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.

- Apply the SEL-787L as primary protection on two terminal lines. The SEL-787L combines line current differential protection and directional and non-directional overcurrent protection.
- Secure the 87L element operation with external fault detection (EFD) and disturbance detection logic.
- Supports a direct serial fiber, IEEE C37.94-compatible communication interface with a range of as far as 25 km.
- Channel monitoring provides measurement of communication quality and prevents misoperation due to channel failure.
- Supports arc-flash protection with optional Slot E card to increase the safety of your personnel and equipment, and significantly reduces incident energy by sending a trip signal to a breaker in as fast as 2 ms.
- 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).
- Increased flexibility for custom logic with 64 SELOGIC variables, 64 SELOGIC counters, 64 SELOGIC latches, and 64 math variables.
- 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 Digital Number 16, 17)	Slot Z Inputs	Slot E Card Option (MOT String Digits Number 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
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
67G	Residual Overcurrent With Directional Control		X[a]	X[b]
50N	Neutral Overcurrent	X	X	X
67N	Neutral Overcurrent With Directional Control			X[b]

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
50INC	Incipient Cable Fault Detection	X	X	X
T50P	87 Tapped Load Phase Overcurrent Elements	X	X	X
T50G	87 Tapped Load Ground Overcurrent Elements	X	X	X
T50Q	87 Tapped Load Negative-Sequence Overcurrent Elements	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]
T51P	87 Tapped Load Phase Inverse-Time Overcurrent Elements	X	X	X
T51G	87 Tapped Load Ground Inverse-Time Overcurrent Elements	X	X	X
T51Q	87 Tapped Load Neg.-Seq. Inverse-Time Overcurrent Elements	X	X	X
SEF	Sensitive Earth Fault			X
HBL	Second- and Fifth-Harmonic Blocking	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)		X	X
27I	Inverse-Time Undervoltage		X	X
59I	Inverse-Time Overvoltage		X	X
60LOP	Loss of Potential		X	X
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
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[d]	X[d]	X[d]
HIF AST	High-Impedance Fault Detection With Arc Sense™ Technology		X[d]	X[d]
AFT	Arc-Flash Detection	X[d]	X[d]	X[d]
PDD	Phase Discontinuity Detection		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 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

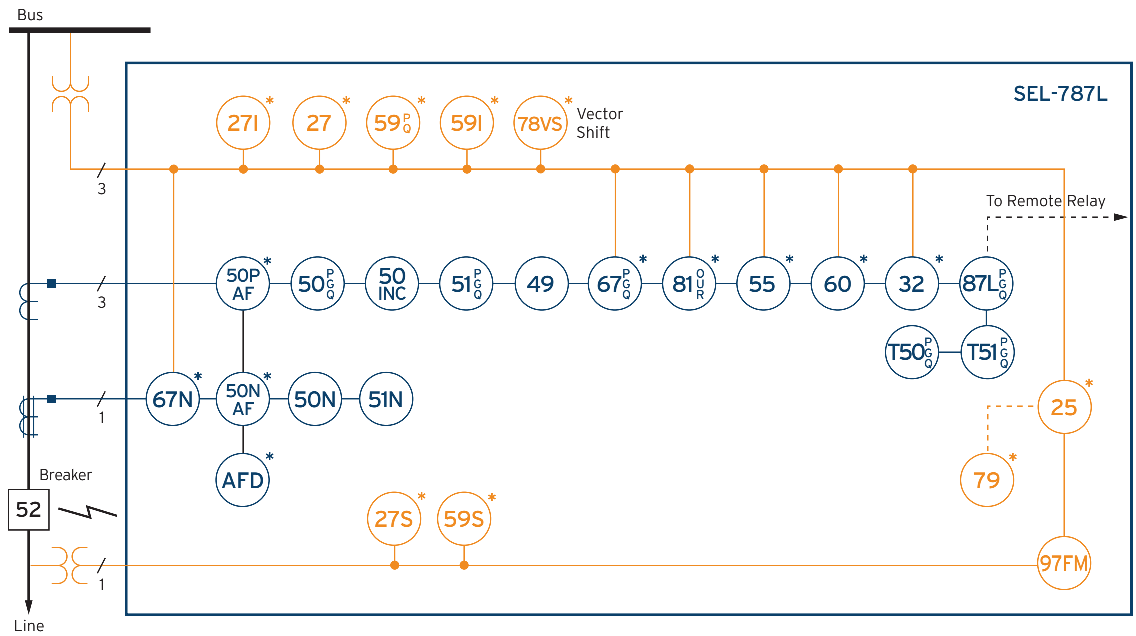
[a] For ordering options, refer to the SEL-787L MOT.

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.
- **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; 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. 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, Q)	Definite-time overvoltage
59S	Synchronism-check overvoltage*
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.

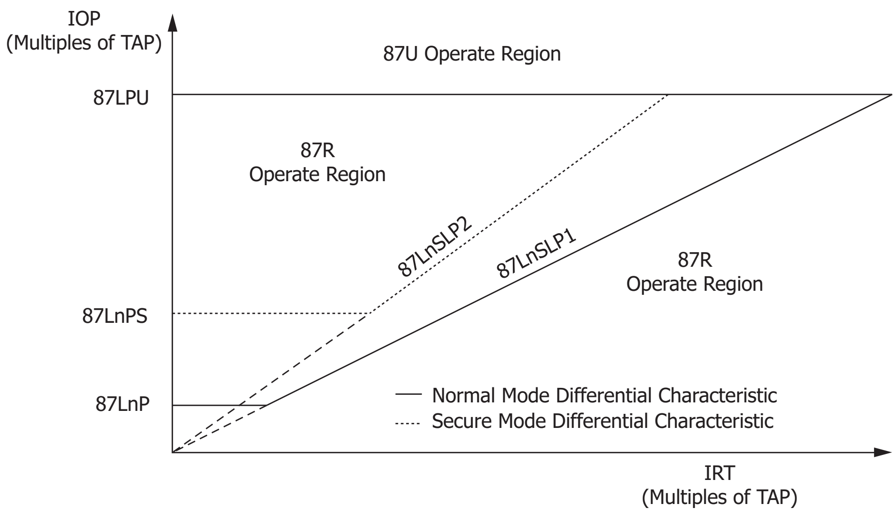


Figure 2 Adaptive-Slope Percentage Restrained Differential Characteristics

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:

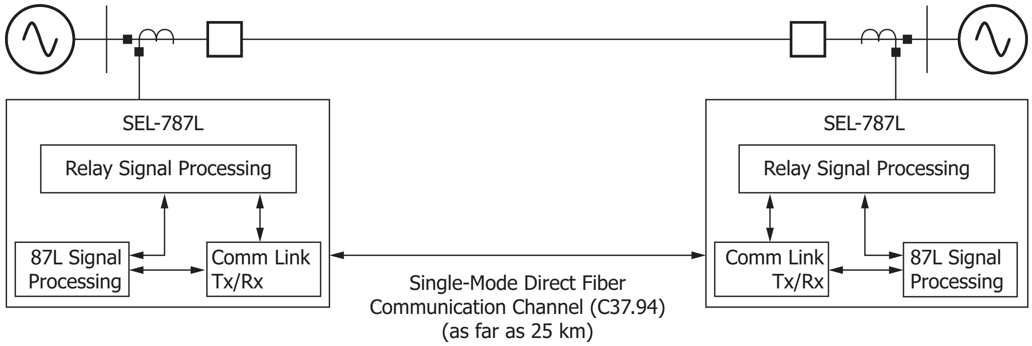


Figure 3 Two-Terminal Application Using Single-Mode Direct Fiber Communications

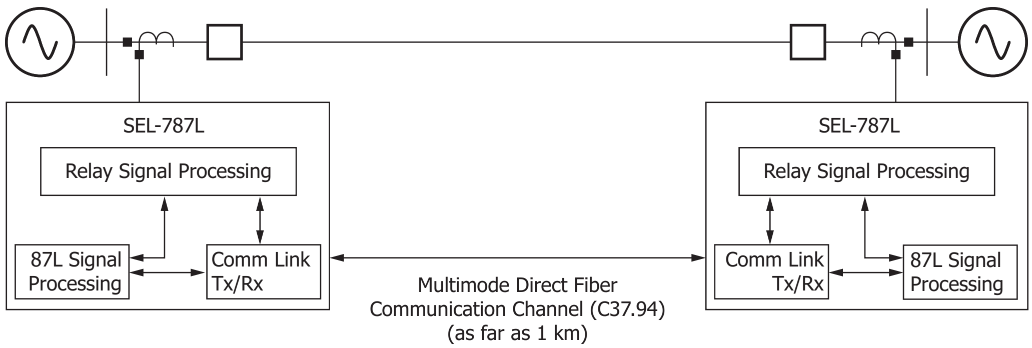


Figure 4 Two-Terminal Application Using Multimode Direct Fiber Communications

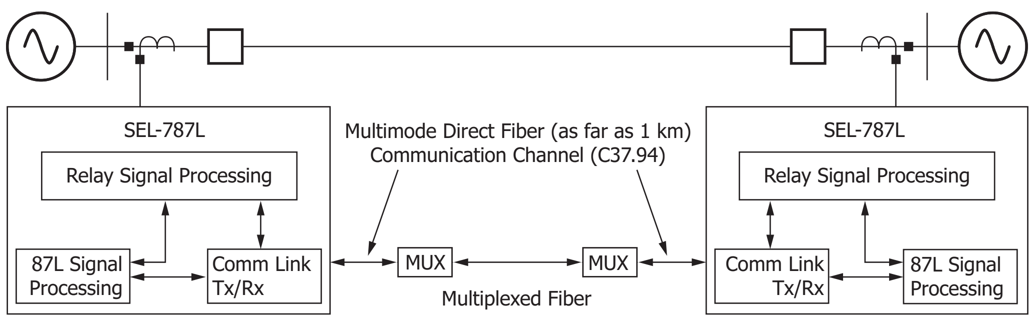


Figure 5 Two-Terminal Application Using Multimode Fiber Communications Over Multiplexer

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 6* 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.

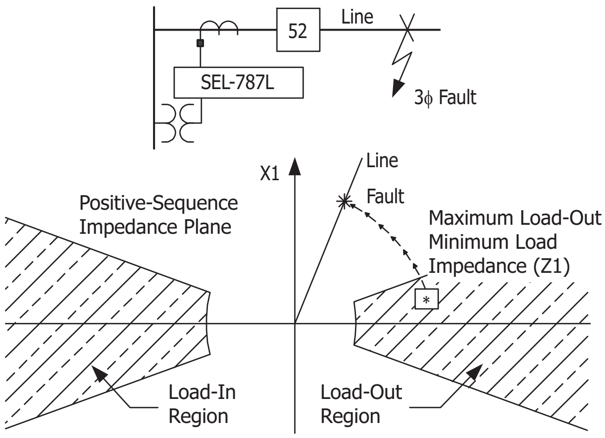


Figure 6 Load-Encroachment Characteristics

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 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 7*). Alarm or trip for the ground fault condition with sensitivity down to 5 mA secondary.

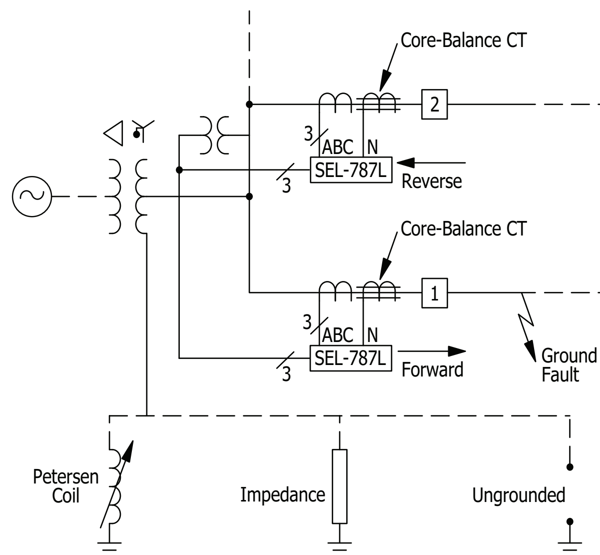


Figure 7 Apply SEL-787L Relays to Petersen Coil-Grounded, Impedance-Grounded, and Ungrounded Systems for Directional Control

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 the overhead lines and cables against thermal damage (including insulation degradation and loss of equipment life) and to monitor the thermal state of the 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 could 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 8*. 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.

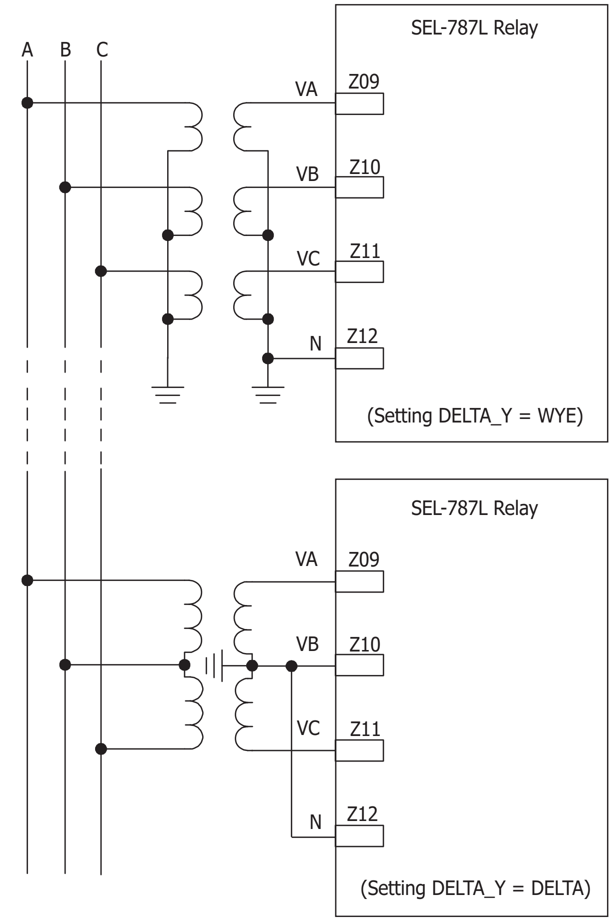


Figure 8 Connect Wye or Open-Delta Voltage to SEL-787L Three-Phase Voltage Inputs

Figure 9 shows the connections for a 3V0 broken-delta input.

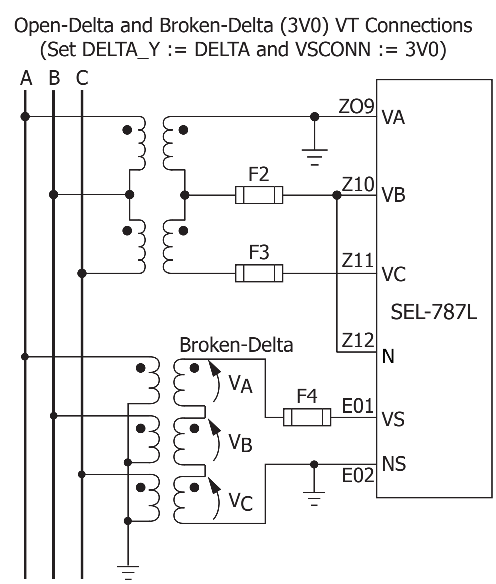


Figure 9 Broken-Delta Connections

In addition, the SEL-787L supports single voltage input. For customers with a single PT input, the SEL-787L assumes 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 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

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

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; it 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 action 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.

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

The fast rate-of-change-of-frequency protection, 81RF, 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 10*) based on the frequency deviation from nominal frequency (DF = FREQ – FNOM) and the rate-of-change of frequency (DF3C) to detect islanding conditions.

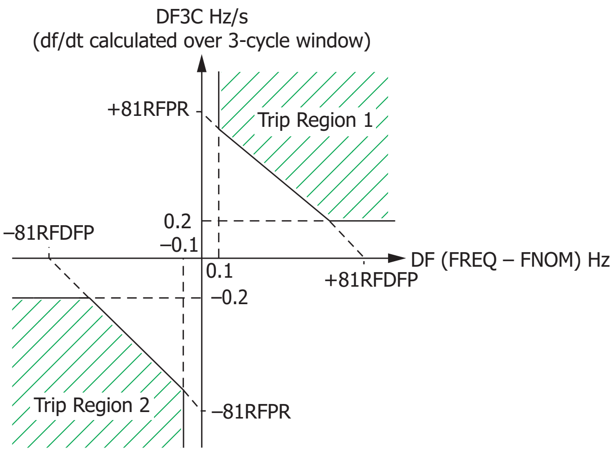


Figure 10 81RF Characteristic Power Element Protection

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 islanded system acceleration, 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, the 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 settable 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 operation 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 personal 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 11* (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 11* (bottom) shows a diagram for the clear-jacketed fiber sensor application.

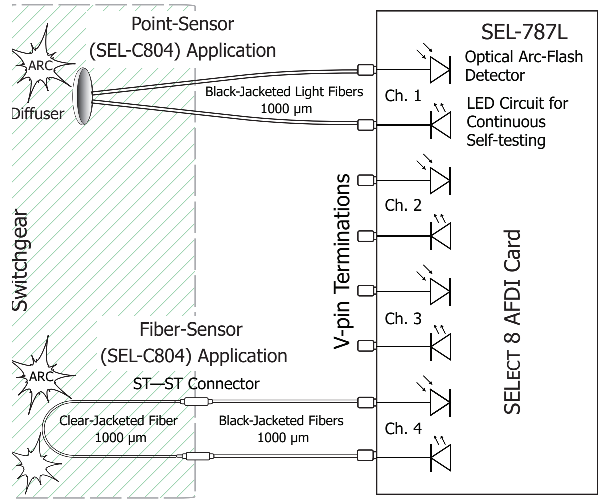


Figure 11 SEL-787L Arc-Flash Detection System

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 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 12*). You can set the SER to track operator controls. Use SELOGIC control equations to change operator control functions. Use configurable labels to change all of the text shown in *Figure 12*.

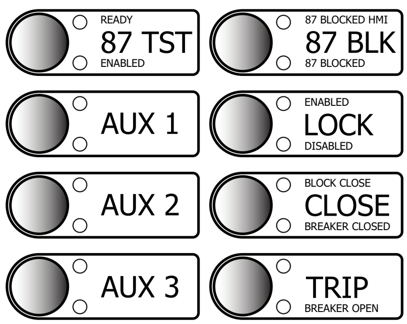


Figure 12 Operator Controls for Standard Model

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 **TRIP**, **CLOSE**, **87 BLK**, and **87 TST** 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 13 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.

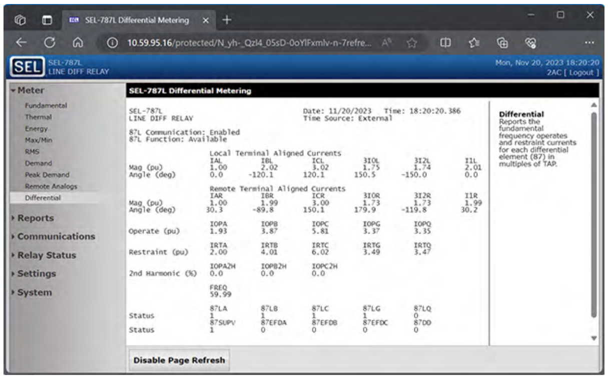


Figure 13 Differential Meter Report Webpage

Figure 14 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.

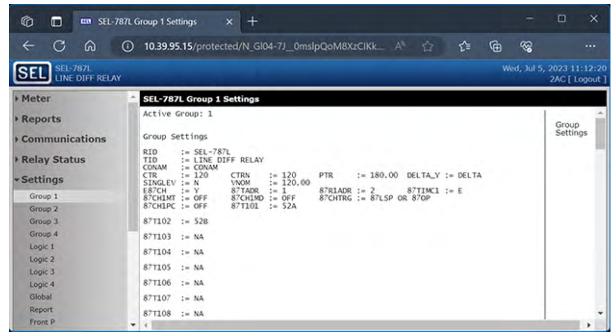


Figure 14 Group 1 Settings Webpage

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 15* shows the firmware upgrade webpage.

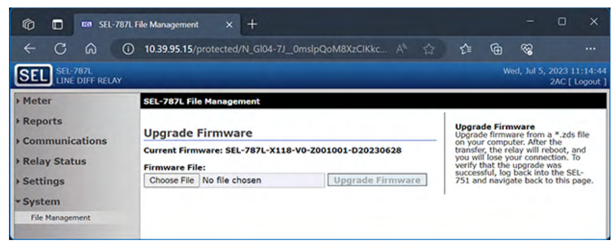


Figure 15 Upgrade the Relay Firmware From File Management Webpage

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.

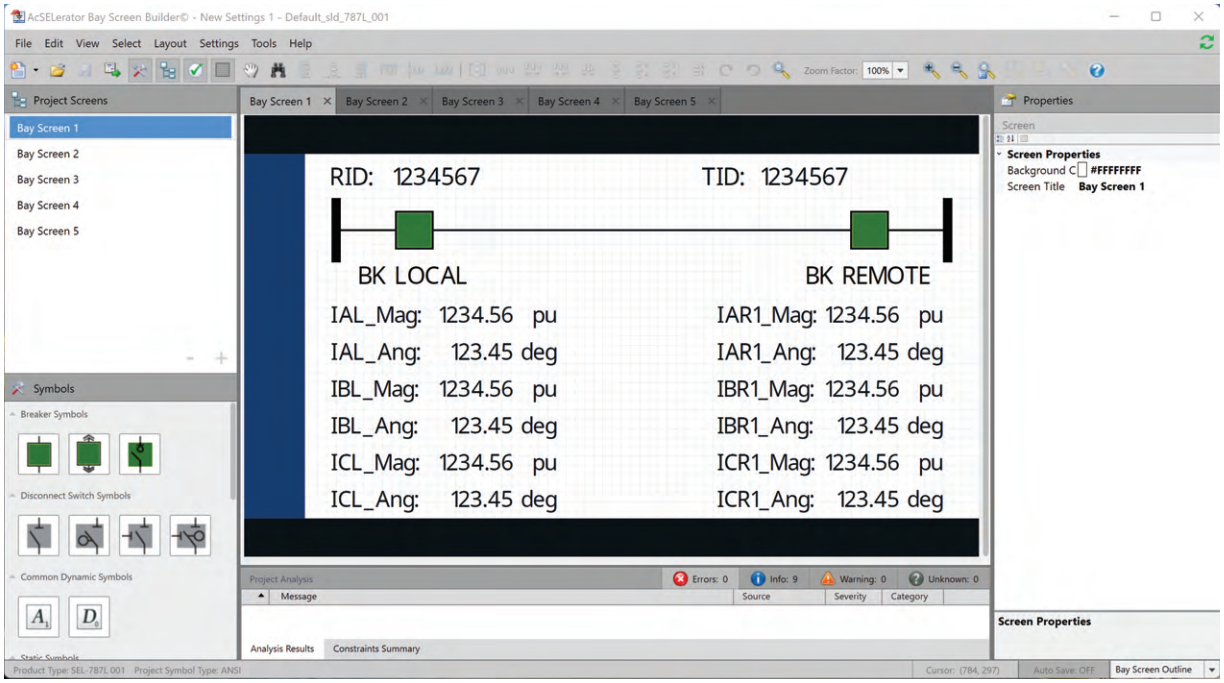


Figure 16 Bay Screen Builder

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) (Sheet 1 of 2)

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

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

Table 5 SEL-787L Metered Values (Model Dependent) (Sheet 2 of 2)

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
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* Current THIEQ*x* pu TCU THTCU*x*% Trip Time THTRIP*x* s 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 (6500 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 17*).

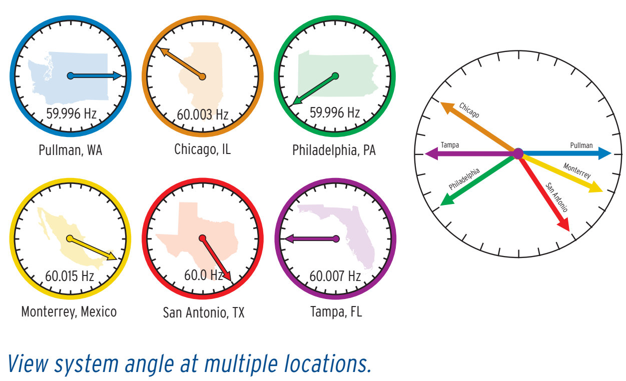


Figure 17 View of System Angle at Multiple Locations

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 necessary lines include synchrophasor measurements, state estimation is no longer necessary. The system state is directly measured.

$$\underbrace{\begin{bmatrix} V_1 \\ V_2 \\ P_{12} \\ Q_{12} \end{bmatrix}}_{\substack{\text{Measurements} \\ \text{10 Minutes}}} = \underbrace{h\,(V,\theta)}_{\text{State}} + error \longrightarrow \underbrace{\begin{bmatrix} \delta_1 \\ \delta_2 \\ V_1 \\ V_2 \end{bmatrix}}_{\substack{\text{Measurements} \\ \text{1 Second}}} = \underbrace{h\,(V,\theta)}_{\text{State}}$$

Figure 18 Synchrophasor Measurements Turn State Estimation Into State Measurement

Improve Situational Awareness

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

- ➤ 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.

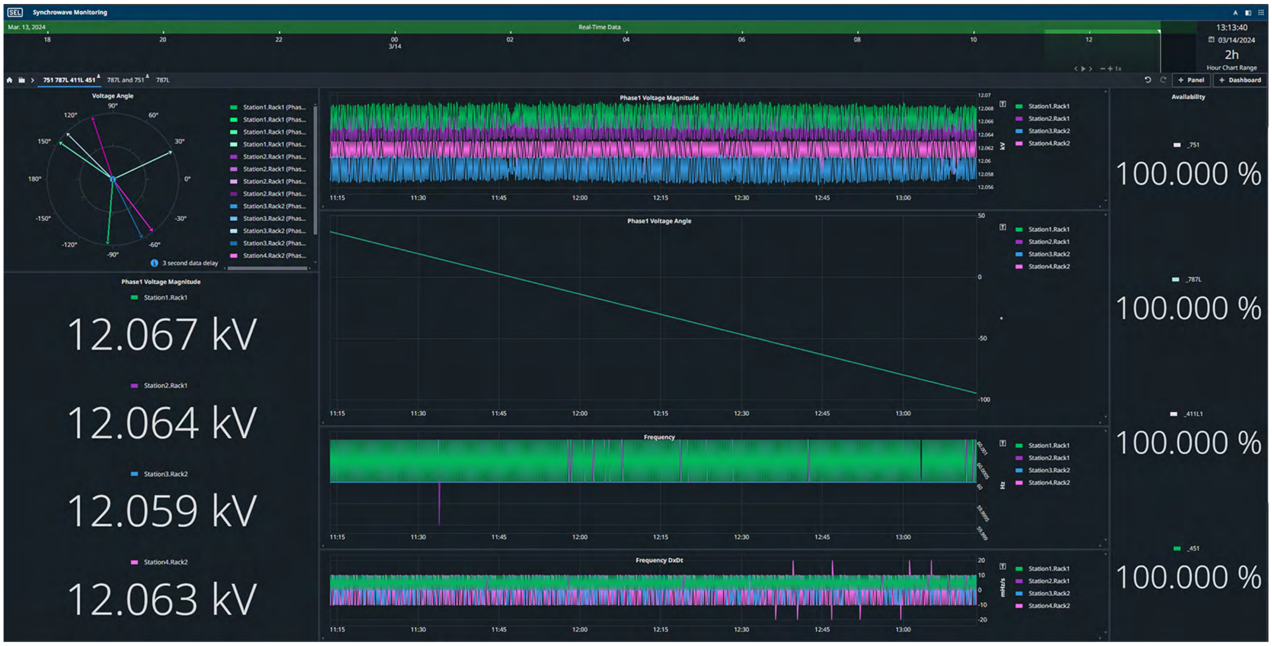


Figure 19 Visualization of Phasor Measurements

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 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 the breaker trips, the relay integrates the measured current information. When the result of this integration exceeds the breaker wear curve threshold (see *Figure 20*), the relay alarms via output contact, communications port, or front-panel display. This kind of information allows timely and economical scheduling of breaker maintenance.

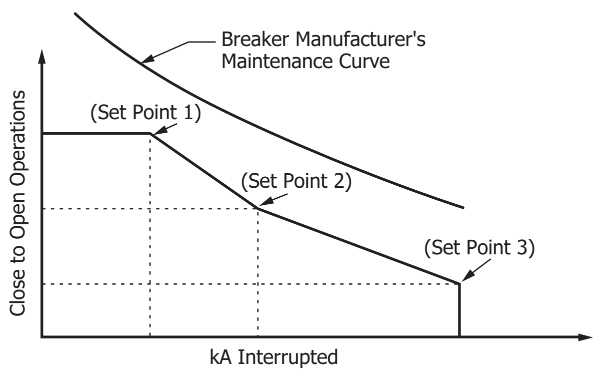


Figure 20 Breaker Contact Wear Curve and Settings

The relay also provides analog quantities that calculate the mechanical operate and 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 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.

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 21*. 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 22* through *Figure 31*.

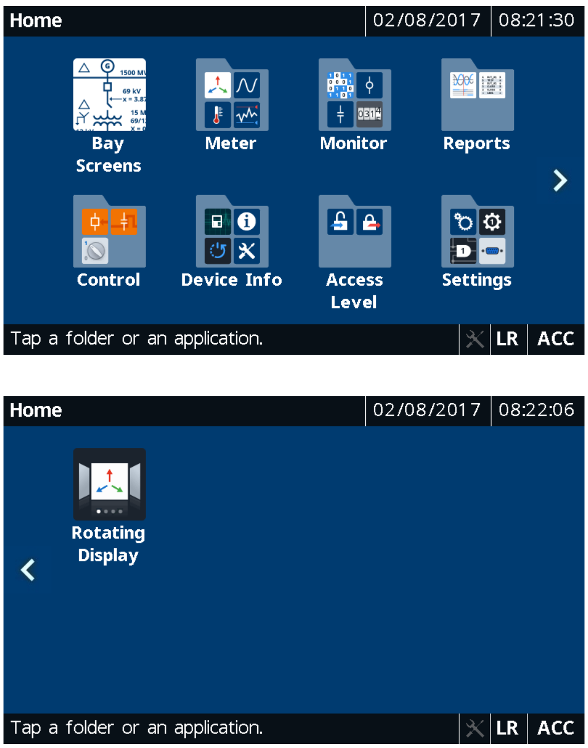


Figure 21 Home (Default FPHOME Screen)

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 22* shows the default SLD for the touchscreen display option.

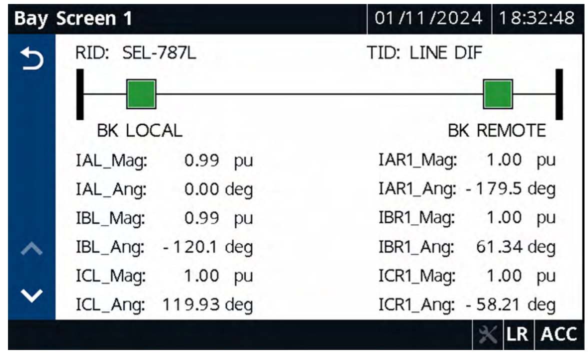


Figure 22 Default Bay Screen

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 23*).

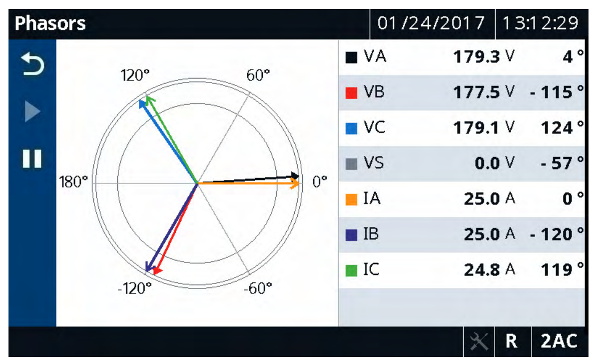


Figure 23 Meter Phasors

Tap the **Differential** application to view the local and remote currents (see *Figure 24*).

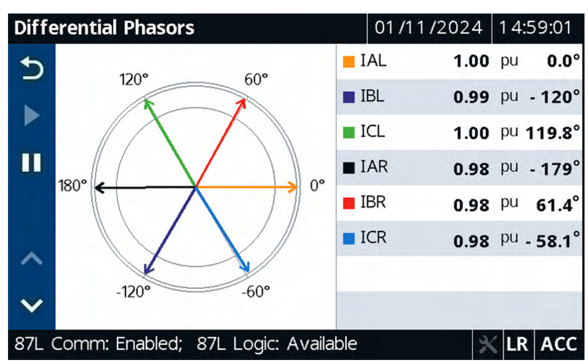


Figure 24 Differential Phasors

Tap the **Energy** application to view the energy metering quantities (see *Figure 25*). A reset feature is provided for the Energy, Max/Min, Demand, and Peak Demand applications. Tap the **Reset** button (see *Figure 25*) to navigate to the reset confirmation screen. Once you confirm the reset, the data are reset to zero.

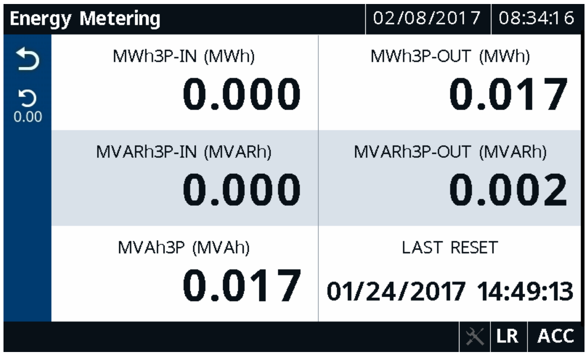


Figure 25 Meter Energy

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 26*) 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.

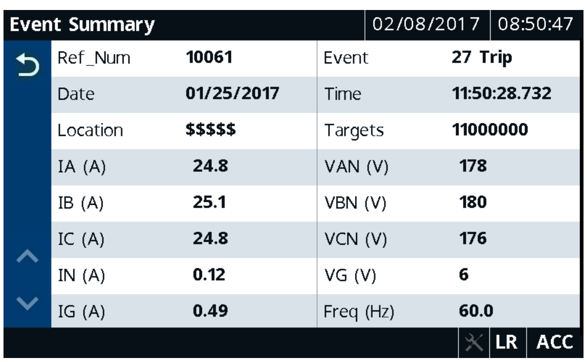


Figure 26 Event Summary

Tap the **Sequential Events Recorder** application to view a history of the SER reports (see *Figure 27*).

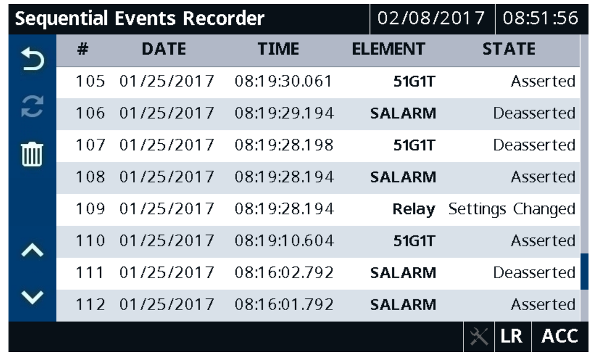


Figure 27 Sequential Events Recorder

Tapping the **Trash** button, shown in *Figure 27*, 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 28*), and control the local bits (*Figure 29*).

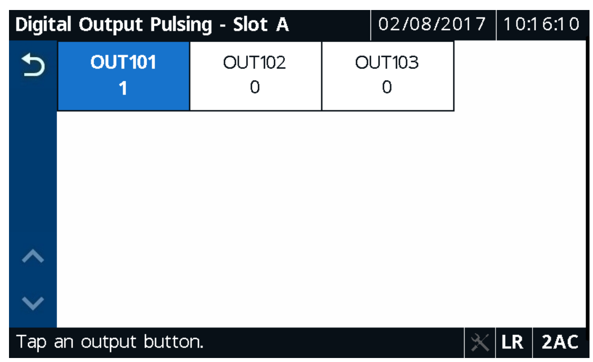


Figure 28 Digital Output Pulsing-Slot A

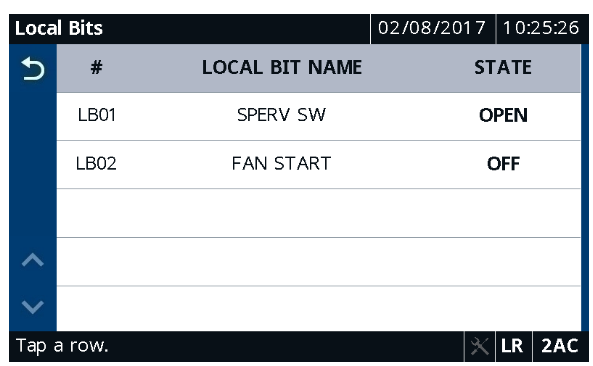


Figure 29 Local Bits

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 30*).

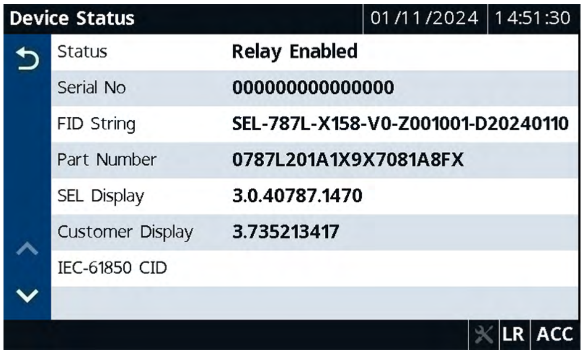


Figure 30 Device Status

To view the trip and diagnostic messages, tap the **Trip & Diag. Messages** application (see *Figure 31*). 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.

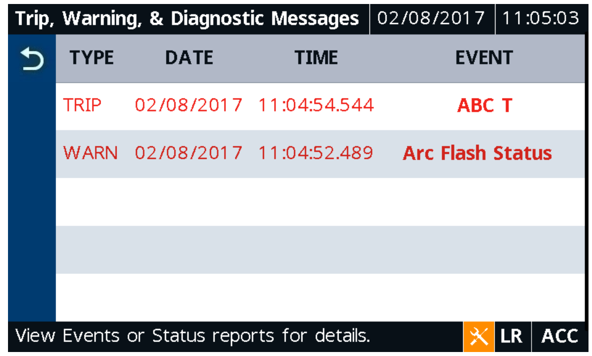


Figure 31 Trip and Diagnostics

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 (Sheet 1 of 2)

Type	Description
Simple ASCII	Plain language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended Fast Meter and Fast Operate	Binary protocol for machine-to-machine communications. Quickly updates SEL communications processors, 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.
Fast SER Protocol	Provides SER events to an automated data collection system.
DNP3	Serial or Ethernet-based DNP3 protocols. 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.

Table 6 Communications Protocols (Sheet 2 of 2)

Type	Description
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.
Event Messenger	The use of SEL-3010 Event Messenger allows you to receive alerts directly on your cell phone. Alerts can be triggered through relay events and can include quantities measured by the relay.
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.
PRP	Provides seamless recovery from any single Ethernet network failure in a dual redundant Ethernet network, in accordance with IEC 62439-3.
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 32*).

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

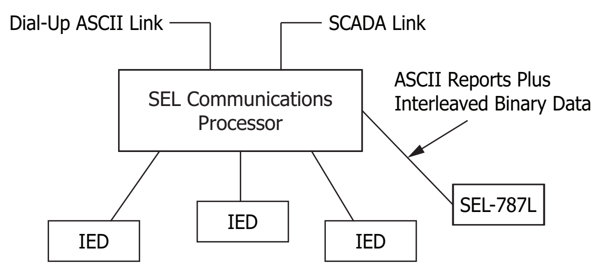


Figure 32 Example Communications System

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 nonvolatile 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, com-

mand, or other programmable conditions. Use these setting groups to cover a wide range of protection and control contingencies. Switching setting groups switches logic and relay element settings. Program groups for different operating conditions, such as feeder paralleling, station maintenance, seasonal operations, emergency contingencies, loading, source changes, and downstream relay setting changes.

Fast SER Protocol

SEL Fast SER provides SER events to an automated data collection system. SEL Fast SER protocol is available on any rear serial port. Devices with embedded processing capability can use these messages to enable and accept unsolicited binary SER messages from SEL-787L relays.

SEL relays and communications processors have two separate data streams that share the same serial port. The normal serial interface consists of ASCII character commands and reports that are intelligible to people using a terminal or terminal emulation package. The binary data streams can interrupt the ASCII data stream to obtain information, and then allow the ASCII data stream to continue. This mechanism allows a single communications channel to be used for ASCII communications (e.g., transmission of a long event report) interleaved with short bursts of binary data to support fast acquisition of metering or SER data.

Ethernet Network Architectures

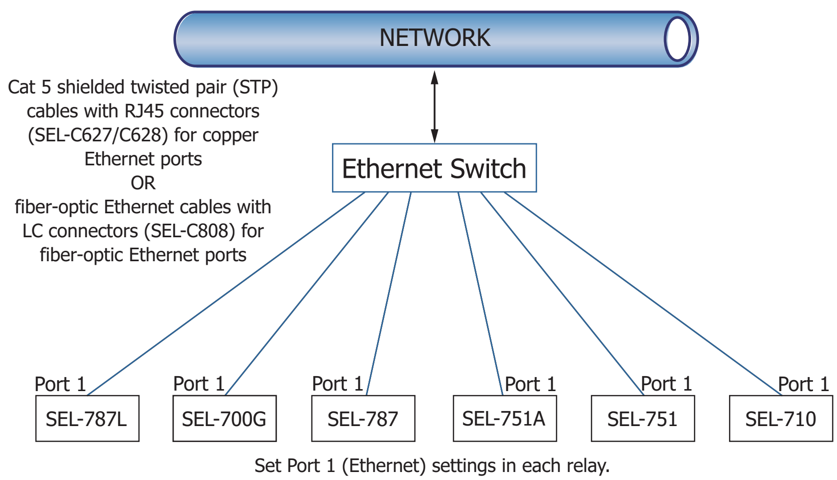


Figure 33 Simple Ethernet Network Configuration

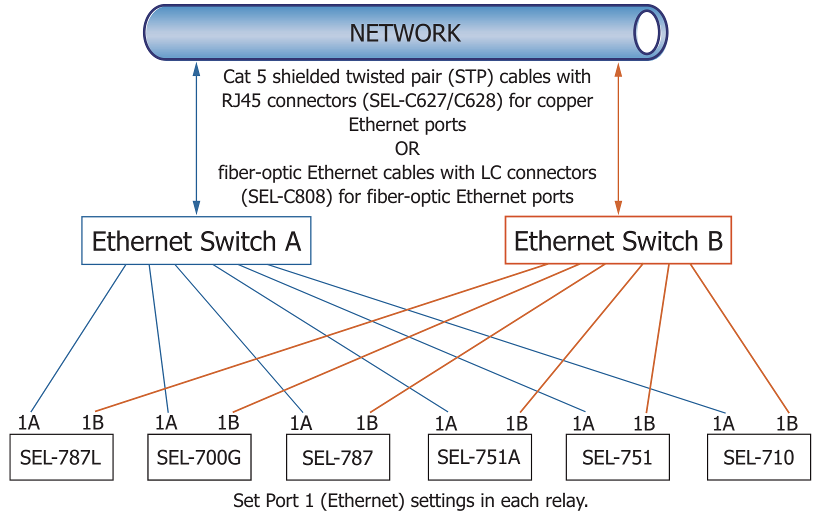


Figure 34 Ethernet Network Configuration With Dual Redundant Connections (Failover Mode)

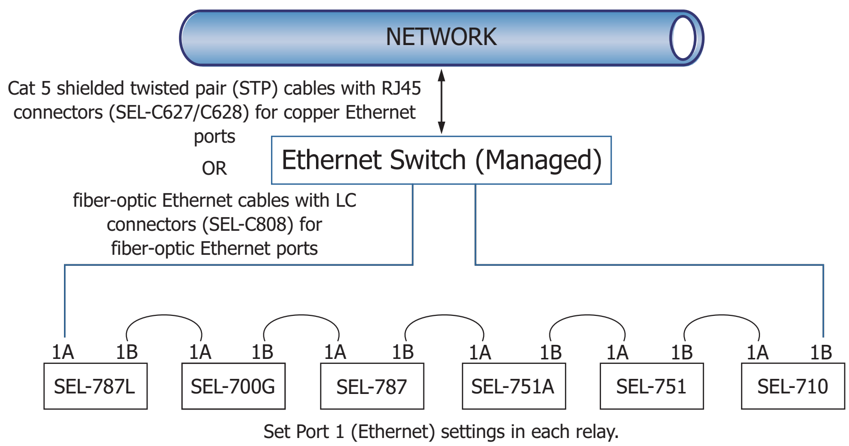


Figure 35 Ethernet Network Configuration With Ring Structure (Switched Mode)

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 36*). 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.

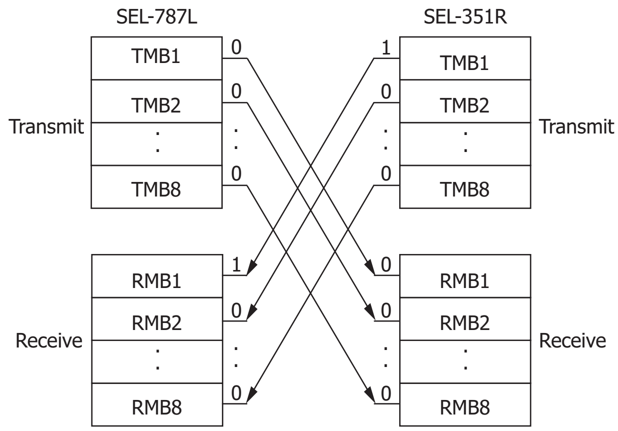


Figure 36 MIRRORED BITS Transmit and Receive Bits

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 39*. 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 39*) 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

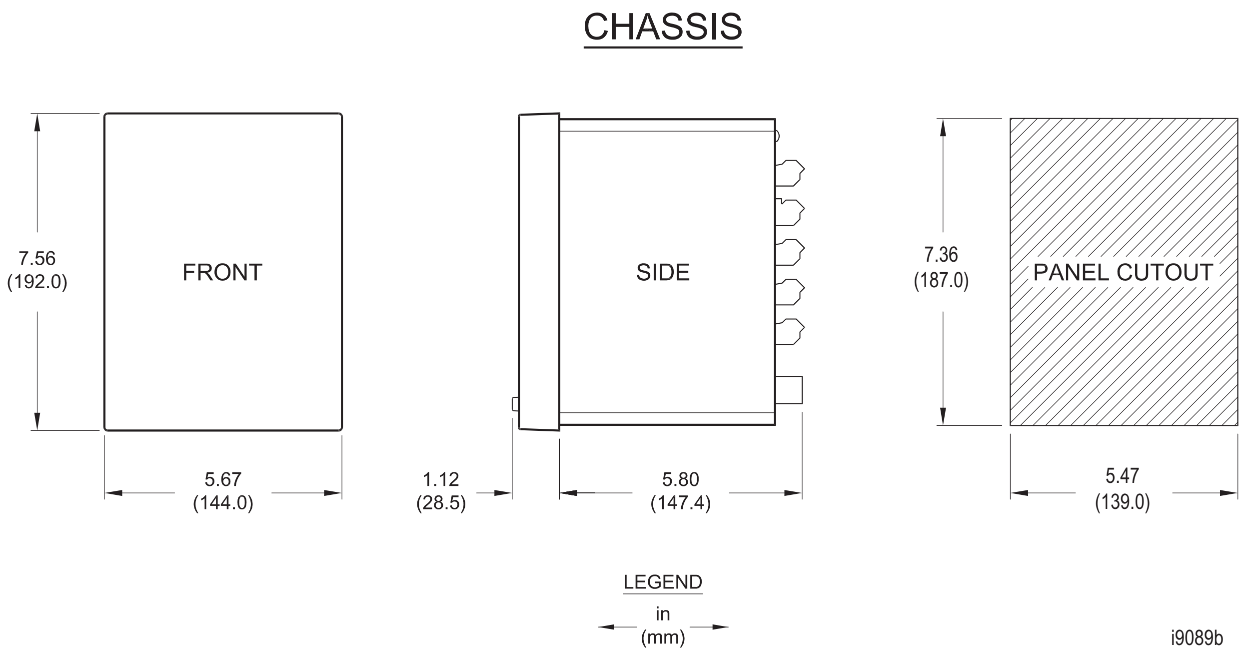


Figure 37 SEL-787L Dimensions for Rack- and Panel-Mount Models

Hardware Overview

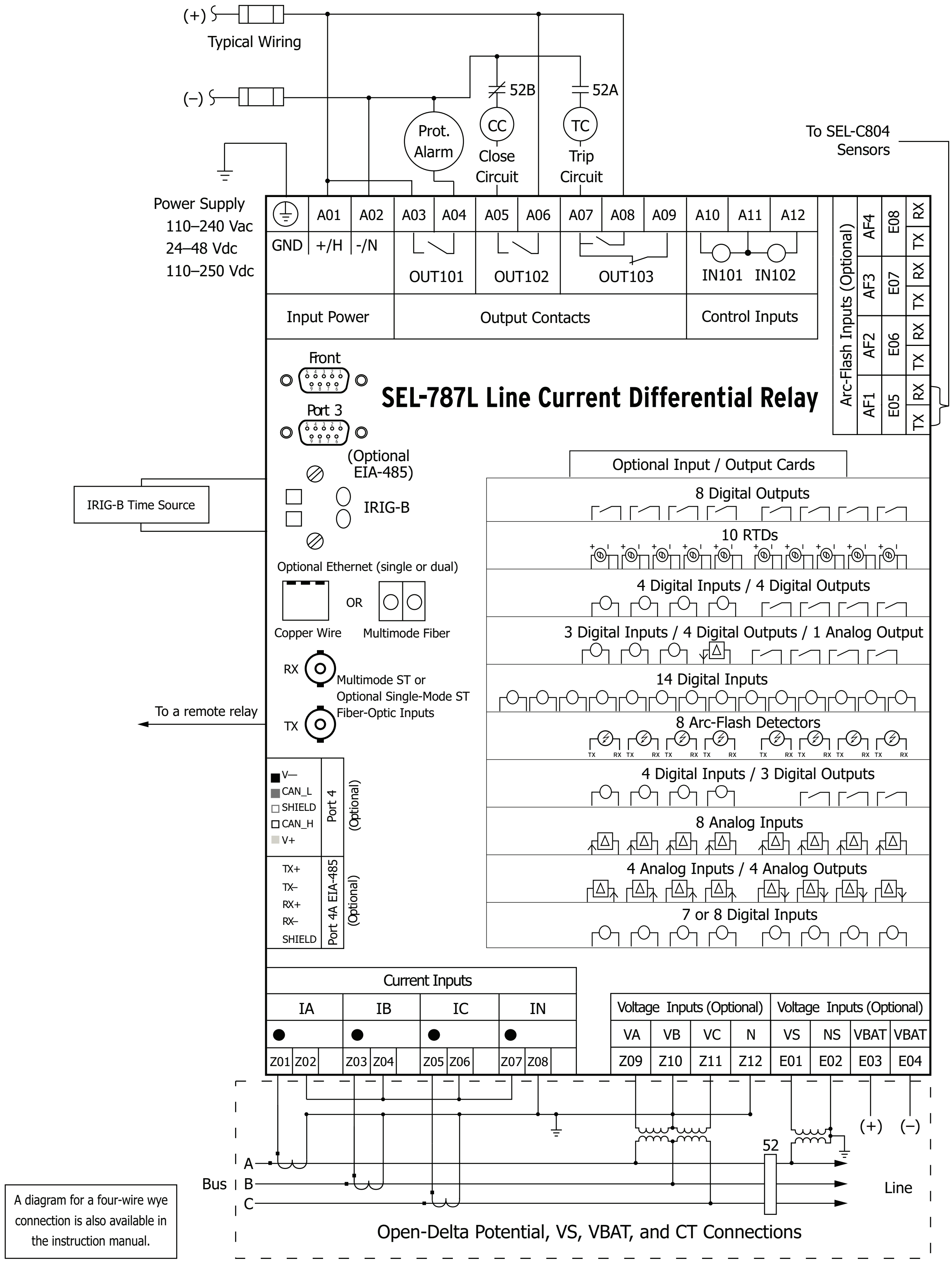


Figure 38 SEL-787L Wiring Diagram

Relay Panel Diagrams

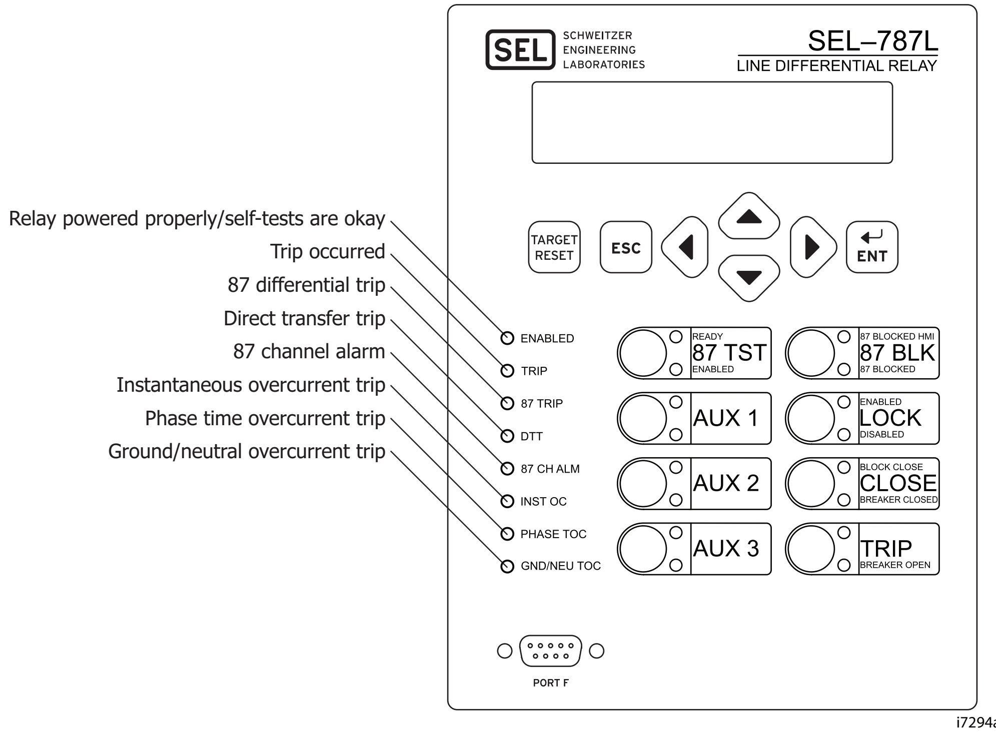
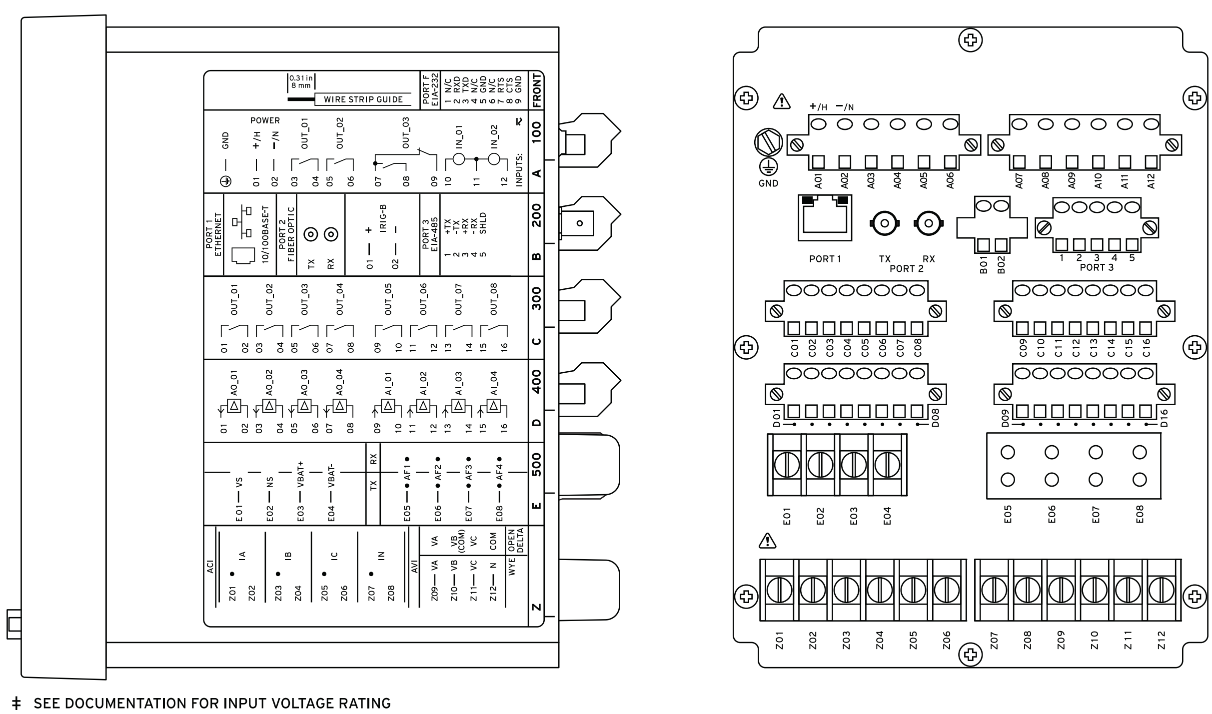


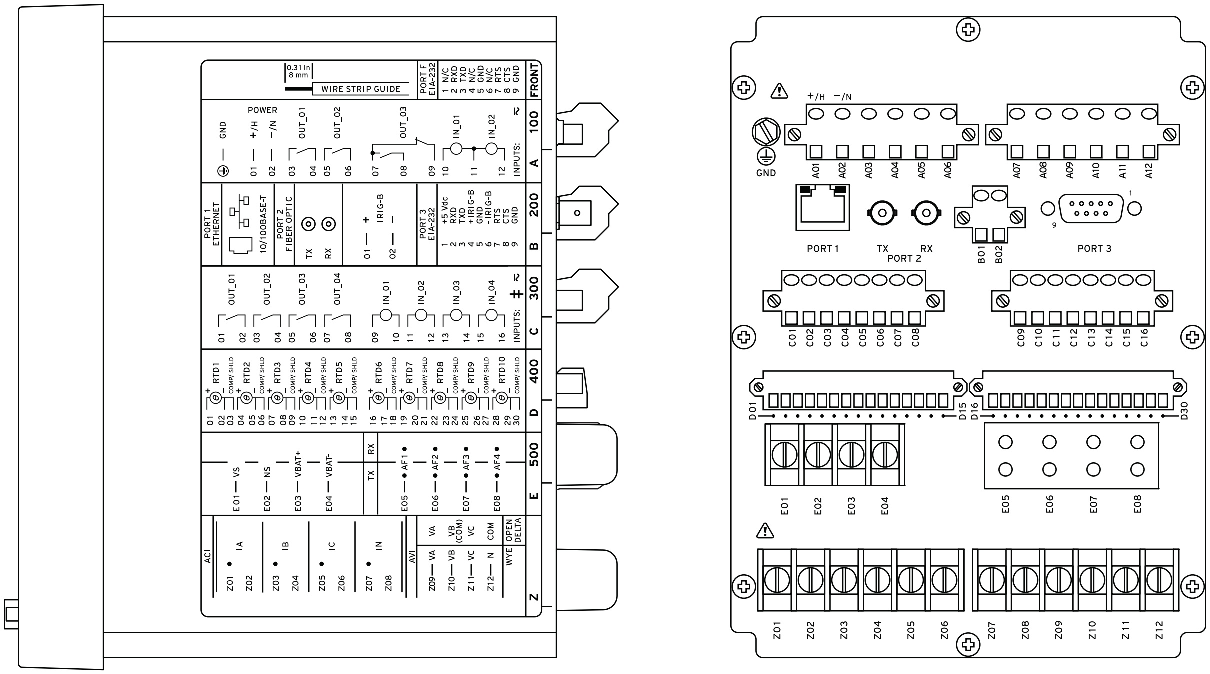
Figure 39 Front Panel With Default Configurable Labels



(A) Side-Panel Input and Output Designations

(B) Rear-Panel Layout

Figure 40 Single Copper Ethernet, EIA-485 Communication, 8 DO (Form A) Card, 4 AI/4 AO Card, and 2 AVI/4 AFDI Voltage Option With Arc-Flash Detector Inputs (Relay MOT 787L201A2A6X70810320)

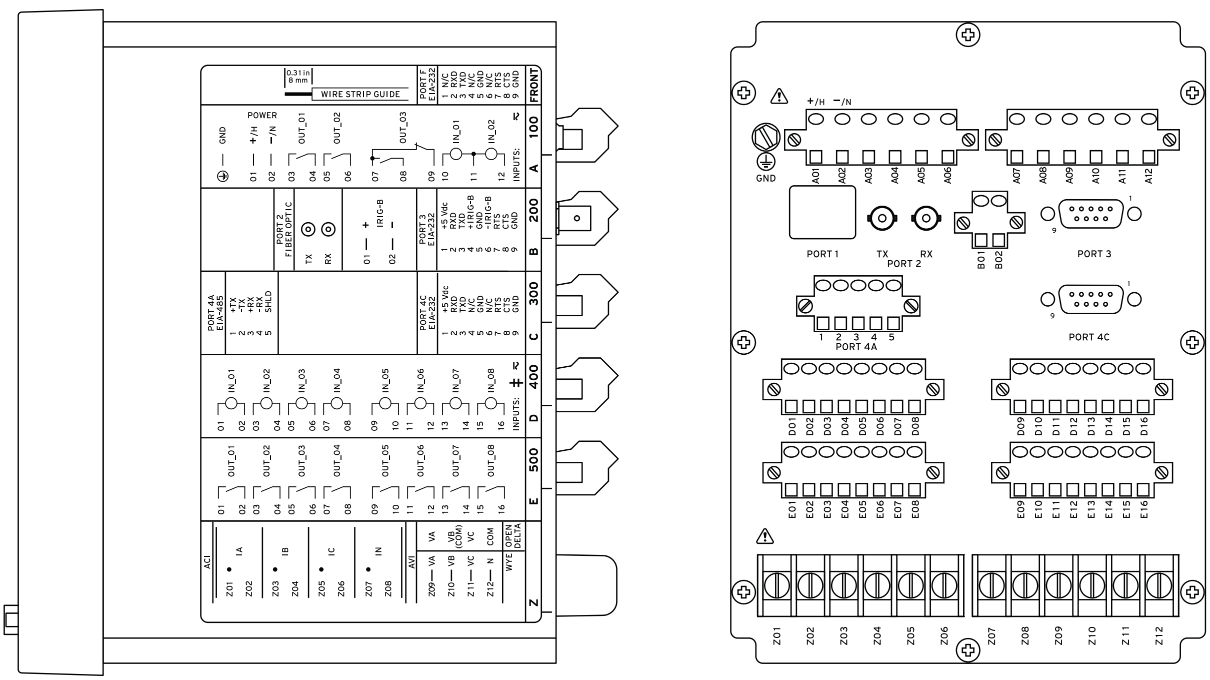


‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(A) Side-Panel Input and Output Designations

(B) Rear-Panel Layout

Figure 41 Single Copper Ethernet With EIA-232 Communication, 10 RTD Card, 4 DI/4 DO Card, and 2 AVI/4 AFDI Voltage Option Card With Arc-Flash Detector Inputs (Relay MOT 787L401A1A9X70850230)

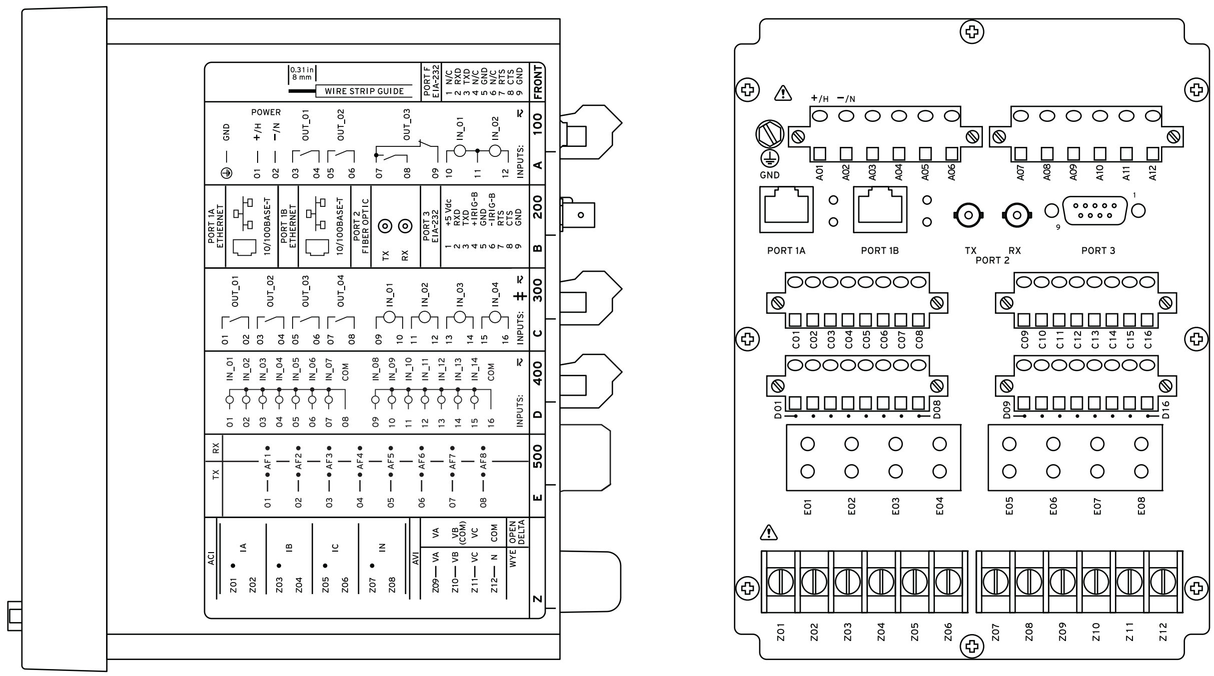


‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(A) Side-Panel Input and Output Designations

(B) Rear-Panel Layout

Figure 42 No Ethernet, EIA-232 Serial Communications, EIA-232/EIA-485 Communications Card, 8 DI Card, and 8 DO Card (Form A) (Relay MOT 787L401AA03A2A850000)

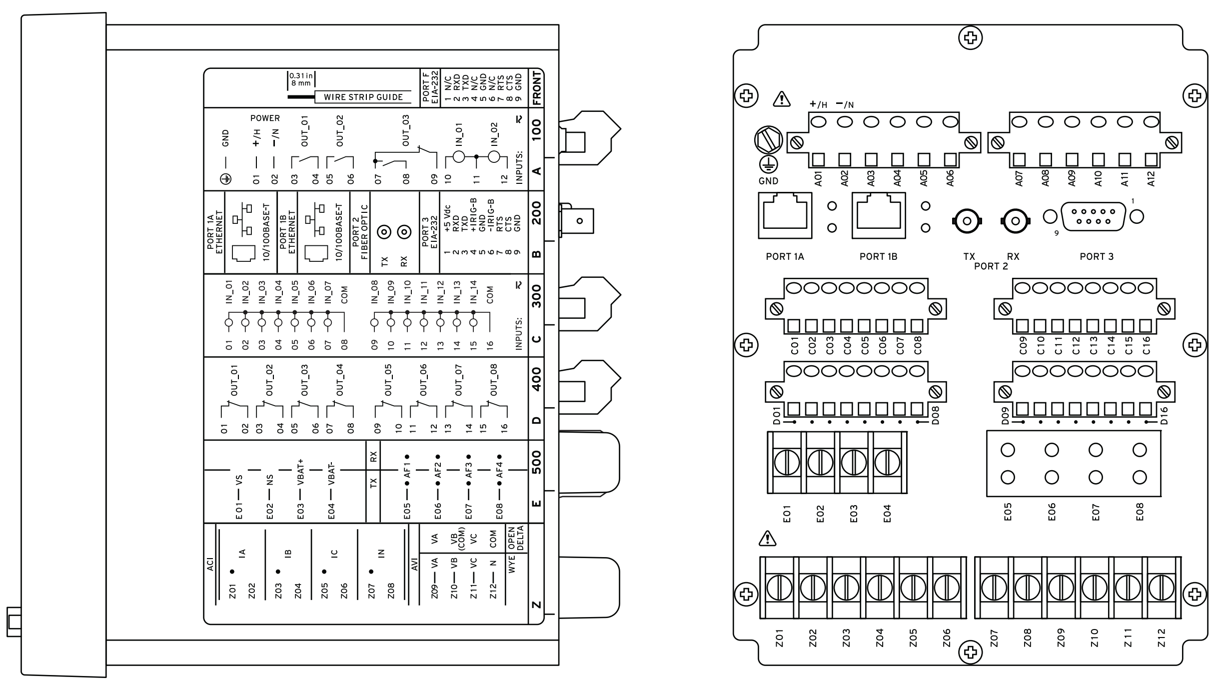


‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(A) Side-Panel Input and Output Designations

(B) Rear-Panel Layout

Figure 43 Dual Copper Ethernet, 4 DI/4 DO Card, 14 DI Card, 8 AFDI Card With Arc-Flash Detector Inputs, 4 ACI/3 AVI Card With 5 A Phase, 200 mA Neutral, and 3-Phase AC Voltage Inputs (300 Vac) (Relay MOT 787L501A1A4A77870671)

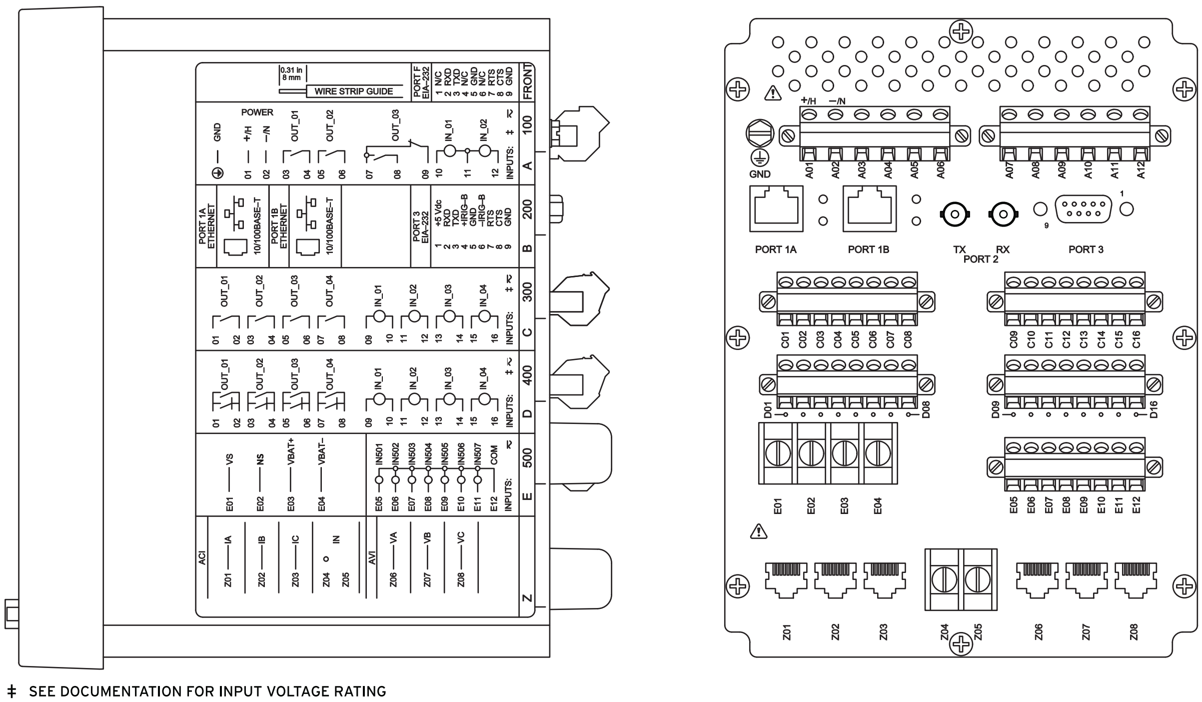


‡ SEE DOCUMENTATION FOR INPUT VOLTAGE RATING

(A) Side-Panel Input and Output Designations

(B) Rear-Panel Layout

Figure 44 Dual Copper Ethernet, 14 DI Card, 8 DO (Form B) Card, 2 AVI/4 AFDI Card With LEA Vsync, Vbat Inputs, and 4 Arc-Flash Detection Inputs, 4 ACI/3 AVI Card With 5 A Phase, 200 mA Neutral, and 3-Phase LEA Voltage Inputs (8 Vac) (Relay MOT 787L501A4A2BL0L70671)



(A) Side-Panel Input and Output Designations

(B) Rear-Panel Layout

Figure 45 Dual 10/100 Base-T Ethernet, EIA-232 Rear Port, 4 DI/4 DO Card, Fast Hybrid 4 DI/4 DO Card, Vsync/Vbat 7 DI Card, and 4 ACI/3 AVI LEA Card (Relay MOT 787L001A1ACALA7LAF30)

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, please 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 50°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 ≤ +50°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 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 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
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
IEC 61869-13

AC Voltage Input

V_{NOM} (L-L) Setting Range: 20–250 V (if DELTA_Y := DELTA)
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)

	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)
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: <55 VA (ac)
<25 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: <25 W (dc)

Interruptions: 10 ms @ 24 Vdc
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: 6 A @ 70°C
4 A @ 85°C

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: 6 A @ 70°C
4 A @ 85°C

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*.

Optoisolated Control Inputs

When Used With DC Control Signals

Pickup/Dropout Time: Depends on the input debounce settings

250 V:	ON for 200.0–312.5 Vdc OFF below 150 Vdc
220 V:	ON for 176–275 Vdc OFF below 132 Vdc
125 V:	ON for 100.0–156.2 Vdc OFF below 75 Vdc
110 V:	ON for 88.0–137.5 Vdc OFF below 66 Vdc
48 V:	ON for 38.4–60.0 Vdc OFF below 28.8 Vdc
24 V:	ON for 15–30 Vdc OFF below 5 Vdc

When Used With AC Control Signals

Pickup Time: 2 ms

Dropout Time: 16 ms

250 V:	ON for 170.6–312.5 Vac OFF below 106 Vac
220 V:	ON for 150.2–275 Vac OFF below 93.3 Vac
125 V:	ON for 85–156.2 Vac OFF below 53 Vac
110 V:	ON for 75.1–137.5 Vac OFF below 46.6 Vac
48 V:	ON for 32.8–60 Vac OFF below 20.3 Vac
24 V:	ON for 14–30 Vac OFF below 5 Vac

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

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:	15–70 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, PRP, 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.

Optoisolated Control Inputs:	As many as 26 inputs are allowed in ambient temperatures of 85°C or less As many as 34 inputs are allowed in ambient temperatures of 75°C or less As many as 44 inputs are allowed in ambient temperatures of 65°C or less

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

144.0 mm (5.67 in) x 192.0 mm (7.56 in) x 147.4 mm (5.80 in)

Weight

2.7 kg (6.0 lb)

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)

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 (2-line display models) IP54 enclosed in panel (touchscreen models) 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.

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 2.5 kVac on contact I/O 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]:	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 IEC 60255-26:2013; Section 7.2.6 2.5 kV common mode 1 kV differential mode 1 kV common mode on comm. ports IEEE C37.90.1-2002 2.5 kV oscillatory 4 kV fast transient Comm. ports, IRIG, and PTC ports Zone B, 2 kV line-to-earth LEA ports compliant with IEC 61869-13 tested to 1 kV, 1 MHz common mode
Conducted RF Immunity:	IEC 61000-4-6:2008 IEC 60255-26:2013; Section 7.2.8 10 Vrms
Magnetic Field Immunity:	IEC 61000-4-8:2009 IEC 60255-26:2013, Section 7.2.10 Severity Level: 1000 A/m for 3 seconds 100 A/m for 1 minute; 50/60 Hz IEC 61000-4-9: 2001 Severity Level: 1000 A/m IEC 61000-4-10:2001 Severity Level: 100 A/m (100 kHz and 1 MHz)
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 61000-4-17:1999 IEC 61000-4-29:2000 IEC 60255-26:2013, Section 7.2.11 IEC 60255-26:2013, Section 7.2.12 IEC 60255-26:2013, Section 7.2.13

EMC Emissions

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

Processing Specifications and Oscillography

AC Voltage and Current Inputs:	32 samples per power system cycle
Frequency Tracking Range:	15–70 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 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.
Processing Rate:	Once every 2 power system cycles

Oscillography

Length:	15, 64, 180, or 300 cycles
Sampling Rate:	32 samples per cycle unfiltered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII 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 Elements (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
Pickup/Dropout Time:	<2.25 cycles (with fast hybrid output contacts)

87L Tapped Load Inverse-Time Overcurrent Elements (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) ±5% of setting plus ±0.02 • I_{NOM} A secondary (transient) ±6% of setting plus ±0.02 • I_{NOM} A secondary (transient for 50Q)
Time Delay:	0.00–400.00 seconds, 0.01 seconds steps
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Reset Ratio:	95% for setting ≥0.1 • I_{NOM} 90% for setting <0.1 • I_{NOM}
Transient Overreach:	<15% for X/R = 10–120
Overshoot Time:	5 ms

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

Arc-Flash Time-Overlight (TOL1–TOL8)

Pickup Setting Range, % of Full Scale:	3.0–80.0% (point sensor) 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 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
Pickup/Dropout Time:	<1.5 cycles

IEC Thermal Element (49IEC)

Setting Range:	Trip pickup, 1%–150% Alarm pickup, 1%–100%
Pickup Accuracy:	±2% (for $I \geq I_{NOM}$) ±5% (for $0.4 \bullet I_{NOM} < I < I_{NOM}$)
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) 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
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Reset Ratio:	106% for setting ≤ 10 V 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) 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
Pickup/Dropout Time:	<1.75 cycles (with fast hybrid output contacts)
Reset Ratio:	96% for setting ≤ 10 V 99% for setting > 10 V
Overshoot:	35 ms

Incipient Cable Fault (50INC)

Pickup Setting Range, A Secondary:	OFF, 0.50–50.00 A (phase), 0.01-A steps for 5 A 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) 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 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) 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 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 Elements (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) ±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
Pickup/Dropout Time:	<10 cycles

Power Factor (55)

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

Frequency (81)

Setting Range:	Off, 15.00–70.00 Hz
Accuracy:	±0.01 Hz (V1 >60 V) with voltage tracking ±0.05 Hz (I1 >$0.8 \bullet I_{NOM}$) with current tracking

Time Delay:	0.00–400.00 seconds, 0.01-second steps
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
Time Delay:	0.10–60.00 seconds, 0.01-second steps

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 3 mA secondary for 1 A
Operating Time (After the Conductor Breaks and Series Arc Extinguishes):	4–8 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

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) ±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)
Voltage Unbalance (%):	±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.

Technical Support

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

Schweitzer Engineering Laboratories, Inc.
2350 NE Hopkins Court
Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.338.3838
Fax: +1.509.332.7990
Internet: selinc.com/support
Email: info@selinc.com

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.332.1890 • Fax: +1.509.332.7990
selinc.com • info@selinc.com

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