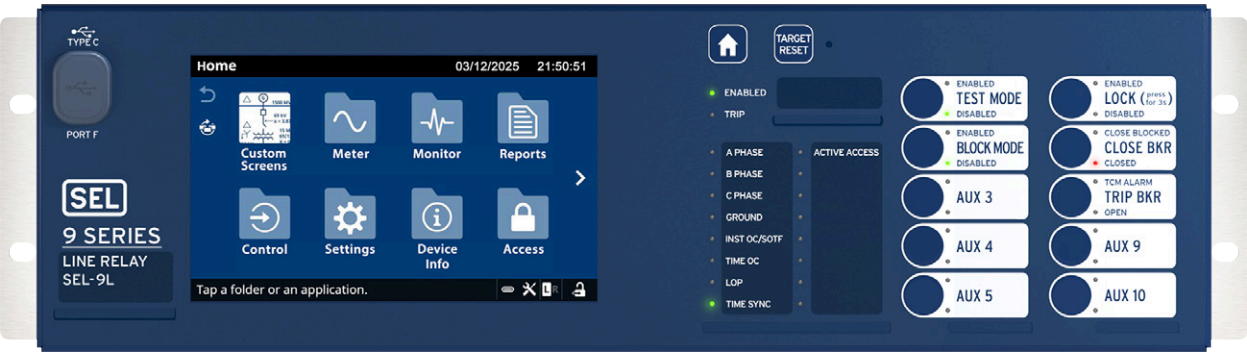
SEL-9L Line Relay



Overview

The SEL-9L Line Relay brings four decades of SEL line protection experience to the new 9 Series relay platform. The 9 Series platform provides powerful hardware, common firmware, and flexible communications with a focus on usability.

Key Features

- **Single- and Dual-Breaker Terminal Support.** One set of three-phase current inputs and a dedicated neutral current input comes standard, with a second set of current inputs and an additional dedicated neutral current input available as an ordering option.
- **Line Current Differential[a].** Two-, three-, or four-terminal line current differential protection using self-installable SFPs with direct fiber (as long as 120 km) or IEEE C37.94 multiplexed communications. Line charging current compensation is included. Backward-compatible with the SEL-311L Line Current Differential Protection and Automation System over IEEE C37.94.
- **Distance Protection.** Five phase and ground distance zones that can be configured with mho or quadrilateral characteristics. Built-in logic for POTT, DCB, and DTT pilot schemes.
- **Reclosing and Synchronism Check.** Integrated reclosing logic for single or dual breakers and synchronism check to supervise closing across an open breaker.
- **Breaker Failure.** Integrated breaker failure logic for single or dual breakers.
- **Universal Hardware.** A power supply and contact inputs that accept a variety of voltages, VT inputs with invertible polarities, and CT inputs with invertible polarities that accept either 5 A or 1 A nominal CTs make ordering easy.
- **Flexible Communications.** Six available SFP ports allow for applications of 1 Gbps and 100 Mbps Ethernet, 87L protection (direct fiber or IEEE C37.94), and the new MIRRORED BITS 16 protocol.
- **Flexible and Safe CT and VT Connections.** Polarity reversal settings for each CT input and each set of VT inputs can be used to correct for errors in field wiring or CT use across multiple protection zones. CT terminal blocks automatically short the CT leads upon removal to improve personnel safety.
- **Advanced I/O Monitoring.** Three contact outputs with integrated circuit monitoring allow for recording the voltage across and the current through the outputs. Because these values are also available to use in custom logic, circuit monitoring functions can be programmed in the relay without any additional wiring. Voltage across the inputs is also recorded and available for use in SELOGIC® control equations.

- **Device Mode and Behavior.** Simplify testing and settings changes by locally or remotely putting the relay into a test mode in which physical contact outputs will not operate.
- **Touchscreen.** Operate the relay and gather data by launching apps on a 7-inch touchscreen.
- **Simpler Event Reports.** Analyze most operations using a single 1 kHz event report that contains raw and filtered current and voltage data as well as the status of all Relay Word bits in the relay. A 10 kHz raw report is also available to analyze high-resolution power system activity.
- **Cybersecurity.** Improve your security infrastructure with secure booting of digitally signed firmware, role-based access control (RBAC), a comprehensive device audit log[a], Syslog[a], secure communications using Transport Layer Security (TLS)[a], and secure file transfer over FTPS[a].
- **Expanded Networking Functions.** Create flexible networks with Parallel Redundancy Protocol (PRP), failover, and three independent IP addresses on as many as six Ethernet ports.
- **Powerful Protocols.** Communicate at protection speeds with IEC 61850 Ed. 2.1 (GOOSE, MMS, and MMS File Transfer), IEC 61869-9:2016 Sampled Values[a], MB16, and MB8 protocols. Accurately synchronize time with PTP[a], SNTP[a], and IRIG-B protocols. DNP3 and FTP are also available.

[a] Available via future firmware upgrade.

Hardware Overview

Figure 1 shows the SEL-9L front panel. It includes a USB-C port for engineering access, a 7-inch color touchscreen, 38 programmable tricolor LEDs, and 10 programmable pushbuttons with configurable labels.

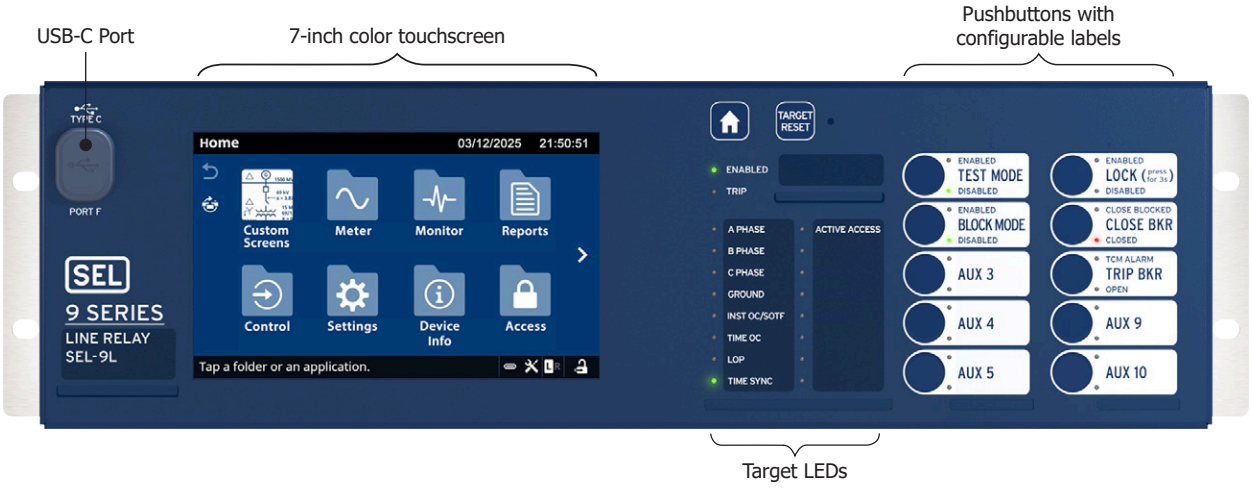


Figure 1 Front Panel

Figure 2 shows the SEL-9L rear panel. All CT inputs come with self-shorting connectors that automatically short the CT leads when the terminal blocks are removed from the relay. All CT inputs universally accept either 5 A or 1 A nominally rated CTs.

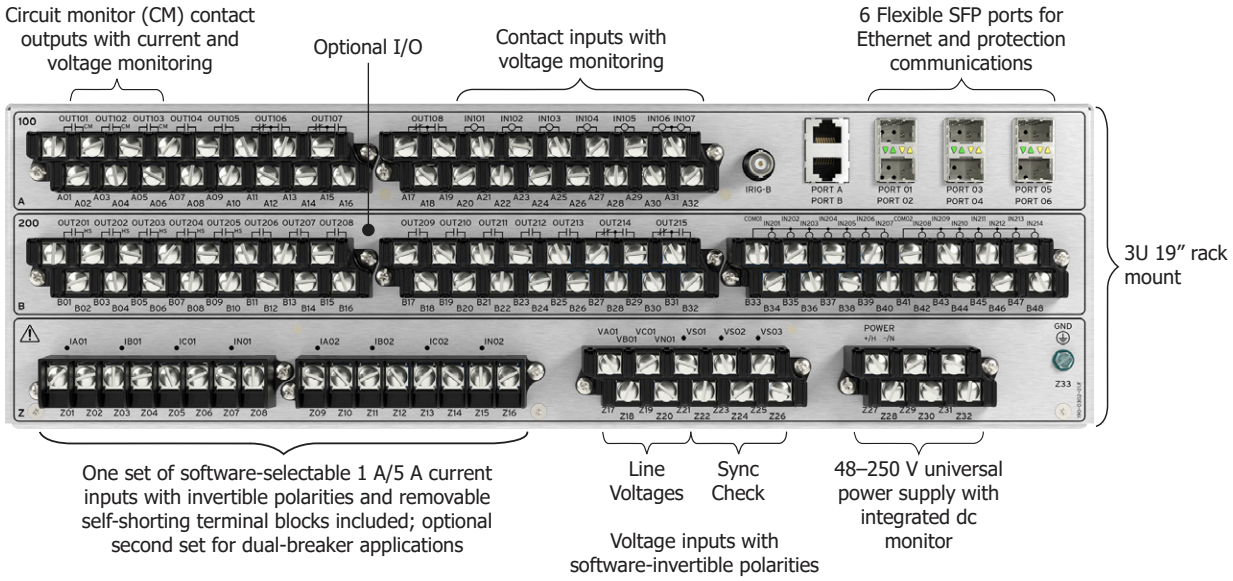


Figure 2 Rear Panel

The SEL-9L includes one set of VT inputs, typically used to measure line voltage, and an additional three single-phase VT inputs that can be used for synchronism-check applications. VTs must be connected in wye and output a voltage of 0–300 Vac rms.

The polarity of each individual CT input and each set of VT inputs can be inverted using relay settings.

The SEL-9L includes a variety of different types of contact inputs and outputs. The operating voltages of the contact inputs are set individually via software. The contact outputs have no voltage settings and can operate over a wide range of voltages as defined in *Specifications on page 27*. More details on the different contact I/O available in the relay can be found in *CT Input Options on page 3*.

CT Input Options

The SEL-9L can be ordered with either one set of CT inputs (A, B, C, and N) for single-breaker applications or two sets of CT inputs for dual-breaker applications.

Contact I/O Options

The SEL-9L comes standard with the top row of contacts shown in *Figure 2*. These contacts are described in *Table 1*.

Table 1 Standard Contact I/O

Quantity	Type	Description
Contact Outputs		
3	Circuit Monitoring, Form A	High-speed, high-current-interrupting with built-in circuit monitoring. Require dc voltage, but are not polarity-dependent.
2	Standard Form A	Operate on dc or ac voltage; not polarity-dependent.

Quantity	Type	Description
3	Standard Form C	Operate on dc or ac voltage; not polarity-dependent.
Contact Inputs		
5	Individual	Each input can be individually set to operate on 24 Vdc, 48 Vdc, 110 Vdc, 125 Vdc, 220 Vdc, 250 Vdc, 110–120 Vac, or 220–240 Vac.
2	Shared reference	

The second row of contacts shown in *Figure 2* is optional and is described in *Table 2*.

Table 2 Optional Contact I/O

Quantity	Type	Description
Contact Outputs		
5	High-Speed Form A	High-speed, high-current-interrupting. Require dc voltage, but are not polarity-dependent.
8	Standard Form A	Operate on dc or ac voltage; not polarity-dependent.
2	Standard Form C	Operate on dc or ac voltage; not polarity-dependent.
Contact Inputs		
14	2 sets of 7, each with a shared reference	Each input can be individually set to operate on 24 Vdc, 48 Vdc, 110 Vdc, 125 Vdc, 220 Vdc, 250 Vdc, 110–120 Vac, or 220–240 Vac.

Accessory Options

The SEL-9L comes standard with a single 100 Mbps Ethernet SFP (SEL part number 8109-01). Additional SFPs can be ordered for use in various applications. *Table 8* provides a list of available SFPs.

Functional Overview

Firmware Features

The firmware in the SEL-9L comes with a base feature package that includes a basic set of protection elements and features. Most transmission line applications will require protection features beyond this base set. You can add optional features as needed to obtain the necessary protection elements and protocols for your specific application. Optional features can be specified at the time of order or added at a later time through a feature file upgrade.

Figure 3 shows the features available in the SEL-9L base feature package (black) as well as available optional features (blue). Each of these features is described in *Table 3* (with both IEEE and IEC 61850 naming conventions, if defined) and detailed further in this data sheet.

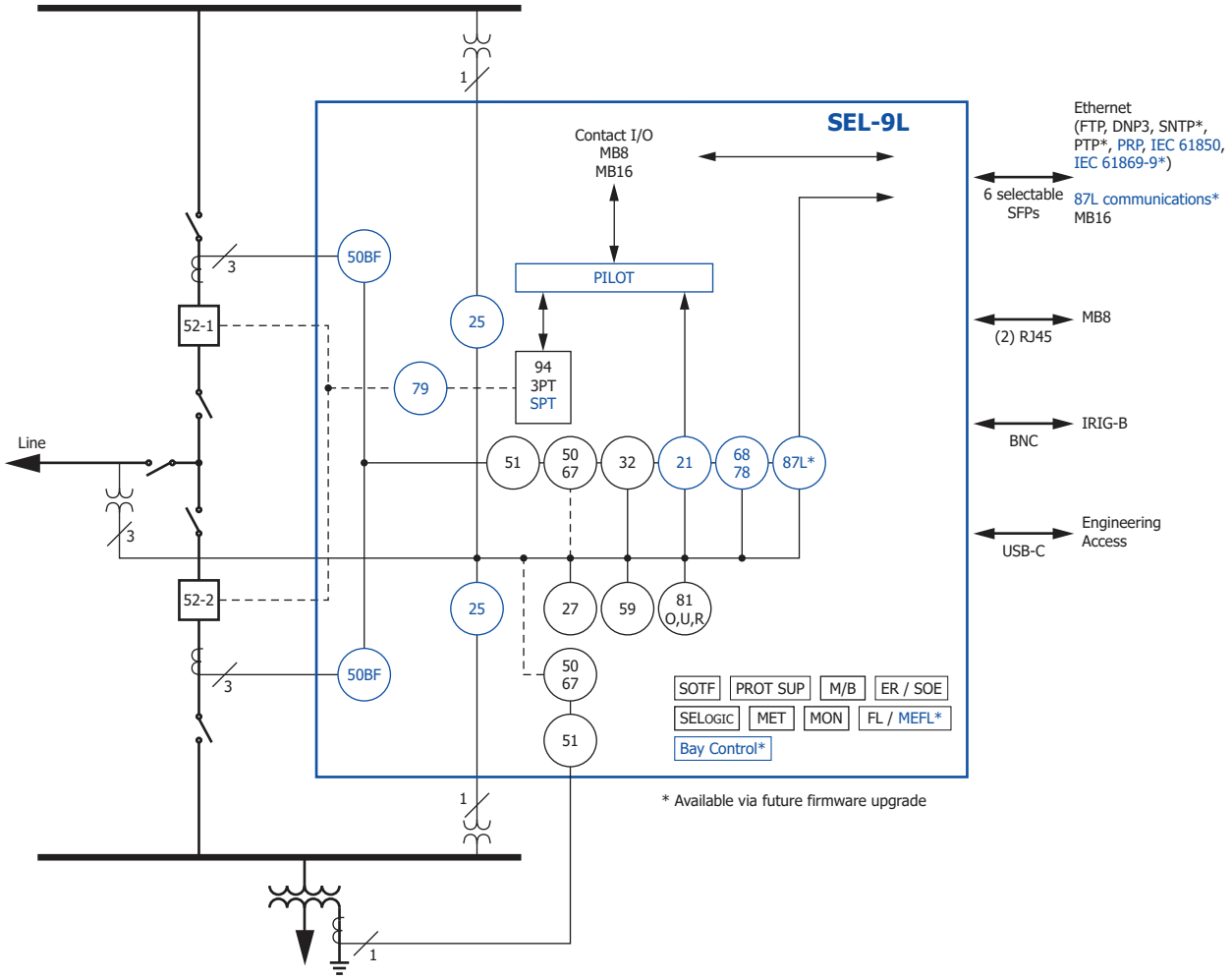


Figure 3 Feature Overview

Table 3 Descriptions of Base and Optional Features

Feature	Description	Quantity/Notes
Base Package		
27 (PTUV)	Undervoltage	Four phase-to-neutral elements (27P). Two phase-to-phase (27PP), positive-sequence (27Pos), VS1, VS2, and VS3 elements. (See *(27) Undervoltage on page 10*)
32 (PDUP/PDOP)	Directional power	Four three-phase underpower (32Un) and overpower (32Ov) elements. (See *(32) Directional Power on page 10*)
50/67 (PIOC/PDOC)	Instantaneous and definite-time directional overcurrent	Six phase-to-neutral (50P, 67P), negative-sequence (50Neg, 67Neg), residual ground (50Gnd, 67Gnd), and neutral (50N, 67N) instantaneous or definite-time elements with optional directionality. Six phase-to-phase (50PP) nondirectional instantaneous elements. (See *(50/67) Instantaneous and Definite-Time Directional Overcurrent on page 11*)
51 (PTOC)	Inverse-time overcurrent	Five maximum phase (51P), negative-sequence (51Neg), residual ground (51Gnd), and neutral (51N) elements. (See *(51) Inverse-Time Overcurrent on page 11*)
59 (PTOV)	Overvoltage	Four phase-to-neutral (59P) elements. Two phase-to-phase (59PP), positive-sequence (59Pos), negative-sequence (59Neg), residual ground (59Gnd), VS1, VS2, and VS3 elements. (See *(59) Overvoltage on page 11*)

Feature	Description	Quantity/Notes
81O, U, R (PTOF, PTUF, PFRC)	Overfrequency, underfrequency, and rate-of-change-of-frequency	Six overfrequency (81Ov), underfrequency (81Un), and rate-of-change-of-frequency (81R) elements. (See *(81/81R) Frequency on page 12*)
SOTF	Switch onto fault	(See *Switch Onto Fault on page 12*)
PROT SUP	Protection supervisory elements	(60LOP) Loss of Potential Directional control Load encroachment Pole-open detection Open-phase detection Disturbance detection Fault-type identification (See *Protection Supervision on page 13*)
3PT (PTRC)	Three-pole tripping	(See *Trip Logic on page 14*)
SELOGIC	User-defined custom logic	100 each: SELOGIC variables, math variables, latch bits, conditioning timers, sequencing timers, and counters. (See *Protection Logic on page 14*)
FL (RFLO)	Single-ended fault location	(See *Fault Location on page 18*)
MET	Metering	(See *Instantaneous Metering on page 9*)
MON	Monitoring	DC monitoring (see *DC Monitor on page 16*) Trip/close circuit monitoring (see *Trip/Close Circuit Monitor on page 17*)
ER/SOE	Event reporting and SOE reports	(See *Reports on page 17*)
M/B	Device mode and behavior	(See *Device Mode and Behavior on page 8*)
Ethernet	1 Gbps and 100 Mbps	Relay includes one 100 Mbps SFP. Additional SFPs can be ordered. Protocols: FTP, DNP3, SNTP[a]. (See *Communications on page 20*)
MB16	MIRRORED BITS 16	Two channels (Ports 5 and 6). (See *MIRRORED BITS Communications on page 21*)
MB8	MIRRORED BITS 8	Two channels (Ports A and B). (See *MIRRORED BITS Communications on page 21*)
IRIG-B	Time protocol	(See *Date and Time on page 9*)
PRP	Parallel Redundancy Protocol	(See *Parallel Redundancy Protocol (PRP) on page 22*)
Distance (Optional)		
21 (PDIS)	Step distance	Five zones of mho or quad for phase (21P) and ground (21Gnd) elements. Includes coupling capacitor voltage transformer (CCVT) transient detection. (See *(21) Distance on page 9*)
68, 78 (RPSB)	Power-swing blocking and tripping	Zero settings. (See *(68/78) Power-Swing Blocking and Tripping on page 11*)
Pilot (Optional)		
PILOT (PSCH)	Pilot schemes	POTT, DCB, and DTT. (See *Pilot on page 12*)
Line Current Differential (Optional)[a]		
87L (PDIF)	Line current differential	(See *(87L) Line Current Differential on page 12*)
MEFL (RFLO)	Multi-ended fault location	(See *Fault Location on page 18*)

Feature	Description	Quantity/Notes
Single-Pole Tripping and Pilot (Optional)		
SPT (PTRC)	Single-pole tripping, reclosing, and pilot schemes	(See *Trip Logic on page 14*)
Breaker Failure (Optional)		
50BF (RBRF)	Breaker failure	One or two breakers. (See *(50BF) Breaker Failure on page 11*)
Reclosing and Sync Check (Optional)		
79 (RREC)	Reclosing	As many as four shots of reclosing in three-pole mode and one shot of reclosing in single-pole mode. Includes integrated leader/follower logic for dual-breaker applications. (See *(79) Autoreclosing on page 16*)
25 (RSYN)	Synchronism check	Three elements with two levels each. (See *(25) Synchronism Check on page 16*)
Bay Control (Optional)[a]		
Bay Control (XCBR, CSWI)	Control breakers and disconnects	Control as many as two breakers and ten disconnect switches using a custom one-line diagram on the touchscreen. (See *Bay Control on page 16*)
Individual Protocols (Optional)		
PTP[a]	Precise Time Protocol	(See *Date and Time on page 9*)
IEC 61850	Share analog and digital data with other devices	IEC 61850 GOOSE, IEC 61850 MMS. (See *IEC 61850 Edition 2.1 on page 23*)
IEC 61869-9 SV Publication[a]	Sampled Values	IEC 61850 GOOSE, IEC 61850 MMS, and IEC 61869-9 Sampled Values Publication. (See *IEC 61869-9 Sampled Values on page 23*)

[a] Available via future firmware upgrade.

Popular Models

To simplify configuration, popular models of the SEL-9L are available to order with preconfigured features for the most common applications, such as retrofitting SEL-311C Transmission Protection Systems or SEL-311L Line Current Differential Protection and Automation Systems.

Device Functions

Settings Groups

Using settings groups in the SEL-9L is not required. For simple applications, only one group of protection and logic settings can be enabled. For more advanced applications, as many as six settings groups can be enabled. These groups can be used to adapt protection to changing system conditions, such as seasonal operations, station maintenance, or emergency contingencies. Select the active settings group using a contact input, front-panel pushbutton, or other programmable conditions.

Device Mode and Behavior

When relay testing is being performed or settings are being changed, the contact outputs of the relay are typically isolated from the trip and close coils of the circuit breakers to avoid unnecessary breaker operation. This isolation is typically done using physical switches on the panel.

The SEL-9L supports a method (defined by IEC 61850-7-4) that emulates these isolation functions within the relay itself. At any given time, the relay is in one of the device modes shown in *Table 4*. Each of these modes defines a different type of relay behavior regarding whether the physical contact outputs will operate or not and how communications protocol messages are sent and received. Remote relays can be programmed to enter a specific device mode based on the device mode of the relay they are communicating with. The ability to remotely block the contact outputs on a remote relay from operating allows more flexibility when designing commissioning procedures, running tests, and performing maintenance.

The SEL-9L supports device modes for the IEC 61850 MMS, IEC 61850 GOOSE, IEC 61869-9 Sampled Values (available via future firmware upgrade), and MIRRORED BITS 16 protocols. These device modes come standard in the base package of the SEL-9L—purchasing the IEC 61850 protocol package is not necessary to use them.

Table 4 Device Modes and Behaviors

Device Mode	Relay Enabled	Physical Contact Output Behavior	Communications Behavior	Notes
On	Yes	Allowed to operate	Send outgoing communications with test flag = False. Receive incoming communications with test flag = False. Ignore incoming communications with test flag = True.	Standard operating mode. Relay is active and will operate physical contact outputs.
On-Blocked	Yes (**ENABLED** LED blinks)	Not allowed to operate	Send outgoing communications with test flag = False. Receive incoming communications with test flag = False. Ignore incoming communications with test flag = True.	Relay is active, but will not operate physical contact outputs.
Test	Yes (**ENABLED** LED blinks)	Allowed to operate	Send outgoing communications with test flag = True. Receive all incoming communications.	Used for testing and operating physical contact outputs.
Test/Blocked	Yes (**ENABLED** LED blinks)	Not allowed to operate	Send outgoing communications with test flag = True. Receive all incoming communications.	Used for testing without operating physical contact outputs.
Off	No	Not allowed to operate	Send outgoing communications with test flag = False and validity flag = Invalid. Ignore most incoming communications.	Relay is disabled.

Instantaneous Metering

The SEL-9L provides metering data that are averaged over a 250 ms interval, including the following:

- Phase, neutral, and positive-, negative-, and zero-sequence current magnitudes and angles
- Phase and positive-, negative-, and zero-sequence voltage magnitudes and angles
- Real (kW), reactive (kVAR), and apparent power (kVA)

Date and Time

The SEL-9L can receive an IRIG-B signal through the BNC port on the back of the relay for high-accuracy timekeeping. It can also receive a time signal via SNTP over an Ethernet network (available via future firmware upgrade). For higher-accuracy timing over Ethernet, the relay can use IEEE 1588 Precision Time Protocol version 2 (PTPv2) (available via future firmware upgrade). When connected directly to a time transmitter clock providing PTP at one-second synchronization intervals, the relay can be synchronized to an accuracy of ±100 ns. The relay can receive as many as 32 sync messages per second.

Protection

(21) Distance

The SEL-9L provides five phase and ground distance element zones. Each type of distance element (phase and ground) for each zone can be configured with either a mho or quadrilateral characteristic. Zones 1–4 are directional zones, which are set to reach in the forward or reverse direction. The zone direction setting applies to both the phase and ground distance elements of that zone. Zone 5 is nondirectional (offset), with separate reach settings for forward and reverse.

Each ground zone uses its own zero-sequence compensation (ZSC) factor. The ZSC factors can be set automatically by the relay using the line impedance settings or they can be set individually for each zone based on short-circuit studies.

Each distance zone is supervised by LOP logic (see *(60LOP) Loss of Potential on page 13*) as well as an associated torque-control equation that can be used to enable or disable the element based on system conditions.

When CCVTs are being used to measure voltage, the automatic CCVT transient security logic controls the Zone 1 phase and ground distance elements to avoid overreaching without any settings necessary.

Figure 4 shows the performance times of the distance elements for a range of faults, locations, and source-to-impedance ratios (SIR).

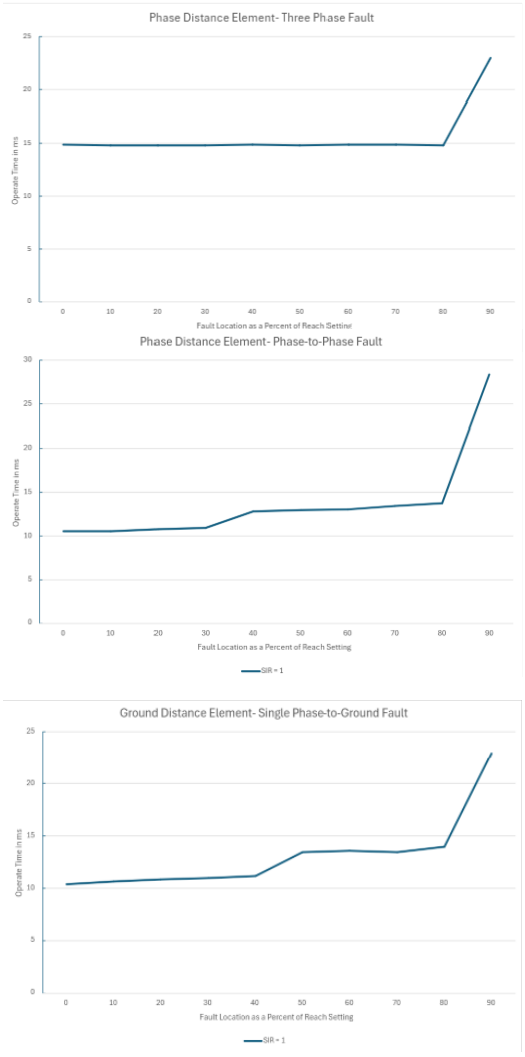


Figure 4 Distance Zone 1 Median Operating Time for Varying Fault Types, Locations, and SIRs

(27) Undervoltage

The SEL-9L includes four levels of undervoltage elements that operate on phase-to-neutral voltages, two levels that operate on phase-to-phase voltages, and two levels that operate on positive-sequence voltage. In addition, there are two levels of undervoltage elements that operate on each phase of the second set of relay voltage inputs (VS1, VS2, and VS3). Each element includes a torque-control equation to enable or block the element based on system conditions as well as an optional definite-time delay.

(32) Directional Power

The SEL-9L includes eight directional power elements that operate on line quantities: four underpower and four overpower. Each group of four elements can be set to operate on three-phase or single-phase power, and each individual element can be set to operate on watts or vars in the forward or reverse direction.

(50/67) Instantaneous and Definite-Time Directional Overcurrent

The SEL-9L includes six levels of maximum phase, negative-sequence, and residual-ground overcurrent elements. Forward or reverse directionality can be added to each of the six levels. There are also six levels of neutral overcurrent elements for each of the neutral current inputs on the relay (as many as two). All the phase, negative-sequence, ground, and neutral overcurrent elements can be applied as instantaneous elements or definite-time elements and include torque-control logic.

In addition, the relay includes six levels of phase-to-phase nondirectional instantaneous overcurrent elements.

(50BF) Breaker Failure

The SEL-9L detects single- and multi-phase failures and issues retrips for as many as two breakers. High-speed open-phase detection logic (see *Protection Supervision on page 13*) supervises the breaker failure element, allowing its current pickup to be set below minimum load. Due to the speed of the logic, an open breaker can be detected quickly even when subsidence current delays the current zero-crossings measured by the relay. This allows for faster breaker failure coordination times and allows for easier coordination with power system stability margins.

(51) Inverse-Time Overcurrent

The SEL-9L includes five levels of maximum phase, negative-sequence, residual-ground, and neutral inverse-time overcurrent elements. These elements support all the customary parameters, such as torque control, curve type (US U1–U5, IEC C1–C5, IEEE E1–E3), and reset time.

(59) Overvoltage

The SEL-9L includes four levels of overvoltage elements that operate on phase-to-neutral voltages and two levels of overvoltage elements that operate on phase-to-phase, positive-sequence, negative-sequence, and residual ground voltages. In addition, there are two levels of overvoltage elements that operate on each phase of the second set of relay voltage inputs (VS1, VS2, and VS3). Each element includes a torque-control equation to enable or block the element based on system conditions as well as an optional definite-time delay.

(68/78) Power-Swing Blocking and Tripping

The SEL-9L includes settings-free power-swing blocking and tripping logic based on the impedance-rate-of-change operating principle. When the change in impedance over time is moving at a speed consistent with a power swing and in a constant direction, the relay declares a stable power swing and blocks the distance elements from operating. If the change in impedance over time changes to being inconsistent with a power swing, the distance element is unblocked.

The power-swing blocking logic can be enabled for each distance zone individually. In addition, the relay implements the power-swing blocking logic independently for each phase and ground distance element, allowing it to reliably block healthy phases while detecting faults and selectively unblocking the faulted phases.

Included out-of-step tripping logic is used to trip for unstable power swings. For security, it follows the trip-on-the-way-out principle—meaning it only operates when an unstable power swing has already passed through the protected line and the system has slipped a pole. The out-of-step tripping logic also provides delayed tripping to avoid overvoltage conditions across the circuit breaker.

(81/81R) Frequency

The SEL-9L includes six underfrequency (81U), six overfrequency (81O), and six rate-of-change-of-frequency (81R) elements. Each element includes a torque-control equation to enable or block the element based on system conditions as well as a settable definite-time delay.

(87L) Line Current Differential

The SEL-9L will include line current differential protection for as many as four terminals in a future firmware upgrade. The element will use an adaptive-slope percent-restrained characteristic with built-in channel asymmetry detection and include line-charging current compensation to enhance the sensitivity of the 87L elements for protection of long high-voltage lines or cables. Communication between relays for the 87L element will be done via Port 5 or 6 via a direct fiber connection (up to 120 km) or an IEEE C37.94 multiplexed connection. See *Table 8* for a list of SFPs that can be used for the 87L communications channel.

Pilot

The SEL-9L includes preconfigured pilot schemes for permissive overreaching transfer trip (POTT), directional comparison blocking (DCB), and direct transfer trip (DTT). The pilot schemes can accept permissive and blocking signals via contact I/O, MIRRORED BITS, or a combination of the two. The pilot schemes can be applied to lines with any number of terminals by using SELOGIC control equations to AND permissive trip signals and OR blocking signals from all remote relays. In addition, SELOGIC control equations and programmable I/O or MIRRORED BITS can be used to implement other types of pilot protection schemes, such as permissive underreaching transfer trip (PUTT) and directional comparison unblocking (DCUB).

The preconfigured POTT scheme includes weak-infeed logic and line-open echo logic to add dependability during specific system conditions. Weak-infeed logic issues an echo to the remote end when the relay detects an abnormal voltage condition and does not see a reverse fault. Line-open echo logic issues an echo to the remote end when the local terminal is open.

Built-in current reversal logic uses the same type of elements that were selected (distance or overcurrent) to detect faults in the reverse direction, improving coordination for POTT and DCB schemes.

Switch Onto Fault

Switch-onto-fault (SOTF) logic solves the polarization and dependability concerns that affect distance and directional elements during and shortly after line energization and when reclosing after a line fault. The logic temporarily enables a short time window after energization during which specified protection

elements (typically instantaneous phase overcurrent and Zone 2 distance) are allowed to trip. The window opens immediately after the breaker closes and can be set to disable automatically either when the voltage stabilizes or after a set delay.

Protection Supervision

(60LOP) Loss of Potential

Distance and directional elements require correct voltage measurements to operate correctly. When a VT measurement is lost due to a blown fuse or other condition, these elements lose their ability to operate reliably. LOP logic detects a lost voltage condition and blocks affected elements from incorrectly operating. When an LOP condition occurs, distance elements are blocked, directional elements are blocked or set to nondirectional, and an alarm is asserted. The LOP element is very fast and can operate in time to block the Zone 1 distance element. The LOP element only needs to be enabled, with no additional settings required.

Directional Control

The SEL-9L uses directional control logic to determine if faults are in the forward or reverse direction. This logic includes three directional elements: phase, negative-sequence, and residual-ground. All three elements operate independently from each other.

The phase directional element is used to determine the direction of balanced three-phase faults. It can be used to directionalize the instantaneous, definite-time, and inverse-time phase overcurrent elements. The element is operational during single-pole tripping and reclosing and allows for detecting the direction of high-current faults during a single-pole open condition.

The negative-sequence directional element is used to determine the direction of any unbalanced fault. It can be used to directionalize the instantaneous, definite-time, and inverse-time ground and negative-sequence overcurrent elements.

The residual-ground directional element is used to determine the direction of unbalanced faults that include ground (phase-to-ground and phase-to-phase-to-ground). It can be used to directionalize the instantaneous, definite-time, and inverse-time residual-ground overcurrent elements.

Load Encroachment

Load-encroachment logic prevents load conditions from causing phase protection to operate. This allows you to set the phase distance and phase overcurrent elements independent of load. Load-encroachment logic can detect load in both directions (export or import) and has separate pickup thresholds for each direction for both phase and ground. Blocking angle settings are used for both phase and ground to define the leading and lagging power factor requirements. Use the provided settings to block specific distance zones and overcurrent elements during load conditions.

Pole-Open Detection

Pole-open detection logic determines if one or more phases of the protected line are disconnected from the local bus. The logic uses current measurements with either breaker status or voltage measurements to operate. Pole-open logic supervises a wide range of protection elements, including distance and directional elements.

Open-Phase Detection

Open-phase detection logic determines when current is not flowing through one or more of the local circuit breakers. The relay contains both standard open-phase detection and open-phase detection with subsidence. The latter method operates faster than the standard method when subsidence current exists.

Disturbance Detection

Disturbance detection logic monitors for small changes in the current and voltage on the power system to ensure that a disturbance has actually occurred, with no settings required. The logic improves security by supervising direct transfer trips and resizing the filtering window for impedance-based protection elements.

Fault-Type Identification

Fault-type identification logic identifies the faulted phases for all fault types, with no settings required. The method uses the angles between sequence quantities and the presence of zero-sequence current to distinguish between fault types.

Logic

Trip Logic

The SEL-9L can perform three-pole or single-pole tripping. The trip logic triggers event reporting and also seals in the trip contact output(s) until customizable unlatch conditions are met. In single-pole tripping applications, the trip logic selects the phases to trip and seals in the trip contact outputs on a per-phase basis. It also converts single-pole trips to three-pole trips based on the ability of the breaker to reclose, the autoreclose logic status, and operator preferences.

Protection Logic

Custom logic in the SEL-9L is done through freeform SELOGIC control equations written in SEL Grid Configurator. SELOGIC programming is a powerful tool that can be used to implement almost any custom protection or control scheme. The logic editor in SEL Grid Configurator, shown in *Figure 5*, allows users to control the processing order of their logic as well as create sections of logic for better organization. Users can also document their logic schemes by adding labels to their variables and comments throughout their logic. Automatic variable color-coding and autocomplete while typing makes writing logic more user-friendly than ever.

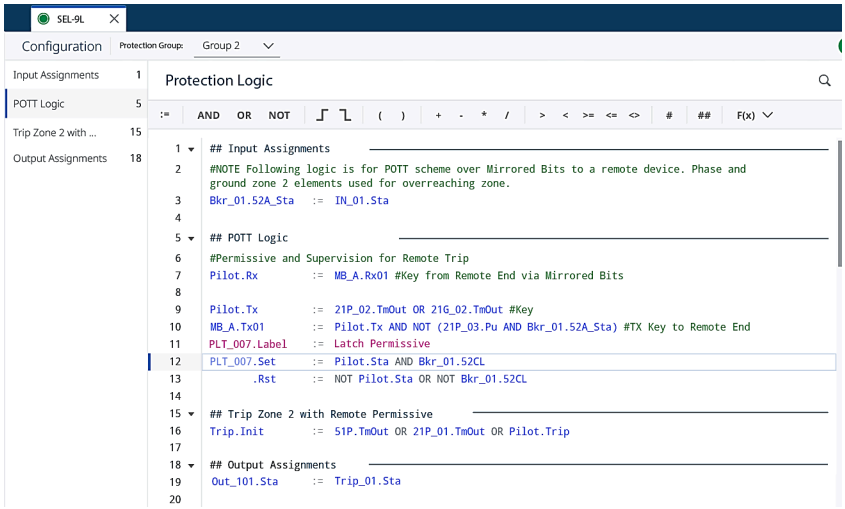


Figure 5 SELOGIC Editor in Grid Configurator

The SELOGIC programming available in the SEL-9L supports 1,500 lines, is processed every 1 ms, and includes the variety of logic elements shown in *Table 5*.

Table 5 SEL-9L Protection Logic Elements

Protection Logic Elements	Maximum Supported Instances
Logic Variables (PSV)	100
Math Variables (PMV)	100
Latch Bits (PLT)	100
Conditioning Timers (PCT)	100
Sequencing Timers (PST)	100
Counters (PCN)	100

Control

Breaker Voltage Source Selection

This logic allows selecting the primary voltage source for the line (incoming) and bus (running) voltages used in synchronism-check and voltage-check logic. You can also dynamically select as many as two alternate sources for the line-side voltage and one alternate source for the bus-side voltage. To account for differences in VT ratios, each source has independent scaling adjustments for magnitude and angle.

Voltage Checks

Live-line/dead-bus, dead-line/live-bus, and dead-line/dead-bus logic can be used to supervise breaker close operations via manual methods or autoreclosing.

(25) Synchronism Check

Synchronism-check elements can be used to block closing across an open breaker when the voltages on either side are not close enough in phase, magnitude, or frequency. The logic compensates for the breaker close time when the difference in frequencies on either side of the breaker is greater than a set limit, minimizing system stress when autoreclosing or closing manually. The SEL-9L includes three synchronism-check elements that can be programmed for a variety of applications. Each element has two levels of programmable angle thresholds that can be used to set different allowable conditions for manual closing and automatic reclosing.

(52) Breaker

Breaker control logic allows for the opening and closing of as many as two breakers through a variety of methods.

(79) Autoreclosing

The SEL-9L has as many as four shots of autoreclosing in three-pole mode and one shot of autoreclosing in single-pole mode. For dual-breaker applications, leader and follower breakers can be set permanently or change dynamically based on system conditions using SELOGIC control equations.

(89) Disconnect

Disconnect control logic allows for the opening and closing of as many as ten disconnect switches. Supported disconnect types are disconnectors, earthing switches, and inverse disconnectors.

Bay Control

Bay control functionality will be available in a future firmware upgrade. With this feature, the touchscreen of the SEL-9L can be used to display interactive bay control diagrams. The screen can be used to control as many as two breakers and monitor the status of a third. It can also control as many as ten disconnect switches. The bay control diagrams will include the ability to add user-configurable labels for the equipment shown as well as user-definable analog quantities to the screens.

Monitor

DC Monitor

The SEL-9L measures and reports the station battery voltage connected to the **+/H** and **–/N** power supply terminals. The measured dc voltage is reported in the meter display via the touchscreen, in the Grid Configurator online HMI, and in the event report. Programmable threshold comparators and associated logic provide alarms for the batteries and charger. The event report also provides an oscillography display of the battery voltage for monitoring of station battery voltage drop during tripping, closing, and other control operations.

Trip/Close Circuit Monitor

Contact outputs **OUT101** through **OUT103** are denoted with **CM** (see *Figure 2*), indicating they are Circuit Monitoring (CM) outputs. These high-speed, high-current-interrupting contact outputs include integrated measurements of the dc voltage across the output as well as the dc current flowing through the output, as shown in *Figure 6*. These measurements are provided as analog quantities that are available for use in SELOGIC programming and recorded in the event report for circuit and breaker analytics.

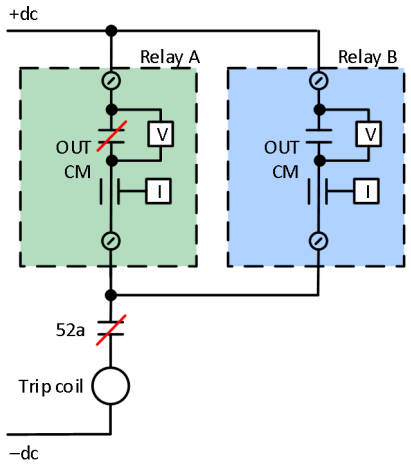


Figure 6 Measurement of Voltage Across and Current Through CM Contact Outputs

In addition, the built-in voltage measurement across the contact output can take the place of traditional trip circuit monitoring wiring, which requires the voltage across the trip contact to be measured via a separate parallel contact input. This allows trip circuit monitoring functions to be programmed in the relay without any additional wiring.

Reports

Event Reporting

The SEL-9L creates an event report whenever the relay trips or a specified trigger condition occurs. The total length of the event report is configurable, with a range from 0.25 to 5 seconds. Event reports are single .CFF files in COMTRADE IEEE C37.111-2013 format that can be downloaded using SEL Grid Configurator or a standard FTP client. There are two versions of each event report:

- Low-resolution (LR) event report
- High-resolution (HR) event report

The differences between the LR and HR event reports are shown in *Table 6*. For most relay operations, the LR event report provides all the information necessary for analysis. All data in *Table 6* is available in the event report without requiring any manual configuration.

Table 6 Differences Between Event Reports

Item	Low-Resolution (LR) Event Reports	High-Resolution (HR) Event Reports
Sample rate	1 kHz	10 kHz
Local currents and voltages at the terminals (oscillography)	Included as filtered data (only nominal frequency of 50 or 60 Hz) and raw data (all frequencies)	Included as raw data only (all frequencies)
Derived analog quantities (e.g., sequence components and calculated line current for dual-breaker applications)	Included	Not included
Relay element status (Relay Word bits)	Included	Not included
Contact input and output status	Included	Not included
Contact input voltage	Included (raw)	Not included
Received IEC 61850 GOOSE messages	Included	Not included
Received IEC 61869-9 Sampled Values messages[a]	Not included	Included
Relay settings at time of event trigger	Included	Included
Applications	Use the filtered data to analyze operations of relay elements that use phasor quantities. Use the raw data to analyze power system activity at off-nominal frequencies (e.g., CT saturation or transformer inrush) as well as analyze operations of relay elements that use raw 1 kHz quantities.	Analyze high-resolution power system activity and operations of relay elements that use raw 10 kHz quantities.

[a] Available via future firmware upgrade.

Each time the relay generates an event report, it also generates a corresponding event summary. This concise description of the event includes information such as the relay name, date and time of the event, measured voltages and currents, type of event, and relay targets that asserted during the fault.

Fault Location

The SEL-9L calculates the fault location for each event report using a single-ended impedance-based method. Multi-terminal fault location will be available in a future firmware upgrade when the 87L function is used.

Sequential Events Recorder (SER) and Sequence of Events (SOE)

The SEL-9L includes an SOE report, which helps users track relay element operation and status over a long period of time. The SOE report contains records of events such as settings changes and relay restarts. In addition, it includes the status of the bits that are configured in the relay's Sequential Events Recorder

(SER). The SER can be populated with as many as 250 digital elements that the user would like to monitor, such as the status of specific relay elements or contact I/O. Any time one of those elements asserts or deasserts, an entry is recorded in the SOE report. Each entry includes a date and time stamp, as well as the status of the element that changed. The SOE report stores as many as 4,096 records, which are retained even when the relay is powered off.

Diagnostics Report

In the rare case that the relay detects a failure or other diagnostic condition, it will trigger the creation of a diagnostic ZIP file. This file contains everything needed for SEL experts to diagnose the problem, including error logs, event reports, settings files, and more. The file can be easily downloaded using SEL Grid Configurator and sent to SEL for root-cause analysis.

Pushbuttons and LEDs

Status and Trip Target LEDs

The SEL-9L includes 38 tricolor LEDs on the front panel, as shown in *Figure 7*. By default, the LEDs on the left side reflect the status of protection elements inside the relay. Most of these LEDs function as targets that assert after a relay trip to let personnel know what elements caused the trip. The LEDs on the right side (next to each pushbutton) reflect the status of control functions that are operated by pushing the associated buttons. You can reprogram and relabel all of the LEDs (except **ENABLED** and **TRIP**) for any application.

Figure 7 Status and Trip Target LEDs

Pushbuttons

The ten pushbuttons in *Figure 7* come preprogrammed to perform the default functions described on the labels. These pushbuttons can be changed through settings to perform any desired function.

Configurable Labels

Configurable labels allow users to easily relabel targets, pushbuttons, and pushbutton LEDs when they are reprogrammed for custom applications. Each relay comes with a blank sheet of labels that can be used with a Microsoft Word template (available online at selinc.com) and a standard printer. It is also possible to write directly on the labels. The small label underneath the **TARGET RESET** button can be used to display the relay name or identifier.

Display

The SEL-9L comes with a 7-inch color touchscreen that makes viewing settings and metering data as well as operating controls quick and efficient. *Figure 8* shows some of the folders and applications that can be used to access information from the touchscreen.

Figure 8 Folders and Applications on the Touchscreen

These applications allow you to perform the following:

- View relay settings, relay status, and firmware version
- View metering and monitoring data
- View event history, summary data, and SOE reports
- Control breaker operations
- Enable the rotating display
- View and control bay screens (available via future firmware upgrade)

Communications

Ports

In addition to the front USB-C port (Port F), there are eight communication ports on the back of the SEL-9L, as shown in *Figure 9*. The RJ45 serial ports labeled **PORT A** and **PORT B** are used to communicate MIRRORED BITS 8 protocol. The remainder of the ports (**PORT 01**–**PORT 06**) are software-configurable SFP fiber-optic LC ports that can be used for a variety of applications, as shown in *Table 7*.

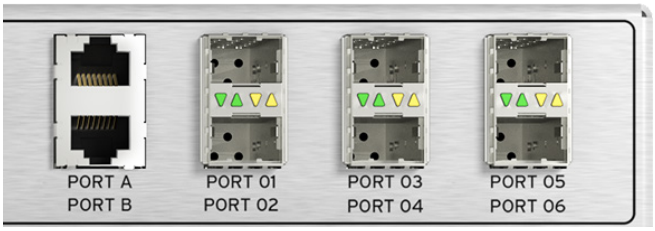


Figure 9 Rear Port Layout

Table 7 Software-Configurable Port Allocation

Communication Protocol	Ports Available
1 Gbps Ethernet	01, 02
100 Mbps Ethernet	01, 02, 03, 04, 05, 06

Communication Protocol	Ports Available
MIRRORED BITS 16[a]	05, 06
87L Line Current Differential[a, b]	05, 06
MIRRORED BITS 8	A, B

[a] Supports IEEE C37.94 and/or direct fiber over distances as far as 120 km.
[b] This feature will be available in a future release.

Due to the flexible nature of the SFP ports, it is necessary to order the required SFPs based on the desired application. A list of available SFPs is given in *Table 8*. All SFPs are dual-fiber with LC connectors. The relay comes standard with one 100 Mbps Ethernet SFP (SEL Part Number 8109-01) installed in Port 01.

Table 8 Available SFPs

Application	SEL Part Number	Interface	Max. Distance	Wavelength	Mode	Power per SFP	Compatible SFP Ports
100 Mbps Ethernet	8109-01	100BASE-FX	2 km	1310 nm	MM	–17 dBm	Ports 01–06
1 Gbps Ethernet	8131-01	1000BASE-SX	0.3 km	850 nm	MM	–2.5 dBm	Ports 01–02
MB16/87L[a] Direct Fiber	8104-01	100BASE-LX	20 km	1310 nm	SM	–8 dBm	Ports 05–06
MB16/87L[a] Direct Fiber	8104-02	100BASE-LX	50 km	1310 nm	SM	0 dBm	Ports 05–06
MB16/87L[a] Direct Fiber	8104-03	100BASE-ZX	80 km	1550 nm	SM	0 dBm	Ports 05–06
MB16/87L[a] Direct Fiber	8104-04	100BASE-ZX	120 km	1550 nm	SM	5 dBm	Ports 05–06
MB16/87L[a] C37.94 MM	8141-01	C37.94 MM (2 Mbps)	2 km	850 nm	MM	–11 dBm	Ports 05–06
MB16/87L[a] C37.94 SM	8141-02	C37.94 SM (2 Mbps)	20 km	1310 nm	SM	–8 dBm	Ports 05–06

[a] Supported via future firmware upgrade.

MIRRORED BITS Communications

MIRRORED BITS communications is an SEL protocol that provides bidirectional relay-to-relay digital communications at protection speeds. The protocol sends a set of user-defined bits to another SEL device while at the same time receiving a set of user-defined bits from that device. Each bit represents the state of a binary piece of information in the relay.

MIRRORED BITS communications is often used to exchange information such as transfer trip signals, breaker status, or element status between relays. Permissive keying for POTT schemes and blocking signals for DCB schemes are often sent between relays using MIRRORED BITS. MIRRORED BITS communications is significantly faster than using contact outputs wired to contact inputs to transmit these signals. MIRRORED BITS communications is also easy to set up and has addressing and error detection built in.

The SEL-9L supports two types of MIRRORED BITS communications:

- **MIRRORED BITS 8 (MB8)** exchanges a set of 8 bits between devices. Two channels of MB8 are supported (**PORT_A** and **PORT_B**). MB8 operates over a direct serial communication channel between devices using the EIA-232 standard.
- **MIRRORED BITS 16 (MB16)** exchanges a set of 16 bits between devices. Two channels of MB16 are supported (**PORT_5** and **PORT_6**). MB16 is encapsulated in an Ethernet packet and can operate over direct fiber at 100 Mbps or an IEEE C37.94 multiplexed channel at 64 kbps, and depending on the SFP being used, can go a longer distance than MB8. MB16 also includes the device mode and behavior status as part of the signal (see *Device Mode and Behavior on page 8*).

The SEL-9L can support two channels of MB8 and two channels of MB16. The MB8 and MB16 protocols are not compatible with each other.

Networking and Ethernet

The SEL-9L provides Ethernet communications capabilities using Ethernet SFPs that transfer data at high speeds (100 Mbps or 1 Gbps) for fast file uploads and data flow.

Each relay can have as many as three different IP addresses on the rear Ethernet ports, with the possibility of setting up failover or PRP schemes for redundancy. *Figure 10* shows two examples of how relays can be set up for various network configurations.

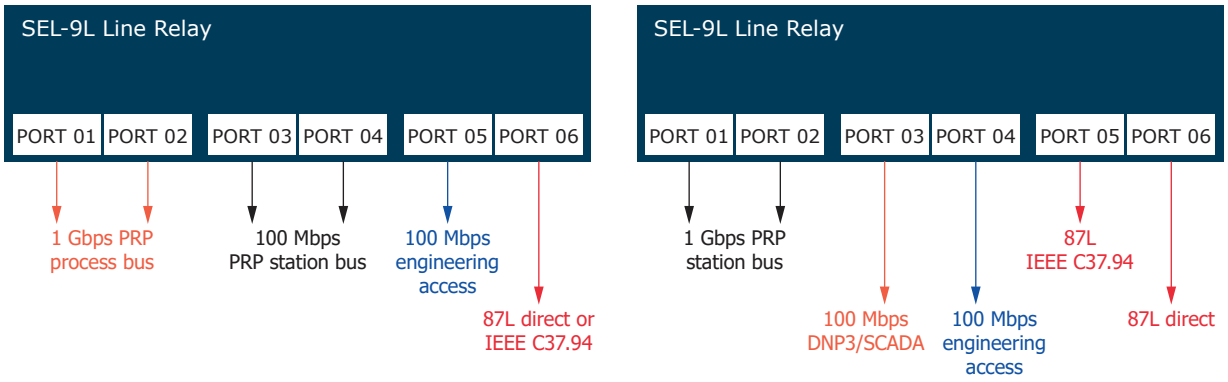


Figure 10 Network Configuration Examples

Parallel Redundancy Protocol (PRP)

PRP is used to provide seamless recovery from any single Ethernet network failure in accordance with IEC 62439-3. When PRP is used, two ports share an IP address and operate on two duplicate parallel networks for redundancy.

File Transfer Protocol (FTP)

FTP is used to transfer event reports, SOE records, settings files, and firmware to and from the relay via the Ethernet ports or the front-panel USB-C port.

DNP3

DNP3 LAN/WAN provides the SEL-9L with DNP3 Level 2 Outstation functionality over Ethernet. As many as six DNP3 sessions can be configured with as many as six custom DNP3 data maps. The relay supports as many as ten unique IP addresses per session.

IEC 61850 Edition 2.1

The IEC 61850 Edition 2.1 Ethernet protocol can be used for sharing analog and digital data with other devices at protection speeds.

MMS

The SEL-9L is equipped with an embedded IEC 61850 data server that supports as many as 12 simultaneous client associations and MMS file transfer. All relay files that can be transferred via FTP can also be transferred via MMS file services.

GOOSE

The SEL-9L can support as many as 16 IEC 61850 GOOSE publications.

The SEL-9L can support as many as 128 IEC 61850 GOOSE subscriptions and map the data to the following:

- 128 measured values (analog values)
- 256 single-point status values (binary status)
- 32 double-point status values (breaker or switch status)
- 32 integer-status values (mode and behavior status; see *Device Mode and Behavior on page 8*)

All of the above quantities received over GOOSE can be used in SELOGIC control equations and are recorded in event reports.

IEC 61869-9 Sampled Values

(Available via future firmware upgrade) The SEL-9L will support IEC 61869-9:2016 Sampled Values (SV) publication of as many as 4 SV streams, compatible with sample rates of 4,800 Hz with 1 or 2 ASDUs, and 4,000 Hz with 1 ASDU. The capability to subscribe to IEC 61869-9 SV streams will also be available.

Cybersecurity

The SEL-9L will provide robust security features, including the following:

- Secure booting of signed firmware
- Role-based access control (RBAC)
- Encrypted communication using Transport Layer Security (TLS)[a]
- Comprehensive device audit logging via Sequence of Events (SOE) and Syslog[a]
- File Transfer Protocol Secure (FTPS)[a]

[a] Available via future firmware upgrade.

SEL Grid Configurator

SEL Grid Configurator software is required for configuring and operating the SEL-9L and is available as a free download from selinc.com. The software allows users to do the following:

- Create a settings file for the relay.
- Connect to the relay locally or remotely.
- Read, send, and change relay settings.
- Create SELOGIC control equations with a user-friendly editor (see *Protection Logic on page 14*).
- Download event data.
- Create a directory of networked relays.
- Keep track of settings changes using versions.
- Upgrade relay firmware.
- Collect relay support and diagnostic information.

Online HMI

The online HMI in Grid Configurator provides users with a powerful, fast, and intuitive interface with the relay. Users can create a dashboard of as many as four different HMI views on one screen as shown in *Figure 11*. Once configured, the dashboard can be saved to reuse with other relays.

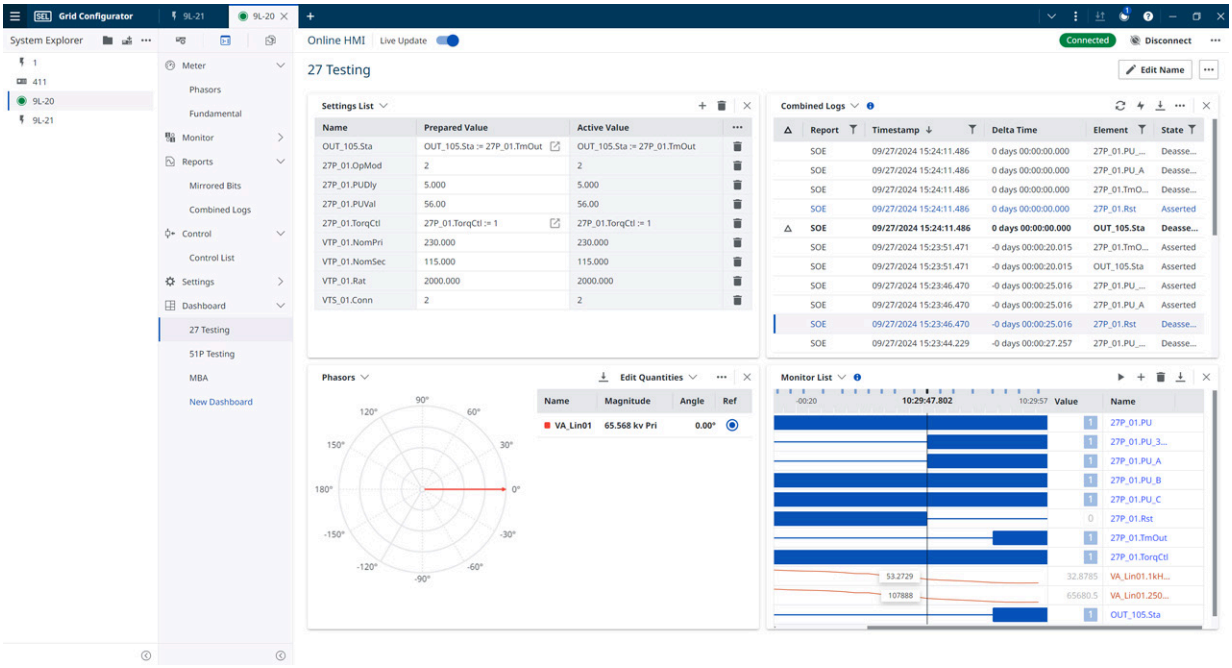


Figure 11 Grid HMI Dashboard

The HMI screens shown on the dashboard in *Figure 11* are Settings List, Combined Logs Report, Meter Phasors, and Monitor List. The following is a complete list of available HMI screens:

- **Device Status:** View information about the connected relay.
- **Device Test Mode:** View or change the device test mode and behavior.

- **Device Configuration:** View information about how the connected relay is configured.
- **Meter Phasors:** View a live phasor plot of currents and voltages measured by the relay.
- **Meter Fundamental:** View line currents, individual breaker currents, and voltages.
- **Monitor List:** Poll the status of any available binary or analog value in the relay. The live view can be paused at any time, and the list keeps a 30-second history of recent data.
- **Mirrored Bits Report:** View information about the MIRRORED BITS channels.
- **Combined Logs Report:** See all event reports and SOE data in the same view. Set a reference and calculate the time between different events. Filter, export, and download event reports and SOE data.
- **PTP Report:** View information about PTP connections.
- **IEC 61850 GOOSE Report:** View GOOSE publications and subscriptions.
- **Port Statistics:** View information about the six SFP ports on the relay.
- **Control List:** Set, clear, or pulse contact outputs and remote bits. Reset event report history and clear SOE reports.
- **Test DB:** Force analog quantities and Relay Word bits to specific values to easily test communications protocols.
- **Settings List:** View, filter, and change the settings in the relay.

Diagrams and Dimensions

The SEL-9L is the same size and has a very similar rear-panel layout as the SEL-311C and SEL-311L, making it an easy direct replacement.

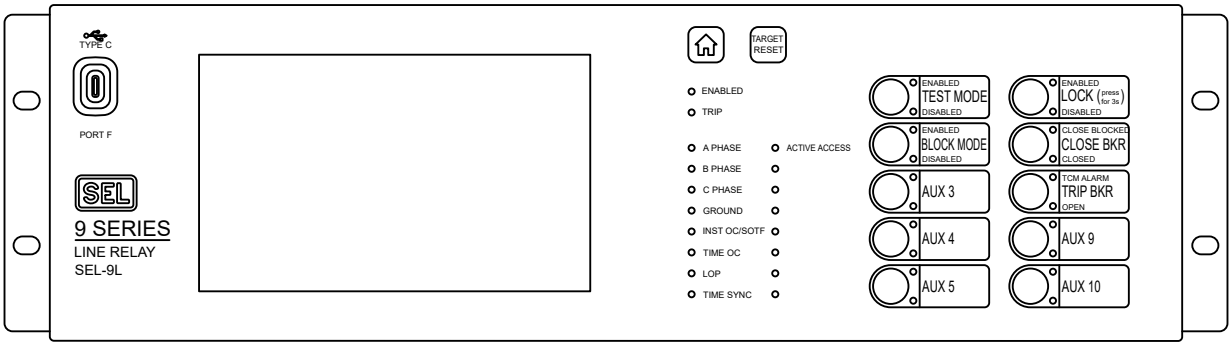


Figure 12 SEL-9L Front Panel

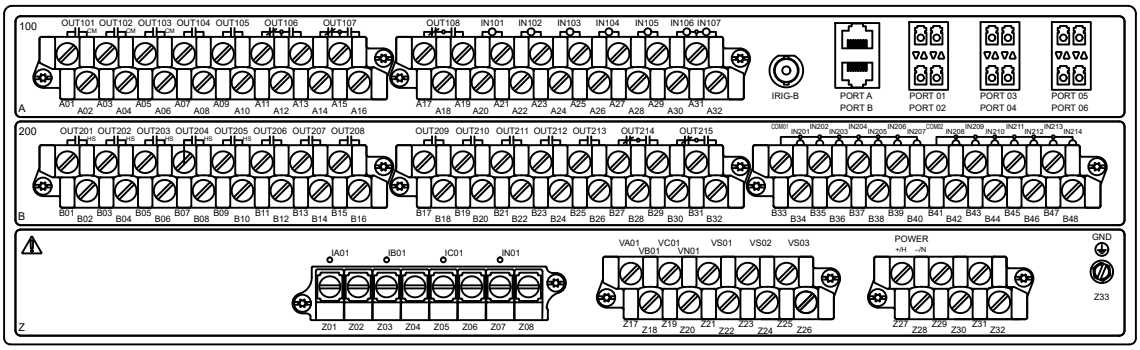


Figure 13 SEL-9L Rear Panel (Single CT Input)

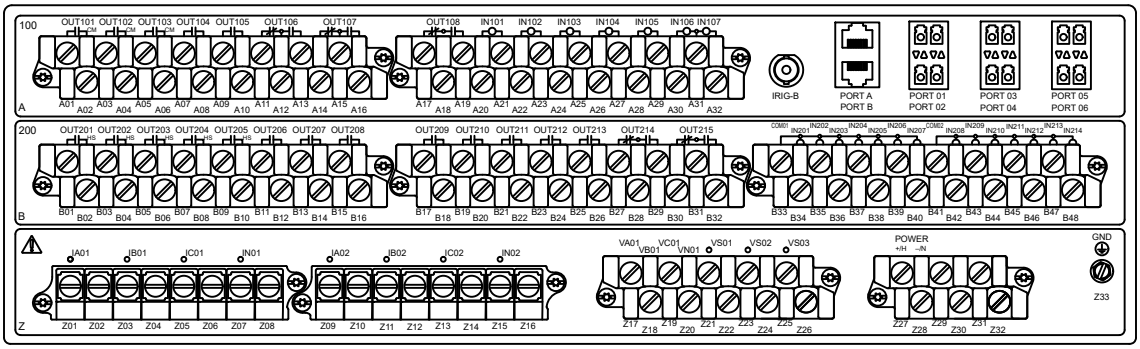


Figure 14 SEL-9L Rear Panel (Dual CT Input)

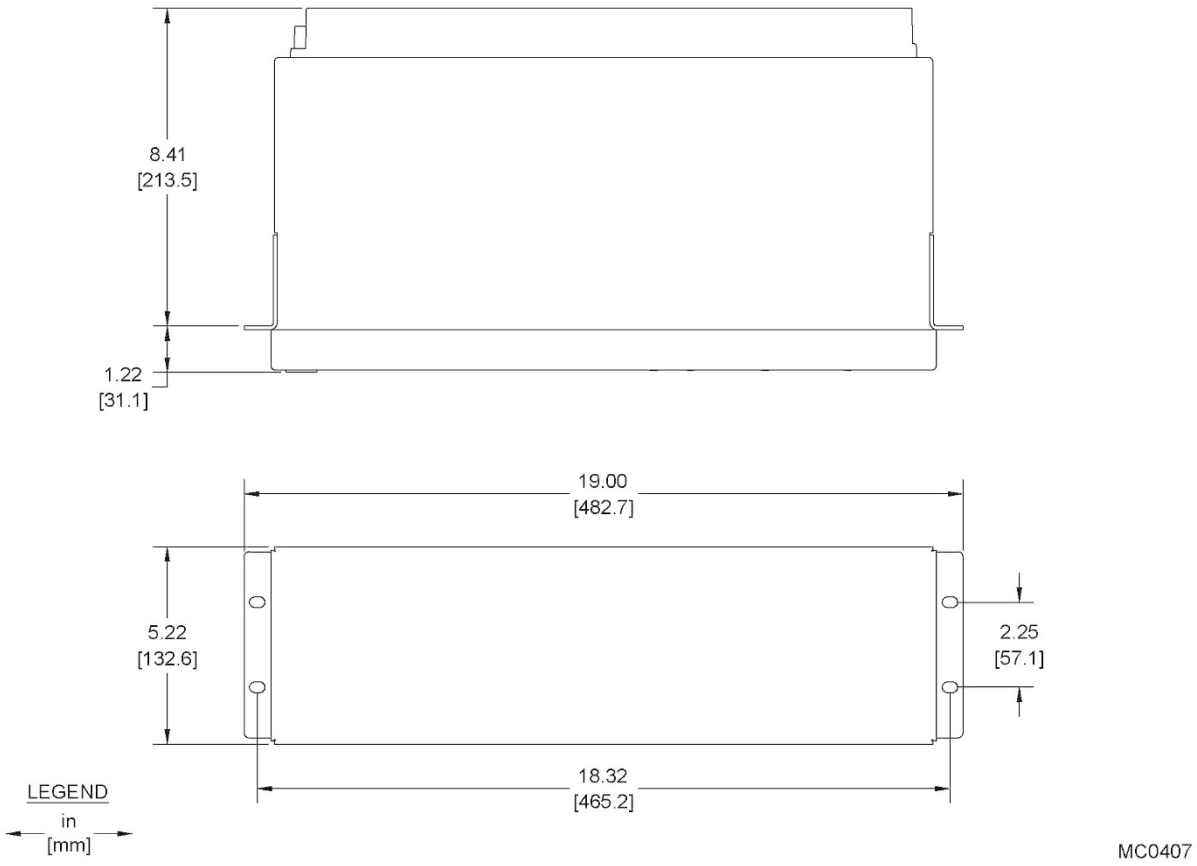


Figure 15 SEL-9L Rack-Mount Dimensions (All Models)

Specifications

AC Analog Inputs

General

Sampling Rate:	10 kHz
Rated Frequency:	50/60 Hz
Operational Frequency Range:	40–70 Hz

AC Current Inputs

CT input accuracy ranges from 0.05 to 4 • INOM for both 1 A and 5 A CTs.

Rated Current (I_{NOM}):	1 A or 5 A (software-selectable)
Continuous Thermal Rating:	20 A rms
One-Second Thermal Rating:	500 A rms
Burden Rating:	≤0.1 VA at 1 A rms at rated frequency
ADC Current Limit:	≥350 A peak

AC Voltage Inputs

Rated Voltage Range (V_{NOM}):	57.7–250 V rms line-to-neutral
Operational Voltage Range:	0–300 V rms line-to-neutral

Ten-Second Thermal Rating:	600 V rms
Burden Rating:	≤0.1 VA at 120 V rms at rated frequency

Contact Inputs

All contact inputs include reinforced isolation.

Sampling Rate:	10 kHz
Operational Polarity:	Bipolar dc; ac
Rated Voltages:	24/48/110/125/220/250 Vdc; 120/240 Vac rms, 50/60 Hz (software-selectable)
Operational Voltage Range:	0–300 Vdc; 0–288 Vac rms
Steady-State Current Draw:	1–4 mA (at rated voltages)
Initial Current Draw:	24 Vdc: 70 mA for 15 ms 48 Vdc: 170 mA for 2 ms 110 Vdc: 155 mA for 2 ms 125 Vdc: 150 mA for 2 ms 220 Vdc: 160 mA for 2 ms 250 Vdc: 160 mA for 2 ms 120 or 240 Vac at 50 or 60 Hz: 180 mA for 2 ms
Burden (Max. Steady-State Power Consumption):	≤0.6 W (at dc rated voltages) ≤0.6 VA (at ac rated voltages)

Pickup and Dropout Thresholds

24 Vdc:	Pickup: 19.2–28.8 Vdc Dropout: <14.4 Vdc
48 Vdc:	Pickup: 38.4–57.6 Vdc Dropout: <28.8 Vdc
110 Vdc:	Pickup: 88–132 Vdc Dropout: <66 Vdc
125 Vdc:	Pickup: 100–150 Vdc Dropout: <75 Vdc
220 Vdc:	Pickup: 176–264 Vdc Dropout: <132 Vdc
250 Vdc:	Pickup: 200–300 Vdc Dropout: <150 Vdc
120 Vac:	Pickup: 88–144 Vac Dropout: <22 Vac
240 Vac:	Pickup: 176–288 Vac Dropout: <50 Vac

Contact Outputs

General

All contact outputs include reinforced isolation.

Update Rate:	≤1 ms
Operational Polarity:	Bipolar dc ac (applies to standard Form A and Form C contacts only)
Continuous Contact Current:	5 A at 70°C (158°F) 4 A at 85°C (185°F)
Breaking Current:	All breaking capacities are given in watts. To calculate breaking current, divide the given rating in watts by the applied voltage.

Standard Form A and Form C Contact Outputs (DC or AC)

Rated Voltage Range:	24–250 Vdc; 100–240 Vac rms, 50/60 Hz
Operational Voltage Range:	0–300 Vdc; 0–264 Vac rms
Operating Time:	Pickup: ≤6 ms Dropout: ≤6 ms

Make[a, b] (Short Duration Contact Current):	30 A at 250 Vdc 2,000 operations
AC Limited Making Capacity (Inductive):	1,000 W at 250 Vac rms (PF = 0.4) 2,000 operations
DC Limited Making Capacity (Inductive):	1,000 W at 250 Vdc (L/R = 40 ms) 2,000 operations
DC Limited Breaking Capacity (Resistive):	50 W, Resistive, 10,000 operations for 24–250 Vdc 10 operations in 4 seconds, followed by 2 minutes idle
DC Limited Breaking Capacity (Inductive):	50 W, L/R = 40 ms, 10,000 operations for 24–250 Vdc 10 operations in 4 seconds, followed by 2 minutes idle
AC Limited Breaking Capacity (Resistive):	50 W, Resistive, 10,000 operations for 100–240 Vac rms 10 operations in 4 seconds, followed by 2 minutes idle
AC Limited Breaking Capacity (Inductive):	50 W, PF = 0.4, 10,000 operations for 100–240 Vac rms 10 operations in 4 seconds, followed by 2 minutes idle
Short-Time Thermal Withstand:	50 A for 1 s
Leakage Current:	≤30 µA for –40° to +85°C (–40° to +185°F) for ≤300 Vdc ≤100 µA for –40° to +85°C (–40° to +185°F) for ≤264 Vac rms, 50/60 Hz

High-Speed, High-Current-Interrupting Contact Outputs (DC Only)

Rated Voltage Range:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time (Resistive Load):	Pickup: ≤10 µs Dropout: ≤8 ms
Make[a, b] (Short Duration Contact Current):	30 A at 250 Vdc 2,000 operations
DC Limited Making Capacity (Inductive):	1,000 W at 250 Vdc (L/R = 40 ms) 2,000 operations
DC Limited Breaking Capacity (Resistive):	1,250 W, Resistive, 10,000 operations for 24–250 Vdc 4 operations in 1 second, followed by 2 minutes idle
DC Limited Breaking Capacity (Inductive):	For 48–250 Vdc: 1,250 W, L/R = 40 ms, 10,000 operations 4 operations in 1 second, followed by 2 minutes idle For 24 Vdc: 625 W, L/R = 40 ms, 10,000 operations 4 operations in 1 second, followed by 2 minutes idle
Short-Time Thermal Withstand:	50 A for 1 s
Leakage Current:	≤100 µA for –40° to +85°C (–40° to +185°F) for ≤300 Vdc

Circuit Monitoring—High-Speed, High-Current-Interrupting Contact Outputs (DC Only)

Rated Voltage Range:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time (Resistive Load):	Pickup: ≤10 µs Dropout: ≤8 ms
Make[a, b] (Short Duration Contact Current):	30 A at 250 Vdc 2,000 operations
DC Limited Making Capacity (Inductive):	1,000 W at 250 Vdc (L/R = 40 ms) 2,000 operations
DC Limited Breaking Capacity (Resistive):	1,250 W, Resistive, 10,000 operations for 24–250 Vdc 4 operations in 1 second, followed by 2 minutes idle

DC Limited Breaking Capacity (Inductive):	For 48–250 Vdc: 1,250 W, L/R = 40 ms, 10,000 operations 4 operations in 1 second, followed by 2 minutes idle For 24 Vdc: 675 W, L/R = 40 ms, 10,000 operations 4 operations in 1 second, followed by 2 minutes idle
Short-Time Thermal Withstand:	50 A for 1 s
Leakage Current:	≤500 µA for –40° to +85°C (–40° to +185°F) for ≤300 Vdc
Voltage Measurement Range:	(0.4–1.2) • V_{NOM} where V_{NOM} = 24/48/110/125/220/250 Vdc
Accuracy:	±5% of reading, ±2 Vdc
Resolution:	≤0.2 Vdc for V_{NOM} = 24 Vdc ≤0.4 Vdc for V_{NOM} = 48 Vdc ≤1 Vdc for V_{NOM} = 110 Vdc ≤1 Vdc for V_{NOM} = 125 Vdc ≤2 Vdc for V_{NOM} = 220 Vdc ≤2 Vdc for V_{NOM} = 250 Vdc
Current Measurement Range:	±0.2 A to ±20 A
Accuracy:	±5% of reading, ±0.2 A
Resolution:	≤0.1 A

[a] According to IEEE C37.90-2005.
[b] According to IEC 60255-27:2023.

Power Supply

General

Rated Voltage Range:	48–250 Vdc/100–240 Vac rms
Operational Voltage Range:	38–300 Vdc/80–264 Vac rms
Rated Frequency:	50/60 Hz
Operational Frequency Range:	40–70 Hz
Burden Rating (Max.):	dc: ≤55 W ac: ≤50 VA (both for rated voltage range)
Vdc Input Ripple:	15% of applied rated dc voltage
Interruption/Ride-Through (30 W Burden):	48, 125, 250 Vdc: ≥1 second

DC Monitor

Rated Voltage Range:	48–250 Vdc
Operational Voltage Range:	38.4–300 Vdc
Accuracy:	±3% of setting, ±2 Vdc over rated voltage range (all elements except ac ripple) ±10% of setting, ±2 Vrms (ac ripple element)
Resolution:	≤0.1 Vdc (all elements except ac ripple) [TBD (ac ripple element)]

Communication Ports

Port 01–Port 06

Connector Type:	Small Form-Factor Pluggable (SFP)
Number of SFP Ports:	6

Protocols Supported:	1 Gbps Ethernet (Port 01, Port 02) 100 Mbps Ethernet (Port 01–Port 06) PRP (Port 01–Port 06) FTP (Port 01–Port 06) DNP3 (Port 01–Port 06) IEC 61850 Edition 2.1 (MMS, MMS File Transfer, GOOSE) (Port 01–Port 06) IEC 61869-9 Sampled Values[a] (Port 01–Port 06) SNTP[a] (Port 01–Port 06) PTP[a] (Port 01–Port 04) SEL MIRRORED BITS 16 over direct fiber or IEEE C37.94 (Port 05, Port 06) Line differential over direct fiber or IEEE C37.94[a] (Port 05, Port 06)
Supported SFP Transceivers:	Refer to *Table 8*

[a] Available via future firmware upgrade.

Port A and Port B

Connector Type:	RJ-45 serial
Protocols Supported:	SEL MIRRORED BITS 8
5 Volt:	Pin 2
Serial Data Speed:	9,600 to 115,200 bps

USB Front-Panel Port F

Connector Type:	USB Type C
USB Type:	2.0
Application:	Engineering Access

Time Inputs

IRIG-B Time Input

Connector Type:	BNC
Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operational Voltage Range:	0–8 Vdc
Logic High Threshold:	≥2.2 Vdc
Logic Low Threshold:	≤0.8 Vdc
Time Accuracy:	±1 µs when connected to a high-accuracy clock [±TBD when connected to a low-accuracy clock]
Input Impedance:	≥1 kΩ

Precise Time Holdover

Drift:	≤100 seconds/year (~4 ppm) at 25°C (77°F) when no external time source is connected

Environmental Operating Parameters

Operating Temperature:	–40° to +85°C (–40° to +185°F) **Note:** The front-panel display is impaired for temperatures below –20°C (–4°F) and above +70°C (+158°F)
Relative Humidity:	5%–95%; noncondensing
Altitude:	≤2,000 m See IEEE C37.90 for derating factors at higher altitudes.
IP Rating:	IP4X for front (with installation of port cover on **PORT F**), top, and sides of chassis IP2X for back (terminals) IP1X for terminal blocks
Pollution Degree:	2 per IEC 60255-27:2023

Overvoltage Category:	III per IEC 60255-27:2023
Insulation Class:	I

Size and Weight

Size:	3U 19-inch horizontal rack-mount
Depth:	22.35 cm (8.80 in) (maximum)
Front-Panel Projection:	3.81 cm (1.50 in) (maximum)
Weight:	6.8 kg (15.0 lb) (maximum)

Terminal Connections

CT Input Terminal Blocks

Supported Wire Gauge for CT Connectors:	14 to 10 AWG
Supported Termination for CT Connectors:	Ring terminal (#8 stud size) Maximum width of 9.65 mm (0.380 in)
Tightening Torque for CT Connector Wiring Terminations:	Range: 9 to 18 in-lb Recommended: 12 in-lb
Tightening Torque for Terminal Block Mounting Ears:	Range: 9 to 12 in-lb Recommended: 9 in-lb

All Other Terminal Blocks (Power, Voltage, and Contact I/O)

Supported Wire Gauge for Screw-Terminal Connectors:	18 to 14 AWG
Supported Termination for Screw-Terminal Connectors:	Ring terminal (#8 stud size) Maximum width of 9.1 mm (0.360 in)
Tightening Torque for Screw-Terminal Connector Wiring Terminations:	Range: 9 to 18 in-lb Recommended: 12 in-lb
Tightening Torque for Terminal Block Mounting Ears:	Range: 9 to 12 in-lb Recommended: 9 in-lb

Note: User terminals and stranded copper wire should have a minimum temperature rating of 105°C (221°F).

Wire Sizes and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks and expected load currents. Use the following table as a guide for selecting wire sizes. The grounding conductor should be as short as possible and sized equal to or greater than any other conductor connected to the device, unless otherwise required by local or national wiring regulations.

Connection Type	Min. Wire Size	Max. Wire Size
Grounding (Earthing) Connection	14 AWG (2.5 mm^2)	N/A
Current Connection	16 AWG (1.5 mm^2)	10 AWG (6.0 mm^2)
Voltage Connection	18 AWG (0.8 mm^2)	14 AWG (2.5 mm^2)
Contact I/O	18 AWG (0.8 mm^2)	10 AWG (6.0 mm^2)
Other Connections	18 AWG (0.8 mm^2)	10 AWG (6.0 mm^2)

Measurement Accuracy

AC Current Inputs

Magnitude Accuracy:	(0.05–4.00) • I_{NOM}: ±0.2% ± 0.0004 • I_{NOM}
Phase Accuracy:	(0.20–4.00) • I_{NOM}: ±0.2° (0.05–0.20) • I_{NOM}: ±0.4°

Note: Measurement accuracies assume 20°C (68°F) temperature and 1-second averaged data at tracked rated frequency.

AC Voltage Inputs

Magnitude Accuracy: (0.1–1.2) • V_{NOM}: ±0.2%

Phase Accuracy: (0.1–1.2) • V_{NOM}: ±0.1°

Note: Measurement accuracies assume 20°C (68°F) temperature and 1-second averaged data at tracked rate frequency.

Total Vector Error

TVE Accuracy	Input Range	Frequency Range
<1%	(0.1–2.0) • I_{NOM} (0.1–1.2) • V_{NOM}	50/60 Hz ± 5 Hz

Reporting Functions

Event Reports

Length: 0.25–5 s (based on Event.Len setting)

Back-to-Back Storage: 3 event reports

Maximum Event Reports Stored: From [TBD] to [TBD], depending on Event.Len setting

Sequence of Events Recorder

Storage: 4,096 entries

Number of Configurable Points: 250

Resolution: 500 µs

Compliance and Type Tests

Designed and manufactured under an ISO 9001 certified quality management system

47 CFR 15B Class A
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 in which case the user will be required to correct the interference at his own expense.

CAN ICES-001 (A) / NMB-001 (A)
This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to ICES-001, Issue 5.

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

CE Mark

Electromagnetic Compatibility (EMC)

Product Standards	**IEC 60255-26:2023** **IEEE C37.90-2005**	
Test	**Methodology**	**Level**
Emissions	CISPR 11/22/32 47 CFR Part 15B Canada ICES-001 (A) / NMB-001 (A) ANSI C63.4	Class A
Harmonics	IEC 61000-3-2:2018	Meets applicable limits
Flicker	IEC 61000-3-3:2013	Meets applicable limits

<table>
<tr><th>Product Standards</th><th colspan="2">IEC 60255-26:2023
IEEE C37.90-2005</th></tr>
<tr><th>Test</th><th>Methodology</th><th>Level</th></tr>
<tr><td>Radiated RF Immunity</td><td>IEC 61000-4-3:2020
IEEE C37.90.2-2024</td><td>
<table>
<tr><th>Frequency (MHz)</th><th>Field Strength</th><th>Modulation</th></tr>
<tr><td>80–3,000</td><td>20 V/m</td><td>AM 80% 1 kHz sine</td></tr>
<tr><td>380/1,600/1,800/1,850/
2,150/2,600/3,500/
3,800/5,000</td><td>10 V/m</td><td>AM 80% 1 kHz sine</td></tr>
<tr><td>80/160/450/900</td><td>20 V/m</td><td>AM 80% 1 kHz sine</td></tr>
<tr><td>900</td><td>20 V/m</td><td>Pulse Mod. 50%</td></tr>
</table>
</td></tr>
<tr><td>Conducted RF Immunity</td><td>IEC 61000-4-6:2023</td><td>150 kHz–80 MHz, 1 kHz 80% AM 10 V rms
Spot Frequencies: 27 MHz and 68 MHz</td></tr>
<tr><td>Electrostatic Discharge</td><td>IEC 61000-4-2:2025
IEEE C37.90.3-2023</td><td>Contact Discharge: ±2, 4, 6, 8 kV
Air Discharge: ±2, 4, 8, 15 kV</td></tr>
<tr><td>Electrical Fast Transient Burst</td><td>IEC 61000-4-4:2012
IEEE C37.90.1-2024</td><td>
<table>
<tr><th>Port Type</th><th>Level</th></tr>
<tr><td>Power, Communication, and Functional Earth</td><td>±4 kV at 5 kHz</td></tr>
<tr><td>Input/Output</td><td>±4 kV at 5 kHz and 2.5 kHz</td></tr>
</table>
</td></tr>
<tr><td>Surge Immunity</td><td>IEC 61000-4-5:2017</td><td>
<table>
<tr><th>Port Type</th><th>Level</th></tr>
<tr><td>Power and Input/Output</td><td>±0.5, 1, 2 kV line-to-line
±0.5, 1, 2, 4 kV line-to-earth</td></tr>
<tr><td>Communication</td><td>±0.5, 1, 2 kV line-to-line</td></tr>
</table>
</td></tr>
<tr><td>Damped Oscillatory Wave Immunity</td><td>IEC 61000-4-18:2019
IEEE C37.90.1-2024</td><td>
<table>
<tr><th>Port Type</th><th>Level</th></tr>
<tr><td>Power</td><td>±2.5 kV common
±2.5 kV differential</td></tr>
<tr><td>Communication</td><td>±2.5 kV common
±1 kV differential</td></tr>
<tr><td>Input</td><td>±2.5 kV common
±1 kV differential</td></tr>
<tr><td>Output</td><td>±2.5 kV differential</td></tr>
</table>
</td></tr>
<tr><td>Power Frequency Immunity</td><td>IEC 60255-26:2023
IEC 61000-4-16:2015</td><td>
<table>
<tr><th>Port Type</th><th>Level</th></tr>
<tr><td>Binary Input</td><td>300 V rms common
150 V rms differential</td></tr>
</table>
</td></tr>
<tr><td>Power Frequency Magnetic Field Immunity</td><td>IEC 61000-4-8:2009</td><td>100 A/m for 60 Seconds
1,000 A/m for 3 Seconds</td></tr>
<tr><td>Pulse Magnetic Field Immunity</td><td>IEC 61000-4-9:2016</td><td>1,000 A/m, Level 5</td></tr>
<tr><td>Damped Oscillatory Magnetic Field Immunity</td><td>IEC 61000-4-10:2016</td><td>100 A/m, Level 5</td></tr>
<tr><td>Startup and Shutdown</td><td>IEC 60255-26:2023</td><td>60 second ramp/5 minute power off</td></tr>
</table>

Environmental

Product Standards	IEC 60255-27:2023	
Test	**Methodology**	**Level**
Cold	IEC 60255-1:2022 IEC 60068-2-1:2007	**Test Type** / **Level** Operational / Test Ad: 16 hours at –40°C Storage / Test Ab: 16 hours at –40°C
Dry Heat	IEC 60255-1:2022 IEC 60068-2-2:2007	**Test Type** / **Level** Operational / Test Bd: 16 hours at +85°C Storage / Test Bb: 16 hours at +85°C
Cyclic Temperature	IEC 60255-1:2022 IEC 60068-2-14:2023	Test Db: –40°C to +85°C, 5 cycles
Damp Heat	IEC 60255-1:2022 IEC 60068-2-78:2012 IEC 60068-2-30:2005	**Test Type** / **Level** Steady State / Test Cab: 93% relative humidity, +40°C, 10 days Cyclic / Test Db: +25° to +55°C, 6 cycles, (12+12-hour cycle), 95% relative humidity
Object Penetration	IEC 60529:2013	**Location** / **Level** Front, Top, Sides (Enclosure) / IP3X Back (Terminals) / IP2X Terminal Block / IP1X
Vibration	IEC 60255-21-1:1988	Class 2 Endurance, Class 2 Response
Shock/Bump	IEC 60255-21-2:1988	**Test Type** / **Level** Shock / Class 1 Withstand, Class 2 Response Bump / Class 1
Seismic	IEC 60255-21-3:1993	Class 2 Quake Response

Safety

Product Standards	IEC 60255-27:2023 IEEE C37.90-2005 UL 61010-1:2024	
Test	**Methodology**	**Level**
Dielectric Strength	IEC 60255-27:2023 IEEE C37.90-2005 UL 61010-1:2024	**Port Type** / **Level** Power / 3.6 kVdc Communication / 1.5 kV rms Input/Output / 3.25 kV rms, 50 or 60 Hz, 1 min
Impulse	IEC 60255-27:2023 IEEE C37.90-2005 UL 61010-1:2024	**Port Type** / **Level** Power / 5 kV Communication / 5 kV Input/Output / 6 kV See IEC 60255-27:2023 Table C.12 - Test site altitude correction factor.
Insulation Resistance	IEC 60255-27:2023 UL 61010-1:2024	Meets applicable levels
Flammability of Insulating Materials	IEC 60255-27:2023 UL 61010-1:2024	Meets applicable levels
Maximum Temperature of Parts and Materials	IEC 60255-27:2023 UL 61010-1:2024	Meets applicable levels, normal use
Protective Bonding/Continuity	IEC 60255-27:2023 UL 61010-1:2024	Meets applicable levels
Laser Safety	IEC 60825-1:2014 21 CFR 1040.10 and 1040.11	Meets applicable levels

Processing Specifications

AC Voltages and Current Inputs

10,000 samples per second, 3 dB low-pass filter cut-off frequency of 500 Hz

Protection and Control Processing

1,000 times per second

Metering Processing

250 times per second

Control Points

1,000 times per second (64 remote bits and 100 latch bits)

Maximum Startup Time (From Energization to Trip)

3.5 seconds

Relay Element Pickup Ranges and Accuracies

(21) Mho Phase Distance Elements

Number of Directional Zones:	4
Number of Nondirectional Zones:	1 (Zone 5)
Pickup Range	
5 A Nominal CTs:	0.05 to 64.00 Ω secondary
1 A Nominal CTs:	0.25 to 320.00 Ω secondary
Directionality:	Forward or reverse, selectable per zone, common to phase and ground distance elements of a zone
Pickup Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Pickup Accuracy (Transient Overreach):	<5% of setting plus steady-state accuracy
Operate Time:	See *Figure 4*

(21) Quadrilateral Phase Distance Elements

Number of Directional Zones:	4
Number of Nondirectional Zones:	1 (Zone 5)
Pickup Range	
5 A Nominal CTs:	0.05 to 64.00 Ω secondary
1 A Nominal CTs:	0.25 to 320.00 Ω secondary
Directionality:	Forward or reverse, selectable per zone, common to phase and ground distance elements of a zone
Pickup Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Pickup Accuracy (Transient Overreach):	<5% of setting plus steady-state accuracy
Operate Time:	See *Figure 4*

(21) Mho Ground Distance Elements

Number of Directional Zones:	4
Number of Nondirectional Zones:	1 (Zone 5)
Pickup Range	
5 A Nominal CTs:	0.05 to 64.00 Ω secondary
1 A Nominal CTs:	0.25 to 320.00 Ω secondary
Directionality:	Forward or reverse, selectable per zone, common to phase and ground distance elements of a zone
Pickup Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Pickup Accuracy (Transient Overreach):	<5% of setting plus steady-state accuracy
Operate Time:	See *Figure 4*

(21) Quadrilateral Ground Distance Elements

Number of Directional Zones:	4
Number of Nondirectional Zones:	1 (Zone 5)
Pickup Range	
5 A Nominal CTs:	0.05 to 64.00 Ω secondary
1 A Nominal CTs:	0.25 to 320.00 Ω secondary

Directionality:	Forward or reverse, selectable per zone, common to phase and ground distance elements of a zone
Pickup Accuracy (Steady State):	±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR ≤ 60
Pickup Accuracy (Transient Overreach):	<5% of setting plus steady-state accuracy
Operate Time:	See *Figure 4*

(21) Step Distance Timers

Number of Timers:	15 (ground, phase, and common, for each of 5 zones)
Timer Range:	0.000 to 10.000 seconds
Timer Operation:	Integrating with user-controllable reset type
Accuracy:	±1 ms

(27) Phase Undervoltage Elements

Number of Elements:	4
Operating Quantity:	Phase-to-neutral line voltage
Pickup Range:	5.00 to 300.00 V secondary
Accuracy	
Steady State:	±1% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(27) Phase-to-Phase Undervoltage Elements

Number of Elements:	2
Operating Quantity:	Phase-to-phase line voltage
Pickup Range:	5.00 to 520.00 V secondary
Accuracy	
Steady State:	±2% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(27) Positive-Sequence Undervoltage Elements

Number of Elements:	2
Operating Quantity:	Positive-sequence line voltage
Pickup Range:	5.00 to 300.00 V secondary
Accuracy	
Steady State:	±2% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds

Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(27) Single-Phase VS Undervoltage Elements

Number of Elements:	6 (2 for each single-phase voltage terminal)
Operating Quantity:	Single-phase VS01/VS02/VS03 terminal voltage
Pickup Range:	5.00 to 300.0 V secondary
Accuracy	
Steady State:	±1% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(32) Directional Overpower Elements

Number of Elements:	4, configurable exclusively as single-phase or three-phase
Operating Quantity:	Configurable as three-phase line watts, three-phase line VARs, single-phase line watts, or single-phase line VARs
Pickup Range	
Three-Phase	
5 A Nominal CTs:	1.00 to 39,000.00 VA secondary
1 A Nominal CTs:	0.20 to 7,800.00 VA secondary
Single-Phase	
5 A Nominal CTs:	0.33 to 13,000.00 VA secondary
1 A Nominal CTs:	0.07 to 2,600.00 VA secondary
Accuracy	
Three-Phase:	±0.005 A • (line-to-line voltage secondary) ± 1% of setting at unity power factor for real power elements and zero power factor for reactive power element
Single-Phase:	±0.005 A • (line-to-neutral voltage secondary) ± 1% of setting at unity power factor for real power elements and zero power factor for reactive power element
Timer Range:	0.000 to 400.000 seconds

(32) Directional Underpower Elements

Number of Elements:	4, configurable exclusively as single-phase or three-phase
Operating Quantity:	Configurable as three-phase line watts, three-phase line VARs, single-phase line watts, or single-phase line VARs
Pickup Range	
Three-Phase	
5 A Nominal CTs:	1.00 to 39,000.00 VA secondary
1 A Nominal CTs:	0.20 to 7,800.00 VA secondary
Single-Phase	
5 A Nominal CTs:	0.33 to 13,000.00 VA secondary
1 A Nominal CTs:	0.07 to 2,600.00 VA secondary

Accuracy	
Three-Phase:	±0.005 A • (line-to-line voltage secondary) ± 1% of setting at unity power factor for real power elements and zero power factor for reactive power element
Single-Phase:	±0.005 A • (line-to-neutral voltage secondary) ± 1% of setting at unity power factor for real power elements and zero power factor for reactive power element
Timer Range:	0.000 to 400.000 seconds

(50/67) Phase Instantaneous and Definite-Time Directional Overcurrent Elements

Number of Elements:	6
Operating Quantity:	Phase-to-neutral line current
Pickup Range	
5 A Nominal CTs:	0.25 to 100.00 A secondary
1 A Nominal CTs:	0.05 to 20.00 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(50) Phase-to-Phase Instantaneous Overcurrent Elements

Number of Elements:	6
Operating Quantity:	Phase-to-phase line current
Pickup Range	
5 A Nominal CTs:	0.25 to 170.00 A secondary
1 A Nominal CTs:	0.05 to 34.00 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting

(50/67) Negative-Sequence Instantaneous and Definite-Time Directional Overcurrent Elements

Number of Elements:	6
Operating Quantity:	Negative-sequence line current
Pickup Range	
5 A Nominal CTs:	0.25 to 100.00 A secondary
1 A Nominal CTs:	0.05 to 20.00 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds

Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(50/67) Residual-Ground Instantaneous and Definite-Time Directional Overcurrent Elements

Number of Elements:	6
Operating Quantity:	Residual-ground line current
Pickup Range	
5 A Nominal CTs:	0.25 to 100.00 A secondary
1 A Nominal CTs:	0.05 to 20.00 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(50/67) Neutral Instantaneous and Definite-Time Overcurrent Elements

Number of Elements:	12 (6 for each neutral current terminal)
Operating Quantity:	Neutral IN terminal current
Pickup Range	
5 A Nominal CTs:	0.25 to 100.00 A secondary
1 A Nominal CTs:	0.05 to 20.00 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(50BF) Breaker Failure

Number of Elements:	2
Operating Quantity:	Phase-to-neutral breaker current and/or residual-ground breaker current
Pickup Range	
5 A Nominal CTs:	0.25 to 100.00 A secondary
1 A Nominal CTs:	0.05 to 20.00 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 100.000 seconds
Timer Accuracy:	±1 ms

Maximum Operate Time:	25 ms
Maximum Reset Time:	15 ms

(51) Phase Inverse-Time Overcurrent Elements

Number of Elements:	5
Operating Quantity:	Maximum phase-to-neutral line current
Pickup Range	
5 A Nominal CTs:	0.25 to 16.00 A secondary
1 A Nominal CTs:	0.05 to 3.20 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting
Time Dial Range	
U.S./IEEE:	0.50 to 15.00 A secondary
IEC:	0.05 to 1.00 A secondary
Curve Timing Accuracy:	±4% ± 0.025 seconds for current between 2 and 30 multiples of pickup. Curves operate on definite time for current greater than 30 multiples of pickup.
Reset Type:	Definite or Inverse
Reset Accuracy	
Inverse:	±4% ± 0.025 seconds for current less than 1 multiple of pickup setting
Definite:	±1 ms

(51) Negative-Sequence Inverse-Time Overcurrent Elements

Number of Elements:	5
Operating Quantity:	Negative-sequence line current
Pickup Range	
5 A Nominal CTs:	0.25 to 16.00 A secondary
1 A Nominal CTs:	0.05 to 3.20 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting
Time Dial Range	
U.S./IEEE:	0.50 to 15.00 A secondary
IEC:	0.05 to 1.00 A secondary
Curve Timing Accuracy:	±4% ± 0.025 seconds for current between 2 and 30 multiples of pickup. Curves operate on definite time for current greater than 30 multiples of pickup.
Reset Type:	Definite or Inverse
Reset Accuracy	
Inverse:	±4% ± 0.025 seconds for current less than 1 multiple of pickup setting
Definite:	±1 ms

(51) Residual-Ground Inverse-Time Overcurrent Elements

Number of Elements:	5
Operating Quantity:	Residual-ground line current
Pickup Range	
5 A Nominal CTs:	0.25 to 16.00 A secondary
1 A Nominal CTs:	0.05 to 3.20 A secondary
Accuracy	
Steady State:	±3% ± 0.01 A
Transient:	±5% of setting
Time Dial Range	
U.S./IEEE:	0.50 to 15.00 A secondary
IEC:	0.05 to 1.00 A secondary
Curve Timing Accuracy:	±4% ± 0.025 seconds for current between 2 and 30 multiples of pickup. Curves operate on definite time for current greater than 30 multiples of pickup.
Reset Type:	Definite or Inverse
Reset Accuracy	
Inverse:	±4% ± 0.025 seconds for current less than 1 multiple of pickup setting
Definite:	±1 ms

(51) Neutral Inverse-Time Overcurrent Elements

Number of Elements:	10 (5 for each neutral current terminal)
Operating Quantity:	Neutral IN terminal current
Pickup Range	
5 A Nominal CTs:	0.25 to 16.00 A secondary
1 A Nominal CTs:	0.05 to 3.20 A secondary
Accuracy	
Steady State:	±3% of setting ± 0.01 A
Transient:	±5% of setting
Time Dial Range	
U.S./IEEE:	0.50 to 15.00 A secondary
IEC:	0.05 to 1.00 A secondary
Curve Timing Accuracy:	±4% ± 0.025 seconds for current between 2 and 30 multiples of pickup. Curves operate on definite time for current greater than 30 multiples of pickup.
Reset Type:	Definite or Inverse
Reset Accuracy	
Inverse:	±4% ± 0.025 seconds for current less than 1 multiple of pickup setting
Definite:	±1 ms

(59) Phase Overvoltage Elements

Number of Elements:	4
Operating Quantity:	Phase-to-neutral line voltage
Pickup Range:	5.00 to 300.00 V secondary

Accuracy	
Steady State:	±1% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 100.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(59) Phase-to-Phase Overvoltage Elements

Number of Elements:	2
Operating Quantity:	Phase-to-phase line voltage
Pickup Range:	5.00 to 520.00 V secondary
Accuracy	
Steady State:	±2% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	1.5 cycles

(59) Positive-Sequence Overvoltage Elements

Number of Elements:	2
Operating Quantity:	Positive-sequence line voltage
Pickup Range:	5.00 to 300.00 V secondary
Accuracy	
Steady State:	±2% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(59) Negative-Sequence Overvoltage Elements

Number of Elements:	2
Operating Quantity:	Negative-sequence line voltage
Pickup Range:	5.00 to 300.00 V secondary
Accuracy	
Steady State:	±2% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(59) Residual-Ground Overvoltage Elements

Number of Elements:	2
Operating Quantity:	Residual-ground line voltage
Pickup Range:	5.00 to 300.00 V secondary
Accuracy	
Steady State:	±2% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(59) Single-Phase VS Overvoltage Elements

Number of Elements:	6 (2 for each single-phase voltage terminal)
Operating Quantity:	Single-phase VS01/VS02/VS03 terminal voltage
Pickup Range:	5.00 to 300.00 V secondary
Accuracy	
Steady State:	±1% of setting ± 0.5 V
Transient:	±5% of setting
Timer Operation:	Integrating with user-controllable reset type
Timer Range:	0.000 to 240.000 seconds
Timer Accuracy:	±1 ms
Maximum Operate Time:	25 ms

(68) Power-Swing Blocking

Operation:	Phase-segregated (six-loop measurement with corresponding selective blocking/unblocking; suitable for systems with single-pole tripping)
Operation Principle:	Continuous measurement of the impedance rate of change
Blocking Action:	Selectable on a per-zone basis
Unblocking for Faults:	Yes

(78) Out-of-Step Tripping

Operation:	Trip on the way out
Operation Principle:	Continuous measurement of the impedance rate of change
Tripping Action:	Delayed to avoid breaker overvoltages

(81) Overfrequency Elements

Number of Elements:	6
Operating Quantity:	Frequency tracked from alpha quantity of line voltage
Pickup Range:	60.01–69.99 Hz (for 60 Hz nominal frequency) 50.01–69.99 Hz (for 50 Hz nominal frequency)
Accuracy:	±0.005 Hz
Undervoltage Blocking Accuracy:	±0.1% of setting ± 0.5 V
Timer Operation:	Integrating
Timer Range:	0.050 to 400.000 seconds
Timer Accuracy:	±5 ms

(81) Underfrequency Elements

Number of Elements:	6
Operating Quantity:	Frequency tracked from alpha quantity of line voltage
Pickup Range:	40.01–59.99 Hz (for 60 Hz nominal frequency) 40.01–49.99 Hz (for 50 Hz nominal frequency)
Accuracy:	±0.005 Hz
Undervoltage Blocking Accuracy:	±0.1% of setting ± 0.5 V
Timer Operation:	Integrating
Timer Range:	0.050 to 400.000 seconds
Timer Accuracy:	±5 ms

(81) Rate-of-Change-of-Frequency Elements

Number of Elements:	6
Operating Quantity:	Frequency tracked from alpha quantity of line voltage
Pickup Range:	0.10 to 29.95 Hz/s
Accuracy:	±0.005 Hz/s
Undervoltage Blocking Accuracy:	±0.1% of setting ± 0.5 V
Timer Operation:	Integrating
Timer Range:	0.050 to 80.000 seconds
Timer Accuracy:	±5 ms

Phase Directional Control Element

Maximum Torque Angle:	0.0° to 90.0° 0.1° steps
Comparator Limit Angle:	20.0° to 90.0° 0.1° steps
Operating Time:	<1.25 cycles

Negative-Sequence Directional Control Element

Maximum Torque Angle:	Fixed at the positive-sequence line angle
Operating Time:	0.5 cycles, typical

Residual-Ground Directional Control Element

Maximum Torque Angle:	Fixed at the residual-ground line angle
Operating Time:	0.5 cycles, typical

Load-Encroachment Element

Operation:	Phase-segregated (six-loop measurement with corresponding selective blocking/unblocking, separate phase and ground settings for systems with single-pole tripping)
Blocking Action:	Selectable on a per-zone basis
Pickup Time:	<1.25 cycles
Reset Time:	<0.75, typical

(25) Synchronism-Check Elements

Number of Elements:	2
Slip Frequency Pickup Accuracy:	±2% of setting ± 0.003 Hz
Close Angle Accuracy:	±5% of setting ± 3°

Metering Accuracy

All metering accuracy is at 20°C (68°F) and nominal frequency.

Type	Range	Magnitude Accuracy	Angle Accuracy
Currents			
Phase Currents	(0.2 – 4.00) • CTP.NomSec	±0.2% ± 0.0004 • CTP.NomSec	±0.2°
	(0.05 – 0.2) • CTP.NomSec	±0.2% ± 0.0004 • CTP.NomSec	±0.4°
Neutral Currents (*n* = 01 or 02)	(0.2 – 4.00) • CTN_*n*.NomSec	±0.2% ± 0.0004 • CTN_*n*.NomSec	±0.2°
	(0.05 – 0.2) • CTN_*n*.NomSec	±0.2% ± 0.0004 • CTN_*n*.NomSec	±0.4°
Sequence Currents	(0.1 – 20.0) • CTP.NomSec	±0.3% or ±0.003 • CTP.NomSec (whichever is larger)	±0.3°
Voltages			
Phase and Phase-to-Phase Voltages	(0.1 – 1.2) • VTP_01.NomSec	±0.2%	±0.1°
Sequence Voltages	(0.1 – 1.2) • VTP_01.NomSec	±0.2% or ±0.002 • VTP_01.NomSec (whichever is larger)	±0.2°
Frequency			
V_{alpha} from voltage terminals VA01, VB01, and VC01 as well as voltages on terminals VS01, VS02, and VS03	40–70 Hz	±0.01 Hz	N/A

Technical Support

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

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⚠ WARNING
Operator safety may be impaired if the device is used in a manner not specified by SEL.

⚠ AVERTISSEMENT
La sécurité de l'opérateur peut être compromise si l'appareil est utilisé d'une façon non indiquée par SEL.

⚠ CAUTION
Equipment components are sensitive to electrostatic discharge (ESD), undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.

⚠ ATTENTION
Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.

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PDS9L-01