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Find the *SEL SEL-351S-5* at our website: *Click HERE*

SEL-351S Protection and Breaker Control Relay

Optimize Distribution Protection, Automation, and Breaker Control



Major Features and Benefits

The SEL-351S Protection and Breaker Control Relay provides an exceptional package of protection, monitoring, control, and fault locating features.

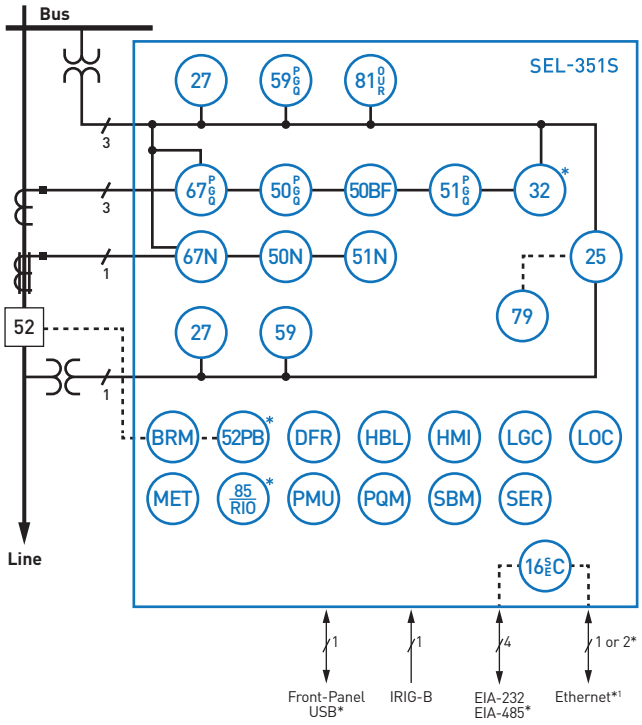
- **Synchrophasors.** Synchrophasors improve operator awareness of system conditions. Use real-time data to view load angles, improve event analysis, and provide state measurements.
- **Protection Features.** Phase, negative-sequence, residual-ground, and neutral-ground overcurrent elements protect lines and equipment (make elements directional for looped systems). Ordering options for non-directional sensitive earth fault (SEF) protection and directional protection for ungrounded, high-impedance grounded, Petersen Coil grounded, and low-impedance grounded systems. Implement load shedding and other control schemes with over- and underfrequency and over- and undervoltage elements.
- **Operator Controls and Reclosing.** Direct action operator controls eliminate expensive panel-mounted control switches and associated wiring. Implement remote and local control functions, and selectively reclose with synchronism and voltage checks.
- **Relay and Logic Settings Software.** ACSELERATOR QuickSet® SEL-5030 software reduces engineering costs for relay settings and logic programming. Graphical tools in ACSELERATOR QuickSet make it easy to develop SELOGIC® control equations.
- **Metering, Monitoring, and Fault Locator.** Built-in, high-accuracy metering functions eliminate expensive, separately mounted metering devices. Improve maintenance scheduling using circuit breaker contact wear and substation battery voltage monitors. Analyze Sequential Events Recorder (SER) reports and oscillographic event reports for rapid commissioning, testing, and post-fault diagnostics. Unsolicited SER protocol allows station-wide collection of binary SER messages.

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➤ **Wye or Delta Voltage Inputs.** Settings allow either wye-connected or open-delta-connected voltage transformers and either synchronism-check or broken-delta (zero-sequence) voltage connection to the relay.

Optional features include DNP3 Level 2 Outstation, MIRRORED BITS® communications, load profile, power elements, voltage sag/swell/interruption recording, expanded I/O, and independent auxiliary trip and close pushbuttons.

Functional Overview



ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
16 SEC	Access Security (Serial, Ethernet)
25	Synchronism Check
27	Undervoltage
32	Directional Power*
50BF	Breaker Failure Overcurrent
50G	Best Choice Ground
50N	Neutral Overcurrent
50 (P, G, Q)	Overcurrent (Phase, Ground, Neg. Seq.)
50/51	Adaptive Overcurrent
51N	Neutral Time-Overcurrent
51 (P, G, Q)	Time-Overcurrent (Phase, Ground, Neg. Seq.)
52PB	Trip/Close Pushbuttons*
59	Overvoltage
59 (P, G, Q)	Overvoltage (Phase, Ground, Neg. Seq.)
67N	Directional Neutral Overcurrent
67 (P, G, Q)	Directional Overcurrent (Phase, Ground, SEF*, Neg. Seq.)
79	Autoreclosing
81 (O, U, R)	Frequency (Over, Under, Rate)
85 RIO	SEL MIRRORED BITS® Communications*
DFR	Event Reports
HMI	Operator Interface
LGC	SELOGIC® Control Equations
MET	High-Accuracy Metering

ADDITIONAL FUNCTIONS	
BRM	Breaker Wear Monitor
HBL	Harmonic Blocking
LDE	Load Encroachment
LDP	Load Data Profiling*
LOC	Fault Locator
PPV	Phantom Phase Voltage
SBM	Station Battery Monitor

[1] Copper or Fiber Optic * Optional Feature

Figure 1 Functional Diagram

Protection Features

The SEL-351S includes a robust set of phase, negative-sequence, residual, and neutral overcurrent elements. Each element type has six levels of instantaneous protection (four of these levels have definite-time functions). Each element type has two time-overcurrent elements (except negative-sequence that has one time-overcurrent element). The relay provides directional control for each of these overcurrent elements.

In addition to the curves listed in *Table 1*, the SEL-351S provides 38 standard types of recloser curves.

Table 1 Time-Overcurrent Curves

US	IEC
Moderately Inverse	Standard Inverse
Inverse	Very Inverse
Very Inverse	Extremely Inverse
Extremely Inverse	Long-Time Inverse
Short-Time Inverse	Short-Time Inverse

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The recloser curves allow easy coordination with downstream reclosers using standard recloser curves. *Figure 2* represents an SEL-351S coordinated to a downstream SEL-351R Recloser Control.

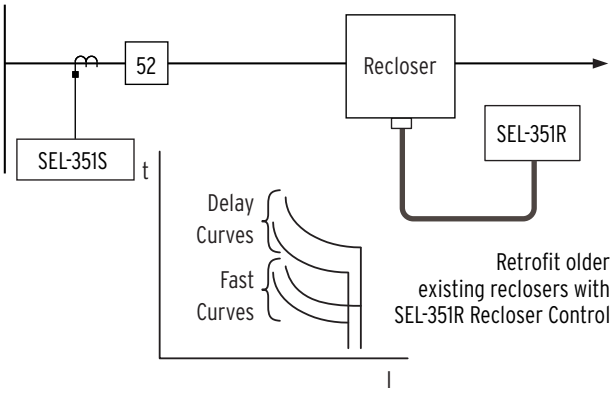


Figure 2 Coordinate Overcurrent Protective Devices

The SEL-351S has two reset characteristic choices for each time-overcurrent element. One choice resets the elements if current drops below pickup for at least one cycle. The other choice emulates electromechanical induction disc elements, where the reset time depends on the time-dial setting, the percentage of disc travel, and the amount of current. This choice is unavailable when using one of the standard recloser curves.

Overcurrent Elements for Phase Fault Detection

Phase and negative-sequence overcurrent elements detect phase faults. Negative-sequence current elements ignore three-phase load to provide more sensitive coverage of phase-to-phase faults. Phase overcurrent elements detect three-phase faults, which do not have significant negative-sequence quantities.

On heavily loaded feeders, the load encroachment logic adds security. This logic allows you to set the phase overcurrent elements below peak load current to see end-of-line phase faults in heavily loaded feeder applications. This load encroachment logic uses positive-sequence load-in and load-out elements to discriminate between load and fault conditions (*Figure 3*). When the load impedance (Z1) resides in a load region, load encroachment logic blocks the phase overcurrent elements. As *Figure 3* shows, when a phase fault occurs, Z1 moves from a load region to the line angle and allows the phase overcurrent elements to operate.

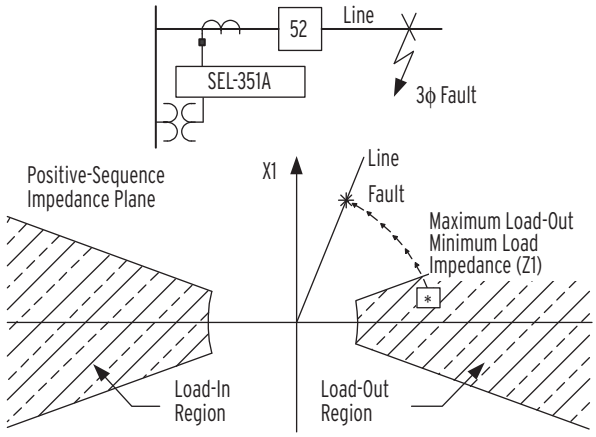


Figure 3 Load Encroachment Characteristics

Overcurrent Elements for Ground Fault Detection

Residual (I_G) and neutral (I_N) overcurrent elements detect ground faults. Increase security by controlling these elements using optoisolated inputs or the internal ground directional element. The ground directional element of this relay includes load-adaptive security logic for heavily or lightly loaded unbalanced feeder applications.

Sensitive Earth Fault (SEF) Element

Set SEF elements with time delay up to 16,000 cycles and as sensitively as 5 mA secondary. Current channel IN ordered with a 0.2 A secondary nominal rating provides this sensitivity.

Connect to Wye or Open-Delta Voltages

Wye-connected (four-wire) voltage or open-delta-connected (three-wire) voltage can be applied to three-phase voltage inputs VA, VB, VC, and N, as shown in *Figure 4*. You only need to make a global setting (PTCONN = WYE or PTCONN = DELTA, respectively) and an external wiring change—no internal relay hardware changes or adjustments are required. Thus, a single SEL-351S model meets all your distribution protection needs, regardless of available three-phase voltage.

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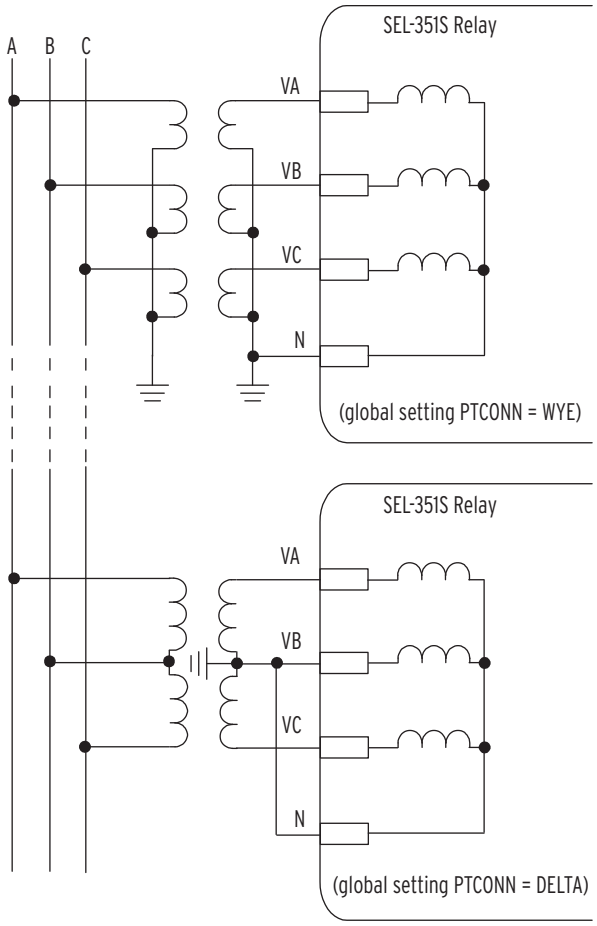


Figure 4 Connect Wye or Open-Delta Voltage to SEL-351S Three-Phase Voltage Inputs

Connect to Synchronism-Check or Broken-Delta Voltage

Traditionally, single-phase voltage (phase-to-neutral or phase-to-phase) is connected to voltage input VS/NS for synchronism check across a circuit breaker (or hot/dead line check), as shown in *Figure 22*.

Alternatively, voltage input VS/NS can be connected to a broken-delta voltage source, as shown in *Figure 5*. This broken-delta connection provides a zero-sequence voltage source (3V0)—useful when zero-sequence voltage is not available via the three-phase voltage inputs VA, VB, VC, and N, (e.g., when open-delta-connected voltage is applied to the three-phase voltage inputs—see *Figure 4*). Zero-sequence voltage is used in zero-sequence voltage-polarized ground directional elements and in the directional protection for Petersen Coil grounded systems.

Choosing between synchronism-check or broken-delta (3V0) voltage source operation for voltage input VS/NS requires only a global setting (VSCONN = VS or VSCONN = 3V0, respectively) and an external wiring change—no internal relay hardware changes or adjustments are required. Therefore, a single SEL-351S model can be used in either traditional synchronism-check applications or broken-delta voltage applications.

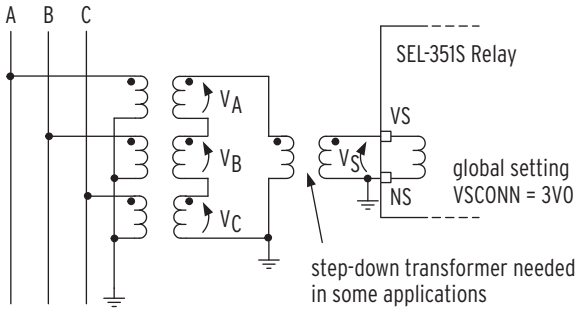


Figure 5 Broken-Delta Connection to SEL-351S Voltage Input VS/NS

Directional Elements Increase Sensitivity and Security

Phase and ground directional elements are standard. An automatic setting mode sets all directional threshold settings based on replica line impedance settings. Phase directional elements provide directional control to the phase- and negative-sequence overcurrent elements. Ground directional elements provide directional control to the ground and neutral overcurrent elements.

Phase directional characteristics include positive-sequence and negative-sequence directional elements that work together. The positive-sequence directional element memory provides a reliable output for close-in, forward- or reverse-bolted three-phase faults where each phase voltage is zero. The negative-sequence directional element uses the same patented principle proven in our SEL-321 Relay. Apply this directional element in virtually any application regardless of the amount of negative-sequence voltage available at the relay location.

The following directional elements work together to provide ground directionality:

- Negative-sequence voltage-polarized element.
- Zero-sequence voltage-polarized element.
- Zero-sequence current-polarized element.

Our patented Best Choice Ground Directional™ logic selects the best ground directional element for the system conditions. This scheme eliminates directional element settings. (You may override this automatic setting feature for special applications.)

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Directional Protection for Various System Grounding Practices

Current channel IN, ordered with a 0.2 A secondary nominal rating, provides directional ground protection for the following systems:

- Ungrounded systems
- High-impedance grounded systems
- Petersen Coil grounded systems
- Low-impedance grounded systems

This directional control allows the faulted feeder to be identified on a multi-feeder bus, with an SEL-351S on each feeder (*Figure 6*). Alarm or trip for the ground fault condition—sensitivity down to 5 mA secondary.

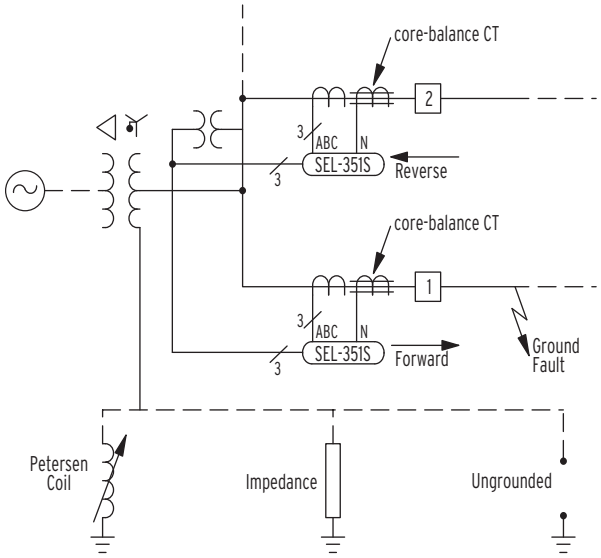


Figure 6 Apply SEL-351S Relays to Petersen Coil Grounded, Impedance-Grounded, and Ungrounded Systems for Directional Control

Best Choice Ground Directional Element logic provides protection for a wide range of ground fault current due to system configuration changes (e.g., the system changes from Petersen Coil "in-service" to "out-of-service" [coil "shorted-out"]).

Directional protection for Petersen Coil grounded systems makes use of the traditional wattmetric method (*Figure 7*) and a new, more-sensitive incremental conductance element (*Figure 8*) for ground fault detection.

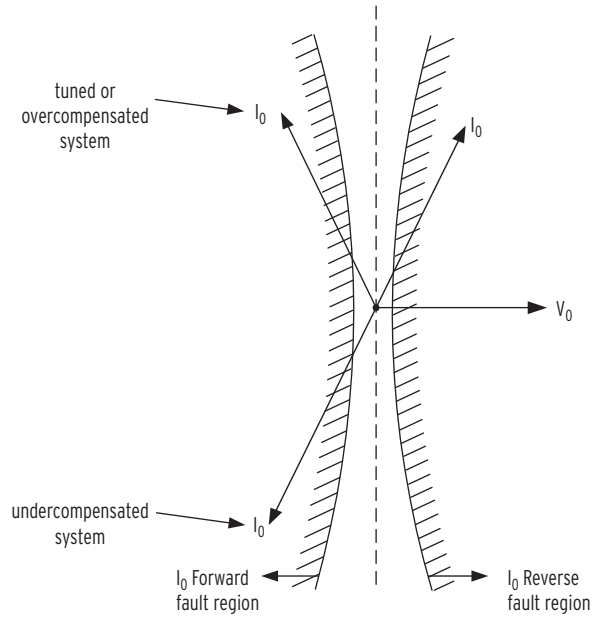


Figure 7 Traditional Wattmetric Element Operating Characteristic (Petersen Coil Grounded System)

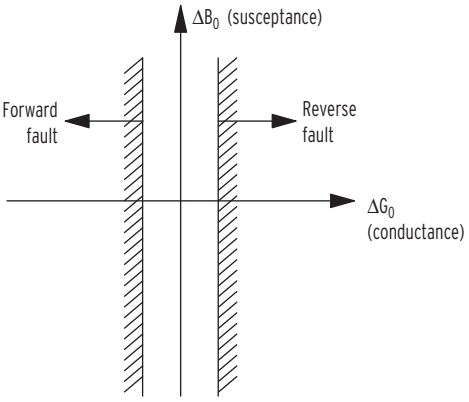


Figure 8 New, More-Sensitive Incremental Conductance Element Operating Characteristic (Petersen Coil Grounded System)

Loss-of-Potential Logic Supervises Directional Elements

Voltage-polarized directional elements rely on valid input voltages to make correct decisions. The SEL-351S includes loss-of-potential logic that detects one, two, or three blown potential fuses and disables the directional elements. For example, in a loss-of-potential condition, you can enable forward-set overcurrent elements to operate nondirectionally. This patented loss-of-potential logic is unique, as it does not require settings and is universally applicable.

The loss-of-potential logic does not monitor the VS voltage input, nor does it affect zero-sequence voltage-polarized ground directional elements when a broken-delta 3V0 voltage source is connected to the VS-NS terminals.

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Power Elements

Four independent directional power elements are available in the SEL-351S-7. For wye-connected applications, enable either single-phase power elements or three-phase power elements (but not both). For delta-connected applications, enable only three-phase power elements. 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 and control.
- Reverse power protection and control.
- VAR control for capacitor banks.

Programmable Torque-Control Feature Handles Cold-Load Energization

When a feeder is reenergized following a prolonged outage, lost load diversity causes large phase currents (cold-load inrush). Avoid phase overcurrent element misoperation during cold-load inrush by programming cold-load block elements into the phase overcurrent element torque controls. One example of a cold-load block element is a time-delayed 52 status (long time-delay pickup and drop-out timer with 52 as the input). An alternative is to detect the long outage condition (breaker open) automatically, and temporarily switch to a setting group with higher phase overcurrent element pickup thresholds.

Voltage and Frequency Elements for Extra Protection and Control

Under- and Overvoltage Elements

Phase (wye-connected only) or phase-to-phase undervoltage (27) and overvoltage (59) elements in the SEL-351S create the following protection and control schemes:

- Torque control for the overcurrent protection.
- Hot-bus (line), dead-bus (line) recloser control.
- Blown transformer high-side fuse detection logic.
- Trip/alarm or event report triggers for voltage sags and swells.
- Undervoltage (27) load shedding scheme. (Having both 27 and 81U load shedding schemes allows detection of system MVAR- and MW-deficient conditions.)
- Control schemes for capacitor banks.

Use the following undervoltage and overvoltage elements, associated with the V_S voltage channel, for additional control and monitoring:

- Hot-line/dead-line recloser control,
- Ungrounded capacitor neutrals,
- Ground fault detection on delta systems,
- Generator neutral overvoltage.
- Broken-delta zero-sequence voltage (see *Figure 5*).

Sequence Voltage Elements

Independently set positive-, negative-, and zero-sequence voltage elements provide protection and control. Applications include transformer bank single-phase trip schemes and delta-load back-feed detection scheme for dead-line recloser control. Note that zero-sequence elements are not available when the relay is delta connected.

Under- and Overfrequency Protection

Six levels of secure over- (81O) or underfrequency (81U) elements detect true frequency disturbances. Use the independently time-delayed output of these elements to shed load or trip local generation. Phase undervoltage supervision prevents undesired frequency element operation during faults.

Implement an internal multistage frequency trip/restore scheme at each breaker location using the multiple over- and underfrequency levels. This avoids the cost of wiring a complicated trip and control scheme from a separate frequency relay.

Synchrophasors

The SEL-351S now includes phasor measurement technology that provides synchrophasor measurements throughout a power system. This technology in a protective relay reduces or eliminates incremental installation and maintenance costs while leaving system reliability unaffected. Incorporate present and future synchrophasor technology control applications without much effort into the same devices that protect and control the power system.

Additional Features and Options

Features

Table 2 lists additional features included in each respective model.

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Ordering Options

Additionally, the following options can be ordered for any SEL-351S model:

- ➤ DNP3 Level 2 Outstation.
- ➤ Nondirectional Sensitive Earth Fault (SEF) protection.
- ➤ Directional protection for ungrounded, high-impedance grounded, Petersen Coil grounded, and low-impedance grounded systems.
- ➤ Auxiliary trip/close pushbuttons and indicators.
- ➤ Guards for auxiliary trip/close pushbuttons.
- ➤ User-Configurable labels for programmable operator controls and target LEDs.

Table 2 SEL-351S Models and Features

Model	ACSELERATOR QuickSet Support	Load Profile & MIRRORED BITS Communications	Voltage Sag, Swell, Interruption Reports	Power Elements
SEL-351S-5	♦			
SEL-351S-6	♦	♦		
SEL-351S-7	♦	♦	♦	♦

Operator Controls and Reclosing

Operator Controls Eliminate Traditional Panel Control Switches

Ten conveniently sized operator controls are located on the relay front panel (see *Figure 9*). The SER can be set to track operator controls. Change operator control functions using SELOGIC control equations.

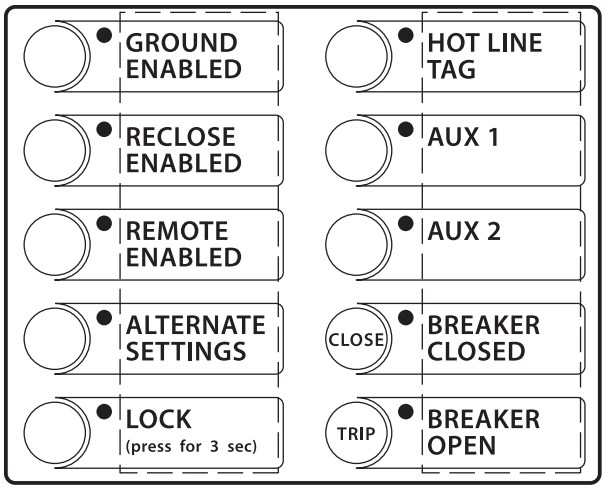


Figure 9 Operator Controls (standard model)

Note: Dashed lines indicate portion that can be changed with the configurable labels option, see *Configurable Labels (Ordering Option) on page 16*.

The following operator control descriptions are for factory-set logic.

Ground Enabled

The **GROUND ENABLED** operator control allows the ground fault overcurrent protection functions in the SEL-351S to operate. The corresponding LED illuminates to indicate the enabled state.

Reclose Enabled

The **RECLOSE ENABLED** operator control causes the autoreclosing scheme to operate. The corresponding LED illuminates to indicate the enabled state. When the LED is off, any trip will drive the relay to lockout.

Remote Enabled

The **REMOTE ENABLED** operator control allows remote operation of the SEL-351S controlled output functions (e.g., via optoisolated input from SCADA, or through the serial port via modem or an SEL-2032, SEL-2030, or SEL-2020 Communications Processor). User-applied settings must first enable this function.

Alternate Settings

The **ALTERNATE SETTINGS** operator control allows the SEL-351S to switch the active setting group between the main setting group (Group 1) and the alternate setting group (Group 2). The corresponding LED illuminates to indicate that the alternate setting group is active.

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Lock

The **LOCK** operator control blocks selected functions. Press it for at least three seconds to engage or disengage the lock function. While "locked" in position, the following operator controls cannot change state if pressed: **GROUND ENABLED**, **RECLOSE ENABLED**, **REMOTE ENABLED**, **ALTERNATE SETTINGS**, **AUX 1**, and **AUX 2**. When the lock function is engaged, the **CLOSE** operator control cannot close the breaker; but the **TRIP** operator control can still open the breaker.

Hot Line Tag

The **HOT LINE TAG** operator control blocks closing and autoreclosing of the circuit breaker. The **HOT LINE TAG** operator control overrides the **RECLOSE ENABLED** and **CLOSE** operator controls.

AUX 1, AUX 2

These user-defined operator controls enable/disable user-programmed auxiliary control functions.

Close, Trip (Standard Models)

Use the **CLOSE** and **TRIP** operator controls (see *Figure 9*) to close and open the connected circuit breaker. They can be programmed with intentional time delays to support operational requirements for breaker-mounted relays. This allows the operator to press the **CLOSE** or **TRIP** pushbutton, then move to an alternate location before the breaker command is executed. The programmable delay ranges from 0 to 60 seconds.

AUX 3, AUX 4 (Auxiliary Trip/Close Pushbutton Models)

Figure 10 shows user-defined operator controls, **AUX 3** and **AUX 4**.

Auxiliary Trip/Close Pushbuttons and Indicating LEDs

Optional auxiliary trip and close pushbuttons (see *Figure 10*) and indicating LEDs allow breaker control independent of the relay. The auxiliary trip/close pushbuttons are electrically separate from the relay, operating even if the relay is powered down. Make the extra connections at terminals **Z15** through **Z22**. See *Figure 26*, and *Figure 27* for front-panel and rear-panel views. *Figure 11* shows one possible set of connections.

The auxiliary trip/close pushbuttons incorporate an arc suppression circuit for interrupting dc trip or close current. To use these pushbuttons with ac trip or close circuits, disable the arc suppression for either pushbutton by changing jumpers inside the SEL-351S Relay. The operating voltage ranges of the **BREAKER CLOSED** and **BREAKER OPEN** indicating LEDs are also jumper selectable.

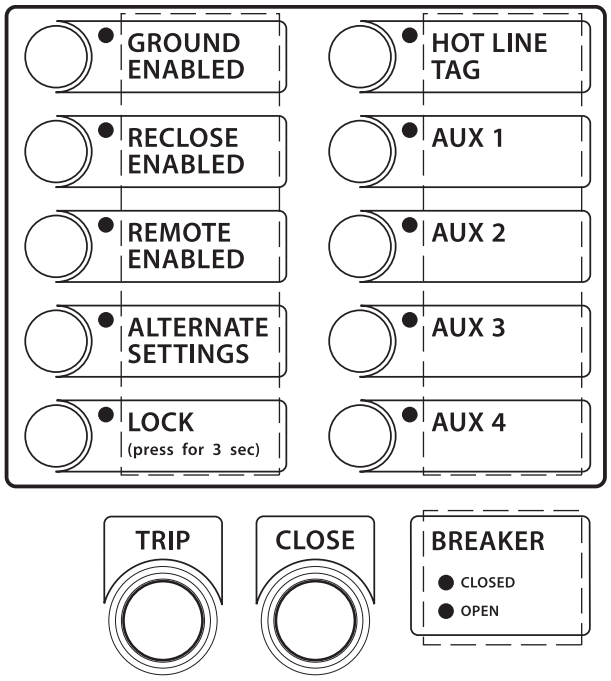


Figure 10 Operator Controls (auxiliary trip/close model)

Note: Dashed lines indicate portion that can be changed with the configurable labels option, see *Configurable Labels (Ordering Option) on page 16*.

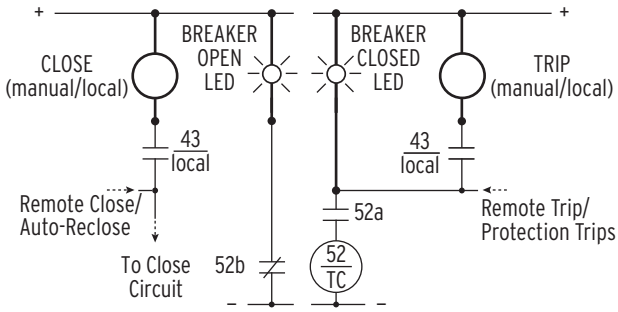


Figure 11 Optional Breaker Trip/Close Control Switches and Indicating Lamps

Local and Remote Control

Under certain operating conditions, such as performing distribution feeder switching, it is desirable to temporarily disable ground fault protection. This is accomplished in a variety of ways using SELOGIC control equations with local and remote control. As shown in *Figure 12*, achieve remote disable/enable control using an optoisolated input or the serial communications port. The operator control pushbutton handles local disable/enable control. Output contacts, serial ports and the local LED indicate both remote and local ground relay operating status. Remote control capabilities require programming SELOGIC control equations.

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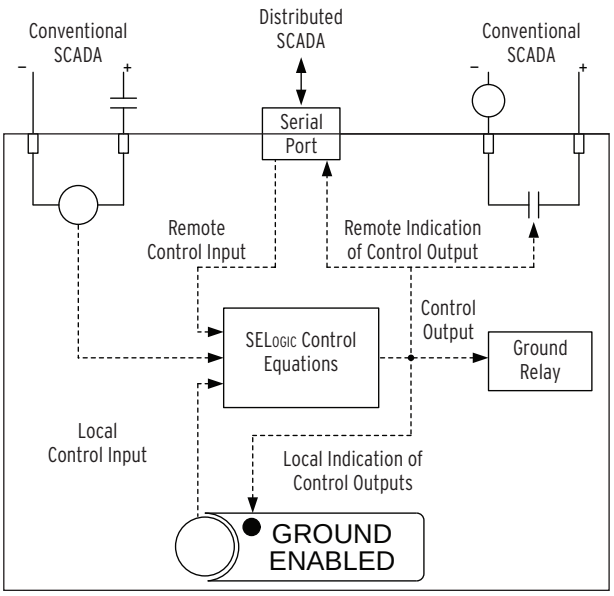


Figure 12 Local and Remote Control Using SELOGIC Control Equations (Ground Relay Example)

Programmable Autoreclosing

The SEL-351S can autoreclose a circuit breaker up to four times before lockout. Use SELOGIC control equations to program the SEL-351S to perform the following reclosing functions:

- Allow closing (e.g., when the load-side line is dead, or when the two systems are in synchronism).
- Advance the shot counter without tripping (e.g. when another protective relay clears a fault, also known as sequence coordination)
- Initiate reclosing (e.g., for particular protection trip operations)
- Drive-to-lockout (e.g., when an optoisolated input is deasserted)
- Delay reclosing (e.g., after a trip due to a close-in, high-duty fault)
- Flexible Reclose Supervision Failure scheme that allows going to lockout or moving to the next available shot.

The recloser shot counter controls which protective elements are involved in each reclose interval. Applications include fuse- and trip-saving schemes. The front-panel LEDs (Reset, Cycle, and Lockout) track the recloser state.

Relay and Logic Settings Software

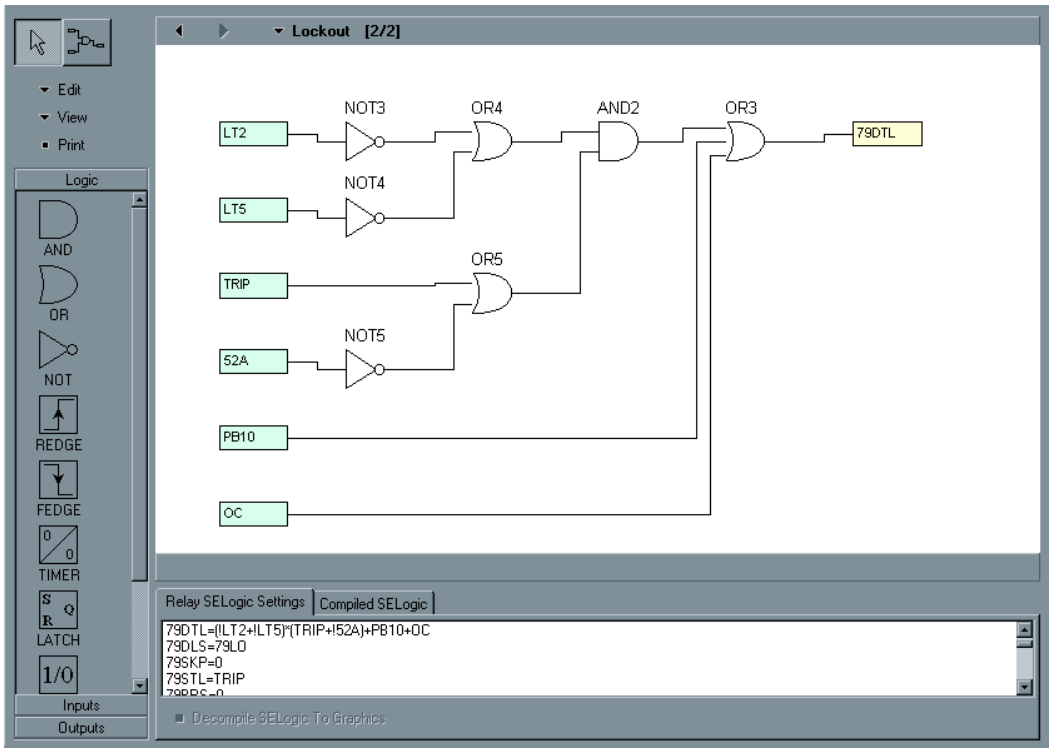


Figure 13 ACSELERATOR QuickSet Software Screen

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The ACSELERATOR QuickSet software program uses the Microsoft® Windows® operating system to simplify settings and provide analysis support for the SEL-351S.

Use ACSELERATOR QuickSet to create and manage relay settings:

- ➤ Develop settings off-line with an intelligent settings editor that only allows valid settings.
- ➤ Create SELOGIC control equations with a drag and drop graphical editor and/or text editor.
- ➤ Use on-line help to assist with configuring proper settings.
- ➤ Organize settings with the relay database manager.
- ➤ Load and retrieve settings using a simple PC communications link.

Use ACSELERATOR QuickSet to verify settings and analyze events:

- ➤ Use the logic simulator to test setting schemes with user or event report input stimulus. (Use for training, too!)
- ➤ Analyze power system events with the integrated waveform and harmonic analysis tools.

Use ACSELERATOR QuickSet to aid with monitoring, commissioning, and testing the SEL-351S:

- ➤ Use the Human Machine Interface (HMI) to monitor meter data, Relay Word bits, and output contacts status during testing.
- ➤ Use the PC interface to remotely retrieve breaker wear, voltage sag/swell/interruption reports, and other power system data.

Metering and Monitoring

Table 3 Metering Capabilities[a]

Quantities	Description
Currents $I_{A,B,C,N}$, I_G	Input currents, residual ground current ($I_G = 3I_0 = I_A + I_B + I_C$).
Voltages $V_{A,B,C}$	Wye-connected voltage inputs.
Voltages $V_{AB,BC,CA}$	Delta-connected voltage inputs.
Voltage V_S	Synchronism-check or broken-delta voltage input.
Power $MW_{A,B,C,3P}$, $MVAR_{A,B,C,3P}$	Single-[b] and three-phase megawatts and megavars.
Energy $MWh_{A,B,C,3P}$, $MVARh_{A,B,C,3P}$	Single-[b] and three-phase megawatt-hours and megavar-hours.
Power Factor $PF_{A,B,C,3P}$	Single-[b] and three-phase power factor; leading or lagging.
Sequence I_1, $3I_2$, $3I_0$, V_1, V_2, $3V_0$	Positive-, negative-, and zero-sequence currents and voltages.
Frequency, FREQ (Hz)	Instantaneous power system frequency (monitored on channel V_A).

[a] If true three-phase voltage is not connected, the voltage ($V_{A,B,C}$), MW/MVAR, MWh/MVARh, and power factor metering values are not available.
[b] Note that single-phase power, energy, and power factor quantities are not available when delta-connected PTs are used.

Complete Metering Capabilities

The SEL-351S provides extensive and accurate metering capabilities. See *Specifications on page 24* for metering and power measurement accuracies.

As shown in *Table 3*, metered quantities include phase voltages and currents (including demand currents); sequence voltages and currents; power (including demand), frequency, and energy; and maximum/minimum logging of selected quantities. The relay reports all metered quantities in primary quantities (current in A primary and voltage in kV primary).

Load Profile

The SEL-351S-6 and -7 feature a programmable Load Profile (LDP) recorder that records up to 15 metering quantities into nonvolatile memory at fixed time intervals. The LDP saves several days to several weeks of the most recent data depending on the LDP settings.

Event Reporting and Sequential Events Recorder (SER)

Event Reports and the SER simplify post-fault analysis and improve understanding of simple and complex protective scheme operations. In response to a user-selected trigger, the voltage, current, frequency, and element status information contained in each event report confirms relay, scheme, and system performance for every fault. Decide how much detail is necessary when you request an event report (e.g., 1/4-cycle or 1/16-cycle resolution;

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filtered or raw analog data). The relay stores the most recent 30-cycle or 15-cycle event reports in nonvolatile memory. The relay stores the most recent eleven 30-cycle or twenty-three 15-cycle event reports in nonvolatile memory. The relay always appends relay settings to the bottom of each event report.

The following analog data formats are available:

- 1/4-cycle or 1/16-cycle resolution.
- Unfiltered or filtered analog.
- ASCII or Compressed ASCII.

The relay SER feature stores the latest 512 entries. Use this feature to gain a broad perspective at a glance. An SER entry helps to monitor input/output change-of-state occurrences, element pickup/dropout, and recloser state changes.

The IRIG-B time-code input synchronizes the SEL-351S time to within ±5 ms of the time-source input. A convenient source for this time code is the SEL-2032, SEL-2030, or SEL-2020 Communications Processor (via Serial Port 2 on the SEL-351S).

Synchrophasor Measurements

Upgrade System Models

Send synchrophasor data using SEL Fast Message protocol to SEL communications processors, or to SEL-5077 SYNCHROWAVE© Server phasor data concentration software, or to an SEL-3306 Synchrophasor Processor. Data rates of as much as one message per second with an accuracy of ±1 electrical degree provide for real-time visualization.

The SEL-5077 SYNCHROWAVE Server software and the SEL-3306 Synchrophasor Processor time correlation data from multiple SEL-351 relays and other phasor measurement and control units (PMCUs). Then, the SEL-5077 sends the concentrated data to visualization tools, such as the SEL-5078 SYNCHROWAVE Console, for use by utility operations.

Use SEL-2032 or SEL-2030 Communications Processors to collect synchrophasor data from multiple SEL-351 relays and incorporate the data into traditional SCADA and EMS systems. Traditional power system models are created based on measurements of voltages and power flows at different points on the system. The system state is then estimated based on a scan of these values and an iterative calculation. The state estimation includes an inherent error caused by measurement inaccuracies, time delays between measurements, and model simplifications. Synchrophasor measurements reduce error and change state estimation into state measurement. The time required for iterative calculation is minimized, and system state values can be directly displayed to system operators and engineers.

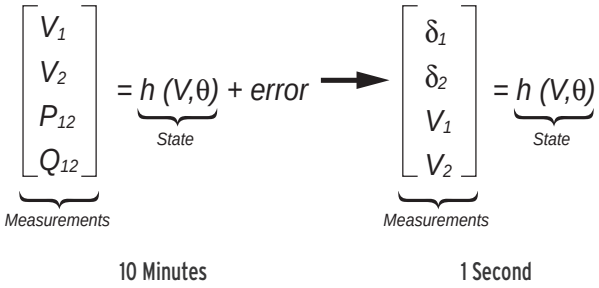


Figure 14 Synchrophasor Measurements Turn State Estimation Into State Measurement

Improve Situational Awareness

Provide improved information to system operators. Advanced synchrophasor-based tools provide a real-time view of system conditions. Use system trends, alarm points, and preprogrammed responses to help operators prevent a cascading system collapse and maximize system stability. Awareness of system trends provides operators with an understanding of future values based on measured data.

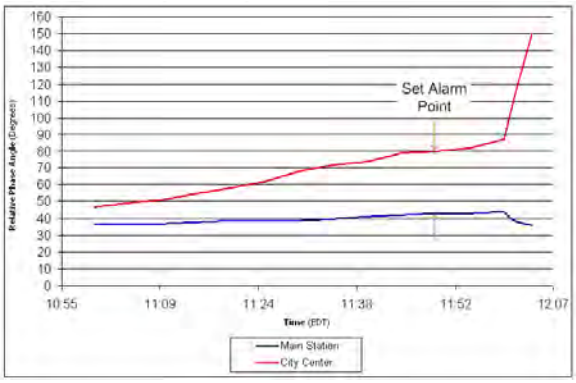


Figure 15 Visualization of Phase Angle Measurements Across a Power System

- Increase system loading while maintaining adequate stability margins.
- Improve operator response to system contingencies such as overload conditions, transmission outages, or generator shutdown.
- Advance system knowledge with correlated event reporting and real-time system visualization.
- Validate planning studies to improve system load balance and station optimization.

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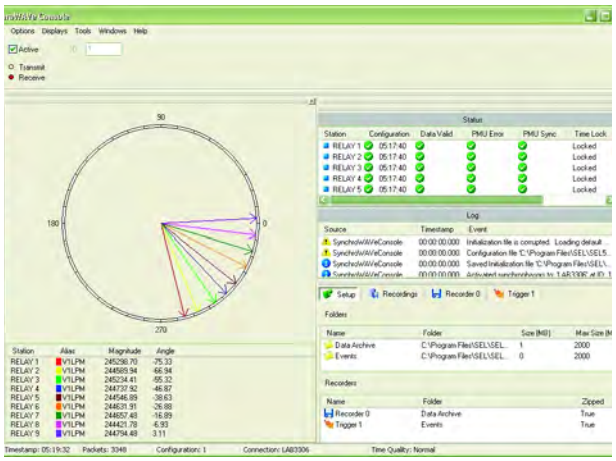


Figure 16 SEL-5078 SYNCHROWAVE Console Real-Time Wide-Area Visualization Tool

Voltage Sag, Swell, Interruption Records

The SEL-351S-7 can perform automatic voltage disturbance monitoring for three-phase systems. The Sag/Swell/Interruption (SSI) Recorder uses the SSI Relay Word bits to determine when to start (trigger) and when to stop recording. The SSI recorder uses nonvolatile memory, so de-energizing the relay will not erase any stored SSI data.

The recorded data is available through the SSI Report, which includes 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.

Demand Current Threshold Alarm

Use overload and unbalanced current threshold alarms for phase, negative-sequence, neutral, and residual demand currents.

Two types of demand-measuring techniques are offered: thermal and rolling.

Select the demand ammeter time constant from 5 to 60 minutes.

Circuit Breaker Contact Wear Monitor

Circuit breakers experience mechanical and electrical wear every time they operate. Intelligent scheduling of breaker maintenance takes into account manufacturer's published data of contact wear versus interruption levels and operation count. With the breaker manufacturer's maintenance curve as input data, the SEL-351S breaker monitor feature compares this input data to the measured (unfiltered) ac current at the time of trip and the number of close to open operations.

Every time the breaker trips, it integrates the measured current information. When the result of this integration exceeds the breaker wear curve threshold (*Figure 17*) the relay alarms via output contact, serial port, or front-panel display. This kind of information allows timely and economical scheduling of breaker maintenance.

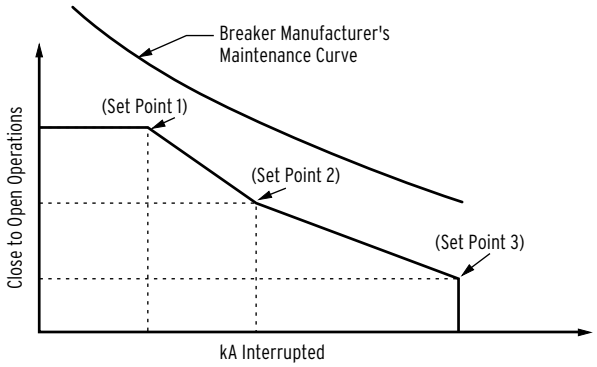


Figure 17 Breaker Contact Wear Curve and Settings

Substation Battery Monitor

The SEL-351S measures and reports the substation battery voltage connected to the power supply terminals. The relay includes two programmable threshold comparators and associated logic for alarm and control. For example, if the battery charger fails, the measured dc falls below a programmable threshold. The SEL-351S alarms operations personnel before the substation battery voltage falls to unacceptable levels. Monitor these thresholds with the SEL-2020 or SEL-2030 Communications Processor and trigger messages, telephone calls, or other actions.

The measured dc voltage appears in the METER display and the VDC column of the event report. Use the event report column data to see an oscillographic display of the battery voltage. You can see how much the substation battery voltage drops during trip, close, and other control operations.

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Fault Locator

The SEL-351S provides an accurate estimate of fault location even during periods of substantial load flow. The fault locator uses fault type, replica line impedance settings, and fault conditions to develop an estimate of fault location without communications channels, special instrument transformers, or prefault information. This feature contributes to efficient dispatch of line crews and fast restoration of service. The fault locator requires three-phase voltage inputs. The fault locator does not operate for ground faults on ungrounded, high-impedance grounded, or Petersen Coil grounded systems.

Automation

Flexible Control Logic and Integration Features

The SEL-351S is equipped with four independently operated serial ports: one EIA-232 port on the front and two EIA-232 ports and one EIA-485 port on the rear. The relay does not require special communications software. Use any system that emulates a standard terminal system. Establish communication by connecting computers, modems, protocol converters, printers, an SEL-2032, SEL-2030 or SEL-2020 Communications Processor, SCADA serial port, and/or RTU for local or remote communication.

Apply an SEL communications processor as the hub of a star network, with point-to-point fiber or copper connection between the hub and the SEL-351S (*Figure 18*). The communications processor supports external communications links including the public switched telephone network for engineering access to dial-out alerts and private line connections of the SCADA system.

SEL manufactures a variety of standard cables for connecting this and other relays to a variety of external devices. Consult your SEL representative for more information on cable availability.

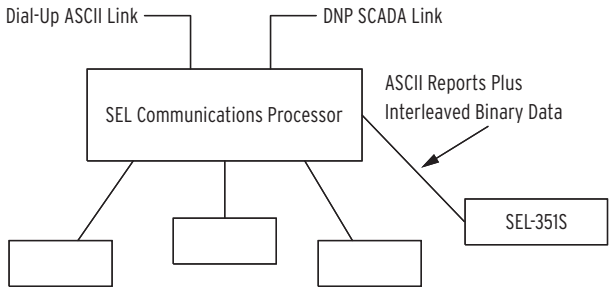


Figure 18 Example Communication System

Table 4 Open Communications Protocols

Type	Description
Simple ASCII	Plain language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended Fast Meter and Fast Operate	Binary protocol for machine-to-machine communications. Quickly updates SEL Communications Processors (SEL-2032, SEL-2030, and SEL-2020), RTUs, and other substation devices with metering information, relay element, I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines so control operator metering information is not lost while a technician is transferring an event report.
Distributed Port Switch Protocol	Enables multiple SEL devices to share a common communications bus (two-character address setting range is 01–99). Use this protocol for low-cost, port-switching applications.
Fast SER Protocol	Provides SER events to an automated data collection system. Available on any port.
DNP3 Level 2 Outstation	Distributed Network Protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and setting groups.

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Control Logic and Integration

SEL-351S control logic improves integration in the following ways:

- **Replaces traditional panel control switches.** Eliminate traditional panel control switches with 16 local control switches. Set, clear, or pulse local control switches with the front-panel pushbuttons and display. Program the local control switches into your control scheme with SELOGIC control equations. Use the local control switches to perform functions such as a trip test or a breaker trip/close.
- **Eliminates RTU-to-relay wiring.** Eliminate RTU-to-relay wiring with 16 remote control switches. Set, clear, or pulse remote control switches using serial port commands. Program the remote control switches into your control scheme with SELOGIC control equations. Use remote control switches for SCADA-type control operations such as trip, close, and settings group selection.
- **Replaces traditional latching relays.** Replace up to 16 traditional latching relays for such functions as "remote control enable" with latch control switches. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the nonvolatile latch control switches using optoisolated inputs, remote control switches, local control switches, or any programmable logic condition. The latch control switches retain their state when the relay loses power.
- **Replaces traditional indicating panel lights.** Replace traditional indicating panel lights with 16 programmable displays. Define custom messages (e.g., Breaker Open, Breaker Closed) to report power system or relay conditions on the front-panel display. Use SELOGIC control equations to control which messages the relay displays.
- **Eliminate external timers.** Eliminate external timers for custom protection or control schemes with 16 general purpose SELOGIC control equation timers. Each timer has independent time-delay pickup and dropout settings. Program each timer input with any desired element (e.g., time qualify a current element). Assign the timer output to trip logic, transfer trip communications, or other control scheme logic
- **Eliminate settings changes.** Selectable setting groups make the SEL-351S ideal for applications requiring frequent setting changes and for adapting the protection to changing system conditions.

  The relay stores six setting groups. Select the active setting group by optoisolated input, command, or other programmable conditions. Use these setting groups to cover a wide range of protection and control contingencies.

  Switching setting groups switches logic and relay element settings. Program groups for different operating conditions, such as feeder paralleling, station maintenance, seasonal operations, emergency contingencies, loading, source changes, and downstream relay setting changes.

Fast SER Protocol

SEL Fast Sequential Events Recorder (SER) Protocol provides SER events to an automated data collection system. SEL Fast SER Protocol is available on any serial port. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary SER messages from SEL-351S Relays.

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 to people 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.

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Added Capabilities

MIRRORED BITS Relay-to-Relay Communications

The SEL-patented MIRRORED BITS communications technology provides bidirectional relay-to-relay digital communications. MIRRORED BITS can operate independently on up to two EIA-232 serial ports on a single SEL-351S-6 or -7 (not available on the SEL-351S-5).

This bidirectional digital communication creates eight additional virtual outputs (transmitted MIRRORED BITS) and eight additional virtual inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS mode (see *Figure 19*). Use these MIRRORED BITS to transmit/receive information between upstream relays and downstream recloser control (e.g., SEL-351R) to enhance coordination and achieve faster tripping for downstream faults. MIRRORED BITS technology also helps reduce total scheme operating time by eliminating the need to assert output contacts to transmit information.

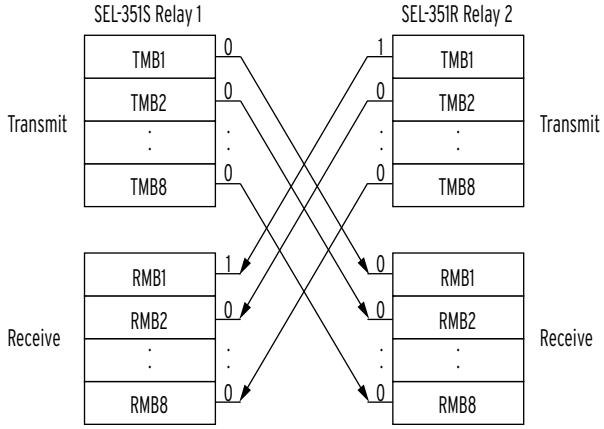


Figure 19 MIRRORED BITS Transmit and Receive Bits

Status and Trip Target LEDs

The SEL-351S includes 16 status and trip target LEDs on the front panel. As shipped from the factory, four LEDs are predefined and fixed in logic. The remaining 12 LEDs are factory-set to follow the reclosing relay state and to latch in on various trip conditions. You can also reprogram these for specific applications. This combination of targets is explained in *Figure 20* and *Table 5* and shown in *Figure 21*. Some front-panel relabeling of LEDs may be needed if you reprogram them for unique or specific applications, see next section.

Table 5 Description of Fixed-Logic and Programmable LEDs

Target LED	Function
ENABLED (fixed logic)	Relay powered properly and self-tests are okay.
TRIP	Trip occurred.
INST	Trip due to instantaneous overcurrent element operation.
COMM	Trip triggered by pilot scheme (e.g., POTT).
SOTF	Switch-onto-fault trip.
50	Inst./def.-time overcurrent trip.
51	Time-overcurrent trip.
81	Underfrequency trip.
RECLOSING STATE	
RESET	Ready for reclose cycle.
CYCLE	Actively in trip/reclose cycle mode.
LOCKOUT	Reclosing relay is in lockout state.
FAULT TYPE	
A, **B**, **C** (fixed logic)	Involved phases latch in on trip.
G	Ground involved in fault.
N	Neutral element (channel IN) trip.

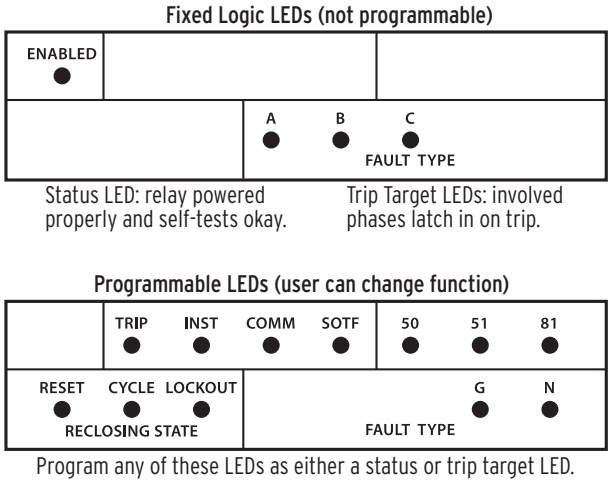


Figure 20 Fixed-Logic and Programmable LEDs

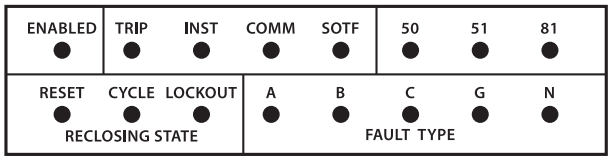


Figure 21 Status and Trip Target LEDs

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Configurable Labels (Ordering Option)

On SEL-351S models ordered with configurable labels, all of the operator controls shown inside the dashed line in *Figure 9* and *Figure 10*, and the status and trip target LEDs shown in *Figure 21*, can be relabeled to suit the installation requirements.

This ordering option includes preprinted labels (with factory default text), blank label media, and a template on CD-ROM for Microsoft Office 2000. This allows quick, professional-looking labels for the SEL-351S. Labels may also be customized without the use of a PC by writing the new label on the blank stock provided.

The ability to customize the control and indication features allows specific utility or industry procedures to be implemented without the need for adhesive labels.

All of the figures in this data sheet show the factory default labels of the SEL-351S, including the standard model shown in *Figure 9*. If ordered with user-configurable labels, this model will not have the CLOSE and TRIP pushbutton text indicated in *Figure 9*.

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Wiring Diagram

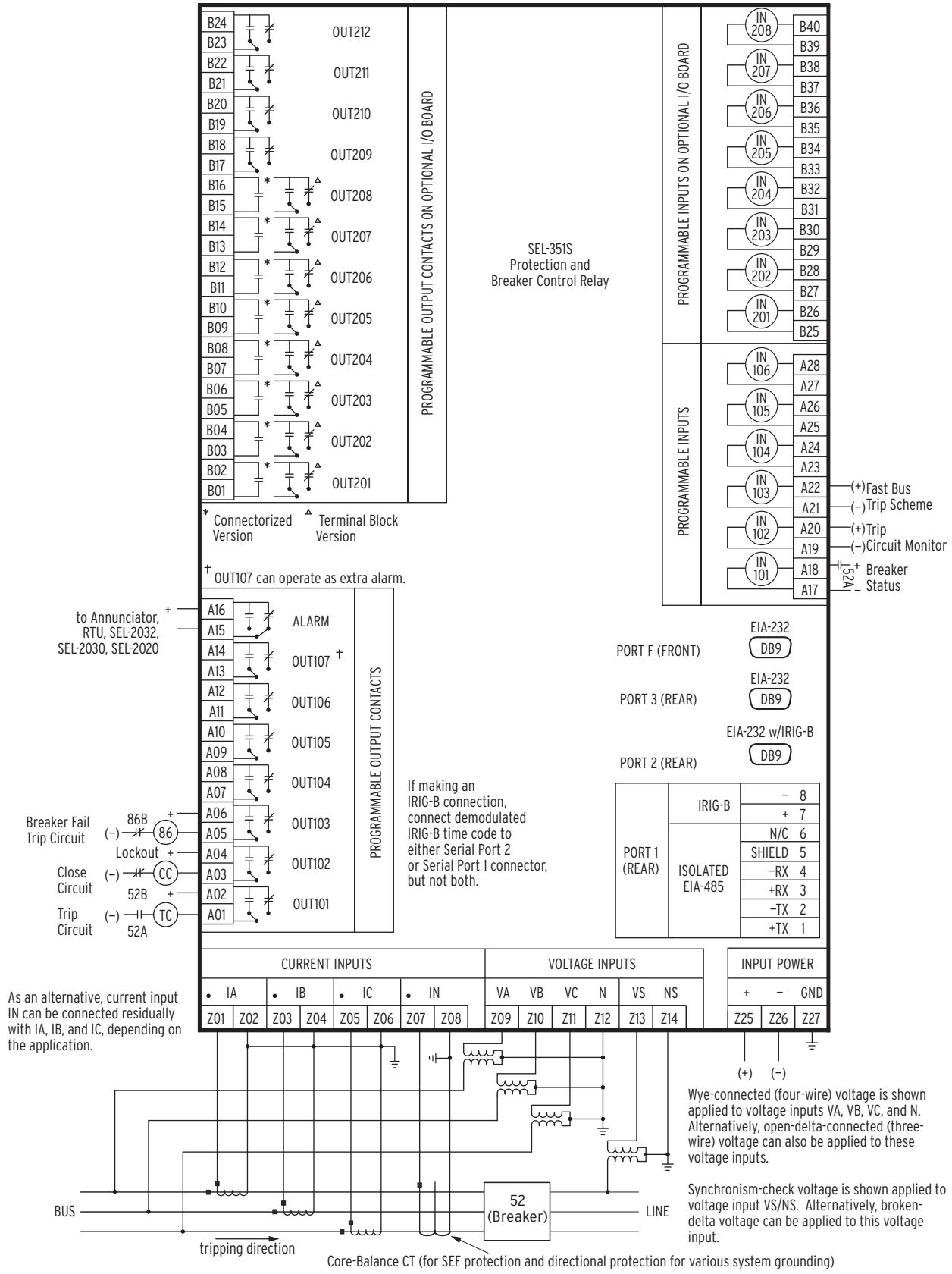


Figure 22 Example SEL-351S Wiring Diagram (Wye-Connected PTs; Synchronism-Check Voltage Input)

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Mechanical Diagrams

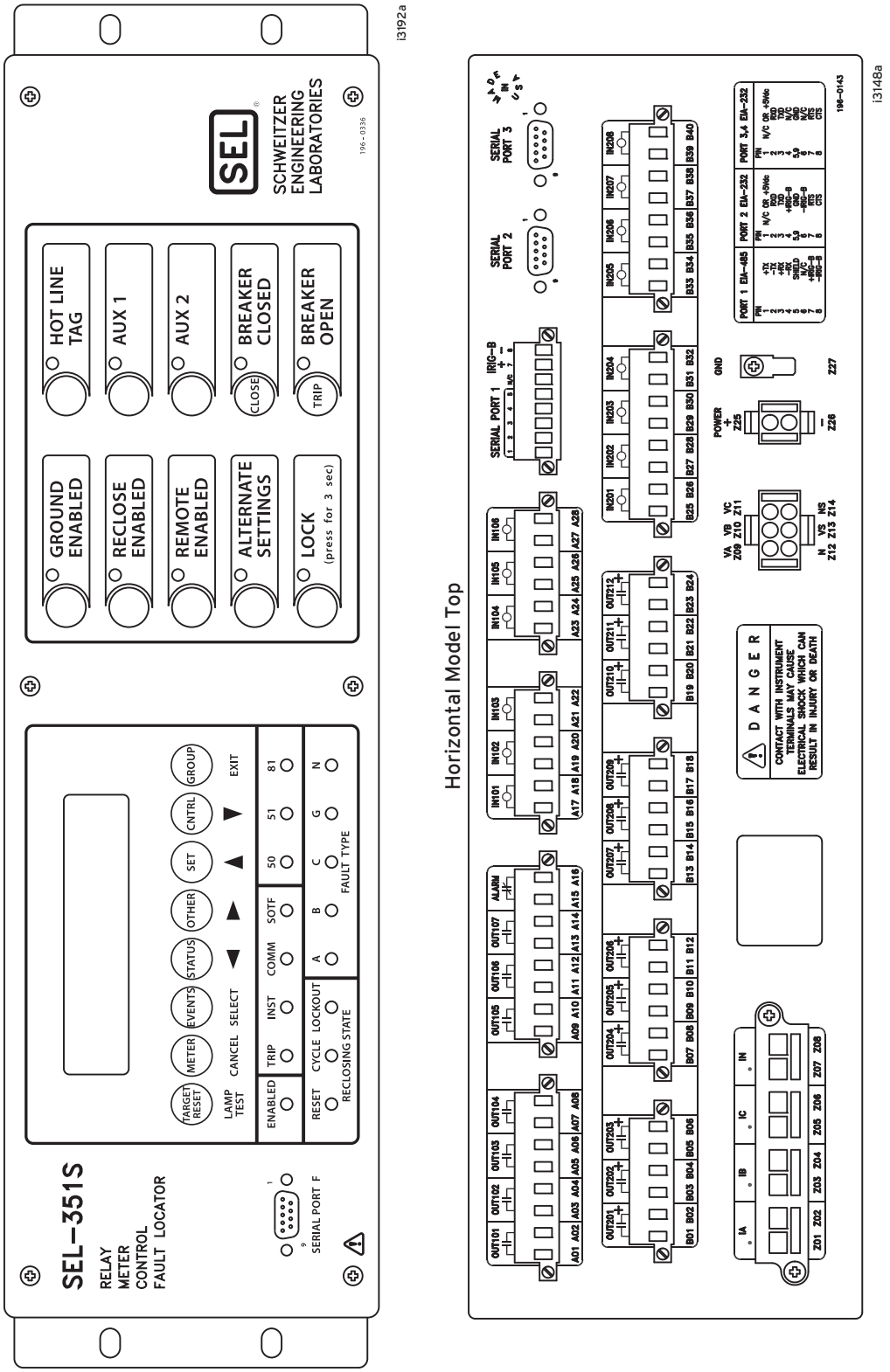


Figure 23 SEL-351S Front- and Rear-Panel Drawings (Model 0351SxYH3xxxx6x); Horizontal Rack Mount Example, (Connectorized, With Additional I/O Board)

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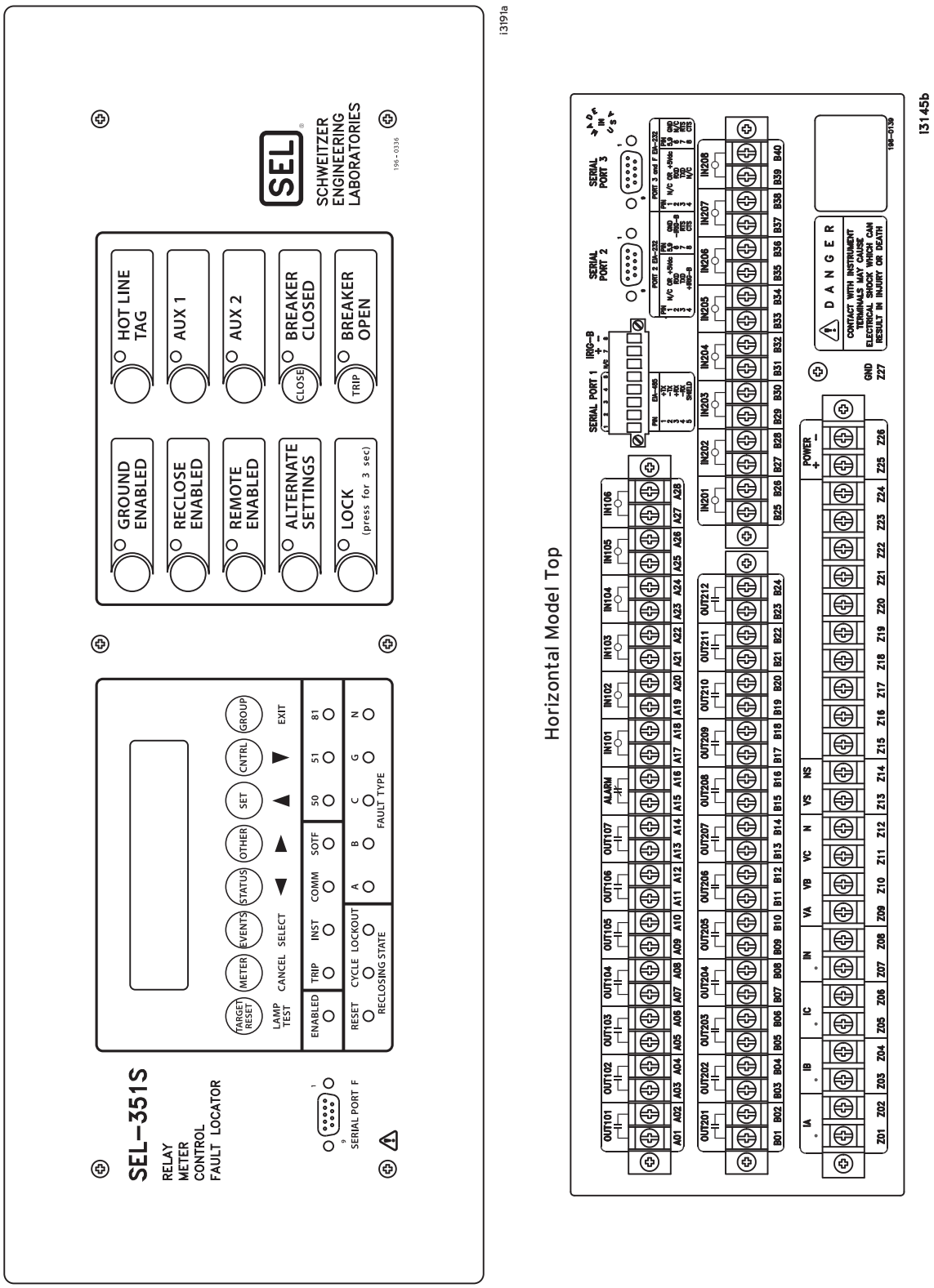


Figure 24 SEL-351S Front- and Rear-Panel Drawings (Model 0351Sx133xxxx2x); Horizontal Panel Mount Example, (Conventional Terminal Blocks, With Additional I/O Board)

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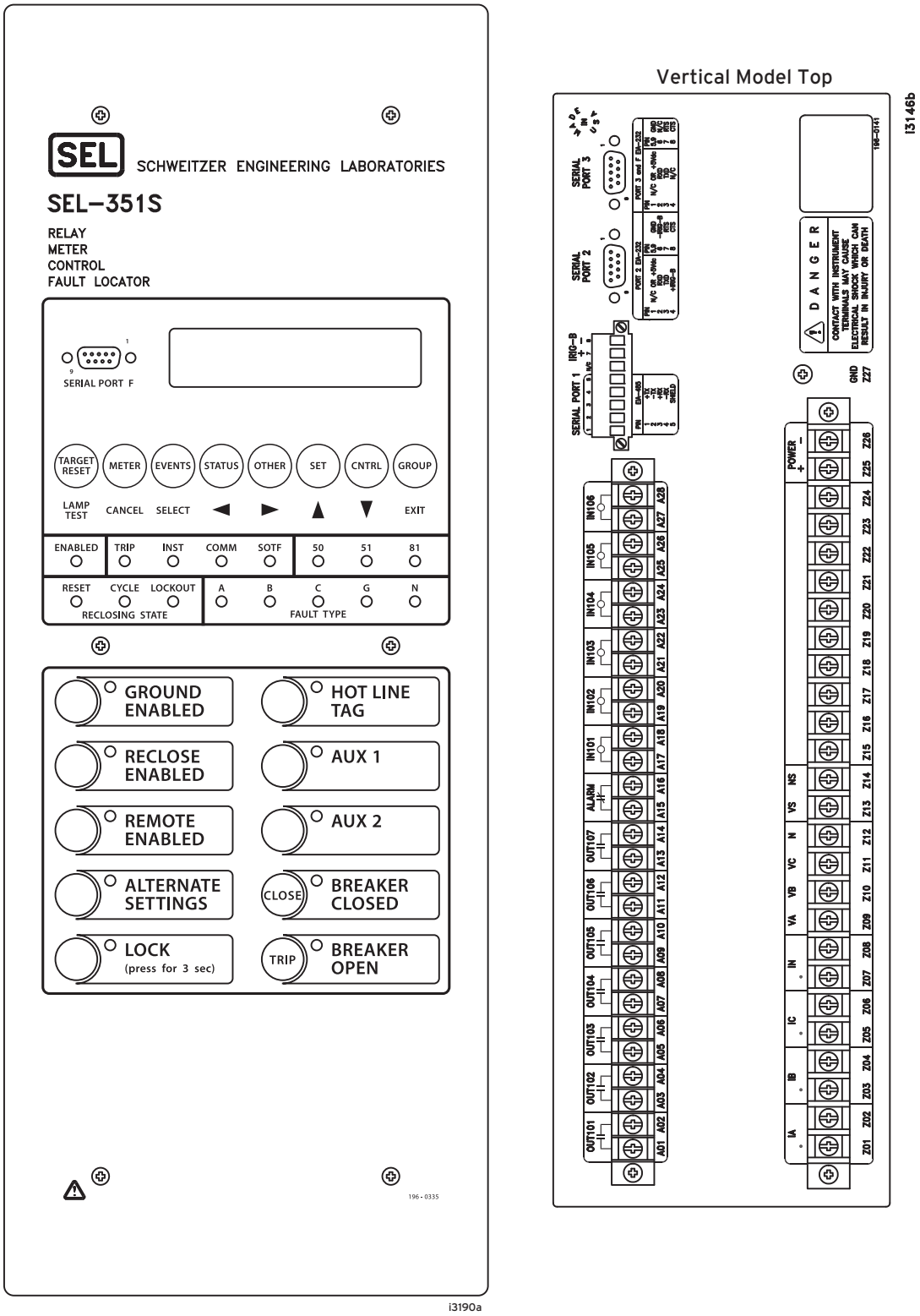


Figure 25 SEL-351S Front- and Rear-Panel Drawings (Model 0351Sx143xxxxXx); Vertical Panel Mount Example, (Conventional Terminal Blocks, No Additional I/O Board)

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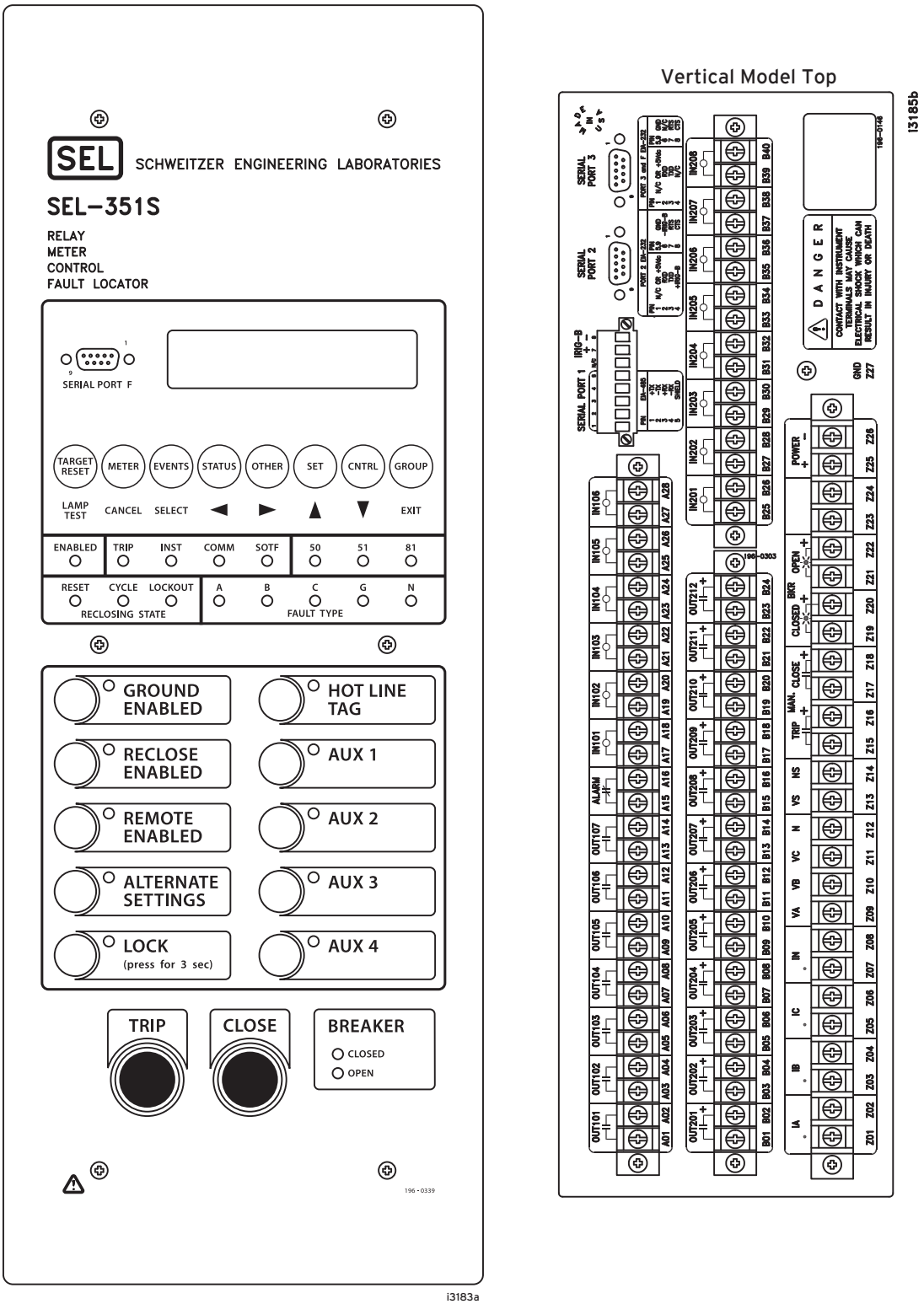


Figure 26 SEL-351S with Auxiliary TRIP/CLOSE Pushbuttons (Model 0351Sx145xxxx6x); Vertical Panel-Mount Example, (Conventional Terminal Blocks, With Additional I/O Board)

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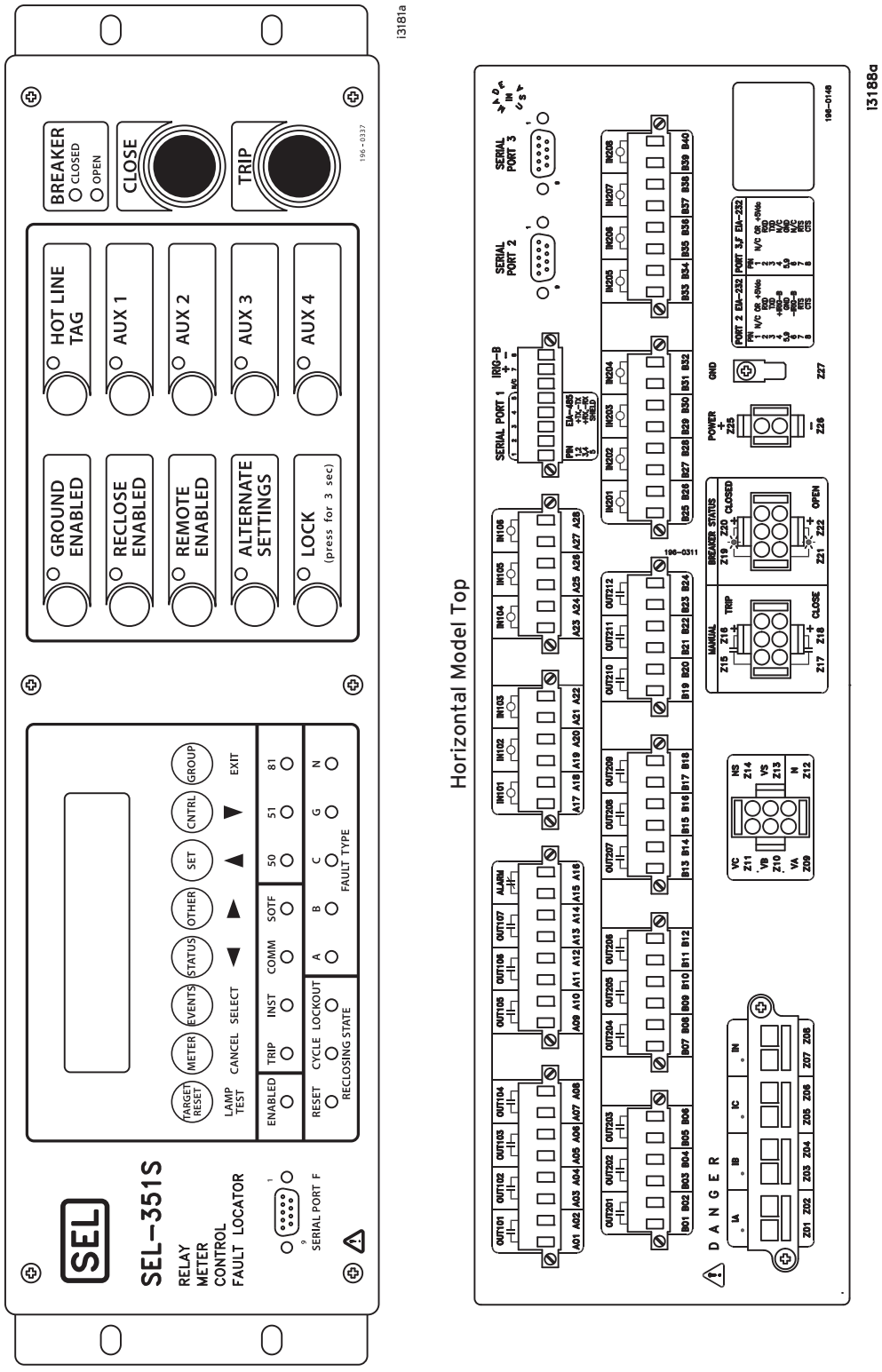


Figure 27 SEL-351S with Auxiliary TRIP/CLOSE Pushbuttons (Model 0351SxYH5xxxx2x); Horizontal Rack-Mount Example, (Connectorized, With Additional I/O Board)

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Relay Mounting

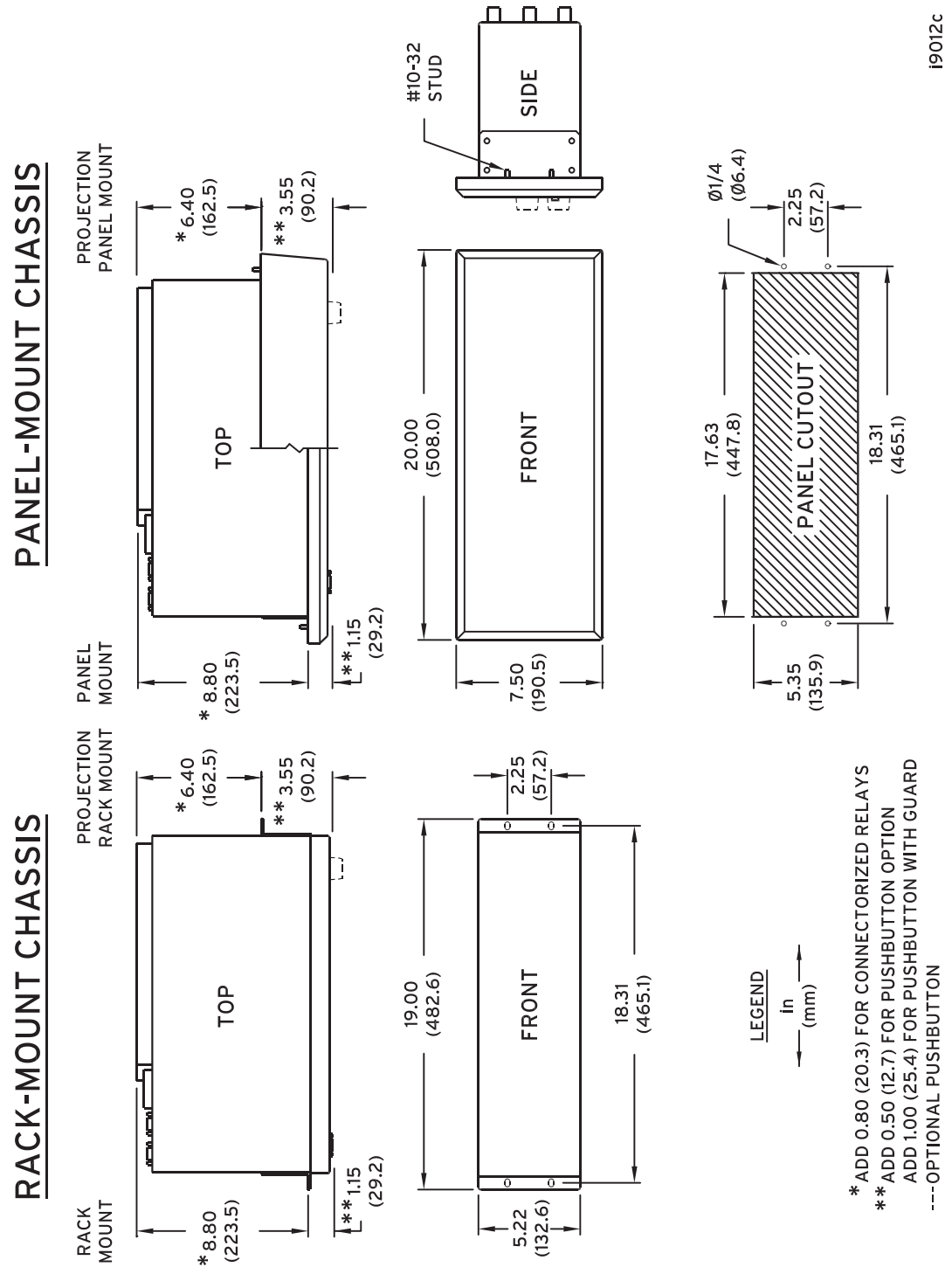


Figure 28 SEL-351S Dimensions and Drill Plan for Rack-Mount and Panel-Mount Models

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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.

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

PARTNO=351Sx1xxxxxxxx
UL Listed to U.S. and Canadian safety standards (File E212775; NRGU, NRGU7)
CE Mark

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 at 67 V; 0.06 VA at 120 V; 0.8 VA at 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 at 5 A, 2.51 VA at 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 at 1 A, 1.31 VA at 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 at 0.2 A, 1.28 VA at 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 at 0.05 A, 0.36 VA at 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. 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

125/250 Vdc or Vac

Range:	85–350 Vdc or 85–264 Vac (50/60 Hz)
Burden:	<25 W

48/125 Vdc or 125 Vac

Range:	38–200 Vdc or 85–140 Vac (50/60 Hz)
Burden:	<25 W

24/48 Vdc

Range:	18–60 Vdc
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

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 Inputs

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 and 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 28*.

Weight

16 lb (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

Electromagnetic Compatibility Emissions

Generic Emissions:	EN 50081-2:1993 EN 55011:1991

Electromagnetic Compatibility Immunity

Conducted RF Immunity:	ENV 50141:1993 Severity Level: 10 V/m IEC 61000-4-6:1996 Severity Level: 10 Vrms
Digital Radio Telephone RF Immunity:	ENV 50204:1995 Severity Level: 10 V/m at 900 MHz and 1.89 GHz
Electrostatic Discharge Immunity:	IEC 60255-22-2:1996 Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air IEC 61000-4-2:1995 Severity Level: 2, 4, 6, 8 kV contact; 2, 4, 8, 15 kV air
Fast Transient/Burst Immunity:	IEC 60255-22-4:1992 Severity Level: 4 kV at 2.5 kHz and 5 kHz Severity Level: 4 kV, 2.5 kHz on power supply, 2 kV, 5 kHz on I/O, signal, data, and control lines
Generic Immunity:	EN 50082-2:1995
Radiated Radio Frequency Immunity:	ENV 50140:1993 Severity Level: 10 V/m IEC 60255-22-3:1989 Severity Level: 10 V/m Exception: 4.3.2.2 Frequency sweep approximated with 200 frequency steps per octave IEEE C37.90.2:1987 Severity Level: 10 V/m 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 Capability Immunity:	IEC 60255-22-1:1988 Severity Level: 2.5 kV peak common mode, 2.5 kV peak differential mode IEEE C37.90.1:1989 Severity Level: 3.0 kV oscillatory, 5.0 kV fast transient

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Environmental

Cold:	IEC 60068-2-1:1990+A1:1993+A2:1994 Severity Level: 16 hours at –40°C
Damp Heat, Cyclic:	IEC 60068-2-30:1980 Exceptions: 6.3.3 Humidity not less than 94% Severity Level: 25°C to 55°C, 6 cycles, Relative Humidity: 95%
Dry Heat:	IEC 60068-2-2:1974+A1:1993+A2:1994 Severity Level: 16 hours at + 85°C
Object Penetration and Dust Ingress:	IEC 60529:1989 Severity Level: IP30 for Category 2 equipment
Vibration:	IEC 60255-21-1:1988 Severity Level: Class 1 Endurance, Class 2 Response IEC 60255-21-2:1988 Severity Level: Class 1–Shock withstand, Bump, and Class 2–Shock Response IEC 60255-21-3:1993 Severity Level: Class 2 (Quake Response)

Safety

Dielectric Strength:	IEC 60255-5:1977 Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type tested for 1 minute. IEEE C37.90:1989 Severity Level: 2500 Vac on contact inputs, contact outputs, and analog inputs. 3100 Vdc on power supply. Type tested for 1 minute.
Impulse:	IEC 60255-5:1977 Severity Level: 0.5 Joule, 5 kV

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* of the Instruction Manual.

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) 0.500–16.000 A, 0.005 A steps (5 A nominal neutral channel (IN) current input) 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) 0.100–3.200 A, 0.001 A steps (1 A nominal neutral channel (IN) current input) 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)

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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.

Temperature Coefficient: $[(0.0002\%)/(°C)^2] \cdot (__°C–20°C)^2$ (see example below)

Phase Angle Accuracy: ±0.5°
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)

Voltages

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

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

V_S: ±0.2% (67.0–300 V)

V_1, V_2, $3V_0$*: ±0.6% (67.0–300 V)
* not available when delta-connected

Currents I_A, I_B, I_C

5 A Nominal: ±2 mA, ±0.1% (0.5–100.0 A)

1 A Nominal: ±0.5 mA, ±0.1% (0.1–20 A)

Currents I_N, I_1, $3I_0$, $3I_2$

5 A Nominal: ±0.05 A, ±3% (0.5–100.0 A)

1 A Nominal: ±0.01 A, ±3% (0.1–20.0 A)

Currents I_N

0.2 A Nominal: ±0.08 mA, ±0.1% (0.005–4.5 A)

0.05 A Nominal: ±1 mA, ±5% (0.01–1.5 A)

Example
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)
Accuracy (MW / MVAR)	**at load angle**
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:
$[(0.0002\%)/(°C)^2] \cdot (40°C – 20°C)^2 = 0.08\%$

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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 Setting 5 A Nominal

0.33–2 VA:	±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
2–13000 VA:	±0.025 A • (L-N voltage secondary) and ±5% of setting at unity power factor

Pickup Setting 1 A Nominal

0.07–0.4 VA:	±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
0.4–2600 VA:	±0.005 A • (L-N voltage secondary) and ±5% of setting at unity power factor

Three-Phase Power Elements

Pickup Setting 5 A Nominal

1–6 VA:	±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
6–39000 VA:	±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

Pickup Setting 1 A Nominal

0.2–1 VA:	±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
1–7800 VA:	±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

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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