104** asserted.
In 56	IN105, IN106	5	Optoisolated input **IN105** asserted.
		6	Optoisolated input **IN106** asserted.
		b	Both **IN105** and **IN106** asserted.
51 P1	51P1, 51P1T, 51P1R	•	Time-overcurrent element reset (51_R).
51 P2	51P2, 51P2T, 51P2R		
51 N1	51N1, 51N1T, 51N1R	p	Time-overcurrent element picked up and timing (51_).
51 N2	51N2, 51N2T, 51PN2R		
51 G1	51G1, 51G1T, 51G1R	T	Time-overcurrent element timed out (51_T).
51 G2	51G2, 51G2T, 51G2R		
51 Q	51Q, 51QT, 51QR	r	Time-overcurrent element timing to reset.
		1	Time-overcurrent element timing to reset after having timed out (when element reset is set for 1 cycle, not electromechanical reset).
50 P	50A, 50B, 50C	A	Single-phase instantaneous overcurrent element 50A picked up.
		B	Single-phase instantaneous overcurrent element 50B picked up.
		C	Single-phase instantaneous overcurrent element 50C picked up.
		a	Both 50A and 50B picked up.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 3 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
		b	Both 50B and 50C picked up.
		c	Both 50C and 50A picked up.
		3	50A, 50B, and 50C picked up.
50 PP	50AB1, 50AB2, 50AB3, 50AB4, 50BC1, 50BC2, 50BC3, 50BC4, 50CA1, 50CA2, 50CA3, 50CA4	A	Phase-to-phase instantaneous overcurrent element 50AB1, 50AB2, 50AB3, or 50AB4 picked up.
		B	Phase-to-phase instantaneous overcurrent element 50BC1, 50BC2, 50BC3, or 50BC4 picked up.
		C	Phase-to-phase instantaneous overcurrent element 50CA1, 50CA2, 50CA3, or 50CA4 picked up.
		a	50AB_ and 50CA_ picked up.
		b	50AB_ and 50BC_ picked up.
		c	50BC_ and 50CA_ picked up.
		3	50AB_, 50BC_, and 50CA_ picked up.
32 PQ	F32P	P	Forward phase directional element F32P picked up.
	R32P	p	Reverse phase directional element R32P picked up.
	F32Q	Q	Forward negative-sequence directional element F32Q picked up.
	R32Q	q	Reverse negative-sequence directional element R32Q picked up.
32 NG	F32QG	Q	Forward negative-sequence directional element F32QG picked up.
	R32QG	q	Reverse negative-sequence R32QG picked up.
	F32V	V	Forward zero-sequence voltage-polarized element F32V picked up.
	R32V	v	Reverse zero-sequence voltage-polarized R32V picked up.
	F32I	I	Forward channel IN current-polarized directional element F32I picked up.
	R32I	i	Reverse channel IN current-polarized directional element R32I picked up.
	F32N	N	Forward element F32N picked up (low-impedance grounded, Petersen Coil grounded [wattmetric element], and ungrounded/high-impedance grounded systems).

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 4 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
	R32N	n	Reverse element R32N picked up (low-impedance grounded, Petersen Coil grounded [wattmetric element], and ungrounded/high-impedance grounded systems).
	F32C	C	Forward conductance element F32C picked up (Petersen Coil grounded system)
	R32C	c	Reverse conductance element R32C picked up (Petersen Coil grounded system)
67 P 67 N 67 G	67P1–67P4 67N1–67N4 67G1–67G4	4	Level 4 instantaneous element 67_4 picked up; levels 1, 2, and 3 not picked up.
67 Q	67Q1–67Q4	3	Level 3 instantaneous element 67_3 picked up; levels 1 and 2 not picked up.
		2	Level 2 instantaneous element 67_2 picked up; Level 1 not picked up.
		1	Level 1 instantaneous element 67_1 picked up.
DM PQ	PDEM, QDEM	P	Phase demand ammeter element PDEM picked up.
		Q	Negative-sequence demand ammeter element QDEM picked up.
		b	Both PDEM and QDEM picked up.
DM NG	NDEM, GDEM	N	Neutral ground demand ammeter element NDEM picked up.
		G	Residual ground demand ammeter element GDEM picked up.
		b	Both NDEM and GDEM picked up.
27 P (wye-connected)	27A1, 27A2, 27B1, 27B2, 27C1, 27C2	A	A-phase instantaneous undervoltage element 27A1 or 27A2 picked up.
		B	B-phase instantaneous undervoltage element 27B1 or 27B2 picked up.
		C	C-phase instantaneous undervoltage element 27C1 or 27C2 picked up.
		a	27A_ and 27B_ elements picked up.
		b	27B_ and 27C_ elements picked up.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 5 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
		c	27C_ and 27A_ elements picked up.
		3	27A_, 27B_,and 27C_ elements picked up.
27 PP	27AB, 27BC, 27CA	A	AB phase-to-phase instantaneous undervoltage element 27AB picked up.
		B	BC phase-to-phase instantaneous undervoltage element 27BC picked up.
		C	CA phase-to-phase instantaneous undervoltage element 27CA picked up.
		a	27AB and 27CA elements picked up.
		b	27AB and 27BC elements picked up.
		c	27BC and 27CA elements picked up.
		3	27AB, 27BC, and 27CA elements picked up.
27 PP2 (delta-connected)	27AB2, 27BC2, 27CA2	A	AB phase-to-phase instantaneous undervoltage element 27AB2 picked up.
		B	BC phase-to-phase instantaneous undervoltage element 27BC2 picked up.
		C	CA phase-to-phase instantaneous undervoltage element 27CA2 picked up.
		a	27AB2 and 27CA2 elements picked up.
		b	27AB2 and 27BC2 elements picked up.
		c	27BC2 and 27CA2 elements picked up.
		3	27AB2, 27BC2, and 27CA2 elements picked up.
27 S	27S	*	Channel **VS** instantaneous undervoltage element 27S picked up.
59 P (wye-connected)	59A1, 59A2, 59B1, 59B2, 59C1, 59C2	A	A-phase instantaneous overvoltage element 59A1 or 59A2 picked up.
		B	B-phase instantaneous overvoltage element 59B1 or 59B2 picked up.
		C	C-phase instantaneous overvoltage element 59C1 or 59C2 picked up.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 6 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
		a	59A_ and 59B_ elements picked up.
		b	59B_ and 59C_ elements picked up.
		c	59C_ and 59A_ elements picked up.
		3	59A_, 59B_, and 59C_ elements picked up.
59 PP	59AB, 59BC, 59CA	A	AB phase-to-phase instantaneous overvoltage element 59AB picked up.
		B	BC phase-to-phase instantaneous overvoltage element 59BC picked up.
		C	CA phase-to-phase instantaneous overvoltage element 59CA picked up.
		a	59AB and 59CA elements picked up.
		b	59AB and 59BC elements picked up.
		c	59BC and 59CA elements picked up.
		3	59AB, 59BC, and 59CA elements picked up.
59 PP2 (delta-connected)	59AB2, 59BC2, 59CA2	A	AB phase-to-phase instantaneous overvoltage element 59AB2 picked up.
		B	BC phase-to-phase instantaneous overvoltage element 59BC2 picked up.
		C	CA phase-to-phase instantaneous overvoltage element 59CA2 picked up.
		a	59AB2 and 59CA2 elements picked up.
		b	59AB2 and 59BC2 elements picked up.
		c	59BC2 and 59CA2 elements picked up.
		3	59AB2, 59BC2, and 59CA2 elements picked up.
59 V1Q (wye-connected)	59V1, 59Q	1	Positive-sequence instantaneous overvoltage element 59V1 picked up.
		Q	Negative-sequence instantaneous overvoltage element 59Q picked up.
		b	Both 59V1 and 59Q picked up.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 7 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
59 V1 (delta-connected)	59V	*	Positive-sequence instantaneous overvoltage element 59V1 picked up.
59 Q (delta-connected)	59Q, 59Q2	1	Negative-sequence instantaneous overvoltage element 59Q picked up.
		2	Negative-sequence instantaneous overvoltage element 59Q2 picked up.
		b	Both 59Q and 59Q2 picked up.
59 N (wye-connected)	59N1, 59N2	1	Zero-sequence instantaneous overvoltage element 59N1 picked up.
		2	Zero-sequence instantaneous overvoltage element 59N2 picked up.
		b	Both 59N1 and 59N2 picked up.
59 S	59S1, 59S2	1	Channel VS instantaneous overvoltage element 59S1 picked up.
		2	Channel VS instantaneous overvoltage element 59S2 picked up.
		b	Both 59S1 and 59S2 picked up.
59 V	59VP, 59VS	P	Phase voltage window element 59VP picked up (used in synchronism check).
		S	Channel VS voltage window element 59VS picked up (used in synchronism check).
		b	Both 59VP and 59VS picked up.
25 SF	SF	*	Slip frequency element SF picked up (used in synchronism check).
25 A	25A1, 25A2	1	Synchronism check element 25A1 element picked up.
		2	Synchronism check element 25A2 element picked up.
		b	Both 25A1 and 25A2 picked up.
81 27B	27B81	*	Frequency logic instantaneous undervoltage element 27B81 picked up.
81 12	81D1, 81D2	1	Frequency element 81D1 picked up.
		2	Frequency element 81D2 picked up.
		b	Both 81D1 and 81D2 picked up.
81 34	81D3, 81D4	3	Frequency element 81D3 picked up.
		4	Frequency element 81D4 picked up.
		b	Both 81D3 and 81D4 picked up.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 8 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
81 56	81D5, 81D6	5	Frequency element 81D5 picked up.
		6	Frequency element 81D6 picked up.
		b	Both 81D5 and 81D6 picked up.
79	RCSF, CF, 79RS, 79CY, 79LO	•	Reclosing relay nonexistent.
		S	Reclose supervision failure co ndition (RCSF asserts for only 1/4 cycle).
		F	Close failure condition (CF asserts for only 1/4 cycle).
		R	Reclosing relay in Reset State (79RS).
		C	Reclosing relay in Reclose Cycle State (79CY).
		L	Reclosing relay in Lockout State (79LO).
Time	OPTMN, RSTMN	o	Recloser open interval timer is timing.
		r	Recloser reset interval timer is timing.
Shot	SH0, SH1, SH2 SH3, SH4	.	Reclosing relay nonexistent.
		0	shot = 0 (SH0).
		1	shot = 1 (SH1).
		2	shot = 2 (SH2).
		3	shot = 3 (SH3).
		4	shot = 4 (SH4).
Zld	ZLIN, ZLOUT	i	Load encroachment “load in” element ZLIN picked up.
		o	Load encroachment “load out” element ZLOUT picked up.
LOP	LOP	*	Loss-of-potential element LOP picked up.
Vdc	DCHI, DCLO	H	Station battery instantaneous overvoltage element DCHI picked up.
		L	Station battery instantaneous undervoltage element DCLO picked up.
		b	Both DCHI and DCLO asserted.
Lcl 12	LB1, LB2	1	Local bit LB1 asserted.
		2	Local bit LB2 asserted.
		b	Both LB1 and LB2 asserted.
Lcl 34	LB3, LB4	3	Local bit LB3 asserted.
		4	Local bit LB4 asserted.
		b	Both LB3 and LB4 asserted.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 9 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
Lcl 56	LB5, LB6	5	Local bit LB5 asserted.
		6	Local bit LB6 asserted.
		b	Both LB5 and LB6 asserted.
Lcl 78	LB7, LB8	7	Local bit LB7 asserted.
		8	Local bit LB8 asserted.
		b	Both LB7 and LB8 asserted.
Rem 12	RB1, RB2	1	Remote bit RB1 asserted.
		2	Remote bit RB2 asserted.
		b	Both RB1 and RB2 asserted.
Rem 34	RB3, RB4	3	Remote bit RB3 asserted.
		4	Remote bit RB4 asserted.
		b	Both RB3 and RB4 asserted.
Rem 56	RB5, RB6	5	Remote bit RB5 asserted.
		6	Remote bit RB6 asserted.
		b	Both RB5 and RB6 asserted.
Rem 78	RB7, RB8	7	Remote bit RB7 asserted.
		8	Remote bit RB8 asserted.
		b	Both RB7 and RB8 asserted.
Rem OC	OC, CC	o	**OPE** (Open) command executed.
		c	**CLO** (Close) command executed.
Ltch 12	LT1, LT2	1	Latch bit LT1 asserted.
		2	Latch bit LT2 asserted.
		b	Both LT1 and LT2 asserted.
Ltch 34	LT3, LT4	3	Latch bit LT3 asserted.
		4	Latch bit LT4 asserted.
		b	Both LT3 and LT4 asserted.
Ltch 56	LT5, LT6	5	Latch bit LT5 asserted.
		6	Latch bit LT6 asserted.
		b	Both LT5 and LT6 asserted.
Ltch 78	LT7, LT8	7	Latch bit LT7 asserted.
		8	Latch bit LT8 asserted.
		b	Both LT7 and LT8 asserted.
SELOGIC Var 1	SV1, SV1T	p	SELOGIC control equation variable timer input SV_ asserted; timer timing on pickup time; timer output SV_T not asserted.
SELOGIC Var 2	SV2, SV2T		
SELOGIC Var 3	SV3, SV3T		
SELOGIC Var 4	SV4, SV4T		

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 10 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
SELOGIC Var 5	SV5, SV5T	T	SELOGIC control equation variable timer input SV_ asserted; timer timed out on pickup time; timer output SV_T asserted.
SELOGIC Var 6	SV6, SV6T		
SELOGIC Var 7	SV7, SV7T		
SELOGIC Var 8	SV8, SV8T		
SELOGIC Var 9	SV9, SV9T		
SELOGIC Var 10	SV10, SV10T	d	SELOGIC control equation variable timer input SV_ not asserted; timer previously timed out on pickup time; timer output SV_T remains asserted while timer timing on dropout time.
SELOGIC Var 11	SV11, SV11T		
SELOGIC Var 12	SV12, SV12T		
SELOGIC Var 13	SV13, SV13T		
SELOGIC Var 14	SV14, SV14T		
SELOGIC Var 15	SV15, SV15T		
SELOGIC Var 16	SV16, SV16T		
3PO	3PO	*	Three pole open condition 3PO asserted.
SOTF	SOTFE	*	Switch-onto-fault SOTF enable asserted.
PT	PT	*	Permissive trip signal to POTT logic PT asserted.
PTRX	PTRX1, PTRX2	1	Permissive trip 1 signal from DCUB logic PTRX1 asserted.
		2	Permissive trip 2 signal from DCUB logic PTRX2 asserted.
		b	Both PTRX1 and PTRX2 asserted
Z3RB	Z3RB	*	Zone (level) 3 reverse block Z3RB asserted.
KEY	KEY	*	Key permissive trip signal start KEY asserted.
EKEY	EKEY	*	Echo key EKEY asserted.
ECTT	ECTT	*	Echo conversion to trip condition ECTT asserted.
WFC	WFC	*	Weak infeed condition WFC asserted.
UBB	UBB1, UBB2	1	Unblocking block 1 from DCUB logic UBB1 asserted.
		2	Unblocking block 2 from DCUB logic UBB2 asserted.
		b	Both UBB1 and UBB2 asserted.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 11 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
Z3XT	Z3XT	*	Logic output from zone (level) 3 extension timer Z3XT asserted.
DSTR	DSTRT	*	Directional carrier start DSTRT asserted.
NSTR	NSTRT	*	Nondirectional carrier start NSTRT asserted.
STOP	STOP	*	Carrier stop STOP asserted.
BTX	BTX	*	Block trip input extension BTX asserted.
TMB A 12	TMB1A, TMB2A	1	MIRRORED BITS® channel A transmit bit 1 TMB1A asserted.
		2	MIRRORED BITS channel A transmit bit 2 TMB2A asserted.
		b	Both TMB1A and TMB2A asserted.
TMB A 34	TMB3A, TMB4A	3	MIRRORED BITS channel A transmit bit 3 TMB3A asserted.
		4	MIRRORED BITS channel A transmit bit 4 TMB4A asserted.
		b	Both TMB3A and TMB4A asserted.
TMB A 56	TMB5A, TMB6A	5	MIRRORED BITS channel A transmit bit 5 TMB5A asserted.
		6	MIRRORED BITS channel A transmit bit 6 TMB6A asserted.
		b	Both TMB5A and TMB6A asserted.
TMB A 78	TMB7A, TMB8A	7	MIRRORED BITS channel A transmit bit 7 TMB7A asserted.
		8	MIRRORED BITS channel A transmit bit 8 TMB8A asserted.
		b	Both TMB7A and TMB8A asserted.
RMB A 12	RMB1A, RMB2A	1	MIRRORED BITS channel A receive bit 1 RMB1A asserted.
		2	MIRRORED BITS channel A receive bit 2 RMB2A asserted.
		b	Both RMB1A and RMB2A asserted.
RMB A 34	RMB3A, RMB4A	3	MIRRORED BITS channel A receive bit 3 RMB3A asserted.
		4	MIRRORED BITS channel A receive bit 4 RMB4A asserted.
		b	Both RMB3A and RMB4A asserted.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 12 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
RMB A 56	RMB5A, RMB6A	5	MIRRORED BITS channel A receive bit 5 RMB5A asserted.
		6	MIRRORED BITS channel A receive bit 6 RMB6A asserted.
		b	Both RMB5A and RMB6A asserted.
RMB A 78	RMB7A, RMB8A	7	MIRRORED BITS channel A receive bit 7 RMB7A asserted.
		8	MIRRORED BITS channel A receive bit 8 RMB8A asserted.
		b	Both RMB7A and RMB8A asserted.
TMB B 12	TMB1B, TMB2B	1	MIRRORED BITS channel B transmit bit 1 TMB1B asserted.
		2	MIRRORED BITS channel B transmit bit 2 bit TMB2B asserted.
		b	Both TMB1B and TMB2B asserted.
TMB B 34	TMB3B, TMB4B	3	MIRRORED BITS channel B transmit bit 3 TMB3B asserted.
		4	MIRRORED BITS channel B transmit bit 4 TMB4B asserted.
		b	Both TMB3B and TMB4B asserted.
TMB B 56	TMB5B, TMB6B	5	MIRRORED BITS channel B transmit bit 5 TMB5B asserted.
		6	MIRRORED BITS channel B transmit bit 6 TMB6B asserted.
		b	Both TMB5B and TMB6B asserted.
TMB B 78	TMB7B, TMB8B	7	MIRRORED BITS channel B transmit bit 7 TMB7B asserted.
		8	MIRRORED BITS channel B transmit bit 8 TMB8B asserted.
		b	Both TMB7B and TMB8B asserted.
RMB B 12	RMB1B, RMB2B	1	MIRRORED BITS channel B receive bit 1 RMB1B asserted.
		2	MIRRORED BITS channel B receive bit 2 RMB2B asserted.
		b	Both RMB1B and RMB2B asserted.
RMB B 34	RMB3B, RMB4B	3	MIRRORED BITS channel B receive bit 3 RMB3B asserted.
		4	MIRRORED BITS channel B receive bit 4 RMB4B asserted.
		b	Both RMB3B and RMB4B asserted.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 13 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
RMB B 56	RMB5B, RMB6B	5	MIRRORED BITS channel B receive bit 5 RMB5B asserted.
		6	MIRRORED BITS channel B receive bit 6 RMB6B asserted.
		b	Both RMB5B and RMB6B asserted.
RMB B 78	RMB7B, RMB8B	7	MIRRORED BITS channel B receive bit 7 RMB7B asserted.
		8	MIRRORED BITS channel B receive bit 8 RMB8B asserted.
		b	Both RMB7B and RMB8B asserted.
ROK	ROKA, ROKB	A	MIRRORED BITS channel A receive ok ROKA asserted.
		B	MIRRORED BITS channel B receive ok ROKB asserted.
		b	Both ROKA and ROKB asserted.
RBAD	RBADA, RBADB	A	MIRRORED BITS channel A extended outage RBADA asserted.
		B	MIRRORED BITS channel B extended outage RBADB asserted.
		b	Both RBADA and RBADB asserted.
CBAD	CBADA, CBADB	A	MIRRORED BITS channel A unavailability CBADA asserted.
		B	MIRRORED BITS channel B unavailability CBADB asserted.
		b	Both CBADA and CBADB asserted.
LBOK	LBOKA, LBOKB	A	MIRRORED BITS channel A loop back ok LBOKA asserted.
		B	MIRRORED BITS channel A loop back ok LBOKB asserted.
		b	Both LBOKA and LBOKB asserted.
[b]PWR A 12	PWRA1, PWRA2	1	Level 1 A-phase power element PWR1A picked up.
		2	Level 2 A-phase power element PWR2A picked up.
		B	Both PWR1A and PWR2A picked up.
[b]PWR A 34	PWRA3, PWRA4	3	Level 3 A-phase power element PWR3A picked up.
		4	Level 4 A-phase power element PWR4A picked up.
		b	Both PWR3A and PWR4A picked up.

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 14 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
[b]PWR B 12	PWRB1, PWRB2	1	Level 1 B-phase power element PWR1B picked up.
		2	Level 2 B-phase power element PWR2B picked up.
		b	Both PWR1B and PWR2B picked up.
[b]PWR B 34	PWRB3, PWRB4	3	Level 3 B-phase power element PWR3B picked up.
		4	Level 4 B-phase power element PWR4B picked up.
		b	Both PWR3B and PWR4B picked up.
[b]PWR C 12	PWRC1, PWRC2	1	Level 1 C-phase power element PWR1C picked up.
		2	Level 2 C-phase power element PWR2C picked up.
		b	Both PWR1C and PWR2C picked up.
[b]PWR C 34	PWRC3, PWRC4	3	Level 3 C-phase power element PWR3C picked up.
		4	Level 4 C-phase power element PWR4C picked up.
		b	Both PWR3C and PWR4C picked up.
[c]PWR 3P 12	3PWR1, 3PWR2	1	Level 1 3-phase power element 3PWR1 picked up.
		2	Level 2 3-phase power element 3PWR2 picked up.
		b	Both 3PWR1 and 3PWR2 picked up.
[c]PWR 3P 34	3PWR3, 3PWR4	3	Level 3 3-phase power element 3PWR3 picked up.
		4	Level 4 3-phase power element 3PWR4 picked up.
		b	Both 3PWR3 and 3PWR4 picked up.
PB	PB1 (see *Figure 11.8*)	1	{GROUND ENABLED} pushbutton output
	PB2	2	{RECLOSE ENABLED} pushbutton output
	PB3	3	{REMOTE ENABLED} pushbutton output
	PB4	4	{ALTERNATE SETTINGS} pushbutton output
	PB5	5	{LOCK} pushbutton output
	PB6 (see *Figure 11.9*)	6	{HOT LINE TAG} pushbutton output

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Table 12.3 Output, Input, and Protection, and Control Element Event Report Columns (Sheet 15 of 15)

Column Heading	Corresponding Elements (Relay Word Bits)	Symbol	Definition
	PB7	7	{AUX 1} pushbutton output
	PB8	8	{AUX 2} pushbutton output
	PB9	9	{CLOSE/AUX 3} pushbutton output
	PB10	0	{TRIP/AUX 4} pushbutton output

[a] Output contacts can be A or B type contacts (see Table 2.3 and Figure 7.27 and Figure 7.28).
[b] Available in Firmware Version 7, when global setting PTCONN = WYE.
[c] Available in Firmware Version 7.

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Sequential Events Recorder (SER) Report

See *Figure 12.7* for an example SER report.

SER Triggering

The relay triggers (generates) an entry in the SER report for a change of state of any one of the elements listed in the SER1, SER2, and SER3 trigger settings. The factory default settings are:

SER1 = **TRIP,51P1T,51G1T,67P1,PB10,OC**

SER2 = **CLOSE,52A,CF,79RS,79CY,79LO,SH0,SH1,SH2 SH3,SH4,PB9,CC**

SER3 =

The elements are Relay Word bits referenced in *Table 9.6*. The relay monitors each element in the SER lists every 1/4 cycle. If an element changes state, the relay time-tags the changes in the SER. For example, setting SER1 contains:

- time-overcurrent element pickups (51P1T and 51G1T)
- instantaneous overcurrent element (67P1)

Thus, any time one of these overcurrent elements time out, the relay time-tags the change in the SER.

The relay adds a message to the SER to indicate power up:

```
Relay newly powered up
```

The relay adds a message to the SER to indicate a settings change has been made (to the active setting group):

```
Relay settings changed
```

Each entry in the SER includes SER row number, date, time, element name, and element state.

Making SER Trigger Settings

Enter up to 24 element names in each of the SER settings via the **SET R** command. See *Table 9.6* for references to valid relay element (Relay Word bit) names. See the **SET R** command in *Table 9.1* and *Sequential Events Recorder and Load Profile Settings (Serial Port Command SET R) on page SET.29*. Use commas to delimit the elements. For example, if you enter setting SER1 as:

SER1 = **51P,51G,51PT,,51GT , 50P1, , 50P2**

The relay displays the setting as:

```
SER1 = 51P,51G,51PT,51GT,50P1,50P2
```

The relay can monitor up to 72 elements in the SER (24 in each of SER1, SER2, and SER3).

Make SER Settings With Care

The relay triggers a row in the SER report for any change of state in any one of the elements listed in the SER1, SER2, or SER3 trigger settings. Nonvolatile memory is used to store the latest 512 rows of the SER report so they can be retained during power loss. The nonvolatile memory is rated for a finite

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number of "writes." Exceeding the limit can result in an EEPROM self-test failure. **An average of one (1) state change every three minutes can be made for a 25-year relay service life.**

Retrieving SER Reports

The relay saves the latest 512 rows of the SER in nonvolatile memory. Row 1 is the most recently triggered row, and row 512 is the oldest. View the SER report by date or SER row number as outlined in the examples below.

Example SER Serial Port Commands	Format
SER	If **SER** is entered with no numbers following it, all available rows are displayed (up to row number 512). They display with the oldest row at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 17	If **SER** is entered with a single number following it (17 in this example), the first 17 rows are displayed, if they exist. They display with the oldest row (row 17) at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 10 33	If **SER** is entered with two numbers following it (10 and 33 in this example; 10 < 33), all the rows between (and including) rows 10 and 33 are displayed, if they exist. They display with the oldest row (row 33) at the beginning (top) of the report and the latest row (row 10) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 47 22	If **SER** is entered with two numbers following it (47 and 22 in this example; 47 > 22), all the rows between (and including) rows 47 and 22 are displayed, if they exist. They display with the newest row (row 22) at the beginning (top) of the report and the oldest row (row 47) at the end (bottom) of the report. **Reverse** chronological progression through the report is down the page and in ascending row number.
SER 3/30/97	If **SER** is entered with one date following it (date 3/30/97 in this example), all the rows on that date are displayed, if they exist. They display with the oldest row at the beginning (top) of the report and the latest row at the end (bottom) of the report, for the given date. Chronological progression through the report is down the page and in descending row number.
SER 2/17/97 3/23/97	If **SER** is entered with two dates following it (date 2/17/97 chronologically **precedes** date 3/23/97 in this example), all the rows between (and including) dates 2/17/97 and 3/23/97 are displayed, if they exist. They display with the oldest row (date 2/17/97) at the beginning (top) of the report and the latest row (date 3/23/97) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SER 3/16/97 1/5/97	If **SER** is entered with two dates **following** it (date 3/16/97 chronologically follows date 1/5/97 in this example), all the rows between (and including) dates 1/5/97 and 3/16/97 are displayed, if they exist. They display with the latest row (date 3/16/97) at the beginning (top) of the report and the oldest row (date 1/5/97) at the end (bottom) of the report. **Reverse** chronological progression through the report is down the page and in ascending row number.

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The date entries in the above example **SER** commands are dependent on the Date Format setting DATE_F. If setting DATE_F = MDY, then the dates are entered as in the above examples (Month/Day/Year). If setting DATE_F = YMD, then the dates are entered Year/Month/Day.

If the requested SER report rows do not exist, the relay responds:

```
No SER Data
```

Clearing SER Report

Clear the SER report from nonvolatile memory with the **SER C** command as shown in the following example:

```
=>SER C <Enter>

Clear the SER
Are you sure (Y/N) ? Y <Enter>
Clearing Complete
```


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Example Standard 15-Cycle Event Report

The following example standard 15-cycle event report in *Figure 12.3* (with wye-connected voltages) also corresponds to the example SER report in *Figure 12.7*. The circled numbers in *Figure 12.3* correspond to the SER row numbers in *Figure 12.7*. The row explanations follow *Figure 12.7*.

In *Figure 12.3*, the arrow (>) in the column following the `Freq` column identifies the "trigger" row. This is the row that corresponds to the `Date` and `Time` values at the top of the event report.

The asterisk (*) in the column following the `Freq` column identifies the row with the maximum phase current, which is determined from the filtered values. The maximum phase current is calculated from the row identified with the asterisk and the row one quarter-cycle previous (see *Figure 12.5* and *Figure 12.6*). These currents are listed at the end of the event report in the event summary. If the trigger row (>) and the maximum phase current row (*) are the same row, the (*) symbol takes precedence. Since the maximum phase current is determined from the filtered values, the asterisk (*) is not displayed in the unfiltered (raw) event report. The asterisk (*) is only displayed in the filtered event report.

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```
FEEDER 1                          Date: 04/12/99    Time: 09:28:31.721
STATION A

FID=SEL-351S-7-R1xx-V0-Zxxxxxx-Dxxxxxxxx    CID=xxxx

                                                                  Out  In
      Currents (Amps Pri)            Voltages (kV Pri)           1357 135
    IA    IB    IC    IN    IG     VA     VB     VC     VS Vdc Freq  246A 246
[1]
   241    26  -268    -1    -1    9.6    1.5  -11.1    0.0  24 60.01 .... b..
  -169   293  -124     0     0   -7.2   11.9   -4.7    0.0  24 60.01 .... b..
  -242   -26   267    -1    -1   -9.6   -1.5   11.0   -0.0  24 60.01 .... b..
   168  -294   124    -1    -2    7.2  -11.9    4.7    0.0  24 60.01 .... b..

       [Two cycles of data not shown in this example]
[4]
   243    22  -266    -1    -1    9.7    1.3  -11.0   -0.0  24 60.01 .... b..
  -166   294  -128     0    -0   -7.1   11.9   -4.8    0.0  24 60.01 .... b..
  -542   -32   255    -1  -319   -8.7   -1.9   10.8    0.0  24 60.01 .... b..
  -485  -271   107     0  -649    6.5  -11.7    4.8   -0.0  24 60.01>.... b..
[5]
  1586    37  -220    -1  1404    6.9    3.1  -10.2   -0.0  24 60.01 .... b..
  1295   226   -82     0  1439   -4.9   11.0   -4.9    0.0  24 59.81 1... b..
 -2332   -33   194     0 -2171   -6.2   -3.6    9.9    0.0  24 59.81 1... b..
 -1460  -208    77    -1 -1590    3.9  -10.5    5.0    0.0  24 59.70 1... b..
[6]
  2328    32  -194     0  2166    6.2    3.6   -9.9   -0.0  24 59.70 1... b..
  1465   207   -79     0  1594   -3.9   10.5   -5.0   -0.0  24 59.70 1... b..
 -2326   -32   193    -1 -2165   -6.2   -3.6    9.9    0.0  24 59.70 1... b..
 -1470  -208    79     0 -1599    3.9  -10.5    5.0    0.0  24 59.89 1... b..
[7]
  2323    31  -194     0  2160    6.2    3.5   -9.9   -0.0  24 59.89 1... b..
  1474   207   -80    -1  1601   -3.9   10.5   -5.0    0.0  24 60.01 1... b..
 -2320   -31   193     0 -2158   -6.2   -3.5    9.9    0.0  24 60.01 1... b..
 -1479  -208    80     0 -1607    3.8  -10.5    5.1    0.0  24 60.01 1... b..

  2317    31  -194     0  2154    6.2    3.5   -9.9   -0.0  24 60.01 1... b..
  1482   207   -80     0  1609   -3.8   10.5   -5.1   -0.0  24 60.01 1... b..
 -2317   -31   193    -1 -2154   -6.2   -3.5    9.9    0.0  24 60.01 1... b..
 -1484  -208    80    -1 -1612    3.8  -10.5    5.1    0.0  24 60.01 1... b..
[9]
  2317    30  -194    -1  2153    6.2    3.5   -9.9   -0.0  24 60.01*1... b..
  1483   207   -80     0  1609   -3.8   10.5   -5.1    0.0  24 60.01 1... b..
 -1965   -41   160     0 -1846   -7.2   -2.9   10.1    0.0  24 60.01 1... b..
  -849  -146    39    -1  -956    4.4  -10.7    5.1   -0.0  24 60.01 1... b..
[10]
   805    26   -64    -1   767    9.0    1.7  -10.6   -0.0  24 60.01 1... b..
   108    41     0     0   149   -6.0   11.4   -5.1    0.0  24 60.25 1... b..
    -1     0     0    -1    -1   -9.8   -1.2   10.9    0.0  24 60.25 1... 2..
     0     0    -1    -1    -1    7.0  -12.0    5.0   -0.0  24 60.32 1... 2..
[11]
    -1    -1     0     0    -1    9.8    1.2  -10.9   -0.0  24 60.32 1... 2..
    -1     0     0     0    -1   -7.0   11.9   -4.9    0.0  24 60.32 1... 2..
     0     0    -1    -1    -1   -9.7   -1.2   10.9    0.0  24 60.32 1... 2..
    -1    -1    -1    -1    -2    7.0  -11.9    4.9   -0.0  24 60.08 1... 2..

       [Two cycles of data not shown in this example]
[14]
    -1     0    -1    -1    -1    9.7    1.2  -11.0    0.0  24 60.01 1... 2..
     0     0     0    -1     0   -7.0   11.9   -4.9    0.0  24 60.01 .... 2..
     0    -1     0    -1    -1   -9.7   -1.2   10.9   -0.0  24 60.01 .... 2..
    -1    -1    -1     0    -2    7.0  -11.9    4.9    0.0  24 60.01 .... 2..
[15]
    -1    -1    -1     0    -2    9.8    1.2  -10.9   -0.0  24 60.01 .... 2..
     0     0     0    -1     0   -7.0   11.9   -5.0    0.0  24 60.01 .... 2..
     0     0     0     0     0   -9.8   -1.1   10.9    0.0  24 60.01 .... 2..
     0    -1    -1    -1    -1    7.0  -11.9    5.0    0.0  24 60.01 .... 2..

Protection and Control Elements
51     50 32 67   Dm 27 59     25  81   TS     Lcl Rem  Ltch SELogic
                          V   5   2     ih ZLV               Variable
        P PN      PN  P  P1   9S  7135 7mo lOd 1357135701357          1111111
ABCPNGQPP QG PNGQ QG PPSPPQNS VFA B246 9et dPc 24682468C2468 1234567890123456
[1]
......... .. .... .. ......... ... .... R.0 ... .............. ................
......... .. .... .. ......... ... .... R.0 ... .............. ................
......... .. .... .. ......... ... .... R.0 ... .............. ................
......... .. .... .. ......... ... .... R.0 ... .............. ................
```

see Figure 12.1

firmware identifier

firmware checksum identifier

one cycle of data

7

see Figure 12.4 and Figure 12.5 for details on this example one cycle of phase A (channel IA) current

3

2

(Continued on next page)

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(Continued from previous page)

```
        [Two cycles of data not shown in this example]
[4]
......... .. .... .. ........ ... .... R.O ... ............. ................
......... .. .... .. ........ ... .... R.O ... ............. ................
.....p... .. .... .. ........ ... .... R.O ... ............. ................
...p.p... .. .... .. ........ ... .... R.O ... ............. ..............>
[5]                                                                          8, 9, 10, 11
...p.p... .. .... .. ........ ... .... R.O ... ............. ................
...p.p.A. .. 1... .. ........ ... .... C.O ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
[6]
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
[7]
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
[8]
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
[9]
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............
...p.p.A. .. 1... .. ........ ... .... CrO ... ............. p...............    6
[10]
...p.p... .. .... .. ........ ... .... CrO ... ............. p...............
...p.p... .. .... .. ........ ... .... CrO ... ............. p...............    5
...r.r... .. .... .. ........ ... .... CrO ... ............. p...............
...r.r... .. .... .. ........ ... .... CrO ... ............. p...............
[11]
...r.r... .. .... .. ........ ... .... C.O ... ............. p...............
...r.r... .. .... .. ........ ... .... C.O ... ............. p...............
......... .. .... .. ........ ... .... C.O ... ............. p...............
......... .. .... .. ........ ... .... C.O ... ............. p...............

        [Two cycles of data not shown in this example]                        2
[14]
......... .. .... .. ........ ... .... C.O ... ............. p...............
......... .. .... .. ........ ... .... CoO ... ............. ................
......... .. .... .. ........ ... .... CoO ... ............. ................
......... .. .... .. ........ ... .... CoO ... ............. ................
[15]
......... .. .... .. ........ ... .... CoO ... ............. ................
......... .. .... .. ........ ... .... CoO ... ............. ................
......... .. .... .. ........ ... .... CoO ... ............. ................
......... .. .... .. ........ ... .... CoO ... ............. ................

     [The communication Elements Section is only available in Firmware Versions 6 and 7]

Communication Elements                                                       The PWR columns are displayed
 S  PZ EE   ZDNS  TMB  RMB  TMB  RMB  RRCL PWR                                only in Firmware Version 7
3O  T3KKCWU 3SSTB A    A    B    B    OBBB A B C 3P
PT PRREETFB XTTOT 1357 1357 1357 1357 KAAO 13131313 P
OF TXBYYTCB TRRPX 2468 2468 2468 2468  DDK 24242424 B
[1]
.. ........ ..... .... .... .... .... .... ........ .
.. ........ ..... .... .... .... .... .... ........ .
.. ........ ..... .... .... .... .... .... ........ .
.. ........ ..... .... .... .... .... .... ........ .
[2]
.. ........ ..... .... .... .... .... .... ........ .
.. ........ ..... .... .... .... .... .... ........ .
.. ........ ..... .... .... .... .... .... ........ .
.. ........ ..... .... .... .... .... .... ........ .

      [Thirteen cycles of data not shown in this example]

[15]
** ........ ..... .... .... .... .... .... ........ .
** ........ ..... .... .... .... .... .... ........ .
** ........ ..... .... .... .... .... .... ........ .
** ........ ..... .... .... .... .... .... ........ .

Event: AG T  Location:    2.36  Shot: 0  Frequency:  60.01                    see Figure 12.1
Targets: 11100100  01010010
Currents (A Pri), ABCNGQ:   2752 pk   209   209     1  2689  2689

(settings follow, but are not shown in this example)
```

Figure 12.3 Example Standard 15-Cycle Event Report 1/4-Cycle Resolution

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Figure 12.5 and *Figure 12.6* look in detail at one cycle of A-phase current (channel **IA**) identified in *Figure 12.3*. *Figure 12.5* shows how the event report ac current column data relates to the actual sampled waveform and RMS values. *Figure 12.6* shows how the event report current column data can be converted to phasor RMS values. Voltages are processed similarly.

```
EVE L2 <Enter>

FEEDER 1                          Date: 02/18/02    Time: 17:57:22.114
STATION A

FID=SEL-351S-7-R1xx-V0-Zxxxxxx-D2002xxxx       CID=xxxx
                                                                  Out  In

      Currents (Amps Pri)             Voltages (kV Pri)           1357 135
    IA    IB    IC    IN    IG    VAB    VBC    VCA     VS Vdc Freq  246A 246
[1]
   124  -173    16     0   -33   23.9  -14.9   -9.0    0.0  23 59.99 .... ...
   148    21  -228    -0   -60    3.4   19.0  -22.4    0.0  23 59.99 .... ...
  -124   173   -17    -0    33  -23.9   14.9    9.0    0.0  23 59.99 .... ...
  -148   -20   228     0    60   -3.4  -18.9   22.4    0.0  23 59.99 .... ...
[2]
   123  -173    17     0   -33   23.9  -14.9   -8.9   -0.0  23 59.99 .... ...
   149    20  -228    -0   -59    3.5   18.9  -22.4   -0.0  23 59.99 .... ...
  -123   173   -18    -0    33  -23.9   15.0    8.9    0.0  23 59.99 .... ...
  -149   -20   228     0    59   -3.5  -18.9   22.4    0.0  23 59.99 .... ...

Protection and Control Elements

51     50 32 67   Dm 27 59     25  81   TS     Lcl Rem  Ltch SELogic
                     P  P    5   2     ih ZLV             Variable
        P PN      PN PP PPV   9S  7135 7mo lOd 1357135701357          1111111
ABCPNGQPP QG PNGQ QG P2SP21QS VFA B246 9et dPc 24682468C2468 1234567890123456
[1]
......... .. .... .. ........ ... .... L.1 ... .............. ................
......... .. .... .. ........ ... .... L.1 ... .............. ................
......... .. .... .. ........ ... .... L.1 ... .............. ................
......... .. .... .. ........ ... .... L.1 ... .............. ................
[2]
......... .. .... .. ........ ... .... L.1 ... .............. ................
......... .. .... .. ........ ... .... L.1 ... .............. ................
......... .. .... .. ........ ... .... L.1 ... .............. ................
......... .. .... .. ........ ... .... L.1 ... .............. ................

(The Communication Elements Section is only in available in
    Firmware Versions 6 and 7.)
(The PWR columns are only available in Firmware Version 7.)

Communication Elements

 S  PZ EE   ZDNS  TMB  RMB  TMB  RMB  RRCL PWR
3O  T3KKCWU 3SSTB A    A    B    B    OBBB 3P
PT PRREETFB XTTOT 1357 1357 1357 1357 KAAO 13 P
OF TXBYYTCB TRRPX 2468 2468 2468 2468  DDK 24 B
[1]
.. ........ ..... .... .... .... .... .... .. .
.. ........ ..... .... .... .... .... .... .. .
.. ........ ..... .... .... .... .... .... .. .
.. ........ ..... .... .... .... .... .... .. .
[2]
.. ........ ..... .... .... .... .... .... .. .
.. ........ ..... .... .... .... .... .... .. .
.. ........ ..... .... .... .... .... .... .. .
.. ........ ..... .... .... .... .... .... .. .

Event: TRIG  Location: $$$$$$$  Shot: 1  Frequency:  59.99
Targets:
Currents (A Pri), ABCNGQ:    191   173   229     0    68    88

Group 1
Group Settings:
****** NOT SHOWN *****
```

Figure 12.4 Example Partial Event Report with Delta-Connected PTs

The event report in *Figure 12.4* is displaying filtered analog data. If the **EVE R** command had been used instead, the analog voltage column headings would be `VA  VB  VC`, as described in *Filtered and Unfiltered Event Reports on page 12.8*.

The event report sample in *Figure 12.4* is not related to the event report sample in *Figure 12.3*, or to the SER sample in *Figure 12.7*.

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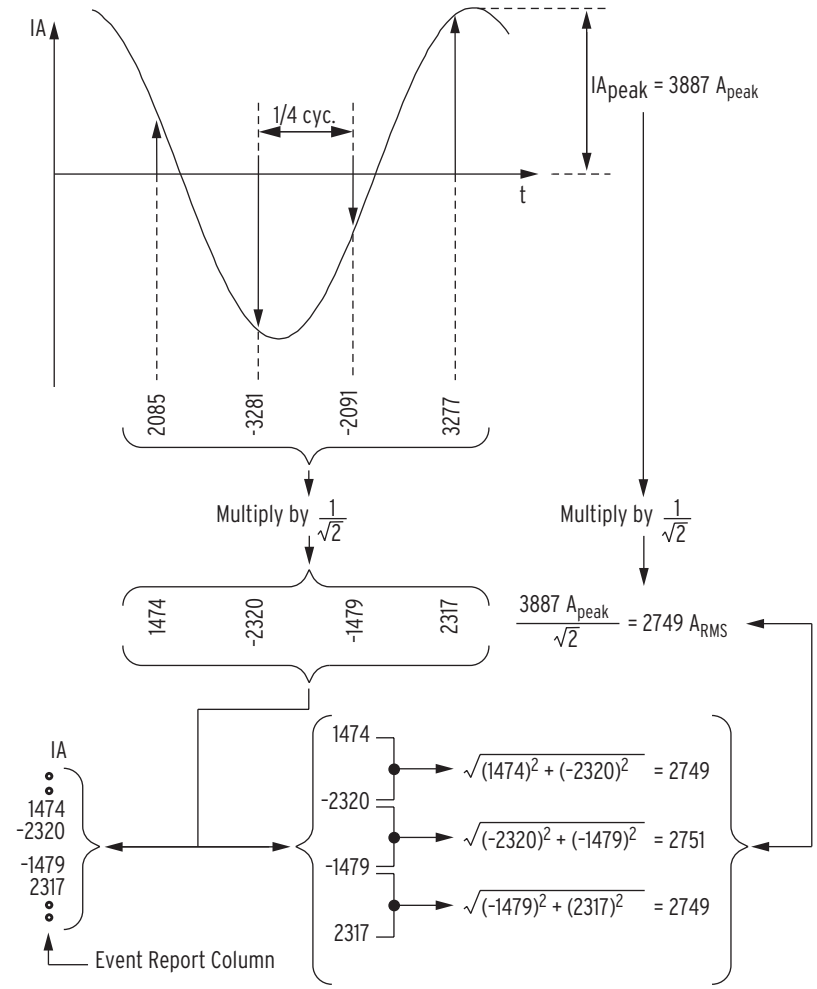


Figure 12.5 Derivation of Event Report Current Values and RMS Current Values From Sampled Current Waveform

In *Figure 12.5*, note that any two rows of current data from the event report in *Figure 12.3*, 1/4 cycle apart, can be used to calculate RMS current values.

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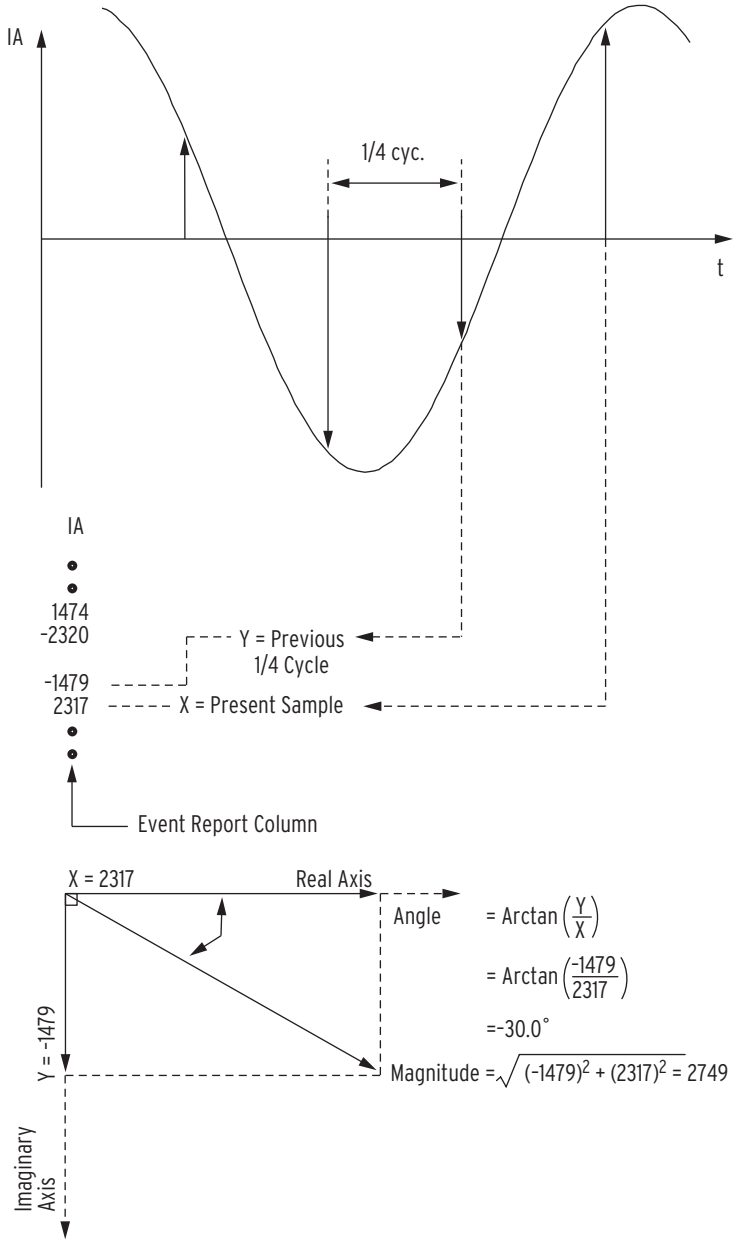


Figure 12.6 Derivation of Phasor RMS Current Values From Event Report Current Values

In *Figure 12.6*, note that two rows of current data from the event report in *Figure 12.3*, 1/4 cycle apart, can be used to calculate phasor RMS current values. In *Figure 12.6*, at the present sample, the phasor RMS current value is:

$$IA = 2749\ A\ \angle -32.6^\circ \qquad \textbf{Equation 12.1}$$

The present sample (IA = 2317 A) is a real RMS current value that relates to the phasor RMS current value:

$$2749\ A * \cos(-32.6^\circ) = 2317\ A \qquad \textbf{Equation 12.2}$$

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Example SER Report

The following example SER report in *Figure 12.7* also corresponds to the example standard 15-cycle event report in *Figure 12.3*.

```
FEEDER 1                          Date: 04/12/99    Time: 10:20:16.896

STATION A

FID=SEL-351S-5-R100-V0-Z001001-D199908xx       CID=2xxxx
#     DATE      TIME           ELEMENT            STATE

19    04/12/99  08:30:33.222    Relay newly powered up
18    04/12/99  09:20:22.830   IN102               Asserted
17    04/12/99  09:27:58.364   LB4                 Asserted
16    04/12/99  09:27:58.364   OUT102              Asserted
15    04/12/99  09:27:58.368   LB4                 Deasserted
14    04/12/99  09:27:58.385   IN101               Asserted
13    04/12/99  09:27:58.385   OUT102              Deasserted
12    04/12/99  09:28:03.385   79LO                Deasserted
11    04/12/99  09:28:31.717   51G                 Asserted
10    04/12/99  09:28:31.721   51P                 Asserted
9     04/12/99  09:28:31.729   50P1                Asserted
8     04/12/99  09:28:31.729   79CY                Asserted
7     04/12/99  09:28:31.729   OUT101              Asserted
6     04/12/99  09:28:31.808   50P1                Deasserted
5     04/12/99  09:28:31.816   51G                 Deasserted
4     04/12/99  09:28:31.816   51P                 Deasserted
3     04/12/99  09:28:31.816   IN101               Deasserted
2     04/12/99  09:28:31.879   OUT101              Deasserted
1     04/12/99  09:28:36.874   OUT102              Asserted
```

Figure 12.7 Example SER Report

The SER report rows in *Figure 12.7* are explained in the following text, numbered in correspondence to the # column. The boxed, numbered comments in *Figure 12.3* also correspond to the # column numbers in *Figure 12.7*. The SER report in *Figure 12.7* contains records of events that occurred before and after the standard event report in *Figure 12.3*.

The settings referenced in the following comments are not necessarily factory settings.

SER Row No.	Explanation
19	Relay newly powered up.
18	Input **IN102** is asserted to enable reclosing. Related setting: 79DTL = !IN102 + ... [=NOT(IN102) + ...]
17, 16	Local bit LB4 is operated from the front panel to assert close output contact **OUT102** to close the circuit breaker (see *Figure 6.1*). Related settings: CL = LB4 (LB4 operates as a manual close) OUT102 = CLOSE
15	Local bit LB4 deasserts automatically the next 1/4 cycle–close signal is latched in by close logic.
14, 13	Input **IN101** asserts, indicating that the circuit breaker closed. Close output contact **OUT102** consequently deasserts. Related setting: 52A = IN101

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SER Row No.	Explanation
12	The relay leaves the Lockout State (79LO) and goes to the Reset State, 300 cycles after the circuit breaker closes. Related setting: 79RSLD = 300.000 cycles Time difference: 09:28:03.385 – 09:27:58.364 = 5.021 seconds (= 300 cycles)
11, 10	Time-overcurrent elements 51PT and 51GT pickup and start timing at fault inception (51P and 51G are the respective pickup indicators).
9, 8, 7	Instantaneous overcurrent element 50P1 picks up and asserts trip output contact **OUT101** to trip the circuit breaker (see *Figure 5.1*). Relay goes to the Reclose Cycle State (79CY). Related settings: TR = ...+ 50P1*SH0 OUT101 = TRIP
6, 5, 4	Instantaneous overcurrent element 50P1 and time-overcurrent element pickups 51P and 51G drop out as the circuit breaker interrupts fault current.
3	Input **IN101** deasserts, indicating that the circuit breaker opened.
2	Trip output contact **OUT101** deasserts after being asserted a minimum of 9 cycles. Related settings: TDURD = 9.000 cycles Time difference: 09:28:31.879 – 09:28:31.729 = 0.150 seconds (= 9 cycles) Open interval 79OI1 does not start timing until trip output contact **OUT101** deasserts. Related settings: 79STL = TRIP
1	Close output contact **OUT102** asserts for first automatic reclose. Related settings: 79OI1 = 30.000 Time difference: 09:28:36.874 – 09:28:31.879 = 4.995 seconds (≅300 cycles)

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Sag/Swell/Interruption (SSI) Report (Available in Firmware Version 7)

See *Figure 12.8* and *Figure 12.9* for an example SSI report.

SSI Triggering and Recording

The SEL-351S-7 can perform automatic voltage disturbance monitoring for three-phase systems. The SSI Recorder uses the SSI Relay Word bits to determine when to start (trigger) and when to stop recording. The recorded data is available through the SSI Report.

See *Voltage Sag, Swell, and Interruption Elements (Available in Firmware Version 7) on page 3.54* for details on the operation of the SSI Relay Word bits.

The SSI recorder operates (adds new entries to the stored SSI report) only when group setting ESSI = Y in the active setting group, although the SSI report can be viewed at any time.

The SSI recorder uses nonvolatile memory, so any stored SSI data will not be erased by de-energizing the relay. The relay needs some time to store new SSI data in nonvolatile memory, so if a system power outage also causes the relay power to fail, there may not be an SSI record of the disturbance. This is not a concern in substations where the relay is powered by a substation battery.

The relay triggers (generates) entries in the SSI report on the assertion of any sag, swell, or interruption relay element (Relay Word bits SAG*p*, SW*p*, INT*p*, where *p* = A, B, or C {wye-connected}; *p* = AB, BC, or CA {delta-connected}), or when manually triggered by the **SSI T** Command.

SSI Report Entries

- Entry number (1 is the most recent entry)
- Date and time stamp of entry
- Phase current magnitudes (Ia,b,c) as a percentage of the nominal current rating of the phase current inputs (5 A or 1 A)
- Calculated residual current magnitude (Ig) as a percentage of the nominal current rating of the phase current inputs (5 A or 1 A)
- Neutral current magnitude (In) as a percentage of the nominal current rating of the neutral current input (5 A, 1 A, 0.2 A, or 0.05 A)
- Phase-neutral voltage magnitudes (V_A, V_B, V_c) as a percentage of Vbase (wye-connected)
  or
  Phase-to-phase voltage magnitudes (V_{AB}, V_{BC}, V_{CA}) as a percentage of Vbase (delta-connected)
- Vs channel voltage magnitude as a percentage of Vbase; displayed value

$$Vs = \frac{Vs\ (secondary) \bullet PTRS}{1000 \bullet Vbase} \bullet 100\%$$

Equation 12.3

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- Base voltage magnitude (Vbase) in kV primary
  Vbase = memorized positive-sequence voltage, V_1 (wye-connected) **or**
  Vbase = •√3 (memorized positive-sequence voltage, V_1) (delta-connected)
- Phase A, B, and C SSI element status columns; see *Table 12.4*
- Trigger state, "*" if present (in the column marked "S")
- SSI recorder status; see *Table 12.5*

NOTE: Any current or voltage value greater than 999 percent will be replaced by $$$ in the SSI report.

Table 12.4 SSI Element Status Columns

Symbol	Meaning (for Each Column A, B, or C)	
	Global Setting PTCONN = WYE Column A represents *p* = A Column B represents *p* = B Column C represents *p* = C	Global Setting PTCONN = DELTA Column A represents *pp* = AB Column B represents *pp* = BC Column C represents *pp* = CA
•	No SSI bits asserted for phase *p*	No SSI bits asserted for phases *pp*
O	Overvoltage (SW*p* asserted)	Overvoltage (SW*pp* asserted)
U	Undervoltage (SAG*p* asserted)	Undervoltage (SAG*pp* asserted)
I	Interruption (INT*p* asserted; SAG*p* asserted, unless setting VSAG = OFF)	Interruption (INT*pp* asserted; SAG*pp* asserted, unless setting VSAG = OFF)

Table 12.5 Status SSI Column

Symbol	Meaning (Action)	Duration
R	Ready (when the SSI logic first acquires a valid V_{BASE} value)	Single entry
P	Pre-disturbance (4 samples per cycle). Always signifies a new disturbance.	12 samples (3 cycles)
F	Fast recording mode (4 samples per cycle)	Varies. At least one SSI element must be asserted.
E	End (post-disturbance at 4 samples per cycle)	Up to 16 samples (4 cycles). No SSI elements asserted.
M	Medium recording mode (one sample per cycle)	Maximum of 176 cycles
S	Slow recording mode (one sample per 64 cycles)	Maximum of 4096 cycles
D	Daily recording mode (one sample per day, just after midnight)	Indefinite
X	Data overflow (single entry that indicates that data was lost prior to the present entry)	Single entry

See *Figure 12.8* for an example Sag/Swell/Interruption (SSI) report.

SSI Recorder Operation: Overview

The SSI Recorder operation can be summarized as follows: When power is first applied to the relay and setting ESSI = "Y", (or setting ESSI is changed from "N" to "Y"), the relay measures the voltage inputs to determine if a valid three-phase signal is present. When the conditions are satisfied for at least twelve seconds, the positive-sequence voltage, V_1, is memorized as the Vbase reference voltage. When global setting PTCONN = DELTA, a factor of √3 is applied so that Vbase is in the phase-to-phase scale. This causes a single "R"

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entry to be placed in the SSI archive, which indicates that the recorder is ready. The Vbase value is allowed to change on a gradual basis to follow normal system voltage variations, but is "locked" when a disturbance occurs.

When any SSI Relay Word Bit asserts or the **SSI T** serial port command is issued, the recorder will begin recording.

When operating, the SSI Recorder archives the following information:

- Currents Ia, Ib, Ic, Ig, and In as a percentage of the nominal current rating (shown in the report heading)
- Voltages Va, Vb, Vc, and Vs as a percentage of the Vbase quantity (wye-connected)
  Voltages Vab, Vbc, Vca, and V_S as a percentage of the Vbase quantity (delta-connected)
- The Vbase quantity, in kV primary
- The state of the Sag/Swell/Interruption Relay Word bits, by phase
- The trigger status
- The recorder status

Entries are made at a varying recording rate: fastest when the SSI Relay Word bits are changing states, and slowest if the SSI Relay Word bits are quiet. Eventually, it can get as slow as one sample per day. The faster recording mode will be initiated from any of the slower recording modes, as soon as any SSI bit or the **SSI T** condition changes state.

Recording is stopped when all SSI Relay Word bits and the trigger condition stay deasserted for at least four cycles.

SSI Recorder Operation: Detailed Description

From the SSI Recorder Ready state, upon the initial assertion of one of the SSI Relay Word bits or a manual trigger condition, the relay records SSI data in the following sequence:

- **Pre-disturbance recording:** Record pre-trigger entries at ¼-cycle intervals with the SSI Recorder status field displaying `P`. Since no SSI elements are asserted, columns `A`, `B`, and `C` will display ".". The pre-disturbance state lasts for a total of 12 samples, or three cycles, unless there are "back-to-back" disturbances that reduce the number of `P` entries.
- **Fast recording (also End recording):** Record one entry every ¼-cycle, with the SSI Recorder status field displaying `F` (if any SSI elements are asserted or the manual trigger condition is asserted), or `E` (if none of the SSI elements are asserted). If the manual trigger condition is present, a "`*`" will be recorded. The SSI element status columns will show one of ".", `O`, `U`, `I`. The Fast/End recording mode continues until four cycles elapse with no SSI element or manual trigger condition changing state. The relay then proceeds to the state determined by the following tests (processed in the order shown):
  - If INT3P is asserted, switch to daily recording mode. (This keeps the relay from recording medium and slow speed detailed information during a complete outage.)
  - Otherwise, if any SSI elements are asserted, switch to the medium recording mode.
  - Otherwise, stop recording.

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- **Medium recording:** Record one entry per cycle, with the SSI Recorder status field displaying M. The phase columns will show one of ".", O, U, I. The medium recording mode continues for 176 cycles, unless one of the SSI elements or the manual trigger condition changes state, which causes the recorder to start over in Fast mode (with up to three samples prior to the change). At the end of medium recording mode, the recorder switches to the slow recording mode.
- **Slow recording:** Record one entry every 64 cycles, with the SSI Recorder status field displaying "S". The phase columns will show one of ".", O, U, I. The slow recording mode continues for 4,096 cycles (64 entries), unless one of the SSI elements or the manual trigger condition changes state, which causes the recorder to start over in fast mode (with up to eight samples prior to the change). At the end of slow recording mode, the recorder switches to the daily recording mode.
- **Daily recording:** record one entry every day just past midnight (00:00:00), with the SSI Recorder status field displaying "D". The phase columns will show one of ".", O, U, I. The daily recording mode continues until any SSI Relay element or the manual trigger condition changes state, which causes the recorder to start over in fast mode (with up to eight samples prior to the change).

An overflow condition can occur when the SSI recorder cannot keep up with the data generated during disturbances that create a large number of SSI entries. The nonvolatile memory that is used for the SSI archive has a longer "write" time than the Random Access Memory (RAM) that is used to temporarily store the SSI data, so it is possible that the data in RAM will overwrite itself if the transfer to Flash memory gets too far behind. The SSI report will show an X in the REC column if this happens, and it will be on the first entry after the overflow. The overflow condition may also occur if the relay is saving an event report to nonvolatile memory, since the memory can only be used by one procedure at a time.

SSI Report Memory Details

The relay retains a minimum of 3855 of the most recent SSI entries in nonvolatile memory. The relay can hold a maximum of 7710 entries. When the recorder memory reaches 7710 entries and further entries occur, the oldest 3855 memory locations are cleared in a block to make room for newer entries. Therefore, the apparent SSI memory size can vary between 3855 and 7710 entries. If the SSI recorder memory clears while an SSI report is being displayed, the SSI report will stop and display this message:

```
Command Aborted, Data overwrite occurred
```

Retrieving the SSI Report

The recorded SSI data can be viewed from any setting group, even if setting ESSI = N. Row 1 is the most recently triggered row. View the SSI report by date or SSI row number as outlined in the examples below.

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Example SSI Serial Port Commands	Format
SSI	If **SSI** is entered with no numbers following it, all available rows are displayed. They display with the oldest row at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SSI 17	If **SSI** is entered with a single number following it (17 in this example), the first 17 rows are displayed, if they exist. They display with the oldest row (row 17) at the beginning (top) of the report and the latest row (row 1) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SSI 10 33	If **SSI** is entered with two numbers following it (10 and 33 in this example; 10 < 33), all the rows between (and including) rows 10 and 33 are displayed, if they exist. They display with the oldest row (row 33) at the beginning (top) of the report and the latest row (row 10) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SSI 47 22	If **SSI** is entered with two numbers following it (47 and 22 in this example; 47 > 22), all the rows between (and including) rows 47 and 22 are displayed, if they exist. They display with the newest row (row 22) at the beginning (top) of the report and the oldest row (row 47) at the end (bottom) of the report. **Reverse** chronological progression through the report is down the page and in ascending row number.
SSI 3/30/00	If **SSI** is entered with one date following it (date 3/30/00 in this example), all the rows on that date are displayed, if they exist. They display with the oldest row at the beginning (top) of the report and the latest row at the end (bottom) of the report, for the given date. Chronological progression through the report is down the page and in descending row number.
SSI 2/17/00 3/23/00	If **SSI** is entered with two dates following it (date 2/17/00 chronologically **precedes** date 3/23/00 in this example), all the rows between (and including) dates 2/17/00 and 3/23/00 are displayed, if they exist. They display with the oldest row (date 2/17/00) at the beginning (top) of the report and the latest row (date 3/23/00) at the end (bottom) of the report. Chronological progression through the report is down the page and in descending row number.
SSI 3/16/00 1/5/00	If **SSI** is entered with two dates following it (date 3/16/00 chronologically **follows** date 1/5/00 in this example), all the rows between (and including) dates 1/5/00 and 3/16/00 are displayed, if they exist. They display with the latest row (date 3/16/00) at the beginning (top) of the report and the oldest row (date 1/5/00) at the end (bottom) of the report. **Reverse** chronological progression through the report is down the page and in ascending row number.

The date entries in the above example **SSI** commands are dependent on the Date Format setting DATE_F. If setting DATE_F = MDY, then the dates are entered as in the above examples (Month/Day/Year). If setting DATE_F = YMD, then the dates are entered Year/Month/Day.

If the requested **SSI** event report rows do not exist, the relay responds:

```
No Voltage Sag/Swell/Interruption Data
```


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Clearing the SSI Report

Clear the **SSI** report from nonvolatile memory with the **SSI C** command as shown in the following example:

```
=>SSI C <Enter>

Clear the Voltage Sag/Swell/Interruption buffer
Are you sure (Y/N)? Y <Enter>
Clearing Complete
```

The **SSI C** command is available in any setting group and on any serial port.

If the **SSI C** command is issued on one serial port while another serial port is being used to display an SSI report, the clearing action will terminate the SSI report retrieval.

If maximum SSI recorder capacity is desired, the SSI Report should be checked periodically, with the data captured to a computer file using a terminal emulation program. Once the data has been viewed or captured, use the **SSI C** command to clear the SSI recorder.

Clearing the SSI recorder makes it easier to tell if any new disturbances have been recorded, and it also allows the SSI Archive to record the maximum of 7710 entries. If more than 7710 entries occur, the oldest half of the SSI archive will be erased to make room for the new entries. The most recent 3855 entries are always available.

Triggering the SSI Recorder

Manually force the SSI Recorder to trigger using the **SSI T** command as shown in the following example:

```
=>SSI T <Enter>
Triggered
```

The **SSI T** command is only available if group setting ESSI = Y in the active setting group.

If an **SSI T** command is issued when setting ESSI = N, the relay will respond as follows:

```
Command is not available
```

If an **SSI T** command is issued before Vbase has initialized, the relay will respond as follows:

```
Did Not Trigger
```

See *Vbase Initialization on page 3.57* for details on the initializing conditions.

The **SSI T** command is useful for testing, because it provides an easy method of creating some SSI Report entries without the need to remove voltage signals or connect a test set, providing Vbase has already been initialized.

Resetting the SSI Recorder Logic

During relay commissioning or test procedures, the SSI recorder may memorize the Vbase quantity when test voltages or settings are applied. This could cause the recorder to declare a false SAG or SWELL condition when

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normal system voltages are applied. Reset the SSI Recorder logic and clear the Vbase value by issuing the **SSI R** command as shown in the following example:

```
=>SSI R <Enter>

Reset the Voltage Sag/Swell/Interruption monitor
Are you sure (Y/N)? Y <Enter>
Voltage Sag/Swell/Interruption monitor reset
```

After the relay detects satisfactory voltage signals for at least 12 seconds, the SSI Recorder is armed and a Ready entry is written to the SSI archive.

The **SSI R** command is only available if group setting ESSI = Y in the active setting group. Attempting the **SSI R** command when ESSI = N will display:

```
Command is not available
```

The relay automatically performs an equivalent action to the **SSI R** command:

- When the relay is powered-up and setting ESSI = Y
- After a group change or setting change that changes active setting ESSI = N to ESSI = Y.
- After a **STA C** command (Level 2)

Sample SSI Report

The Sag/Swell/Interruption (SSI) report in *Figure 12.8* shows a voltage sag on B-phase and a voltage swell on C-phase caused by a single-phase fault on B-phase that is cleared by a remote device. (Relay inputs IN and VS are not connected.)

```
=>SSI <Enter>

FEEDER A27                        Date: 12/06/00    Time: 09:12:07.369
CROWN SUB

FID=SEL-351-7-R3xx-V0-Zxxxxxx-D2000xxxx       CID=xxxx

                I nom. A B C G = 5 Amp  N = 5 Amp

                            Current(% I nom.)   Voltage(% Vbase) Vbase  Ph ST
#     Date     Time         Ia  Ib  Ic  Ig  In  Va  Vb  Vc  Vs  (kV)   ABC
36    11/22/00 08:47:24.272  11  13  15   3   0 100  99 100   0  14.94 ... R
                                                                (Continued on next page)
```


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```
                                                                    (Continued from previous page)
35    12/05/00 16:21:12.635  20  23  28   7   0  98  98  98   0  15.29 ... P
34    12/05/00 16:21:12.639  20  22  29   8   0  98  98  98   0  15.29 ... P
33    12/05/00 16:21:12.644  20  22  28   7   0  98  98  98   0  15.29 ... P
32    12/05/00 16:21:12.648  20  23  28   7   0  98  98  98   0  15.29 ... P
31    12/05/00 16:21:12.652  20  23  28   8   0  98  98  98   0  15.29 ... P
30    12/05/00 16:21:12.656  20  22  29   8   0  98  98  98   0  15.29 ... P
29    12/05/00 16:21:12.660  20  31  29  26   0  98  98  99   0  15.29 ... P
28    12/05/00 16:21:12.664  20  62  30  40   0  98  90 101   0  15.29 ... P
27    12/05/00 16:21:12.669  20  67  32  50   0  98  89 105   0  15.29 ... P
26    12/05/00 16:21:12.673  20 112  33  88   0  98  78 108   0  15.29 ... P
25    12/05/00 16:21:12.677  20 111  34  86   0  98  78 111   0  15.29 ... P
24    12/05/00 16:21:12.681  20 125  34  99   0  98  75 111   0  15.29 ... P
23    12/05/00 16:21:12.685  20 125  34  99   0  98  75 111   0  15.29 .U. F
22    12/05/00 16:21:12.689  20 125  35  99   0  98  75 111   0  15.29 .U. F
21    12/05/00 16:21:12.694  20 122  34  94   0  98  76 110   0  15.29 .UO F
20    12/05/00 16:21:12.698  20  88  33  62   0  98  82 108   0  15.29 .UO F
19    12/05/00 16:21:12.702  20  88  31  60   0  98  83 104   0  15.29 .UO F
18    12/05/00 16:21:12.706  20  34  30   8   0  98  94 101   0  15.29 .UO F
17    12/05/00 16:21:12.710  20  34  29   9   0  98  94  98   0  15.29 .UO F
16    12/05/00 16:21:12.714  20  15  28  12   0  98  98  98   0  15.29 .U. F
15    12/05/00 16:21:12.718  19  15  28  12   0  98  98  98   0  15.29 .U. F
14    12/05/00 16:21:12.723  20  14  29  12   0  98  98  98   0  15.29 ... E
13    12/05/00 16:21:12.727  20  14  28  12   0  98  98  98   0  15.29 ... E
12    12/05/00 16:21:12.731  20  15  28  12   0  98  98  98   0  15.29 ... E
11    12/05/00 16:21:12.735  20  15  29  12   0  98  98  98   0  15.29 ... E
10    12/05/00 16:21:12.739  20  14  29  12   0  98  98  98   0  15.29 ... E
9     12/05/00 16:21:12.743  20  14  28  12   0  98  98  98   0  15.29 ... E
8     12/05/00 16:21:12.748  20  15  28  12   0  98  98  98   0  15.29 ... E
7     12/05/00 16:21:12.752  19  15  28  12   0  98  98  98   0  15.29 ... E
6     12/05/00 16:21:12.756  19  14  28  12   0  98  98  98   0  15.29 ... E
5     12/05/00 16:21:12.760  20  14  28  12   0  98  98  98   0  15.29 ... E
4     12/05/00 16:21:12.764  20  15  28  12   0  98  98  98   0  15.29 ... E
3     12/05/00 16:21:12.768  19  15  28  12   0  98  98  98   0  15.29 ... E
2     12/05/00 16:21:12.773  19  14  29  12   0  98  98  98   0  15.29 ... E
1     12/05/00 16:21:12.777  20  14  28  12   0  98  98  98   0  15.29 ... E
```

Figure 12.8 Example Sag/Swell/Interruption (SSI) Report (PTCONN = WYE)

The Sag/Swell/Interruption (SSI) report in *Figure 12.9* shows the format of the SSI report headings when the relay is configured for delta-connected PTs (global setting PTCONN = DELTA). In this case, the `Ph ABC` column represents the Relay Word bits as shown on the right-hand side of *Table 12.4*. Note that the voltage column headings are now `Vab`, `Vbc`, and `Vca`, and that the Vbase value is scaled by √3 to account for the phase-to-phase quantities (as compared to *Figure 12.8*).

```
=>SSI 32 36 <Enter>
FEEDER A27                          Date: 02/06/02    Time: 09:12:07.369
CROWN SUB

FID=SEL-351-7-R3xx-V0-Zxxxxxx-D2002xxxx       CID=xxxx

                I nom. A B C G = 5 Amp  N = 5 Amp

                          Current(% I nom.)   Voltage(% Vbase) Vbase  Ph ST
#     Date     Time         Ia  Ib  Ic  Ig  In  Vab Vbc Vca Vs  (kV)   ABC

36    11/22/00 08:47:24.272  11  13  15   3   0 100  99 100   0  25.88 ... R
35    12/05/00 16:21:12.635  20  23  28   7   0  98  98  98   0  26.48 ... P
34    12/05/00 16:21:12.639  20  22  29   8   0  98  98  98   0  26.48 ... P
33    12/05/00 16:21:12.644  20  22  28   7   0  98  98  98   0  26.48 ... P
32    12/05/00 16:21:12.648  20  23  28   7   0  98  98  98   0  26.48 ... P

=>
```

Figure 12.9 Example Sag/Swell/Interruption (SSI) Report (PTCONN = DELTA)

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Using the SSI Recorder on Ungrounded/High-Impedance Grounded and Petersen Coil Systems

In ungrounded/high-impedance grounded and Petersen Coil systems, the loss of one phase voltage (caused by a phase-to-ground fault) does not affect the delivery of power to the phase-to-phase connected loads on the distribution system. Depending on the relay PT connection (and global setting PTCONN), the SSI Report may or may not capture data during a single-line-to-ground fault:

- **If PTCONN = WYE**, the SSI Relay Word bits respond to single-phase voltages. The SSI report treats a single-line-to-ground fault as a sag (or interrupt) on one phase, and a swell on the other two phases (subject to the actual settings in use, and the fault characteristics). In this situation, the SSI Report can be used as a fault analysis tool, capturing the phase and duration of faults that are significant enough to cause a single-phase voltage SAG*p* element to assert.
- **If PTCONN = DELTA**, the SSI Relay Word bits respond to phase-to-phase voltages. The SSI report will likely not trigger during a single-line-to-ground fault, because the phase-to-phase voltage quantities do not change materially. In this situation, the SSI Report is strictly a power quality tool, reporting disturbances actually experienced by the phase-to-phase connected load on the power system.

For both wye- and delta-connected PT systems, the SSI Report will capture disturbances caused by phase-to-phase and three-phase faults (subject to the actual settings in use, and the fault characteristics).

For details on the ungrounded/high-impedance grounded and Petersen Coil directional elements, see *Directional Control for Neutral Ground and Residual Ground Overcurrent Elements on page 4.9*.

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Section 13

Testing and Troubleshooting

Introduction

This section provides guidelines for determining and establishing test routines for the SEL-351S Relay. Included are discussions on testing philosophies, methods, and tools. Relay self-tests and troubleshooting procedures are shown at the end of the section.

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Testing Philosophy

Protective relay testing may be divided into three categories: acceptance, commissioning, and maintenance testing. The categories are differentiated by when they take place in the life cycle of the relay as well as in the test complexity.

The paragraphs below describe when to perform each type of test, the goals of testing at that time, and the relay functions that you need to test at each point. This information is intended as a guideline for testing SEL relays.

Acceptance Testing

When: When qualifying a relay model to be used on the utility system.

Goals:

1. Ensure relay meets published critical performance specifications such as operating speed and element accuracy.
2. Ensure that the relay meets the requirements of the intended application.
3. Gain familiarity with relay settings and capabilities.

What to test: All protection elements and logic functions critical to the intended application.

SEL performs detailed acceptance testing on all new relay models and versions. We are certain the relays we ship meet their published specifications. It is important for you to perform acceptance testing on a relay if you are unfamiliar with its operating theory, protection scheme logic, or settings. This helps ensure the accuracy and correctness of the relay settings when you issue them.

Commissioning Testing

When: When installing a new protection system.

Goals:

1. Ensure that all system ac and dc connections are correct.
2. Ensure that the relay functions as intended using your settings.
3. Ensure that all auxiliary equipment operates as intended.

What to test: All connected or monitored inputs and outputs, polarity and phase rotation of ac connections, simple check of protection elements.

SEL performs a complete functional check and calibration of each relay before it is shipped. This helps ensure that you receive a relay that operates correctly and accurately. Commissioning tests should verify that the relay is properly connected to the power system and all auxiliary equipment. Verify control signal inputs and outputs. Check breaker auxiliary inputs, SCADA control inputs, and monitoring outputs. Use an ac connection check to verify that the relay current and voltage inputs are of the proper magnitude and phase rotation.

Brief fault tests ensure that the relay settings are correct. It is not necessary to test every relay element, timer, and function in these tests.

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At commissioning time:

1. Use the relay **METER** command to verify the ac current and voltage magnitude and phase rotation.
2. Use the **PULSE** command to verify relay output contact operation.
3. Use the **TARGET** command to verify optoisolated input operation.

Maintenance Testing

When: At regularly scheduled intervals or when there is an indication of a problem with the relay or system.

Goals:

1. Ensure that the relay is measuring ac quantities accurately.
2. Ensure that scheme logic and protection elements are functioning correctly.
3. Ensure that auxiliary equipment is functioning correctly.

What to test: Anything not shown to have operated during an actual fault within the past maintenance interval.

SEL relays use extensive self-testing capabilities and feature detailed metering and event reporting functions that lower the utility dependence on routine maintenance testing.

1. Use the SEL relay reporting functions as maintenance tools.

   Periodically verify that the relay is making correct and accurate current and voltage measurements by comparing the relay METER output to other meter readings on that line.
2. Review relay event reports in detail after each fault.

   Using the event report current, voltage, and relay element data, you can determine that the relay protection elements are operating properly.

   Using the event report input and output data, you can determine that the relay is asserting outputs at the correct instants and that auxiliary equipment is operating properly.
3. At the end of your maintenance interval, the only items that need testing are those that have not operated during the maintenance interval.

The basis of this testing philosophy is simple: If the relay is correctly set and connected, is measuring properly, and no self-test has failed, there is no reason to test it further.

Each time a fault occurs, the protection system is tested. Use event report data to determine areas requiring attention. Slow breaker auxiliary contact operations and increasing or varying breaker operating time can be detected through detailed analysis of relay event reports.

Because SEL relays are microprocessor-based, their operating characteristics do not change over time. Time-overcurrent operating times are affected only by the relay settings and applied signals. It is not necessary to verify operating characteristics as part of maintenance checks.

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At SEL, we recommend that maintenance tests on SEL relays be limited under the guidelines provided above. The time saved may be spent analyzing event data and thoroughly testing those systems that require more attention.

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Testing Methods and Tools

Test Features Provided by the Relay

The following features assist you during relay testing.

METER Command. The **METER** command shows the ac currents and voltages (magnitude and phase angle) presented to the relay in primary values. In addition, the command shows power system frequency (FREQ) and the voltage input to the relay power supply terminals (VDC). Compare these quantities against other devices of known accuracy. The **METER** command is available at the serial ports and front-panel display. See *Section 10: Serial Port Communications and Commands* and *Section 11: Front-Panel Interface*.

EVENT Command. The relay generates a 15- or 30-cycle event report in response to faults or disturbances. Each report contains current and voltage information, relay element states, and input/output contact information. If you question the relay response or your test method, use the event report for more information. The **EVENT** command is available at the serial ports. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

SER Command. The relay provides a Sequential Events Recorder (SER) event report that time-tags changes in relay element and input/output contact states. The SER provides a convenient means to verify the pickup/dropout of any element in the relay. The **SER** command is available at the serial ports. See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

TARGET Command. Use the **TARGET** command to view the state of relay control inputs, relay outputs, and relay elements individually during a test. The **TARGET** command is available at the serial ports and the front panel. See *Section 10: Serial Port Communications and Commands* and *Section 11: Front-Panel Interface*.

PULSE Command. Use the **PULSE** command to test the contact output circuits. The **PULSE** command is available at the serial ports and the front panel. See *Section 10: Serial Port Communications and Commands*.

Low-Level Test Interface

The SEL-351S has a low-level test interface between the calibrated input module and the separately calibrated processing module. You may test the relay in either of two ways:

- By applying ac current signals to the relay inputs, or
- By applying low magnitude ac voltage signals to the low-level test interface. Access the test interface by removing the relay front panel.

Figure 2.32 shows the location of the processing module input connector (J10) for low-level test interface connections. The output connector (J1) of the input module is below connector J10.

Figure 13.1 shows the low-level test interface (J1 and J10) connector information. *Table 13.1* shows the output (J1) value of the input module (for a given input value into the relay rear panel). The processing module input (J10)

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⚠CAUTION
The relay contains devices sensitive to Electrostatic Discharge (ESD). When working on the relay with the front panel removed, work surfaces and personnel must be properly grounded or equipment damage may result.

⚠CAUTION
Never apply voltage signals greater than 9 V peak-peak to the low-level test interface (J10) or equipment damage may result.

has a maximum 9 V p-p voltage damage threshold. Remove the ribbon cable between the two modules to access the outputs (J1) of the input module and the inputs (J10) to the processing module (relay main board).

You can test the relay-processing module (via input J10) using signals from the SEL-RTS Low-Level Relay Test System. *Table 13.1* shows the resultant signal scale factor information for the calibrated input module. These scale factors are used in the SEL-5401 program, which is part of the SEL-RTS.

You can test the input module two different ways:

1. Measure the outputs from the input module with an accurate voltmeter (measure signal pin to GND pin), and compare the readings to accurate instruments in the relay input circuits, or
2. Replace the ribbon cable, press the front-panel {**METER**} pushbutton, and compare the relay readings to other accurate instruments in the relay input circuits.

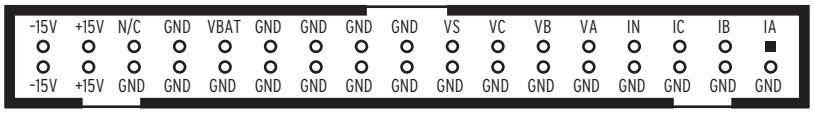


Figure 13.1 Low-Level Test Interface (J1 or J10) Connector

Table 13.1 Resultant Scale Factors for Input Module

Input Channels (Relay Rear Panel)	Input Channel Nominal Rating	Input Value	Corresponding J1 Output Value	Scale Factor (Input/Output) (A/V or V/V)
IA, IB, IC, IN	1 A	1 A	100 mV	10.00
IA, IB, IC, IN	5A	5 A	100 mV	50.00
IN	0.2 A	0.2 A	114.1 mV	1.753
IN	0.05 A	0.05 A	50 mV	1.00
VA, VB, VC, VS	150 V	67 V_{LN}	1313.7 mV	51.00
VA, VB, VC, VS	300 V	134 V_{LN}	1313.7 mV	102.00
Power (+, –)	48/125 Vdc or 125/250 Vdc	125 Vdc	1.25 Vdc	100.00

Scale factor calculation examples:

$$\frac{134\ \text{V}}{1.3137\ \text{V}} = 102.00\left(\frac{\text{V}}{\text{V}}\right) \qquad \textbf{Equation 13.1}$$

$$\frac{5\ \text{A}}{0.1\ \text{V}} = 50.00\left(\frac{\text{A}}{\text{V}}\right) \qquad \textbf{Equation 13.2}$$

Using the Low-Level Test Interface When Global Setting PTCONN = DELTA

When simulating a delta PT connection with the low-level test interface referenced in *Figure 13.1*, apply the following signals:

Apply low-level test signal V_{AB} to pin VA.

Apply low-level test signal $-V_{BC}$ (equivalent to V_{CB}) to pin VC.

Do not apply any signal to pin VB.

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Refer to *Delta-Connected Voltages (Global Setting PTCONN = DELTA) on page 2.19* for more information on the delta connection.

Test Methods

Test the pickup and dropout of relay elements using one of three methods: target command indication, output contact closure, or sequential events recorder (SER).

The examples below show the settings necessary to route the phase time-overcurrent element 51P1T to the output contacts and the SER. The 51P1T element, like many in the SEL-351S, is controlled by enable settings and/or torque control SELOGIC® control equations. To enable the 51P1T element, set the E51P enable setting and 51P1TC torque control settings to the following:

- E51P = 1 (via the **SET** command)
- 51P1TC = 1 (set directly to logical 1, via the **SET L** command)

Testing Via TARGET Commands

Display the state of relay elements, inputs, and outputs using the front-panel or serial port **TAR** commands. Use this method to verify the pickup settings of protection elements.

Testing With the Front-Panel TAR Command

Access the front-panel **TAR** command from the front-panel **{OTHER}** pushbutton menu.

Step 1. To display the state of the 51P1T element on the front-panel display, press the **{OTHER}** pushbutton
   a. Cursor to the `TAR` option
   b. Press **{SELECT}**.
   c. Press the up arrow pushbutton until `TAR 5` is displayed on the top row of the LCD.

The bottom row of the LCD displays all elements asserted in Relay Word Row 5. The relay maps the state of the elements in Relay Word Row 5 on the bottom row of LEDs. The 51P1T element state is reflected on the LED labeled **B**.

See *Table 9.6* for the correspondence between the Relay Word elements and the **TAR** command.

Testing With the Serial Port TAR Command

To view the 51P1T element status from the serial port, issue the **TAR 51P1T** command. The relay will display the state of all elements in the Relay Word row containing the 51P1T element.

Review **TAR** command descriptions in *Section 10: Serial Port Communications and Commands* and *Section 11: Front-Panel Interface* for further details on displaying element status via the **TAR** commands.

Testing Via Output Contacts

You can set the relay to operate an output contact for testing a single element. Use the **SET L** command (SELOGIC control equations) to set an output contact (e.g., **OUT101**–**OUT107**) to the element under test. The available elements are the Relay Word bits referenced in *Table 9.6*.

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Use this method especially for time testing time-overcurrent elements. For example, to test the phase time-overcurrent element 51P1T via output contact **OUT104**, make the following setting:

OUT104 = **51P1T**

Time-overcurrent curve and time-dial information can be found in *Section 9: Setting the Relay*.

Do not forget to reenter the correct relay settings when you are finished testing and ready to place the relay in service.

Testing Via Sequential Events Recorder

You can set the relay to generate an entry in the Sequential Events Recorder (SER) for testing relay elements. Use the **SET R** command to include the element(s) under test in any of the SER trigger lists (SER1–SER3). See *Section 12: Standard Event Reports, Sag/Swell/Interruption Report, and SER*.

To test the phase time-overcurrent element 51P1T with the SER, make the following setting:

SER1 = **51P1 51P1T**

Element 51P1 asserts when phase current is above the pickup of the phase time-overcurrent element. Element 51P1T asserts when the phase time-overcurrent element times out. The assertion and deassertion of these elements is time-stamped in the SER report. Use this method to verify timing associated with time-overcurrent elements, reclosing relay operation, etc.

Do not forget to reenter the correct relay settings when you are ready to place the relay in service.

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Relay Self-Tests

The relay runs a variety of self-tests. The relay takes the following corrective actions for out-of-tolerance conditions (see *Table 13.2*):

- Protection Disabled: The relay disables overcurrent elements and trip/close logic. All output contacts are de-energized. The **ENABLED** front-panel LED is extinguished.
- ALARM Output: The **ALARM** output contact signals an alarm condition by going to its de-energized state. If the **ALARM** output contact is a B contact (normally closed), it closes for an alarm condition or if the relay is de-energized. If the **ALARM** output contact is an A contact (normally open), it opens for an alarm condition or if the relay is de-energized. Alarm condition signaling can be a single five-second pulse (Pulsed) or permanent (Latched).
- The relay generates automatic STATUS reports at the serial port for warnings and failures.
- The relay displays failure messages on the relay LCD display for failures.

Use the serial port **STATUS** command or front-panel **{STATUS}** pushbutton to view relay self-test status.

Table 13.2 Relay Self-Tests (Sheet 1 of 2)

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
IA, **IB**, **IC**, **IN**, **VA**, **VB**, **VC**, **VS** Offset	Warning	30 mV	No	Pulsed	Measures the dc offset at each of the input channels every 10 seconds.
Master Offset	Warning	20 mV	No	Pulsed	Measures the dc offset at the A/D every 10 seconds.
	Failure	30 mV	Yes	Latched	
+5 V PS	Warning	+4.80 V +5.20 V	No	Pulsed	Measures the +5 V power supply every 10 seconds.
	Failure	+4.65 V +5.40 V	Yes	Latched	
±5 V REG	Warning	±4.75 V +5.20, –5.25 V	No	Pulsed	Measures the regulated 5 V power supply every 10 seconds.
	Failure	±4.50 V +5.40, –5.50 V	Yes	Latched	
±12 V PS	Warning	±11.50 V ±12.50 V	No	Pulsed	Measures the 12 V power supply every 10 seconds.
	Failure	±11.20 V ±14.00 V	Yes	Latched	
±15 V PS	Warning	±14.40 V ±15.60 V	No	Pulsed	Measures the 15 V power supply every 10 seconds.
	Failure	±14.00 V ±16.00 V	Yes	Latched	

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Table 13.2 Relay Self-Tests (Sheet 2 of 2)

Self-Test	Condition	Limits	Protection Disabled	ALARM Output	Description
TEMP	Warning	–40° C +85° C	No		Measures the temperature at the A/D voltage reference every 10 seconds.
	Failure	–50° C +100° C	Yes	Latched	
RAM	Failure		Yes	Latched	Performs a read/write test on system RAM every 60 seconds.
ROM	Failure	checksum	Yes	Latched	Performs a checksum test on the relay program memory every 10 seconds.
A/D	Failure		Yes	Latched	Validates proper number of conversions each 1/4 cycle.
CR_RAM	Failure	checksum	Yes	Latched	Performs a checksum test on the active copy of the relay settings every 10 seconds.
EEPROM	Failure	checksum	Yes	Latched	Performs a checksum test on the nonvolatile copy of the relay settings every 10 seconds.
The following self-tests are performed by dedicated circuitry in the microprocessor and the SEL-351S main board. Failures in these tests shut down the microprocessor and are not shown in the STATUS report.					
Microprocessor Crystal	Failure		Yes	Latched	The relay monitors the microprocessor crystal. If the crystal fails, the relay displays `CLOCK STOPPED` on the LCD display. The test runs continuously.
Microprocessor	Failure		Yes	Latched	The microprocessor examines each program instruction, memory access, and interrupt. The relay displays `VECTOR nn` on the LCD upon detection of an invalid instruction, memory access, or spurious interrupt. The test runs continuously.

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Relay Troubleshooting

Inspection Procedure

Complete the following procedure before disturbing the relay. After you finish the inspection, proceed to the *Troubleshooting Procedure*.

Step 1. Measure and record the power supply voltage at the power input terminals.

Step 2. Check to see that the power is on. Do not turn the relay off.

Step 3. Measure and record the voltage at all control inputs.

Step 4. Measure and record the state of all output relays.

Troubleshooting Procedure

All Front-Panel LEDs Dark

1. Input power not present or fuse is blown.
2. Self-test failure.

Cannot See Characters on Relay LCD Screen

1. Relay is de-energized. Check to see if the **ALARM** contact is closed.
2. LCD contrast is out of adjustment. Use the steps below to adjust the contrast.
   a. Press and hold down the **{OTHER}** front-panel pushbutton.
   b. Use the UP and DOWN arrow pushbuttons to adjust the contrast.

Relay Does Not Respond to Commands From Device Connected to Serial Port

1. Communications device not connected to relay.
2. Relay or communications device at incorrect baud rate or other communication parameter incompatibility, including cabling error.
3. Relay serial port has received an XOFF, halting communications. Type **<Ctrl + Q>** to send relay an XON and restart communications.

Relay Does Not Respond to Faults

1. Relay improperly set.
2. Improper test source settings.
3. CT or PT input wiring error.

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4. Analog input cable between transformer secondary and main board loose or defective.
5. Failed relay self-test.

Relay Meter Command Does Not Respond as Expected

1. Global settings PTCONN, VSCONN, NFREQ, or PHROT not set correctly.
2. Group Settings CTR, CTRN, PTR or PTRN not set correctly.
3. Relay analog inputs not connected correctly.

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Relay Calibration

The SEL-351S is factory-calibrated. If you suspect that the relay is out of calibration, please contact the factory.

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Factory Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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2350 NE Hopkins Court
Pullman, WA 99163-5603
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Internet: www.selinc.com

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Appendix A
Firmware and Manual Versions

Firmware

Determining the Firmware Version in Your Relay

To find the firmware revision number in your relay, view the status report using the serial port **STATUS** command or the front-panel **{STATUS}** pushbutton. The status report displays the Firmware Identification (FID) label:

FID=SEL-351S-x-Rxxx-V0-Z001001-Dxxxxxxxx

The firmware revision number is after the R and the release date is after the D. The single x after SEL-351S is the firmware version number and will be a 5, 6, or 7, depending on the firmware features ordered with the relay:

x = 5	Standard Features
x = 6	Standard Features plus MIRRORED BITS® and Load Profile
x = 7	Same as x = 6, plus Power Elements and Voltage Sag/Swell/Interrupt Elements

For example, the following is firmware version number 7, firmware revision number 102, release date September 10, 1999:

FID = SEL-351S-7-R102-V0-Z001001-D19990910

Table A.1 lists the firmware versions, a description of modifications, and the instruction manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.1 Firmware Revision History (Sheet 1 of 5)

Firmware Identification (FID) Number	Description of Changes	Manual Date Code
This firmware differs from the previous version as follows:		
SEL-351S-x-R402-V0-Z008006-D20080103	➤ Changed default length of compressed event reports to match LER setting. ➤ Corrected an event reporting problem that occurred in the presence of heavily distorted current waveforms. This problem led to errors in oscillography, event summary currents, and "pk" current indicators. (Note: This problem did not affect protection functions.) ➤ Changed operation of manual LCD contrast adjustment to store changes in nonvolatile memory.	20080103
This firmware differs from the previous version as follows:		
SEL-351S-x-R401-V0-Z008006-D20070725	➤ Corrected problem that caused intermittent 50G element operation. The problem only manifests on systems with load current very near nominal current and with high harmonic content. ➤ Improved timing accuracy on traditional recloser curves.	20070725

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Table A.1 Firmware Revision History (Sheet 2 of 5)

Firmware Identification (FID) Number	Description of Changes	Manual Date Code
This firmware differs from the previous version as follows:		
SEL-351S-x-R400-V0-Z008006-D20070117	➤ Added support for new SEL Fast Message Synchrophasor protocol, event reporting, and metering. ➤ Changed default event report and compressed event report command length to follow Global Setting LER. ➤ Lowered Port 1 maximum speed from 38.4 kbps to 19.2 kbps. ➤ Added minimum threshold for current and voltage metering (1% of I_{NOM} and 0.10 V secondary) below which magnitudes are set to zero.	20070117
This firmware differs from the previous version as follows:		
SEL-351S-x-R116-V0-Z007005-D20060727	➤ Corrected negative-sequence directional element operation for delta systems when Z1ANG is set low. ➤ Improved fault targeting for ungrounded systems. ➤ Added Z0MTA setting to allow use of Best Choice Ground Directional Element™ logic on earthed systems with loads connected phase-to-phase. ➤ Lowered single-phase power element minimum pickup to .33 VA. ➤ Fixed possible station dc battery monitor malfunction after a settings or group change.	20060727
This firmware applies to the manual date code listed		
SEL-351S-x-R114-V0-Z006005-D20041210	➤ Manual update only. See *Table A.2* for a summary of manual updates.	20050518
This firmware differs from the previous version as follows:		
SEL-351S-x-R114-V0-Z006005-D20041210	➤ Added E79 setting options for enhanced recloser supervision applications. ➤ Allow phase and negative-sequence time-overcurrent element pickups to be set more sensitively ➤ Allow three-phase power element pickups to be set more sensitively. ➤ Improved accuracy specification of voltage elements. ➤ Improved password security ➤ Removed * (indication of where maximum current is) from raw event report. ➤ Allow Z1ANG and Z0ANG settings to be set as low as 5 degrees. ➤ Power Factor values found in DNP and ASCII communication now match in resolution when polled simultaneously. ➤ Improved the timing of the setting group Relay Word Bit SG*n* to update after a settings group change instead of during. ➤ DNP event report now uses peak values instead of cosine-filtered values when an event is triggered by the Adaptive Overcurrent Element. ➤ Improved the voltage scaling in the loss-of-potential (LOP) logic. ➤ DNPE was improved to automatically refresh all stored values upon any DNPE settings change. ➤ Improved initialization of communication ports when changing protocols. ➤ Setting PSTDLY in DNP setting to 0 time delay was improved to end communications faster.	20041210

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Table A.1 Firmware Revision History (Sheet 3 of 5)

Firmware Identification (FID) Number	Description of Changes	Manual Date Code
This firmware differs from the previous version as follows:		
SEL-351S-x-R113-V0-Z005005-D20030908	➤ CT saturation protection was enhanced to improve security with low-set instantaneous values. ➤ Corrected rounding error in breaker wear monitor.	20030908
This firmware differs from the previous version as follows:		
SEL-351S-x-R112-V0-Z005005-D20030714	➤ Optimized calibration settings for Petersen Coil units to improve the factory calibration process.	20030714
This firmware differs from the previous version as follows:		
SEL-351S-x-R111-V0-Z005005-D20030212	➤ Corrected improper metering and protection on 0.05 A neutral CT for secondary currents in the range of 0.045–0.120A. This affects firmware versions R108–R110 with part numbers 0351Sxxxxxx(8 or 9)xxx.	20030212
This firmware differs from the previous version as follows:		
SEL-351S-x-R110-V0-Z005005-D20021106	➤ Added CT Saturation Protection. ➤ Limited TCLOSD setting step size to 0.25 cycle increments. ➤ Added Rollover feature for all Energy Values ($MWhA_{IN}$, $MWhA_{OUT}$, $MWhB_{IN}$, etc.). All Energy Values will rollover at 100000.	20021106
This firmware applies to the manual date code listed:		
SEL-351S-x-R110-V0-Z005005-D20020725	➤ Manual update only. See *Table A.2* for a summary of manual updates.	20021009
This firmware differs from the previous version as follows:		
SEL-351S-x-R109-V0-Z005005-D20020725	➤ Updated the calibration settings for manufacturing. (This is the first shipping released that includes all of the changes listed under R108 below, which was never shipped.)	20020725
This firmware differs from the previous version as follows:		
SEL-351S-x-R108-V0-Z005005-D20020711	➤ Added global setting PTCONN to allow the relay **VA**, **VB**, **VC**, and **N** input terminals to be connected to wye-connected PTs (as before), or open-delta connected PTs. ➤ Added global setting VSCONN to allow the relay VS-NS terminals to be connected to a synchronism check voltage source (as before), or a broken-delta zero-sequence voltage source. ➤ Added ground directional element options for low-impedance, Petersen coil, and ungrounded/high-impedance grounded systems (expanded setting options for setting ORDER [S, P, and U]). These new directional element options require the new option of a 0.2 A nominal neutral channel (**IN**) current input. ➤ Supervising LOP (loss-of-potential) logic is removed from directional element logic (with outputs F32x and R32x) and put into preceding internal enable logic (with outputs 32xE). ➤ Extended the lower end of the pickup setting range of the residual ground instantaneous/definite-time overcurrent elements 50G1–50G6/67G1T–67G6T (from 0.05 A to 0.01 A for 1 A nominal phase current inputs; from 0.25 A to 0.05 A for 5 A nominal phase current inputs). Also, an intentional 2-cycle built-in delay is added to the residual ground instantaneous/ definite-time overcurrent elements—this delay is active for the new extended lower range only. ➤ Extended the lower end of the pickup setting range of the residual ground time-overcurrent elements 51G1T and 51G2T (from 0.1 A to 0.02 A for 1 A nominal phase current inputs; from 0.5 A to 0.1 A for 5 A nominal phase current inputs).	20020711

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Table A.1 Firmware Revision History (Sheet 4 of 5)

Firmware Identification (FID) Number	Description of Changes	Manual Date Code
	➤ Added following setting for all settings groups: VNOM, including an OFF position to indicate when the relay **VA**, **VB**, **VC**, and **N** input terminals are not connected to valid three-phase voltage source. ➤ Modified the zero-sequence voltage-polarized ground directional elements to accept zero-sequence 3V0 from either a calculated value (as before) or from a measurement on the VS voltage channel (typically connected to a broken-delta zero-sequence voltage source). ➤ Modified the undervoltage block for the frequency elements (27B81) to check only **VA** (or VAB for PTCONN = DELTA) when group setting VNOM = OFF. ➤ Updated loss-of-potential logic to allow a latched-in LOP condition to stay asserted through a settings change or group change operation. ➤ Modified the logic for the phase and negative-sequence directional elements to cause them to be disabled when group setting VNOM = OFF. ➤ Added SEL Fast Sequential Events Recorder (SER) protocol. ➤ Added the following settings for all settings groups (for 0.2 A nominal neutral channel (**IN**) current input): 50NFP, 50NRP, a0N, 59RES, 32WFP, 32WRP, and 32WD. ➤ Added the following Relay Word Bits: V1GOOD, V0GAIN, INMET, ICMET, IBMET, IAMET, GNDSW, 50NF, 50 NR, 32NE, F32N, R32N, 32NF, 32NR, F32W, R32W, F32C, R32C, NSA, NSB, NSC, SSLOW, AND SFAST. ➤ Added variable scaling of analog quantities in event reports (i.e., variable number of digits behind the decimal point, depending on magnitude). Added additional event report fault types for Petersen coil and ungrounded/high-impedance grounded systems. ➤ Added capability to frequency track with positive-sequence voltage (V1), if **VA** too low (VA < 20 V). ➤ Revised demand, peak demand, and energy metering quantities data in display points, and added new control format to allow description and control string of time-overcurrent element to be set to one display point. ➤ Added Y1 and N1 settings options to global setting RSTLED (for defeating the 3-second delay of the **{LOCK}** operator control). ➤ Redesigned Maximum/Minimum Metering Logic. ➤ Updated **BRE W** command to allow for trip counters, accumulated interrupted current values, and percent breaker wear to be pre-loaded for each individual phase. ➤ Corrected the **TAR** command to default to row zero when the serial port time-out occurs. ➤ Reduced event report storage capacity to accommodate increased number of Relay Word bits ➤ Updated A5C0 relay definition block response, A5D1 Fast Meter data block, DNA command, and ID command responses. ➤ Corrected substation battery monitor implementation to allow both Relay Word bits DCLO and DCHI to assert when DCLOP is set higher than DCHIP. ➤ Corrected an error in compressed event reports in which large negative values caused a comma delimiter to be omitted. ➤ Corrected the front-panel breaker monitor reset function to return to the BRK_MON menu after selecting Yes or No.	

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Table A.1 Firmware Revision History (Sheet 5 of 5)

Firmware Identification (FID) Number	Description of Changes	Manual Date Code
This firmware differs from the previous version as follows:		
SEL-351S-x-R107-V0-Z003003-D20011129	➤ Internal changes to support new part numbers for User Interface options for models 0351Sx1x4 (Operator Controls, LCD and Targets—User Configurable Labels) and 0351Sx1x6 (Auxiliary Trip/ Close Pushbuttons—Configurable Labels).	20011129
This firmware differs from the previous version as follows:		
SEL-351S-x-R106-V0-Z003003-D20010110	➤ Redesigned the Voltage Sag, Swell, Interruption (VSSI) logic and VSSI recorder. ➤ Added Extended Metering **MET X** command, which includes phase-to-phase voltages. ➤ Increased event report storage capacity in 0351S7 models to match that of 0351S5 and 0351S6 models. ➤ Corrected front-panel target logic so that previously latched A, B, C target LEDs now clear when a trip is received and no fault current is present. ➤ Improved front-panel target logic so that correct phase targeting appears when tripping with no intentional delay, most noticeable during testing. ➤ Corrected substation battery monitor DCLO to prevent it from asserting when the relay is powered by AC. ➤ Improved fault locator event type determination during short duration faults, most likely seen during testing. ➤ Added setting choice to support SEL-DTA2 Display/Transducer Adapter in serial port AUTO settings. ➤ Lowered the minimum allowable setting for 27B81P (undervoltage block for frequency elements) to 25.00 from 40.00 V secondary. ➤ Added AC mode for optoisolated input debounce timers in global settings IN101D–IN106D, IN201D–IN208D. This allows AC control signals to be sensed on selected inputs. ➤ Added metering quantities and breaker wear monitor data to display points.	20010112
This firmware differs from the previous version as follows:		
SEL-351S-x-R105-V0-Z002002-D20001018	➤ No noticeable effect, internal procedures only.	20001031
This firmware differs from the previous version as follows:		
SEL-351S-x-R104-V0-Z002002-D20000802	➤ Made internal changes to support Flash memory revision and battery-backed clock hardware change. ➤ Improved relay firmware initialization after upgrade. ➤ Added recloser curves. ➤ Added new feature to Rotating Display Points. ➤ Target LEDs can no longer be reset if a TRIP condition is present. ➤ Changed target information to binary format in compressed ASCII commands CHI and CEV. ➤ Added Extended Mode (DNPE) settings to models with DNP. ➤ Added support for ACSELERATOR® SEL-5030 software.	20000803
This firmware differs from the previous version as follows:		
SEL-351S-x-R103-V0-Z001001-D19991014	➤ Enhanced communications with SEL-2030 Communications Processor.	991015
SEL-351S-x-R102-V0-Z001001-D19990910	➤ Original firmware release.	990913

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Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table A.2 lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.2 Instruction Manual Revision History (Sheet 1 of 11)

Revision Date	Summary of Revisions
This manual differs from the previous version as follows:	
20080103	**Section 8** ➤ Added Small Signal Cutoff for Metering subsection. **Section 12** ➤ Added paragraph in Fault Location subsection that explains how the fault locator algorithm uses overcurrent elements as fault detectors, and how to avoid fault location errors in applications where a load detector element is needed. **Appendix A** ➤ Updated for firmware version R402. **Appendix G** ➤ Corrected Table G.3: Processing Order of Relay Elements and Logic (Top to Bottom) to include Relay Word bits PMDOK, TIRIG, and TSOK (added in firmware version R400).
This manual differs from the previous version as follows:	
20070725	**Appendix A** ➤ Updated for firmware version R401.
This manual differs from the previous version as follows:	
20070117	**Section 1** ➤ Updated serial communications baud rate range for Port 1. ➤ Added time-code input accuracy for synchrophasor measurement. ➤ Added synchrophasor accuracy. **Section 2** ➤ Modified Figure 2.34 to correct jumpers. ➤ Added note recommending the disabling of arc suppression for high-impedance loads. **Section 4** ➤ Corrected Reverse Threshold note in Figure 4.9, Figure 4.10, Figure 4.12, and Figure 4.20. **Section 7** ➤ Corrected Figure 7.15 and Figure 7.18. ➤ Clarified OPSCTR in Table 7.9. **Section 8** ➤ Added Synchrophasor Metering section. **Section 9** ➤ Added Global synchrophasor settings to Table 9.1. ➤ Added new Relay Word bits PMDOK, TSOK, and TIRIG to Table 9.6. ➤ Added new Relay Word bit definitions for PMDOK, TSOK, and TIRIG to Table 9.7. **Setting Sheets** ➤ Added Synchronized Phasor settings to Global settings. ➤ Updated serial communications baud rate range for Port 1.

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Table A.2 Instruction Manual Revision History (Sheet 2 of 11)

Revision Date	Summary of Revisions
	Section 10 ➤ Added new Relay Word bit definitions TSOK and TIRIG to IRIG-B section. ➤ Added new SEL Fast Message Synchrophasor protocol to communications protocol list. ➤ Added **MET PM** command explanation. ➤ Added time parameter to **TRI** command. **Command Summary** ➤ Updated to include all commands. **Section 11** ➤ Corrected *Figure 11.4*. **Section 12** ➤ Added P parameter to **EVE** command. ➤ Added *Synchrophasor-Level Accuracy* in *Event Reports* section. ➤ Added P parameter note and DT column information to *Table 12.2*. **Appendix A** ➤ Updated for firmware version R400. **Appendix E** ➤ Added P parameter to **CEV** command. **Appendix H** ➤ Updated serial communications baud rate for Port 1. **Appendix I** ➤ Updated serial communications baud rate for Port 1. **Appendix L** ➤ Added a new appendix *SEL Synchrophasors* appendix.
This manual differs from the previous version as follows:	
20060727	**Section 1** ➤ Updated Power Element Accuracy specifications. **Section 3** ➤ Updated *Power Elements (Available in Firmware Version 7)* subsection. **Section 4** ➤ Updated *Figure 4.10*. ➤ Updated *Figure 4.12*. ➤ Updated *Directional Control Settings* subsection. **Section 9** ➤ Updated *Line Settings* subsection and added *Figure 9.22*. **Setting Sheets** ➤ Updated range for Power Elements ➤ Added setting Z0MTA. **Appendix A** ➤ Updated for firmware version R116.
This manual differs from the previous version as follows:	
20050518	**Entire Manual** ➤ Updated format of instruction manual. **Section 1** ➤ Updated *Steady-State Pickup Accuracy* specifications of *Under- and Overvoltage Elements*. **Section 4** ➤ Added information about loss-of-potential logic while 3PO is asserted.

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Table A.2 Instruction Manual Revision History (Sheet 3 of 11)

Revision Date	Summary of Revisions
This manual differs from the previous version as follows:	
20041210	**Section 1** ➤ Updated subsection: *Time-Overcurrent Elements*. ➤ Updated subsection: *Under- and Overvoltage Elements*. ➤ Updated subsection: *Power Element Accuracy*. **Section 3** ➤ Updated subsection: *Time-Overcurrent Elements*. ➤ Updated subsection: *Voltage Elements*. ➤ Updated subsection: *Voltages VP and VS are "Static" or Setting TCLOSD = 0.00*. **Section 6** ➤ Modification of E79 setting, which affects how the relay reacts to Reclose Supervision Failure. **Settings Sheet** ➤ Modification to ranges of Z1ANG, Z0ANG, E79, 51P1P, 51P2P, 51QP, 3PWR1P, 3PWR2P, 3PWR3P, and 3PWR4P settings. **Section 10** ➤ Updated subsection: *PAS Command (Change Passwords)*. **Section 12** ➤ Updated subsection: *Example Standard 15-Cycle Event Report*. **Appendix A** ➤ Updated for firmware version R114. **Command Summary** ➤ Updated **PAS** commands.
This manual differs from the previous version as follows:	
20030908	**Section 1** ➤ Updated text in CT Saturation Protection. ➤ Added EA Certification statement to *Specifications*. **Section 12** ➤ Updated text in *Standard Event Report Summary*. **Appendix A** ➤ Updated for firmware version R113.
This manual differs from the previous version as follows:	
20030714	➤ Updated the manual date code to match new firmware release. **Appendix A** ➤ Updated for firmware version R112.
This manual differs from the previous version as follows:	
20030212	➤ Updated the manual date code to match new firmware release. **Appendix A** ➤ Updated for firmware version R111.
This manual differs from the previous version as follows:	
20021106	**Section 1** ➤ Updated subsection: *Auxiliary Trip and Close Pushbuttons*. ➤ Added *CT Saturation Protection* information. ➤ Modified *Output Contacts* specification. ➤ Corrected typographical errors.

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Table A.2 Instruction Manual Revision History (Sheet 4 of 11)

Revision Date	Summary of Revisions
	Section 2 ➤ Added subsection: *User-Configurable Label Option for the Front Panel.* ➤ Added *Figures 2.7–2.11*. ➤ Added *Table 2.1*. ➤ Updated *Figure 2.31*. ➤ Updated *Table 2.9*. **Section 3** ➤ Updated curve timing in subsection*: Neutral Ground Time-Overcurrent Elements*. **Section 4** ➤ Added a note describing Z2F and Z2R calculation upper limit. ➤ Added a note describing Z0F and Z0R calculation upper limit. **Section 5** ➤ Updated *Table 5.1*. **Section 8** ➤ Added a description of accumulated energy metering value function. ➤ Updated *Table 8.2.* ➤ Updated subsection: *View or Reset Demand Metering Information*. ➤ Updated subsection: *Load Profile Report (Available in Firmware Versions 6 and 7).* **Section 9** ➤ Added CT sizing information and examples. ➤ Corrected the cycle steps value for breaker close time for angle compensation in the synchronism check elements. ➤ Updated *Table 9.5* ➤ Updated subsection: *Line Settings*. **Section 10** ➤ Added a description of accumulated energy metering values function. ➤ Updated subsection: *Serial Port Access Levels*. **Section 11** ➤ Modified *Figure 11.4*. ➤ Updated subsection: *Reclosing Relay Shot Counter Screen*. ➤ Updated subsection: *Rotating Default Display.* ➤ Updated subsection: *Operator Controls*. **Section 12** ➤ Modified *Standard Event Report Summary* discussion. ➤ Added “pk” to Figure 12.1. ➤ Added “pk” to the event summary in the *Example Standard 15-Cycle Event Report.* ➤ Updated *Table 12.3.* **Appendix A** ➤ Updated for firmware version R110. ➤ Updated *Table A.1.* ➤ Updated *Table A.2*. **Appendix D** ➤ Corrected *Length* value for A5D1 Fast Meter Data Block. ➤ Added ESV information under **SET** command. ➤ Moved **SET** command information before **SET L** command information. ➤ Corrected *Fast Operate* reset description string for A5CD Fast Operate Reset Definition Block.
This manual differs from the previous version as follows:	
20020725	**Appendix A** ➤ Added firmware version information.

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Table A.2 Instruction Manual Revision History (Sheet 5 of 11)

Revision Date	Summary of Revisions
This manual differs from the previous version as follows:	
20020711	➤ The changes in this revision relate to the new global setting PTCONN that allows the relay to be configured for either wye- or delta-connected PTs; new global setting VSCONN that allows the relay to be configured for a synchronism check or broken delta voltage input to the VS-NS terminals; new group setting VNOM, and the addition of the 0.2 A nominal neutral channel (**IN**) current input option. This option provides ground directional control for low-impedance grounded, Petersen Coil grounded, and ungrounded/high-impedance grounded systems (see *Table 4.1*). **Section 1** ➤ Added subsection: *Potential Transformer Connections*. ➤ Added voltage input notes to *Figure 1.2*. ➤ Added information on the following to the *General Specifications* subsection: 0.2 A nominal neutral channel (**IN**) current input option, frequency tracking with positive-sequence voltage V_1 (when V_A not available), and extended lower end of pickup setting range for residual ground overcurrent elements. ➤ Added *AC Input Voltage and Metering* specifications for open-delta connected PTs. **Section 2** ➤ Updated *Figure 2.1* to include projection panel-mount option. ➤ Added subsection*: Voltage Input Rating*. ➤ Added subsection: *Wye-Connected Voltages (Global Setting PTCONN = WYE).* ➤ Added subsection: *Delta-Connected Voltages (Global setting PTCONN = DELTA).* ➤ Added subsection: *Synchronism Check VS Connection (Global setting VSCONN = VS).* ➤ Added subsection: *Broken-Delta VS Connection (Global setting VSCONN = 3V0).* ➤ Added subsection: *Polarity Check for VSCONN = 3V0.* ➤ Added *Figure 2.8–Figure 2.11*. ➤ Added *Figure 2.20–Figure 2.25*. **Section 3** ➤ Added additional pickup setting ranges for neutral ground overcurrent elements operating from the 0.2 A nominal neutral channel (**IN**) current input. ➤ Added lower pickup setting ranges for residual ground overcurrent elements. ➤ Added *Table 3.9, 3.10.* ➤ Added *Figure 3.23* and *Figure 3.24.* ➤ Updated subsection: *Voltage Input VS Connected Phase-to-Phase or Beyond Delta-Wye Transformer.* ➤ Updated *Table 3.7* and *Table 3.11*. ➤ Added Delta-connected voltages to subsection: *Setting SYNCP.* ➤ Added Delta-connected voltages to subsection: *Setting Synchronism Check Elements Voltage Inputs*. ➤ Added Relay Word bits SFAST and SSLOW to *Figure 3.26* for indication of relative speed of systems (fast or slow slip) on either side of an open breaker. ➤ Updated *Figure 3.27.* ➤ Updated subsection: *System Frequencies Determined from Voltages VA (or VAB for Delta) and VS*. ➤ Updated *Figure 3.29.* ➤ Added *Figure 3.30*. ➤ Updated *Table 3.12* and added frequency element time delay setting recommendation. ➤ Updated subsection: *Frequency Element Voltage Control*. ➤ Updated *Figure 3.32–Figure 3.34*, and accompanying text. ➤ Updated *Table 3.13*. ➤ Updated subsection: *Positive-Sequence Reference Voltage, Vbase*. ➤ Updated subsection: *Vbase Initialization*. ➤ Updated subsection: *Vbase Tracking Range.* ➤ Added *Table 3.14*. ➤ Added subsection: *Power Element Time Delay Setting Considerations*. ➤ Added subsection: *Using Power Elements in the Relay Trip Equation*. ➤ Added subsection: *Single-Phase Power Element Calculations.* ➤ Added subsection: *Three-Phase Power Element Calculations*.

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Table A.2 Instruction Manual Revision History (Sheet 6 of 11)

Revision Date	Summary of Revisions
	Section 4 ➤ Added VNOM setting (and resultant V1GOOD Relay Word bit output) to *Figure 4.1* and explained certain thresholds in the loss-of-potential logic, relative to setting VNOM. ➤ Updated subsection: *Loss-of-Potential Logic*. ➤ Extensive changes in the balance of this section, dealing with the addition of ground directional elements for low-impedance grounded, Petersen Coil grounded, and ungrounded/high-impedance grounded systems. *Figures 4.4 and 4.5* and *Tables 4.1, 4.2, and 4.3* provide the general overview and references for all these changes. ➤ Added subsection: *Switch between IN and IG for Low-Impedance Grounded and Ungrounded/High-Impedance Grounded Systems.* ➤ Added subsection: *Zero-Sequence Voltage Sources*. ➤ Removed *Figure 4.7.* ➤ Added *Figures 4.5, 4.8, 4.12, 4.13, 4.14, 4.16,* and *4.18.* ➤ Supervising LOP (loss-of-potential) logic is removed from directional element *Figures 4.9, 4.10, 4.11*, and *4.20* and put into preceding internal enable logic *Figures 4.6, 4.7, and 4.8.* ➤ Updated *Figure 4.23 and Figure 4.24* (added Setting VNOM = OFF input). ➤ Updated *Figures 4.4, 4.6, 4.7, 4.15*, and *4.17*. ➤ Added *Figures 4.25–4.28*. ➤ Added subsection: *59RES—Wattmetric 3V0 Overvoltage Pickup (Petersen Coil Grounded System).* ➤ Added subsection: *32WFP and 32WRP—Wattmetric Forward and Reverse Pickups (Petersen Coil Grounded System).* ➤ Added subsection: *Settings Considerations for Petersen Coil Grounded Systems.* ➤ Added *Table 4.5*. **Section 5** ➤ Added information on fault-type targeting (A, B, C) for Petersen Coil grounded, and ungrounded/high-impedance grounded systems. **Section 6** ➤ Added an additional condition for the reclosing relay going to the Lockout State (new reclose initiation occurs during open interval timing; this feature had always existed, just not documented). **Section 7** ➤ Renamed subsection: *Displaying Values (other than user-entered text) on the Rotating Default Display.* ➤ Added *Table 7.8–Table 7.11*. ➤ Added subsection: *Values Displayed for Incorrect Settings*. ➤ Added subsection: *Extra Details for Displaying Metering Values on the Rotating Default Display.* ➤ Added subsection: *Extra Details for Breaker Wear Monitor Quantities on the Rotating Default Display.* ➤ Added subsection: *Extra Details for Displaying Time-Overcurrent Elements on the Rotating Default Display.* **Section 8** ➤ Updated subsections: *Demand Metering, Energy Metering, and Maximum/ Minimum Metering*.

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Table A.2 Instruction Manual Revision History (Sheet 7 of 11)

Revision Date	Summary of Revisions
	Section 9 ➤ Added subsection: *In Some Applications, Make Global Settings (SET G) First*. ➤ Added the following Relay Word bits to Table 9.4 and Table 9.5: SSLOW, SFAST, V1GOOD, V0GAIN, INMET, ICMET, IBMET, IAMET, GNDSW, 50NF, 50NR, 32NE, F32N, R32N, 32NF, 32NR, F32W, R32W, F32C, R32C, NSA, NSB, and NSC. ➤ Added subsection: *Settings for Voltage Input Configuration*. ➤ Added *Table 9.6* through *Table 9.8*. ➤ Added *Figure 9.21*. ➤ Updated subsection: *Potential Transformer Ratios and PT Nominal Secondary Voltage Settings*. ➤ Added two Settings Sheets and updated Settings Sheets 1-9, 12-14, 20-24. ➤ Added the following settings for all settings groups: VNOM, Z0SMAG, and Z0SANG. ➤ Added the following directional settings for all settings groups [for 0.2 A nominal neutral channel (IN) current input]: 50NFP, 50NRP, a0N, 59RES, 32WFP, 32WRP, and 32WD ➤ Added S, P, and U (for low-impedance grounded, Petersen Coil grounded, and ungrounded/high-impedance grounded systems, respectively) to setting range for setting ORDER. ➤ Added Global Settings PTCONN and VSCONN. **Section 10** ➤ Added SEL Fast Sequential Events Recorder (SER) Protocol. ➤ Added event-type options A, B, and C (for Petersen Coil grounded or ungrounded/high-impedance grounded systems), under **HIS** command. ➤ Added delta voltage information to subsection *MET Command (Metering Data)*. ➤ Updated the SHO G screen display in subsection *SHO Command (Show/View Settings)* to include the new settings PTCONN and VSCONN. ➤ Updated **TAR** commands in subsection *TAR Command (Display Relay Element Status)* to include TAR ROW and TAR LIST and an example. ➤ Updated **BRE W** command to allow trip counters and accumulated interrupted current values to be preloaded for each individual phase. ➤ Updated VER example printout in subsection *VER Command*. **Section 11** ➤ Added note to subsection: *LOCK Operator Control Pushbutton Output*. **Section 12** ➤ Updated event report capacity in *Introduction.* ➤ Added event-type options A, B, and C (for Petersen Coil grounded or ungrounded/high-impedance grounded systems) to *Table 12.1*. ➤ Updated subsection: *Filtered and Unfiltered Event Reports*. ➤ Added subsection: *Unfiltered Event Reports With PTCONN = DELTA*. ➤ Updated *Table 12.2*. ➤ Added variable scaling for analog values in event reports. ➤ Updated *Table 12.3*. ➤ Added *Figure 12.3.* ➤ Updated subsection: *Sag/Swell/Interruption Report (Available in Firmware Version 7).* ➤ Updated *Table 12.4*. ➤ Added *Figure 12.8.* **Section 13** ➤ Revised low-level test interface subsection. ➤ Added 0.2 A nominal neutral channel (IN) current input information for low-level test interface. ➤ Added subsection: *Using the Low-Level Test Interface when Global Setting PTCONN=DELTA*. ➤ Added subsection: *Relay Meter Command Does Not Respond as Expected*. **Appendix A** ➤ Added firmware details for R108. **Appendix B** ➤ Updated firmware upgrade instructions.

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Table A.2 Instruction Manual Revision History (Sheet 8 of 11)

Revision Date	Summary of Revisions
	Appendix D ➤ Updated A5C0 Relay Definition Block. ➤ Updated A5C1 Fast Meter Configuration Block. ➤ Updated A5D1 Fast Meter Data Block. ➤ Updated A5D2/A5D3 Demand/Peak Demand Fast Meter Message. ➤ Updated ID Message. ➤ Updated DNA Message. **Appendix E** ➤ Updated **CAS** command response ➤ Updated **CEV** command response. **Appendix G** ➤ Updated *Table G.3* to include the addition of new Relay Word bits to the SEL-351S. **Appendix H** ➤ Revised *Table H.3* to reflect addition of delta PT configuration features. **Appendix J** ➤ New *Appendix J: SEL-351S Fast SER Protocol*. ➤ Old Appendix J becomes *Appendix K*.
This manual differs from the previous version as follows:	
20011129	**Section 1** ➤ Updated *Terminal Connections* and *Auxiliary Trip/Close Pushbuttons* in *General Specifications*. **Section 2** ➤ Updated jumper information in *Circuit Board Connections*. **Appendix A** ➤ Updated firmware version information.
This manual differs from the previous version as follows:	
20010905	➤ Replaced the Standard Product Warranty page with the warranty statement on the cover page. **Section 1** ➤ Added 220 V control input voltage option to *General Specifications*.
This manual differs from the previous version as follows:	
20010112	**Section 1** ➤ Updated *Power Supply* information to include medium range *Power Supply* Specification. ➤ Added optoisolated input ratings for ac control signals to *General Specifications.* **Section 2** ➤ Updated *Optoisolated Inputs* subsection to include ac input selection. ➤ Added caution note to the *Clock Battery* subsection. ➤ Added cable for SEL-DTA2 to *Table 2.1*. **Section 3** ➤ Expanded setting range for 27B81P in *Table 3.11*. ➤ Updated subsection *Voltage Sag, Swell, and Interruption Elements (Available in Firmware Version 7).* **Section 5** ➤ Added SELOGIC *Control Equation Setting FAULT* subsection. **Section 7** ➤ Added ac setting description to *Input Debounce Timers* subsection. ➤ Added subsections *Displaying Metering Quantities on the Rotating Default Display, Displaying Metering Values Example, Displaying Breaker Monitor Output Information on the Rotating Default Display, and Displaying Breaker Monitor Outputs Example*.

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Table A.2 Instruction Manual Revision History (Sheet 9 of 11)

Revision Date	Summary of Revisions
	Section 9 ➤ Expanded setting range for 27B81P in Settings Sheet 8. ➤ Updated setting ranges for VINT, VSAG, and VSWELL on Settings Sheet 12. ➤ Added ac setting choice to optoisolated input timers on Setting Sheets 19 and 20. ➤ Added AUTO = DTA setting choice to the Port Settings Sheet. **Section 10** ➤ Added DTA2 compatibility information. ➤ Added MIRRORED BITS *Communications* subsection. ➤ Added notes about powering down the relay after setting the date and time. ➤ Changed the **HIS** command information. ➤ Added **MET X** command description. ➤ Updated password information. ➤ Added warning note to the *PAS Command (View/Change Passwords)* subsection. ➤ Updated Command Summary to include **MET X**, **SSI R**, and **SSI T** commands. **Section 12** ➤ Updated event report capacity, and removed *Table 12.1*. ➤ Updated subsection *Sag/Swell/Interruption (SSI) Report (Available in Firmware Version 7)*. **Appendix A** ➤ Updated firmware version information.
This manual differs from the previous version as follows:	
20001031	**Section 7** ➤ Updated subsection *Note: Make Latch Control Switch Settings With Care.* ➤ Updated subsection *Note: Make Active Setting Group Switching Settings With Care*. **Section 9** ➤ Added note at end of *Table 9.5* for Relay Word bit row 51. **Section 10** ➤ Updated **STA** command display. **Section 11** ➤ Corrected figure cross reference on page 11-33. **Section 12** ➤ Updated subsection *Make SER Settings With Care.* **Appendix A** ➤ Updated firmware version information. **Appendix B** ➤ Clarified firmware upgrade instructions.
This manual differs from the previous version as follows:	
20000803	➤ Reissued the entire manual—Removed -5-6-7 from the manual title. Title now reads *SEL-351S Instruction Manual*. **Sections 1, 2, 5, 6, 9, 11, 12** ➤ Added detail on new model 0351Sxxx5 with auxiliary trip/close pushbuttons. **Section 1** ➤ Added recloser curve time dial range information to time-overcurrent elements. **Section 2** ➤ Added new *Figures 2.5* and *2.6*. ➤ Added new *Figure 2.16*. ➤ Added new *Figure 2.20*. ➤ Added Note to *Table 2.6* (Fast Operate). ➤ Added *Tables 2.8 and 2.9*.

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Table A.2 Instruction Manual Revision History (Sheet 10 of 11)

Revision Date	Summary of Revisions
	Section 3 ➤ Corrected pickup setting ranges for Channel IN elements 50N1P–50N6P, 51N1P, 51N2P. ➤ Corrected settings range for 59Q in *Table 3.6*. ➤ Corrected accuracy for angle pickup of the synchronism check elements. ➤ Clarified the operation of the synchronism check elements for breaker close time setting TCLOSD = 0.00 in the *Synchronism Check Elements* subsection (see *Figure 3.25*). **Section 5** ➤ Corrected *Figure 5.6*. ➤ Added explanation to the *Target Reset/Lamp Test Front-Panel Pushbutton* subsection to indicate that the targets cannot be reset when a TRIP condition is still present. **Section 7** ➤ Added subsection *Details on the Remote Control Switch MOMENTARY Position*. ➤ Clarified the operation of the latch control switches when the SEL-351S loses power (see *Latch Control Switches* subsection). ➤ Corrected subsection *Relay Disabled Momentarily During Active Setting Group Change*. ➤ Corrected the number of local, latch, and remote bits to 16. ➤ Added subsections *Displaying Time-Overcurrent Elements on the Rotating Default Display* and *Displaying Time-Overcurrent Elements Example*. **Section 8** ➤ Added qualifying statement about changing the LDAR setting. **Section 9** ➤ Added recloser curves as a time-overcurrent elements settings choice (see *Table 9.3* and *Figures 9.11–9.20*). Updated *Settings Sheets* with the recloser curves settings choice. ➤ Corrected Relay Word Bits 51N1 and 51P2R in *Table 9.4*. ➤ Corrected error in Relay Word bit description for 51G2 (*Table 9.5*). ➤ Added subsections *Neutral Ground Overcurrent Settings* and *Demand Metering Settings*. ➤ Corrected pickup settings ranges for Channel IN elements (50N1P-50N6P, 51N1P, 51N2P, and NDEMP). ➤ Added Power Elements Time Delay Setting increment information. ➤ Changed Front-Panel Display time-out selection. ➤ Added description of MBT setting choice for port settings. **Section 10** ➤ Demand Meter screen capture corrected. ➤ Added clarification to **SHO** command examples. ➤ Corrected **TAR *n k*** command information. ➤ Added note to **TAR R** command description. ➤ Added details to **COP *m n*** command description. ➤ Revised the SEL-351S Command Summary. **Section 12** ➤ Added *Table 12.1*. ➤ Added a cautionary note on SER settings. **Section 13** ➤ Changed front-panel LCD contrast adjustment instructions in subsection *Cannot See Characters on Relay LCD Screen*. **Appendix A** ➤ Updated firmware version information. **Appendix B** ➤ Added information to Step 11 of upgrade procedure.

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Table A.2 Instruction Manual Revision History (Sheet 11 of 11)

Revision Date	Summary of Revisions
	Appendix D ➤ Correction to A5CO Relay Definition Block and description. ➤ Correction to A5EO Fast Operate Remote Bit Control. ➤ Updated **ID** Command information. ➤ Corrected **DNA** Command Relay Word. Appendix E ➤ Corrected compressed ASCII data format line information. Appendix G ➤ Revised *Figures G.1 and G.2*. ➤ Revised SELOGIC® Control Equation settings limitations (see *Table G.2*). ➤ Corrected index error in Relay Summary Event Data paragraph. Appendix H ➤ Corrected spelling of DECPLA, DECPLV, and DECPLM settings for DNP. ➤ Added Extended Mode DNP details and settings. ➤ Corrected index error in Relay Summary Event Data paragraph. ➤ Added Settings Sheet for Extended Mode DNP. Appendix I ➤ Added settings sheet for MIRRORED BITS protocol. Appendix J ➤ Added new *Appendix J:* ACSELERATOR® *SEL-5030 Software.*
This manual differs from the previous version as follows:	
991123	Section 9 ➤ Corrected typos in Row column in Relay Word bits table on page 9-8. Appendix H ➤ Corrected documentation errors in DNP 3.00 Device Profile, page H-5.
This manual differs from the previous version as follows:	
991015	Section 9 ➤ Added SELOGIC Control Equation settings for the Target and Operator Control LEDs (settings LED1–LED26) on Page 17 of 27 of the Settings Sheets. These settings were mistakenly omitted from the Settings Sheets. Appendix A ➤ Firmware revision number R103 released.
990913	➤ Original manual release.

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Appendix B

SEL-300 Series Relays Firmware Upgrade Instructions

Overview

From time to time, SEL issues firmware upgrades for this relay. The instructions which follow explain how you can install new firmware in your SEL-300 series relay. In addition, SEL issues firmware upgrades for the optional Ethernet ports (*Ethernet Port Firmware Upgrade Instructions on page B.18*).

Relay Firmware Upgrade Instructions

Introduction for Relay Firmware Upgrades

These firmware upgrade instructions apply to all SEL-300 series relays except the SEL-321 series relays (which use EPROM instead of Flash).

SEL occasionally offers firmware upgrades to improve the performance of your relay. Changing physical components is unnecessary because the relay stores firmware in Flash memory.

A firmware loader program called SELBOOT resides in the relay. To upgrade firmware, use the SELBOOT program to download an SEL-supplied file from a personal computer to the relay via any communications port. This procedure is described in the following steps.

NOTE: SEL strongly recommends that you upgrade firmware at the location of the relay and with a direct connection from the personal computer to one of the relay serial ports. Do not load firmware from a remote location; problems can arise that you will not be able to address from a distance. When upgrading at the substation, do not attempt to load the firmware into the relay through an SEL communications processor.

Perform the firmware upgrade process in the following sequence:

A. Prepare the Relay

B. Establish a Terminal Connection

C. Save Settings and Other Data

D. Start SELBOOT

E. Download Existing Firmware

F. Upload New Firmware

G. Check Relay Self-Tests

H. Verify Settings, Calibration, Status, Breaker Wear, and Metering

I. Return the Relay to Service

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Required Equipment

Gather the following equipment before starting this firmware upgrade:

- Personal computer
- Terminal emulation software that supports 1K Xmodem or Xmodem (these instructions use HyperTerminal® from a Microsoft® Windows® operating system)
- Serial communications cable (SEL Cable C234A or equivalent)
- Disk containing the firmware upgrade (.s19 or .exe) file
- Firmware Upgrade Instructions (these instructions)

Optional Equipment

These items help you manage relay settings and understand firmware upgrade procedures:

- SEL-5010 Relay Assistant software or ACSELERATOR® QuickSet™ SEL-5030 software

  The SEL-5010 Relay Assistant software has a feature that guides you through the conversion process. This upgrade guide will assist you with steps C, D, E, F, and G of these upgrade instructions. If you do not have the latest SEL-5010 software, please contact your customer service representative or the factory for details on getting the SEL-5010 Relay Assistant software.
- Your relay instruction manual

Upgrade Procedure

A. Prepare the Relay

Step 1. If the relay is in use, follow your company practices for removing a relay from service.

Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

Step 3. From the relay front panel, press the **{SET}** pushbutton.

Step 4. Use the arrow pushbuttons to navigate to PORT.

Step 5. Press the **{SELECT}** pushbutton.

Step 6. Use the arrow pushbuttons to navigate to the relay serial port you plan to use (usually the front port).

Step 7. Press the **{SELECT}** pushbutton.

Step 8. With SHOW selected, press the **{SELECT}** pushbutton.

Step 9. Press the **{Down Arrow}** pushbutton to scroll through the port settings; write down the value for each setting.

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Step 10. At the `EXIT SETTINGS?` prompt, select `Yes` and press the **{SELECT}** pushbutton.

Step 11. Connect an SEL Cable C234A (or equivalent) serial communications cable to the relay serial port selected in *Step 6* above.

B. Establish a Terminal Connection

To establish communication between the relay and a personal computer, you must be able to modify the computer serial communications parameters (i.e., data transmission rate, data bits, parity) and set the file transfer protocol to 1K Xmodem or Xmodem protocol.

Step 1. Connect a serial communications cable to the computer serial port:

a. Check the computer for a label identifying the serial communications ports.

b. Choose a port and connect an SEL Cable C234A (or equivalent) serial communications cable to the personal computer serial port.

If there is no identification label, connect the cable to any computer serial port. Note that you might later change this computer serial port to a different port in order to establish communication between the relay and the computer.

Step 2. Disconnect any other serial port connection(s).

Step 3. From the computer, open **HyperTerminal**.

On a personal computer running Windows, you would typically click the **Start > Programs > Accessories**.

Step 4. Enter a name, select any icon, and click **OK** (*Figure B.1*).

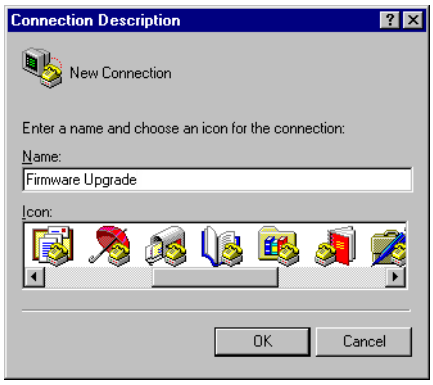


Figure B.1 Establishing a Connection

Step 5. Select the computer serial port you are using to communicate with the relay (*Figure B.2*) and click **OK**. This port matches the port connection that you made in *Step 1 on page B.3*.

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Figure B.2 Determining the Computer Serial Port

Step 6. Establish serial port communications parameters.

The settings for the computer (*Figure B.3*) must match the relay settings you recorded earlier.

a. Enter the serial port communications parameters (*Figure B.3*) that correspond to the relay settings you recorded in *Step 9 on page B.2*.

If the computer settings do not match the relay settings, change the computer settings to match the relay settings.

b. Click **OK**.

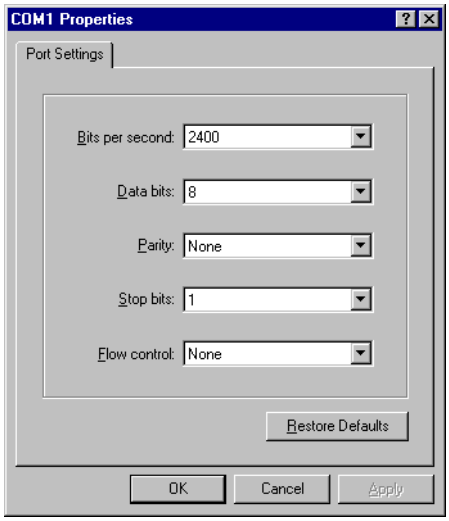


Figure B.3 Determining Communications Parameters for the Computer

Step 7. Set the terminal emulation to VT100:

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Firmware Upgrade Properties** dialog box (*Figure B.4*).

c. Select **VT100** from the **Emulation:** list box and click **OK**.

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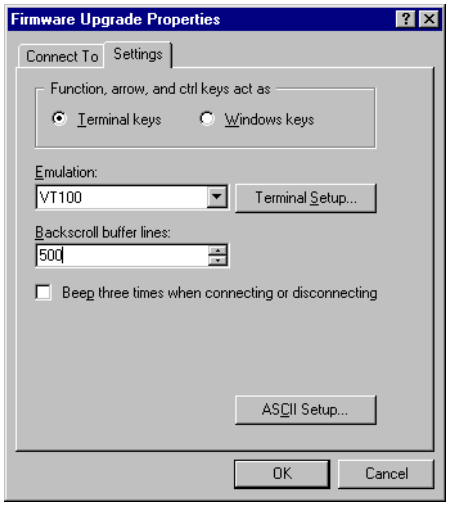


Figure B.4 Setting Terminal Emulation

Step 8. Confirm serial communication.

Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 = prompt, similar to that in *Figure B.5*.

If this is successful, proceed to *C. Save Settings and Other Data on page B.6*.

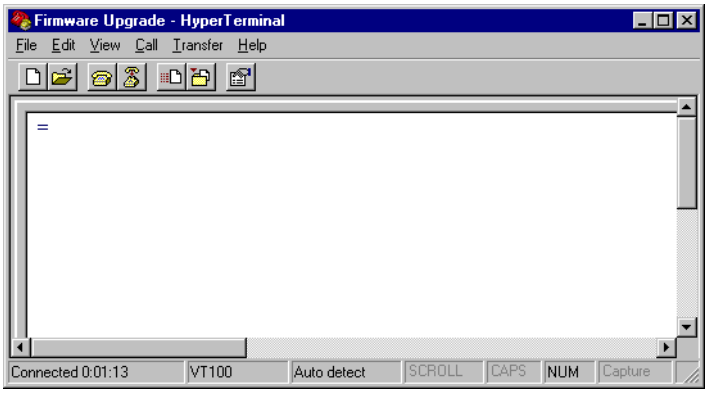


Figure B.5 Terminal Emulation Startup Prompt

Failure to Connect

If you do not see the Access Level 0 = prompt, press **<Enter>** again. If you still do not see the Access Level 0 = prompt, you have either selected the incorrect serial communications port on the computer, or the computer speed setting does not match the data transmission rate of the relay. Perform the following steps to reattempt a connection:

Step 9. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 10. Correct the port setting:

a. From the **File** menu, choose **Properties**.

You should see a dialog box similar to *Figure B.6*.

b. Select a different port in the **Connect using:** list box.

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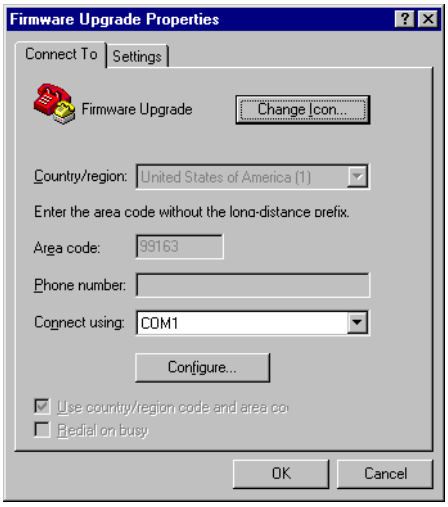


Figure B.6 Correcting the Port Setting

Step 11. Correct the communications parameters:

a. From the filename **Properties** dialog box shown in *Figure B.6*, click **Configure**.

You will see a dialog box similar to *Figure B.7*.

b. Change the settings in the appropriate list boxes to match the settings you recorded in *Step 9 on page B.2* and click **OK** twice to return to the terminal emulation window.

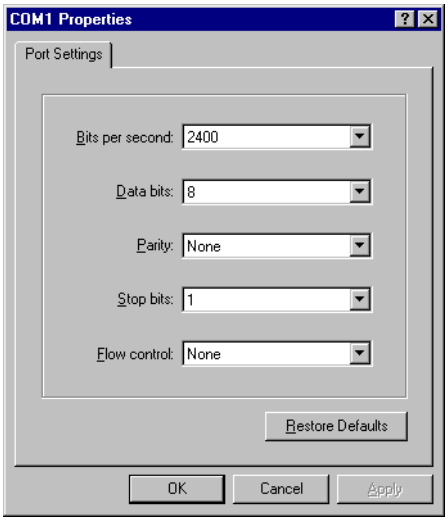


Figure B.7 Correcting the Communications Parameters

Step 12. Press **<Enter>**. In the terminal emulation window, you should see the Access Level 0 = prompt, similar to that in *Figure B.5*.

C. Save Settings and Other Data

Before upgrading firmware, retrieve and record any History (**HIS**), Event (**EVE**), Metering (**MET**), Breaker Wear Monitor (**BRE**), Communications Log Summary (**COM X** or **COM Y**) or Sequential Events Recorder (**SER**) data that you want to retain (see the relay instruction manual for these procedures).

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Enter Access Level 2

NOTE: If the relay does not prompt you for Access Level 1 and Access Level 2 passwords, check whether the relay has a password jumper in place. With this jumper in place, the relay is unprotected from unauthorized access (see the relay instruction manual).

Step 1. Type **ACC <Enter>** at the Access Level 0 = prompt.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Type **2AC <Enter>**.

Step 4. Type the Access Level 2 password and press **<Enter>**.

You will see the Access Level 2 =>> prompt.

Backup Relay Settings

The relay preserves settings and passwords during the firmware upgrade process. However, interruption of relay power during the upgrade process can cause the relay to lose settings. Make a copy of the original relay settings in case you need to reenter the settings. Use either the SEL-5010 Relay Assistant software or ACSELERATOR QuickSet to record the existing relay settings and proceed to *D. Start SELBOOT on page B.8*. Otherwise, perform the following steps:

Step 1. From the **Transfer** menu in **HyperTerminal**, select **Capture Text**.

Step 2. Enter a directory and filename for a text file where you will record the existing relay settings.

Step 3. Click **Start**.

The **Capture Text** command copies all the information you retrieve and all the keystrokes you type until you send the command to stop capturing text. The terminal emulation program stores these data in the text file.

Step 4. Execute the Show Calibration (**SHO C**) command to retrieve the relay calibration settings.

Use the following Show commands to retrieve the relay settings: **SHO G**, **SHO 1**, **SHO L 1**, **SHO 2**, **SHO L 2**, **SHO 3**, **SHO L 3**, **SHO 4**, **SHO L 4**, **SHO 5**, **SHO L 5**, **SHO 6**, **SHO L 6**, **SHO P 1**, **SHO P 2**, **SHO P 3**, **SHO P F**, **SHO R**, and **SHO T**.

Issue the Password (**PAS**) command and save the original password settings.

NOTE: Settings classes can vary among SEL relays. See the relay instruction manual for a listing.

Step 5. From the **Transfer** menu in **HyperTerminal**, select **Capture Text** and click **Stop**.

Step 6. The computer saves the text file you created to the directory you specified in *Step 2*.

Step 7. Write down the present relay data transmission setting (SPEED).

This setting is SPEED in the **SHO P** relay settings output. The SPEED value should be the same as the value you recorded in *A. Prepare the Relay on page B.2*.

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D. Start SELBOOT

Step 1. Find and record the firmware identification string (FID):

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Properties** dialog box (*Figure B.4*).

c. Click **ASCII Setup**.

You should see a dialog box similar to *Figure B.8*.

d. Under **ASCII Receiving**, select the check box to **Append line feeds to incoming line ends**.

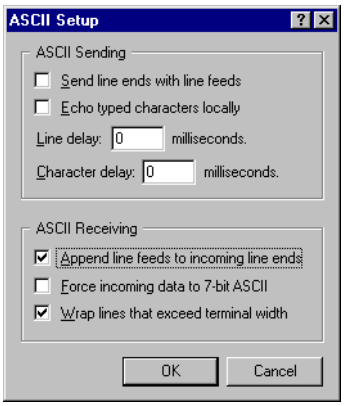


Figure B.8 Preparing HyperTerminal for ID Command Display

e. Click **OK** twice to go back to the terminal emulation window.

f. Type **ID <Enter>** and record the FID number the relay displays.

g. Repeat *Step a* through *Step c*, then uncheck the **Append line feeds to incoming line ends** check box. (This feature can cause problems when uploading firmware to the relay.)

Step 2. From the computer, start the SELBOOT program:

a. From the Access Level 2 =>> prompt, type the following:

L_D <Enter>.

The relay responds with the following:

```
Disable relay to send or receive firmware (Y/
N)?
```

b. Type **Y <Enter>**.

The relay responds with the following:

```
Are you sure (Y/N)?
```

c. Type **Y <Enter>**.

The relay responds with the following:

```
Relay Disabled
```


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Step 3. Wait for the SELBOOT program to load.

The front-panel LCD screen displays the SELBOOT firmware number (e.g., SLBT-3xx-R100). The number following the R is the SELBOOT revision number. This number is different from the relay firmware revision number.

After SELBOOT loads, the computer will display the SELBOOT !> prompt.

Step 4. Press **<Enter>** to confirm that the relay is in SELBOOT.

You will see another SELBOOT !> prompt.

Commands Available in SELBOOT

For a listing of commands available in SELBOOT, type **HELP <Enter>**. You should see a screen similar to *Figure B.9*.

```
!>HELP <Enter>
SELboot-3xx-R100
bau "rate"  ; Set baud rate to 300, 1200, 2400, 4800, 9600, 19200, or 38400 baud
era         ; Erase the existing relay firmware
exi         ; Exit this program and restart the device
fid         ; Print the relays firmware id
rec         ; Receive new firmware for the relay using xmodem
sen         ; Send the relays firmware to a pc using xmodem
hel         ; Print this list
FLASH Type : 040         Checksum = 370E  OK
```

Figure B.9 List of Commands Available in SELBOOT

Establish a High-Speed Connection

Step 5. Type **BAU 38400 <Enter>** at the SELBOOT !> prompt.

Match Computer Communications Speed to the Relay

Step 6. From the **Call** menu, choose **Disconnect** to terminate communication.

Step 7. Correct the communications parameters:

a. From the **File** menu, choose **Properties**.

b. Choose **Configure**.

c. Change the computer communications speed to match the new data transmission rate in the relay (*Figure B.10*).

d. Click **OK** twice.

Step 8. Press **<Enter>** to check for the SELBOOT !> prompt indicating that serial communication is successful.

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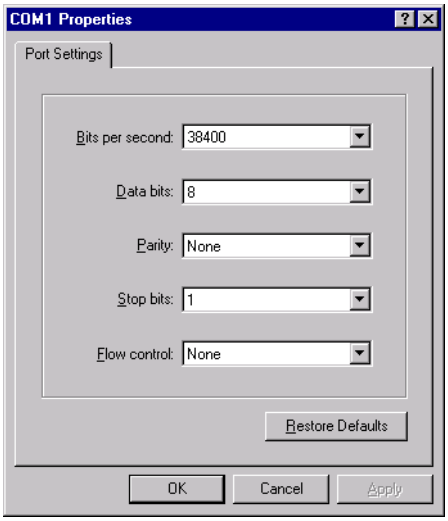


Figure B.10 Matching Computer to Relay Parameters

E. Download Existing Firmware

Copy the firmware presently in the relay, in case the new firmware upload is unsuccessful. To make a backup of the existing firmware, the computer will need as much as 3 MB of free disk space. This backup procedure takes 5–10 minutes at 38400 bps.

Step 1. Type **SEN <Enter>** at the SELBOOT !> prompt to initiate the firmware transfer from the relay to the computer.

Step 2. From the **Transfer** menu in **HyperTerminal**, select **Receive File**.

You should see a dialog box similar to *Figure B.11*.

Step 3. Enter the pathname of a folder on the computer hard drive where you want to record the existing relay firmware.

Step 4. Select **1K Xmodem** if this protocol is available on the PC.

If the computer does not have **1K Xmodem**, choose **Xmodem**.

Step 5. Click **Receive**.

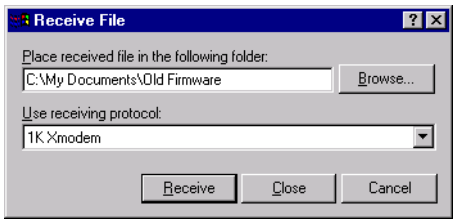


Figure B.11 Example Receive File Dialog Box

Step 6. Enter a filename that clearly identifies the existing firmware version (*Figure B.12*), using the version number from the FID you recorded earlier in *Step 1 on page B.8* and click **OK**.

SEL lists the firmware revision number first, then the product number.

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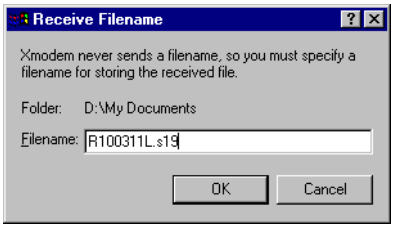


Figure B.12 Example Filename Identifying Old Firmware Version

If Xmodem times out before the download completes, repeat the process from *Step 1 on page B.10*.

For a successful download, you should see a dialog box similar to *Figure B.13*. After the transfer, the relay responds with the following:

NOTE: HyperTerminal stored any pathname you entered in *Step 3* and any filename you entered in *Step 6* during the earlier download attempt; this saves you from reentering these on a subsequent attempt.

```
Download completed successfully!
```

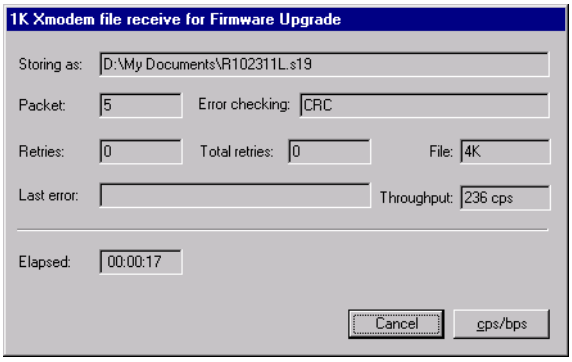


Figure B.13 Downloading Old Firmware

F. Upload New Firmware

Step 1. Prepare to load the firmware:

a. Insert the disk containing the new firmware into the appropriate disk drive on the computer.

b. Some firmware is in self-extracting compressed files (files with .exe extensions). For firmware in such files, from Windows Explorer double-click on the file and select the directory on the hard drive where you want to access the uncompressed files. Verify that these uncompressed files have an .s19 extension.

NOTE: This example shows uploading new firmware directly from a disk. For a faster upload (and less potential for file corruption), copy the new firmware to the local hard drive and upload the new firmware from the hard drive.

Step 2. Type **REC <Enter>** at the SELBOOT !> prompt to command the relay to receive new firmware.

```
!>REC <Enter>

Caution! -  This command erases the relays firmware.

If you erase the firmware, new firmware must be loaded into the relay
before it can be put back into service.
```

The relay asks whether you want to erase the existing firmware.

```
Are you sure you wish to erase the existing firmware? (Y/N) Y
```


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Step 3. Type **Y** to erase the existing firmware and load new firmware. (To abort, type **N** or press **<Enter>**).

The relay responds with the following:

```
Erasing

Erase successful
Press any key to begin transfer, then start transfer at the PC <Enter>
```

Step 4. Press **<Enter>** to start the file transfer routine.

Step 5. Send new firmware to the relay.

a. From the **Transfer** menu in **HyperTerminal**, choose **Send File** (*Figure B.14*).

b. In the **Filename** text box, type the location and filename of the new firmware or use the **Browse** button to select the firmware file.

c. In the **Protocol** text box, select **1K Xmodem** if this protocol is available.

If the computer does not have **1K Xmodem**, select **Xmodem**.

d. Click **Send** to send the file containing the new firmware.

You should see a dialog box similar to *Figure B.14*. Incrementing numbers in the **Packet** box and a bar advancing from left to right in the **File** box indicate that a transfer is in progress.

Receiving software takes 10–15 minutes at 38400 bps, depending on the relay. If you see no indication of a transfer in progress within a few minutes after clicking **Send**, use the **REC** command again and reattempt the transfer.

After the transfer completes, the relay displays the following:

```
Upload completed successfully. Attempting a restart.
```

A successful restart sequence can take as long as two minutes, after which time the relay leaves SELBOOT. You will see no display on your PC to indicate a successful restart.

NOTE: Unsuccessful uploads can result from Xmodem time-out, a power failure, loss of communication between the relay and the computer, or voluntary cancellation. Check connections, reestablish communication, and start again at Step 2 on page B.11.

If you want to reload the previous firmware, begin at Step 2 on page B.11 and use the firmware you saved in E. Download Existing Firmware on page B.10. Contact the factory for assistance in achieving a successful firmware upgrade.

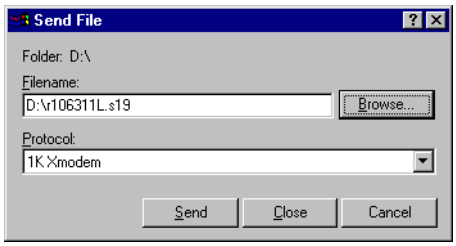


Figure B.14 Selecting New Firmware to Send to the Relay

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NOTE: The relay restarts in SELBOOT if relay power fails while receiving new firmware. Upon power-up, the relay serial port will be at the default 2400 baud. Perform the steps beginning in B. Establish a Terminal Connection on page B.3 to increase the serial connection data speed. Then resume the firmware upgrade process at F. Upload New Firmware on page B.11.

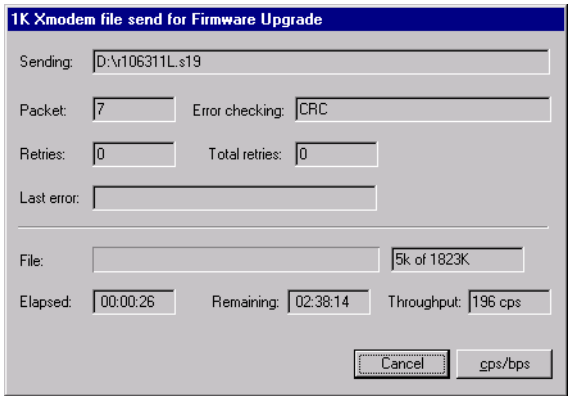


Figure B.15 Transferring New Firmware to the Relay

Step 6. Press **<Enter>** and confirm that the Access Level 0 = prompt appears on the computer screen.

Step 7. If you see the Access Level 0 = prompt, proceed to *G. Check Relay Self-Tests on page B.14*.

No Access Level 0 = Prompt

If no Access Level 0 = prompt appears in the terminal emulation window, one of three things could have occurred. Refer to *Table B.1* to determine the best solution:

Table B.1 Troubleshooting New Firmware Upload (Sheet 1 of 2)

Problem	Solution
The restart was successful, but the relay data transmission rate reverted to the rate at which the relay was operating prior to entering SELBOOT (the rate you recorded in *A. Prepare the Relay on page B.2*).	Change the computer terminal speed to match the relay data transmission rate you recorded in *A. Prepare the Relay on page B.2*. (See *Match Computer Communications Speed to the Relay on page B.9*): Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to the values you recorded in *A. Prepare the Relay on page B.2*. Step 3. From the **Call** menu, choose **Connect** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful. Step 5. If you get no response, proceed to *Match Computer Communications Speed to the Relay on page B.9*.
The restart was successful, but the relay data transmission rate reverted to 2400 bps (the settings have been reset to default).	Match the computer terminal speed to a relay data transmission rate of 2400 bps: Step 1. From the **Call** menu, choose **Disconnect** to terminate relay communication. Step 2. Change the communications software settings to 2400 bps, 8 data bits, no parity, and 1 stop bit (See *Match Computer Communications Speed to the Relay on page B.9*). Step 3. From the **Call** menu, choose **Connect** to reestablish communication. Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating successful serial communication.

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Table B.1 Troubleshooting New Firmware Upload (Sheet 2 of 2)

Problem	Solution
	If you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. Check for the Access Level 0 = prompt. If you see the Access Level 0 = prompt, proceed to *G. Check Relay Self-Tests*.
The restart was unsuccessful, in which case the relay is in SELBOOT.	Reattempt to upload the new firmware (beginning at *Step 5* under *Establish a High-Speed Connection on page B.9*) or contact the factory for assistance.

G. Check Relay Self-Tests

The relay can display various self-test fail status messages. The troubleshooting procedures that follow depend upon the status message the relay displays.

Step 1. Type **ACC <Enter>**.

Step 2. Type the Access Level 1 password and press **<Enter>**.

You will see the Access Level 1 => prompt.

Step 3. Enter the **STATUS** command (**STA <Enter>**) to view relay status messages.

If the relay displays no fail status message, proceed to *H. Verify Settings, Calibration, Status, Breaker Wear, and Metering on page B.16*.

IO_BRD Fail Status Message

Perform this procedure only if you have only an IO_BRD Fail Status message; for additional fail messages, proceed to *CR_RAM, EEPROM, and IO_BRD Fail Status Messages on page B.15*.

Step 1. From Access Level 2, type **INI <Enter>** to reinitialize the I/O board(s). If this command is unavailable, go to *CR_RAM, EEPROM, and IO_BRD Fail Status Messages on page B.15*.

The relay asks the following:

```
Are the new I/O board(s) correct (Y/N)?
```

a. Type **Y <Enter>**.

b. After a brief interval (as long as a minute), the **EN** LED will illuminate.

If the **EN** LED does not illuminate and you see a SELBOOT !> prompt, type **EXI <Enter>** to exit SELBOOT. After a brief interval, the **EN** LED will illuminate. Check for Access Level 0 = prompt.

c. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

d. Enter the **SHO *n*** command to view relay settings and verify that these match the settings you saved (see *Backup Relay Settings on page B.7*).

NOTE: Depending upon the relay, n can be 1-6, G, P, L, T, R, X, or Y.

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Step 2. If the settings do not match, reenter the settings you saved earlier.

a. If you have SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by issuing the necessary **SET *n*** commands, where ***n*** can be 1–6, G, P, L, T, R, X, or Y (depending upon the settings classes in the relay).

Step 3. Use the **PAS** command to set the relay passwords.

For example, type **PAS 1 <Enter>** to set the Access Level 1 password.

Use a similar format for other password levels. SEL relay passwords are case sensitive, so the relay treats lowercase and uppercase letters as different letters.

Step 4. Go to *H. Verify Settings, Calibration, Status, Breaker Wear, and Metering on page B.16*.

CR_RAM, EEPROM, and IO_BRD Fail Status Messages

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

The factory default passwords are in effect; use the default relay passwords listed in the **PAS** command description in the relay instruction manual.

Step 2. Type **R_S <Enter>** to restore factory default settings in the relay (type **R_S 1 <Enter>** for a 1 A SEL-387 or 1 A SEL-352 relay).

The relay asks whether to restore default settings. If the relay does not accept the **R_S** (or **R_S 1**) command, contact your customer service representative or the factory for assistance.

Step 3. Type **Y <Enter>**.

The relay can take as long as two minutes to restore default settings. The relay then reinitializes, and the **EN** LED illuminates.

NOTE: If the relay prompts you to enter a part number, use either the number from the firmware envelope label or the number from the new part number sticker (if supplied).

Step 4. Press **<Enter>** to check for the Access Level 0 = prompt indicating that serial communication is successful.

Step 5. Use the **ACC** and **2AC** commands and type the corresponding passwords to reenter Access Level 2.

Step 6. Restore the original settings:

a. If you have SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by following the instructions for the respective software.

b. If you do not have the SEL-5010 Relay Assistant software or ACSELERATOR QuickSet, restore the original settings by issuing the necessary **SET *n***

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commands, where ***n*** can be 1–6, G, P, L, T, R, X, or Y (depending upon the settings classes available in the relay).

Step 7. Use the **PAS** command to set the relay passwords.

For example, type **PAS 1 <Enter>** to set the Access Level 1 password.

Use a similar format for other password levels. SEL relay passwords are case sensitive, so the relay treats lowercase and uppercase letters as different letters.

Step 8. If any failure status messages still appear on the relay display, see the troubleshooting section in the relay instruction manual or contact your customer service representative or the factory for assistance.

H. Verify Settings, Calibration, Status, Breaker Wear, and Metering

Step 1. Use the **ACC** and **2AC** commands with the associated passwords to enter Access Level 2.

Step 2. Use the **SHO** command to view the relay settings and verify that these match the settings you saved earlier (see *Backup Relay Settings on page B.7*).

If the settings do not match, reenter the settings you saved earlier (see *Step 6* under *CR_RAM, EEPROM, and IO_BRD Fail Status Messages on page B.15*).

Step 3. Type **SHO C <Enter>** to verify the relay calibration settings.

If the settings do not match the settings contained in the text file you recorded in *C. Save Settings and Other Data on page B.6*, contact your customer service representative or the factory for assistance.

Step 4. Use the firmware identification string (FID) to verify download of the correct firmware:

a. From the **File** menu, choose **Properties**.

b. Select the **Settings** tab in the **Properties** dialog box (*Figure B.4*).

c. Click **ASCII Setup**.

You should see a dialog box similar to *Figure B.16*.

d. Under **ASCII Receiving**, select the check box to **Append line feeds to incoming line ends**.

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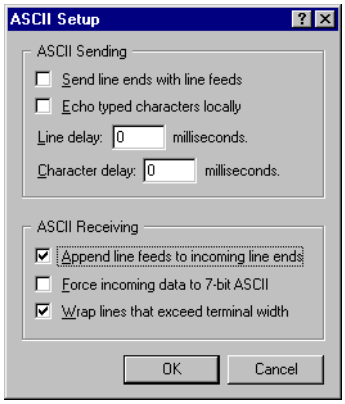


Figure B.16 Preparing HyperTerminal for ID Command Display

e. Click **OK** twice to return to the terminal emulation window.

f. Type **ID <Enter>** and compare the number the relay displays against the number from the firmware envelope label.

g. If the label FID and part number match the relay display, proceed to *Step 5*.

h. For a mismatch between a displayed FID or part number, and the firmware envelope label, reattempt the upgrade or contact the factory for assistance.

Step 5. Type **STA <Enter>** and verify that all relay self-test parameters are within tolerance.

Step 6. If you use the Breaker Wear Monitor, type **BRE <Enter>** to check the data and see if the relay retained breaker wear data through the upgrade procedure.

If the relay did not retain these data, use the **BRE W*n*** command to reload the percent contact wear values for each pole of Circuit Breaker ***n*** (***n*** = 1, 2, 3, or 4) you recorded in *C. Save Settings and Other Data on page B.6*.

Step 7. Apply current and voltage signals to the relay.

Step 8. Type **MET <Enter>** and verify that the current and voltage signals are correct.

Step 9. Use the **TRIGGER** and **EVENT** commands to verify that the magnitudes of the current and voltage signals you applied to the relay match those displayed in the event report.

If these values do not match, check the relay settings and wiring.

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I. Return the Relay to Service

Step 1. Follow your company procedures for returning a relay to service.

Step 2. Autoconfigure the SEL communications processor port if you have an SEL communications processor connected to the relay.

This step reestablishes automatic data collection between the SEL communications processor and the relay. Failure to perform this step can result in automatic data collection failure when cycling communications processor power.

The relay is now ready for your commissioning procedure.

Ethernet Port Firmware Upgrade Instructions

Introduction

Perform the firmware upgrade process in the following sequence:

A. Prepare the Relay

B. Establish an FTP Connection

C. Transfer New Firmware

D. Establish a Telnet Connection

E. Verify Firmware Transfer

NOTE: SEL-300 series relays with Ethernet capability support one CID file, which should be transferred only if a change in the relay configuration is required. If an invalid CID file is transferred, the relay will no longer have a valid IEC 61850 configuration, and the protocol will stop operating. To restart protocol operation, a valid CID must be transferred to the relay.

A new default CID file might have been included with your firmware upgrade. Do not load this file into your relay if you have already configured your relay for IEC 61850 communications. Doing so will overwrite your existing configuration and disrupt communications with the relay as a result. Performing a firmware upgrade will not overwrite or corrupt the CID file already stored in your relay.

Required Equipment

Gather the following equipment before starting this firmware upgrade:

- Personal computer
- FTP client software (e.g., Microsoft Internet Explorer)
- Disk containing the communications card firmware upgrade (.s19) file
- Firmware upgrade instructions (these instructions)

Upgrade Procedure

A. Prepare the Relay

Step 1. If the relay is in use, follow your company practices for removing a relay from service. Typically, these include changing settings, or disconnecting external voltage sources or output contact wiring, to disable relay control functions.

Step 2. Apply power to the relay.

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Step 3. These instructions assume that the Ethernet port (**PORT 5**) settings are set as follows:

IPADDR = 10.201.0.213
SUBNETM = 255.255.0.0
DEFRTR = 10.201.0.1
ETELNET = Y
TPORTC = 1024
EFTPSERV = Y
FTPUSER = 2AC

B. Establish an FTP Connection

The following instructions use Internet Explorer operating on Microsoft Windows XP as the FTP client to establish communication between the relay and a personal computer. The instructions assume both devices are on the same side of any firewalls.

Step 1. Connect an Ethernet communications cable between the relay Ethernet port (**PORT 5**) and the computer Ethernet port.

Alternatively, connect an Ethernet communications cable from the relay Ethernet port to an Ethernet network and another cable from the personal computer Ethernet port to the same Ethernet network.

Step 2. From the computer, open Internet Explorer.

On a personal computer running Windows, you would typically click **Start > Programs > Internet Explorer**.

Step 3. In the **Address** bar, enter the user name (default for FTPUSER setting is 2AC, **2AC** password, and the FTP IP address of the relay (*Figure B.17*) at the same time (ftp://user:password@host:port/path), and press **<Enter>**.

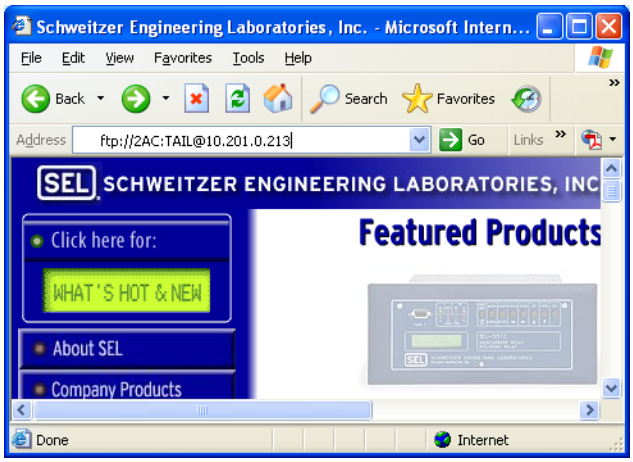


Figure B.17 Establishing an FTP Connection

You can omit the user name and the password if you want to enter the user name and password using the following form. Ensure there is no trailing forward slash (/).

Step 4. Enter the user name and the **2AC** password when the window shown in *Figure B.18* appears.

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Step 5. Click the **Log On** button.

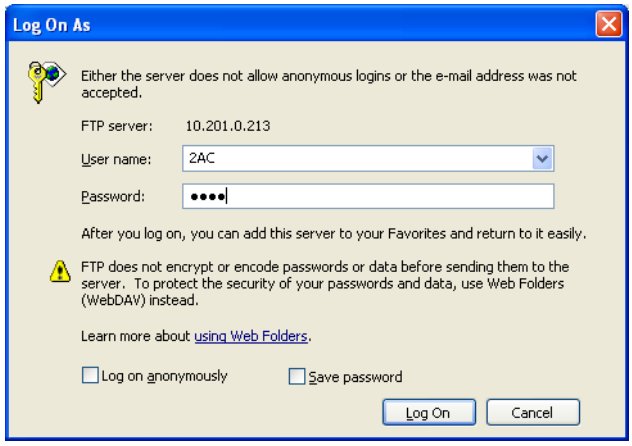


Figure B.18 Alternate Method of Establishing an FTP Connection

Step 6. Right-click on the file that you would like to copy.

Step 7. Click **Copy to Folder** (*Figure B.19*).

Step 8. Browse for folder.

Step 9. Click **OK**.

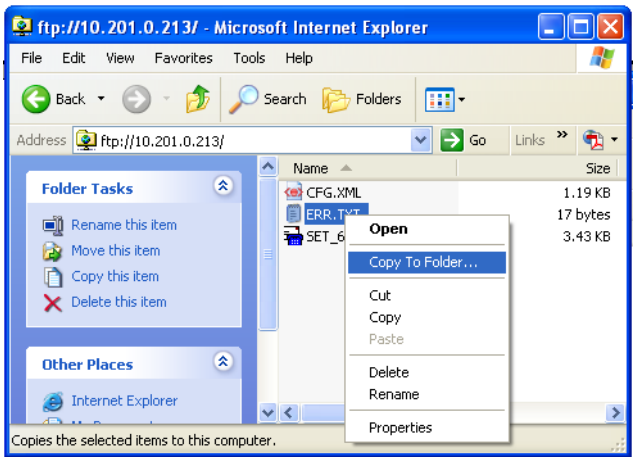


Figure B.19 Read (Open) File

If a window opens with the message, "The page cannot be displayed," as shown in *Figure B.20*, you might have logged on improperly. Retry the login process described in the steps above.

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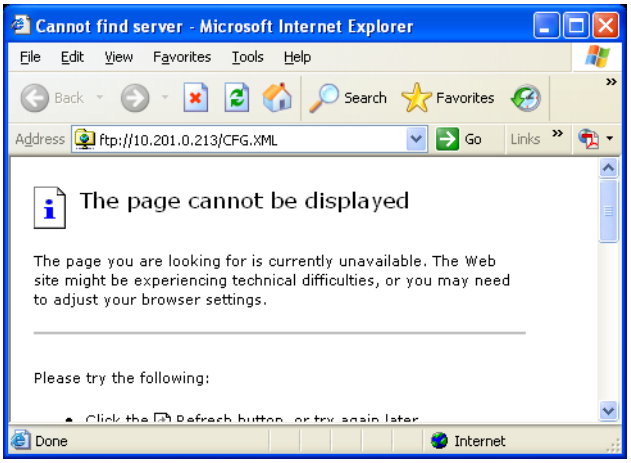


Figure B.20 Page Cannot Be Displayed Window

C. Transfer New Firmware

Following the file transfer process, Ethernet communications will be halted, and the relay will reboot. The relay will take up to a minute to reinitialize after rebooting.

Step 1. Right-click on **Start** and click on **Explore** to launch Windows Explorer.

Step 2. Locate the folder containing the new firmware (extension .s19).

Step 3. Click and drag the file to the Internet Explorer window.

The **Copying** dialog box appears until the upload is complete.

If the **Confirm File Replace** dialog box appears, click on **Yes** and the file will transfer.

D. Establish a Telnet Connection

To establish a Telnet-to-card connection, perform the following steps.

Step 1. Click **Start > Run**.

Step 2. Type **cmd** in the dialog box, and press **<Enter>** to launch a DOS command window.

Step 3. Type **Telnet <IP Address> port** at the prompt (e.g., **Telnet 10.201.0.213 1024**).

Step 4. Press **<Enter>** several times until you see the = prompt.

E. Verify Firmware Transfer

To verify the firmware transfer completed properly, perform the following steps after establishing a Telnet connection.

Step 1. Issue a **STA** command.

Step 2. Verify that the **STA** report does not include any warnings or failures.

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Step 3. Verify that the **STA** report includes `Device Enabled` at the end of the report.

Step 4. Verify that the **STA** report FID matches the FID of the firmware you transferred.

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Appendix C

SEL Distributed Port Switch Protocol

SEL Distributed Port Switch Protocol (LMD) permits multiple SEL relays to share a common communications channel. It is appropriate for low-cost, low-speed port switching applications where updating a real-time database is not a requirement.

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Settings

Use the front-panel **{SET}** pushbutton or the serial port **SET P** command to activate the LMD protocol. Change the port PROTO setting from the default SEL to LMD to reveal the following settings:

PREFIX: One character to precede the address. This should be a character that does not occur in the course of other communications with the relay. Valid choices are one of the following: "@", "#", "$", "%", "&". The default is "@".

ADDR: Two-character ASCII address. The range is "01" to "99". The default is "01".

SETTLE: Time in seconds that transmission is delayed after the request to send (RTS line) asserts. This delay accommodates transmitters with a slow rise time.

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Operation

NOTE: You can use the front-panel {SET} pushbutton to change the port settings to return to SEL protocol.

1. The relay ignores all input from this port until it detects the prefix character and the two-byte address.
2. Upon receipt of the prefix and address, the relay enables echo and message transmission.
3. Wait until you receive a prompt before entering commands to avoid losing echoed characters while the external transmitter is warming up.
4. Until the relay connection terminates, you can use the standard commands that are available when PROTO is set to SEL.
5. The **QUIT** command terminates the connection. If no data are sent to the relay before the port time-out period, it automatically terminates the connection.
6. Enter the sequence **<Ctrl+X> <QUIT> <Enter>** before entering the prefix character if all relays in the multidrop network do not have the same prefix setting.

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Appendix D

Configuration, Fast Meter, and Fast Operate Commands

Overview

SEL relays have two separate data streams that share the same serial port. Data communications with the relay consist of ASCII character commands and reports that are intelligible using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information and then allow the ASCII data stream to continue.

This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering data. The device connected to the other end of the link requires software that uses the separate data streams to exploit this feature. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

SEL Application Guide AG95-10, *Configuration and Fast Meter Messages*, is a comprehensive description of the SEL binary messages. Below is a description of the messages provided in the SEL-351S.

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Message Lists

Binary Message List

Table D.1 Binary Message List

Request to Relay (hex)	Response From Relay
A5C0	Relay Definition Block
A5C1	Fast Meter Configuration Block
A5D1	Fast Meter Data Block
A5C2	Demand Fast Meter Configuration Block
A5D2	Demand Fast Meter Data Message
A5C3	Peak Demand Fast Meter Configuration Block
A5D3	Peak Demand Fast Meter Data Message
A5B9	Fast Meter Status Acknowledge
A5CE	Fast Operate Configuration Block
A5E0	Fast Operate Remote Bit Control
A5E3	Fast Operate Breaker Control

ASCII Configuration Message List

Table D.2 ASCII Configuration Message List

Request to Relay (ASCII)	Response From Relay
ID	ASCII Firmware ID String and Terminal ID Setting (TID)
DNA	ASCII Names of Relay Word bits
BNA	ASCII Names of bits in the A5B9 Status Byte

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Message Definitions

A5C0 Relay Definition Block

In response to the A5C0 request, the relay sends the following block:

Table D.3 A5C0 Relay Definition Block

Data	Description
A5C0	Command
24	Message length
04	Support four protocols: SEL, MIRRORED BITS®, DNP, and LMD.
03	Support Fast Meter, fast demand, and fast peak
01	Status flag for Settings change
A5C1	Fast Meter configuration
A5D1	Fast Meter message
A5C2	Fast demand configuration
A5D2	Fast demand message
A5C3	Fast peak configuration
A5D3	Fast peak message
0004	Settings change bit
A5C100000000	Reconfigure Fast Meter on settings change
0300	SEL protocol with Fast Operate and fast message (unsolicited SER messaging)
0301	LMD protocol with Fast Operate and fast message (unsolicited SER messaging)
0005	DNP3
0006	MIRRORED BITS protocol, no Fast Operate
00	Reserved
xx	Checksum

A5C1 Fast Meter Configuration Block

In response to the A5C1 request, the relay sends the following block:

Table D.4 A5C1 Fast Meter Configuration Block (Sheet 1 of 3)

Data	Description
A5C1	Fast Meter command
84	Length
01	One status flag byte
00	Scale factors in Fast Meter message
00	No scale factors
0A	# of analog input channels
02	# of samples per channel
42	# of digital banks
01	One calculation block
0004	Analog channel offset
0054	Time stamp offset
005C	Digital offset

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Table D.4 A5C1 Fast Meter Configuration Block (Sheet 2 of 3)

Data	Description
494100000000	Analog channel name (**IA**)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494200000000	Analog channel name (**IB**)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494300000000	Analog channel name (**IC**)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494E00000000	Analog channel name (**IN**)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564100000000	Analog channel name (**VA** or VAB for delta-connected voltages)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564200000000	Analog channel name (**VB** or VBC for delta-connected voltages)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564300000000	Analog channel name (**VC** or VCA for delta-connected voltages)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
565300000000	Analog channel name (**VS**)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
465245510000	Analog channel name (FREQ)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
564241540000	Analog channel name (VBAT)
01	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message

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Table D.4 A5C1 Fast Meter Configuration Block (Sheet 3 of 3)

Data	Description
00	Line Configuration (00-ABC wye, 01-ACB wye, 02-ABC delta, 03-ACB delta)
00	Power Calculations (00 for wye-connected, 01 for delta-connected voltages)
FFFF	No Deskew angle
FFFF	No Rs compensation (–1)
FFFF	No Xs compensation (–1)
00	IA channel index
01	IB channel index
02	IC channel index
04	VA channel index (VAB for delta)
05	VB channel index (VBC for delta)
06	VC channel index (VCA for delta)
00	Reserved
checksum	1-byte checksum of all preceding bytes

A5D1 Fast Meter Data Block

In response to the A5D1 request, the relay sends the following block:

Table D.5 A5D1 Fast Meter Data Block

Data	Description
A5D1	Command
A0	Length
1 byte	1 Status Byte
80 bytes	X and Y components of: IA, IB, IC, IN, VA/VAB, VB/VBC, VC/VCA, VS, Freq and Vbatt in 4-byte IEEE FPS
8 bytes	Time stamp
66 bytes	Two target LED rows and 64 digital banks: TAR0–TAR65
1 byte	Reserved
checksum	1-byte checksum of all preceding bytes

A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages

In response to the A5C2 or A5C3 request, the relay sends the following block:

Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 1 of 4)

Data	Description
A5C2 or A5C3	Command; Demand (A5C2) or Peak Demand (A5C3)
EE	Length
01	# of status flag bytes
00	Scale factors in meter message
00	# of scale factors
16	# of analog input channels
01	# of samples per channel
00	# of digital banks

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Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 2 of 4)

Data	Description
00	# of calculation blocks
0004	Analog channel offset
00B4	Time stamp offset
FFFF	Digital offset
494100000000	Analog channel name (IA)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494200000000	Analog channel name (IB)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494300000000	Analog channel name (IC)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494E00000000	Analog channel name (IN)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
494700000000	Analog channel name (IG)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
334932000000	Analog channel name (3I2)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50412B000000	Analog channel name (PA+)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50422B000000	Analog channel name (PB+)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50432B000000	Analog channel name (PC+)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message

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Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 3 of 4)

Data	Description
50332B000000	Analog channel name (P3+)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51412B000000	Analog channel name (QA+)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51422B000000	Analog channel name (QB+)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51432B000000	Analog channel name (QC+)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51332B000000	Analog channel name (Q3+)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50412D000000	Analog channel name (PA-)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50422D000000	Analog channel name (PB-)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50432D000000	Analog channel name (PC-)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
50332D000000	Analog channel name (P3-)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51412D000000	Analog channel name (QA-)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message

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Table D.6 A5C2/A5C3 Demand/Peak Demand Fast Meter Configuration Messages (Sheet 4 of 4)

Data	Description
51422D000000	Analog channel name (QB-)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51432D000000	Analog channel name (QC-)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
51332D000000	Analog channel name (Q3-)
02	Analog channel type
FF	Scale factor type
0000	Scale factor offset in Fast Meter message
00	Reserved
checksum	1-byte checksum of preceding bytes

A5D2/A5D3 Demand/Peak Demand Fast Meter Message

In response to the A5D2 or A5D3 request, the relay sends the following block:

Table D.7 A5D2/A5D3 Demand/Peak Demand Fast Meter Message

A5D2 or A5D3	Command
BE	Length
1 byte	1 Status Byte
176-bytes	Demand: IA, IB, IC, IN, IG, 3I2, MWA I, MWB I, MWC I, MW3PI, MVA I, MVB I, MVC I, MV3PI, MWA O, MWB O, MWC O, MW3PO, MVA O, MVB O, MVC O, MV3PO in 8-byte IEEE FPS
8 bytes	Time stamp
1 byte	Reserved
1 byte	1-byte checksum of all preceding bytes

NOTE: When global setting PTCONN = DELTA, the single-phase power values [MWA __, MWB __, MWC __, MVARA __, MVARB __, MVARC __] are set to zero.

A5B9 Fast Meter Status Acknowledge Message

In response to the A5B9 request, the relay clears the Fast Meter (message A5D1) Status Byte. The SEL-351S Status Byte contains one active bit, STSET (bit 4). The bit is set on power up and on settings changes. If the STSET bit is set, the external device should request the A5C1, A5C2, and A5C3 messages. The external device can then determine if the scale factors or line configuration parameters have been modified.

A5CE Fast Operate Configuration Block

In response to the A5CE request, the relay sends the following block:

Table D.8 A5CE Fast Operate Configuration Block (Sheet 1 of 3)

Data	Description
A5CE	Command
3C	Length
01	Support 1 circuit breaker
0010	Support 16 remote bit set/clear commands

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Table D.8 A5CE Fast Operate Configuration Block (Sheet 2 of 3)

Data	Description
0100	Allow remote bit pulse commands
31	Operate code, open breaker 1
11	Operate code, close breaker 1
00	Operate code, clear remote bit RB1
20	Operate code, set remote bit RB1
40	Operate code, pulse remote bit RB1
01	Operate code, clear remote bit RB2
21	Operate code, set remote bit RB2
41	Operate code, pulse remote bit RB2
02	Operate code, clear remote bit RB3
22	Operate code, set remote bit RB3
42	Operate code, pulse remote bit RB3
03	Operate code, clear remote bit RB4
23	Operate code, set remote bit RB4
43	Operate code, pulse remote bit RB4
04	Operate code, clear remote bit RB5
24	Operate code, set remote bit RB5
44	Operate code, pulse remote bit RB5
05	Operate code, clear remote bit RB6
25	Operate code, set remote bit RB6
45	Operate code, pulse remote bit RB6
06	Operate code, clear remote bit RB7
26	Operate code, set remote bit RB7
46	Operate code, pulse remote bit RB7
07	Operate code, clear remote bit RB8
27	Operate code, set remote bit RB8
47	Operate code, pulse remote bit RB8
08	Operate code, clear remote bit RB9
28	Operate code, set remote bit RB9
48	Operate code, pulse remote bit RB9
09	Operate code, clear remote bit RB10
29	Operate code, set remote bit RB10
49	Operate code, pulse remote bit RB10
0A	Operate code, clear remote bit RB11
2A	Operate code, set remote bit RB11
4A	Operate code, pulse remote bit RB11
0B	Operate code, clear remote bit RB12
2B	Operate code, set remote bit RB12
4B	Operate code, pulse remote bit RB12
0C	Operate code, clear remote bit RB13
2C	Operate code, set remote bit RB13

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Table D.8 A5CE Fast Operate Configuration Block (Sheet 3 of 3)

Data	Description
4C	Operate code, pulse remote bit RB13
0D	Operate code, clear remote bit RB14
2D	Operate code, set remote bit RB14
4D	Operate code, pulse remote bit RB14
0E	Operate code, clear remote bit RB15
2E	Operate code, set remote bit RB15
4E	Operate code, pulse remote bit RB15
0F	Operate code, clear remote bit RB16
2F	Operate code, set remote bit RB16
4F	Operate code, pulse remote bit RB16
00	Reserved
checksum	1-byte checksum of all preceding bytes

A5E0 Fast Operate Remote Bit Control

The external device sends the following message to perform a remote bit operation:

Table D.9 AFE0 Fast Operate Remote Bit Control

Data	Description
A5E0	Command
06	Length
1 byte	Operate code: 00–0F clear remote bit RB1–RB16 20–2F set remote bit RB1–RB16 40–4F pulse remote bit for RB1–RB16 for one processing interval
1 byte	Operate validation: 4 • Operate code + 1
checksum	1-byte checksum of preceding bytes

The relay performs the specified remote bit operation if the following conditions are true:

- The Operate code is valid.
- The Operate validation = 4 • Operate code + 1.
- The message checksum is valid.
- The FASTOP port setting is set to Y.
- The relay is enabled.

Remote bit set and clear operations are latched by the relay. Remote bit pulse operations assert the remote bit for one processing interval (1/4 cycle).

It is common practice to route remote bits to output contacts to provide remote control of the relay outputs. If you wish to pulse an output contact closed for a specific duration, SEL recommends using the remote bit pulse command and SELOGIC® control equations to provide secure and accurate contact control. The remote device sends the remote bit pulse command; the relay controls the timing of the output contact assertion. You can use any remote bit (RB1–RB16), and any SELOGIC control equation timer (SV1–SV16) to

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control any of the output contacts (OUT101–OUT107). For example, to pulse output contact OUT104 for 30 cycles with Remote Bit RB4 and SELOGIC control equation timer SV4, issue the following relay settings:

Via the **SET** command:

ESV = **4** enable 4 SELOGIC control equations

SV4PU = **0** SV4 pickup time = 0

SV4DO = **30** SV4 dropout time is 30 cycles

Via the **SET L** command:

SV4 = **RB4** SV4 input is RB4

OUT104 = **SV4T** route SV4 timer output to OUT104

To pulse the contact, send the **A5E006430DDB** command to the relay.

A5E3 Fast Operate Breaker Control

The external device sends the following message to perform a fast breaker open/close:

Table D.10 A5E3 Fast Operate Breaker Control

Data	Description
A5E3	Command
06	Length
1 byte	Operate code: 31—OPEN breaker 11—CLOSE breaker
1 byte	Operate Validation: 4 • Operate code + 1
Checksum	1-byte checksum of preceding bytes

The relay performs the specified breaker operation if the following conditions are true:

- Conditions 1–5 defined in the A5E0 message are true.
- The breaker jumper (JMP2B) is in place on the SEL-351S main board.

A5CD Fast Operate Reset Definition Block

In response to an A5CD request, the relay sends the configuration block for the Fast Operate Reset message:

Table D.11 A5CD Fast Operate Reset Definition Block

Data	Description
A5CD	Command
0E	Message length
01	The number of Fast Operate reset codes supported
00	Reserved for future use
	Per Fast Operate reset code, repeat:
00	Fast Operate reset code (e.g., “00” for target reset)
54415220520D00	Fast Operate reset description string (e.g., “TAR R”)
xx	Checksum

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A5ED Fast Operate Reset Command

The Fast Operate Reset commands take the following form:

Table D.12 A5ED Fast Operate Reset Command

Data	Description
A5ED	Command
06	Message Length—always 6
00	Operate Code (e.g., “00” for target reset, “TAR R”)
01	Operate Validation—(4 • Operate Code) + 1
xx	Checksum

ID Message

In response to the **ID** command, the relay sends the firmware ID (FID), boot firmware ID (BFID), firmware checksum (CID), relay TID setting (DEVID), Modbus® device code (DEVCODE)—for use by SEL-2032, SEL-2030, and SEL-2020 Communications Processors), relay part number (PARTNO), and configuration string (CONFIG)—for use by other IEDs or software.

A sample response is shown below; responses will differ depending on relay model, settings, and firmware.

```
<STX>"FID=SEL-351S-x-R…-V0-Z……-D2000….","yyyy"<CR><LF>
"BFID=SELBOOT-35R-R…","yyyy"<CR><LF>
"CID=xxxx","yyyy"<CR><LF>
"DEVID=STATION A","yyyy"<CR><LF>
"DEVCODE=49","yyyy"<CR><LF>
"PARTNO=0351S71H34554X1","yyyy"<CR><LF>
"CONFIG=111122","yyyy"<CR><LF>
"SPECIAL=1","yyyy"<CR><LF><ETX>
```

where:

- <STX> is the STX character (02)
- <ETX> is the ETX character (03)
- xxxx is the 4-byte ASCII hex representation of the checksum of the relay firmware
- yyyy is the 4-byte ASCII hex representation of the checksum for each line

The ID message is available from Access Level 0 and higher.

DNA Message

In response to the **DNA** command, the relay sends names of the Relay Word bits transmitted in the A5D1 message. The first name is associated with the MSB, the last name with the LSB. These names are listed in the Relay Word Bits table for the appropriate model in *Section 9: Setting the Relay* of this manual. The **DNA** command is available from Access Level 1 and higher.

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The DNA message for an SEL-351S with a 0.2 A nominal neutral channel (**IN**), is shown below:

```
<STX>
"TLED11","TLED12","TLED13","TLED14","TLED15","TLED16","TLED17","TLED18","yyyy"
<CR><LF>
"TLED19","TLED20","TLED21","TLED22","TLED23","TLED24","TLED25","TLED26","yyyy"
<CR><LF>
"50A1","50B1","50C1","50A2","50B2","50C2","50A3","50B3","yyyy"<CR><LF>
"50C3","50A4","50B4","50C4","50AB1","50BC1","50CA1","50AB2","yyyy"<CR><LF>
"50BC2","50CA2","50AB3","50BC3","50CA3","50AB4","50BC4","50CA4","yyyy"<CR><LF>
"50A","50B","50C","51P1","51P1T","51P1R","51N1","51N1T","yyyy"<CR><LF>
"51N1R","51G1","51G1T","51G1R","51P2","51P2T","51P2R","51N2","yyyy"<CR><LF>
"51N2T","51N2R","51G2","51G2T","51G2R","51Q","51QT","51QR","yyyy"<CR><LF>
"50P1","50P2","50P3","50P4","50N1","50N2","50N3","50N4","yyyy"<CR><LF>
"67P1","67P2","67P3","67P4","67N1","67N2","67N3","67N4","yyyy"<CR><LF>
"67P1T","67P2T","67P3T","67P4T","67N1T","67N2T","67N3T","67N4T","yyyy"<CR><LF>
"50G1","50G2","50G3","50G4","50Q1","50Q2","50Q3","50Q4","yyyy"<CR><LF>
"67G1","67G2","67G3","67G4","67Q1","67Q2","67Q3","67Q4","yyyy"<CR><LF>
"67G1T","67G2T","67G3T","67G4T","67Q1T","67Q2T","67Q3T","67Q4T","yyyy"<CR><LF>
"50P5","50P6","50N5","50N6","50G5","50G6","50Q5","50Q6","yyyy"<CR><LF>
"50QF","50QR","50GF","50GR","32VE","32QGE","32IE","32QE","yyyy"<CR><LF>
"F32P","R32P","F32Q","R32Q","F32QG","R32QG","F32V","R32V","yyyy"<CR><LF>
"F32I","R32I","32PF","32PR","32QF","32QR","32GF","32GR","yyyy"<CR><LF>
"27A1","27B1","27C1","27A2","27B2","27C2","59A1","59B1","yyyy"<CR><LF>
"59C1","59A2","59B2","59C2","27AB","27BC","27CA","59AB","yyyy"<CR><LF>
"59BC","59CA","59N1","59N2","59Q","59V1","27S","59S1","yyyy"<CR><LF>
"59S2","59VP","59VS","SF","25A1","25A2","3P27","3P59","yyyy"<CR><LF>
"81D1","81D2","81D3","81D4","81D5","81D6","27B81","50L","yyyy"<CR><LF>
"81D1T","81D2T","81D3T","81D4T","81D5T","81D6T","VPOLV","LOP","yyyy"<CR><LF>
"SFAST","SSLOW","IN106","IN105","IN104","IN103","IN102","IN101","yyyy"<CR><LF>
"LB1","LB2","LB3","LB4","LB5","LB6","LB7","LB8","yyyy"<CR><LF>
"LB9","LB10","LB11","LB12","LB13","LB14","LB15","LB16","yyyy"<CR><LF>
"RB1","RB2","RB3","RB4","RB5","RB6","RB7","RB8","yyyy"<CR><LF>
"RB9","RB10","RB11","RB12","RB13","RB14","RB15","RB16","yyyy"<CR><LF>
"LT1","LT2","LT3","LT4","LT5","LT6","LT7","LT8","yyyy"<CR><LF>
"LT9","LT10","LT11","LT12","LT13","LT14","LT15","LT16","yyyy"<CR><LF>
"SV1","SV2","SV3","SV4","SV1T","SV2T","SV3T","SV4T","yyyy"<CR><LF>
"SV5","SV6","SV7","SV8","SV5T","SV6T","SV7T","SV8T","yyyy"<CR><LF>
"SV9","SV10","SV11","SV12","SV9T","SV10T","SV11T","SV12T","yyyy"<CR><LF>
"SV13","SV14","SV15","SV16","SV13T","SV14T","SV15T","SV16T","yyyy"<CR><LF>
"79RS","79CY","79LO","SH0","SH1","SH2","SH3","SH4","yyyy"<CR><LF>
"CLOSE","CF","RCSF","0PTMN","RSTMN","FSA","FSB","FSC","yyyy"<CR><LF>
"LED9","50P32","LED10","59VA","TRGTR","52A","PB10","PB9","yyyy"<CR><LF>
"SG1","SG2","SG3","SG4","SG5","SG6","ZLOUT","ZLIN","yyyy"<CR><LF>
"ZLOAD","BCWA","BCWB","BCWC","COMMT","FAULT","SOTFT","BCW","yyyy"<CR><LF>
"ALARM","OUT107","OUT106","OUT105","OUT104","OUT103","OUT102","OUT101","yyyy"
<CR><LF>
"3P0","SOTFE","Z3RB","KEY","EKEY","ECTT","WFC","PT","yyyy"<CR><LF>
"PTRX2","PTRX","PTRX1","UBB1","UBB2","UBB","Z3XT","DSTRT","yyyy"<CR><LF>
"NSTRT","STOP","BTX","TRIP","OC","CC","DCHI","DCLO","yyyy"<CR><LF>
"67P2S","67N2S","67G2S","67Q2S","PDEM","NDEM","GDEM","QDEM","yyyy"<CR><LF>
"OUT201","OUT202","OUT203","OUT204","OUT205","OUT206","OUT207","OUT208","yyyy"
<CR><LF>
"OUT209","OUT210","OUT211","OUT212","*","*","*","*","yyyy"<CR><LF>
"IN208","IN207","IN206","IN205","IN204","IN203","IN202","IN201","yyyy"<CR><LF>
"*","*","*","*","*","*","*","*","yyyy"<CR><LF>
"PB1","PB2","PB3","PB4","PB5","PB6","PB7","PB8","yyyy"<CR><LF>
"LED1","LED2","LED3","LED4","LED5","LED6","LED7","LED8","'yyyy"<CR><LF>
"LED19","LED20","LED21","LED22","LED23","LED24","LED25","LED26","yyyy"<CR><LF>
"RMB8A","RMB7A","RMB6A","RMB5A","RMB4A","RMB3A","RMB2A","RMB1A","yyyy"
<CR><LF>
"TMB8A","TMB7A","TMB6A","TMB5A","TMB4A","TMB3A","TMB2A","TMB1A","yyyy"
<CR><LF>
"RMB8B","RMB7B","RMB6B","RMB5B","RMB4B","RMB3B","RMB2B","RMB1B","yyyy"
<CR><LF>
"TMB8B","TMB7B","TMB6B","TMB5B","TMB4B","TMB3B","TMB2B","TMB1B","yyyy"
<CR><LF>
"LBOKB","CBADB","RBADB","ROKB","LBOKA","CBADA","RBADA","ROKA","yyyy"<CR><LF>
"PWRA1","PWRB1","PWRC1","PWRA2","PWRB2","PWRC2","INTC","INT3P","yyyy"<CR><LF>
"PWRA3","PWRB3","PWRC3","PWRA4","PWRB4","PWRC4","INTA","INTB","yyyy"<CR><LF>
"SAGA","SAGB","SAGC","SAG3P","SWA","SWB","SWC","SW3P","yyyy"<CR><LF>
"SAGAB","SAGBC","SAGCA","SWAB","SWBC","SWCA","TSOK","TIRIG","yyyy"<CR><LF>
"3PWR1","3PWR2","3PWR3","3PWR4","INTAB","INTBC","INTCA","DELTA","yyyy"<CR><LF>
"27AB2","27BC2","27CA2","59AB2","59BC2","59CA2","59Q2","3VO","yyyy"<CR><LF>
"V1GOOD","*","*","VOGAIN","INMET","ICMET","IBMET","IAMET","yyyy"<CR><LF>
"GNDSW","50NF","50NR","32NE","F32N","R32N","32NF","32NR","yyyy"<CR><LF>
"PMDOK","F32W","R32W","F32C","R32C","NSA","NSB","NSC","yyyy"<CR><LF>
<ETX>
```


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where:

<STX>	is the STX character (02)
<ETX>	is the ETX character (03)
the last field in each line (yyyy)	is the 4-byte ASCII hex representation of the checksum for the line
"*"	indicates an unused bit location

Messages for other relay models may be derived from the appropriate tables in *Section 9: Setting the Relay* of this manual, using the above format.

BNA Message

In response to the **BNA** command, the relay sends names of the bits transmitted in the Status Byte in the A5D1 message. The first name is the MSB, the last name is the LSB. The BNA message is:

```
<STX>"*","*","*","STSET","*","*","*","*","yyyy"<CR><LF><ETX>
```

where:

"yyyy"	is the 4-byte ASCII representation of the checksum
"*"	indicates an unused bit location

The **BNA** command is available from Access Level 1 and higher.

SNS Message

In response to the **SNS** command, the relay sends the name string of the SER (SER1 SER2 SER3) settings. The **SNS** command is available at Access Level 1.

The relay responds to the **SNS** command with the name string in the SER settings. The name string starts with SER1, followed by SER2 and SER3.

For example, if

SER1 = 50A1 OUT101

SER2 = 67P1T 81D1T

SER3 = OUT102 52A

The name string will be

"50A1","OUT101","67P1T","81D1T","OUT102","52A".

If there are more than eight settings in SER, the SNS message will have several rows. Each row will have eight strings, followed by the checksum and carriage return. The last row may have less than eight strings.

The SNS message for the SEL-351S is shown below:

```
<STX>"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","yyyy"<CR><LF>
     "xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","yyyy"<CR><LF>
     "xxxx","xxxx","xxxx",<CR><LF><ETX>
```

where:

xxxx	is a string from the settings in SER (SER1, SER2 and SER3)
yyyy	is the 4-byte ASCII representation of the checksum

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Appendix E
Compressed ASCII Commands

The SEL-351S Relay provides Compressed ASCII versions of some of the relay ASCII commands. The Compressed ASCII commands allow an external device to obtain data from the relay, in a format that directly imports into spreadsheet or database programs, and that can be validated with a checksum.

The SEL-351S provides the following Compressed ASCII commands:

- CASCII—configuration message
- CSTATUS—status message
- CHISTORY—history message
- CEVENT—event message

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CASCII Command–General Format

The Compressed ASCII configuration message provides data for an external computer to extract data from other Compressed ASCII commands. To obtain the configuration message for the Compressed ASCII commands available in an SEL relay, type:

CAS <CR>

The relay sends the following message:

```
<STX>"CAS",n,"yyyy"<CR><LF>
"COMMAND 1",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",.......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",.......,"ddd","yyyy"<CR><LF>
"COMMAND 2",ll,"yyyy"<CR><LF>
"#h","ddd","ddd",.......,"ddd","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",.......,"ddd","yyyy"<CR><LF>
.
.
.
"COMMAND n",ll,"yyyy"<CR><LF>
"#H","xxxxx","xxxxx",.......,"xxxxx","yyyy"<CR><LF>
"#D","ddd","ddd","ddd","ddd",.......,"ddd","yyyy"<CR><LF><ETX>
```

where:

- `n` is the number of Compressed ASCII command descriptions to follow.
- `COMMAND` is the ASCII name for the Compressed ASCII command as sent by the requesting device. The naming convention for the Compressed ASCII commands is a C preceding the typical command. For example, **CSTATUS** (abbreviated to **CST**) is the compressed **STATUS** command.
- `ll` is the minimum access level at which the command is available.
- `#H` identifies a header line to precede one or more data lines; # is the number of subsequent ASCII names. For example, 21H identifies a header line with 21 ASCII labels.
- `#h` identifies a header line to precede one or more data lines; # is the number of subsequent format fields. For example, 8h identifies a header line with 8 format fields.
- `xxxxx` is an ASCII name for corresponding data on following data lines. Maximum ASCII name width is 10 characters.
- `#D` identifies a data format line; # is the maximum number of subsequent data lines.
- `ddd` identifies a format field containing one of the following type designators:
  - I Integer data
  - F Floating point data
  - mS String of maximum m characters (e.g., 10S for a 10 character string)
- `yyyy` is the 4-byte hex ASCII representation of the checksum.

A Compressed ASCII command may require multiple header and data configuration lines.

If a Compressed ASCII request is made for data that are not available, (e.g., the history buffer is empty or invalid event request), the relay responds with the following message:

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```
<STX>"No Data Available","0668"<CR><LF><ETX>
```


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CASCII Command–SEL-351S

Display the SEL-351S Compressed ASCII configuration message by sending:

CAS <CR>

The relay sends:

```
<STX>
"CAS",5,"yyyy"<CR><LF>
"CST",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"23H","IA","IB","IC","IN","VA","VB","VC","VS","MOF","+5V_PS","+5V_REG",
"-5V_REG","+12V_PS","-12V_PS","+15V_PS",
"-15V_PS","TEMP","RAM","ROM","A/D","CR_RAM",
"EEPROM","IO_BRD","yyyy"<CR><LF>
"1D","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S","9S",
"9S","9S","9S","9S","9S","9S","9S","9S","yyyy"<CR><LF>
"CHI",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"15H","REC_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC",
"EVENT","LOCATION","CURR","FREQ","GROUP","SHOT","TARGETS",
"yyyy"<CR><LF>
"30D","I","I","I","I","I","I","I","I","6S","F","I","F","I","I","22S","yyyy"<CR><LF>
"CEV",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","0BB9"
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"14H","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT",
"LOCATION","SHOT","TARGETS","IA","IB","IC","IN","IG","3I2","yyyy"<CR><LF>
"1D","F","I","I","I","6S","F","I","22S","I","I","I","I","I","I","yyyy"<CR><LF>
"13H","IA","IB","IC","IN","IG","VA(kV)"/"VAB(kV)","VB(kV)"/"VBC(kV)","VC(kV)"/
    "VCA(kV)","VS(kV)","VDC","FREQ","TRIG","Names of elements in the relay word rows
    2 - 65 separated by spaces ","yyyy"<CR><LF>
"60D","F","F","F","F","F","F","F","F","F","F","I","F","2S","128S","yyyy"<CR><LF>
"CEV C",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"14H","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT",
"LOCATION","SHOT","TARGETS","IA","IB","IC","IN","IG","3I2","yyyy"<CR><LF>
"1D","F","I","I","I","6S","F","I","22S","I","I","I","I","I","I","yyyy"<CR><LF>
"13H","IA","IB","IC","IN","IG","VA(kV)"/"VAB(kV)","VB(kV)"/"VBC(kV)","VC(kV)"/
    "VCA(kV)","VS(kV)","VDC","FREQ",TRIG","Names of elements in the relay word rows
    2 - 65 separated by spaces ","yyyy"<CR><LF>
"240D","F","F","F","F","F","F","F","F","F","F","I","F","2S","128S","yyyy"<CR><LF>
"CEV R",1,"yyyy"<CR><LF>
"1H","FID","yyyy"<CR><LF>
"1D","45S","yyyy"<CR><LF>
"7H","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
"1D","I","I","I","I","I","I","I","yyyy"<CR><LF>
"14H","FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT",
"LOCATION","SHOT","TARGETS","IA","IB","IC","IN","IG","3I2","1B57"
"1D","F","I","I","I","6S","F","I","22S","I","I","I","I","I","I","yyyy"<CR><LF>
"13H","IA","IB","IC","IN","IG","VA(kV)","VB(kV)","VC(kV)","VS(kV)","VDC",
"FREQ","TRIG","Names of elements in the relay word rows 2 - 65 separated by spaces
","yyyy"<CR><LF>
"256D","F","F","F","F","F","F","F","F","F","F","I","F","2S","128S","yyyy"<CR><LF>
<ETX>
```

where:

`yyyy` is the 4-byte hex ASCII representation of the checksum.

See the **CEVENT** command for definition of the "*Names of elements in the relay word Rows 2 – 65 separated by spaces*" field.

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CSTATUS Command–SEL-351S

Display status data in Compressed ASCII format by sending:

CST <CR>

Relay models 0351*x*0 and 0351*x* send the following message:

```
<STX>"FID","yyyy"<CR><LF>
"Relay FID string","yyyy"<CR><LF>
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR><LF>
"IA","IB","IC","IN","VA","VB","VC","VS","MOF","+5V_PS","+5V_REG","
5V_REG","+12V_PS","-12V_PS","+15V_PS","-15V_PS",
"TEMP","RAM","ROM","A/D","CR_RAM","EEPROM","IO_BRD","yyyy"<CR><LF>
,"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx",
"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx",
"xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","xxxx","yyyy"<CR><LF><ETX>
```

where:

`xxxx` are the data values corresponding to the first line labels

`yyyy` is the 4-byte hex ASCII representation of the checksum

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CHISTORY Command–SEL-351S

Display history data in Compressed ASCII format by sending:

CHI <CR>

The relay sends the following message:

```
<STX>"FID","yyyy"<CR><LF>
"Relay FID string","yyyy"<CR><LF>
"REC_NUM","MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC",
"EVENT","LOCATION","CURR","FREQ","GROUP","SHOT","TARGETS",
"yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"xxxx",xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
"xxxx","yyyy"<CR><LF><ETX>
(the last line is then repeated for each record)
```

where:

- `xxxx` are the data values corresponding to the first line labels
- `yyyy` is the 4-byte hex ASCII representation of the checksum

If the history buffer is empty, the relay responds:

```
<STX>"No Data Available","0668"<CR><LF><ETX>
```


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CEVENT Command–SEL-351S

Display event report in Compressed ASCII format by sending:

CEV [*n* S*x* L*y* L R C] (parameters in [ ] are optional)

where:

n is event number (1–29) if LER = 15, (1–15) if LER = 30, defaults to 1

S*x* is *x* samples per cycle (4 or 16); defaults to 4
If the S*x* parameter is present, it overrides the L parameter

L*y* is *y* cycles event report length (1 to LER) for filtered event reports, (1 to LER + 1) for raw event reports; defaults to LER if not specified

L is 16 samples per cycle; overridden by the S*x* parameter, if present

R specifies raw (unfiltered) data; defaults to 16 samples per cycle unless overridden by the S*x* parameter. Defaults to LER + 1 cycles in length unless overridden with the L*y* parameter.

C specifies 16 samples per cycle, LER cycle length

P precise to synchrophasor-level accuracy for signal content at nominal frequency. This option is available when TSOK = logical 1.

The relay responds to the **CEV** command with the ***nth*** event report as shown below. Items in *italics* will be replaced with the actual relay data.

```
<STX>"FID","yyyy"<CR><LF>
"Relay FID string","yyyy"<CR><LF>
"MONTH","DAY","YEAR","HOUR","MIN","SEC","MSEC","yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,"yyyy"<CR><LF>
"FREQ","SAM/CYC_A","SAM/CYC_D","NUM_OF_CYC","EVENT",
"LOCATION","SHOT","TARGETS","IA","IB","IC","IN","IG","3I2","yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,"xxxx",xxxx,xxxx,"xxxx",xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,
"yyyy"<CR><LF>
"IA","IB","IC","IN","IG","VA(kV)"/"VAB(kV)","VB(kV)"/"VBC(kV)","VC(kV)"/"VCA(kV)",
"VS(kV)","VDC","FREQ","TRIG",
"Names of elements in the relay word separated by spaces ","yyyy"<CR><LF>
xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,xxxx,z,"HEX-ASCII Relay
    Word","yyyy"<CR><LF>
"SETTINGS","yyyy"<CR><LF>
"Relay group, global, and logic settings as displayed with the showset command
    (surrounded by quotes)","yyyy"<CR><LF><ETX>
```

where:

`xxxx` are the data values corresponding to the line labels

`yyyy` is the 4-byte hex ASCII representation of the checksum

`FREQ` is the power system frequency at the trigger instant

`SAM/CYC_A` is the number of analog data samples per cycle (4 or 16)

`SAM/CYC_D` is the number of digital data samples per cycle (4 or 16)

`NUM_OF_CYC` is the number of cycles of data in the event report

`EVENT` is the event type

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LOCATION	is the fault location
SHOT	is the recloser shot counter
TARGETS	are the front-panel tripping targets
IA, IB, IC, IN, IG, 3I2	is the fault current
TRIG	refers to the trigger record
z	is ">" for the trigger row, "*" for the fault current row and empty for all others. If the trigger row and fault current row are the same, both characters are included (e.g., ">*")
HEX-ASCII Relay Word	is the hex ASCII format of the relay word. The first element in the relay word is the most significant bit in the first character.

If samples per cycle are specified as 16, the analog data are displayed at 1/16-cycle intervals and digital data at 1/4-cycle intervals. The digital data are displayed as a series of hex ASCII characters. The relay displays digital data only when they are available. When no data are available, the relay sends only the comma delimiter in the digital data field.

If the specified event does not exist, the relay responds:

```
<STX>"No Data Available","0668"<CR><LF><ETX>
```

The "Names of Relay Word bits separated by spaces" field is shown below. (This sample taken from an SEL-351S-7 with the nominal neutral channel (IN) = 0.2 A.)

```
"50A1 50B1 50C1 50A2 50B2 50C2 50A3 50B3 50C3 50A4 50B4 50C4 50AB1 50BC1 50CA1
 50AB2 50BC2 50CA2 50AB3 50BC3 50CA3 50AB4 50BC4 50CA4 50A 50B 50C 51P1 51P1T
 51P1R 51N1 51N1T 51N1R 51G1 51G1T 51G1R 51P2 51P2T 51P2R 51N2 51N2T 51N2R
 51G2 51G2T 51G2R 51Q 51QT 51QR 50P1 50P2 50P3 50P4 50N1 50N2 50N3 50N4 67P1
 67P2 67P3 67P4 67N1 67N2 67N3 67N4 67P1T 67P2T 67P3T 67P4T 67N1T 67N2T 67N3T
 67N4T 50G1 50G2 50G3 50G4 50Q1 50Q2 50Q3 50Q4 67G1 67G2 67G3 67G4 67Q1 67Q2
 67Q3 67Q4 67G1T 67G2T 67G3T 67G4T 67Q1T 67Q2T 67Q3T 67Q4T 50P5 50P6 50N5 50N6
 50G5 50G6 50Q5 50Q6 50QF 50QR 50GF 50GR 32VE 32QGE 32IE 32QE F32P R32P F32Q
 R32Q F32QG R32QG F32V R32V F32I R32I 32PF 32PR 32QF 32QR 32GF 32GR 27A1 27B1
 27C1 27A2 27B2 27C2 59A1 59B1 59C1 59A2 59B2 59C2 27AB 27BC 27CA 59AB 59BC
 59CA 59N1 59N2 59Q 59V1 27S 59S1 59S2 59VP 59VS SF 25A1 25A2 3P27 3P59 81D1 81D2
 81D3 81D4 81D5 81D6 27B81 50L 81D1T 81D2T 81D3T 81D4T 81D5T 81D6T VPOLV LOP
 SFAST SSLOW IN106 IN105 IN104 IN103 IN102 IN101 LB1 LB2 LB3 LB4 LB5 LB6 LB7
 LB8 LB9 LB10 LB11 LB12 LB13 LB14 LB15 LB16 RB1 RB2 RB3 RB4 RB5 RB6 RB7 RB8
 RB9 RB10 RB11 RB12 RB13 RB14 RB15 RB16 LT1 LT2 LT3 LT4 LT5 LT6 LT7 LT8 LT9
 LT10 LT11 LT12 LT13 LT14 LT15 LT16 SV1 SV2 SV3 SV4 SV1T SV2T SV3T SV4T SV5
 SV6 SV7 SV8 SV5T SV6T SV7T SV8T SV9 SV10 SV11 SV12 SV9T SV10T SV11T SV12T
 SV13 SV14 SV15 SV16 SV13T SV14T SV15T SV16T 79RS 79CY 79LO SH0 SH1 SH2 SH3
 SH4 CLOSE CF RCSF OPTMN RSTMN FSA FSB FSC LED9 50P32 LED10 59VA TRGTR
 52A PB10 PB9 SG1 SG2 SG3 SG4 SG5 SG6 ZLOUT ZLIN ZLOAD BCWA BCWB BCWC
 COMMT FAULT SOTFT BCW ALARM OUT107 OUT106 OUT105 OUT104 OUT103
 OUT102 OUT101 3PO SOTFE Z3RB KEY EKEY ECTT WFC PT PTRX2 PTRX PTRX1
 UBB1 UBB2 UBB Z3XT DSTRT NSTRT STOP BTX TRIP OC CC DCHI DCLO 67P2S
 67N2S 67G2S 67Q2S PDEM NDEM GDEM QDEM OUT201 OUT202 OUT203 OUT204
 OUT205 OUT206 OUT207 OUT208 OUT209 OUT210 OUT211 OUT212 * * * * IN208 IN207
 IN206 IN205 IN204 IN203 IN202 IN201 * * * * * * * * PB1 PB2 PB3 PB4 PB5 PB6 PB7 PB8
 LED1 LED2 LED3 LED4 LED5 LED6 LED7 LED8 LED19 LED20 LED21 LED22 LED23
 LED24 LED25 LED26 RMB8A RMB7A RMB6A RMB5A RMB4A RMB3A RMB2A RMB1A
 TMB8A TMB7A TMB6A TMB5A TMB4A TMB3A TMB2A TMB1A RMB8B RMB7B
 RMB6B RMB5B RMB4B RMB3B RMB2B RMB1B TMB8B TMB7B TMB6B TMB5B
 TMB4B TMB3B TMB2B TMB1B LBOKB CBADB RBADB ROKB LBOKA CBADA
 RBADA ROKA PWRA1 PWRB1 PWRC1 PWRA2 PWRB2 PWRC2 INTC INT3P PWRA3
 PWRB3 PWRC3 PWRA4 PWRB4 PWRC4 INTA INTB SAGA SAGB SAGC SAG3P SWA
 SWB SWC SW3P SAGAB SAGBC SAGCA SWAB SWBC SWCA TSOK TIRIG 3PWR1 3PWR2
 3PWR3 3PWR4 INTAB INTBC INTCA DELTA 27AB2 27BC2 27CA2 59AB2 59BC2 59CA2
 59Q2 3V0 V1GOOD * * VOGAIN INMET ICMET IBMET IAMET GNDSW 50NF 50NR 32NE
 F32N R32N 32NF 32NR PMDOK F32W R32W F32C R32C NSA NSB NSC"
```


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These names are listed in *Table 9.6*. Lists for other relay models may be derived from the appropriate tables in *Section 9* of this manual, using the above format.

A typical *HEX-ASCII Relay Word* is shown below:

```
10000004924900000000000000000000000000000020000000000000000000000000280020800000
800000000000000000C2000000000000000000000001F8000
```

Each bit in the *HEX-ASCII Relay Word* reflects the status of a Relay Word bit. The order of the labels in the *Names of elements in the relay word separated by spaces* field matches the order of the *HEX-ASCII Relay Word*.

In the example above, the first two bytes in the *HEX-ASCII Relay Word* are 10. In binary, this evaluates to 00010000. Mapping the labels to the bits yields the following:

Labels	50A1	50B1	50C1	50A2	50B2	50C2	50A3	50B3
Bits	0	0	0	1	0	0	0	0

In this example, the 50A2 element is asserted (logical 1); all others are deasserted (logical 0).

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Appendix F

Setting Negative-Sequence Overcurrent Elements

Setting Negative-Sequence Definite-Time Overcurrent Elements

Negative-sequence instantaneous overcurrent elements 50Q1–50Q6 and 67Q1–67Q4 should not be set to trip directly. This is because negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears.

To avoid tripping for this transient condition, use negative-sequence definite-time overcurrent elements 67Q1T–67Q4T with at least 1.5 cycles of time delay (transient condition lasts less than 1.5 cycles). For example, make time delay setting:

67Q1D = **1.50**

for negative-sequence definite-time overcurrent element 67Q1T.

Refer to *Figure 3.12* and *Figure 3.13* for more information on negative-sequence instantaneous and definite-time overcurrent elements.

Negative-sequence instantaneous overcurrent elements 50Q5 and 50Q6 do not have associated timers (compare *Figure 3.13* to *Figure 3.12*). If 50Q5 or 50Q6 need to be used for tripping, run them through SELOGIC® control equation variable timers (see *Figure 7.25* and *Figure 7.26*) and use the outputs of the timers for tripping.

Continue reading in *Coordinating Negative-Sequence Overcurrent Elements on page F.3* for guidelines on coordinating negative-sequence definite-time overcurrent elements and a following coordination example. The coordination example uses time-overcurrent elements, but the same principles can be applied to definite-time overcurrent elements.

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Setting Negative-Sequence Time-Overcurrent Elements

Negative-sequence time-overcurrent element 51QT should not be set to trip directly when it is set with a low time-dial setting 51QTD, that results in curve times below 3 cycles (see curves in *Figure 9.1–Figure 9.10*). This is because negative-sequence current can transiently appear when a circuit breaker is closed and balanced load current suddenly appears. Refer to *Figure 3.20* for more information on negative-sequence time-overcurrent element 51QT.

To avoid having negative-sequence time-overcurrent element 51QT with such low time-dial settings trip for this transient negative-sequence current condition, make corresponding minimum response time setting:

51QMR = **1.50 cycles** (minimum response time; transient condition lasts less than 1.5 cycles)

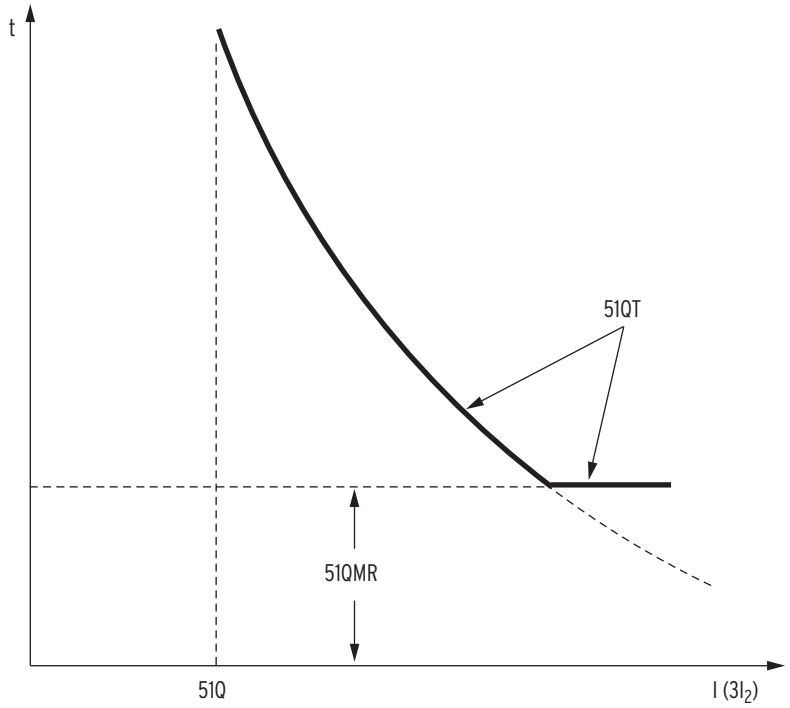


Figure F.1 Minimum Response Time Added to a Negative-Sequence Time-Overcurrent Element 51QT

Continue reading in *Coordinating Negative-Sequence Overcurrent Elements on page F.3* for guidelines on coordinating negative-sequence time-overcurrent elements and a following coordination example.

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Coordinating Negative-Sequence Overcurrent Elements

The following coordination guidelines and example assume that the negative-sequence overcurrent elements operate on $3I_2$ magnitude negative-sequence current and that the power system is radial. The negative-sequence overcurrent elements in the SEL-351S Relay operate on $3I_2$ magnitude negative-sequence current.

The coordination example is a generic example that can be used with any relay containing negative-sequence overcurrent elements that operate on $3I_2$ magnitude negative-sequence current. The SEL-351S can be inserted as the feeder relay in this example.

Note that the overcurrent element labels in the example are not the same as the labels of the corresponding SEL-351S overcurrent elements.

Coordination Guidelines

Step 1. Start with the furthest downstream negative-sequence overcurrent element (e.g., distribution feeder relay in a substation).

Step 2. Identify the phase overcurrent device (e.g., line recloser, fuse) downstream from the negative-sequence overcurrent element that is of greatest concern for coordination.

This is usually the phase overcurrent device with the longest clearing time.

Step 3. Consider the negative-sequence overcurrent element as an "equivalent" phase overcurrent element.

Derive pickup, time dial (lever), curve type, or time-delay settings for this "equivalent" element to coordinate with the downstream phase overcurrent device, as any phase coordination would be performed.

Load considerations can be disregarded when deriving the "equivalent" phase overcurrent element settings.

Step 4. Multiply the "equivalent" phase overcurrent element pickup setting by √3 to convert it to the negative-sequence overcurrent element pickup setting in terms of $3I_2$ current.

$$\left.\begin{array}{c}\text{Negative-}\\ \text{sequence}\\ \text{overcurrent}\\ \text{element}\\ \text{pick-up}\end{array}\right\} = \sqrt{3} \cdot (\text{"equivalent" phase overcurrent element pickup})$$

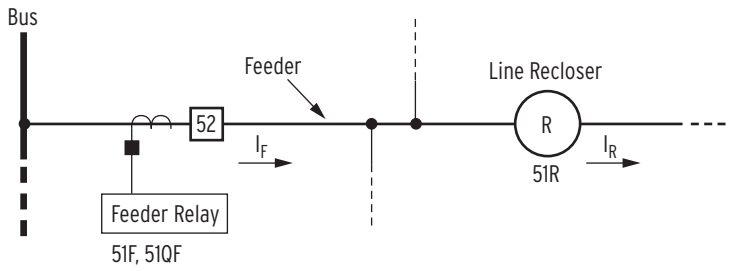
Any time dial (lever), curve type, or time delay calculated for the equivalent phase overcurrent element is also used for the negative-sequence overcurrent element with no conversion factor applied.

Step 5. Set the next upstream negative-sequence overcurrent element to coordinate with the first downstream negative-sequence overcurrent element and so on. Again, coordination is not influenced by load considerations.

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Coordination Example

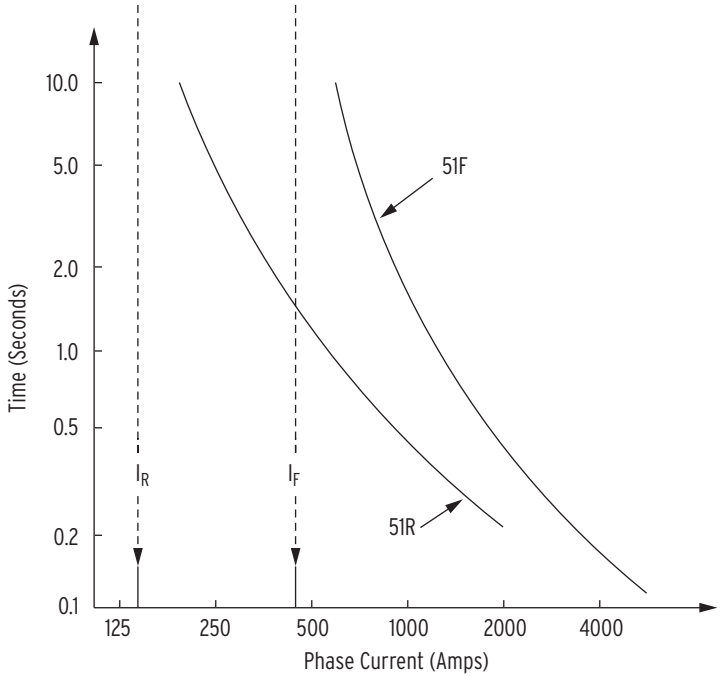
In *Figure F.2*, the phase and negative-sequence overcurrent elements of the feeder relay (51F and 51QF, respectively) must coordinate with the phase overcurrent element of the line recloser (51R).



I_F = Maximum load current through feeder relay = 450 A; I_R = Maximum load current through line recloser = 150 A; 51F = Feeder relay phase time-overcurrent element; 51QF = Feeder relay negative-sequence time-overcurrent element; 51R = Line recloser phase time-overcurrent element (phase "slow curve")

Figure F.2 Distribution Feeder Protective Devices

Traditional Phase Coordination



51F: pickup = 600 A (above max. feeder load, I_F); 51R: pickup = 200 A (above max. line recloser load, I_R)

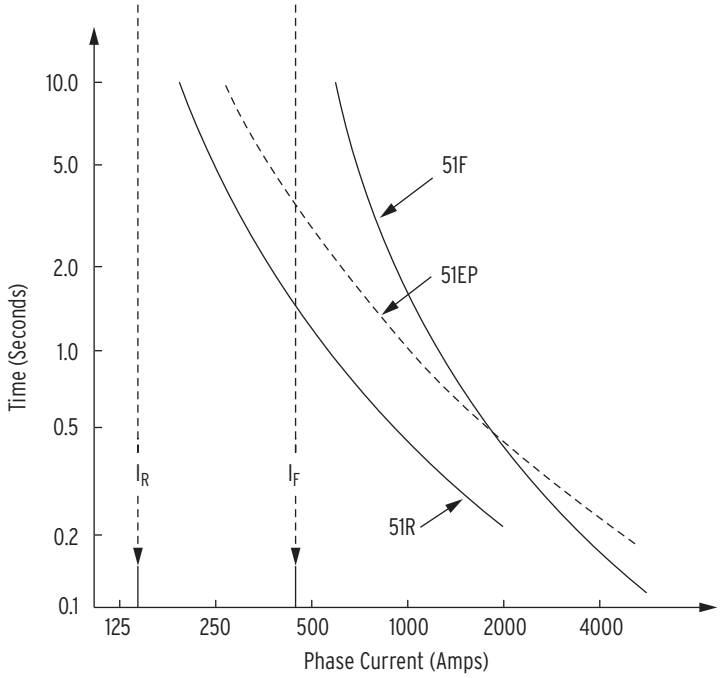
Figure F.3 Traditional Phase Coordination

Figure F.3 shows traditional phase overcurrent element coordination between the feeder relay and line recloser phase overcurrent elements. Phase overcurrent elements must accommodate load and cold load pickup current. The 450 A maximum feeder load current limits the sensitivity of the feeder phase overcurrent element, 51F, to a pickup of 600 A. The feeder relay cannot back-up the line recloser for phase faults below 600 A.

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Apply the Feeder Relay Negative-Sequence Overcurrent Element (Guidelines 1 to 3)

Applying negative-sequence overcurrent element coordination Guidelines 1 to 3 results in the feeder relay "equivalent" phase overcurrent element (51EP) in *Figure F.4*. Curve for 51F is shown for comparison only.



51EP: pickup = 300 A (below max. feeder load, I_F

Figure F.4 Phase-to-Phase Fault Coordination

Considerable improvement in sensitivity and speed of operation for phase-to-phase faults is achieved with the 51EP element. The 51EP element pickup of 300 A has twice the sensitivity of the 51F element pickup of 600 A. The 51EP element speed of operation for phase-to-phase faults below about 2000 A is faster than that for the 51F element.

Convert "Equivalent" Phase Overcurrent Element Settings to Negative-Sequence Overcurrent Element Settings (Guideline 4)

The "equivalent" phase overcurrent element (51EP element in *Figure F.4*) converts to true negative-sequence overcurrent element settings (51QF in *Figure F.5*) by applying the equation given in Guideline 4. The time dial (lever) and curve type of the element remain the same (if the element is a definite-time element, the time delay remains the same).

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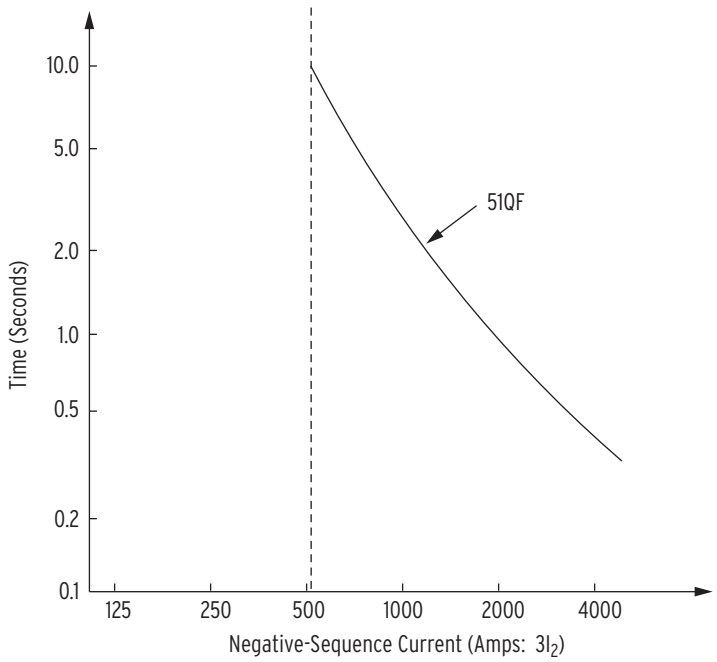


Figure F.5 Negative-Sequence Overcurrent Element Derived from Equivalent Phase Overcurrent Element, 51EP

Having achieved coordination between the feeder relay negative-sequence overcurrent element (51QF) and the downstream line recloser phase overcurrent element (51R) for phase-to-phase faults, coordination between the two devices for other fault types is also achieved.

Negative-Sequence Overcurrent Element Applied at a Distribution Bus (Guideline 5)

The preceding example was for a distribution feeder. A negative-sequence overcurrent element protecting a distribution bus provides an even more dramatic improvement in phase-to-phase fault sensitivity.

The distribution bus phase overcurrent element pickup must be set above the combined load of all the feeders on the bus, plus any emergency load conditions. The bus phase overcurrent element pickup is often set at least four times greater than the pickup of the feeder phase overcurrent element it backs up. Thus, sensitivity to both bus and feeder phase faults is greatly reduced. Feeder relay backup by the bus relay is limited.

Negative-sequence overcurrent elements at the distribution bus can be set significantly below distribution bus load levels and provide dramatically increased sensitivity to phase-to-phase faults. It is coordinated with the distribution feeder phase or negative-sequence overcurrent elements and provides more sensitive and faster phase-to-phase fault backup.

Ground Coordination Concerns

If the downstream protective device includes ground overcurrent elements, in addition to phase overcurrent elements, there should be no need to check the coordination between the ground overcurrent elements and the upstream negative-sequence overcurrent elements. The downstream phase overcurrent element, whether it operates faster or slower than its complementary ground overcurrent element, will operate faster than the upstream negative-sequence overcurrent element for all faults, including those that involve ground.

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Other Negative-Sequence Overcurrent Element References

The following IEEE paper is the source of the coordination guidelines and example given in this appendix. The paper also includes analyses of system unbalances and faults and the negative-sequence current generated by such conditions:

> A. F. Elneweihi, E. O. Schweitzer, M. W. Feltis, "Negative-Sequence Overcurrent Element Application and Coordination in Distribution Protection," IEEE Transactions on Power Delivery, Volume 8, Number 3, July 1993, pp. 915-924.

The following conference paper gives many good application examples for negative-sequence overcurrent elements. The focus is on the transmission system, where negative-sequence overcurrent elements provide better sensitivity than zero-sequence overcurrent elements in detecting some single-line-to-ground faults:

> A. F. Elneweihi, "Useful Applications for Negative-Sequence Overcurrent Relaying," 22nd Annual Western Protective Relay Conference, Spokane, Washington, October 24-26, 1995.

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Appendix G

Setting SELOGIC Control Equations

SELOGIC® control equations combine relay protection and control elements with logic operators to create custom protection and control schemes. This appendix shows how to set the protection and control elements (Relay Word bits) in the SELOGIC control equations.

Additional SELOGIC control equation setting details are available in *Section 9: Setting the Relay* (see also *SELOGIC Control Equation Settings (Serial Port Command SET L) on page SET.18*). See the *SHO Command (Show/View Settings) on page 10.27* for a list of the factory settings the SEL-351S Relay ships with in a standard relay shipment.

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Relay Word Bits

Most of the protection and control element **logic outputs** shown in the various figures in *Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements*–*Section 8: Breaker Monitor, Metering, and Load Profile Functions* are Relay Word bits (labeled as such in the figures). Each Relay Word bit has a label name and can be in either of the following states:

1 (logical 1) or 0 (logical 0)

Logical 1 represents an element being picked up, timed out, or otherwise asserted.

Logical 0 represents an element being dropped out or otherwise deasserted.

Table 9.6 and *Table 9.7* provide a complete listing of Relay Word bits and corresponding descriptions.

Relay Word Bit Operation Example—Phase Time-Overcurrent Element 51P1T

As an example of protection element operation via the logic output of Relay Word bits, a phase time-overcurrent element is examined. Refer to phase time-overcurrent element 51P1T in *Figure 3.14*. Read the text that accompanies *Figure 3.14* (*Table 3.3* and following text).

The following Relay Word bits are the logic outputs of the phase time-overcurrent element:

Table G.1 Logic Outputs of the Phase Time-Overcurrent Element

Logic Output	Description
51P1	indication that the maximum phase current magnitude is above the level of the phase time-overcurrent pickup setting 51P1P
51P1T	indication that the phase time-overcurrent element has timed out on its curve
51P1R	indication that the phase time-overcurrent element is fully reset

Phase Time-Overcurrent Element 51P1T Pickup Indication

If the maximum phase current is **at or below** the level of the phase time-overcurrent pickup setting 51P1P, Relay Word bit 51P1 is in the following state:

51P1 = 0 (logical 0)

If the maximum phase current is **above** the level of the phase time-overcurrent pickup setting 51P1P, Relay Word bit 51P1 is in the following state:

51P1 = 1 (logical 1)

If the maximum phase current is **above** the level of the phase time-overcurrent pickup setting 51P1P, phase time-overcurrent element 51P1T is either timing on its curve or is already timed out.

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Phase Time-Overcurrent Element 51P1T Time–Out Indication

If phase time-overcurrent element 51P1T is **not timed out** on its curve, Relay Word bit 51P1T is in the following state:

51P1T = 0 (logical 0)

If phase time-overcurrent element 51P1T is **timed out** on its curve, Relay Word bit 51P1T is in the following state:

51P1T = 1 (logical 1)

Phase Time-Overcurrent Element 51P1T Reset Indication

If phase time-overcurrent element 51P1T is **not fully reset**, Relay Word bit 51P1R is in the following state:

51P1R = 0 (logical 0)

If phase time-overcurrent element is **fully reset**, Relay Word bit 51P1R is in the following state:

51P1R = 1 (logical 1)

If phase time-overcurrent element 51P1T is **not fully reset**, the element is either:

- Timing on its curve
- Already timed out
- Is timing to reset (one-cycle reset or electromechanical emulation—see setting 51P1RS)

Relay Word Bit Application Examples–Phase Time-Overcurrent Element 51P1T

Table G.2 describes common uses for Relay Word bits 51P1, 51P1T, and 51P1R:

Table G.2 Common Uses for Relay Word bits 51P1, 51P1T, and 51P1R

Relay Word Bit	Common Use
51P1	testing (e.g., assign to an output contact for pickup testing) trip unlatch logic (see SELOGIC control equation unlatch trip setting ULTR example later in this section)
51P1T	trip logic (see SELOGIC control equation trip setting TR example later in this section)
51P1R	used in testing (e.g., assign to an output contact for reset indication)

Other Relay Word Bits

The preceding example was for a phase time-overcurrent element, demonstrating Relay Word bit operation for pickup, time-out, and reset conditions. Other Relay Word bits (e.g., those for definite-time overcurrent elements, voltage elements, frequency elements) behave similarly in their assertion or deassertion to logical 1 or logical 0, respectively. The time-

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overcurrent elements (like the preceding phase time-overcurrent element example) are rather unique because they have a Relay Word bit (e.g., 51P1R) that asserts for the reset state of the element.

Relay Word bits are used in SELOGIC control equations, which are explained in the following subsection.

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SELOGIC Control Equations

Many of the protection and control element **logic inputs** shown in the various figures in *Section 3: Overcurrent, Voltage, Synchronism Check, Frequency, and Power Elements*–*Section 8: Breaker Monitor, Metering, and Load Profile Functions* are SELOGIC control equations (labeled SELOGIC Settings in most of the figures).

SELOGIC control equations are set with combinations of Relay Word bits to accomplish such functions as:

- Tripping circuit breakers
- Assigning functions to optoisolated inputs
- Operating output contacts
- Torque-controlling overcurrent elements
- Switching active setting groups
- Enabling/disabling reclosing

Traditional or advanced custom schemes can be created with SELOGIC control equations.

SELOGIC Control Equation Operators

SELOGIC control equation settings use logic similar to Boolean algebra logic, combining Relay Word bits together using one or more of the six SELOGIC control equation operators listed in *Table G.3*.

Table G.3 SELOGIC Control Equation Operators (Listed in Processing Order)

Operator	Logic Function
/	rising edge detect
\	falling edge detect
()	parentheses
!	NOT
*	AND
+	OR

Operators in a SELOGIC control equation setting are processed in the order shown in *Table G.3*.

SELOGIC Control Equation Parentheses Operator ( )

More than one set of parentheses ( ) can be used in a SELOGIC control equation setting. For example, the following SELOGIC control equation setting has two sets of parentheses:

SV7 = (SV7+IN101)*(50P1+50N1)

In the above example, the logic within the parentheses is processed first and then the two parentheses resultants are ANDed together. The above example is from *Figure 7.27*. Parentheses cannot be nested (parentheses within parentheses) in a SELOGIC control equation setting.

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SELOGIC Control Equation NOT Operator !

The NOT operator ! is applied to a single Relay Word bit and also to multiple elements (within parentheses). Following are examples of both.

Example of NOT Operator ! Applied to Single Element

The internal circuit breaker status logic in the SEL-351S operates on 52a circuit breaker auxiliary contact logic. The SELOGIC control equation circuit breaker status setting is labeled 52A. See *Optoisolated Inputs on page 7.2* and *Close Logic on page 6.2* for more information on SELOGIC control equation circuit breaker status setting 52A.

When a circuit breaker is closed, the 52a circuit breaker auxiliary contact is closed. When a circuit breaker is open, the 52a contact is open.

The opposite is true for a 52b circuit breaker auxiliary contact. When a circuit breaker is closed, the 52b circuit breaker auxiliary contact is open. When the circuit breaker is open, the 52b contact is closed.

If a 52a contact is connected to optoisolated input **IN101**, the SELOGIC control equation circuit breaker status setting 52A is set:

52A = **IN101**

Conversely, if a 52b contact is connected to optoisolated input **IN101**, the SELOGIC control equation circuit breaker status setting 52A is set:

52A = **!IN101** [=NOT(IN101)]

With a 52b contact connected, if the circuit breaker is closed, the 52b contact is open and input **IN101** is de-energized [IN101 = 0 (logical 0)]:

52A = **!IN101** = NOT(IN101) = NOT(0) = 1

Thus, the SELOGIC control equation circuit breaker status setting 52A sees a closed circuit breaker.

With a 52b contact connected, if the circuit breaker is open, the 52b contact is closed and input **IN101** is energized [IN101 = 1 (logical 1)]:

52A = **!IN101** = NOT(IN101) = NOT(1) = 0

Thus, the SELOGIC control equation circuit breaker status setting 52A sees an open circuit breaker.

Example of NOT Operator ! Applied to Multiple Elements (Within Parentheses)

The SELOGIC control equation trip unlatch setting is set as follows:

ULTR = !(51P1 + 51G1)

Refer also to *Trip Logic on page 5.1*.

In this factory setting example, the unlatch condition comes true only when **both** the 51P1 (phase time-overcurrent element pickup indication) and 51G1 (residual ground time-overcurrent element pickup indication) Relay Word bits deassert:

ULTR = **!(51P1 + 51G1)** = NOT(51P1 + 51G1)

As stated previously, the logic within the parentheses is performed first. In this example, the states of Relay Word bits 51P1 and 51G1 are ORed together. Then the NOT operator is applied to the logic resultant from the parentheses.

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If either one of 51P1 or 51G1 is still asserted [e.g., 51G1 = 1 (logical 1)], the unlatch condition is not true:

ULTR = **NOT(51P1 + 51G1)** = NOT(0 + 1) = NOT(1) = 0

If **both** 51P1 and 51G1 are deasserted [i.e., 51P1 = 0 and 51G1 = 0 (logical 0)], the unlatch condition is true:

ULTR = **NOT(51P1 + 51G1)** = NOT(0 + 0) = NOT(0) = 1

and the trip condition can unlatch, subject to other conditions in the trip logic (see *Figure 5.1*).

SELOGIC Control Equation Rising Edge Operator /

The rising edge operator / is applied to individual Relay Word bits only—not to groups of elements within parentheses. For example, the SELOGIC control equation event report generation setting uses rising edge operators:

ER = **/51P1 + /51G1 + /OUT103**

The Relay Word bits in this factory setting example are in *Table G.4*:

Table G.4 Relay Word Bits in Factory Setting Example

Relay Word Bit	Description
51P1	Maximum phase current above pickup setting 51P1P for phase time-over-current element 51P1T (see *Figure 3.14*)
51G1	Maximum residual ground current above pickup setting 51G1P for residual ground time-overcurrent element 51G1T (see *Figure 3.18*)
OUT103	Output contact **OUT103** is set as a breaker failure trip output (see *Output Contacts on page 7.32*)

When setting ER sees a logical 0 to logical 1 transition, it generates an event report (if the relay is not already generating a report that encompasses the new transition). The rising edge operators in the above factory setting example allow setting ER to see each transition individually.

Suppose a ground fault occurs and a breaker failure condition finally results. *Figure G.1* demonstrates the action of the rising edge operator / on the individual elements in setting ER.

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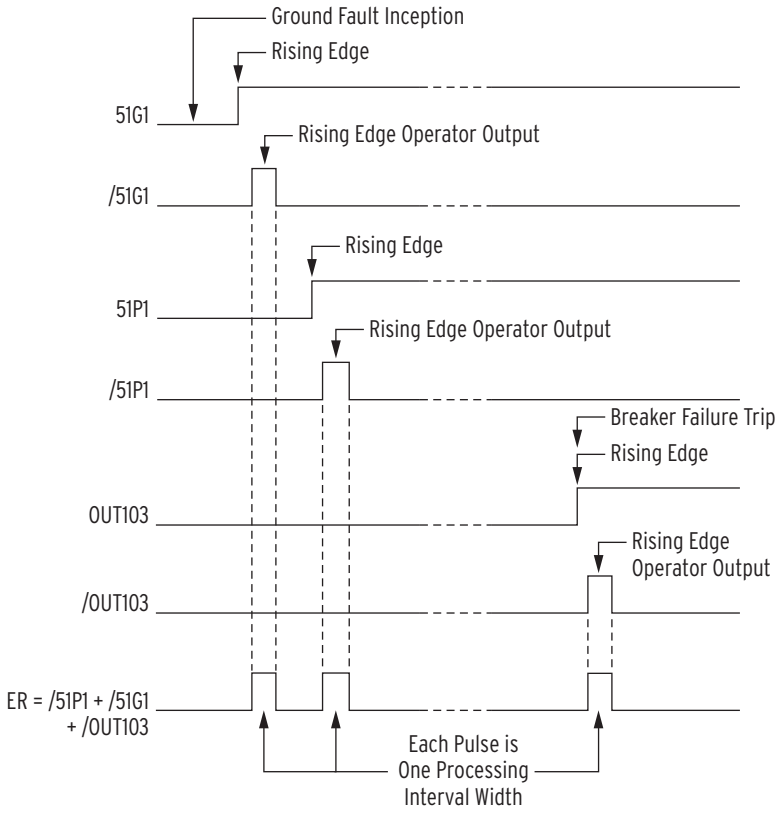


Figure G.1 Result of Rising Edge Operators on Individual Elements in Setting ER

Note in *Figure G.1* that setting ER sees three separate rising edges, due to the application of rising edge operators /. The rising edge operator / in front of a Relay Word bit sees this logical 0 to logical 1 transition as a "rising edge" and the resultant asserts to logical 1 for one processing interval. The assertions of 51G1 and 51P1 are close enough that they will be on the same event report (generated by 51G1 asserting first). The assertion of OUT103 for a breaker failure condition is some appreciable time later and will generate another event report, if the first event report capture has ended when OUT103 asserts.

If the rising edge operators / were not applied and setting ER was

ER = **51P1 + 51G1 + OUT103**

the ER setting would not see the assertion of OUT103, because 51G1 and 51P1 would continue to be asserted at logical 1, as shown in *Table G.3*.

SELOGIC Control Equation Falling Edge Operator \

The falling edge operator \ is applied to individual Relay Word bits only—not to groups of elements within parentheses. The falling edge operator \ operates similar to the rising edge operator, but looks for Relay Word bit deassertion (element going from logical 1 to logical 0). The falling edge operator \ in front of a Relay Word bit sees this logical 1 to logical 0 transition as a "falling edge" and asserts to logical 1 for one processing interval.

For example, suppose the SELOGIC control equation event report generation setting is set with the detection of the falling edge of an underfrequency element:

ER = **... + \81D1T**

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When frequency goes above the corresponding pickup level 81D1P, Relay Word bit 81D1T deasserts and an event report is generated (if the relay is not already generating a report that encompasses the new transition). This allows a recovery from an underfrequency condition to be observed. See *Figure 3.31* and *Table 3.12*. *Figure G.2* demonstrates the action of the falling edge operator \ on the underfrequency element in setting ER.

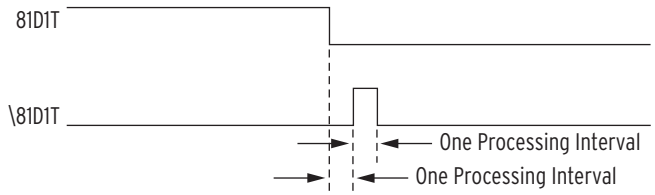


Figure G.2 Result of Falling Edge Operator on a Deasserting Underfrequency Element

SELOGIC Control Equation Operation Example—Tripping

If tripping does not involve communications-assisted or switch-onto-fault trip logic, the SELOGIC control equation trip setting TR is the only trip setting needed. Refer to *Trip Logic on page 5.1*.

Note that *Figure 5.1* appears quite complex. But since tripping does not involve communications-assisted or switch-onto-fault trip logic in this example, respective SELOGIC control equation trip settings TRCOMM and TRSOTF are not used. The only effective input into logic gate OR-1 in *Figure 5.1* is SELOGIC control equation trip setting TR.

TR = **51P1T+51G1T+50P1*SH0** (fuse saving example)

TRCOMM = **0** (not used—set directly to logical 0)

TRSOTF = **0** (not used—set directly to logical 0)

ULTR = **!(51P1 + 51G1)** (discussed in preceding subsection)

Analysis of SELOGIC Control Equation Trip Setting TR

Again, the example trip equation is:

TR = **51P1T+51G1T+50P1*SH0**

The Relay Word bit definitions are as follows:

51P1T	phase time-overcurrent element timed out
51G1T	residual ground time-overcurrent element timed out
50P1	phase instantaneous overcurrent element asserted
SH0	reclosing relay shot counter at shot = 0

In the trip equation, the AND operator * is executed before the OR operators +, *Table G.3*:

50P1*SH0

Element 50P1 can only cause a trip if the reclosing relay shot counter is at shot = 0. When the reclosing relay shot counter is at shot = 0 (see *Table 6.3*), Relay Word bit SH0 is in the following state:

SH0 = 1 (logical 1)

If maximum phase current is **above** the phase instantaneous overcurrent element pickup setting 50P1P (see *Figure 3.1*), Relay Word bit 50P1 is in the following state:

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50P1 = 1 (logical 1)

With SH0 = 1 and 50P1 = 1, the ANDed combination results in:

50P1*SH0 = 1*1 = 1 (logical 1)

and an instantaneous trip results. This logic is commonly used in fuse saving schemes for distribution feeders.

If the reclosing relay shot counter advances to shot = 1 for the reclose that follows the trip, Relay Word bit SH0 is in the following state:

SH0 = 0 (logical 0)

If maximum phase current is **above** the phase instantaneous overcurrent element pickup setting 50P1P for the recurring fault, Relay Word bit 50P1 is in the following state:

50P1 = 1 (logical 1)

With SH0 = 0 and 50P1 = 1, the ANDed combination results in:

50P1*SH0 = 1*0 = 0 (logical 0)

and no trip results from phase instantaneous overcurrent element 50P1.

A trip will eventually result if time-overcurrent element 51P1T or 51G1T times out. If residual ground time-overcurrent element 51G1T times out, Relay Word bit 51G1T is in the following state:

51G1T = 1 (logical 1)

When shot = 1, SH0 = 0 and the result is:

TR = 51P1T+51G1T+50P1*SH0 = 0 + 1 + 1*0 = 0 + 1 + 0 = 1

and a time-delayed trip results from residual ground time-overcurrent element 51G1T.

Set an Output Contact for Tripping

To assert output contact **OUT101** to trip a circuit breaker, make the following SELOGIC control equation output contact setting (see *Output Contacts on page 7.32*):

OUT101 = **TRIP**

All SELOGIC Control Equations Must Be Set

All SELOGIC control equations must be set one of the following ways (they cannot be blank):

- single Relay Word bit (e.g., 52A = IN101)
- combination of Relay Word bits (e.g., TR = 51P1T+51G1T+50P1*SH0)
- directly to logical 1 (e.g., 67P1TC = 1)
- directly to logical 0 (e.g., TRCOMM = 0)

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Set SELOGIC Control Equations Directly to 1 or 0

SELOGIC control equations can be set directly to:

1 (logical 1) or (logical 0)

instead of with Relay Word bits. If a SELOGIC control equation setting is set directly to 1, it is always asserted/on/enabled. If a SELOGIC control equation setting is set equal to 0, it is always deasserted/off/disabled.

NOTE: SELOGIC control equation torque control settings (e.g., 67P1TC, 51P1TC) cannot be set directly to logical 0.

Under the *SHO Command (Show/View Settings) on page 10.27*, note that a number of the factory SELOGIC control equation settings are set directly to 1 or 0.

The individual SELOGIC control equation settings explanations (referenced in *SELOGIC Control Equation Settings (Serial Port Command SET L) on page SET.18)* discuss whether it makes logical sense to set the given SELOGIC control equation setting to 0 or 1 for certain criteria.

Set SELOGIC Control Equations Directly to 1 or 0–Example

Of special concern are the SELOGIC control equation torque control settings 67P1TC–51QTC for the overcurrent elements. In the **factory settings** the SEL-351S ships with in a standard relay shipment, these are all set directly to logical 1. See these factory settings in *SHO Command (Show/View Settings) on page 10.27*.

If one of these torque control settings is **set directly to logical 1**

e.g., 51P1TC = 1 (set directly to logical 1)

then the corresponding overcurrent element (e.g., phase time-overcurrent element 51P1T) is subject only to the directional control. See *Figure 3.14* for phase time-overcurrent element 51P1T logic.

If the directional control enable setting E32 = N (and 51P1TC = 1), then time-overcurrent element 51P1T is enabled (assuming pickup setting 51P1P is made) and nondirectional.

SELOGIC Control Equation Limitations

Any single SELOGIC control equation setting is **limited to 15 Relay Word bits** that can be combined together with the SELOGIC control equation operators listed in *Table G.3*. If this limit must be exceeded, use a SELOGIC control equation variable (SELOGIC control equation settings SV1–SV12) as an intermediate setting step.

For example, assume that the trip equation (SELOGIC control equation trip setting TR) needs more than 15 Relay Word bits in its equation setting. Instead of placing all Relay Word bits into TR, program some of them into the SELOGIC control equation setting SV1. Next use the resultant SELOGIC control equation variable output (Relay Word bit SV1) in the SELOGIC control equation trip setting TR.

Note in *Table G.3* that the SELOGIC control equation variables (SELOGIC control equation settings SV1–SV16) are processed after the trip equation (SELOGIC control equation trip setting TR). Thus, any tripping via Relay Word bits SV1–SV16 can be delayed as much as 1/4 cycle. For most applications, this is probably of no consequence.

The SELOGIC control equation settings as a whole in a particular setting group have the following limitations:

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Table G.5 SELOGIC Control Equation Settings Limitations

Model Number	SELOGIC Control Equation Settings Limitations per Setting Group
0351S	Total number of elements ≤ 400 Total number of rising edge or falling edge operators ≤ 30

SELOGIC control equation settings that are set directly to 1 (logical 1) or 0 (logical 0) also have to be included in these limitations—each such setting counted as one Relay Word bit.

After SELOGIC control equation settings changes have been made and the settings are saved, the SEL-351S responds with the following message:

```
xxx Elements and yy Edges remain available
```

indicating that xxx Relay Word bits can still be used and yy rising or falling edge operators can still be applied in the SELOGIC control equations for the particular settings group.

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Processing Order and Processing Interval

The relay elements and logic (and corresponding SELOGIC control equation settings and resultant Relay Word bits) are processed in the order shown in *Table G.6* (top to bottom). They are processed every quarter-cycle (1/4-cycle), and the Relay Word bit states (logical 1 or logical 0) are updated with each quarter-cycle pass. Thus, the relay processing interval is 1/4-cycle. Once a Relay Word bit is asserted, it retains the state (logical 1 or logical 0) until it is updated again in the next processing interval.

Table G.6 Processing Order of Relay Elements and Logic (Top to Bottom) (Sheet 1 of 3)

Relay Elements and Logic (related SELOGIC Control Equations listed in parentheses)	Order of processing of the SELOGIC Control Equations (listed in parentheses) and Relay Word Bits	Reference Instruction Manual Section
Analog and digital data acquisition	DCLO, DCHI, IN101–IN106, IN201–IN208, IAMET, IBMET, ICMET, INMET, V0GAIN	*Section 7*, *Section 8*, and *Section 9*
Polarizing Voltage	VPOLV	*Section 4*
Received MIRRORED BITS® elements	ROKA, LBOKA, RMB8A–RMB1A, ROKB, LBOKB, RMB8B–RMB1B	*Appendix I*
Local Control Switches	LB8–LB1, LB16–LB9	*Section 7*
Remote Control Switches	RB8–RB1, RB16–RB9	*Section 7*
Power Elements	PWRA1, PWRA2, PWRA3, PWRA4, PWRB1, PWRB2, PWRB3, PWRB4, PWRC1, PWRC2, PWRC3, PWRC4, 3PWR1, 3PWR2, 3PWR3, 3PWR4	*Section 3*
Miscellaneous Instantaneous Overcurrent Elements	50A1–50A4, 50B1–50B4, 50C1–50C4, 50A, 50B, 50C, 50AB1–50AB4, 50BC1–50BC4, 50CA1–50CA4, 50L, 50P5, 50P6, 50QF, 50QR, 50Q5, 50Q6, 50GF, 50GR, 50G5, 50G6, 50N5, 50N6	*Section 3*
Open Breaker Logic (52A)	(52A), 52A, 3PO	*Section 5*
Loss-of-Potential	LOP, V1GOOD	*Section 4*
Fault Identification Logic	FSA, FSB, FSC	*Section 5*
Load Encroachment	ZLOAD, ZLOUT, ZLIN	*Section 4*
Latch Control Switches (SET*n*, RST*n*, where *n* = 1 to 16)	{(SET*n*), (RST*n*), where *n* = 1 to 16}, LT1–LT16	*Section 7*
Voltage Sag/Swell/Interruption Elements	SAGA, SAGB, SAGC, SAGAB, SAGBC, SAGCA, SAG3P, SWA, SWB, SWC, SWAB, SWBC, SWCA, SW3P, INTA, INTB, INTC, INTAB, INTBC, INTCA, INT3P	*Section 3*
Frequency Elements	27B81, 81D1, 81D1T, 81D2, 81D2T, 81D3, 81D3T, 81D4, 81D4T, 81D5, 81D5T, 81D6, 81D6T	*Section 3*

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Table G.6 Processing Order of Relay Elements and Logic (Top to Bottom) (Sheet 2 of 3)

Relay Elements and Logic (related SELOGIC Control Equations listed in parentheses)	Order of processing of the SELOGIC Control Equations (listed in parentheses) and Relay Word Bits	Reference Instruction Manual Section
Voltage Elements	59A1, 27A1, 59A2, 27A2, 59B1, 27B1, 59B2, 27B2, 59C1, 27C1, 59C2, 27C2, 59AB, 27AB, 59AB2, 27AB2, 59BC, 27BC, 59BC2, 27BC2, 59CA, 27CA, 59CA2, 27CA2, 3P27, 3P59, 59S1, 27S, 59S2, 59V1, 59Q, 59Q2, 59N1, 59N2	*Section 3*
Synchronism Check Elements and Vs (BSYNCH)	(BSYNCH), 59VS, 59VP, 59VA, SSLOW, SFAST, SF, 25A1, 25A2	*Section 3*
Directional Elements (E32IV)	(E32IV), 32VE, 32IE, 32QE, 32QGE, GNDSW, 50NF, 50NR, 32NE, F32N, R32N, 50P32, F32P, R32P, F32I, R32I, F32V, R32V, F32QG, R32QG, F32Q, R32Q, 32PF, 32QR, 32QF, 32PR, 32GR, 32GF, 32NF, 32NR, NSA, NSB, NSC, F32C, R32C, F32W, R32W	*Section 4*
Torque Control for Instantaneous/ Definite-Time Overcurrent Elements (67P1TC–67P4TC, 67N1TC–67N4TC, 67G1TC–67G4TC, 67Q1TC–67Q4TC)	(67P1TC–67P4TC, 67N1TC–67N4TC, 67G1TC–67G4TC, 67Q1TC–67Q4TC)	*Section 3*
Switch-onto-Fault Logic (CLMON)	(CLMON)	*Section 5*
Instantaneous/Definite-Time Overcurrent Elements (67P1TC–67P4TC, 67N1TC–67N4TC, 67G1TC–67G4TC, 67Q1TC–67Q4TC)	50P1, 67P1, 67P1T, 50P2, 67P2, 67P2S, 67P2T, 50P3, 67P3, 67P3T, 50P4, 67P4, 67P4T, 50N1, 67N1, 67N1T, 50N2, 67N2, 67N2S, 67N2T, 50N3, 67N3, 67N3T, 50N4, 67N4, 67N4T, 50G1, 67G1, 67G1T, 50G2, 67G2, 67G2S, 67G2T, 50G3, 67G3, 67G3T, 50G4, 67G4, 67G4T, 50Q1, 67Q1, 67Q1T, 50Q2, 67Q2, 67Q2S, 67Q2T, 50Q3, 67Q3, 67Q3T, 50Q4, 67Q4, 67Q4T	*Section 3*
Time-Overcurrent Elements (51P1TC, 51N1TC, 51G1TC, 51P2TC, 51N2TC, 51G2TC, 51QTC)	(51P1TC, 51N1TC, 51G1TC, 51P2TC, 51N2TC, 51G2TC, 51QTC), 51P1, 51P1T, 51P1R, 51P2, 51P2T, 51P2R, 51N1, 51N1T, 51N1R, 51N2, 51N2T, 51N2R, 51G1, 51G1T, 51G1R, 51G2, 51G2T, 51G2R, 51Q, 51QT, 51QR	*Section 3*
Switch-onto-Fault Logic (CLMON)	SOTFE	*Section 5*
Trip Logic (TR, TRSOTF, TRCOMM, DTT, ULTR) and Communications-Assisted Trip (PT1, LOG1, PT2, LOG2, BT) Schemes	(TR, TRCOMM, TRSOTF, DTT, ULTR, PT1, LOG1, PT2, LOG2, BT), PT, Z3RB, EKEY, KEY, WFC, ECTT, UBB2, PTRX2, UBB1, PTRX1, UBB, DSTRT, Z3XT, NSTRT, STOP, BTX, PTRX, SOTFT, COMMT, TRIP	*Section 5*
Close Logic (CL, ULCL) Reclosing Relay (79RI, 79RIS, 79DTL, 79DLS, 79SKP, 79STL, 79BRS, 79SEQ, 79CLS)	(CL, ULCL, 79RI, 79RIS, 79DTL, 79DLS, 79SKP, 79STL, 79BRS, 79SEQ, 79CLS), CF, 79LO, 79CY, 79RS, RCSF, RSTMN, OPTMN, CLOSE, SH0, SH1, SH2, SH3, SH4	*Section 6*
Breaker Monitor (BKMON)	(BKMON), BCWA, BCWB, BCWC, BCW	*Section 8*

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Table G.6 Processing Order of Relay Elements and Logic (Top to Bottom) (Sheet 3 of 3)

Relay Elements and Logic (related SELOGIC Control Equations listed in parentheses)	Order of processing of the SELOGIC Control Equations (listed in parentheses) and Relay Word Bits	Reference Instruction Manual Section
SELOGIC Control Equation Variables/Timers (SV1–SV16)	{(SV*n*), SV*n*, SV*n*T, where *n* = 1 to 16}	*Section 7*
OUT101–OUT107 OUT201–OUT212 (extra I/O board)	OUT101–OUT107 OUT201–OUT212 (extra I/O board)	*Section 7*
Display Points (DP1–DP16)	(DP1–DP16)	*Section 7*
Setting Group control (SS1–SS6)	(SS1–SS6)	*Section 7*
Event Report Trigger (ER)	(ER)	*Section 12*
Fault detector for Target Logic and Metering (FAULT)	(FAULT), FAULT	*Section 5* and *Section 8*
Transmit MIRRORED BITS (TMB1A–TMB8A, TMB1B–TMB8B)	{(TMB*m*A), TMB*m*A, where *m* = 1 to 8} {(TMB*n*B), TMB*n*B, where *n* = 1 to 8}	*Appendix I*
Alarm	ALARM	*Section 13*
Programmable LEDs (LED1–LED10) and Programmable Target LEDs (LED12–LED21, LED25, LED26)	{(LED*m*), LED*m*, where *m* = 1 to 10}, (LED12–LED19), LED19, (LED20), LED20, (LED21), LED21, (LED25), LED25, (LED26), LED26, LED22, LED23, LED24	*Section 5* and *Section 11*
Operator Controls	PB*n*, where *n* = 1 to 10	*Section 11*

Asynchronous processing: The Relay Word bits in *Table G.7* are processed separately from the above list. They can be thought of as being processed just before (or just after) *Table G.6*.

Table G.7 Asynchronous Processing Order of Relay Elements

Relay Elements and Logic (related SELOGIC Control Equations listed in parentheses)	Order of processing of the SELOGIC Control Equations (listed in parentheses) and Relay Word Bits	Reference Instruction Manual Section
Target Reset	TRGTR	*Section 5*
Setting Group indication (SS1–SS6)	SG6–SG1	*Section 7*
Breaker remote control bits	CC, OC	*Section 10*
Demand Ammeters	QDEM, GDEM, NDEM, PDEM	*Section 8*
MIRRORED BITS element status	RBADA, CBADA, RBADB, CBADB	*Appendix I*
Voltage input configuration	DELTA, 3V0	*Section 9*
IRIG-B and Synchrophasor status	PMDOK, TIRIG, TSOK	*Appendix L*

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Appendix H
Distributed Network Protocol

Overview

NOTE: The response to the **VER** command will indicate "DNP" under Extended Relay Features if the relay has DNP.

The SEL-351S is available with Distributed Network Protocol (DNP3) L2 Slave protocol. This includes access to metering data, protection elements (Relay Word), contact I/O, targets, sequential events recorder, breaker monitor, relay summary event reports, settings groups, and time synchronization.

The SEL-351S supports DNP point re-mapping. Two modes of operation are available:

- Standard, for backwards and cross-platform compatibility
- Extended, with additional features

Both modes of operation are detailed in this appendix.

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Configuration

Although standard or extended mode DNP may be selected on any of the available ports, DNP may not be enabled on more than one port at a time.

Standard Mode DNP Operation

To configure a port for Standard Mode DNP, set the port PROTO setting to DNP. *Table H.1* lists the settings that configure a port for DNP operation.

Table H.1 Port Settings for Standard Mode DNP Operation

Label	Description	Default
SPEED	Baud Rate (300–38400)[a]	2400
DNPADR	DNP Address (0–65534)	0
ECLASS	Class for Event Data (0–3)	2
TIMERQ	Minutes for Request Interval (0–32767)	0
DECPLA	Currents Scaling Decimal Places (0–3)	1
DECPLV	Voltages Scaling Decimal Places (0–3)	1
DECPLM	Misc Data Scaling Decimal Places (0–3)	1
STIMEO	Seconds to Select/Operate Time-out (0.0–30)	1.0
DRETRY	Data Link Retries (0–15)	3
DTIMEO	Seconds to Data Link Time-out (0–5)	1
MINDLY	Minimum Seconds from DCD to Tx (0.00–1)	0.05
MAXDLY	Maximum Seconds from DCD to Tx (0.00–1)	0.10
PREDLY	Settle Time from RTS ON to Tx (OFF,0.00–30 sec)	0.00
PSTDLY	Settle Time from Tx to RTS OFF (0.00–30 sec)	0.00
ANADB	Analog Reporting Dead Band Counts (0–32767)	100
UNSOL	Enable Unsolicited Reporting (Y,N)	N
PUNSOL	Enable Unsolicited Reporting at Power-up (Y,N)	N
REPADR	DNP Address to Report to (0–65534)	0
NUMEVE	Number of Events to Transmit on (1–200)	10
AGEEVE	Seconds until Oldest Event to Tx on (0.0–60)	2.0
UTIMEO	Seconds to Event Message Confirm Time-out (1–50)	2

[a] 38400 is not available on Port 1.

Extended Mode DNP Operation

To configure a port for extended mode DNP, set the port PROTO setting to DNPE (extended mode). *Table H.2* lists the settings that configure a port for DNPE operation.

Table H.2 Port Settings for Extended Mode DNP Operation (Sheet 1 of 2)

Label	Description	Default
SPEED	Baud Rate (300–38400)[a]	2400
DNPADR	DNP Address (0–65534)	0
TIMERQ	Minutes for Request Interval (0–32767)	0
CLASSA	Class for Analog Event Data (0–3)	2
CLASSB	Class for Binary Event Data (0–3)	2
CLASSC	Class for Counter Event Data (0–3)	2

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Table H.2 Port Settings for Extended Mode DNP Operation (Sheet 2 of 2)

Label	Description	Default
DECPLA	Currents Scaling Decimal Places (0–3)	1
DECPLV	Voltages Scaling Decimal Places (0–3)	1
DECPLM	Misc Data Scaling Decimal Places (0–3)	1
STIMEO	Seconds to Select/Operate Time-out (0.0–30)	1.0
DRETRY	Data Link Retries (0–15)	3
DTIMEO	Seconds to Data Link Time-out (0–5)	1
MINDLY	Minimum Seconds from DCD to Tx (0.00–1)	0.05
MAXDLY	Maximum Seconds from DCD to Tx (0.00–1)	0.10
PREDLY	Settle Time from RTS ON to Tx (OFF,0.00–30 sec)	0.00
PSTDLY	Settle Time from Tx to RTS OFF (0.00–30 sec)	0.00
ANADBA	Amps Reporting Dead Band Counts (0–32767)	100
ANADBV	Volts Reporting Dead Band Counts (0–32767)	100
ANADBM	Misc Data Reporting Dead Band Counts (0–32767)	100
UNSOL	Enable Unsolicited Reporting (Y,N)	N
PUNSOL	Enable Unsolicited Reporting at Power-up (Y,N)	N
REPADR	DNP Address to Report to (0–65534)	0
NUMEVE	Number of Events to Transmit on (1–200)	10
AGEEVE	Seconds until Oldest Event to Tx on (0.0–60)	2.0
UTIMEO	Seconds to Event Message Confirm Time-out (1–50)	2

[a] 38400 is not available on Port 1.

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EIA-232 Physical Layer Operation

The RTS signal may be used to control an external transceiver. The CTS signal is used as a DCD input, indicating when the medium is in use. Transmissions are only initiated if DCD is deasserted. When DCD drops, the next pending outgoing message may be sent once an idle time is satisfied. This idle time is randomly selected between the minimum and maximum allowed idle times (i.e., MAXDLY and MINDLY).

In addition, the SEL-351S monitors received data and treats receipt of data as a DCD indication. This allows RTS to be looped back to CTS in cases where the external transceiver does not support DCD. When the SEL-351S transmits a DNP message, it delays transmitting after asserting RTS by at least the time in the PREDLY setting. After transmitting the last byte of the message, the SEL-351S delays for at least PSTDLY milliseconds before deasserting RTS. If the PSTDLY time delay is in progress (RTS still high) following a transmission, and another transmission is initiated, the SEL-351S transmits the message without completing the PSTDLY delay and without any preceding PREDLY delay.

The RTS/CTS handshaking may be completely disabled by setting PREDLY to OFF. In this case, RTS is forced high and CTS is ignored, with only received characters acting as a DCD indication. The timing is the same as above, but PREDLY functions as if it were set to 0, and RTS is not actually deasserted after the PSTDLY time delay expires.

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Data-Link Operation

It is necessary to make two important decisions about the data-link layer operation. One is how to handle data-link confirmation, the other is how to handle data-link access. If a highly reliable communications link exists, the data-link access can be disabled altogether, which significantly reduces communications overhead. Otherwise, it is necessary to enable confirmation and determine how many retries to allow and what the data-link time-out should be. The noisier the communications channel, the more likely a message will be corrupted. Thus, the number of retries should be set higher on noisy channels. Set the data-link time-out long enough to allow for the worst-case response of the master plus transmission time. When the SEL-351S decides to transmit on the DNP link, it has to wait if the physical connection is in use. The SEL-351S monitors physical connections by using CTS input (treated as a Data Carrier Detect) and monitoring character receipt. Once the physical link goes idle, as indicated by CTS being deasserted and no characters being received, the SEL-351S will wait a configurable amount of time before beginning a transmission. This hold-off time will be a random value between the MINDLY and MAXDLY setting values. The hold-off time is random, which prevents multiple devices waiting to communicate on the network from continually colliding.

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Data Access Method

Based on the capabilities of the system, it is necessary to determine which method is desired to retrieve data on the DNP connection. *Table H.3* summarizes the main options, listed from least to most efficient, and corresponding key related settings are indicated.

Table H.3 Data Access Methods

Data Retrieval Method	Description	Relevant SEL-351S DNP (Standard) Settings	Relevant SEL-351S DNPE (Extended) Settings
Polled Static	The master polls for static (Class 0) data only.	Set ECLASS = 0 Set UNSOL = N	Set CLASSA = 0 Set CLASSB = 0 Set CLASSC = 0 Set UNSOL = N
Polled Report-by-Exception	The master polls frequently for event data and occasionally for static data.	Set ECLASS to a non-zero value Set UNSOL = N	Set CLASSA = to a non-zero value Set CLASSB = to a non-zero value Set CLASSC = to a non-zero value Set UNSOL = N
Unsolicited Report-by-Exception	The slave devices send unsolicited event data to the master and the master occasionally sends integrity polls for static data.	Set ECLASS to a non-zero value Set UNSOL = Y Set NUMEVE and AGEEVE according to how often messages are desired to be sent.	Set CLASSA = to a non-zero value Set CLASSB = to a non-zero value Set CLASSC = to a non-zero value Set UNSOL = Y Set NUMEVE and AGEEVE according to how often messages are desired to be sent.
Quiescent	The master never polls and relies on unsolicited reports only.	Set ECLASS to a non-zero value Set UNSOL = Y Set NUMEVE and AGEEVE according to how often messages are desired to be sent.	Set CLASSA = to a non-zero value Set CLASSB = to a non-zero value Set CLASSC = to a non-zero value Set UNSOL = Y Set NUMEVE and AGEEVE according to how often messages are desired to be sent.

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Device Profile

Table H.4 summarizes the device profile as specified in the *DNP3 Subset Definitions* document.

Table H.4 SEL-351S DNP3 Device Profile (Sheet 1 of 2)

Parameter	Value
Vendor name	Schweitzer Engineering Laboratories
Device name	SEL-351S
Highest DNP request level	Level 2
Highest DNP response level	Level 2
Device function	Slave
Notable objects, functions, and/or qualifiers supported	Supports enabling/disabling of unsolicited reports on a class basis
Maximum data link frame size transmitted/received (octets)	292
Maximum data link retries	Configurable, range 0 to 15
Requires data link layer confirmation	Configurable by setting
Maximum application fragment size transmitted/received (octets)	2048
Maximum application layer retries	None
Requires application layer confirmation	When reporting Event Data
Data link confirm time-out	Configurable
Complete application fragment time-out	None
Application confirm time-out	Configurable
Complete Application response time-out	None
Executes control WRITE binary outputs	Always
Executes control SELECT/OPERATE	Always
Executes control DIRECT OPERATE	Always
Executes control DIRECT OPERATE–NO ACK	Always
Executes control count greater than 1	Never
Executes control Pulse On	Always
Executes control Pulse Off	Always
Executes control Latch On	Always
Executes control Latch Off	Always
Executes control Queue	Never
Executes control Clear Queue	Never
Reports binary input change events when no specific variation requested	Only time-tagged
Reports time-tagged binary input change events when no specific variation requested	Binary Input change with time
Sends unsolicited responses	Configurable with enable/disable unsolicited
Sends static data in unsolicited responses	Never

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Table H.4 SEL-351S DNP3 Device Profile (Sheet 2 of 2)

Parameter	Value
Default counter object/variation	Object 20, Variation 6
Counter roll-over	16 bits
Sends multifragment responses	No

In all cases within the device profile that an item is configurable, it is controlled by SEL-351S settings.

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Object Table

The supported object, function, and qualifier code combinations are given by *Table H.5*.

Table H.5 SEL-351S DNP Object Table (Sheet 1 of 5)

Object			Request[a]		Response[b]	
Obj	Var	Description	Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
1	0	Binary Input—All Variations	1	0,1,6,7,8		
1	1	Binary Input	1	0,1,6,7,8	129	0,1,7,8
1	2[e]	Binary Input with Status	1	0,1,6,7,8	129	0,1,7,8
2	0	Binary Input Change—All Variations	1	6,7,8		
2	1	Binary Input Change without Time	1	6,7,8	129	17,28
2	2[e]	Binary Input Change with Time	1	6,7,8	129,130	17,28
2	3	Binary Input Change with Relative Time	1	6,7,8	129	17,28
10	0	Binary Output—All Variations	1	0,1,6,7,8		
10	1	Binary Output				
10	2[e]	Binary Output Status	1	0,1,6,7,8	129	0,1
12	0	Control Block—All Variations				
12	1	Control Relay Output Block	3,4,5,6	17,28	129	echo of request
12	2	Pattern Control Block				
12	3	Pattern Mask				
20	0	Binary Counter—All Variations	1	0,1,6,7,8		
20	1	32-Bit Binary Counter				
20	2	16-Bit Binary Counter				
20	3	32-Bit Delta Counter				
20	4	16-Bit Delta Counter				
20	5	32-Bit Binary Counter without Flag	1	0,1,6,7,8	129	0,1,7,8
20	6[e]	16-Bit Binary Counter without Flag	1	0,1,6,7,8	129	0,1,7,8
20	7	32-Bit Delta Counter without Flag				
20	8	16-Bit Delta Counter without Flag				
21	0	Frozen Counter—All Variations				
21	1	32-Bit Frozen Counter				
21	2	16-Bit Frozen Counter				
21	3	32-Bit Frozen Delta Counter				
21	4	16-Bit Frozen Delta Counter				

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Table H.5 SEL-351S DNP Object Table (Sheet 2 of 5)

Object			Request[a]		Response[b]	
Obj	Var	Description	Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
21	5	32-Bit Frozen Counter with Time of Freeze				
21	6	16-Bit Frozen Counter with Time of Freeze				
21	7	32-Bit Frozen Delta Counter with Time of Freeze				
21	8	16-Bit Frozen Delta Counter with Time of Freeze				
21	9	32-Bit Frozen Counter without Flag				
21	10	16-Bit Frozen Counter without Flag				
21	11	32-Bit Frozen Delta Counter without Flag				
21	12	16-Bit Frozen Delta Counter without Flag				
22	0	Counter Change Event—All Variations	1	6,7,8		
22	1	32-Bit Counter Change Event without Time	1	6,7,8	129	17,28
22	2[e]	16-Bit Counter Change Event without Time	1	6,7,8	129,130	17,28
22	3	32-Bit Delta Counter Change Event without Time				
22	4	16-Bit Delta Counter Change Event without Time				
22	5	32-Bit Counter Change Event with Time	1	6,7,8	129	17,28
22	6	16-Bit Counter Change Event with Time	1	6,7,8	129	17,28
22	7	32-Bit Delta Counter Change Event with Time				
22	8	16-Bit Delta Counter Change Event with Time				
23	0	Frozen Counter Event—All Variations				
23	1	32-Bit Frozen Counter Event without Time				
23	2	16-Bit Frozen Counter Event without Time				
23	3	32-Bit Frozen Delta Counter Event without Time				
23	4	16-Bit Frozen Delta Counter Event without Time				
23	5	32-Bit Frozen Counter Event with Time				

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Table H.5 SEL-351S DNP Object Table (Sheet 3 of 5)

Object			Request[a]		Response[b]	
Obj	Var	Description	Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
23	6	16-Bit Frozen Counter Event with Time				
23	7	32-Bit Frozen Delta Counter Event with Time				
23	8	16-Bit Frozen Delta Counter Event with Time				
30	0	Analog Input—All Variations	1	0,1,6,7,8		
30	1	32-Bit Analog Input	1	0,1,6,7,8	129	0,1,7,8
30	2	16-Bit Analog Input	1	0,1,6,7,8	129	0,1,7,8
30	3	32-Bit Analog Input without Flag	1	0,1,6,7,8	129	0,1,7,8
30	4[e]	16-Bit Analog Input without Flag	1	0,1,6,7,8	129	0,1,7,8
31	0	Frozen Analog Input—All Variations				
31	1	32-Bit Frozen Analog Input				
31	2	16-Bit Frozen Analog Input				
31	3	32-Bit Frozen Analog Input with Time of Freeze				
31	4	16-Bit Frozen Analog Input with Time of Freeze				
31	5	32-Bit Frozen Analog Input without Flag				
31	6	16-Bit Frozen Analog Input without Flag				
32	0	Analog Change Event—All Variations	1	6,7,8		
32	1	32-Bit Analog Change Event without Time	1	6,7,8	129	17,28
32	2[e]	16-Bit Analog Change Event without Time	1	6,7,8	129,130	17,28
32	3	32-Bit Analog Change Event with Time	1	6,7,8	129	17,28
32	4	16-Bit Analog Change Event with Time	1	6,7,8	129	17,28
33	0	Frozen Analog Event—All Variations				
33	1	32-Bit Frozen Analog Event without Time				
33	2	16-Bit Frozen Analog Event without Time				
33	3	32-Bit Frozen Analog Event with Time				
33	4	16-Bit Frozen Analog Event with Time				

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Table H.5 SEL-351S DNP Object Table (Sheet 4 of 5)

Object			Request[a]		Response[b]	
Obj	Var	Description	Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
40	0	Analog Output Status—All Variations	1	0,1,6,7,8		
40	1	32-Bit Analog Output Status	1	0,1,6,7,8	129	0,1,7,8
40	2[e]	16-Bit Analog Output Status	1	0,1,6,7,8	129	0,1,7,8
41	0	Analog Output Block—All Variations				
41	1	32-Bit Analog Output Block	3,4,5,6	17,28	129	echo of request
41	2	16-Bit Analog Output Block	3,4,5,6	17,28	129	echo of request
50	0	Time and Date—All Variations				
50	1	Time and Date	1,2	7,8 index = 0	129	07, quantity =1
50	2	Time and Date with Interval				
51	0	Time and Date CTO—All Variations				
51	1	Time and Date CTO				
51	2	Unsynchronized Time and Date CTO				07, quantity =1
52	0	Time Delay—All Variations				
52	1	Time Delay Coarse				
52	2	Time Delay Fine			129	07, quantity =1
60	0	All Classes of Data	1,20,21	6		
60	1	Class 0 Data	1	6		
60	2	Class 1 Data	1,20,21	6,7,8		
60	3	Class 2 Data	1,20,21	6,7,8		
60	4	Class 3 Data	1,20,21	6,7,8		
70	1	File Identifier				
80	1	Internal Indications	2	0,1 index = 7		
81	1	Storage Object				
82	1	Device Profile				
83	1	Private Registration Object				
83	2	Private Registration Object Descriptor				
90	1	Application Identifier				
100	1	Short Floating Point				
100	2	Long Floating Point				
100	3	Extended Floating Point				

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Table H.5 SEL-351S DNP Object Table (Sheet 5 of 5)

Object			Request[a]		Response[b]	
Obj	Var	Description	Func. Codes[c]	Qual. Codes[d]	Func. Codes[c]	Qual. Codes[d]
101	1	Small Packed Binary-Coded Decimal				
101	2	Medium Packed Binary-Coded Decimal				
101	3	Large Packed Binary-Coded Decimal				
		No object	13,14,23			

[a] Supported in requests from master
[b] May generate in response to master
[c] Decimal
[d] Hexadecimal
[e] Default variation

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Data Map

The data map may change when newer versions of relay firmware with added capabilities are introduced. *Table H.6* describes the default object map supported by the SEL-351S firmware version R108.

Table H.6 SEL-351S DNP Data Map (Sheet 1 of 3)

DNP Object Type	Index	Description
01,02	000–499	Relay Word, where 50B3 is 0 and V1GOOD is 495.
01,02	500–999	Relay Word from the SER, encoded same as inputs 000–499 with 500 added.
01,02	1000–1015	Relay front-panel targets, where 1015 is RESET (LED19), 1008 is N (LED26), 1007 is ENABLED (LED11) and 1000 is 81 (LED18).
01,02[a]	1016–1019	Power factor leading for A-, B-, C-, and 3-phase.
01,02	1020	Relay Disabled.
01,02	1021	Relay diagnostic failure.
01,02	1022	Relay diagnostic warning.
01,02	1023	New relay event available.
01,02	1024	Settings change or relay restart.
01,02[b]	1025	A more recent unread relay event is available.
01,02[b,c]	1026–1041	Relay Word rows 64 & 65.
01,02[b,c]	1042–1057	Relay Word rows 64 & 65 from the SER, encoded same as inputs 1026–1041 with 16 added.
10,12	00–15	Remote bits RB1–RB16
10,12	16	Pulse Open command OC.
10,12	17	Pulse Close command CC.
10,12	18	Reset demands.
10,12	19	Reset demand peaks.
10,12	20	Reset energies.
10,12	21	Reset breaker monitor.
10,12	22	Reset front-panel targets.
10,12	23	Read next relay event.
10,12	24–31	Remote bit pairs RB1–RB16.
10,12	32	Open/Close pair OC & CC.
20,22	00	Active settings group.
20,22	01	Internal breaker trips.
20,22	02	External breaker trips.
30,32	00,01	IA magnitude and angle.
30,32	02,03	IB magnitude and angle.
30,32	04,05	IC magnitude and angle.
30,32	06,07	IN magnitude and angle.
30,32[d]	08,09	VA magnitude (kV) and angle.

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Table H.6 SEL-351S DNP Data Map (Sheet 2 of 3)

DNP Object Type	Index	Description
30,32[d]	10,11	VB magnitude (kV) and angle.
30,32[d]	12,13	VC magnitude (kV) and angle.
30,32	14,15	VS magnitude (kV) and angle.
30,32	16,17	IG magnitude and angle.
30,32	18,19	I1 magnitude and angle.
30,32	20,21	3I2 magnitude and angle.
30,32[a]	22,23	3V0 magnitude (kV) and angle.
30,32	24,25	V1 magnitude (kV) and angle.
30,32	26,27	V2 magnitude (kV) and angle.
30,32[a]	28–31	MW A-, B-, C-, and 3-phase.
30,32[a]	32–35	MVAR A-, B-, C-, and 3-phase.
30,32[a]	36–39	Power factor A-, B-, C-, and 3-phase.
30,32	40	Frequency.
30,32	41	VDC.
30,32[a]	42,43	A-phase MWhr in and out.
30,32[a]	44,45	B-phase MWhr in and out.
30,32[a]	46,47	C-phase MWhr in and out.
30,32	48,49	3-phase MWhr in and out.
30,32[a]	50,51	A-phase MVARhr in and out.
30,32[a]	52,53	B-phase MVARhr in and out.
30,32[a]	54,55	C-phase MVARhr in and out.
30,32	56,57	3-phase MVARhr in and out.
30,32	58–63	Demand IA, IB, IC, IN, IG, and 3I2 magnitudes.
30,32[a]	64–67	A-, B-, C-, and 3-phase demand MW in.
30,32[a]	68–71	A-, B-, C-, and 3-phase demand MVAR in.
30,32[a]	72–75	A-, B- C-, and 3-phase demand MW out.
30,32[a]	76–79	A-, B-, C-, and 3-phase demand MVAR out.
30,32	80–85	Peak demand IA, IB, IC, IN, IG, and 3I2 magnitudes.
30,32[a]	86–89	A-, B-, C-, and 3-phase peak demand MW in.
30,32[a]	90–93	A-, B-, C-, and 3-phase peak demand MVAR in.
30,32[a]	94–97	A-, B-, C-, and 3-phase peak demand MW out.
30,32[a]	98–101	A-, B-, C-, and 3-phase peak demand MVAR out.
30,32	102–104	Breaker contact wear percentage (A, B, C).
30,32[e]	105	Fault type (see table for definition).
30,32[e]	106	Fault location.
30,32[e]	107	Fault current.
30,32[e]	108	Fault frequency.
30,32[e]	109	Fault settings group.
30,32[e]	110	Fault recloser shot counter.
30,32[e]	111–113	Fault time in DNP format (high, middle, and low 16 bits).

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Table H.6 SEL-351S DNP Data Map (Sheet 3 of 3)

DNP Object Type	Index	Description
30,32[b]	114	Relay internal temperature
30,32[b]	115	Number of unread faults
30,32[b]	116	51P1P setting in primary units
30,32[b]	117	51P2P setting in primary units
30,32[b]	118	51G1P setting in primary units
30,32[b]	119	51G2P setting in primary units
30,32[b]	120	51QP setting in primary units
30,32[b]	121	51N1P setting in primary units
30,32[b]	122	51N2P setting in primary units
40,41	00	Active settings group.

[a] For Delta configuration {setting PTCONN = DELTA}, the per phase values and 3V0 are undefined and set to 0. Three-phase values are defined and valid.
[b] Extended mode (DNPE) only.
[c] Only on relays with 0.2 A nominal neutral rating.
[d] For Delta configuration {setting PTCONN = DELTA}, WYE values of VA, VB, and VC are replaced with Delta values of VAB, VBC, and VCA respectively.
[e] Object type 32 event messages are generated for these points in DNP extended mode (DNPE) only.

Binary inputs (Objects 1 and 2) are supported as defined by the previous table. Binary inputs 0–499, 1000–1023, and 1025–1041 are scanned approximately once per second to generate events. When time is reported with these event objects, it is the time at which the scanner observed the bit change. This may be significantly delayed from when the original source changed and should not be used for sequence-of-events determination.

In order to determine an element's point index, consult *Table 9.6*. Locate the element in question in the table and note the Relay Word row number. From that row number, subtract the row number of the first Relay Word row (usually 2) and multiply that result by 8. This is the index of the right-most element of the Relay Word row of the element in question. Count over to the original element and add that to get the point index. For rows 64 and 65 of the Relay Word, use a similar method, then add 530 to the result to obtain the bit Binary Input number 1026–1041 in Extended mode (DNPE) only. Binary Inputs 500–999 and 1042–1057 are derived from the Sequential Events Recorder (**SER**) and carry the time stamp of actual occurrence. Static reads from these inputs will show the same data as a read from the corresponding index in the 0–499 and 1026–1041 group. Only points that are actually in the SER list (**SET R**) will generate events in the 500–999 and 1042–1057 group.

Analog inputs (objects 30 and 32) are supported as defined by *Table H.6*. The values are reported in primary units (including inputs 116–122 in extended mode). Analog inputs 28–35, 42–57, 64–79, 86–104, and 106 are further scaled according to the DECPLM setting (e.g., if DECPLM is 3, then the value is multiplied by 1000). Analog inputs 58–63, 80–85, 107, 115–119, and the even-numbered points in 0–7 and 16–21 (current magnitudes) are scaled according to the DECPLA setting. The even-numbered points in 8–15 and 22–27 (voltage magnitudes) are scaled according to the DECPLV setting. Analog inputs 36–41, 108, and the odd-numbered points in 0–27 (angles) are scaled by 100, and input 114 is scaled by 10. The remaining analogs are not scaled.

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Event-class messages are generated whenever an input changes beyond the value given by the ANADB setting. The dead-band check is done after any scaling is applied. The angles (the odd numbered points in 0–27) will only generate an event if, in addition to their dead-band check, the corresponding magnitude (the preceding point) contains a value greater than the value given by the ANADB setting.

In standard mode, analog inputs are scanned at approximately a 1-second rate, except for analogs 105–113. During a scan, all events generated will use the time the scan was initiated. Analogs 105–113 are derived from the history queue data for the most recently read fault. In standard mode, analogs 105–113 do not generate event messages. In extended mode, events for these inputs will use the time the scan was initiated. Analog input 115 is derived from the history queue. Analog 105 is a 16-bit composite value, where the upper byte is defined as in *Table H.7*.

Table H.7 Analog 105 Upper Byte Definitions

Value	Event Cause
1	Trigger command
2	Pulse command
4	Trip element
8	ER element

The lower byte is defined as in *Table H.8*.

Table H.8 Analog 105 Lower Byte Definitions

Value	Fault Type
0	Indeterminate
1	A-Phase
2	B-Phase
4	C-Phase
8	Ground

The lower byte may contain any combination of the above bits (e.g., a 6 is a B to C fault and a 9 is an A to Ground fault). If Analog 105 is 0, fault information has not been read and the related analogs (106–113) do not contain valid data. Analog inputs 116–122 are derived from the present active group settings. If the associated setting is set to OFF, the value will be reported as –1.

Control Relay Output Blocks (object 12, variation 1) are supported. The control relays correspond to the remote bits and other functions, as shown above. The Trip/Close bits take precedence over the control field. The control field is interpreted as in *Table H.9*.

Table H.9 Control Field (Sheet 1 of 2)

Index	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
0–15	Set	Clear	Set	Clear	Pulse	Clear
16–22	Pulse	Do nothing	Pulse	Do nothing	Pulse	Do nothing
23	Read Oldest	Read Newest[a]	Read Oldest	Read Newest[a]	Read Oldest	Read Newest[a]
24	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1	Pulse RB2	Pulse RB1
25	Pulse RB4	Pulse RB3	Pulse RB4	Pulse RB3	Pulse RB4	Pulse RB3

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Table H.9 Control Field (Sheet 2 of 2)

Index	Close (0x4X)	Trip (0x8X)	Latch On (3)	Latch Off (4)	Pulse On (1)	Pulse Off (2)
26	Pulse RB6	Pulse RB5	Pulse RB6	Pulse RB5	Pulse RB6	Pulse RB5
27	Pulse RB8	Pulse RB7	Pulse RB8	Pulse RB7	Pulse RB8	Pulse RB7
28	Pulse RB10	Pulse RB9	Pulse RB10	Pulse RB9	Pulse RB10	Pulse RB9
29	Pulse RB12	Pulse RB11	Pulse RB12	Pulse RB11	Pulse RB12	Pulse RB11
30	Pulse RB14	Pulse RB13	Pulse RB14	Pulse RB13	Pulse RB14	Pulse RB13
31	Pulse RB16	Pulse RB15	Pulse RB16	Pulse RB15	Pulse RB16	Pulse RB15
32	Pulse CC	Pulse OC	Pulse CC	Pulse OC	Pulse CC	Pulse OC

[a] This function is only available in extended mode (DNPE). It functions as "Do Nothing" in standard mode (DNP).

The Status field is used exactly as defined. All other fields are ignored. A pulse operation asserts a point for a single processing interval. Caution should be exercised with multiple remote bit pulses in a single message (i.e., point count > 1), as this may result in some of the pulse commands being ignored and returning an already active status.

Analog Outputs (objects 40 and 41) are supported as defined by the preceding table. Flags returned with object 40 responses are always set to 0. The Control Status field of object 41 requests are ignored. If the value written to index 0 is outside of the range 1 through 6, the relay will not accept the value and will return a hardware error status.

Relay Summary Event Data

In standard mode (DNP), the Relay Event Summary data are available on a first in, first out (FIFO) basis. In extended mode (DNPE), the Relay Event Summary data can be read two ways: first in, first out (FIFO); or last in, first out (LIFO).

To use the FIFO method, the master should monitor binary input point 1023, which will be on when there is an unread relay event summary. To read the oldest relay event summary, the master should Pulse-On binary output point 23. This will load the relay event summary analogs (points 105–113) with information from the oldest relay event summary, discarding the values from the previous load. After reading the analogs, the master should again check binary input point 1023, which will be on if there is another unread relay event summary. The master should continue this process until binary input point 1023 is off. If the master attempts to load values using output point 23 when binary input point 1023 is off, the relay event type analog (point 105) will be loaded with zero. With the FIFO method, the relay event summaries will always be collected in chronological order.

In extended mode (DNPE) *only*, the LIFO method is available. To use the LIFO method, the master should monitor binary input point 1023, which will be set when there is an unread relay event summary. To read the newest relay event summary, the master should Pulse-Off binary output point 23. This will load the relay event summary analogs (points 105–113) with information from the newest relay event summary, discarding the values from the previous load.

After reading the analogs, the master should again check binary input point 1023, which will still be on if there is another unread relay event summary. The master should continue this process until binary input point 1023 is off. If the master attempts to load values using output point 23 when binary input point 1023 is off, the event type analog (point 105) will be loaded with zero. With the LIFO method the relay event summaries will be collected in reverse chronological order, unless binary input point 1025 is set, which the master can use to identify when a newer relay event summary is available.

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In extended mode (DNPE), DNP events are generated whenever the values in points 105–113 change. Events are detected every second by the scanning process. The master can collect relay event summaries using event data rather than the static data polling described above. In order for this to work successfully, binary output 23 must be pulsed no faster than once every two seconds. If binary output 23 is pulsed faster, some data may not be recognized and processed by the DNP event scanner.

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Point Remapping

The analog and binary input points (objects 1, 2, 30, and 32) may be remapped via the **DNP** command. The map is composed of 2 lists of indices: one for the analogs (30 and 32) and the other for the binaries (1 and 2).

The indices correspond to those given by the relay's default DNP data map. The order they occur in the list determines the index that the corresponding value is reported as to the DNP master. If a value is not in the list, it is not available to the DNP master.

All 1026 binaries and 123 analogs may be included in the list, but may occur only once. In relays with 0.2 A nominal neutral rating, all 1058 binaries are available in extended mode (DNPE). The maps are stored in nonvolatile memory. The **DNP** command is only available if DNP has been selected on one of the ports. The **DNP** command has the following format:

DNP [type]

where type may be **A**, **B**, **S**, **T**, or omitted.

If the **DNP** command is issued without parameters, the relay displays both the analog and binary maps, which have the following format:

```
=>DNP <STX>

Analogs  =112 28 17 35 1 56 57 58 59 60 61 62 63 64 65 \
    66 67 100 101 102 103

Binaries =Default Map <ETX>
=>
```

If the **DNP** command is issued with an **S** parameter, the relay displays only the analog map; likewise, a **T** causes the relay to display only the binary map. If the map checksum is determined to be invalid, the map will be reported as corrupted during a display command, as follows:

```
=>DNP T <STX>

Binaries = Map Corrupted <ETX>
=>
```

If the map is determined to be corrupted, DNP will respond to all master data requests with an unknown point error. If the **DNP** command is issued with an **A** or **B** parameter at level 2 or greater, the relay requests the user enter indices for the corresponding list, where a parameter of **A** specifies the Analog list and **B** specifies the Binary list.

The relay accepts lines of indices until a line without a final continuation character (\) is entered. Each line of input is constrained to 80 characters, but all the points may be re-mapped, using multiple lines with continuation characters (\) at the end of the intermediate lines. If a single blank line is entered as the first line, the re-mapping is disabled for that type (i.e., the relay uses the default analog or binary map).

For example, the first example remap could be produced with the following commands:

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```
=>DNP A

Enter the new DNP Analog map
112 28 17 \ <Enter>
35 1 56 57 58 59 60 61 62 63 64 65 66 67 100 101 102 \ <Enter>
103 <Enter>

Save Changes (Y/N)? Y <Enter>

=>DNP B
Enter the new DNP Binary map <Enter>

Save Changes (Y/N)? Y <Enter>
=>
```


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SEL-351S Settings Sheets

Standard Mode DNP Port–SET P Command

Protocol (SEL, LMD, DNP, DNPE, MBA, MBB, MB8A, MB8B)	**PROTO**	= DNP
Baud rate (300, 600, 1200, 2400, 4800, 9600,19200, 38400) (38400 is not available on Port 1.)	**SPEED**	=
DNP Address (0–65534)	**DNPADR**	=
Class for Event Data (0 for no event, 1–3)	**ECLASS**	=
Minutes for Request Interval, (0 for never, 1–32767)	**TIMERQ**	=
Currents Scaling Decimal Places (0–3)	**DECPLA**	=
Voltages Scaling Decimal Places (0–3)	**DECPLV**	=
Misc Data Scaling Decimal Places (0–3)	**DECPLM**	=
Seconds to Select/Operate Time-out (0.0–30.0)	**STIMEO**	=
Data Link Retries (0 for no confirm, 1–15)	**DRETRY**	=
Seconds to Data Link Time-out interval (0–5)	**DTIMEO**	=
Minimum Seconds from DCD to Tx (0.00–1.00)	**MINDLY**	=
Maximum Seconds from DCD to Tx (0.00–1.00)	**MAXDLY**	=
Settle Time from RTS ON to Tx (OFF, 0.00–30.00 sec.)	**PREDLY**	=
Settle Time from Tx to RTS OFF (0.00–30.00 sec.)	**PSTDLY**	=
Analog Reporting Deadband Counts (0–32767)	**ANADB**	=
Enable Unsolicited Reporting (Y/N)	**UNSOL**	=
Enable Unsolicited Reporting at Power-up (Y/N)	**PUNSOL**	=
DNP Address to Report to (0–65534)	**REPADR**	=
Number of Events to Transmit on (1–200)	**NUMEVE**	=
Seconds until Oldest Event to Tx on (0.0–60.0)	**AGEEVE**	=
Seconds to Event Message Confirm Time-out (1–50)	**UTIMEO**	=

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Date_____

Extended Mode DNP Port–SET P Command

Protocol (SEL, LMD, DNP, DNPE, MBA, MBB, MB8A, MB8B)	**PROTO**	= DNPE
Baud rate (300, 600, 1200, 2400, 4800, 9600,19200, 38400) (38400 is not available on Port 1.)	**SPEED**	=
DNP Address (0–65534)	**DNPADR**	=
Minutes for Request Interval, (0 for never, 1–32767)	**TIMERQ**	=
Class for Analog Event Data (0 for no event, 1–3)	**CLASSA**	=
Class for Binary Event Data (0 for no event, 1–3)	**CLASSB**	=
Class for Counter Event Data (0 for no event, 1–3)	**CLASSC**	=
Currents Scaling Decimal Places (0–3)	**DECPLA**	=
Voltages Scaling Decimal Places (0–3)	**DECPLV**	=
Misc Data Scaling Decimal Places (0–3)	**DECPLM**	=
Seconds to Select/Operate Time-out (0.0–30.0)	**STIMEO**	=
Data Link Retries (0 for no confirm, 1–15)	**DRETRY**	=
Seconds to Data Link Time-out interval (0–5)	**DTIMEO**	=
Minimum Seconds from DCD to Tx (0.00–1.00)	**MINDLY**	=
Maximum Seconds from DCD to Tx (0.00–1.00)	**MAXDLY**	=
Settle Time from RTS ON to Tx (OFF, 0.00–30.00 sec.)	**PREDLY**	=
Settle Time from Tx to RTS OFF (0.00–30.00 sec.)	**PSTDLY**	=
Amps Reporting Deadband Counts (0–32767)	**ANADBA**	=
Volts Reporting Deadband Counts (0–32767)	**ANADBV**	=
Misc Data Reporting Deadband Counts (0–32767)	**ANADBM**	=
Enable Unsolicited Reporting (Y/N)	**UNSOL**	=
Enable Unsolicited Reporting at Power-up (Y/N)	**PUNSOL**	=
DNP Address to Report to (0–65534)	**REPADR**	=
Number of Events to Transmit on (1–200)	**NUMEVE**	=
Seconds until Oldest Event to Tx on (0.0–60.0)	**AGEEVE**	=
Seconds to Event Message Confirm Time-out (1–50)	**UTIMEO**	=

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Appendix I

MIRRORED BITS Communications (In Firmware Versions 6 and 7)

Overview

MIRRORED BITS® communications is a direct relay-to-relay communications protocol that allows protective relays to exchange information quickly and securely, and with minimal expense.

The information exchanged can facilitate remote control, remote sensing, or communications-assisted protection schemes such as POTT, DCB, etc. The SEL-351S Relay supports two MIRRORED BITS channels, differentiated by the channel specifiers A and B.

Bits transmitted are called TMB1*x* through TMB8*x*, where *x* is the channel specifier (e.g., A or B), and are controlled by the corresponding SELOGIC® control equations. Bits received are called RMB1*x* through RMB8*x* and are usable as inputs to any SELOGIC control equations. Channel status bits are called ROK*x*, RBAD*x*, CBAD*x* and LBOK*x* and are also usable as inputs to any SELOGIC control equations. Further channel status information is available via the **COM** command.

Table I.1 MIRRORED BITS (Sheet 1 of 2)

Label	Description	Default
SPEED	Baud Rate (300–38400)[a]	19200
RTSCTS	Enable Hardware Handshaking (Y, N, MBT)	N
RBADPU	Seconds to MIRRORED BITS Channel Bad Pickup (1–10000)	60
CBADPU	PPM MIRRORED BITS Channel Bad Pickup (1–10000)	10000
RXID	MIRRORED BITS Receive Identifier (1–4)	1
TXID	MIRRORED BITS Transmit Identifier (1–4)	2
RXDFLT	MIRRORED BITS Receive Default State (string of 1s, 0s, or Xs)	XXXXXXXX
RMB1PU	MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	1
RMB1DO	MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	1
RMB2PU	MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	1
RMB2DO	MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	1
RMB3PU	MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	1
RMB3DO	MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	1
RMB4PU	MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	1
RMB4DO	MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	1

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Table I.1 MIRRORED BITS (Sheet 2 of 2)

Label	Description	Default
RMB5PU	MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	1
RMB5DO	MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	1
RMB6PU	MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	1
RMB6DO	MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	1
RMB7PU	MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	1
RMB7DO	MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	1
RMB8PU	MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	1
RMB8DO	MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	1

[a] 38400 is not available on Port 1.

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Operation

Message Transmission

All messages are transmitted without idle bits between characters. Idle bits are allowed between messages.

- At 4800 baud, one message is transmitted each 1/2 power system cycle.
- At 9600 baud, one message is transmitted each 1/4 power system cycle.
- At 19200 and 38400 baud, one message is transmitted each 1/8 power system cycle for the SEL-321 and 1/4 power system cycle for the SEL-351 and the SEL-351S.

Message Decoding and Integrity Checks

The relay will deassert a user-accessible flag per channel (hereafter called ROK*x*) upon failing any of the following received-data checks:

- Parity, framing, or overrun errors.
- Receive data redundancy error.
- Receive message identification error.
- No message received in the time three messages have been sent.

While ROK*x* is not asserted, the relay will:

1. Prevent new data from being transferred to the pickup dropout security counters described later. Instead, the relay will send one of the following user-selectable values (hereafter called default values) to the security counter inputs:
   - 1
   - 0
   - The last valid value

   The user will be allowed to select one of the default values for each RMB.
2. Enter the synchronization process described below.

The relay will assert ROK*x* only after successful synchronization as described below and two consecutive messages pass all of the data checks described above. After ROK*x* is reasserted, received data may be delayed while passing through the security counters described below.

Transfer of received data to RMB1*x*–RMB8*x* is supervised by eight user-programmable pickup/dropout security counters settable from 1 (allow every occurrence to pass) to at least 8 (require 8 consecutive occurrences to pass). The pickup and dropout security count settings are separate.

A pickup/dropout security counter operates identically to a pickup/dropout timer, except that it is set in counts of received messages instead of time. An SEL-351S talking to another SEL-351S sends and receives MIRRORED BITS messages four times per power system cycle. Therefore, a security counter set to two counts will delay a bit by about 1/2 power system cycle.

Things become slightly more complicated when two relays of different processing rates are connected via MIRRORED BITS (for instance, an SEL-321 talking to an SEL-351S). The SEL-321 processes power system information each 1/8 power system cycle but processes the pickup/dropout security

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counters as messages are received. Because the SEL-321 is receiving messages from the SEL-351S, it will receive a message per 1/4 cycle processing interval. Therefore, a counter set to two will again delay a bit by about 1/2 cycle. However, in that same example, a security counter set to two on the SEL-351S will delay a bit by 1/4 cycle, because the SEL-351S is receiving new MIRRORED BITS messages each 1/8 cycle from the SEL-321.

Synchronization

When a node detects a communications error, it deasserts ROK*x*. If a node detects two consecutive communications errors, it transmits an attention message, which includes its TXID setting.

When a node receives an attention message, it checks to see if its TXID is included.

If its own TXID is included and at least one other TXID is included, the node transmits data.

If its own TXID is not included, the node deasserts ROK*x*, includes its TXID in the attention message, and transmits the new attention message.

If its own TXID is the only TXID included, the relay assumes the message is corrupted unless the loopback mode has been enabled. If loop back is not enabled, the node deasserts ROKx and transmits the attention message with its TXID included. If loop back is enabled, the relay transmits data.

In summary, when a node detects two consecutive errors, it transmits attention until it receives an attention with its own TXID included. If three or four relays are connected in a ring topology, then the attention message will go all the way around the loop and eventually will be received by the originating node. It will then be killed and data transmission will resume. This method of synchronization allows the relays to determine reliably which byte is the first byte of the message. It also forces mis-synchronized UARTs to become re-synchronized. On the down side, this method takes down the entire loop for a receive error at any node in the loop. This decreases availability. It also makes one-way communications impossible.

Loopback Testing

Use the **LOOP** command to enable loopback testing.

While in loopback mode, ROK*x* is deasserted, and another user-accessible flag, LBOK*x*, will assert and deassert based on the received data checks.

Channel Monitoring

Based on the results of data checks described above, the relay will collect information regarding the 255 most recent communications errors. Each record will contain at least the following fields:

- Dropout Time/Date
- Pickup Time/Date
- Time elapsed during dropout
- Reason for dropout (See *Table I.2*)

Table I.2 Error Types Reported by the Communications Report (Sheet 1 of 2)

Error type	Description
Parity error	Data failed UART parity check.
Underrun	Three MIRRORED BITS messages transmitted without one being received.
Overrun	UART data buffer overrun.

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Table I.2 Error Types Reported by the Communications Report (Sheet 2 of 2)

Error type	Description
Re-sync	The MIRRORED BITS device at the other end of the link detected an error.
Data error	Received data was not self-consistent, or the address was wrong.
Relay disabled	Relay protection functions disabled as during power up or change in settings or settings group.
Loopback	Loop back enabled. Error conditions followed by "(L)" occurred while the system was in loop back.
Framing error	The UART did not detect a stop bit in the received MIRRORED BITS data.

NOTE: The user typically will combine RBADx with other alarm conditions through the use of SELOGIC control equations.

NOTE: The user typically will combine CBADx with other alarm conditions through the use of SELOGIC control equations.

Use the **COMM** command to generate a long or summary report of the communications errors.

There is only a single record for each outage, but an outage can evolve. For example, the initial cause could be a data disagreement, but the outage can be perpetuated by framing errors. If the channel is presently down, the COMM record will only show the initial cause, but the COMM summary will display the present cause of failure.

When the duration of an outage exceeds a user-settable threshold, the relay will assert a user-accessible flag, hereafter called RBAD*x*.

When channel unavailability exceeds a user-settable threshold, the relay will assert a user accessible flag, hereafter called CBAD*x*.

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MIRRORED BITS Protocol for the Pulsar 9600 Baud Modem

The user indicates that a Pulsar MBT modem is to be used by responding "MBT" to the RTS/CTS setting prompt. When the user selects MBT, the baud rate setting will be limited to 9600 baud.

NOTE: The MBT mode will not work with PROTO=MB8A or MB8B.

The MIRRORED BITS protocol compatible with the Pulsar MBT-9600 modem is identical to the standard MIRRORED BITS protocol with the following exceptions:

The relay injects a delay (idle time) between messages. The length of the delay is one relay processing interval.

NOTE: An idle processing interval guarantees at least 19 idle bits at 9600 baud in an SEL-321 Relay with the system frequency at 65 Hz.

The relay resets RTS (to a negative voltage at the EIA-232 connector) for MIRRORED BITS communications using this specification. The relay sets RTS (to a positive voltage at the EIA-232 connector) for MIRRORED BITS communications, using the R6 or original R version of MIRRORED BITS.

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Settings

```
Protocol(SEL,LMD,DNP,DNPE,MBA,MBB,MB8A,MB8B)      PROTO = MB8A      ?
```

Set PROTO = MBA or MB8A to enable the MIRRORED BITS protocol channel A on this port. Set PROTO = MBB or MB8B to enable the MIRRORED BITS protocol channel B on this port. The standard MIRRORED BITS protocols MBA and MBB use a 7-data bit format for data encoding. The MB8 protocols MB8A and MB8B use an 8-data bit format, which allows MIRRORED BITS to operate on communication channels requiring an 8-data bit format. For the remainder of this section, PROTO = MBA is assumed.

```
Baud Rate(300-38400)                              SPEED = 9600      ?
```

Use the SPEED setting to control the rate at which the MIRRORED BITS messages are transmitted, in power system cycles (~), based on the following table:

Table I.3 SPEED Setting and MIRRORED BITS Messages

SPEED	SEL-321	SEL-351S
38400[a]	1 message per 1/8 cycle	1 message per 1/4 cycle
19200	1 message per 1/8 cycle	1 message per 1/4 cycle
9600	1 message per 1/4 cycle	1 message per 1/4 cycle
4800	1 message per 1/2 cycle	1 message per 1/2 cycle

[a] Not available on Port 1.

```
Enable Hardware Handshaking(Y,N,MBT)              RTSCTS= N         ?
```

Use the MBT option if you are using a Pulsar MBT 9600 baud modem. With this option set, the relay will transmit a message every 1/2 power system cycle and the relay will deassert the RTS signal on the EIA-232 connector. Also, the relay will monitor the CTS signal on the EIA-232 connector, which the modem will deassert if the channel has too many errors. The modem uses the relay's RTS signal to determine whether the new or old MIRRORED BITS protocol is in use.

```
Seconds to Mirrored Bits Rx Bad Pickup(1-10000)   RBADPU= 60        ?
```

Use the RBADPU setting to determine how long a channel error must last before the relay element RBADA is asserted. RBADA is deasserted when the channel error is corrected. RBADPU is accurate to ±1 second.

```
PPM Mirrored Bits Channel Bad Pickup(1-10000)     CBADPU= 1000      ?
```

Use the CBADPU setting to determine the ratio of channel down time to the total channel time before the relay element CBADA is asserted. The times used in the calculation are those that are available in the COMM records. See the **COMM** command in *Section 10: Serial Port Communications and Commands* for a description of the COMM records.

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```
Mirrored Bits Receive Identifier(1-4)            RXID  = 1        ?
Mirrored Bits Transmit Identifier(1-4)           TXID  = 2        ?
```

Set the RXID of the local relay to match the TXID of the remote relay. For example, in the three-terminal case, where Relay X transmits to Relay Y, Relay Y transmits to Relay Z, and Relay Z transmits to Relay X.

Table I.4 Example Three-Terminal MIRRORED BITS ID Setup

	TXID	RXID
Relay X	1	3
Relay Y	2	1
Relay Z	3	2

```
Mirrored Bits Receive Default State(string of 1s, 0s or Xs)

       87654321
RXDFLT=XXXXXXXX
     ?
```

Use the RXDFLT setting to determine the default state the MIRRORED BITS should use in place of received data if an error condition is detected. The setting is a mask of 1s, 0s and/or Xs, for RMB1A–RMB8A, where X represents the most recently received valid value.

```
Mirrored Bits RMB_ Pickup Debounce msgs(1-8)      RMB1PU= 1        ?
Mirrored Bits RMB_ Dropout Debounce msgs(1-8)     RMB1DO= 1        ?
Mirrored Bits RMB_ Pickup Debounce msgs(1-8)      RMB2PU= 1        ?
Mirrored Bits RMB_ Dropout Debounce msgs(1-8)     RMB2DO= 1        ?
Mirrored Bits RMB_ Pickup Debounce msgs(1-8)      RMB3PU= 1        ?
Mirrored Bits RMB_ Dropout Debounce msgs(1-8)     RMB3DO= 1        ?
Mirrored Bits RMB_ Pickup Debounce msgs(1-8)      RMB4PU= 1        ?
Mirrored Bits RMB_ Dropout Debounce msgs(1-8)     RMB4DO= 1        ?
Mirrored Bits RMB_ Pickup Debounce msgs(1-8)      RMB5PU= 1        ?
Mirrored Bits RMB_ Dropout Debounce msgs(1-8)     RMB5DO= 1        ?
Mirrored Bits RMB_ Pickup Debounce msgs(1-8)      RMB6PU= 1        ?
Mirrored Bits RMB_ Dropout Debounce msgs(1-8)     RMB6DO= 1        ?
Mirrored Bits RMB_ Pickup Debounce msgs(1-8)      RMB7PU= 1        ?
Mirrored Bits RMB_ Dropout Debounce msgs(1-8)     RMB7DO= 1        ?
Mirrored Bits RMB_ Pickup Debounce msgs(1-8)      RMB8PU= 1        ?
Mirrored Bits RMB_ Dropout Debounce msgs(1-8)     RMB8DO= 1        ?
```

Supervise the transfer of received data (or default data) to RMB1A–RMB8A with the MIRRORED BITS pickup and dropout security counters. Set the pickup and dropout counters individually for each bit.

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SEL-351S Settings Sheets

MIRRORED BITS–SET P Command

Baud Rate (300–38400) (38400 is not available on Port 1)	SPEED	= _____
Enable Hardware Handshaking (Y,N,MBT)	RTSCTS	= _____
Seconds to MIRRORED BITS Rx Bad Pickup (1–10000)	RBADPU	= _____
PPM MIRRORED BITS Channel Bad Pickup (1–10000)	CBADPU	= _____
MIRRORED BITS Receive Identifier (1–4)	RXID	= _____
MIRRORED BITS Transmit Identifier (1–4)	TXID	= _____
MIRRORED BITS Receive Default State (string of 1s, 0s, or Xs)	RXDFLT	= _____
MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	RMB1PU	= _____
MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	RMB1DO	= _____
MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	RMB2PU	= _____
MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	RMB2DO	= _____
MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	RMB3PU	= _____
MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	RMB3DO	= _____
MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	RMB4PU	= _____
MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	RMB4DO	= _____
MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	RMB5PU	= _____
MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	RMB5DO	= _____
MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	RMB6PU	= _____
MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	RMB6DO	= _____
MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	RMB7PU	= _____
MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	RMB7DO	= _____
MIRRORED BITS RMB_Pickup Debounce msgs (1–8)	RMB8PU	= _____
MIRRORED BITS RMB_Dropout Debounce msgs (1–8)	RMB8DO	= _____

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Appendix J

SEL-351S Fast SER Protocol

Introduction

This appendix describes special binary Fast Sequential Events Recorder (SER) messages that are not included in *Section 10: Serial Port Communications and Commands*. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary Fast SER messages from the SEL-351S Relay.

SEL relays and communications processors have two separate data streams that share the same serial port. The normal serial interface consists of ASCII character commands and reports that are intelligible using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information, and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering or SER data. To exploit this feature, the device connected to the other end of the link requires software that uses the separate data streams. The binary commands and ASCII commands can also be accessed by a device that does not interleave the data streams.

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Make Sequential Events Recorder (SER) Settings With Care

The relay triggers a row in the Sequential Events Recorder (SER) event report for any change of state in any one of the elements listed in the SER1, SER2, or SER3 trigger settings. Nonvolatile memory is used to store the latest 512 rows of the SER event report so they can be retained during power loss. The nonvolatile memory is rated for a finite number of writes. Exceeding the limit can result in an EEPROM self-test failure. **An average of one state change every three minutes can be made for a 25-year relay service life.**

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Recommended Message Usage

Use the following sequence of commands to enable unsolicited binary Fast SER messaging in the SEL-351S:

1. On initial connection, send the **SNS** command to retrieve and store the ASCII names for the digital I/O points assigned to trigger SER records.

   The order of the ASCII names matches the point indices in the unsolicited binary Fast SER messages. Send the "Enable Unsolicited Fast SER Data Transfer" message to enable the SEL-351S to transmit unsolicited binary Fast SER messages.

2. When SER records are triggered in the SEL-351S, the relay responds with an unsolicited binary Fast SER message. If this message has a valid checksum, it must be acknowledged by sending an acknowledge message with the same response number as contained in the original message. The relay will wait approximately 100 ms to 500 ms to receive an acknowledge message, at which time the relay will resend the same unsolicited Fast SER message with the same response number.

3. Upon receiving an acknowledge message with a matching response number, the relay increments the response number, and continues to send and seek acknowledgment for unsolicited Fast SER messages, if additional SER records are available. When the response number reaches three it wraps around to zero on the next increment.

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Functions and Function Codes

In the messages shown below, all numbers are in hexadecimal, unless otherwise noted.

01—Function Code: Enable Unsolicited Fast SER Data Transfer, Sent From Master to Relay

Upon power-up, the SEL-351S disables its own unsolicited transmissions. This function enables the SEL-351S to begin sending unsolicited data to the device that sent the enable message, if the SEL-351S has such data to transfer. The message format for function code 01 is shown in *Table J.1*.

Table J.1 Function Code 01 Message Format

Data	Description
A546	Message header
12	Message length in bytes (18 decimal)
0000000000	Five bytes reserved for future use as a routing address
YY	Status byte (LSB = 1 indicates an acknowledge is requested)
01	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 00, 01...).
18	Function to enable (18—unsolicited SER messages)
0000	Reserved for future use as function code data
nn	Maximum number of SER records per message, 01–20 hex
cccc	Two byte CRC-16 check code for message

The SEL-351S verifies the message by checking the header, length, function code, and enabled function code against the expected values. It also checks the entire message against the CRC-16 field. If any of the checks fail, except the function code or the function to enable, the message is ignored.

If an acknowledge is requested as indicated by the least significant bit of the status byte, the relay transmits an acknowledge message with the same response number received in the enable message.

The “nn” field is used to set the maximum number of SER records per message. The relay checks for SER records approximately every 500 ms. If there are new records available, the relay immediately creates a new unsolicited Fast SER message and transmits it. If there are more than “nn” new records available, or if the first and last record are separated by more than 16 seconds, the relay will break the transmission into multiple messages so that no message contains more than “nn” records, and the first and last record of each message are separated by no more than 16 seconds.

If the function to enable is not 18 or the function code is not recognized, the relay responds with an acknowledge message containing a response code 01 (function code unrecognized), and no functions are enabled. If the SER triggers are disabled (SER1, SER2, and SER3 are all set to NA), the unsolicited Fast SER messages are still enabled, but the only SER records generated are due to settings changes and power being applied to the relay. If the SER1, SER2, or SER3 settings are subsequently changed to any non-NA value and SER entries are triggered, unsolicited SER messages will be generated with the new SER records.

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02—Function Code: Disable Unsolicited Fast SER Data Transfer, Sent From Master to Relay

This function disables the SEL-351S from transferring unsolicited data. The message format for function code 02 is shown in *Table J.2*.

Table J.2 02 Function Code Message Format

Data	Description
A546	Message header
10	Message length (16 decimal)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status byte (LSB = 1 indicates an acknowledge is requested)
02	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 01, 02...)
18	Function to disable (18 = Unsolicited SER)
00	Reserved for future use as function code data
cccc	Two byte CRC-16 check code for message

The SEL-351S verifies the message by checking the header, length, function code, and disabled function code against the expected values, and checks the entire message against the CRC-16 field. If any of the checks fail, except the function code or the function to disable, the message is ignored.

If an acknowledge is requested as indicated by the least significant bit of the status byte, the relay transmits an acknowledge message with the same response number received in the enable message.

If the function to disable is not 18 or the function code is not recognized, the relay responds with an acknowledge message containing the response code 01 (function code unrecognized) and no functions are disabled.

18—Function: Unsolicited Fast SER Response, Sent From Relay to Master

The function 18 is used for the transmission of unsolicited Fast Sequential Events Recorder (SER) data from the SEL-351S. This function code is also passed as data in the "Enable Unsolicited Data Transfer" and the "Disable Unsolicited Data Transfer" messages to indicate which type of unsolicited data should be enabled or disabled. The message format for function code 18 is shown in *Table J.3*.

Table J.3 Function Code 18 Message Format (Sheet 1 of 2)

Data	Description
A546	Message header
ZZ	Message length (Up to 34 + 4 • *nn* decimal, where *nn* is the maximum number of SER records allowed per message as indicated in the "Enable Unsolicited Data Transfer" message.)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status Byte (01 = need acknowledgment; 03 = settings changed and need acknowledgment. If YY=03, the master should re-read the SNS data because the element index list may have changed.)
18	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 01, 02...)
00000000	Four bytes reserved for future use as a return routing address.

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Table J.3 Function Code 18 Message Format (Sheet 2 of 2)

Data	Description
dddd	Two-byte day of year (1–366)
yyyy	Two-byte, four-digit year (e.g., 1999 or 07CF hex)
mmmmmmmm	Four-byte time of day in milliseconds since midnight
XX	1st element index (match with the response to the SNS command; 00 for 1st element, 01 for second element, and so on)
uuuuuu	Three-byte time tag offset of 1st element in microseconds since time indicated in the time of day field.
XX	2nd element index
uuuuuu	Three-byte time tag offset of 2nd element in microseconds since time indicated in the time of day field.
.	
.	
.	
xx	last element index
uuuuuu	Three-byte time tag offset of last element in microseconds since time indicated in the time of day field.
FFFFFFFE	Four-byte end-of-records flag
ssssssss	Packed four-byte element status for up to 32 elements (LSB for the 1st element)
cccc	Two-byte CRC-16 checkcode for message

If the relay determines that SER records have been lost, it sends a message with the following format:

Table J.4 Message Format for Lost SER Records

Data	Description
A546	Message header
22	Message length (34 decimal)
0000000000	Five bytes reserved for future use as a routing address.
YY	Status Byte (01 = need acknowledgment; 03 = settings changed and need acknowledgment)
18	Function code
C0	Sequence byte (Always C0. Other values are reserved for future use in multiple frame messages.)
XX	Response number (XX = 00, 01, 02, 03, 00, 01, ...)
00000000	Four bytes reserved for future use as a return routing address.
dddd	Two-byte day of year (1–366) of overflow message generation
yyyy	Two-byte, four-digit year (e.g., 1999 or 07CF hex) of overflow message generation.
mmmmmmmm	Four-byte time of day in milliseconds since midnight
FFFFFFFE	Four-byte end-of-records flag
00000000	Element status (unused)
cccc	Two byte CRC-16 checkcode for message

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Acknowledge Message Sent from Master to Relay, and From Relay to Master

The acknowledge message is constructed and transmitted for every received message that contains a status byte with the LSB set (except another acknowledge message), and that passes all other checks, including the CRC. The acknowledge message format is shown in *Table J.5*.

Table J.5 Acknowledge Message Format

Data	Description
A546	Message header
0E	Message length (14 decimal)
0000000000	Five bytes reserved for future use as a routing address.
00	Status byte (always 00)
XX	Function code, echo of acknowledged function code with MSB set.
RR	Response code (see below)
XX	Response number (XX = 00, 01, 02, 03, 00, 01, ...) must match response number from message being acknowledged.)
cccc	Two byte CRC-16 checkcode for message

The SEL-351S supports the response codes in *Table J.6*.

Table J.6 Supported Response Codes

RR	Response
00	Success.
01	Function code not recognized.

Examples

1. Successful acknowledge for “Enable Unsolicited Fast SER Data Transfer” message from a relay with at least one of SER1, SER2, or SER3 not set to NA:

   A5 46 0E 00 00 00 00 00 00 81 00 XX cc cc (XX is the same as the Response Number in the “Enable Unsolicited Data Transfer” message to which it responds)

2. Unsuccessful acknowledge for “Enable Unsolicited Fast SER Data Transfer” message from a relay with all of SER1, SER2, and SER3 set to NA:

   A5 46 0E 00 00 00 00 00 00 81 02 XX cc cc (XX is the same as the response number in the “Enable Unsolicited Data Transfer” message to which it responds.)

3. Disable Unsolicited Fast SER Data Transfer message, acknowledge requested:

   A5 46 10 00 00 00 00 00 01 02 C0 XX 18 00 cc cc (XX = 0, 1, 2, 3)

4. Successful acknowledge from the relay for the “Disable Unsolicited Fast SER Data Transfer” message:

   A5 46 0E 00 00 00 00 00 00 82 00 XX cc cc (XX is the same as the response number in the “Disable Unsolicited Fast SER Data Transfer” message to which it responds.)

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5. Successful acknowledge message from the master for an unsolicited Fast SER message:

   A5 46 0E 00 00 00 00 00 00 98 00 XX cccc (XX is the same as the response number in the unsolicited Fast SER message to which it responds.)

Notes:

Once the relay receives an acknowledge with response code 00 from the master, it will clear the settings changed bit (bit 1) in its status byte, if that bit is asserted, and it will clear the settings changed bit in fast meter, if that bit is asserted.

An element index of FE indicates that the SER record is due to power up. An element index of FF indicates that the SER record is due to a setting change. An element index of FD indicates that the element identified in this SER record is no longer in the SER trigger settings.

When the relay sends an SER message packet, it will put a sequential number (0, 1, 2, 3, 0, 1, ...) into the response number. If the relay does not receive an acknowledge from the master before approximately 500 mS, the relay will resend the same message packet with the same response number until it receives an acknowledge message with that response number. For the next SER message, the relay will increment the response number (it will wrap around to zero from three).

A single Fast SER message packet from the relay can have a maximum number of 32 records and the data may span a time period of no more than 16 seconds. The master can limit the number of records in a packet with the third byte of function code data in the “Enable Unsolicited Data Transfer” message (function code 01). The relay can generate an SER packet with fewer than the requested number of records, if the record time stamps span more than 16 seconds.

The relay always requests acknowledgment in unsolicited Fast SER messages (LSB of the status byte is set).

Unsolicited Fast SER messages can be enabled on multiple ports simultaneously.

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Appendix K

ACSELERATOR QuickSet SEL-5030 Software

Introduction

The ACSELERATOR® QuickSet™ SEL-5030 software is an easy-to-use, yet powerful tool to help you get the most out of your SEL-351S Relay.

Using ACSELERATOR QuickSet, you will be able to:

- Create, test, and manage settings with a Windows® interface.
- Visually design SELOGIC® control equations with a powerful Logic Editor.
- Verify SELOGIC control equations with an integrated Logic Simulator.
- Analyze power system events from SEL relays with integrated Waveform and Harmonic Analysis tools.
- Communicate with SEL devices via an HMI interface with integrated Meter and Control functions.
- Create, manage, copy, merge, and read relay settings with a settings database manager.

This document gives instructions for installing ACSELERATOR QuickSet. A Quick Tour guide is available as part of the online help. After installation, the Quick Tour will show how to create a circuit breaker (CB) simulator. The CB simulator is useful for testing and evaluation.

NOTE: Like all SEL relay products, the SEL-351S can also be set and operated by a simple ASCII terminal.

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ACSELERATOR QuickSet System Requirements

ACSELERATOR QuickSet has the following requirements:

CPU:	Pentium® class (recommended 90 MHz or faster)
Operating System:	Windows® 95/98 with 16 MB ram (32 MB ram recommended) Windows NT®4 SP3 or later with 32 MB ram (64 MB ram recommended) Windows 2000 with 64 MB ram
Disk Space:	25 Mb
Communications:	EIA-232 serial port for communicating with the relay
CD drive:	required for installation

NOTE: Using ACSELERATOR QuickSet in SEL-351S relays requires relay Firmware Version R104 or later.

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Installation

NOTE: Your PC must be restarted after the installation for the changes to take effect.

To install ACSELERATOR QuickSet, perform the following steps.

Step 1. Close all other software applications on the PC.

Step 2. Insert the ACSELERATOR QuickSet SEL-5030 software CD into the PC CD-ROM drive. The installation program should start automatically.

If the installation program does not start, select **Run** from the Windows **Start** menu and type the following command: **D:\SETUP** (substitute D:\ with the PC CD-ROM drive letter).

Step 3. Follow the steps that appear on the screen. The installation program will perform all the necessary steps to load ACSELERATOR QuickSet onto the PC.

It is necessary to have the correct comctl32.dll file installed on the computer in order to see the toolbar buttons. If you do not see the toolbar buttons, run the 40ComUpd.exe, located in the install directory. This file will install the proper Windows system drivers.

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Starting ACSELERATOR QuickSet

You can start ACSELERATOR QuickSet in the following ways:

Step 1. Double-click the ACSELERATOR QuickSet icon if you have a desktop shortcut.

Step 2. Choose **Programs > SEL Applications** and select the ACSELERATOR QuickSet icon to start the program.

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Appendix L
SEL Synchrophasors

Overview

The SEL-351S provides Phasor Measurement Control Unit (PMCU) capabilities when connected to an IRIG-B time source with an accuracy of ±10 µs or better. Synchrophasor data are available via the **MET PM** ASCII command and the SEL Fast Message Unsolicited Write message.

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Introduction

Synchrophasor measurement refers to the concept of providing measurements taken on a synchronized schedule at precise instants in time. A high-accuracy clock, commonly called a Global Positioning System (GPS) receiver such as the SEL-2407 Satellite-Synchronized Clock, makes synchrophasor measurement possible.

The availability of an accurate time reference over a large geographic area allows multiple devices, such as SEL-351S relays, to synchronize the gathering of power system data. The accurate clock allows precise event report analysis and other off-line analysis functions.

The value of synchrophasor data increases greatly when the data can be shared over a communications network in real time. Some possible uses of a system-wise synchrophasor system include the following:

- Power-system state measurement
- Wide-are network protection and control schemes
- Small-signal analysis
- Power-system disturbance analysis

The SEL-351S Global settings class contains the synchrophasor settings, including the choice of transmitted synchrophasor data set. The Port settings class selects which serial port(s) can be used for synchrophasor protocol use. See *Settings on page L.8*. Synchrophasor measurement cannot be enabled if global setting PTCONN = DELTA.

The SEL-351S timekeeping function generates status Relay Word bits that are important for synchrophasor measurement. See *Synchrophasor Relay Word Bits on page L.11*.

When synchrophasor measurement is enabled, the SEL-351S creates the synchrophasor data set at a user-defined rate. Synchrophasor data are available in ASCII format over a serial port set to PROTO = SEL.

Synchrophasor data is collected with an SEL communications processor (i.e., SEL-2032) or a dedicated synchrophasor processor.

The SEL Fast Message Synchrophasor protocol is able to share the same physical port with separate data streams; see *Overview on page D.1*.

Synchrophasor measurement provides the option to display event report data aligned to a high-accuracy time source. See *Synchrophasor-Level Accuracy in Event Reports on page 12.7*.

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Synchrophasor Measurement

The phasor measurement unit in the SEL-351S measures three voltages and three currents at each one-second instant, as determined by the IRIG-B time source. The phase angle is measured relative to an absolute reference, which is represented by a cosine function in *Figure L.1*. The reference is consistent with the phase reference defined in the C37.118 standard. During steady-state conditions, the SEL-351S synchrophasor values can be directly compared to values from other phasor measurement units that conform to C37.118. Synchrophasor values are available for the full frequency range of the SEL-351S.

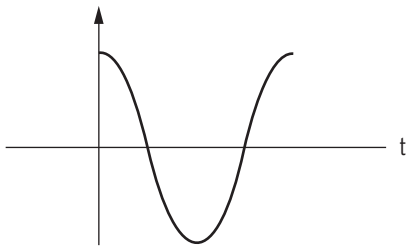


Figure L.1 Phase Reference

The TSOK Relay Word bit asserts when the SEL-351S has determined that the IRIG-B time source has sufficient accuracy and the synchrophasor data meets the specified accuracy. Synchrophasors are still measured if the time source threshold is not met, as indicated by Relay Word bit TSOK = logical 0. The **MET PM** command is not available in this case.

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External Equipment Compensation

The instrumentation transformers (PTs or CTs) and the interconnecting cables may shift the measured signal, as shown in *Figure L.2*.

The angular shift is entered into the relay as Global settings VCOMP and ICOMP, which are internally added to the measured phasor angles in order to create the corrected phasor angles as shown in *Figure L.2*. The VCOMP and ICOMP settings may be positive or negative in value.

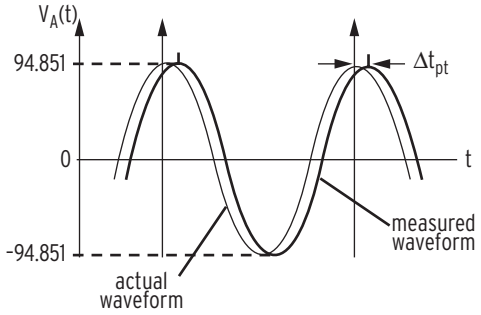


Figure L.2 Waveform at Relay Terminals May Have Phase Shift

If the shift of the measured signal is known in the time domain, it can be converted into an angular shift using *Equation L.1*.

$$\text{Compensation Angle} = \frac{\Delta t_{pt}}{\left(\frac{1}{\text{freq}}\right)} \bullet 360^\circ$$

$$= \Delta t_{pt} \bullet \text{freq} \bullet 360^\circ$$

Equation L.1

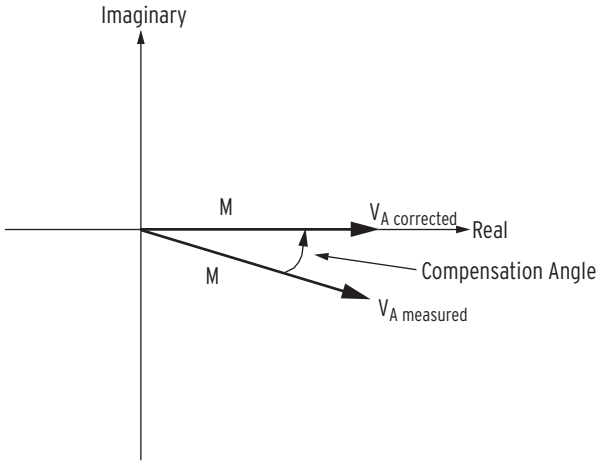


Figure L.3 Correction of Measured Phase Angle

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Protocol Operation

SEL Fast Message Unsolicited Write (synchrophasor) messages are general Fast Messages (A546h) that transport measured synchrophasor information.

Transmit Mode Control

The SEL-351S begins transmitting synchrophasors when an enable message is received from the connected device. The relay stops synchrophasor transmission on a particular serial port when the disable command is received from the connected device, or when the relay settings are changed. The SEL-351S responds to configuration block request messages regardless of the present transmit status, waiting only as long as it takes for any partially sent messages to be completely transmitted.

Table L.1–Table L.3 list the Synchrophasor Fast Message protocol formats, including the specific construction of the enable and disable messages. SEL *Application Guide AG2002-08* provides additional information on the SEL Fast Message Synchrophasor protocol and example applications. This application guide refers to the SEL-421 Relay and differs slightly from the SEL-351S implementation.

Table L.1 SEL Fast Message Protocol Format

Field	Description	Hex Data
Header	Synchrophasor Fast Message	A546
Frame Size	Synchrophasor Data Size[a]	XX
Routing	Must be 0000000000 for this application	0000000000
Status Byte	Must be 00 for this application	00
Function Code	20h Code for unsolicited write messages	20
Sequence	C0 for single frame messages. Maximum frame size 255 bytes	C0
Response Number	Response Number (always 00)	00
PM Data Address	Address of Synchrophasor Measurement Data (PMID setting)	00000000
Register Count	Data size in registers (1 Register = 2 Bytes)	XXXX
Sample Number	0-based index into SOC of this packet	0000
SOC	Second of century[b]	XXXXXXXX
Frequency	IEEE 32-bit floating point[c]	XXXXXXXX
Phasor Mag.	Synchrophasor Data Magnitude (IEEE 32-bit floating point)[d]	XXXXXXXX
Phasor Angle	Synchrophasor Data Angle ±180° (IEEE 32-bit floating point)[d]	XXXXXXXX
Digital Data	TSOK, Time Synchronization OK. PMDOK, Phasor Measurement Data OK. SV3–SV16 bits	XXXX
Check Word	2-byte CRC-16 check code for message	XXXX

[a] The synchrophasor data size is dependent on the PHDATAV and PHDATAI settings as shown in Table L.8.
[b] Provided as an offset referenced to 1900 A.D.
[c] From ANSI/IEEE Std. 754-1985, The IEEE Standard for Binary Floating-Point Arithmetic.
[d] The number and transmit order of Magnitude and Angle data values are determined by the PHDATAV and PHDATAI setting as shown in Table L.8.

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Table L.2 Unsolicited Fast Message Enable Packet

Field	Description	Hex Data
Header	Synchrophasor Fast Message	A546
Frame Size	18 bytes	12
Routing	Must be 0000000000 for this application	0000000000
Status Byte	YY = 00 acknowledge is not requested YY = 01 acknowledge is requested	YY
Function Code	01h Enable unsolicited write messages	01
Sequence	C0 for single frame message. Maximum frame size 255 bytes	C0
Response Number	XX = 00, 01, 02, 03	XX
Application	20h Synchrophasor	20
Message Period	Data message period	nnnn[a]
Check Word	2-byte CRC-16 check code for message	XXXX

[a] See Table L.4 for permissible data message period values.

Table L.3 Unsolicited Fast Message Disable Packet

Field	Description	Hex Data
Header	Synchrophasor Fast Message	A546
Frame Size	16 bytes	10
Routing	Must be 0000000000 for this application	0000000000
Status Byte	YY = 00 acknowledge is not requested YY = 01 acknowledge is requested	YY
Function Code	02h Disable unsolicited write messages	02
Sequence	C0 for single frame message. Maximum frame size 255 bytes	C0
Response Number	XX = 00, 01, 02, 03	XX
Application	20h Synchrophasor	20
Check Word	2-byte CRC-16 check code for message	XXXX

In the SEL Fast Message format, the synchrophasor processor must request a particular data message period, which is embedded in the enable message. If the requested message period can be supported, the SEL-351S will acknowledge the request (if an acknowledgement was requested) and begin transmitting synchrophasors. If the requested message period is not permitted, the SEL-351S will respond with a bad data message (if an acknowledge was requested), and will not transmit any synchrophasor data. *Table L.4* lists the permissible data message periods that can be requested by the enable message. Note that each Fast Message is transmitted at a fixed time after the beginning of each minute.

The SEL-351S will only transmit synchrophasor messages over serial ports that have setting PROTO = SEL. The connected device will typically be a synchrophasor processor or a communications processor, such as the SEL-2032. The connected device controls the PMCU functions of the SEL-351S with SEL Fast Message commands, including commands to start and stop synchrophasor data transmission.

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Table L.4 Permissible Message Periods Requested by Enable Message

Message Period (Hex)	Fast Messages Sent This Number of Seconds After the Top of Each Minute	Number of Fast Messages per Minute
0064h	0,1,2,3,4,5,...,59	60
00C8h	0,2,4,6,8,10,...58	30
012Ch	0,3,6,9,12,15,...57	20
0190h	0,4,8,12,15,...56	15
01F4h	0,5,10,15,20,...55	12
0258h	0,6,12,18,24,...54	10
03E8h	0,10,20,30,40,50	6
05DCh	0,15,30,45	4
07D0h	0,20,40	3
0BB8h	0,30	2
1770h	0	1

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Settings

The phasor measurement control unit (PMCU) settings are listed in *Table L.5*. The Global enable setting EPMU must be set to Y before the remaining SEL-351S synchrophasor settings are available. No synchrophasor data collection can take place when EPMU = N. Use the serial port settings in *Table L.6* to transmit data using the SEL Fast Message Synchrophasor protocol.

Table L.5 SEL-351S Global Settings for Synchrophasors

Global Settings	Description	Default
EPMU[a]	Enable Synchronized Phasor Measurement (Y, N)	N[b]
PMID	PMU Hardware ID	1
PHDATAV	Phasor Data Set, Voltages (V1, ALL)	V1
VCOMP	Voltage Angle Compensation Factor (–179.99 to 180 degrees)	0.00
PHDATAI[c]	Phasor Data Set, Currents (ALL, NA)	NA
ICOMP	Current Angle Compensation Factor (–179.99 to 180 degrees)	0.00
TS_TYPE	Time Source Type (IRIG, IEEE)	IRIG

[a] EPMU is not available if global setting PTCONN = DELTA.
[b] Set EPMU = Y to access the remaining settings.
[c] Setting hidden when PHDATAV = V1.

Certain settings in *Table L.5* are hidden, depending on the status of other settings. For example, if PHDATAV = V1, the PHDATAI setting is hidden to limit the number of settings for your synchrophasor application.

Table L.6 SEL-351S Serial Port Settings for Synchrophasors

Port Setting	Description	Default
PROTO	Protocol (SEL, LMD, DNP, MBA, MBB, MB8A, MB8B, MBGA, MBGB)[a]	SEL[b]
SPEED	Baud Rate (300 to 38400)[c]	2400
BITS	Data Bits (6, 7, 8)	8
PARITY	Parity (O, E, N)	N
STOP	Stop Bits (1, 2)	1
RTSCTS	Enable Hardware Handshaking (Y, N, MBT)	N
FASTOP	Fast Operate Enable (Y, N)	N

[a] Some of the other PROTO setting choices may not be available.
[b] Set PROTO = SEL to enable (on this port) the SEL Fast Message Synchrophasor protocol.
[c] Maximum Port 1 speed is 19200.

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Descriptions of Synchrophasor Settings

Definitions of the settings in *Table L.5* follow.

EPMU

This setting enables synchrophasor operation.

PMID

This setting defines the four-byte destination address used in the SEL Fast Message Unsolicited Write message.

The PMID setting is a 32-bit numeric value.

When connected to an SEL-2032 or an SEL-2030 Communications Processor, the PMID specifies the memory location for data storage. In this case the upper-most byte indicates the communications processor port and the lower two bytes specify the user region address for that port. See the *SEL-2032 Communications Processor Instruction Manual* for more details.

PHDATAV and VCOMP

PHADATAV selects which voltage synchrophasors to include in the Fast Message data packet. Consider the synchrophasor processor burden and offline storage requirements when deciding how much data to transmit. PHDATAV and PHDATAI determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Table L.8*.

- PHDATAV = V1 will transmit only positive-sequence voltage, V1
- PHDATAV = ALL will transmit V1, VA, VB, and VC

Table L.8 describes the order of synchrophasors inside the data packet.

The VCOMP setting allows correction for any steady-state voltage phase errors (from the potential transformer or wiring characteristics).

PHDATAI and ICOMP

PHDATAI selects which current synchrophasors to include in the data packet. Consider the synchrophasor processor burden and offline storage requirements when deciding how much data to transmit. PHDATAV and PHDATAI determine the minimum port SPEED necessary to support the synchrophasor data packet rate and size—see *Table L.8*.

- PHDATAI = ALL will transmit I1, IA, IB, and IC
- PHDATAI = NA will not transmit any currents

Table L.8 describes the order of synchrophasors inside the data packet.

The ICOMP setting allows correction for any steady-state phase errors (from the current transformers or wiring characteristics).

TS_TYPE

This setting defines the type of connection clock.

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When TS_TYPE is set to IRIG, the IRIG message is expected to contain seconds, minutes, hours, and days. The IRIG source gives no additional information to the SEL-351S as to its accuracy. The SEL-351S qualifies the IRIG field to ensure that the time is valid, and then asserts the TIRIG and TSOK Relay Word bits. The local time, as received by the IRIG source, is used for all synchrophasor time values. Under these conditions, the specified SEL-351S synchrophasor accuracy does not include the inaccuracy of the IRIG time source.

When TS_TYPE is set to IEEE, the IRIG message is expected to conform to the IEEE C37.118 standard. Note that time sources conforming to IEEE C37.118 may be marked as IEEE 1344 compliant. The IRIG message includes a UTC offset, time quality information, a year, and a parity bit. The SEL-351S qualifies the IRIG field to ensure that the time is valid, checks for a time quality value better than or equal to ±10 us, and checks for the consistent parity. If all conditions are met, the TSOK Relay Word bit asserts. As in the IRIG case, the TIRIG Relay Word bit asserts when the time field has valid data and does not include additional checks. When the Time Source Type is set to IEEE, the UTC time value is used in the synchrophasor fast message. The **MET PM** command still displays the local time.

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Synchrophasor Relay Word Bits

The Time Synchronization Relay Word bits in *Table L.7* indicate the present status of the timekeeping function of the SEL-351S. See *IRIG-B on page 10.2*.

Table L.7 Time Synchronization Relay Word Bits

Name	Description
TIRIG	Asserts while relay time is based on IRIG-B time source.
TSOK	Time Synchronization OK. Asserts while time accuracy is of sufficient accuracy for synchrophasor measurement and satisfies TS_TYPE requirements.
PMDOK	Phasor Measurement Data OK. Asserts when the SEL-351S is enabled, synchrophasors are enabled (Global setting EPMU = Y), and TSOK is asserted.

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View Synchrophasors by Using the MET PM Command

The **MET PM** serial port ASCII command may be used to view the SEL-351S synchrophasor measurements. See *MET Command (Metering Data) on page 10.20* for general information on the **MET** command.

There are multiple ways to use the **MET PM** command:

- As a test tool, to verify connections, phase rotation, and scaling
- As an analytical tool, to capture synchrophasor data at an exact time, in order to compare this information with similar data captured in other phasor measurement unit(s) at the same time.
- As a method of periodically gathering synchrophasor data through a communications processor.

The **MET PM** command displays the same set of analog synchrophasor information, regardless of the Global settings PHDATAV and PHDATAI. The **MET PM** command can function even when no serial ports are sending fast message synchrophasor data.

The **MET PM** command only displays data when the Relay Word bit TSOK = logical 1. *Figure L.4* shows a sample **MET PM** command response. The synchrophasor data are also available in ACSELERATOR® QuickSet™ and have a similar format to *Figure L.4*.

The **MET PM [*time*]** command can be used to direct the SEL-351S to display the synchrophasor for an exact specified time, in 24-hour format. For example, entering the command **MET PM 14:14:12** will result in a response similar to *Figure L.4* occurring just after 14:14:12, with the time stamp 14:14:12.000.

This method of data capture always reports from the exact second, even if the time parameter is entered with fractional seconds. For example, entering **MET PM 14:14:12.200** results in the same data capture as **MET PM 14:14:12**, because the relay ignored the fractional seconds.

See *MET PM—Synchrophasor Metering on page 10.25* for complete command options, and error messages.

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```
=>MET PM <Enter>

                                  Date: 03/31/2007 Time: 15:51:00.000
Time Quality   Maximum time synchronization error:    0.000 (ms)  TSOK = 1


Synchrophasors
                     Phase Voltages             Pos. Sequence Voltage
                  VA         VB         VC                 V1
MAG (kV)          11.691     11.686     11.669             11.682
ANG (DEG)        129.896     10.262   -111.764            129.485

                     Phase Currents             Pos. Sequence Current
                  IA         IB         IC                 I1
MAG (A)          195.146    192.614    198.090            195.283
ANG (DEG)        114.930     -2.786   -120.238            117.338

FREQ (Hz) 60.029

Digitals

SV3     SV4     SV5     SV6     SV7     SV8     SV9     SV10
 0       0       0       0       0       0       0       0
SV11    SV12    SV13    SV14    SV15    SV16
 0       0       0       0       0       0

=>
```

Figure L.4 Sample MET PM Command Response

The Maximum time synchronization error field is take directly from the TQUAL status field of the IRIG-B message. If TS_TYPE = IRIG, the maximum time synchronization error will be displayed as $.$$$.

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Communications Bandwidth

A phasor measurement control until (PMCU) that is configured to transmit a single synchrophasor quantity (positive-sequence voltage, for example) at a message period of one second places little burden on the communications channel. As more synchrophasors or interleaved protocols are added, some communications channel restrictions come into play.

The SPEED setting on any serial port set with PROTO = PMU should be set as high as possible, but no higher that 19200 baud, to allow for the largest possible number of message period requests to be successful.

The SEL-351S Fast Message synchrophasor format always includes 32 bytes for the message header and terminal ID, time information, frequency, and status bits. The selection of synchrophasor data will add to the byte requirements. Each synchrophasor quantity will add eight bytes to the message length. *Table L.8* shows the effect that adding synchrophasor quantities has on the minimum allowed SPEED setting.

The number of interleaved protocols sharing the same physical port will also impact the minimum allowed SPEED setting. *Table L.8* shows the setting if the Fast Message Synchrophasor format is the only data stream transmitted; additional data streams will necessitate a higher SPEED setting.

Table L.8 SEL Fast Message Voltage and Current Selections Based on PHDATAV and PHDATAI

Global Settings	Number of Synchrophasor Magnitude and Angle Pairs Transmitted	Synchrophasor Magnitude and Angle Pairs to Transmit, and the Transmit Order	Synchrophasor Data Size (Bytes)	Minimum Baud Rate (SPEED Setting) at One Second Message Period
PHDATAV = V1 PHDATAI = NA	1	V1	40	1200 Baud
PHDATAV = ALL PHDATAI = NA	4	VA, VB, VC, V1	64	2400 Baud
PHDATAV = ALL PHDATAI = ALL	8	VA, VB, VC, V1, IA, IB, IC, I1	96	4800 Baud

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SEL-351S Relay
Command Summary

SEL-351S Relay Commands (Sheet 1 of 3)

Command	Description
2AC	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
ACC	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
BAC	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts the user for the Access Level B password.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE *n*	Enter **BRE W** to preload breaker wear. Enter **BRE R** to reset breaker monitor data.
CLO	Close circuit breaker (assert Relay Word bit CC).
COM[a] *p*	Show communications summary report (COM report) on MIRRORED BITS® channel *p* (where *p* = A or B) using all failure records in the channel calculations.
COM[a] *p n*	Show a COM report for MIRRORED BITS channel *p* using the latest *n* failure records (*n* = 1–512, where 1 is the most recent entry).
COM[a] *p m n*	Show COM report for MIRRORED BITS channel *p* using failure records *m*–*n* (*m* = 1–512).
COM[a] *p d1*	Show COM report for MIRRORED BITS channel *p* using failures recorded on date *d1* (see **DAT** command for date format).
COM[a] *p d1 d2*	Show COM report for MIRRORED BITS BITS channel *p* using failures recorded between dates *d1* and *d2* inclusive.
COM[a] . . . L	For all **COM** commands, L causes the specified COM report records to be listed after the summary.
COM[a] *p* C	Clears communications records for MIRRORED BITS channel *p* (or both channels if *p* is not specified, **COM C** command).
CON *n*	Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1–16). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following: **SRB *n*** set Remote Bit *n* (assert RB*n*). **CRB *n*** clear Remote Bit *n* (deassert RB*n*). **PRB *n*** pulse Remote Bit *n* (assert RB*n* for 1/4 cycle).
COP *m n*	Copy relay and logic settings from group *m* to group *n* (*m* and *n* are numbers 1–6).
DAT	Show date.
DAT mm/dd/yy	Enter date in this manner if global Date Format setting, DATE_F, is set to MDY.
DAT yy/mm/dd	Enter date in this manner if global Date Format setting, DATE_F, is set to YMD.
EVE *n*	Show event report *n* with 4 samples per cycle (*n* = 1 to highest numbered event report, where 1 is the most recent report: see **HIS** command). If *n* is omitted (**EVE** command), most recent report is displayed.
EVE *n* R	Show event report *n* in raw (unfiltered) format with 16 samples-per-cycle resolution.
EVE *n* C	Show event report *n* in compressed ASCII format for use with the SEL-5601 Analytic Assistant.
EVE *n* A	Show event report *n* with analog section only.
EVE *n* D	Show event report *n* with digital section only.
EVE *n* M	Show event report *n* with communications section only.
EVE *n* S*x*	Show event report *n* with *x* samples per cycle (*x* = 4 or 16).
EVE *n* L	Show event report *n* with 16 samples per cycle (similar to **EVE *n* S16**).

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SEL-351S Relay Commands (Sheet 2 of 3)

Command	Description
EVE *n* L*y*	Show first *y* cycles of event report *n* (*y* = 1 to global setting LER).
EVE *n* V	Show event report *n* with variable scaling for analog values.
EVE *n* P	Show event report *n* with synchrophasor-level accuracy time adjustment.
GRO	Display active group number.
GRO *n*	Change active group to group *n* (*n* = 1–6).
HIS *n*	Show brief summary of *n* latest event reports, where 1 is the most recent entry. If *n* is not specified, (**HIS** command) all event summaries are displayed.
HIS C	Clear all event reports from nonvolatile memory.
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
LDP[a]	Show entire Load Profile (LDP) report.
LDP[a] *n*	Show latest *n* rows in the LDP report (*n* = 1 to several thousand, where 1 is the most recent entry).
LDP[a] *m n*	Show rows *m*–*n* in the LDP report (*m* = 1 to several thousand).
LDP[a] *d1*	Show all rows in the LDP report recorded on the specified date (see **DAT** command for date format).
LDP[a] *d1 d2*	Show all rows in the LDP report recorded between dates *d1* and *d2*, inclusive.
LDP[a] D	Display the number of days of LDP storage capacity before data overwrite will occur.
LDP[a] C	Clears the LDP report from nonvolatile memory.
LOO[a] *p t*	Set MIRRORED BITS port *p* to loopback (*p* = A or B). The received MIRRORED BITS elements are forced to default values during the loopback test; *t* specifies the loopback duration in minutes (*t* = 1–5000, default is 5).
LOO[a] *p* DATA	Set MIRRORED BITS port *p* to loopback. DATA allows the received MIRRORED BITS elements to change during the loopback test.
MET *k*	Display instantaneous metering data. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET X *k*	Display same as **MET** command with phase-to-phase voltages and Vbase. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET D	Display demand and peak demand data. Select **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Select **MET RE** to reset.
MET M	Display maximum/minimum metering data. Select **MET RM** to reset.
MET PM [*time*] [*k*]	Display synchrophasor measurements (available when TSOK = logical 1). Enter *time* to display the synchrophasor for an exact specified time, in 24-hour format. Enter *k* for repeat count.
OPE	Open circuit breaker (assert Relay Word bit OC).
PAS 1	Change Access Level 1 password.
PAS B	Change Access Level B password.
PAS 2	Change Access Level 2 password. Entering DISABLE as the password disables the password requirement for the specified access level.
PUL *n k*	Pulse output contact *n* (where *n* is one of ALARM, OUT101–OUT107, OUT201–OUT212) for *k* seconds. Specify parameter *n*; *k* = 1–30 seconds; if not specified, default is 1.
QUI	Quit. Returns to Access Level 0. Terminates SEL Distributed Port Switch Protocol (LMD) connection.
SER	Show entire Sequential Events Recorder (SER) report.
SER *n*	Show latest *n* rows in the SER report (*n* = 1–512, where 1 is the most recent entry).
SER *m n*	Show rows *m*–*n* in the SER report (*m* = 1–512).
SER *d1*	Show all rows in the SER report recorded on the specified date (see **DAT** command for date format).
SER *d1 d2*	Show all rows in the SER report recorded between dates *d1* and *d2*, inclusive.
SER C	Clears SER report from nonvolatile memory.

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SEL-351S Relay Commands (Sheet 3 of 3)

Command	Description
SET *n*	Change relay settings (overcurrent, reclosing, timers, etc.) for group *n* (*n* = 1–6, if not specified, default is active setting group).
SET *n* L	Change SELOGIC® control equation settings for group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SET G	Change global settings.
SET R	Change SER and LDP Recorder[a] settings.
SET T	Change text label settings.
SET P *p*	Change serial port *p* settings, (*p* = 1, 2, 3, or F; if not specified, default is active port).
SET . . . *name*	For all **SET** commands, jump ahead to specific setting by entering setting name.
SET . . . TERSE	For all **SET** commands, TERSE disables the automatic **SHO** command after settings entry.
SHO *n*	Show relay settings (overcurrent, reclosing, timers, etc.) for group *n* (*n* = 1–6, if not specified, default is active setting group).
SHO *n* L	Show SELOGIC control equation settings for group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SHO G	Show global settings.
SHO R	Show SER and LDP Recorder[a] settings.
SHO T	Show text label settings.
SHO P *p*	Show serial port *p* settings, (*p* = 1, 2, 3, or F; if not specified, default is active port).
SHO . . . *name*	For all **SHO** commands, jump ahead to specific setting by entering setting name.
SSI[b]	Show entire Voltage Sag/Swell/Interruption (SSI) report.
SSI[b] *n*	Show latest *n* rows in SSI report (*n* = 1 to several thousand, where 1 is the most recent entry).
SSI[b] *m n*	Show rows *m*–*n* in SSI report (*m* = 1 to several thousand).
SSI[b] *d1*	Show all rows in SSI report recorded on the specified date (see **DAT** command for date format).
SSI[b] *d1 d2*	Show all rows in SSI report recorded between dates *d1* and *d2*, inclusive.
SSI[b] C	Clears SSI report from nonvolatile memory.
SSI[b] R	Resets Vbase element. See Vbase initialization.
SSI[b] T	Trigger the SSI recorder.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots the relay.
TAR R	Reset front-panel tripping targets.
TAR *n k*	Display Relay Word row. If *n* = 0–59, display row *n*. If *n* is an element name (e.g., 50A1), display row containing element *n*. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
TAR LIST	Shows all the Relay Words in all of the rows.
TAR ROW. . .	Shows the Relay Word row number at the start of each line, with other selected **TARGET** commands as described above, such as *n*, *name*, *k*, and LIST.
TIM	Show or set time (24-hour time). Show current relay time by entering **TIM**. Set the current time by entering **TIM** followed by the time of day (e.g., set time 22:47:36 by entering **TIM 22:47:36**).
TRI [*time*]	Trigger an event report. Enter *time* to trigger an event at an exact specified time, in 24-hour format.
VER	Show relay configuration and firmware version.

[a] Available in firmware versions 6 and 7.
[b] Available in firmware version 7.

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Key Stroke Commands

Key Stroke	Description	Key Stroke When Using SET Command	Description
Ctrl + Q	Send **XON** command to restart communications port output previously halted by XOFF.	**<Enter>**	Retains setting and moves on to next setting.
Ctrl + S	Send **XOFF** command to pause communications port output.	**^<Enter>**	Returns to previous setting.
Ctrl + X	Send **CANCEL** command to abort current command and return to current access level prompt.	**<<Enter>**	Returns to previous setting section.
		><Enter>	Skips to next setting section.
		END <Enter>	Exits setting editing session, then prompts user to save settings.
		Ctrl + X	Aborts setting editing session without saving changes.

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SEL-351S Relay
Command Summary

SEL-351S Relay Commands (Sheet 1 of 3)

Command	Description
2AC	Enter Access Level 2. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 2 password in order to enter Access Level 2.
ACC	Enter Access Level 1. If the main board password jumper is not in place, the relay prompts for the entry of the Access Level 1 password in order to enter Access Level 1.
BAC	Enter Breaker Access Level (Access Level B). If the main board password jumper is not in place, the relay prompts the user for the Access Level B password.
BRE	Display breaker monitor data (trips, interrupted current, wear).
BRE *n*	Enter **BRE W** to preload breaker wear. Enter **BRE R** to reset breaker monitor data.
CLO	Close circuit breaker (assert Relay Word bit CC).
COM[a] *p*	Show communications summary report (COM report) on MIRRORED BITS® channel *p* (where *p* = A or B) using all failure records in the channel calculations.
COM[a] *p n*	Show a COM report for MIRRORED BITS channel *p* using the latest *n* failure records (*n* = 1–512, where 1 is the most recent entry).
COM[a] *p m n*	Show COM report for MIRRORED BITS channel *p* using failure records *m*–*n* (*m* = 1–512).
COM[a] *p d1*	Show COM report for MIRRORED BITS channel *p* using failures recorded on date *d1* (see **DAT** command for date format).
COM[a] *p d1 d2*	Show COM report for MIRRORED BITS BITS channel *p* using failures recorded between dates *d1* and *d2* inclusive.
COM[a] . . . L	For all **COM** commands, L causes the specified COM report records to be listed after the summary.
COM[a] *p* C	Clears communications records for MIRRORED BITS channel *p* (or both channels if *p* is not specified, **COM C** command).
CON *n*	Control Relay Word bit RB*n* (Remote Bit *n*; *n* = 1–16). Execute **CON *n*** and the relay responds: CONTROL RB*n*. Then reply with one of the following: **SRB *n*** set Remote Bit *n* (assert RB*n*). **CRB *n*** clear Remote Bit *n* (deassert RB*n*). **PRB *n*** pulse Remote Bit *n* (assert RB*n* for 1/4 cycle).
COP *m n*	Copy relay and logic settings from group *m* to group *n* (*m* and *n* are numbers 1–6).
DAT	Show date.
DAT mm/dd/yy	Enter date in this manner if global Date Format setting, DATE_F, is set to MDY.
DAT yy/mm/dd	Enter date in this manner if global Date Format setting, DATE_F, is set to YMD.
EVE *n*	Show event report *n* with 4 samples per cycle (*n* = 1 to highest numbered event report, where 1 is the most recent report: see **HIS** command). If *n* is omitted (**EVE** command), most recent report is displayed.
EVE *n* R	Show event report *n* in raw (unfiltered) format with 16 samples-per-cycle resolution.
EVE *n* C	Show event report *n* in compressed ASCII format for use with the SEL-5601 Analytic Assistant.
EVE *n* A	Show event report *n* with analog section only.
EVE *n* D	Show event report *n* with digital section only.
EVE *n* M	Show event report *n* with communications section only.
EVE *n* S*x*	Show event report *n* with *x* samples per cycle (*x* = 4 or 16).
EVE *n* L	Show event report *n* with 16 samples per cycle (similar to **EVE *n* S16**).

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SEL-351S Relay Commands (Sheet 2 of 3)

Command	Description
EVE *n* L*y*	Show first *y* cycles of event report *n* (*y* = 1 to global setting LER).
EVE *n* V	Show event report *n* with variable scaling for analog values.
EVE *n* P	Show event report *n* with synchrophasor-level accuracy time adjustment.
GRO	Display active group number.
GRO *n*	Change active group to group *n* (*n* = 1–6).
HIS *n*	Show brief summary of *n* latest event reports, where 1 is the most recent entry. If *n* is not specified, (**HIS** command) all event summaries are displayed.
HIS C	Clear all event reports from nonvolatile memory.
IRI	Force synchronization attempt of internal relay clock to IRIG-B time-code input.
LDP[a]	Show entire Load Profile (LDP) report.
LDP[a] *n*	Show latest *n* rows in the LDP report (*n* = 1 to several thousand, where 1 is the most recent entry).
LDP[a] *m n*	Show rows *m*–*n* in the LDP report (*m* = 1 to several thousand).
LDP[a] *d1*	Show all rows in the LDP report recorded on the specified date (see **DAT** command for date format).
LDP[a] *d1 d2*	Show all rows in the LDP report recorded between dates *d1* and *d2*, inclusive.
LDP[a] D	Display the number of days of LDP storage capacity before data overwrite will occur.
LDP[a] C	Clears the LDP report from nonvolatile memory.
LOO[a] *p t*	Set MIRRORED BITS port *p* to loopback (*p* = A or B). The received MIRRORED BITS elements are forced to default values during the loopback test; *t* specifies the loopback duration in minutes (*t* = 1–5000, default is 5).
LOO[a] *p* DATA	Set MIRRORED BITS port *p* to loopback. DATA allows the received MIRRORED BITS elements to change during the loopback test.
MET *k*	Display instantaneous metering data. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET X *k*	Display same as **MET** command with phase-to-phase voltages and Vbase. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
MET D	Display demand and peak demand data. Select **MET RD** or **MET RP** to reset.
MET E	Display energy metering data. Select **MET RE** to reset.
MET M	Display maximum/minimum metering data. Select **MET RM** to reset.
MET PM [*time*] [*k*]	Display synchrophasor measurements (available when TSOK = logical 1). Enter *time* to display the synchrophasor for an exact specified time, in 24-hour format. Enter *k* for repeat count.
OPE	Open circuit breaker (assert Relay Word bit OC).
PAS 1	Change Access Level 1 password.
PAS B	Change Access Level B password.
PAS 2	Change Access Level 2 password. Entering DISABLE as the password disables the password requirement for the specified access level.
PUL *n k*	Pulse output contact *n* (where *n* is one of ALARM, OUT101–OUT107, OUT201–OUT212) for *k* seconds. Specify parameter *n*; *k* = 1–30 seconds; if not specified, default is 1.
QUI	Quit. Returns to Access Level 0. Terminates SEL Distributed Port Switch Protocol (LMD) connection.
SER	Show entire Sequential Events Recorder (SER) report.
SER *n*	Show latest *n* rows in the SER report (*n* = 1–512, where 1 is the most recent entry).
SER *m n*	Show rows *m*–*n* in the SER report (*m* = 1–512).
SER *d1*	Show all rows in the SER report recorded on the specified date (see **DAT** command for date format).
SER *d1 d2*	Show all rows in the SER report recorded between dates *d1* and *d2*, inclusive.
SER C	Clears SER report from nonvolatile memory.

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SEL-351S Relay Commands (Sheet 3 of 3)

Command	Description
SET *n*	Change relay settings (overcurrent, reclosing, timers, etc.) for group *n* (*n* = 1–6, if not specified, default is active setting group).
SET *n* L	Change SELOGIC® control equation settings for group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SET G	Change global settings.
SET R	Change SER and LDP Recorder[a] settings.
SET T	Change text label settings.
SET P *p*	Change serial port *p* settings, (*p* = 1, 2, 3, or F; if not specified, default is active port).
SET . . . *name*	For all **SET** commands, jump ahead to specific setting by entering setting name.
SET . . . TERSE	For all **SET** commands, TERSE disables the automatic **SHO** command after settings entry.
SHO *n*	Show relay settings (overcurrent, reclosing, timers, etc.) for group *n* (*n* = 1–6, if not specified, default is active setting group).
SHO *n* L	Show SELOGIC control equation settings for group *n* (*n* = 1–6, if not specified, default is the SELOGIC control equations for the active setting group).
SHO G	Show global settings.
SHO R	Show SER and LDP Recorder[a] settings.
SHO T	Show text label settings.
SHO P *p*	Show serial port *p* settings, (*p* = 1, 2, 3, or F; if not specified, default is active port).
SHO . . . *name*	For all **SHO** commands, jump ahead to specific setting by entering setting name.
SSI[b]	Show entire Voltage Sag/Swell/Interruption (SSI) report.
SSI[b] *n*	Show latest *n* rows in SSI report (*n* = 1 to several thousand, where 1 is the most recent entry).
SSI[b] *m n*	Show rows *m*–*n* in SSI report (*m* = 1 to several thousand).
SSI[b] *d1*	Show all rows in SSI report recorded on the specified date (see **DAT** command for date format).
SSI[b] *d1 d2*	Show all rows in SSI report recorded between dates *d1* and *d2*, inclusive.
SSI[b] C	Clears SSI report from nonvolatile memory.
SSI[b] R	Resets Vbase element. See Vbase initialization.
SSI[b] T	Trigger the SSI recorder.
STA	Show relay self-test status.
STA C	Resets self-test warnings/failures and reboots the relay.
TAR R	Reset front-panel tripping targets.
TAR *n k*	Display Relay Word row. If *n* = 0–59, display row *n*. If *n* is an element name (e.g., 50A1), display row containing element *n*. Enter *k* for repeat count (*k* = 1–32767, if not specified, default is 1).
TAR LIST	Shows all the Relay Words in all of the rows.
TAR ROW. . .	Shows the Relay Word row number at the start of each line, with other selected **TARGET** commands as described above, such as *n*, *name*, *k*, and LIST.
TIM	Show or set time (24-hour time). Show current relay time by entering **TIM**. Set the current time by entering **TIM** followed by the time of day (e.g., set time 22:47:36 by entering **TIM 22:47:36**).
TRI [*time*]	Trigger an event report. Enter *time* to trigger an event at an exact specified time, in 24-hour format.
VER	Show relay configuration and firmware version.

[a] Available in firmware versions 6 and 7.
[b] Available in firmware version 7.

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Key Stroke Commands

Key Stroke	Description	Key Stroke When Using SET Command	Description
Ctrl + Q	Send **XON** command to restart communications port output previously halted by XOFF.	**<Enter>**	Retains setting and moves on to next setting.
Ctrl + S	Send **XOFF** command to pause communications port output.	**^<Enter>**	Returns to previous setting.
Ctrl + X	Send **CANCEL** command to abort current command and return to current access level prompt.	**<<Enter>**	Returns to previous setting section.
		><Enter>	Skips to next setting section.
		END <Enter>	Exits setting editing session, then prompts user to save settings.
		Ctrl + X	Aborts setting editing session without saving changes.

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