# SEL-787L Line Current Differential Relay

## Simple Line Current Differential Relay With Directional Overcurrent Protection, Arc-Flash, and High-Impedance Fault Detection

## Key Features and Benefits

The SEL-787L offers a wide range of protection features in a compact industrial package, including economical line differential protection for short cables, critical feeders, and distributed generation tie-lines. The line current differential feature combines proven protection algorithms with next-generation hardware and design practices to provide economical, fast, secure, and dependable protection with a simplified, intuitive interface.

- Expand I/O flexibility with as many as four extended I/O modules, each with either 21 programmable inputs or 12 electromechanical outputs, to increase the number of available inputs and outputs for various applications.
- Secure the 87L element operation with external fault detection (EFD) and disturbance detection logic.
- Provides measurement of communication quality and prevents misoperation due to channel failure by using channel monitoring.
- Detect abnormal sustained voltage conditions with the phase-to-phase overvoltage three-second rms (593SRMS) element based on the CEI 0-16 standard.
- Detect abnormal sustained voltage conditions with the phase-to-phase overvoltage three-second rms (593SRMS) element.
- Improve ground fault detection in resonant-grounded and ungrounded systems by using the zero-sequence PHI and intermittent ground fault elements.
- Provide network redundancy with PRP, RSTP, and High-availability Seamless Redundancy (HSR) protocols.
- Simplify integration with Modus RTU/TCP, DNP3 serial, DNP3 LAN/WAN, IEC 61850 Edition 2.1, IEC 60870-5-103, EtherNet/IP, SNTP, and IEEE 1588-2008 Precision Time Protocol (PTP).
- Supports low-energy analog (LEA) voltage sensor inputs and Rogowski coil or low power current transformer (LPCT) inputs with optional Slot Z card.

# Model Overview

The SEL-787L protection features depend on the model selected. Each model is configured with specific current/voltage input cards. *Table 1* shows current (ACI) and voltage (AVI) card selection options for the SEL-787L models. For all the available card options, refer to the SEL-787L model option table (MOT) available at selinc.com.

**Table 1 Current (ACI) and Voltage (AVI) Card Selection for SEL-787L Models**

| Model Description | Slot Z Card Option (MOT String Digit Numbers 16, 17) | Slot Z Inputs | Slot E Card Option (MOT String Digit Numbers 14, 15) | Slot E Inputs |
|---|---|---|---|---|
| Base SEL-787L AC Currents Only | 4 ACI (A1, A2, A3, A5, A6, A7) | IA, IB, IC, IN | None (0X) | None |
| SEL-787L With AC Voltages (300 Vac) | 4 ACI/3 AVI (81, 82, 83, 85, 86, 87) | IA, IB, IC, IN, VA, VB, VC | None (0X) | None |
| SEL-787L With LEA AC Voltages (8 Vac) | 4 ACI/3 AVI (L1, L2, L3, L5, L6, L7) | IA, IB, IC, IN, VA, VB, VC | None (0X) | None |
| SEL-787L With AC Phase Voltages (300 Vac), Vsync (300 Vac), Vbat (300 V) Input, and 4 Arc-Flash Detection Inputs | 4 ACI/3 AVI (81, 82, 83, 85, 86, 87) | IA, IB, IC, IN, VA, VB, VC | 2 AVI/4 AFDI (70) | VS, VBAT, AF1, AF2, AF3, AF4 |
| SEL-787L With LEA AC Phase Voltages (8 Vac), LEA Vsync (8 Vac), Vbat (300 V) Input, and 4 Arc-Flash Detection Inputs | 4 ACI/3 AVI (L1, L2, L3, L5, L6, L7) | IA, IB, IC, IN, VA, VB, VC | 2 AVI/4 AFDI (L0) | VS, VBAT, AF1, AF2, AF3, AF4 |
| SEL-787L With LEA Voltage Sensor Inputs, Rogowski Coil or Low-Power Current Transformer Inputs, 200 mA Neutral Input, Vsync (300 Vac), Vbat (300 V) Input, and 7 Digital Inputs | 4 ACI/3 AVI (7L) | IA, IB, IC, IN, VA, VB, VC | 2 AVI/7 DI (LA, LB, LC, LD, LG, LH) | VS, VBAT, 7 DI |

The SEL-787L is available with the following fiber-optic current differential communications interfaces:

- 850 nm multimode fiber (IEEE C37.94-compatible) with maximum 1 km point-to-point range
- 1310 nm single-mode fiber (IEEE C37.94-compatible) with maximum 25 km point-to-point range

The SEL-787L offers an extensive variety of protection features, depending on the models and options selected. *Table 2* lists the protection features available in each model.

**Table 2 SEL-787L Protection Elements (Sheet 1 of 3)**

| Protection Element | | Slot Z 4 ACI Card (Current Only Model) With 1 A or 5 A Neutral Channel | Slot Z 4 ACI/3 AVI Card With 1 A or 5 A Neutral Channel | Slot Z 4 ACI/3 AVI Card With 200 mA Neutral Channel |
|---|---|---|---|---|
| 87L | Line Differential Element | X | X | X |
| | Charging Current Compensation | | X | X |
| 87HBL | 87 Second-Harmonic Blocking | X | X | X |
| T50P/Q/G | 87 Tapped Load Overcurrent Elements | X | X | X |
| T51P/Q/G | 87 Tapped Load Inverse-Time Overcurrent Elements | X | X | X |
| 50P | Max. Phase Overcurrent | X | X | X |
| 67P | Max. Phase Overcurrent With Directional Control | | X[a] | X[b] |
| 50Q | Neg.-Seq. Overcurrent | X | X | X |
| 67Q | Neg.-Seq. Overcurrent With Directional Control | | X[a] | X[b] |
| 50G | Residual Overcurrent | X | X | X |

**Table 2 SEL-787L Protection Elements (Sheet 2 of 3)**

| Protection Element | | Slot Z 4 ACI Card (Current Only Model) With 1 A or 5 A Neutral Channel | Slot Z 4 ACI/3 AVI Card With 1 A or 5 A Neutral Channel | Slot Z 4 ACI/3 AVI Card With 200 mA Neutral Channel |
|---|---|---|---|---|
| 67G | Residual Overcurrent With Directional Control | | X[a] | X[b] |
| 50N | Neutral Overcurrent | X | X | X |
| 67N | Neutral Overcurrent With Directional Control | | | X[b] |
| 50INC | Incipient Cable Fault Detection | X | X | X |
| 51*m*P | Phase Time Overcurrent (*m* = A, B, C) | X | X | X |
| 51P | Max. Phase Time Overcurrent | X | X | X |
| 51P | Max. Phase Time Overcurrent With Directional Control | | X[a] | X[b] |
| 51G | Residual Time Overcurrent | X | X | X |
| 51G | Residual Time Overcurrent With Directional Control | | X[a] | X[b] |
| 51Q | Neg.-Seq. Time Overcurrent | X | X | X |
| 51Q | Neg.-Seq. Time Overcurrent With Directional Control | | X[a] | X[b] |
| 51N | Neutral Time Overcurrent | X | X | X |
| 51N | Neutral Time Overcurrent With Directional Control | | | X[b] |
| SEF | Sensitive Earth Fault | | | X |
| HBL | Second- and Fifth-Harmonic Blocking (Overcurrent) | X | X | X |
| FLOC | Fault Locator | | X | X |
| 27 | Undervoltage (Phase, Phase-to-Phase, Vsync) | | X | X |
| 59 | Overvoltage (Phase, Phase-to-Phase, Seq., Vsync, 3SRMS) | | X | X |
| 27I | Inverse Time Undervoltage | | X | X |
| 59I | Inverse Time Overvoltage | | X | X |
| 60LOP | Loss of Potential | | X | X |
| 47 | Phase Reversal Element | X | X | X |
| IGF | Intermittent Ground Fault | X[d] | X[d] | X[d] |
| 32 | Directional Power | | X | X |
| 49T | IEC Thermal (Line/Cable) | X | X | X |
| 55 | Power Factor | | X | X |
| 78VS | Vector Shift | | X | X |
| 81 | Over- and Underfrequency | X | X | X |
| 81R | Rate-of-Change of Frequency | | X | X |
| 81RF | Fast Rate-of-Change of Frequency | | X | X |
| VTHD | Phase Voltage THD | | X | X |
| 25 | Synchronism Check | | X[c] | X[c] |
| BF | Breaker Failure | X | X | X |
| 49RTD | Resistance Temperature Detectors (RTDs) | X[d] | X[d] | X[d] |

**Table 2 SEL-787L Protection Elements (Sheet 3 of 3)**

| Protection Element | | Slot Z 4 ACI Card (Current Only Model) With 1 A or 5 A Neutral Channel | Slot Z 4 ACI/3 AVI Card With 1 A or 5 A Neutral Channel | Slot Z 4 ACI/3 AVI Card With 200 mA Neutral Channel |
|---|---|---|---|---|
| 97FM | Frequency Component Detection | | X | X |
| 79 | Reclosing | X | X | X |
| HIF AST | High-Impedance Fault Detection With Arc Sense Technology | | X[d] | X[d] |
| AFD | Arc-Flash Detection | X[d] | X[d] | X[d] |
| PDD | Phase Discontinuity Detection | X | X | X |
| BCD | Broken Conductor Detection | | X[d, e] | X[d, e] |
| CLPU | Cold Load Pickup Element | X | X | X |

[a] Available when ordered with the directional option. The 1 A/5 A neutral channel is suitable for solidly grounded systems and also low-impedance grounded systems, depending on the available fault current level.

[b] Available when ordered with the advanced directional option. The 200 mA neutral channel is suitable for ungrounded, low-impedance grounded, high-impedance grounded, and Petersen coil-grounded applications.

[c] Available with the 2 AVI/4 AFDI card in Slot E.

[d] Available as ordering options.

[e] Available only for models with Arc Sense™ technology included.

The SEL-787L offers two front-panel HMI layouts. *Table 3* lists the HMI options for the SEL-787L front panel.

**Table 3 SEL-787L Front-Panel Options**

| Model/Display Description[a] | Front-Panel Option (MOT String Digit Number 19) | Number of Pushbuttons | LED Type |
|---|---|---|---|
| SEL-787L With Two-Line Display (2 x 16 characters) | 0 | 8 | Tricolor |
| SEL-787L With Touchscreen Display (5-inch, color, 800 x 480 pixels) | A | 8 | Tricolor |

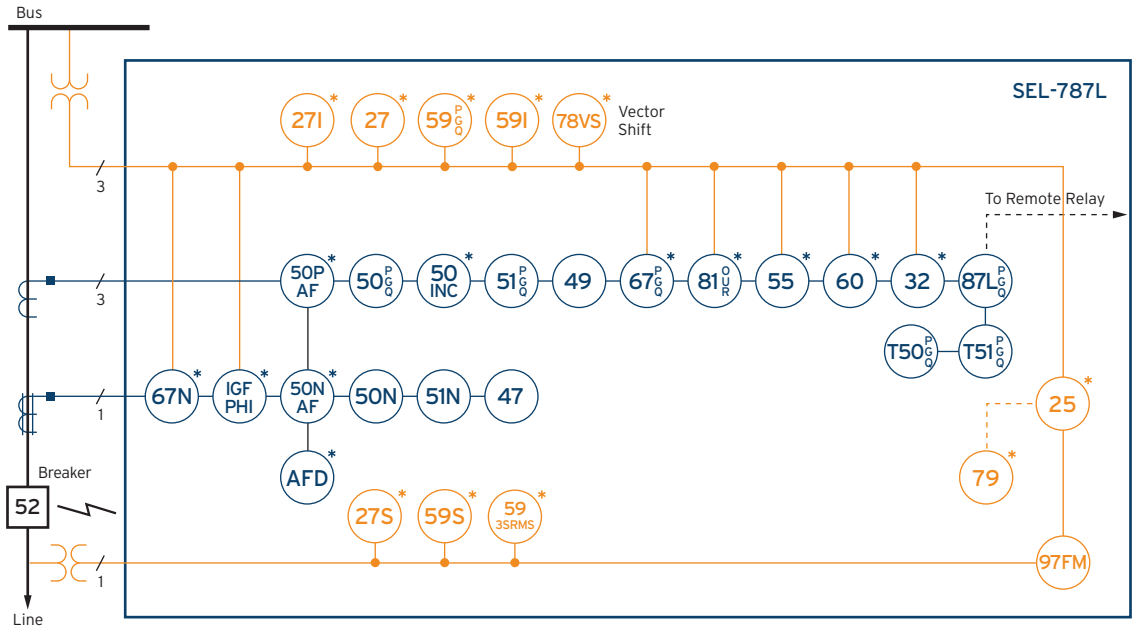
[a] For ordering options, refer to the SEL-787L MOT.

# Features

- **Standard Protection Features.** The line current differential relay is simple to set up and provides security against CT saturation and local or remote data corruption for medium voltage lines as long as 25 km. The relay offers a wide range of protection elements, including overcurrent elements, over- and underfrequency elements, second- and fifth-harmonic current blocking (inrush blocking), demand metering elements, breaker failure protection, and incipient cable fault detection. Implement load shedding and other control schemes with under- and overfrequency elements, breaker failure protection, and powerful SELOGIC® control equations. Also protect and control equipment with cable or line thermal elements that conform to the IEC 60255-149 standard.
- **Optional Protection Features.** Use the SEL-787L with a voltage input option to protect lines and equipment with charging current compensation, rate-of-change-of-frequency elements, fast rate-of-change-of-frequency elements, definite-time and inverse-time over- and undervoltage elements, and load encroachment and directional power elements. Also take advantage of vector shift elements to aid in islanding detection.
- **Optional Directional Control.** Use overcurrent elements with directional control on looped networks. Best Choice Ground Directional Element® logic optimizes directional element performance and eliminates the need for many directional settings.
- **Optional High-Impedance Fault Detection.** Use the high-impedance fault (HIF) detection element to detect small-current ground faults that typically result from downed conductors on ground surfaces, such as earth, reinforced concrete, or other poorly conductive materials. HIF event data are available in COMTRADE or Compressed ASCII format.

- **Optional Arc-Flash Protection.** Reduce or eliminate damage from arc-flash events with the optional four- or eight-channel fiber-optic arc-flash detector inputs and protection elements. Settable arc-flash phase and neutral overcurrent elements combined with arc-flash light detection elements provide secure, reliable, and fast arc-flash event protection.
- **Optional Broken Conductor Detection.** Use the broken conductor detection (BCD) element to reliably detect and locate broken conductors. BCD is only available for models with the Arc Sense technology (AST) option included and wye-connected VTs. The BCD function is designed for single-conductor line configurations and can help in mitigating a fire or other public hazard.
- **Optional LEA Voltage Inputs.** Measure voltages as high as 8 Vac rms.
- **Optional LEA Voltage Sensor Inputs, Rogowski Coil/LPCT Current Inputs, and Conventional 200 mA Sensitive Neutral Inputs.** The LEA input range for voltages is as high as 8 Vac rms. LEA current channel inputs support multiple gains, which supports a wide range of primary currents.
- **Optional Synchronism Check and DC Station Battery Monitor.** Check single-phase voltage across a circuit breaker and measure dc voltage levels in the substation battery.
- **Operator Controls and Reclosing.** Trip and close the breaker easily with eight programmable front-panel pushbuttons, each with two tricolor LEDs. Implement remote and local control functions, and selectively reclose with synchronism and voltage checks.
- **Optional I/O Modules.** In addition to I/O cards, add as many as 4 I/O modules. Each module contains either 21 programmable inputs or 12 electromechanical outputs.
- **Integrated Web Server.** Log in to the built-in web server to view metering and monitoring data and to download events. Use the web server to view relay settings and to perform relay firmware upgrades.
- **Relay and Logic Settings Software.** Reduce engineering costs by using ACSELERATOR QuickSet® SEL-5030 Software for relay settings and logic programming and to simplify development of SELOGIC control equations.
- **Metering and Monitoring.** Use built-in metering functions to eliminate separately mounted metering devices. 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.
- **Optional Fault Location.** Reduce fault location and repair time with built-in, impedance-based fault location and faulted phase indication.
- **Wye or Delta Voltage Inputs.** Connect voltage inputs that are wye-connected, open-delta-connected, or single voltage.
- **Additional Standard Features.** Improve your feeder protection with these additional standard features in every SEL-787L: Modbus RTU; Event Messenger support and MIRRORED BITS® communications; load profile and breaker wear monitoring; IRIG-B input; advanced SELOGIC; and IEEE C37.118-2005-compliant synchrophasor protocol to provide real-time measurement data.
- **Optional Features.** Communicate with a number of additional optional communications protocols and ports, digital/analog I/O, and RTDs. Optional communications protocols include IEC 61850 Edition 2.1; Modbus TCP/IP; Simple Network Time Protocol (SNTP); PTP; HSR; Parallel Redundancy Protocol (PRP) for dual Ethernet models; EtherNet/IP; DNP3 LAN/WAN; DNP3 serial; and IEC 60870-5-103. With an Ethernet equipped relay, use the integrated web server to view settings and metering and monitoring data, download reports, and upgrade firmware. Elective communications ports include EIA-232 or EIA-485 multimode fiber-optic serial port and single or dual, copper or fiber-optic Ethernet ports. Several digital/analog I/O options are available. These include 4 AI/4 AO, 4 DI/4 DO, 8 DI, 8 DO, 8 AI, 3 DI/4 DO/1 AO, 4 DI/3 DO, 2 AVI/7 DI, and 14 DI cards and as many as 4 I/O modules. Each module contains either 21 programmable inputs or 12 electromechanical outputs. An optional 10 internal RTD card is also available for the SEL-787L. Conformal coating for chemically harsh and/or high-moisture environments is also available as an option.
- **Supported Languages.** Choose English or Spanish for your serial ports, including the front-panel serial port. The standard relay front-panel overlay is in English; a Spanish overlay is available as an ordering option.

# Protection Overview




| ANSI Functions | |
|---|---|
| 25 | Synchronism check* |
| 27I | Inverse-time undervoltage |
| 27S | Synchronism-check undervoltage* |
| 32 | Directional power* |
| 49 | IEC cable/line thermal |
| 49R | RTD* |
| 50 | Adaptive overcurrent |
| 50INC | Incipient cable fault detection |
| 50 (P, G, Q, N) | Overcurrent |
| 50PAF/50NAF | Arc-flash overcurrent* |
| T50 (P, G, Q) | 87 tapped load overcurrent |
| 51 (P, G, Q, N) | Time overcurrent |
| T51 (P, G, Q) | 87 tapped load inverse-time overcurrent |
| 52PB | Trip/Close pushbuttons |
| 55 | Power factor* |
| 59 (P, G, Q) | Definite-time overvoltage |
| 59S | Synchronism-check overvoltage* |
| 593SRMS | Overvoltage three-second rms |
| 60 | Loss of potential* |
| 67 (P, G, Q) | Directional overcurrent |
| 67N | Directional neutral overcurrent* |
| 78VS | Vector shift* |
| 79 | Autoreclosing* |
| 81 (O, U, R, RF) | Over- and underfrequency* |
| 87L (P, G, Q) | Line differential |
| 97FM | Frequency component detection |

* Optional feature

| Additional Functions | |
|---|---|
| 85 RIO | SEL MIRRORED BITS communications |
| AFD | Arc-flash detector* |
| BCD | Broken conductor detection* |
| BW | Breaker wear monitoring |
| CLPU | Cold load pickup |
| DFR | Event reports |
| HBL | Harmonic blocking |
| HIZ | AST |
| HMI | Operator interface |
| LDE | Load encroachment |
| LDP | Load data profiling |
| LEA | Rogowski coil or LPCT inputs and LEA ac voltage inputs (8 Vac RMS) |
| LGC | SELOGIC control equations |
| LOC | Fault locator |
| PDD | Phase discontinuity detection |
| PMU | Synchrophasors |
| RTD | 10 internal RTD inputs* |
| RTU | Remote terminal unit |
| SBM | Station battery monitor |
| SER | Sequential Events Recorder |
| WEB | Web server |

* Optional feature

**Figure 1 Functional Diagrams**

# Protection Features

## Line Current Differential

The SEL-787L provides simple yet very dependable and cost affective line current differential protection (87L). It is suitable for application on overhead lines or cables over direct serial fiber communications as far as 25 km.

The relay offers the following key features:

- Two-terminal applications
- Phase (87LA, 87B, and 87LC), ground (87G), and negative-sequence (87Q) differential elements
- Adaptive-slope percentage restrained differential with normal and secure mode characteristics
- Sensitive and adaptive disturbance detectors to improve security against corruption of local or remote data
- EFD to secure differential elements under heavy CT saturation conditions

Each of the differential elements uses operate and restraint currents calculated using the normalized and time-aligned local and remote phasor currents. With the voltage option, local and remote currents are compensated for line charging current when compensation is enabled. The 87L elements use the normal slope characteristics represented by the solid line shown in *Figure 2* under normal operating conditions. The elements use the secure mode differential characteristics represented by the dotted line if an external fault is detected to secure the 87L element against CT saturation. All the supported elements (phase [87LA, 87LB, and 87LC], ground [87LG], and negative-sequence [87LQ]) use common characteristics with independent pickup settings.

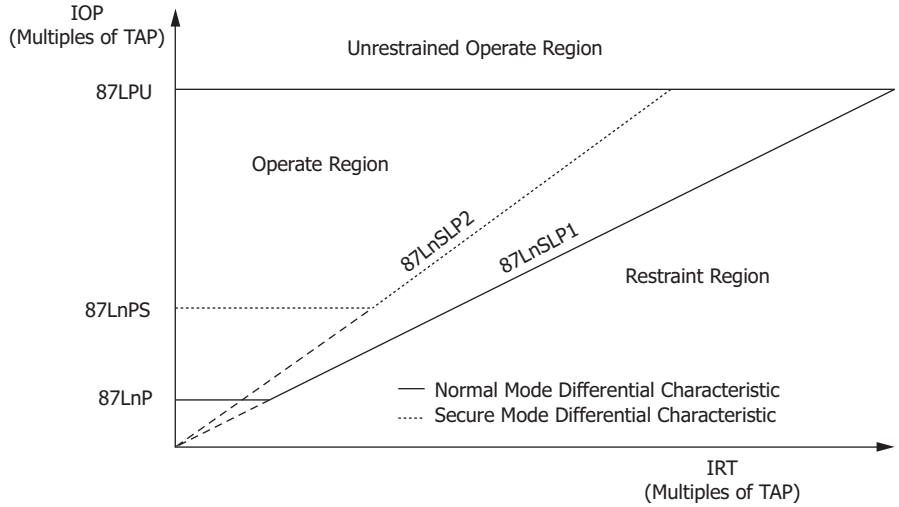



**Figure 2 Adaptive-Slope Percentage Restrained Differential Characteristics**

The relay applies disturbance detection logic on both the local and remote currents. The 87L element is supervised by both the local and remote disturbance detectors. The disturbance detectors are sensitive, but they will not assert under load conditions for periodic current or voltages, even for heavily distorted load current or voltages. No user settings are necessary for the disturbance detection logic.

The EFD logic is intended to provide security against CT saturation under heavy external fault conditions. The EFD logic is run on each phase using the corresponding phase operate and restraint currents. The EFD element asserts if it detects an increase in the restraint current without an increase in the corresponding operate current. Assertion of the EFD element forces the relay to use the secure mode characteristics shown in *Figure 2*.

## Two-Terminal Line Current Differential Protection

The SEL-787L is available with the following fiber-optic current differential communication interfaces for two-terminal line differential protection applications:

- IEEE C37.94-compliant 850 nm multimode-mode interface
- IEEE C37.94-compliant 1310 nm single-mode interface

Based on these communication interfaces, the SEL-787L can be configured as follows:

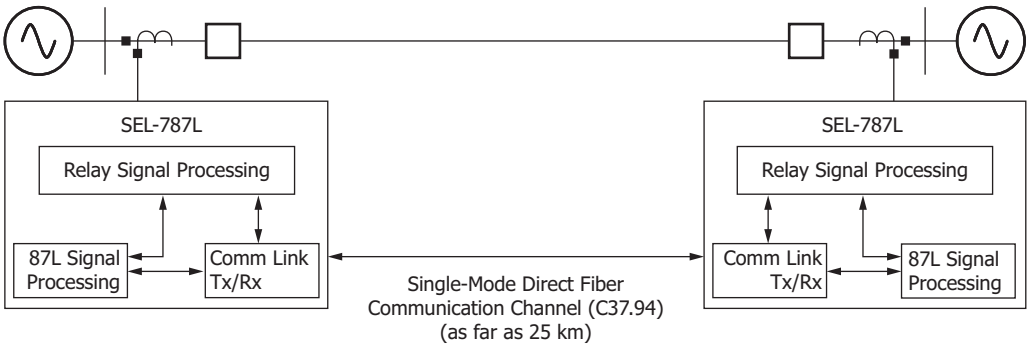



**Figure 3 Two-Terminal Application Using Single-Mode Direct Fiber Communications**

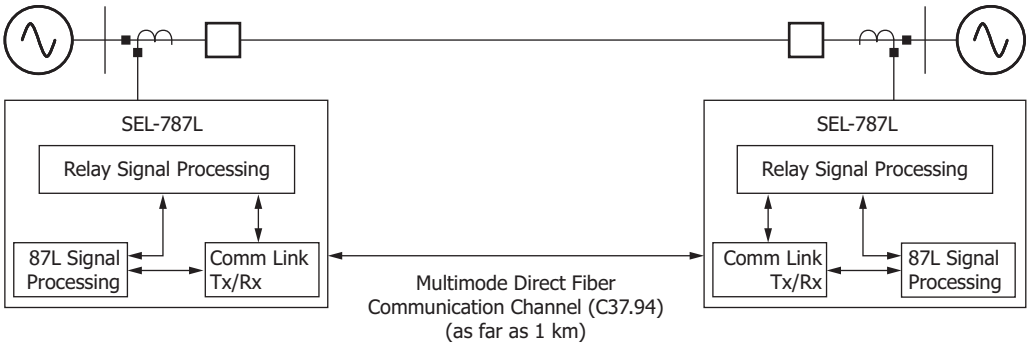



**Figure 4 Two-Terminal Application Using Multimode Direct Fiber Communications**

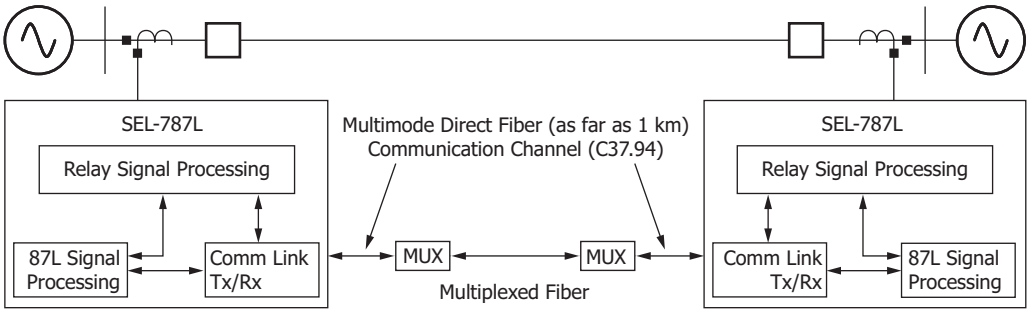



**Figure 5 Two-Terminal Application Using Multimode Fiber Communications Over Multiplexer**

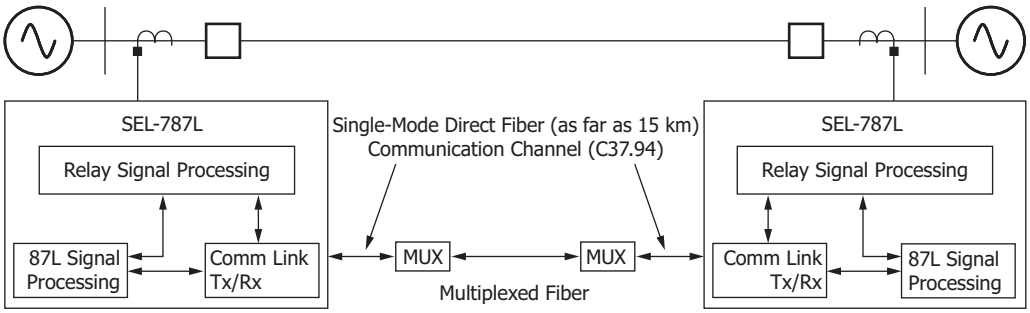



**Figure 6 Two-Terminal Application Using Single-Mode Fiber Communications Over Multiplexer**

# 87L Channel Monitoring

To aid in commissioning and to help maintain security and dependability, the SEL-787L provides a set of channel monitoring and alarming functions. Considering that the 87L function is communications-dependent, it is beneficial to monitor the status of the communications channels during in-service operation to detect abnormal or unexpected conditions and initiate corrective actions. The 87L function itself responds to monitored channel characteristics in real time to maintain proper security and dependability. Also, checking for specified performance of the communications channels is an integral part of a typical commissioning procedure for the 87L function.

The monitoring functions of the SEL-787L include a round-trip channel delay, step change in the round-trip delay signifying path switching, channel asymmetry detection and compensation during path switching, momentary channel break detection, lost packet counts, and a data integrity alarm. These monitoring functions provide an overall assessment of channel quality and feed into the internal 87L logic for security.

# 87L Communications Report

The SEL-787L provides an 87L communications report to visualize and summarize basic 87L configuration as well as real-time and historical channel monitoring and alarming values. The report covers three major areas:

- 87L configuration and overall status such as relay identification, channel problems, Test Mode status, etc.
- Detailed channel configuration, diagnostics, and channel health information. Such information includes the remote relay address, data synchronization status, channel alarms, and round-trip channel delay.
- Long-term channel characteristics such as a channel delay histogram and worst-case channel delay with a time stamp.

# 87 Overcurrent and Time-Overcurrent Elements for Tapped Line Applications

The SEL-787L offers phase (T50P), ground (T50G), and negative-sequence (T50Q) overcurrent elements that operate on the respective differential currents. Likewise, the relay offers phase (T51P), ground (T51G), and negative-sequence (T51Q) time-overcurrent elements that operate on the respective differential currents. The same curves as shown in *Table 4* are supported by T51 elements. Apply overcurrent (T50) and time-overcurrent (T51) elements in SEL-787L to coordinate with the fuse or relays on the tapped line applications.

# Overcurrent Elements

The SEL-787L includes a robust set of phase, negative-sequence, residual, and neutral overcurrent elements. Each element type has four levels of instantaneous protection with individual torque control and definite-time delay settings. Each element type has two inverse-time overcurrent elements (except negative-sequence, which has one time-overcurrent element). *Table 4* lists the curves available in the SEL-787L.

**Table 4 Inverse-Time Overcurrent Curves**

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

The SEL-787L 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.

## Overcurrent Elements for Phase Fault Detection

The SEL-787L provides the tools necessary for sensitive fault protection while accommodating heavily loaded circuits. Where heavy loading prevents sufficiently sensitive setting of the phase overcurrent elements to detect lower magnitude phase-to-ground faults, residual-ground overcurrent elements are available to provide sensitive ground fault protection without tripping under balanced heavy load conditions. Similarly, when heavy loading prevents sufficiently sensitive setting of the phase overcurrent elements to detect lower magnitude phase-to-phase faults, negative-sequence overcurrent elements are available to provide more sensitive phase-to-phase fault detection without tripping under balanced heavy load conditions. You can set phase overcurrent element pickup sufficiently high to accommodate heavy loads while retaining sensitivity to higher magnitude three-phase faults.

On extremely heavily loaded feeders, SEL-787L load-encroachment logic adds security in cases when you cannot set phase overcurrent elements to provide adequate three-phase fault sensitivity while also accommodating

load. With this logic, you can set the phase overcurrent elements below peak load current so that the relay can detect 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 based on the magnitude and angle of the positive-sequence impedance. When the measured positive-sequence load impedance (Z1) is within a region the load-encroachment settings define, load-encroachment logic blocks the phase overcurrent elements. As *Figure 7* shows, a phase fault causes Z1 to move from a load region to the line angle and leads to operation of the phase overcurrent elements.

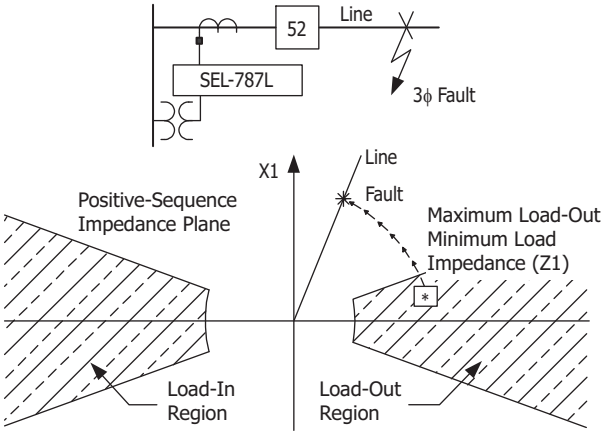



**Figure 7 Load-Encroachment Characteristics**

## Overcurrent Elements for Ground Fault Detection

Residual-ground ($I_G$) and neutral ($I_N$) overcurrent elements detect ground faults. The SEL-787L protection system includes patented Best Choice Ground Directional Element logic, providing a selection of negative-sequence impedance, zero-sequence impedance, and zero-sequence current polarizing techniques for optimum directional ground element control.

# Directional Elements Increase Sensitivity and Security

Phase and ground directional elements come standard in an SEL-787L with the directional control option. An automatic setting mode (EDIR := AUTO or AUTO2) sets all directional threshold settings according to replica positive-sequence and zero-sequence line impedance settings (Z1MAG, Z1ANG, Z0MAG, and Z0ANG) for line protection applications. For all non-line protection applications, set EDIR := Y to enable and set appropriate directional element thresholds. Phase directional elements provide directional control to the phase- and negative-sequence overcurrent elements.

Phase directional characteristics include positive-sequence and negative-sequence directional elements working together. The positive-sequence directional element memory provides a reliable output for close-in, forward, or reverse three-phase faults where each phase voltage is zero.

Ground directional elements provide directional control to the residual-ground and neutral overcurrent elements. Patented negative-sequence, zero-sequence impedance directional elements, and the zero-sequence current directional element use the same principles proven in our SEL transmission line relays. Our patent-pending zero-sequence PHI directional element is a fully customizable element in the zero-sequence complex plane that allows you to flexibly apply the element in ungrounded, impedance-grounded, and Petersen coil-grounded systems. Our patented Best Choice Ground Directional Element logic selects the best available ground directional element for the ORDER setting you provide.

# Directional Protection for Various System Grounding Practices

Current channel IN, ordered with an optional 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 optional directional control allows the faulted feeder to be identified on a multifeeder bus with an SEL-787L on each feeder (*Figure 8*). Alarm or trip for the ground fault condition with sensitivity down to 5 mA secondary. Our patent-pending directional intermittent ground fault element can be used to detect and trip for arcing faults that can quickly self-extinguish.

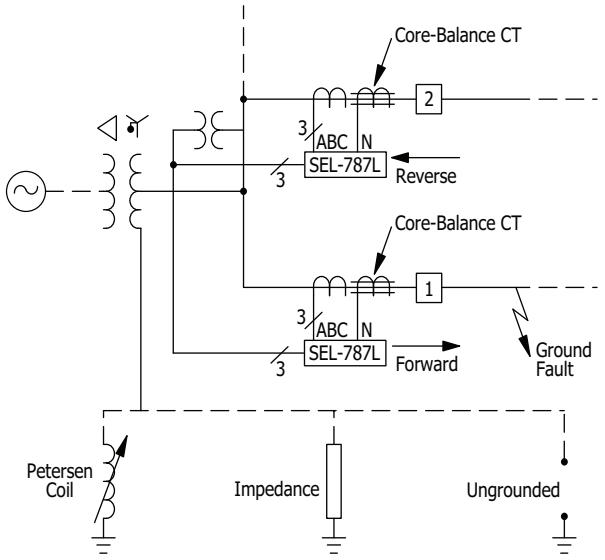



**Figure 8 Apply SEL-787L Relays to Petersen Coil-Grounded, Impedance-Grounded, and Ungrounded Systems for Directional Control**

## Line/Cable Thermal Elements

Power lines and cables are designed to operate under a certain temperature range. Because equipment is often used as close to the operating limits as possible, the importance of protecting equipment against thermal overloads becomes more critical. The thermal overload protection element is used to protect overhead lines and cables against thermal damage (including insulation degradation and loss of equipment life) and to monitor the thermal state of overhead lines and cables. The temperature is calculated using a thermal model according to IEC 60255-149.

## Incipient Cable Fault Detection

Cable insulation degrades over time. The incipient cable fault detection element can monitor for self-extinguishing, half-cycle overcurrent events that precede typical cable insulation failure. Monitoring the number of incipient faults can provide an early warning of cable insulation breakdown. This information can be used for preventative maintenance.

## Cold Load Pickup

Cold load pickup is the phenomenon that takes place when a distribution circuit is re-energized following an extended outage of that circuit. It can result in current levels that are significantly higher than normal peak load levels. This excess amount of current draw can be falsely identified as an overcurrent condition by the relay. The cold load pickup element identifies possible cold load pickup events based on the settings in a distribution line after an outage.

## Wye or Open-Delta Voltages

You can apply wye-connected (four-wire) voltages or open-delta-connected (three-wire) voltages to three-phase voltage inputs VA, VB, VC, and N, as shown in *Figure 9*. You only need to make a setting change (DELTA_Y := WYE or DELTA_Y := DELTA) and an external wiring change—no internal relay hardware changes or adjustments are necessary. Thus, a single SEL-787L model meets all your distribution protection needs, regardless of available three-phase voltages.

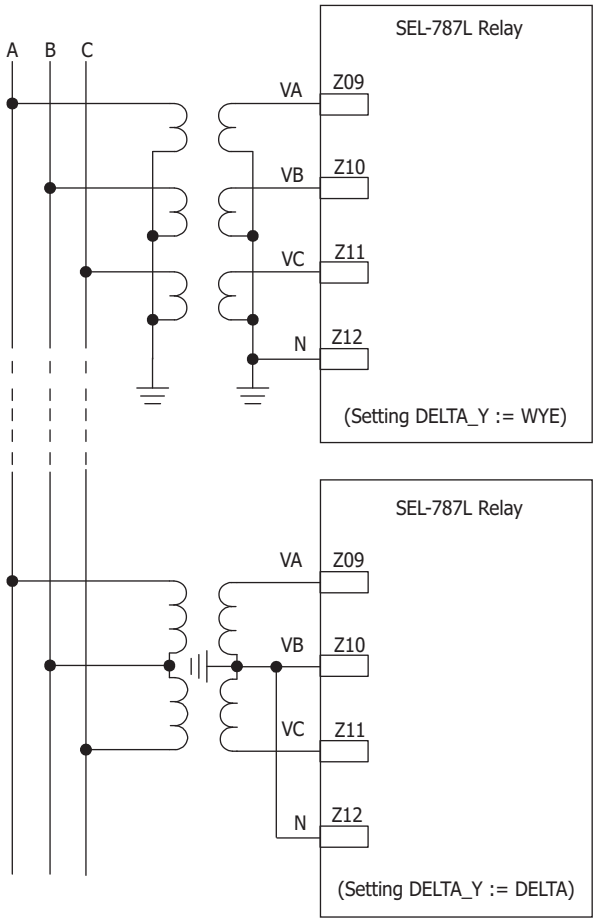



**Figure 9 Connect Wye or Open-Delta Voltage to SEL-787L Three-Phase Voltage Inputs**

*Figure 10* shows the connections for a 3V0 broken-delta input.

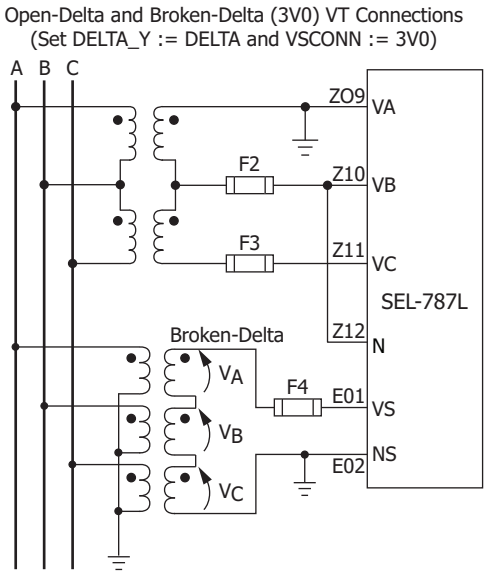



**Figure 10 Broken-Delta Connections**

In addition, the SEL-787L supports a single voltage input. For customers with a single PT input, the SEL-787L assumes a balanced voltage input for all protection and metering functions.

# Loss-of-Potential Logic

The SEL-787L includes loss-of-potential (LOP) logic that detects one, two, or three blown potential fuses. This patented LOP logic is unique because it does not require settings and is universally applicable. The LOP feature allows the blocking of protection elements to add security during fuse failure.

# Synchronism Check

When you order the Vsync, Vbat voltage input and 4 arc-flash detection inputs card (SELECT 2 AVI/4 AFDI) or the Vsync, Vbat voltage input and 7 digital inputs card (SELECT 2 AVI/7 DI), 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). You can use the synchronism-check voltage to coordinate reclosing with a recloser control.

# Voltage and Frequency Elements for Extra Protection and Control

## Over- and Undervoltage Elements

You can use phase-to-ground, phase-to-phase, negative-sequence, residual overvoltage (59), and phase-to-ground or phase-to-phase undervoltage (27) elements in the SEL-787L to create the following protection and control schemes.

- Trip/alarm or event report triggers for over- and undervoltage conditions
- Undervoltage (27) load-shedding scheme (having both 27 and 81U load-shedding schemes allows detection of system MVAR- and MW-deficient conditions)

## Inverse-Time Over- and Undervoltage Elements

Programmable, IEC equation-based inverse-time overvoltage (59I) and undervoltage (27I) elements in the SEL-787L add flexibility in voltage protection and control schemes.

## Overvoltage 3-Second RMS Element

The overvoltage 3-second rms (593SRMS) element in the SEL-787L is designed to detect abnormal sustained overvoltage conditions in power systems. It is particularly effective in networks with inverter-based resources (IBR) where voltage behavior can be highly dynamic. The element calculates a 10-minute averaged rms voltage, updated every 3 seconds, to reliably identify sustained conditions. Voltage at the point of interconnection (POI) can fluctuate due to rapid changes in generation, variations in grid strength, and reactive power dynamics. These fluctuations make it essential to distinguish between transient voltage excursions and sustained overvoltage conditions.

# Over- and Underfrequency Protection

Six levels of secure overfrequency (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. The SEL-787L uses the voltage input to make frequency measurements; the relay switches automatically to current input when voltages are insufficient.

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

# Rate-of-Change-of-Frequency Protection

Four independent rate-of-change-of-frequency elements are provided with individual time delays for use when frequency changes occur (e.g., when there is a sudden unbalance between generation and load). The elements can call for control or switching action, such as network decoupling or load shedding. Each element includes logic to detect either increasing or decreasing frequency and frequency above or below nominal frequency.

## Frequency Component Detection With the 97FM Element

The 97FM elements monitor the magnitude of a user-selected frequency component in different analog signals by evaluating an individual term of the discrete Fourier transform (DFT).

You can use 97FM elements to detect low-frequency power oscillations resulting from sub-synchronous resonance or load oscillations.

## Phase Reversal Protection

Relay phase reversal protection detects phase rotation and trips after a delay if the phase rotation is incorrect. The SEL-787L provides this protection even if phase voltages are not available.

## Fast Rate-of-Change-of-Frequency Protection for Aurora Vulnerability Mitigation

The fast rate-of-change-of-frequency protection (81RF) element, provides a faster response compared to the frequency (81) and rate-of-change-of-frequency (81R) elements. Fast operating speed makes the 81RF element suitable for detecting islanding conditions. The element uses a characteristic (see *Figure 11*) based on the frequency deviation from the nominal frequency (DF = FREQ – FNOM) and the rate-of-change of frequency (DF3C) to detect islanding conditions.

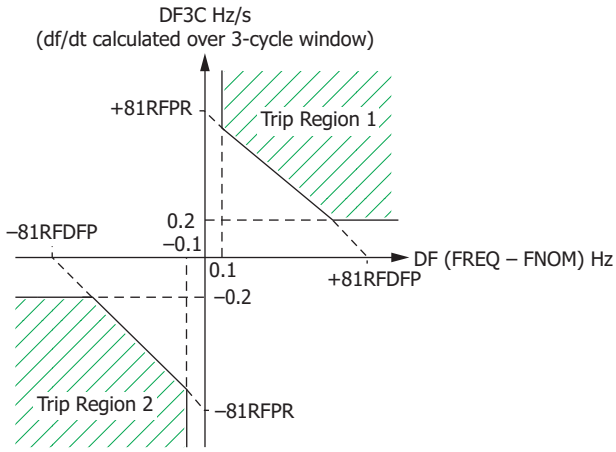



**Figure 11 81RF Characteristic Power Element Protection**

A time window of three cycles is used to calculate the value of DF3C. Under steady state conditions, the operating point is close to the origin. During islanding conditions, depending on the acceleration of the islanded system, the operating point enters Trip Region 1 or Trip Region 2 of the characteristic. 81RFDFP (in Hz) and 81RFRP (in Hz sec.) are the settings used to configure the characteristic.

# Vector Shift (78VS) Protection

When distributed generators (DG) are connected to a utility network, the vector shift (78VS) element is used to detect islanding conditions and trip the DG. Failure to trip islanded generators can lead to problems such as personnel safety, out-of-synchronization reclosing, and degradation of power quality. Based on the change in the angle of the voltage waveform, an islanding condition can be detected by the vector shift function.

Use the vector shift element with the 81RF element as a backup for fast and secure islanding detection. The vector shift element operates within three cycles, which is fast enough to prevent reclosing out-of-synchronism with the network feeders to avoid generator damage.

# Harmonic Blocking Elements Secure Protection During Transformer Energization

Transformer inrush can cause sensitive protection to operate. Use the second- and fifth-harmonic blocking feature to detect an inrush condition and block selected tripping elements until the inrush subsides. Select the blocking threshold as a percentage of fundamental current, and optimize security and dependability with setta-

ble pickup and dropout times. Use the programmable torque control equation only to enable the blocking element immediately after closing the breaker.

## Power Element Protection

The SEL-787L provides two power elements for detecting real (watts) or reactive (VARS) positive- or negative-power flow levels for the feeder application. Each power element has a definite-time delay setting.

## High-Impedance Fault (HIF) Detection

High-impedance faults are short-circuit faults with fault currents smaller than what a traditional overcurrent protective relay can detect. The main causes of HIFs are tree branches touching a phase conductor, dirty or failing insulators that cause flashovers between a phase conductor and the ground, or downed conductors touching the ground. The SEL-787L with the AST option includes logic that can detect HIF signatures without being affected by loads or other system operating conditions. A running average provides a stable pre-fault reference, and adaptive tuning learns and tunes out feeder ambient noise conditions. Decision logic differentiates an HIF condition from other system conditions, such as switching operations and noisy loads. The relay stores as many as 20 minutes of HIF activity in 2-cycle resolution Compressed ASCII and COMTRADE formats and it stores a summary of HIF activity that you can access through the use of ASCII commands.

## Broken Conductor Detection (BCD)

The BCD algorithm is only available for SEL-787L models with the AST option included. BCD uses the charging current of the line to reliably detect and estimate the location of broken conductors. It can be used to trip the breakers before the conductor touches the ground and creates a shunt fault. The algorithm can prevent such faults and block any attempt to reclose the line. The BCD function is designed for single-conductor line configurations and can help to mitigate the possibility of a fire or other public hazard.

## Phase Discontinuity Detection (PDD)

The PDD element uses current unbalance to detect an open conductor. The PDD logic detects phase discontinuity only for cases that result in an open phase condition for a minimum of eight power system cycles.

## Arc-Flash Protection

An arcing short circuit or a ground fault in low- or medium-voltage switchgear can cause serious equipment damage and personnel injury, resulting in prolonged and expensive downtime.

The best way to minimize the impact of an arc-flash event is to reduce the detection and circuit breaker tripping times. Conventional protection may need several cycles to detect the resulting overcurrent fault and trip the breaker. In some cases, there may not be sufficient current to detect an overcurrent fault. Tripping may be delayed hundreds of milliseconds for sensitivity and selectivity reasons in some applications.

The arc-flash detection-based (AFD) protection can act on the circuit breaker in a few milliseconds (2–5 ms). This fast response can limit the arc-flash energy, thus preventing injury to personnel and limiting or eliminating equipment damage.

The arc-flash protection option in the SEL-787L adds four- or eight-channel fiber-optic AFD inputs and protection elements. Each channel has a fiber-optic receiver and an LED-sourced fiber-optic transmitter that continuously self-tests and monitors the optical circuit to detect and alarm for any malfunction. There are two types of applications supported by the SEL-787L: point-sensor applications and fiber-sensor applications.

### Point-Sensor Application

The arc is detected by transmitting the arc-flash light captured by the optical diffuser (located appropriately in the switchgear) over a 1000 µm plastic fiber-optic cable to the optical detector in the relay. The relay performs sensor loopback tests on the optical system using an LED-based transmitter to transmit light pulses at regular intervals to the point-sensor assembly (through a second fiber-optic cable). If the relay optical receiver does not detect this light, the relay declares a malfunction and alarms. *Figure 12* (top) shows a diagram for the point-sensor application.

### Fiber-Sensor Application

Fiber sensor AFD uses a clear-jacketed 1000 µm plastic fiber-optic cable located in the switchgear equipment. One end of the fiber is connected to the optical detector in the relay and the other end is connected to the LED transmitter in the relay. The LED transmitter injects periodic light pulses into the fiber as a sensor loopback test to verify the integrity of the loop. The relay detects and alarms for any malfunction. *Figure 12* (bottom) shows a diagram for the clear-jacketed fiber sensor application.

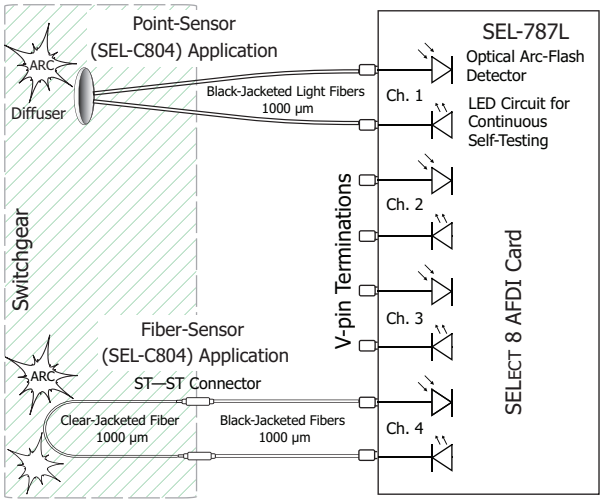



**Figure 12 SEL-787L Arc-Flash Detection System**

The SEL-787L AFD system provides four or eight channels per relay that can be configured for the point-sensor or the clear-jacketed fiber-sensor applications. The optional fast hybrid outputs (high-speed and high-current) of the relay provide fast-acting trip outputs to the circuit breaker (less than 50 µs). The fast breaker tripping can prevent serious damage or personnel injury in the case of an arc-flash event. The relay also provides light metering and light event capture to aid in setting the relay and capturing the arc-flash event for records and analysis.

Settable arc-flash phase and neutral overcurrent elements are combined with arc-flash light detection elements to provide secure, reliable, and fast-acting arc-flash event protection.

## RTD Thermal Protection

When the SEL-787L is equipped with the optional 10 RTD input expansion card, you can program as many as 10 thermal elements in the relay for two levels of thermal protection per element. Each RTD input provides an alarm and trip thermal pickup setting in degrees Celsius, open and shorted RTD detection, and is compatible with the following three-wire RTD types:

- PT100 (100 Ω platinum)
- NI100 (100 Ω nickel)
- NI120 (120 Ω nickel)
- CU10 (10 Ω copper)

# Operator Controls and Reclosing

Operator controls eliminate traditional panel control switches. Eight conveniently sized operator controls, each with two programmable tricolor LEDs, are located on the relay front panel (see *Figure 13*). You can set the SER to track the operator controls. Use SELOGIC control equations to change the operator control functions. Use configurable labels to change all of the text shown in *Figure 13*.

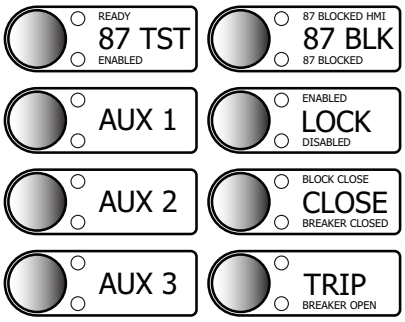



**Figure 13 Operator Controls for Standard Model**

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

**LOCK:** The **LOCK** operator control blocks selected functions. Press it for at least three seconds to engage or disengage the lock function. When the **LOCK** pushbutton is engaged, the **87 TST**, **87 BLK**, **CLOSE**, and **TRIP** operators are blocked.

**CLOSE** and **TRIP:** Use the **CLOSE** and **TRIP** operator controls to close and open the circuit breaker. You can program these controls with intentional time delays to support operational requirements for breaker-mounted relays. This allows you to press the **CLOSE** or **TRIP** pushbutton, then move to an alternate location before the breaker command is executed.

**87 BLK** and **87 TST:** Use the **87 BLK** operator control to block the 87L function. Use the **87 TST** operator control to enable Test Mode supervision. Use the **87 TEST** ASCII command to put the relay into Test Mode.

**AUX n:** You can program the **AUX n** (*n* = 1, 2, or 3) pushbuttons for additional control of your specific application.

In the SEL-787L with the touchscreen display, you can use the front-panel operator control pushbuttons to jump to a specific screen while also using them for LOCK/

TRIP/CLOSE operations, etc. You can program the selectable operator pushbutton screen settings under the Touchscreen settings category in QuickSet to map the button to the specific screen.

## Programmable Autoreclosing

The SEL-787L can autoreclose a circuit breaker as many as four times before lockout. Use SELOGIC control equations to program the SEL-787L 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 (optional).
- ➤ 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 caused by a close-in, high-current fault.
- ➤ Flexible reclose supervision failure scheme that allows going to lockout or moving to the next available shot.

The reclosing shot counter controls which protective elements are involved in each reclose interval. Applications include fuse- and trip-saving schemes. The front-panel LEDs (**RECL RESET** and **RECL LOCKOUT**) track the reclosing state.

# Built-In Web Server

Every Ethernet-equipped SEL-787L includes a built-in web server. Interface with the relay by using any standard web browser to perform the following actions:

- ➤ Log in with password protection.
- ➤ Safely read the relay settings.
- ➤ Verify the relay self-test status and view the relay configuration.
- ➤ Inspect meter reports.
- ➤ Download SER and event reports.
- ➤ Upload new firmware (firmware upgrade).

*Figure 14* shows the differential metering screen that can be accessed by selecting **Meter** > **Differential**. Use the Meter menu to view all the available relay metering statistics.

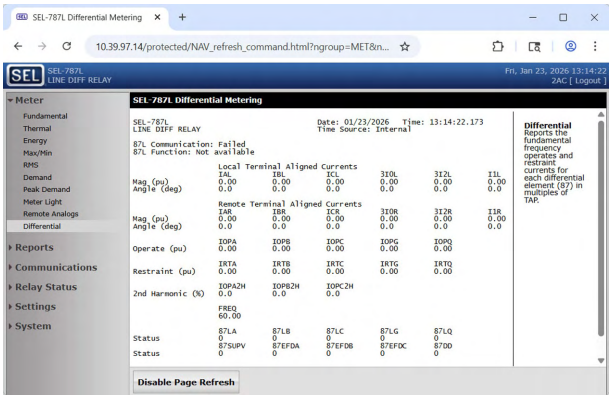



**Figure 14 Differential Meter Report Webpage**

*Figure 15* shows the Group 1 settings webpage. You can view the settings of each relay settings class by selecting **Settings** and the respective relay settings class.

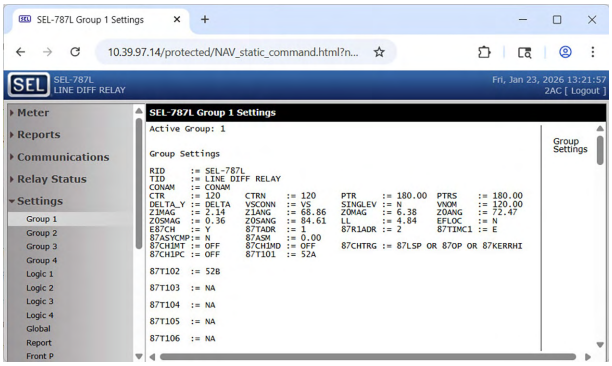



**Figure 15 Group 1 Settings Webpage**

You can upgrade the relay firmware through the relay web server by selecting **System** > **File Management** (available at Access Level 2) and selecting the firmware upgrade file. *Figure 16* shows the firmware upgrade webpage.

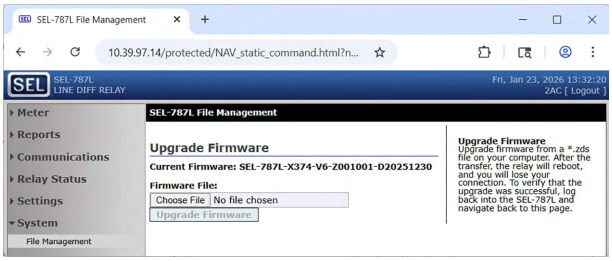



**Figure 16 Upgrade the Relay Firmware From File Management Webpage**

# Relay and Logic Settings Software

QuickSet simplifies settings and provides analytical support for the SEL-787L. There are several ways to create and manage relay settings with QuickSet.

- Develop settings offline with an intelligent settings editor that only allows valid settings.
- Create SELOGIC control equations with a drag-and-drop text editor.
- Configure proper settings using online help.
- Organize settings with the relay database manager.
- Load and retrieve settings using a simple PC communications link.

With QuickSet, you can verify settings and analyze power system events with the integrated waveform and harmonic analysis tools.

Use the following features of QuickSet to monitor, commission, and test the SEL-787L.

- Use the HMI to monitor meter data, Relay Word bits, and output contact statuses during testing.
- Use the PC interface to remotely retrieve power system data.
- Use the Event Report Analysis tool for easy retrieval and visualization of ac waveforms and digital inputs and outputs the relay processes.
- Use the graphical current phasor display in the HMI to visualize differential current relationships.
- Use bay control to design new bay screens and edit existing bay screens by launching ACSELERATOR Bay Screen Builder SEL-5036 Software for SEL-787L relays with the touchscreen display.

## ACSELERATOR Bay Screen Builder SEL-5036 Software

The SEL-787L with the touchscreen display option provides you with the ability to design bay configuration screens to meet your system needs. You can display the bay configuration as a single-line diagram (SLD) on the touchscreen. You can use ANSI and IEC symbols, along with analog and digital labels, for the SLD to indicate the status of the breaker and disconnects, bus voltages, and power flow through the breaker. In addition to SLDs, you can design the screens to show the status of various relay elements via Relay Word bits or to show analog quantities for commissioning or day-to-day operations. You can design these screens with the help of Bay Screen Builder in conjunction with QuickSet. Bay Screen Builder provides an intuitive and powerful interface to design bay screens to meet your application needs.

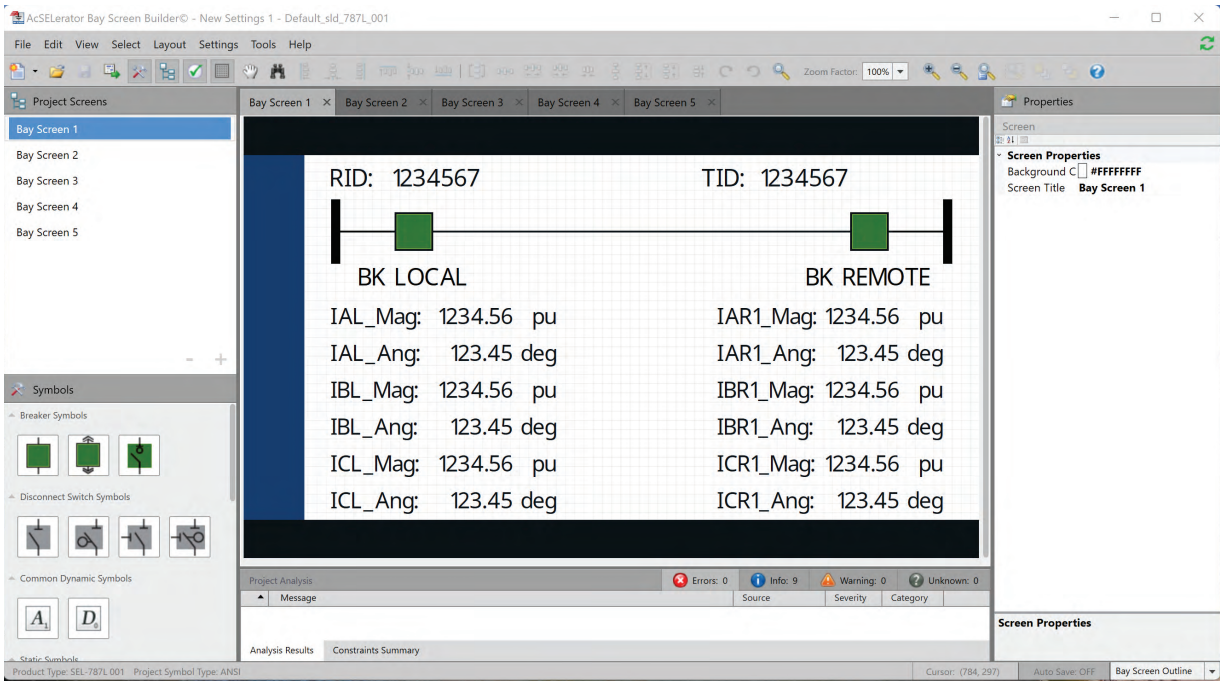



**Figure 17 Bay Screen Builder**

# Metering and Monitoring

The SEL-787L provides the extensive metering capabilities shown in *Table 5*. See *Specifications on page 34* for metering and power measurement accuracies.

**Table 5 SEL-787L Metered Values (Model Dependent)**

| Types of Metering | | | |
|---|---|---|---|
| Instantaneous | Differential | Analog Inputs | Energy |
| Math Variables | Light | Remote Analogs | Thermal |
| Demand and Peak Demand | RMS | Max/Min | HIF |
| Harmonics | Synchrophasors | | |

| Quantities | Description |
|---|---|
| Currents IA, IB, IC | Phase current magnitude and angle, primary A |
| IN | Neutral current magnitude and angle, primary A |
| IG | Residual-ground fault current and angle, primary A (IG = 3I0 = IA + IB + IC) |
| Currents IAV, UBI | Average current magnitude, current unbalance |
| Voltages VA, VB, VC | Phase voltage and angles, primary volts, for wye-connected voltage inputs |
| Voltages VAB, VBC, VCA | Phase-to-phase voltages and angles, primary volts, for delta-connected voltage inputs |
| Voltages VAVE, UBV | Average voltage magnitude, voltage unbalance |
| Voltage VS | Synchronism-check voltage magnitude and angle, primary volts |
| IAL, IBL, ICL, IGL, IQL | Aligned local phase and sequence currents, per unit |
| IAR, IBR, ICR, IGR, IQR | Aligned remote phase and sequence currents, per unit |
| IOPA, IOPB, IOPC, IOPG, IOPQ | Phase and sequence operate currents, per unit |
| IRTA, IRTB, IRTC, IRTG, IRTQ | Phase and sequence restraint currents, per unit |
| Power kVA, kW, kVAR[a] | Calculated apparent, real, and reactive power scales to primary values (single- and three-phase) |
| Energy MWh, MVARh, MVAh | Three-phase positive and negative megawatt-hours, megavar-hours, and megavolt-amp-hours |
| Power Factor PF[a] | Single- and three-phase power factor (leading or lagging) |
| Sequence I1, 3I2, 3I0, V1, 3V2, 3V0 | Positive-, negative-, and zero-sequence currents and voltages |
| Voltage VDC | Station battery voltage |
| Frequency FREQ | Instantaneous system frequency (Hz) |
| Frequency FREQS | Instantaneous frequency (Hz) of synchronism-check voltage channel |
| Light Intensity (%) LS1–LS8 | Arc-flash light inputs in percentage of full scale |
| AI*x*01–AI*x*08 (*x* = 3, 4, or 5) | Analog inputs |
| MV01–MV64 | Math variables |
| COU01–COU32 | SELOGIC counters |
| RA001–RA128 | Remote analogs |
| Thermal Element *x*<br>Current THIEQ*x* pu<br>TCU THTCU*x*%<br>Trip Time THTRIP*x* s<br>Release Time THRLS*x* s | Element *x* pu current level, thermal capacity, time to trip, and time to reset values, where *x* = 1, 2, or 3 |
| RTD1–RTD10 | RTD temperature measurement (degrees C) |

[a] Single-phase power and power factor quantities are not available when delta-connected PTs are used.

## 87L Communications Report

The line current differential protection function is communications-dependent, which makes it necessary to monitor the status of the communications channels during in-service operation to detect abnormal or unexpected conditions and initiate corrective actions. The relay provides a set of channel-monitoring and alarming functions.

The COM 87L report provides:

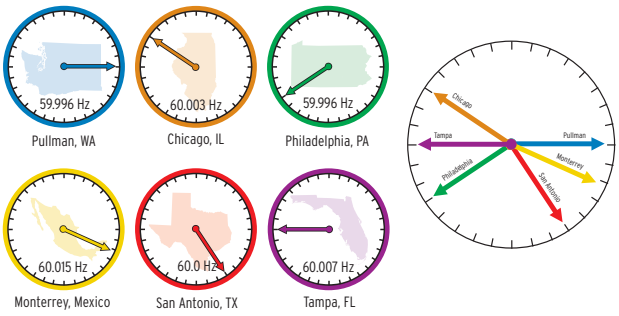
- 87L configuration and overall status (e.g., relay identification, channel problems, test condition, etc.)
- Detailed channel configuration, diagnostics, and health (e.g., remote relay address, data synchronization method and status, specific channel alarms, etc.)
- Long-term channel characteristics (e.g., channel delay histogram, worst-case channel delay, etc.)

## Load Profile

The SEL-787L features a programmable Load Data Profile (LDP) recorder that records as many as 17 metering quantities into nonvolatile memory at fixed time intervals. The LDP recorder saves several days to several weeks of the most recent data depending on the LDP settings (6,500 entries total).

## Synchrophasor Measurements

Combine the SEL-787L with an SEL-IRIG-B time source to measure the system angle in real time with a timing accuracy of ±10 µs. Measure instantaneous voltage and current phase angles in real time to improve system operation with synchrophasor information. Replace state measurement, study validation, or track system stability. Use SEL-5702 Synchrowave® Operations Software or SEL-5703 Synchrowave Monitoring Software to view system angles at multiple locations for precise system analysis and system-state measurement (see *Figure 18*).




*View system angle at multiple locations.*

**Figure 18 View of System Angle at Multiple Locations**

Use IEEE C37.118-2005 protocol to send synchrophasor data to SEL synchrophasor applications. These include the SEL-3378 Synchrophasor Vector Processor (SVP), the SEL-3530 Real-Time Automation Controller (RTAC), and the Synchrowave Operations and Synchrowave Monitoring software suites.

The SEL-3373 Station Phasor Data Concentrator (PDC) and the SEL-5073 SYNCHROWAVE® PDC Software correlate data from multiple SEL-787L relays and concentrate the result into a single output data stream. These products also provide synchrophasor data archiving capability. The SEL-3378 SVP enables control applications based on synchrophasors. Directly measure the oscillation modes of your power system and then act on the result. Use wide-area phase angle slip and acceleration measurements to properly control islanding of distributed generation. With the SVP, you can customize a synchrophasor control application according to the unique requirements of your power system.

The data rate of SEL-787L synchrophasors is selectable with a range of 1–60 messages per second. This flexibility is important for efficient use of communication capacity.

The SEL-787L phasor measurement accuracy meets the highest IEEE C37.118-2005 Level 1 requirement of 1 percent total vector error (TVE). This means you can use any SEL-787L model in an application that otherwise would require purchasing a separate dedicated phasor measurement unit (PMU).

Use the SEL-787L with SEL communications processors, or the SEL-3530 RTAC, to change nonlinear state estimation into linear state estimation. If all the lines include synchrophasor measurements, state estimation is no longer necessary. The system state is directly measured.

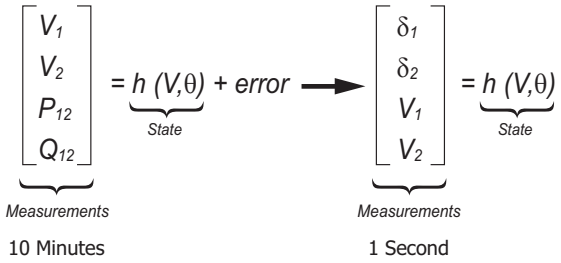



**Figure 19 Synchrophasor Measurements Turn State Estimation Into State Measurement**

# Improve Situational Awareness

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

- Increase system loading while maintaining adequate stability margins.
- Improve operator response to system contingencies such as overload conditions, transmission outages, or generator shutdowns.

- ➤ Advance system knowledge with correlated event reporting and real-time system visualization.
- ➤ Validate planning studies to improve system load balance and station optimization.

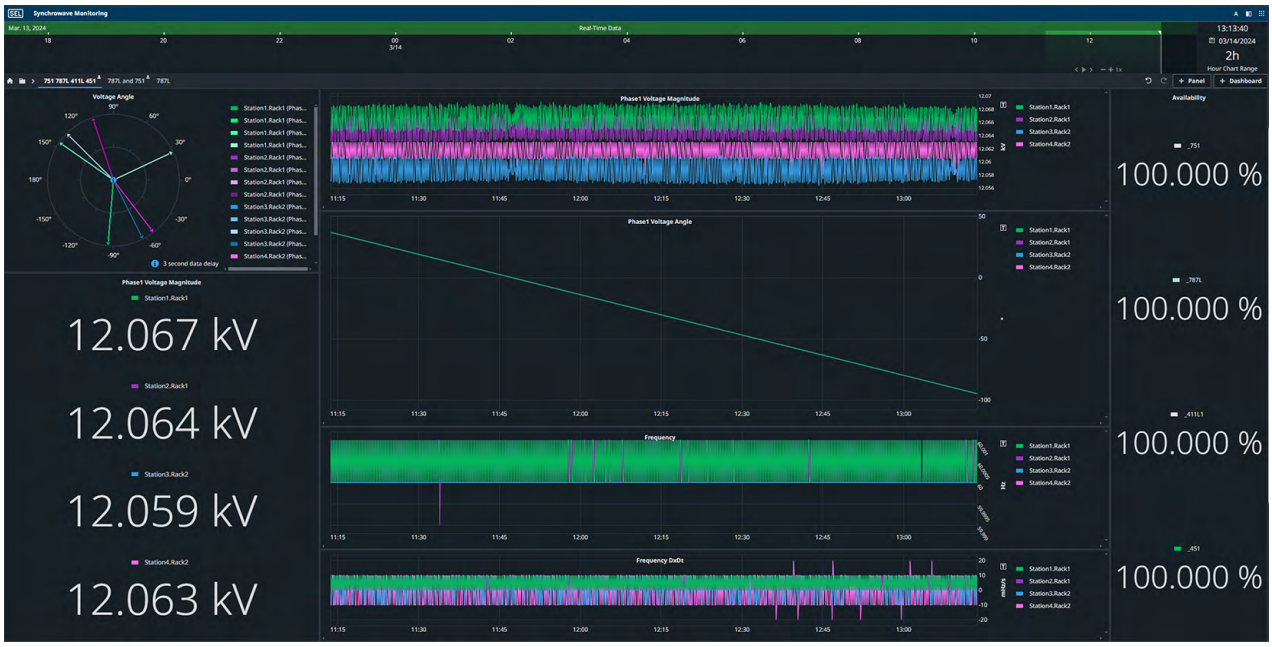



**Figure 20 Visualization of Phasor Measurements**

## Event Reporting and 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 1/32-cycle resolution, filtered or raw analog data, respectively).

The relay stores as many as 5 of the most recent 300-cycle event reports, 8 of the most recent 180-cycle event reports, 20 of the most recent 64-cycle event reports, or 40 of the most recent 15-cycle event reports in nonvolatile memory. The relay always appends the relay settings to the bottom of each event report.

The following analog data formats are available:

- ➤ 1/4-cycle or 1/32-cycle resolution, filtered or unfiltered analog, ASCII or Compressed ASCII reports
- ➤ 1/32-cycle resolution COMTRADE reports

The relay SER feature stores the latest 1,024 entries. Use this feature to gain a broad perspective at a glance. An SER entry helps to monitor input/output change-of-state occurrences and element pickup/dropout.

## Synchronized Measurements

The IRIG-B time-code input synchronizes the SEL-787L internal clock time to within ±1 µs of the time-source input. Convenient sources for this time code are an SEL-2401 Satellite-Synchronized Clock, an SEL communications processor, or an SEL RTAC (via Serial Port 3 on the SEL-787L). For time accuracy specifications for metering, synchrophasors, and events, see *Specifications*.

## Substation Battery Monitor

SEL-787L relay models that include the enhanced voltage option with the monitoring package measure and report the substation battery voltage connected to the VBAT 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-787L alarms to alert operations personnel before the substation battery voltage falls to unacceptable levels. Monitor these thresholds with an SEL 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. This display shows how much the substation battery voltage drops during trip, close, and other control operations.

## Circuit Breaker Contact Wear Monitor

Circuit breakers experience mechanical and electrical wear every time they operate. Intelligent scheduling of breaker maintenance takes into account a 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-787L breaker monitor feature compares this input data to the measured (unfiltered) ac current at the time of a trip and the number of close-to-open operations.

Every time a breaker trips, the relay integrates the measured current information. When the result of this integration exceeds the breaker wear curve threshold (see *Figure 21*), the relay alarms via output contact, communications port, or front-panel display. This information allows timely and economical scheduling of breaker maintenance.

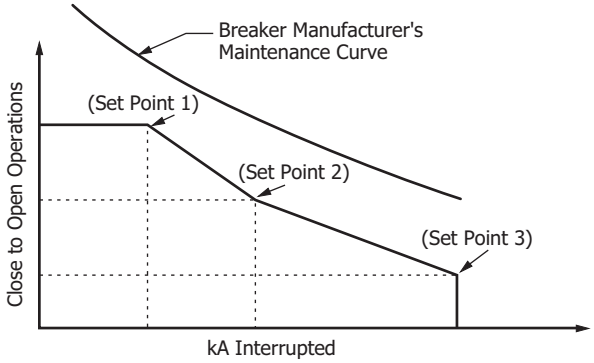



**Figure 21 Breaker Contact Wear Curve and Settings**

The relay also provides analog quantities that calculate the mechanical and electrical operate times along with the mechanical close time for the circuit breaker. The operate and close time Relay Word bits can be accessed via SELOGIC, HMI, Display Point, Fast Meter, Modbus, DNP3, EtherNet/IP, or IEC 61850.

## Fault Locator

The SEL-787L provides a valuable 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 calculate fault location. This feature, which operates without the use of communications channels, special instrument transformers, or pre-fault information, contributes to the efficient dispatch of line crews and fast restoration of service. The fault locator uses three-phase voltage inputs. Wye-connected voltages are necessary for phase and ground fault distance calculations.

Only phase fault distance calculations are available with delta-connected voltages. The fault locator is unavailable in the absence of voltage or single-phase voltage connections.

## IEC 61850 Test Mode

Test Mode allows you to test an in-service relay without operating control output contacts. Test Mode includes five different modes.

**On:** In On mode, the relay operates as normal; it reports IEC 61850 Mode/Behavior status as On and processes all inputs and outputs as normal. If the quality of the subscribed GOOSE messages satisfies the GOOSE processing, the relay processes the received GOOSE messages as valid.

**Test:** In Test mode, the relay processes valid incoming test signals and normal messages and operates physical contact outputs, if the outputs are triggered.

**Blocked:** This mode is similar to On mode, except that the relay does not trip any physical contact outputs.

**Test/Blocked:** This is similar to Test mode, except that the relay does not trip any physical contact outputs.

**Off:** The relay does not process any incoming data or control commands (except commands to change the mode). All protection logic is disabled and all data quality is marked as invalid.

**Simulation:** In this mode, the relay continues to process normal GOOSE or Fixed GOOSE messages until a simulated GOOSE or Fixed GOOSE message is received for a subscription. Once a simulated GOOSE or Fixed GOOSE message is received, only simulated GOOSE or Fixed GOOSE messages are processed for that subscription. The simulation mode only terminates when LPHD-SIM is returned to FALSE. When the relay is not in simulation mode, only normal GOOSE or Fixed GOOSE messages are processed for all subscriptions.

# Touchscreen Display

You can order the SEL-787L Line Current Differential Relay with an optional touchscreen display (5-inch, color, 800 x 480 pixels). The touchscreen display makes relay data metering, monitoring, and control quick and efficient. The touchscreen display option in the SEL-787L features a straightforward, application-driven control structure and includes intuitive and graphical screen designs.

The touchscreen display allows you to:

- View and control bay screens
- Access metering and monitoring data
- Inspect targets
- View event history, summary data, and SER information
- View relay status and configuration
- Control relay operations
- View and edit settings
- Enable the rotating display
- Program control pushbuttons to jump to a specific screen

You can navigate the touchscreen by tapping the folders and applications. The folders and applications of the **Home** screen are shown in *Figure 22*. Folders and applications are labeled according to functionality. Additional folder and application screens for the SEL-787L touchscreen display option can be seen in *Figure 23* through *Figure 32*.

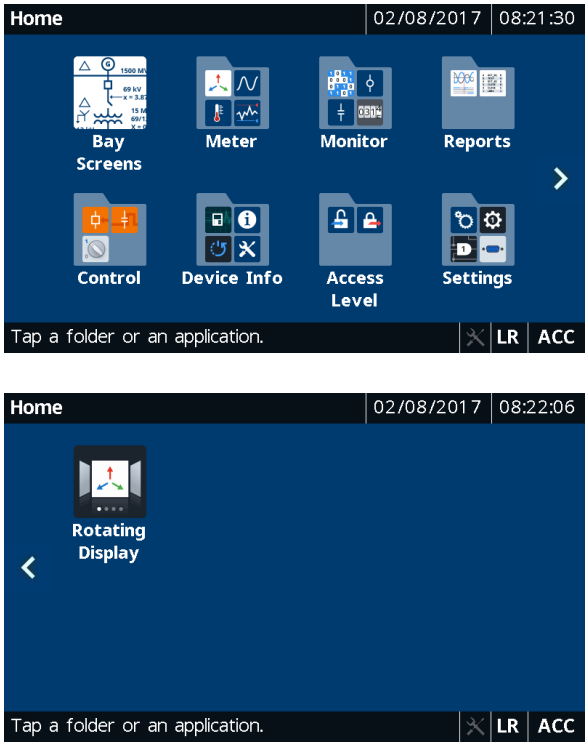



**Figure 22 Home (Default FPHOME Screen)**

## Bay Screens Application

The SEL-787L with the touchscreen display option provides you with the ability to design bay configuration screens to meet your system needs. The bay configuration can be displayed as an SLD on the touchscreen. You can create as many as five bay screens with one controllable breaker, one monitor-only breaker, eight controllable two-position disconnects, and two controllable three-position disconnects. ANSI and IEC symbols, along with analog and digital labels, are available for you to create detailed SLDs of the bay to indicate the status of the breaker and disconnects, bus voltages, and power flow through the breaker. *Figure 23* shows the default SLD for the touchscreen display option.

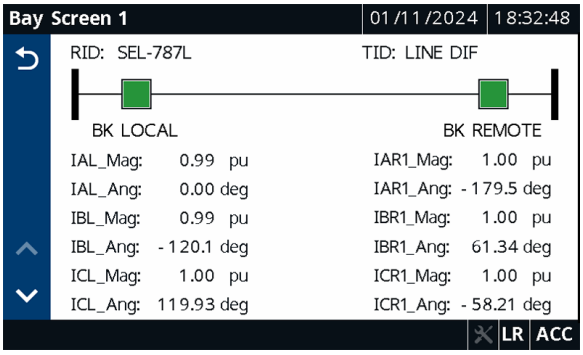



**Figure 23 Default Bay Screen**

# Meter Folder Applications

The applications in the Meter folder are part-number dependent. Only those metering applications specific to your part number appear in the Meter folder. Tapping an application in the Meter folder shows you the report for that particular application. Tap the **Phasor** application to view the current and voltage phasors (see *Figure 24*).

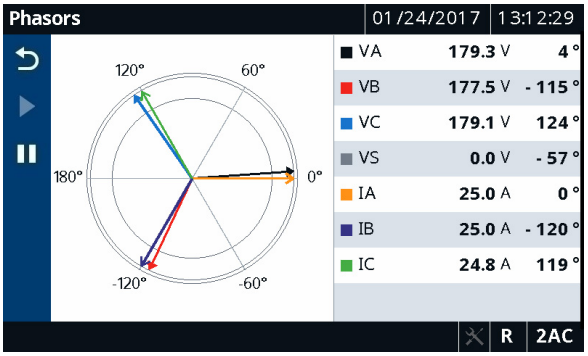



**Figure 24 Meter Phasors**

Tap the **Differential** application to view the local and remote currents (see *Figure 25*).

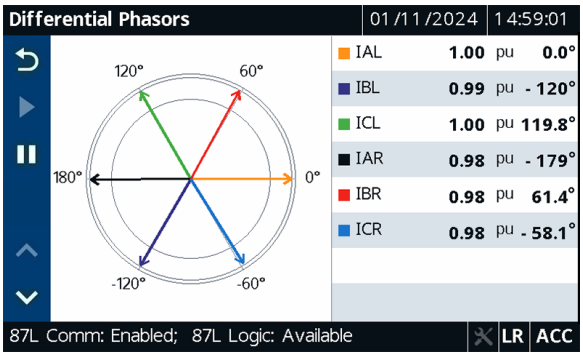



**Figure 25 Differential Phasors**

Tap the **Energy** application to view the energy metering quantities (see *Figure 26*). A reset feature is provided for the Energy, Max/Min, Demand, and Peak Demand applications. Tap the **Reset** button (see *Figure 26*) to navigate to the reset confirmation screen. Once you confirm the reset, the data are reset to zero.

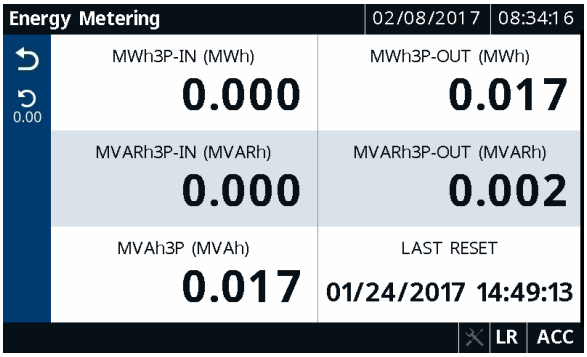



**Figure 26 Meter Energy**

# Reports Folder Applications

Tapping the **Reports** folder navigates you to the screen where you can access the Events, HIF Events (if available), and SER applications. Use these applications to view events and SERs. To view the event summary (see *Figure 27*) of a particular event record, tap the event record on the Event History screen (for Events and HIF Events). You can also trigger an event report from the Event History screen.

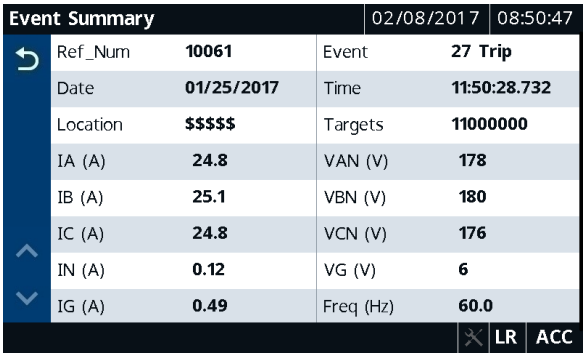



**Figure 27 Event Summary**

Tap the **Sequential Events Recorder** application to view a history of the SER reports (see *Figure 28*).

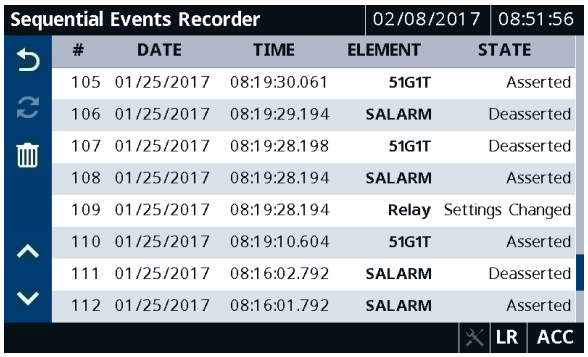



**Figure 28 Sequential Events Recorder**

Tapping the **Trash** button, shown in *Figure 28*, on the Event History, HIF Event History, and Sequential Events Recorder screens and confirming the delete action removes the records from the relay.

# Control Folder Applications

Tapping the **Control** folder navigates you to the screen where you can access the Breaker Control, Output Pulsing, and Local Bits applications. Use the applications to perform breaker control operations, pulse output contacts (*Figure 29*), and control the local bits (*Figure 30*).

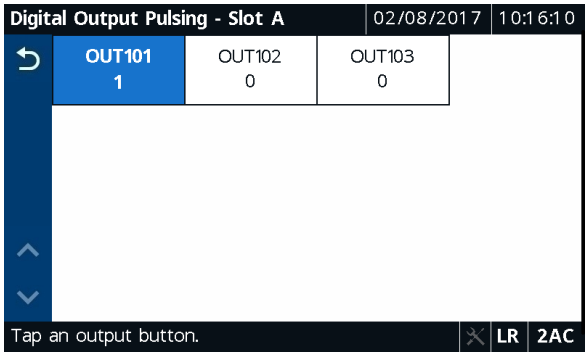



**Figure 29 Digital Output Pulsing-Slot A**

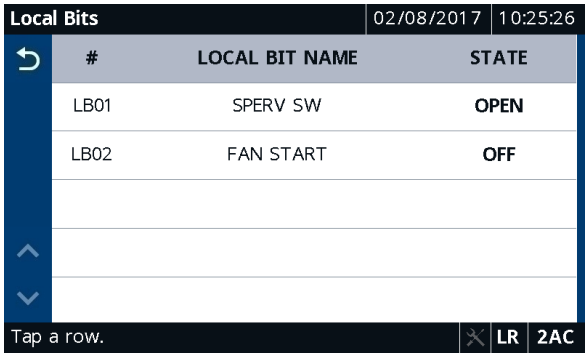



**Figure 30 Local Bits**

# Device Info Folder Applications

Tapping the **Device Info** folder navigates you to the screen where you can access specific device information applications (Status, Configuration, Arc-Flash Diagnostics, and Trip & Diag. Messages) and the Reboot application. Tap the **Status** application to view the relay status, firmware version, part number, etc. (see *Figure 31*).

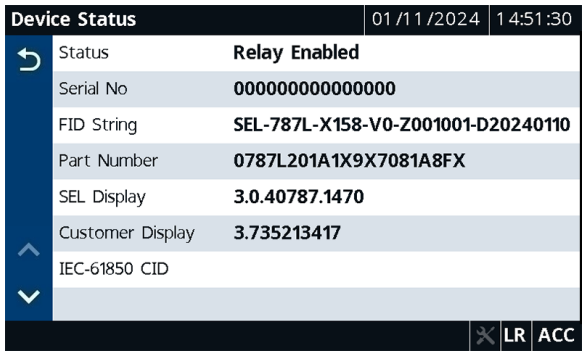



**Figure 31 Device Status**

To view the trip and diagnostic messages, tap the **Trip & Diag. Messages** application (see *Figure 32*). When a diagnostic failure, trip, or warning occurs, the relay displays the diagnostic message on the screen until it is either overridden by the restart of the rotating display or the inactivity timer expires.

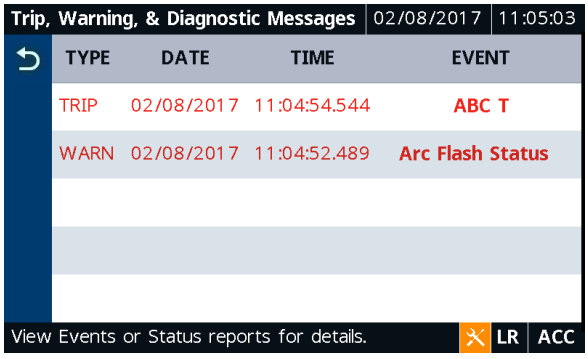



**Figure 32 Trip and Diagnostics**

# Automation

## Flexible Control Logic and Integration Features

The SEL-787L can be ordered with as many as four independently operated serial ports:

- EIA-232 port on the front panel
- EIA-232 or EIA-485 port on the Slot B card in the rear
- EIA-232 or EIA-485 port on the optional communications card in Slot C in the rear

Optionally, the relay supports single or dual, copper or fiber-optic Ethernet ports. The relay does not require special communications software. You can use any system that emulates a standard terminal system for engineering access to the relay. Establish local or remote communication by connecting computers, modems, protocol converters, printers, an SEL RTAC, SEL communications processor, SEL computing platform, SCADA serial port, or RTUs. Refer to *Table 6* for a list of communications protocols available in the SEL-787L.

**Table 6 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. |
| SEL Fast Meter and SEL Fast Operate | Binary protocol for machine-to-machine communications.<br>Quickly updates SEL communications processors, RTUs, and other substation devices with metering information, relay elements, 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. |
| SEL Fast SER | Provides SER events to an automated data collection system. |
| DNP3 | Serial or Ethernet-based DNP3 protocols.<br>Provides default and mappable DNP3 objects that include access to metering data, protection elements, Relay Word bits, contact I/O, targets, SER, relay summary event reports, and setting group selection. |
| Modbus | Serial- or Ethernet-based Modbus protocol with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and setting groups. |
| IEC 61850 Edition 2.1 | Ethernet-based international standard for interoperability between intelligent devices in a substation. Operates remote bits and I/O. Monitors Relay Word bits and analog quantities. |
| Synchrophasors | IEEE C37.118-2005-compliant synchrophasors for system state, response, and control capabilities. |
| SNTP | Ethernet-based protocol that provides time synchronization of the relay. |
| IEEE 1588-2008 PTP | Ethernet-based protocol that provides time synchronization of the relay. Hardware- or firmware-based PTP is available based on the network operating mode, PTP profile, PTP transport mechanism, PTP path delay mechanism settings, and the firmware version. |
| PRP | Provides seamless recovery from any single Ethernet network failure in a dual redundant Ethernet network in accordance with IEC 62439-3. |
| RSTP | Provides faster recovery in response to changes and failures in switched mode, dual redundant Ethernet networks in accordance with IEEE 802.1Q-2014. |
| HSR | Provides faster recovery in response to changes and failures in switched mode, dual redundant Ethernet networks in accordance with IEC 61784. |
| IEC 60870-5-103 | Serial communications protocol—international standard for interoperability between intelligent devices in a substation. |
| EtherNet/IP | Ethernet-based protocol that provides access to metering data, protection elements, targets, and contact I/O. |

Apply an SEL communications processor as the hub of a star network with a point-to-point fiber or copper connection between the hub and the SEL-787L (see *Figure 33*).

The communications processor supports external communication links, including the public switched telephone network, for engineering access to dial-out alerts and private line connections of the SCADA system.

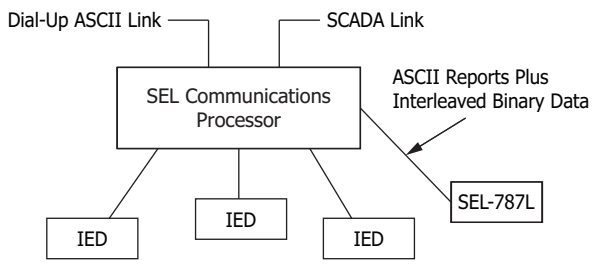



**Figure 33 Example Communications System**

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.

SEL-787L control logic improves integration in the following ways.

- **Replaces traditional panel control switches.** Eliminate traditional panel control switches with 32 local bits. Set, clear, or pulse local bits with the front-panel pushbuttons and display. Program the local bits into your control scheme with SELOGIC control equations. Use the local bits to perform functions such as a trip test or a breaker trip/close.
- **Eliminates RTU-to-relay wiring with 32 remote bits.** Set, clear, or pulse remote bits using serial port commands. Program the remote bits into your control scheme with SELOGIC control equations. Use remote bits for SCADA-type control operations such as trip, close, and settings group selection.
- **Replaces traditional latching relays.** Replace as many as 64 traditional latching relays for such functions as remote control enable with latch bits. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the non-volatile latch bits using optoisolated inputs, remote bits, local bits, or any programmable logic condition. The latch bits retain their state when the relay loses power.
- **Replaces traditional indicating panel lights.** Replace traditional indicating panel lights with 32 programmable displays. Define custom messages (e.g., `Breaker Open`, `Breaker Closed`) to report power system or relay conditions on the front-panel display. Use advanced SELOGIC control equations to control which messages the relay displays.
- **Eliminates external timers.** Eliminate external timers for custom protection or control schemes with 64 general purpose SELOGIC control equation timers. Each timer has independent time-delay pickup and dropout settings. Program each timer input with the element you want (e.g., time qualify a current element). Assign the timer output to trip logic, transfer trip communications, or other control scheme logic.
- **Eliminates setting changes.** Selectable setting groups make the SEL-787L ideal for applications requiring frequent setting changes and for adapting the protection to changing system conditions. The relay stores four 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.

# Ethernet Network Architectures

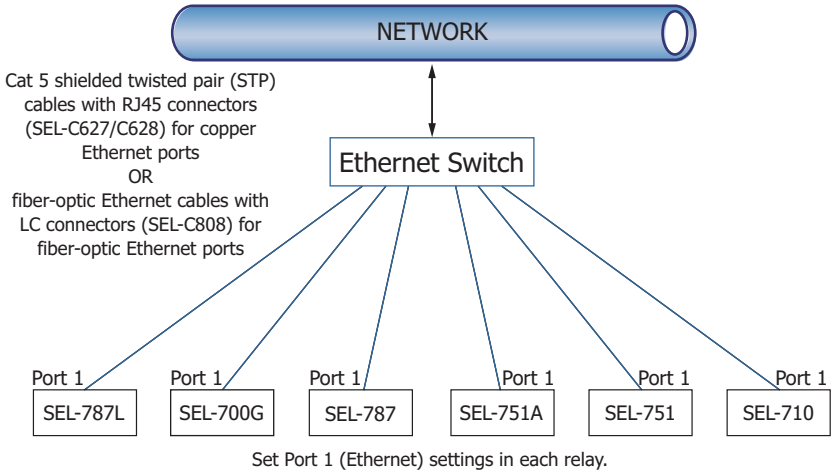



**Figure 34 Simple Ethernet Network Configuration**

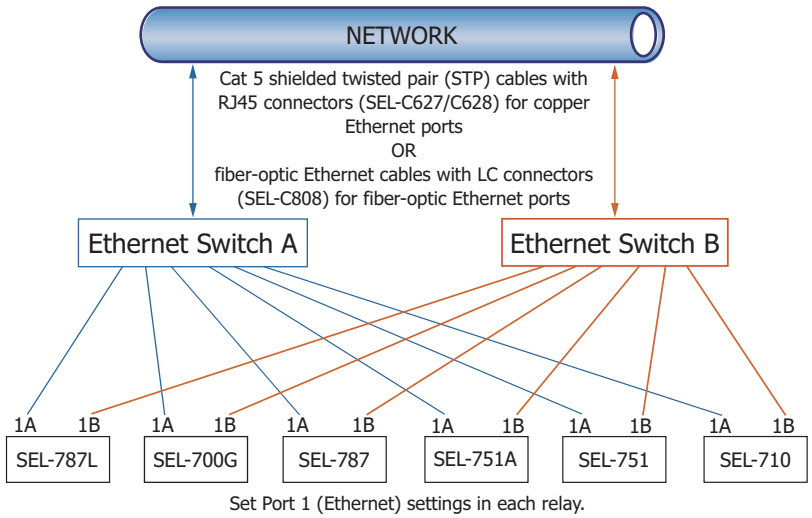



**Figure 35 Ethernet Network Configuration With Dual Redundant Connections (Failover Mode)**

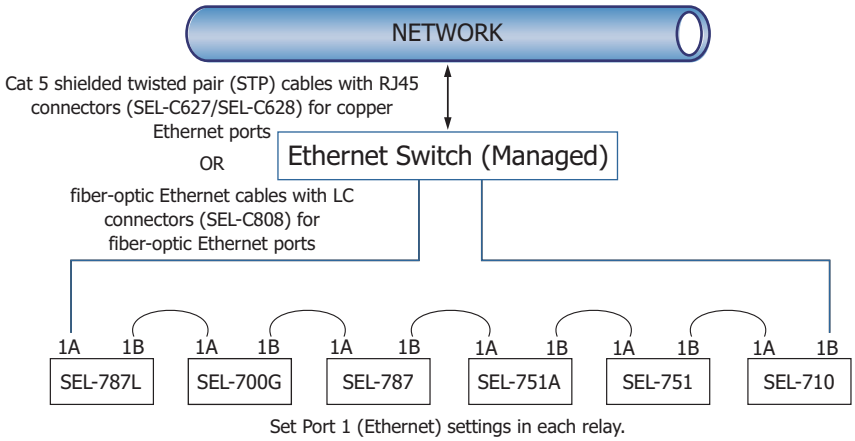



**Figure 36 Ethernet Network Configuration With Ring Structure (Switched Mode)**

# Additional Features

## MIRRORED BITS Relay-to-Relay Communications

The SEL-patented MIRRORED BITS communications technology provides bidirectional relay-to-relay digital communications. MIRRORED BITS communications can operate independently on as many as two EIA-232 rear serial ports and one fiber-optic rear serial port on a single SEL-787L.

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 37*). Use these MIRRORED BITS to transmit/receive information between upstream relays and a 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.

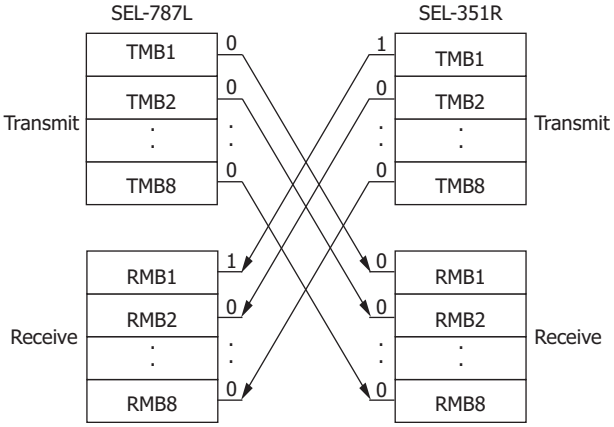



**Figure 37 MIRRORED BITS Transmit and Receive Bits**

## Status and Trip Target LEDs

The SEL-787L includes 24 status and trip target tricolor LEDs on the front panel. When shipped from the factory, all LEDs are predefined and fixed in settings. You can reprogram these LEDs for specific applications. This combination of targets is explained and shown in *Figure 42*. Some front-panel relabeling of LEDs may be needed if you reprogram them for unique or specific applications—see *Configurable Labels*.

## Event Messenger Points

The SEL-787L, when used with the SEL-3010, allows for ASCII-to-voice translation of as many as 32 user-defined messages, along with analog data that has been measured or calculated by the relay. This combination allows you to receive voice message alerts (on any phone) regarding Relay Word bit transitions in the relay.

Verbal notification of breaker openings, fuse failures, RTD alarms, etc., can be sent directly to your cell phone through the use of your SEL-787L and an SEL-3010 (must be connected to an analog telephone line). In addition, messages can include an analog value such as current, voltage, or power measurements made by the SEL-787L.

## Configurable Labels

Use the configurable labels to relabel the operator controls and LEDs (shown in *Figure 42*) to suit your installation requirements. This feature includes preprinted labels (with factory-default text), blank label media, and a Microsoft Word template. The Microsoft Word template is available at selinc.com. This allows you to create quick, professional-looking labels for the SEL-787L. 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.

## Web Server

The web server allows you to communicate with the relay via the Ethernet port without the need for additional communication software (web browser required). The web server allows you to access metering and monitoring data and to perform firmware upgrades.

## Firmware Download Via Ethernet Ports

Relay firmware can be securely downloaded to your relay via the Ethernet port. The firmware is digitally signed to prevent malicious modification. Additionally, the Ethernet firmware download allows you to access and update all your network relays simultaneously.

# Relay Dimensions

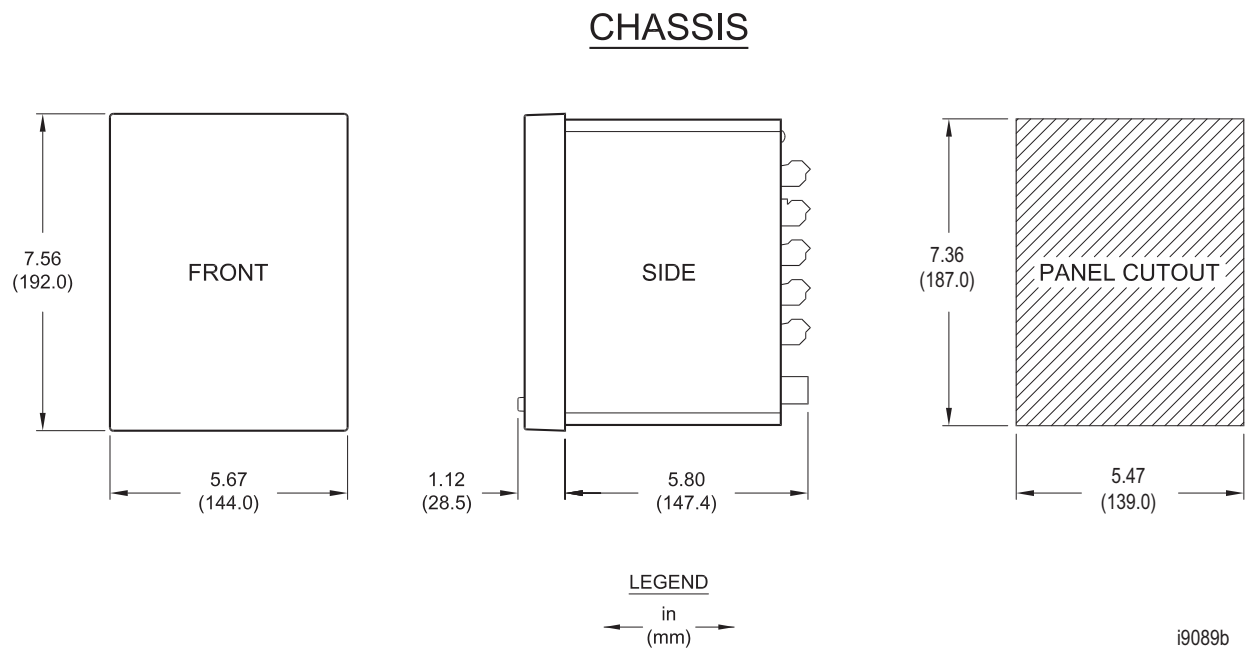



**Figure 38 SEL-787L Dimensions for Rack- and Panel-Mount Models**

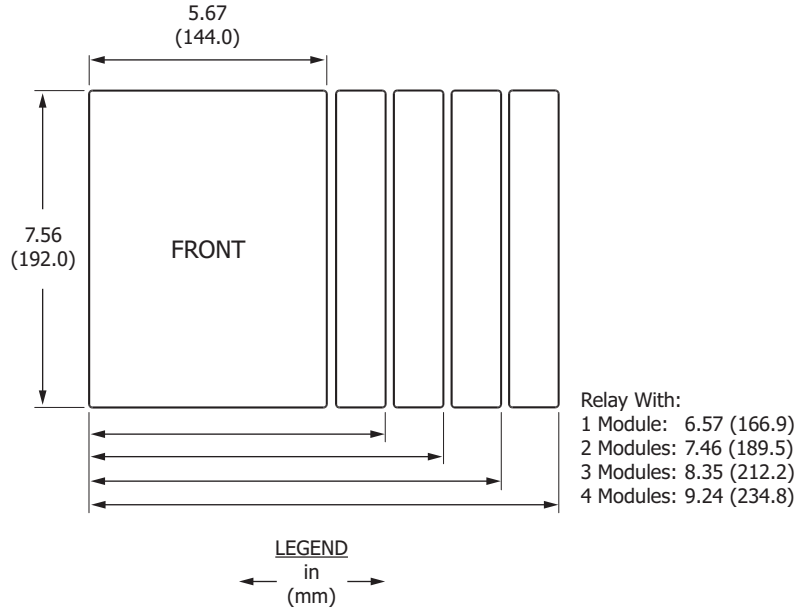



**Figure 39 SEL-787L With I/O Module(s) Dimensions**

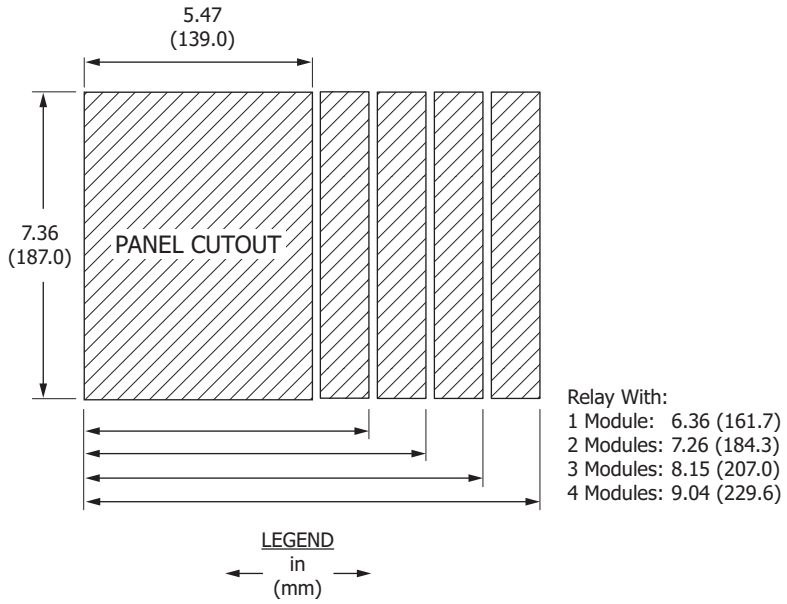



**Figure 40 SEL-787L With I/O Modules Cutout Dimensions**

# Hardware Overview

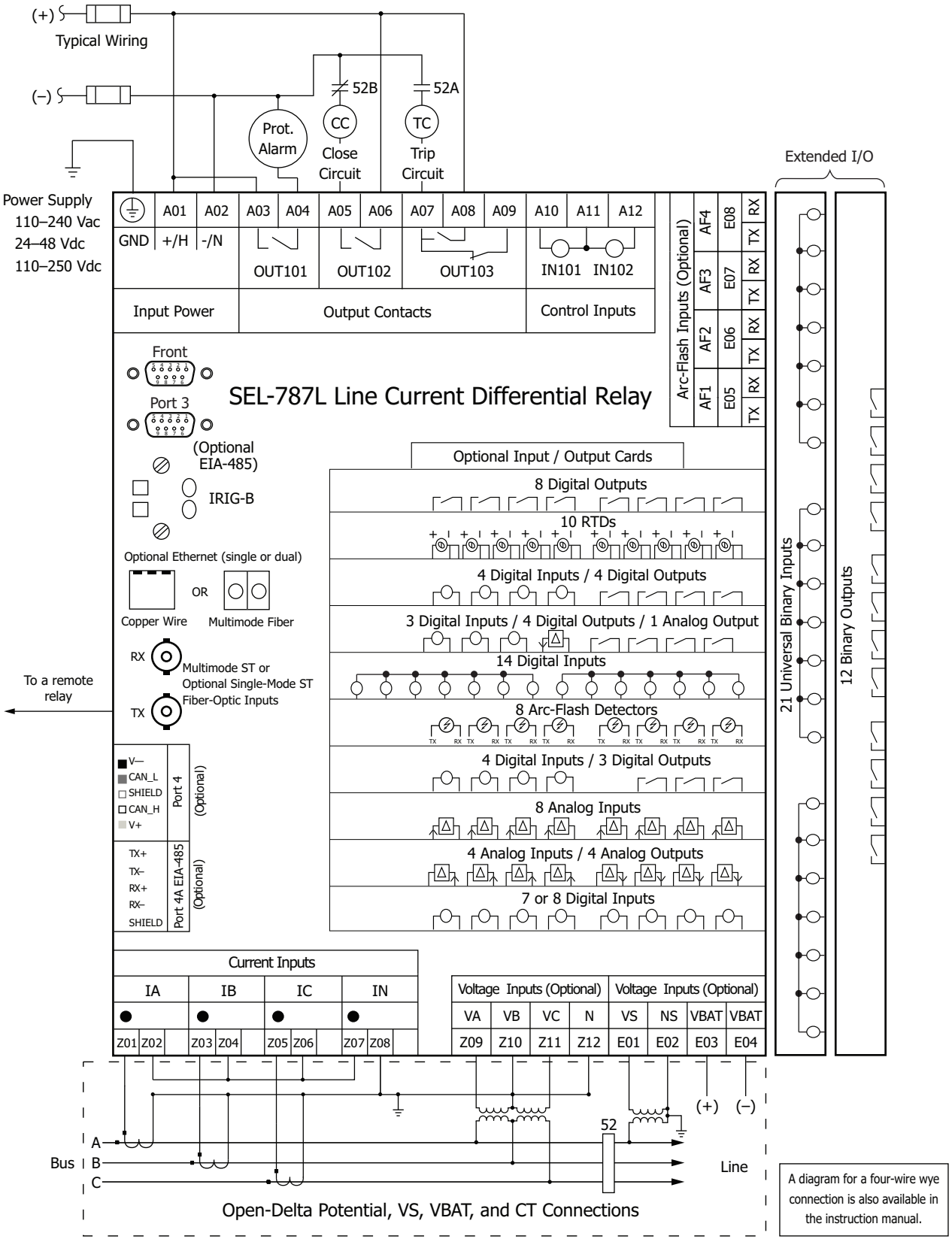



**Figure 41 SEL-787L Hardware Overview**

# Relay Panel Diagrams

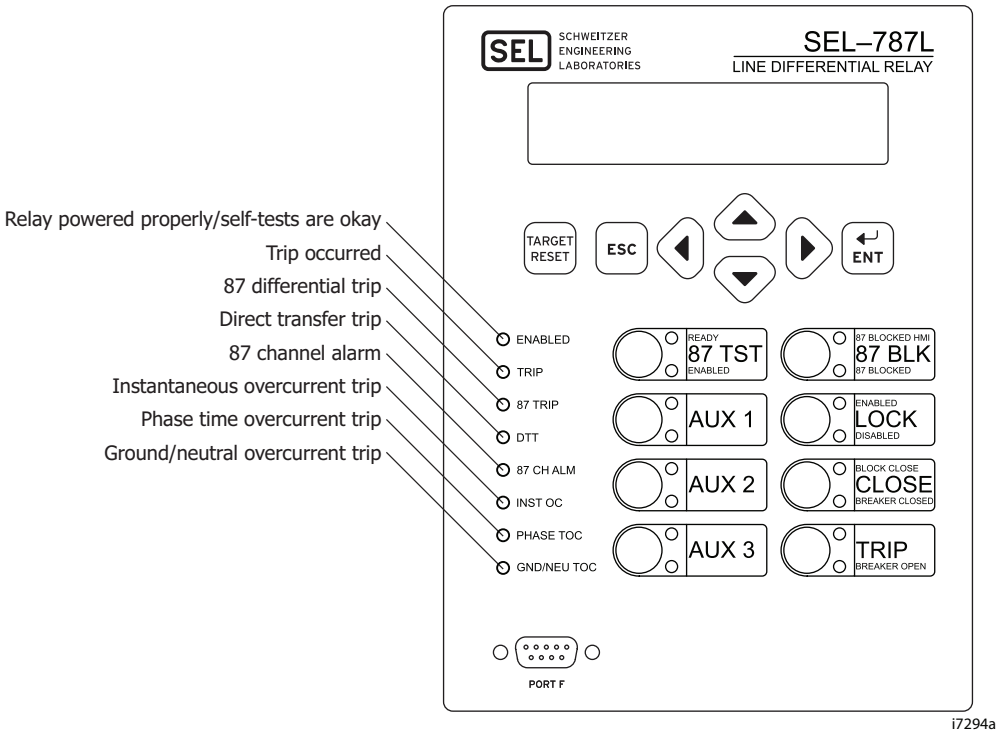
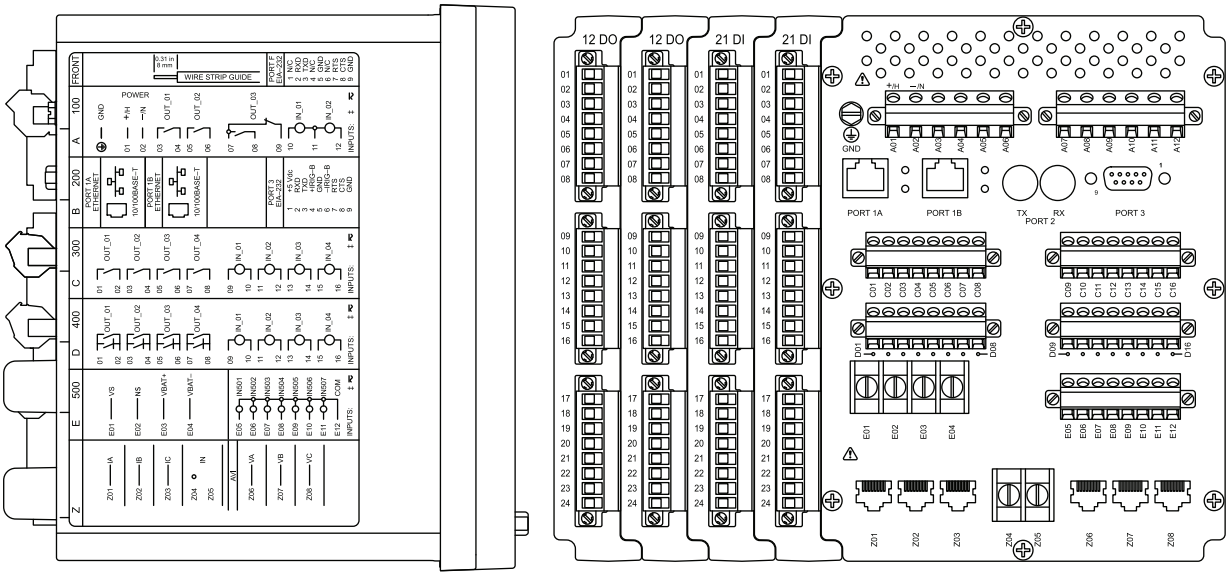
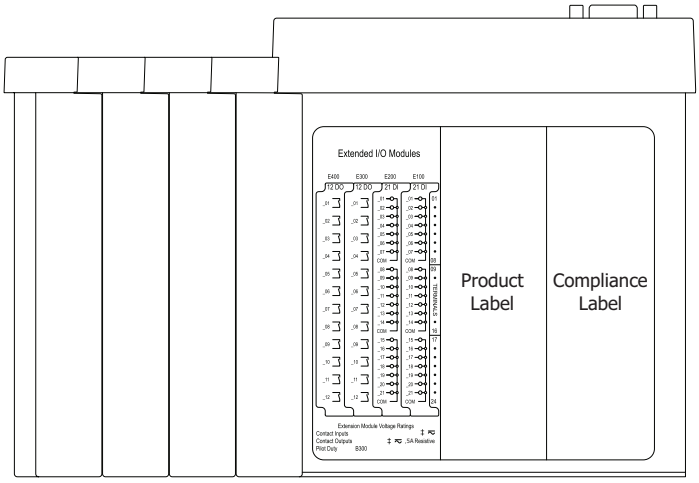



**Figure 42 Front Panel With Default Configurable Labels**




(A) Side-Panel Input and Output Designations

(B) Rear-Panel Layout




(C) Top-Panel Input and Output Designations

**Figure 43 Dual 10/100 Base-T Ethernet, EIA-232 Rear Port, 4 DI/4 DO Card, Fast Hybrid 4 DI/4 DO Card, LEA Vsync/Vbat (300 Vdc) 7 DI Card, and 4 ACI/3 AVI LEA Card With 4 Extended I/O Modules (Two With 21 Inputs and Two With 12 Outputs) (Relay MOT 0787L091A1ACALA7LAF30)**

# Specifications

## Compliance

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B, Class A

**Note**: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

CE Mark in accordance with the requirements of the European Union

RCM Mark in accordance with the requirements of Australia

UKCA Mark in accordance with the requirements of United Kingdom

### Normal Locations

UL Listed to U.S. and Canadian safety standards (File E212775, NRGU, NRGU7)

**Note**: UL has not yet developed requirements for products intended to detect and mitigate an arc flash; consequently, UL has not evaluated the performance of this feature. While UL is developing these requirements, it will place no restriction on the use of this product for arc-flash detection and mitigation. For test results performed by an independent laboratory and other information on the performance and verification of this feature, contact SEL customer service.

### Hazardous Locations

UL Certified for Hazardous Locations to U.S. and Canadian standards CL 1, DIV 2; GP A, B, C, D; T3C, maximum surrounding air temperature of 40°C (File E470448)

EU

SEL 19 ATEX 0001X
II 3 G
Ex ec nC IIC T3 Gc

EN 60079-0:2012 + A11:2013, EN 60079-7:2015, EN 60079-15:2010, EN 60079-11:2012

Ambient air temperature shall not exceed –20°C ≤ Ta ≤ +40°C

**Note**: Where so marked, ATEX and UL Hazardous Location Certification tests are applicable to rated supply specifications only and do not apply to the absolute operating ranges, continuous thermal, or short circuit duration specifications.

## General

### AC Current Input

$I_{NOM}$ = 200 mA, 1 A, or 5 A secondary, depending on the model.

Measurement Category: II

Phase and Neutral Currents

**$I_{NOM}$ = 5 A**

| | |
|---|---|
| Continuous Rating: | 3 • $I_{NOM}$ @ 85°C<br>4 • $I_{NOM}$ @ 55°C |
| A/D Measurement Limit: | 217 A peak (154 Arms symmetrical) |
| Saturation Current Rating: | Linear to 96 A symmetrical |
| 1-Second Thermal: | 500 A |
| Burden (per phase): | <0.1 VA @ 5 A |

**$I_{NOM}$ = 1 A**

| | |
|---|---|
| Continuous Rating: | 3 • $I_{NOM}$ @ 85°C<br>4 • $I_{NOM}$ @ 55°C |
| A/D Measurement Limit: | 43 A peak (31 Arms symmetrical) |
| Saturation Current Rating: | Linear to 19.2 A symmetrical |
| 1-Second Thermal: | 100 A |
| Burden (per phase): | <0.01 VA @ 1 A |

**$I_{NOM}$ = 200 mA**

| | |
|---|---|
| Continuous Rating: | 4 A |
| A/D Measurement Limit: | 8.4 A peak (6 Arms symmetrical) |
| Saturation Current Rating: | Linear to 4 A symmetrical |
| 1-Second Thermal: | 500 A |
| Burden (per phase): | <0.01 VA @ 0.2 A |

### Rogowski Coil-Based AC Current Inputs—Phase Currents

| | |
|---|---|
| Continuous Rating: | 30 Vrms |
| Nominal Input Voltage: | 65 mV to 4.16 Vrms |
| Number of Gain Ranges: | 6 |
| Full Scale Voltage: | 4, 8, 16, 32, 64, 128 Vrms @ 60 Hz |
| A/D Measurement Limit: | ±185 $V_{peak}$ @ 60 Hz |
| 10-Second Thermal: | 200 Vac |
| Input Impedance: | 2 MΩ‖50 pF |
| Standard Compliance: | IEC 61869-6<br>IEC 61869-13 |

### Low-Power Current Transformer (LPCT) Inputs—Phase Currents

| | |
|---|---|
| Continuous Rating: | 4 Vrms |
| Nominal Input Voltage: | 16 mV to 260 mVrms |
| Number of Gain Ranges: | 4 |
| Full Scale Voltage: | 1, 2, 4, 8 Vrms |
| A/D Measurement Limit: | ±11.3 $V_{peak}$ |
| 10-Second Thermal: | 200 Vac |
| Input Impedance: | 2 MΩ‖50 pF |
| Standard Compliance: | IEC 61869-6<br>IEC 61869-13 |

### AC Voltage Input

| | |
|---|---|
| $V_{NOM}$ (L-L) Setting Range: | 20–250 V (if DELTA_Y := DELTA)<br>20–480 V (if DELTA_Y := WYE) |

300 Vac Voltage Inputs

| | |
|---|---|
| Rated Continuous Voltage: | 300 Vac (phase-to-neutral) |
| 10-Second Thermal: | 600 Vac (phase-to-neutral) |
| A/D Measurement Limit: | 315 Vrms |

| | Burden | Input Impedance (Per Phase) | Input Impedance (Phase-to-Phase) |
|---|---|---|---|
| Vphase | 0.008 VA @ 120 Vac | 2 MΩ | 4 MΩ |
| Vbat/Vs | 0.003 VA @ 120 Vac | 5 MΩ | |

Low-Energy Analog (LEA) Voltage Inputs (Euro Connector Input)

| | |
|---|---|
| Rated Continuous Voltage: | 8 Vac (phase-to-neutral) |
| Nominal LEA Voltage: | 0.5–6.8 Vrms (phase-to-neutral) |
| A/D Measurement Limit: | ±12 $V_{peak}$ |
| 10-Second Thermal: | 300 Vac (phase-to-neutral) |
| Input Impedance: | 2 MΩ single-ended (phase-to-neutral)<br>4 MΩ differential (phase-to-phase) |

### Low-Energy Analog Voltage Sensor Inputs (RJ45 Input)

| | |
|---|---|
| Continuous Rating: | 8 Vrms |
| Nominal Input Voltage: | 0.5–6.8 Vrms |
| Full-Scale Voltage: | 8 Vrms |
| A/D Measurement Limit: | ±12 $V_{peak}$ |
| 10-Second Thermal: | 200 Vac |

Input Impedance: 2 MΩ||50 pF

Standard Compliance: IEC 61869-6
IEC 61869-13

## Power Supply

Relay Start-Up Time: Approximately 5–10 seconds (after power is applied until the **ENABLED** LED turns on)

### High-Voltage Supply

Rated Supply Voltage: 110–240 Vac, 50/60 Hz
110–250 Vdc

Input Voltage Range (Design Range): 85–264 Vac
85–300 Vdc

Power Consumption: <75 VA (ac)
<30 W (dc)

Interruptions: 50 ms @ 125 Vac/Vdc
100 ms @ 250 Vac/Vdc

### Low-Voltage Supply

Rated Supply Voltage: 24–48 Vdc

Input Voltage Range (Design Range): 19.2–60.0 Vdc

Power Consumption: <30 W (dc)

Interruptions: 10 ms @ 24 Vdc (with no more than 67 outputs energized simultaneously)
50 ms @ 48 Vdc

## Fuse Ratings

### Low-Voltage Power Supply Fuse

Rating: 3.15 A

Maximum Rated Voltage: 300 Vdc, 250 Vac

Breaking Capacity: 1500 A at 250 Vac

Type: Time-lag T

### High-Voltage Power Supply Fuse

Rating: 3.15 A

Maximum Rated Voltage: 300 Vdc, 250 Vac

Breaking Capacity: 1500 A at 250 Vac

Type: Time-lag T

## Output Contacts

### General

The relay supports Form A, B, and C outputs.

Dielectric Test Voltage: 2500 Vac

Impulse Withstand Voltage ($U_{IMP}$): 5000 V

Mechanical Durability: 100,000 no-load operations

### Standard Contacts

Pickup/Dropout Time: ≤8 ms (coil energization to contact closure)

**DC Output Ratings**

Rated Operational Voltage: 250 Vdc

Rated Voltage Range: 19.2–275 Vdc

Rated Insulation Voltage: 300 Vdc

Make: 30 A @ 250 Vdc per IEEE C37.90

Continuous Carry: Refer to the graph in *Operating Temperature*

1-Second Thermal: 50 A

Contact Protection: 360 Vdc, 115 J MOV protection across open contacts

Breaking Capacity (10,000 Operations) per IEC 60255-0-20:1974:

| | | |
|---|---|---|
| 24 Vdc | 0.75 A | L/R = 40 ms |
| 48 Vdc | 0.50 A | L/R = 40 ms |
| 125 Vdc | 0.30 A | L/R = 40 ms |
| 250 Vdc | 0.20 A | L/R = 40 ms |

Cyclic (2.5 Cycles/Second) per IEC 60255-0-20:1974:

| | | |
|---|---|---|
| 24 Vdc | 0.75 A | L/R = 40 ms |
| 48 Vdc | 0.50 A | L/R = 40 ms |
| 125 Vdc | 0.30 A | L/R = 40 ms |
| 250 Vdc | 0.20 A | L/R = 40 ms |

**AC Output Ratings**

Maximum Operational Voltage ($U_e$) Rating: 240 Vac

Insulation Voltage ($U_i$) Rating (excluding EN 61010-1): 300 Vac

1-Second Thermal: 50 A

Contact Rating Designation: B300

| B300 (5 A Thermal Current, 300 Vac Max) | | | |
|---|---|---|---|
| | Maximum Current | | Max VA |
| Voltage | 120 Vac | 240 Vac | — |
| Make | 30 A | 15 A | 3600 |
| Break | 3 A | 1.5 A | 360 |
| PF < 0.35, 50–60 Hz | | | |

Utilization Category: AC-15

| AC-15 | | |
|---|---|---|
| Operational Voltage (Ue) | 120 Vac | 240 Vac |
| Operational Current (Ie) | 3 A | 1.5 A |
| Make Current | 30 A | 15 A |
| Break Current | 3 A | 1.5 A |
| Electromagnetic loads > 72 VA, PF < 0.3, 50–60 Hz | | |

Voltage Protection Across Open Contacts: 270 Vac, 40 J

### Fast Hybrid (High-Speed, High-Current Interrupting)

**DC Output Ratings**

Rated Operational Voltage: 250 Vdc

Rated Voltage Range: 19.2–275 Vdc

Rated Insulation Voltage: 300 Vdc

Make: 30 A @ 250 Vdc per IEEE C37.90

Carry: Refer to the graph in *Operating Temperature*

1-Second Thermal: 50 A

Open State Leakage Current: <500 µA

MOV Protection (maximum voltage): 250 Vac/330 Vdc

Pickup Time: <50 µs, resistive load

Dropout Time: <8 ms, resistive load

Breaking Capacity (10,000 Operations):

| | | |
|---|---|---|
| 48 Vdc | 10.0 A | L/R = 40 ms |
| 125 Vdc | 10.0 A | L/R = 40 ms |
| 250 Vdc | 10.0 A | L/R = 20 ms |

Cyclic Capacity (4 Cycles in 1 Second, Followed by 2 Minutes Idle for Thermal Dissipation):

| | | |
|---|---|---|
| 48 Vdc | 10.0 A | L/R = 40 ms |
| 125 Vdc | 10.0 A | L/R = 40 ms |
| 250 Vdc | 10.0 A | L/R = 20 ms |

**AC Output Ratings**

See ***AC Output Ratings*** for *Standard Contacts*.

## Digital Inputs

### Optoisolated Contact Inputs (SELECT I/O)

When Used With DC/AC Control Signals:

Pickup/Dropout Time ($V_{DC}$): Depends on the input debounce settings

Pickup/Dropout Time ($V_{AC}$): 2 ms pickup
16 ms dropout

| Nominal Voltage AC/DC | Deassertion Range | | Assertion Range | |
|---|---|---|---|---|
| | $V_{DC}$ (V) | $V_{AC}$ (V) | $V_{DC}$ (V) | $V_{AC}$ (V) |
| 24 V | 0.0–5.0 | 0.0–5.0 | 19.2–30.0 | 18.0–30.0 |
| 48 V | 0.0–28.8 | 0.0–20.3 | 38.4–60.0 | 32.8–60.0 |
| 110 V | 0.0–66.0 | 0.0–46.6 | 88.0–137.5 | 75.1–137.5 |
| 125 V | 0.0–75.0 | 0.0–53.0 | 100.0–156.2 | 85.0–156.2 |
| 220 V | 0.0–132.0 | 0.0–93.3 | 176.0–275.0 | 150.2–275.0 |
| 250 V | 0.0–150.0 | 0.0–106.0 | 200.0–312.5 | 170.6–312.5 |

Current Draw at Nominal DC Voltage: 2 mA (at 220–250 V)
4 mA (at 48–125 V)
10 mA (at 24 V)

Rated Impulse Withstand Voltage ($U_{imp}$): 4000 V

### Universal Binary Inputs (UBI) (Extended Module)

Rated Range: 24, 48, 110, 125, 220, and 250 Vdc/Vac, setting selectable

Maximum Current Draw: 2 mA (at 24/48 V)
1 mA (at 110/125 V)
0.5 mA (at 220/250 V)

Refer to the graph in *Operating Temperature* for the thermal derating curve.

Pickup Time: 2 ms plus ±1 ms (48–250 Vac/Vdc)
4 ms plus ±1 ms (24 Vac/Vdc)

Dropout Time: 10 ms plus ±1 ms (24–250 Vac)
2 ms plus ±1 ms (48–250 Vdc)
4 ms plus ±1 ms (24 Vdc)

| Nominal Voltage AC/DC | Deassertion Range (±5%) | | Assertion Range (±5%) | |
|---|---|---|---|---|
| | $V_{DC}$ (V) | $V_{AC}$ (V) | $V_{DC}$ (V) | $V_{AC}$ (V) |
| 24 V | 0.0–14.4 | 0.0–10.1 | 19.2–30.0 | 16.8–26.4 |
| 48 V | 0.0–28.8 | 0.0–20.2 | 38.4–60.0 | 33.6–52.6 |
| 110 V | 0.0–66.0 | 0.0–46.2 | 88.0–132.0 | 77.0–116.2 |
| 125 V | 0.0–75.0 | 0.0–52.5 | 100.0–156.2 | 87.5–137.5 |
| 220 V | 0.0–132.0 | 0.0–92.4 | 176.0–264.0 | 154.0–232.3 |
| 250 V | 0.0–150.0 | 0.0–105.0 | 200.0–300.0 | 175.0–264.0 |

## Analog Output (Optional)

| | 1 AO | 4 AO |
|---|---|---|
| Current: | 4–20 mA | ±20 mA |
| Voltage: | — | ±10 V |
| Load at 1 mA: | — | 0–15 kΩ |
| Load at 20 mA: | 0–300 Ω | 0–750 Ω |
| Load at 10 V: | — | >2000 Ω |
| Refresh Rate: | 100 ms | 100 ms |
| % Error, Full Scale, at 25°C: | <±1% | <±0.55% |

Select From: Analog quantities available in the relay

## Analog Inputs (Optional)

Maximum Input Range: ±20 mA
±10 V
Operational range set by user

Input Impedance: 200 Ω (current mode)
>10 kΩ (voltage mode)

Accuracy at 25°C

With User Calibration: 0.05% of full scale (current mode)
0.025% of full scale (voltage mode)

Without User Calibration: Better than 0.5% of full scale at 25°C

Accuracy Variation With Temperature: ±0.015% per °C of full-scale (±20 mA or ±10 V)

## Arc-Flash Detectors (Optional)

Multimode fiber-optic receiver/transmitter pair

Fiber Type: 1000 µm diameter, 640 nm wavelength, plastic, clear-jacketed, or black-jacketed

Connector Type: V-pin

## Frequency and Phase Rotation

System Frequency: 50, 60 Hz

Phase Rotation: ABC, ACB

Frequency Tracking: 40–65 Hz

## Time-Code Input

Format: Demodulated IRIG-B

On (1) State: $V_{ih} \geq 2.2$ V

Off (0) State: $V_{il} \leq 0.8$ V

Input Impedance: 2 kΩ

### Synchronization Accuracy

Internal Clock: ±1 µs

Synchrophasor Reports (e.g., **MET PM**): ±10 µs

All other reports: ±5 ms

PTP Accuracy: ±1 ms for firmware-based PTP
±250 ns for hardware-based PTP

SNTP Accuracy: ±1 ms

Unsynchronized Clock Drift Relay Powered: 2 minutes per year typical

## Communications Ports

### Standard EIA-232 (2 ports)

Location: Front Panel
Rear Panel

Data Speed: 300–38400 bps

### EIA-485 Port (optional)

Location: Rear panel

Data Speed: 300–19200 bps

### Ethernet Port (optional)

Single/Dual 10/100BASE-T copper (RJ45 connector)
Single/Dual 100BASE-FX (LC connector)

## Port 2 87L Differential Communications

### 850 nm Multimode, C37.94

Tx Mean Power: –16 dBm

Rx Sensitivity: –24 dBm to –10 dBm

Link Budget: >8 dB

Extinction Ratio: >10 dB

Approximate Range: ~1 km

1310 nm Single-Mode, C37.94

| | |
|---|---|
| Tx Mean Power: | –12 dBm |
| Rx Sensitivity: | –32 dBm to 0 dBm |
| Link Budget: | >13 dB |
| Extinction Ratio: | >10 dB |
| Approximate Range: | ~15 km |

1310 nm Single-Mode, Direct Fiber Communications

| | |
|---|---|
| Tx Mean Power: | –3 dBm |
| Rx Sensitivity: | –32 dBm to 0 dBm |
| Link Budget: | >29 dB |
| Extinction Ratio: | >10 dB |
| Approximate Range: | ~25 km |

## Fiber-Optic Ports Characteristics

Port 1 (or 1A, 1B) Ethernet

| | |
|---|---|
| Wavelength: | 1300 nm |
| Optical Connector Type: | LC |
| Fiber Type: | Multimode |
| Link Budget: | 16.1 dB |
| Typical TX Power: | –15.7 dBm |
| RX Min. Sensitivity: | –31.8 dBm |
| Fiber Size: | 62.5/125 µm |
| Approximate Range: | ~6.4 km |
| Data Rate: | 100 Mbps |
| Typical Fiber Attenuation: | –2 dB/km |

Channels 1-8 Arc-Flash Detectors (AFDI)

| | |
|---|---|
| Diagnostic Wavelength: | 640 nm |
| Optical Connector Type: | V-pin |
| Fiber Type: | Multimode |
| Typical TX Power: | –12 dBm |

Point Sensor

| | |
|---|---|
| Minimum Receive Sensitivity: | –52.23 dB |
| Point Sensor Diagnostic Worst Case Loss: | –28 dB |
| Link Budget: | 12.23 dB |
| Black-Jacketed Fiber Worst Case Loss: | –0.19 dBm |
| Black-Jacketed Fiber Typical Loss: | –0.17 dBm |
| ST or V-Pin Connector Splice Loss: | –2.00 dB |
| Approximate Range: | As much as 35 m |

Fiber Sensor

| | |
|---|---|
| Minimum Receive Sensitivity: | –29.23 dB |
| Link Budget: | 17.23 dB |
| Clear-Jacketed Fiber Worst Case Loss: | –0.19 dBm |
| Clear-Jacketed Fiber Typical Loss: | –0.17 dBm |
| ST or V-Pin Connector Splice Loss: | –2.00 dB |
| Approximate Range: | As much as 70 m |

## Optional Communications Cards

| | |
|---|---|
| Option 1: | EIA-232 or EIA-485 communications card |

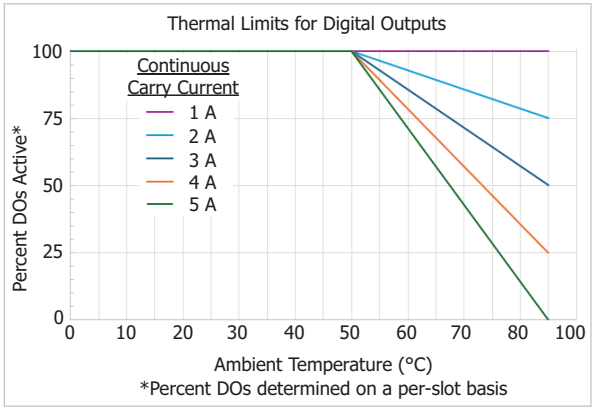
## Communications Protocols

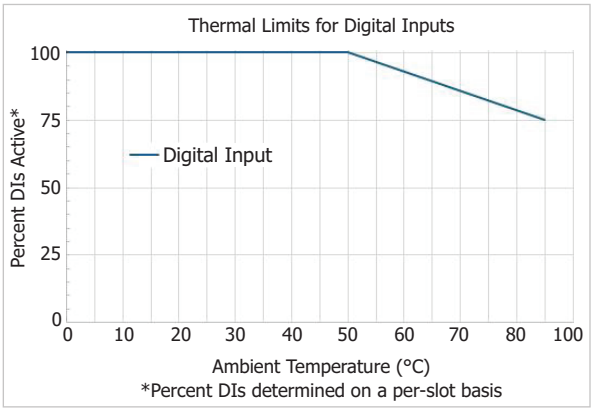
SEL, Modbus RTU and TCP/IP, DNP3 serial and LAN/WAN, FTP, Telnet, SNTP, IEEE 1588-2008 PTP, IEC 61850 Edition 2.1, IEC 60870-5-103, EtherNet/IP, IEC 62439-3 PRP, IEC 62439-3 HSR, IEEE 802.1Q-2014 RSTP, MIRRORED BITS, EVMSG, and IEEE C37.118-2005 (synchrophasors)

## Operating Temperature

| | |
|---|---|
| IEC Performance Rating: | –40° to +85°C (–40° to +185°F) (per IEC/EN 60068-2-1 and IEC/EN 60068-2-2) |

**Note:** Not applicable to UL applications.
**Note:** The front-panel display is impaired for temperatures below –20°C and above +70°C.




## Operating Environment

| | |
|---|---|
| Insulation Class: | 1 |
| Pollution Degree: | 2 |
| Overvoltage Category: | II |
| Atmospheric Pressure: | 80–110 kPa |
| Relative Humidity: | 5%–95%, noncondensing |
| Maximum Altitude Without Derating (Consult the Factory for Higher Altitude Derating): | 2000 m |

## Dimensions

| | |
|---|---|
| Base Model: | 144.0 mm (5.67 in) x 192.0 mm (7.56 in) x 147.4 mm (5.80 in) |
| With 1 Extended I/O Module: | 166.9 mm (6.57 in) x 192.0 mm (7.56 in) x 147.4 mm (5.80 in) |

With 2 Extended I/O Modules: 189.5 mm (7.46 in) x 192.0 mm (7.56 in) x 147.4 mm (5.80 in)

With 3 Extended I/O Modules: 212.2 mm (8.35 in) x 192.0 mm (7.56 in) x 147.4 mm (5.80 in)

With 4 Extended I/O Modules: 234.8 mm (9.24 in) x 192.0 mm (7.56 in) x 147.4 mm (5.80 in)

### Weight

2.7 kg (6.0 lb) + 0.34 kg (0.75 lb) per extended I/O module (max 4)

### Relay Mounting Screw (#8-32) Tightening Torque

Minimum: 1.4 Nm (12 in-lb)

Maximum: 1.7 Nm (15 in-lb)

### Terminal Connections

Terminal Block

Screw Size: #6

Ring Terminal Width: 0.310-inch maximum

Terminal Block Tightening Torque

Minimum: 0.9 Nm (8 in-lb)

Maximum: 1.4 Nm (12 in-lb)

Compression Plug Tightening Torque

Minimum: 0.5 Nm (4.4 in-lb)

Maximum: 1.0 Nm (8.8 in-lb)

Compression Plug Mounting Ear Screw Tightening Torque

Minimum: 0.18 Nm (1.6 in-lb)

Maximum: 0.25 Nm (2.2 in-lb)

RTD Compression Plug Tightening Torque

Maximum: 0.25 Nm (2.2 in-lb)

## Product Standards

Electromagnetic Compatibility: IEC 60255-26:2013

Safety Standards: IEC 60255-27:2013
UL 508
CSA C22.2 No. 14-05

## Type Tests

### Environmental Tests

Enclosure Protection: IEC 60529:2001 + CRDG:2003
IP65 enclosed in panel
IP50 for terminals enclosed in the dust-protection assembly (protection against solid foreign objects only) (SEL Part #915900170). The 10°C temperature derating applies to the temperature specifications of the relay.
IP10 for terminals and the relay rear panel
IP20 for terminals and the relay rear panel with optional terminal block cover

**Note:** If rear terminals are accessible during normal use, the product must be mounted in a locked enclosure or restricted area accessible by trained maintenance or operation personnel only.

Mixed Gas Corrosion: IEC 60068-2-60, Method 3
ISA 71.04-2013, Class G3

Vibration Resistance: IEC 60255-21-1:1988
IEC 60255-27:2013, Section 10.6.2.1
Endurance: Class 2
Response: Class 2

Shock Resistance: IEC 60255-21-2:1988
IEC 60255-27:2013, Section 10.6.2.2
IEC 60255-27:2013, Section 10.6.2.3
Withstand: Class 1
Response: Class 2
Bump: Class 1

Seismic (Quake Response): IEC 60255-21-3:1993
IEC 60255-27:2013, Section 10.6.2.4
Response: Class 2

Cold: IEC 60068-2-1:2007
IEC 60255-27:2013, Section 10.6.1.2
IEC 60255-27:2013, Section 10.6.1.4
–40°C, 16 hours

Dry Heat: IEC 60068-2-2:2007
IEC 60255-27:2013, Section 10.6.1.1
IEC 60255-27:2013, Section 10.6.1.3
85°C, 16 hours

Damp Heat, Steady State: IEC 60068-2-78:2001
IEC 60255-27:2013, Section 10.6.1.5
40°C, 93% relative humidity, 10 days

Damp Heat, Cyclic: IEC 60068-2-30:2001
IEC 60255-27:2013, Section 10.6.1.6
25° to 55°C, 95% relative humidity, 6 cycles

Change of Temperature: IEC 60068-2-14:2009
IEC 60255-1:2010, Section 6.12.3.5
–40° to +85°C, ramp rate 1°C/min, 5 cycles

### Dielectric Strength and Impulse Tests

Dielectric (Hi-Pot): IEC 60255-27:2013, Section 10.6.4.3
IEEE C37.90-2005
1.0 kVac on analog outputs, Ethernet ports, Port 3, IRIG
2.0 kVac on analog inputs and extended I/O module contact inputs
2.5 kVac on SELECT I/O card contact inputs and all contact outputs
3.6 kVdc on power supply, current, and voltage inputs

Impulse: IEC 60255-27:2013, Section 10.6.4.2
0.5 J, 5 kV on power supply, contact I/O, ac current, and voltage inputs
0.5 J, 1 kV on Port 3, RTD, and IRIG ports
0.5 J, 530 V on analog outputs
IEEE C37.90:2005
0.5 J, 5 kV
0.5 J, 530 V on analog outputs

### RFI and Interference Tests

Electrostatic Discharge Immunity: IEC 61000-4-2:2008
IEC 60255-26:2013; Section 7.2.3
IEEE C37.90.3:2001
Severity Level 4
8 kV contact discharge
15 kV air discharge

Radiated RF Immunity: IEC 61000-4-3:2010
IEC 60255-26:2013; Section 7.2.4
10 V/m
IEEE C37.90.2-2004
20 V/m

Fast Transient, Burst Immunity[a]: IEC 61000-4-4:2011
IEC 60255-26:2013; Section 7.2.5
4 kV @ 5.0 kHz
2 kV @ 5.0 kHz for comm. ports

Surge Immunity[a, b]: IEC 61000-4-5:2005
IEC 60255-26:2013; Section 7.2.7
2 kV line-to-line
4 kV line-to-earth

| | |
|---|---|
| Surge Withstand Capability Immunity[a]: | EN 61000-4-18:2010<br>IEC 60255-26:2013; Section 7.2.6<br>2.5 kV common mode<br>1 kV differential mode<br>1 kV common mode on comm. ports<br>IEEE C37.90.1-2002<br>2.5 kV oscillatory<br>4 kV fast transient<br>Comm. ports, IRIG, and PTC ports<br>Zone B, 2 kV line-to-earth<br>LEA ports compliant with<br>IEC 61869-13 tested to 1 kV, 1 MHz common mode |
| Conducted RF Immunity: | IEC 61000-4-6:2008<br>IEC 60255-26:2013; Section 7.2.8<br>10 Vrms |
| Magnetic Field Immunity: | IEC 61000-4-8:2009<br>IEC 60255-26:2013, Section 7.2.10<br>Severity Level:<br>1000 A/m for 3 seconds<br>100 A/m for 1 minute; 50/60 Hz<br>IEC 61000-4-9: 2001<br>Severity Level: 1000 A/m<br>IEC 61000-4-10:2001<br>Severity Level: 100 A/m<br>(100 kHz and 1 MHz) |
| Power Frequency Immunity (DC Inputs): | IEC 61000-4-16:2015<br>Zone A:<br>Differential: 150 VRMS<br>Common Mode: 300 VRMS |
| Power Supply Immunity: | IEC 61000-4-11:2004<br>IEC 61000-4-17:1999<br>IEC 61000-4-29:2000<br>IEC 60255-26:2013, Section 7.2.11<br>IEC 60255-26:2013, Section 7.2.12<br>IEC 60255-26:2013, Section 7.2.13 |

EMC Emissions

| | |
|---|---|
| Conducted Emissions: | IEC 60255-26:2013 Class A<br>FCC 47 CFR Part 15.107 Class A<br>Canada ICES-001 (A) / NMB-001 (A)<br>EN 55011:2009 + A1:2010 Class A<br>EN 55022:2010 + AC:2011 Class A<br>EN 55032:2012 + AC:2013 Class A<br>CISPR 11:2009 + A1:2010 Class A<br>CISPR 22:2008 Class A<br>CISPR 32:2015 Class A |
| Radiated Emissions: | IEC 60255-26:2013 Class A<br>FCC 47 CFR Part 15.109 Class A<br>Canada ICES-001 (A) / NMB-001 (A)<br>EN 55011:2009 + A1:2010 Class A<br>EN 55022:2010 + AC:2011 Class A<br>EN 55032:2012 + AC:2013 Class A<br>CISPR 11:2009 + A1:2010 Class A<br>CISPR 22:2008 Class A<br>CISPR 32:2015 Class A |

## Processing Specifications and Oscillography

| | |
|---|---|
| AC Voltage and Current Inputs: | 32 samples per power system cycle |
| Frequency Tracking Range: | 40–65 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: | Processing interval is 4 times per power system cycle (except for math variables and analog quantities, which are processed every 25 ms). Analog quantities for rms data are derived from data averaged from the previous 8 cycles. |
| Arc-Flash Processing: | Arc-flash light is sampled 32 times per cycle.<br>Arc-flash current, light, and 2 fast hybrid outputs are processed 16 times per cycle. |
| Phase Discontinuity Detection: | Processing rate is once every 2 power system cycles. |
| Cold Load Pickup: | Processing rate is once every 2 power system cycles. |
| Broken Conductor Detection: | Processing rate is once every 2 power system cycles. |

### Oscillography

| | |
|---|---|
| Length: | 15, 64, 180, or 300 cycles |
| Sampling Rate: | 32 samples per cycle unfiltered<br>4 samples per cycle filtered |
| Trigger: | Programmable with Boolean expression |
| Format: | ASCII and Compressed ASCII<br>Binary COMTRADE (32 samples per cycle unfiltered) |

**Note:** Binary COMTRADE format as per IEEE C37.111-2013, IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems.

| | |
|---|---|
| Time-Stamp Resolution: | 1 ms |
| Time-Stamp Accuracy: | ±5 ms |

### Sequential Events Recorder

| | |
|---|---|
| Time-Stamp Resolution: | 1 ms |
| Time-Stamp Accuracy (With Respect to Time Source): | ±1 ms |

## Functional Requirements

| | |
|---|---|
| Over- and Undercurrent Protection: | IEC 60255-151:2009 |
| Over- and Undervoltage Protection: | IEC 60255-127:2010 |
| Frequency Protection: | IEC 60255-181:2019 |

## Relay Elements

### Line Current Differential (87L)

| | |
|---|---|
| Unrestrained (87LU) Pickup: | OFF, 0.5–15.0 in per unit of TAP |
| Phase Restrained (87LP) Pickup | |
| Normal: | OFF, 0.10–2.00 in per unit of TAP |
| Secure: | AUTO, 0.10–3.00 in per unit of TAP |
| Zero-Sequence (87LG) Pickup | |
| Normal: | OFF, 0.10–2.00 in per unit of TAP |
| Secure: | 0.10–3.00 in per unit of TAP |
| Negative-Sequence (87LQ) Pickup | |
| Normal: | OFF, 0.50–2.00 in per unit of TAP |
| Secure: | 0.50–3.00 in per unit of TAP |
| Slope Settings (87LP, 87LG, 87LQ) | |
| Normal: | 5%–70% |
| Secure: | 5%–90% |
| Pickup Accuracy | |
| 1 A/5 A models: | ±5% plus ±0.05 per unit of TAP |
| Operate Time | |

Refer to *87L Element Operate Time Curves* in *Section 4* of the instruction manual.

### Second-Harmonic Blocking (87HBL)

| | |
|---|---|
| Pickup Range (% of fundamental): | OFF, 5%–100% |
| Pickup Accuracy | |
| 1 A/5 A models: | ±5% plus ±0.05 per unit of TAP |

### Line-Charging Current Compensation

| | |
|---|---|
| Positive-Sequence Line Susceptance Setting Range: | 0.00 to 250.00 ms, 0.01 ms steps |
| Zero-Sequence Line Susceptance Setting Range: | 0.00 to 100.00 ms, 0.01 ms steps |

### 87L Tapped Load Overcurrent (T50P, T50G, T50Q)

| | |
|---|---|
| Supported Setting Range, A secondary | |
| 5 A models: | 0.25–100.00 A, 0.01 A steps |
| 1 A models: | 0.05–20.00 A, 0.01 A steps |
| Pickup Accuracy | |
| 1 A/5 A models: | ±5% plus ±0.05 per unit of TAP |
| Time Delay: | 0.00–400.00 seconds, 0.01 second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |
| Pickup/Dropout Time: | <2.25 cycles (with fast hybrid output contacts) |

### 87L Tapped Load Inverse-Time Overcurrent (T51P, T51G, T51Q)

| | |
|---|---|
| Supported Setting Range, A secondary | |
| 5 A models: | 0.25–24.00 A, 0.01 A steps |
| 1 A models: | 0.05–4.80 A, 0.01 A steps |
| Time Dial | |
| U.S./IEEE: | 0.50–15.00, 0.01 steps |
| IEC: | 0.01–1.50, 0.01 steps |
| Pickup Accuracy | |
| 1 A/5 A models: | ±5% plus ±0.05 per unit of TAP |
| Accuracy (Operate Time): | ±1.5 cycles, ±4% between 2 and 30 multiples of pickup (within A/D measurement limit) |
| Accuracy (Reset Time): | ±1.5 cycles, ±4% between 0.5 and 0 multiples of pickup |

### Instantaneous/Definite-Time Overcurrent (50P, 50G, 50N, 50Q)

| | |
|---|---|
| Supported and Effective Setting Range, A Secondary: | |
| 5 A models: | 0.25–100.00 A, 0.01 A steps |
| 1 A models: | 0.05–20.00 A, 0.01 A steps |
| 200 mA models: | 0.010–4.000 A, 0.001 A steps (50N) |
| Accuracy: | ±3% of setting plus ±0.02 • $I_{NOM}$ A secondary (steady state)<br>±5% of setting plus ±0.02 • $I_{NOM}$ A secondary (transient)<br>±6% of setting plus ±0.02 • $I_{NOM}$ A secondary (transient for 50Q) |
| Time Delay: | 0.00–400.00 seconds, 0.01 seconds steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |
| Pickup/Dropout Time: | <1.75 cycles (with fast hybrid output contacts)<br>8 ms + <1.75 cycles (with standard contacts) |
| Reset Ratio: | 95% for setting ≥0.1 • $I_{NOM}$<br>90% for setting <0.1 • $I_{NOM}$ |
| Transient Overreach: | <15% for X/R = 10–120 |
| Overshoot Time: | 5 ms |

### Zero-Sequence PHI Directional

| | |
|---|---|
| Pickup Setting Range, A Secondary: | |
| 5 A models: | 0.25–100.00 A, 0.01-A steps |
| 1 A models: | 0.05–20.00 A, 0.01 A-steps |
| 200 mA models: | 0.005–4.000 A, 0.001-A steps |
| Pickup Accuracy: | ±3% of setting plus ±0.02 • $I_{NOM}$ A secondary (for 200 mA model, IN ≥ 0.01 A) |
| Pickup Setting Range, V Secondary: | |
| | 1–430 V, 1 V steps |
| Pickup Accuracy: | ±1% of setting plus ±0.5 V |
| Angle Range: | 0.0°–360.0° |
| Angle Accuracy: | ±2° for currents greater than 30 mA secondary<br>±3° for currents 10 mA–30 mA secondary<br>±5° for currents greater than 5 mA secondary |
| Time Delay: | 0.00–400.00 seconds, 0.01 second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |
| Pickup/Dropout Time: | <1.75 cycles (with fast hybrid contacts)<br>8 ms + <1.75 cycles (with standard contacts) |

### Directional Intermittent Ground Fault

| | |
|---|---|
| Pickup Setting Range, V Secondary: | 1–430 V, 1 V steps |
| Activation Window: | 1.00–3600.00 seconds, 0.01-second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |

### Arc-Flash Instantaneous Overcurrent (50PAF, 50NAF)

| | |
|---|---|
| Pickup Setting Range, A Secondary: | |
| 5 A models: | 0.50–100.00 A, 0.01-A steps |
| 1 A models: | 0.10–20.00 A, 0.01 A-steps |
| Accuracy: | 0 to +10% of setting plus ±0.02 • $I_{NOM}$ A secondary (steady state pickup) |
| Pickup/Dropout Time: | 2–5 ms/1 cycle |

### Phase Reversal (47)

| | |
|---|---|
| Setting Range: | OFF, ON |
| Fixed Time Delay: | 500 ±6 ms |

### Arc-Flash Time-Overlight (TOL1–TOL8)

| | |
|---|---|
| Pickup Setting Range, % of Full Scale: | 3.0–80.0% (point sensor)<br>0.6–80.0% (fiber sensor) |
| Pickup/Dropout Time: | 2–5 ms/1 cycle |

### Inverse-Time Overcurrent (51P, 51G, 51N, 51Q)

| | |
|---|---|
| Supported Setting Range, A Secondary: | |
| 5 A models: | 0.25–24.00 A, 0.01 A steps |
| 1 A models: | 0.05–4.8 A, 0.01 A steps |
| 200 mA models: | 10–960 mA, 0.01 mA steps (51N) |
| Effective Setting Range (IEC), A Secondary: | |
| 5 A models: | 0.5–5.165 A, 0.01 A steps |
| 1 A models: | 0.1–1.03 A, 0.01 A steps |
| 200 mA models: | 10–206 mA, 0.01 mA steps (51N) |
| Lowest Value of Input Energizing Quantity for which the Relay is Guaranteed to Operate ($G_T$): | 1.30 times setting |

| | |
|---|---|
| Threshold at which the Relay Switches from Dependent Time Operation to Independent Time Operation ($G_D$): | >30 times setting |
| Accuracy: | ±5% of setting plus ±0.02 • $I_{NOM}$ A secondary (steady state pickup) |
| Time Dial | |
| U.S./IEEE: | 0.50–15.00, 0.01 steps |
| IEC: | 0.01–1.50, 0.01 steps |
| Accuracy (Operate Time): | ±1.5 cycles, ±4% between 2 and 30 multiples of pickup (within A/D measurement limit) |
| Accuracy (Reset Time): | ±1.5 cycles, ±4% between 0.5 and 0 multiples of pickup |
| Reset Ratio: | 95% for setting ≥ 0.1 • I_NOM<br>90% for setting < 0.1 • I_NOM |
| Transient Overreach: | <15% for X/R = 10–120 |
| Overshoot Time: | 5–30 ms |

### Breaker Failure Instantaneous Overcurrent

| | |
|---|---|
| Pickup Setting Range, A Secondary: | |
| 5 A models: | 0.10–10.00 A, 0.01 A steps |
| 1 A models: | 0.02–2.00 A, 0.01 A steps |
| Accuracy: | ±3% of setting plus ±0.02 • $I_{NOM}$ A secondary (steady state) |
| Time Delay: | 0.00–2.00 seconds, 0.01 second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |
| Pickup/Dropout Time: | <1.5 cycles |

### IEC Thermal (49IEC)

| | |
|---|---|
| Setting Range: | Trip pickup, 1%–150%<br>Alarm pickup, 1%–100% |
| Pickup Accuracy: | ±2% (for I ≥ $I_{NOM}$)<br>±5% (for 0.4 • $I_{NOM}$ < I < $I_{NOM}$) |
| Time to Trip/Reset Accuracy: | ±5% plus ±0.5 s of the calculated value |

### Undervoltage (27P, 27PP, 27S)

| | |
|---|---|
| Supported and Effective Setting Range: | OFF, 2.00–300.00 V, 0.01 V steps (phase elements, phase-to-phase elements with delta inputs or synchronism voltage input)<br>OFF, 2.00–520.00 V, 0.01 V steps (phase-to-phase elements with wye inputs) |
| Accuracy: | ±1% of setting plus ±0.5 V |
| Time Delay: | 0.00–120.00 seconds, 0.01-second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |
| Pickup/Dropout Time: | <1.75 cycles (with fast hybrid output contacts) |
| Reset Ratio: | 106% for setting ≤ 10 V<br>101% for setting > 10 V |
| Overshoot: | 35 ms |

### Overvoltage (59P, 59PP, 59G, 59Q, 59S)

| | |
|---|---|
| Supported and Effective Setting Range: | OFF, 2.00–300.00 V, 0.01 V steps (phase elements, phase-to-phase elements with delta inputs or synchronism voltage input)<br>OFF, 2.00–520.00 V, 0.01 V steps (phase-to-phase elements with wye inputs) |
| Accuracy: | ±1% of setting plus ±0.5 V |
| Time Delay: | 0.00–120.00 seconds, 0.01 second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |
| Pickup/Dropout Time: | <1.75 cycles (with fast hybrid output contacts) |
| Reset Ratio: | 96% for setting ≤ 10 V<br>99% for setting > 10 V |
| Overshoot: | 35 ms |

### Overvoltage 3-Second RMS

| | |
|---|---|
| Setting Range: | OFF, 2.00–300.00 V, 0.01 V steps (phase-to-phase elements with delta inputs)<br>OFF, 2.00–520.00 V, 0.01 V steps (phase-to-phase elements with wye inputs) |
| Accuracy: | ±2.5% of the setting value (during frequency tracking, FREQTRK := 1) |

### Incipient Cable Fault (50INC)

| | |
|---|---|
| Pickup Setting Range, A Secondary: | OFF, 0.50–50.00 A (phase), 0.01-A steps for 5 A<br>OFF, 0.10–10.00 A (phase), 0.01-A steps for 1 A |
| Accuracy: | ±5% of setting A secondary |
| Pickup time: | <1/2 cycle |

### Inverse-Time Undervoltage (27I)

| | |
|---|---|
| Supported and Effective Setting Range: | OFF, 2.00–300.00 V, 0.01 V steps (phase elements, positive-sequence elements, phase-to-phase elements with delta inputs or synchronism-check voltage input)<br>OFF, 2.00–520.00 V, 0.01 V steps (phase-to-phase elements with wye inputs) |
| Accuracy: | ±1% of setting plus ±0.5 V |
| Pickup/Dropout Time: | <1.75 cycles (with fast hybrid output contacts) |
| Time Dial: | 0.00–16.00 s |
| Accuracy: | ±1.5 cyc plus ±4% between 0.95 and 0.1 multiples of pickup |
| Reset Ratio: | 103% for setting ≤ 10 V<br>102% for setting > 10 V |
| Overshoot Time: | 5–30 ms |

### Inverse-Time Overvoltage (59I)

| | |
|---|---|
| Supported and Effective Setting Range: | OFF, 2.00–300.00 V, 0.01 V steps (phase elements, sequence elements, or phase-to-phase elements with delta inputs or synchronism voltage input)<br>OFF, 2.00–520.00 V, 0.01 V steps (phase-to-phase elements with wye inputs) |
| Accuracy: | ±1% of setting plus ±0.5 V |
| Time Dial: | 0.00–16.00 s, 0.01 s steps |
| Accuracy: | ±1.5 cyc plus ±4% between 1.05 and 5.5 multiples of pickup |
| Pickup/Dropout Time: | <1.75 cycles (with fast hybrid output contacts) |
| Reset Ratio: | 96% for setting ≤ 10 V<br>99% for setting > 10 V |
| Overshoot Time: | 5–30 ms |

### Harmonic Blocking

| | |
|---|---|
| Pickup Range (% of fundamental): | 5%–100% |
| Pickup Accuracy (A secondary): | |
| 5 A models: | ±5% plus ±0.10 A of harmonic current |
| 1 A models: | ±5% plus ±0.02 A of harmonic current |
| Time Delay Accuracy: | ±0.5% plus ±0.25 cycle |

### Vector Shift (78VS)

| | |
|---|---|
| Pickup Setting Range: | 2.0°–30.0°, 0.1-degree increment |
| Accuracy: | ±10% of the pickup setting, ±1 degree |
| Voltage Supervision Threshold: | 20.0%–100.0% • VNOM |
| Pickup Time: | <3 cycles |

### Power (32)

| | |
|---|---|
| Instantaneous/Definite Time, Three-Phase Elements Type: | +W, –W, +VAR, –VAR |
| Pickup Setting Range, VA Secondary: | |
| 5 A models: | 1.0–6500.0 VA, 0.1 VA steps |
| 1 A models: | 0.2–1300.0 VA, 0.1 VA steps |
| Accuracy: | ±0.10 A • (L-L voltage secondary) plus ±5% of setting at unity power factor for power elements and zero power factor for reactive power elements (5 A nominal)<br>±0.02 A • (L-L voltage secondary) plus ±5% of setting at unity power factor for power elements and zero power factor for reactive power elements (1 A nominal) |
| Time Delay: | 0.0–240.0 seconds, 0.1-second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |
| Pickup/Dropout Time: | <10 cycles |

### Power Factor (55)

| | |
|---|---|
| Setting Range: | OFF, 0.05–0.99 |
| Accuracy: | ±5% of full scale for current ≥ 0.5 • $I_{NOM}$ |
| Time Delay: | 1–240 seconds, 1-second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |

### Frequency (81)

| | |
|---|---|
| Setting Range: | OFF, 40.00–65.00 Hz |
| Accuracy: | ±0.01 Hz (V1 >60 V) with voltage tracking<br>±0.05 Hz (I1 >0.8 • $I_{NOM}$) with current tracking |
| Time Delay: | 0.00–400.00 seconds, 0.01-second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |
| Pickup/Dropout Time: | <5.5 cycles (with fast hybrid output contacts) |
| Reset Hysteresis: | <0.02 Hz |

### Rate-of-Change of Frequency (81R)

| | |
|---|---|
| Setting Range: | OFF, 0.10–15.00 Hz/s |
| Accuracy: | ±100 mHz/s, plus ±3.33% of pickup (over a range of 0.23–15.00 Hz/s) |
| Time Delay: | 0.10–60.00 seconds, 0.01-second steps |
| Accuracy: | ±0.5% plus ±0.25 cycle |

### Synchronism Check (25)

| | |
|---|---|
| Pickup Range, Secondary Voltage: | 0.00–300.00 V |
| Pickup Accuracy, Secondary Voltage: | ±1% plus ±0.5 V (over the range of 2–300 V) |
| Slip Frequency Pickup Range: | 0.05 Hz–0.50 Hz |
| Slip Frequency Pickup Accuracy: | ±0.02 Hz |
| Phase Angle Range: | 0°–80° |
| Phase Angle Accuracy: | ±4° |

### Load-Encroachment Detection

| | |
|---|---|
| Pickup Setting Range | |
| 5 A Model: | 0.10–128.00 Ω secondary, 0.01 Ω steps |
| 1 A Model: | 0.50–640.00 Ω secondary, 0.01 Ω steps |
| Forward Load Angle: | –90° to +90° |
| Forward Load Angle: | +90° to +270° |
| Accuracy | |
| Impedance Measurement: | ±5% plus ±0.5 Ω |
| Angle Measurement: | ±3° |

### Phase Discontinuity Detection

| | |
|---|---|
| Pickup Setting Range: | 0.01–1.00 pu, 0.01 steps |
| Accuracy: | ±5% of setting above 0.15 pu |
| Processing rate: | Once every 2 power system cycles |

### Broken Conductor Detection

| | |
|---|---|
| Sensitivity (Minimum Line Charging Current Required for Broken Conductor Detection): | 15 mA secondary for 5 A<br>3 mA secondary for 1 A |
| Minimum Operating Time (After the Conductor Breaks and Series Arc Extinguishes): | 4 cycles |
| Maximum Operating Time (After the Conductor Breaker and Series Arc Extinguishes): | 8 cycles |
| Time Delay for Zone 2: | OFF, 0–600 cycles, 1-cycle steps |
| Timer Accuracy: | ±2 cycles |
| Processing Rate: | Once every 2 power system cycles |

### Phase Voltage THD (VTHD)

| | |
|---|---|
| Pickup Setting Range: | OFF, 1%–50% (includes 2nd–5th harmonic) |
| Pickup Accuracy: | ±3% of reading ±0.5 |
| Arming Delay: | OFF, 0.00–120.00 s |
| Trip Delay: | OFF, 0.00–120.00 s |
| Timer Accuracy: | ±0.5% plus ±0.25 cycle |

### Cold-Load Pickup

| | |
|---|---|
| Pickup Setting Range: | 0–500 minutes, 1-minute steps |
| Accuracy: | 0.5% ±2 cycles |
| Processing rate: | Once every 2 power system cycles |

### Station Battery Voltage Monitor

| | |
|---|---|
| Operating Range: | 0–350 Vdc (300 Vdc for UL purposes) |
| Pickup Range: | 20.00–300.00 Vdc |
| Pickup accuracy: | ±2% of setting plus ±2 Vdc |

### Timers

| | |
|---|---|
| Setting Range: | Various |
| Accuracy: | ±0.5% of setting plus ±1/4 cycle |

### RTD Protection

| | |
|---|---|
| Setting Range: | OFF, 1°–250°C |
| Accuracy: | ±2°C |
| RTD Open-Circuit Detection: | >250°C |
| RTD Short-Circuit Detection: | <–50°C |
| RTD Types: | PT100, NI100, NI120, CU10 |
| RTD Lead Resistance: | 25 Ω max. per lead |
| Update Rate: | <3 s |

| | |
|---|---|
| Noise Immunity on RTD Inputs: | As high as 1.4 Vac (peak) at 50 Hz or greater frequency |
| RTD Fault/Alarm/Trip Time Delay: | Approx. 12 s |

## Metering

Accuracies are specified at 20°C, nominal frequency, ac currents within (0.2–20.0) • $I_{NOM}$ A secondary, and ac voltages within 50–250 V secondary (1.33–6.67 V secondary with 8 V LEA option), unless otherwise noted.

| | |
|---|---|
| Phase Currents: | ±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with $I_{NOM}$ = 1 A) |
| Differential Quantities | ±5% of reading ±0.05 per unit of TAP |
| Three-Phase Average Current: | ±1% of reading |
| IG (Residual Current): | ±2% of reading, ±2° (±5.0° at 0.2–0.5 A for relays with $I_{NOM}$ = 1 A) |
| IN (Neutral Current): | ±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with $I_{NOM}$ = 1 A)<br>±1.6 mA and ±1% (0.04–4.0 A) (0.2 A nominal channel IN current input) |
| I1 Positive-Sequence Current: | ±2% of reading |
| 3I2 Negative-Sequence Current: | ±2% of reading |
| System Frequency: | ±0.01 Hz of reading for frequencies within 15–70 Hz (V1 > 60 V) |
| Line-to-Line Voltages: | ±1% of reading, ±1° for voltages |
| Three-Phase Average Line-to-Line Voltage: | ±1% of reading for voltages within 24–264 V |
| Line-to-Ground Voltages: | ±1% of reading, ±1° for voltages within 24–264 V (0.64–7.04 V for LEA inputs) |
| Three-Phase Average Line-to-Ground Voltages: | ±1% of reading for voltages within 24–264 V (0.64–7.04 V for LEA inputs) |
| Accuracy Harmonic Range: | 1%–100% (includes 2nd–5th harmonic) ±3% of reading ±0.5 |
| Accuracy THD Range: | 1%–100% (includes 2nd–5th harmonic) ±3% of reading ±0.5 |
| Voltage Imbalance (%): | ±2% of reading |
| V1 Positive-Sequence Voltage: | ±2% of reading for voltages within 24–264 V (0.64–7.04 V for LEA inputs) |
| 3V2 Negative-Sequence Voltage: | ±2% of reading for voltages within 24–264 V (0.64–7.04 V for LEA inputs) |
| Real Three-Phase Power (kW): | ±3% of reading for 0.10 < pf < 1.00 |
| Reactive Three-Phase Power (kVAR): | ±3% of reading for 0.00 < pf < 0.90 |
| Apparent Three-Phase Power (kVA): | ±3% of reading |
| Power Factor: | ±2% of reading |
| RTD Temperatures: | ±2°C |

### Energy Meter

| | |
|---|---|
| Accumulators: | Separate IN and OUT accumulators updated once per second, transferred to nonvolatile storage 4 times per day |
| ASCII Report Resolution: | 0.001 MWh |
| Accuracy: | The accuracy of the energy meter depends on applied current and power factor as shown in the power metering accuracy specifications above. The additional error introduced by accumulating power to yield energy is negligible when power changes slowly compared to the processing rate of once per second. |

## Synchrophasor Accuracy

### Maximum Message Rate

| | |
|---|---|
| Nominal 60 Hz System: | 60 messages per second |
| Nominal 50 Hz System: | 50 messages per second |

The voltage accuracy specifications are only applicable for the model options with standard voltage inputs (not applicable to LEA option).
The current accuracy specifications are applicable for all 1 A and 5 A options.
**Note**: For the SEL-787L current only model, the accuracy specifications for currents are only applicable when the applied signal frequency equals FNOM.

### Accuracy for Voltages

Level 1 compliant as specified in IEEE C37.118 under the following conditions for the specified range.

Conditions

- At maximum message rate
- When phasor has the same frequency as the positive-sequence voltage
- Frequency-based phasor compensation is enabled PHCOMP := Y)
- The narrow bandwidth filter is selected (PMAPP := N)

Range

| | |
|---|---|
| Frequency: | ±5.0 Hz of nominal (50 or 60 Hz) |
| Magnitude: | 30 V–250 V |
| Phase Angle: | –179.99° to 180.00° |
| Out-of-Band Interfering Frequency (Fs): | 10 Hz ≤ Fs ≤ (2 • FNOM) |

### Accuracy for Currents

Level 1 compliant as specified in IEEE C37.118 under the following conditions for the specified range.

Conditions

- At maximum message rate
- When phasor has the same frequency as the positive-sequence voltage
- Frequency-based phasor compensation is enabled (PHCOMP := Y)
- The narrow bandwidth filter is selected (PMAPP := N)

Range

| | |
|---|---|
| Frequency: | ±5.0 Hz of nominal (50 or 60 Hz) |
| Magnitude: | (0.4–2) • $I_{NOM}$ ($I_{NOM}$ = 1 A or 5 A) |
| Phase Angle: | –179.99° to 180.00° |
| Out-of-Band Interfering Frequency (Fs): | 10 Hz ≤ Fs ≤ (2 • FNOM) |

[a] Front port serial cable (non-fiber) lengths assumed to be <3 m.

[b] RTD cable lengths assumed to be <10 m.

# Technical Support

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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