SEL-751 Feeder Protection Relay

Directional Overcurrent, Arc-Flash Detection, and High-Impedance Fault Detection

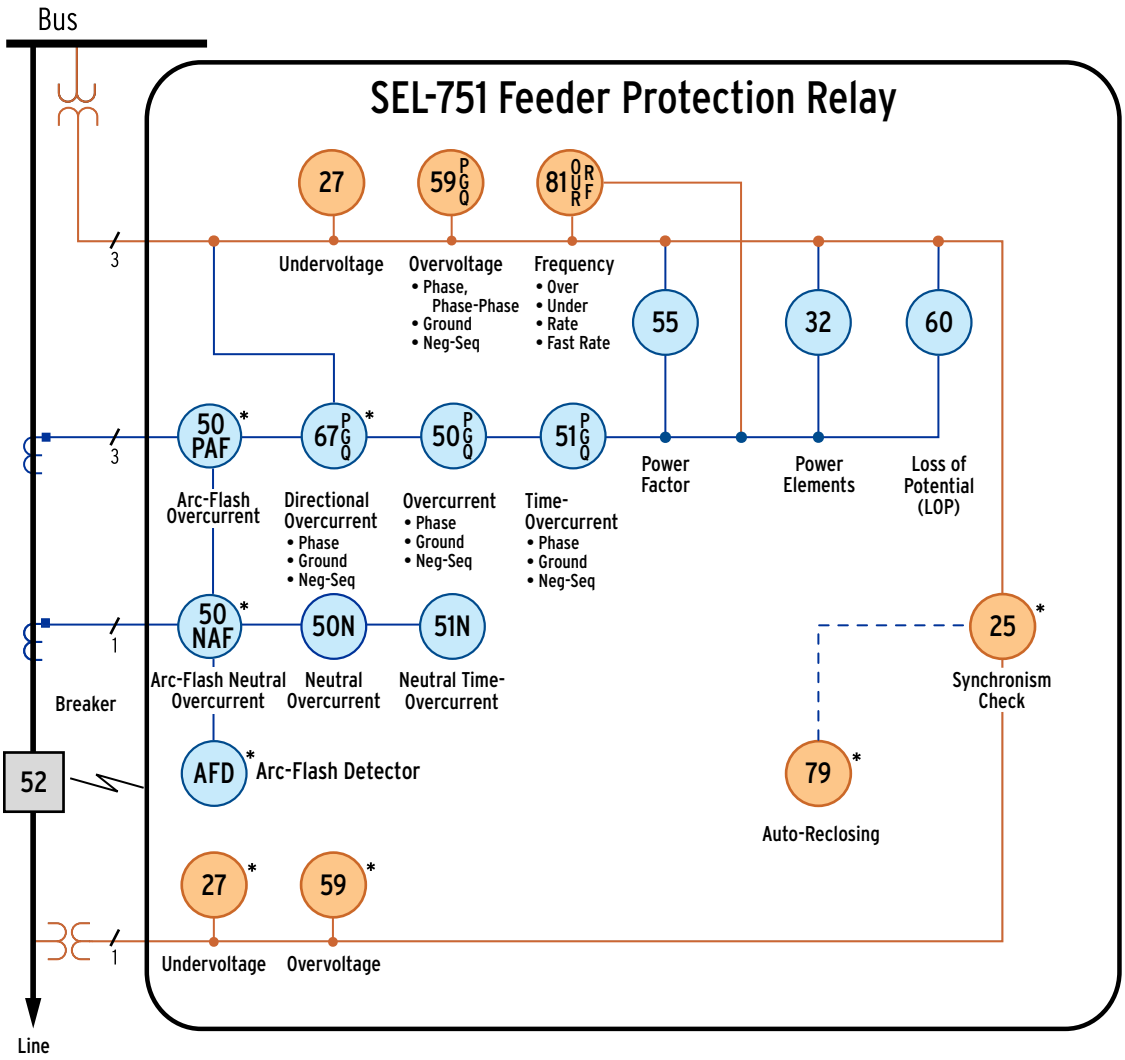
Major Features and Benefits

The SEL-751 Feeder Protection Relay provides a comprehensive combination of protection, fault-locating features, monitoring, control, and communication in an industrial package.

- **Standard Protection Features.** Protect lines and equipment with an extensive range of protection elements, including overcurrent elements, over- and underfrequency elements, rate-of-change-of-frequency and fast rate-of-change-of-frequency elements, over- and undervoltage elements, directional power elements, load encroachment, demand metering elements, and breaker failure protection. Implement load shedding and other control schemes with under- and overfrequency elements, under- and overvoltage elements, and powerful SELOGIC® control equations.
- **Optional Directional Control.** Use overcurrent elements with directional control to optimize radial and looped network protection for lines and equipment. 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 operate for small current ground faults typically resulting from downed conductors on ground surfaces such as earth, concrete, or other poorly conductive materials. HIF event data is available in compressed ASCII format.
- **Optional Arc-Flash Protection.** Reduce or eliminate damage from arc-flash events with the optional four-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 Synchronism Check and DC Station Battery Monitor.** Check single-phase voltage across a circuit breaker; 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.
- **Relay and Logic Settings Software.** Reduce engineering costs by using ACSELERATOR QuickSet® SEL-5030 Software for relay settings and logic programming. Tools in ACSELERATOR QuickSet make it easy to develop 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.
- **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 features, standard in every SEL-751, Modbus® RTU, Event Messenger support and MIRRORED BITS® communications, load profile and breaker wear monitoring, support for 12 external RTDs (SEL-2600), IRIG-B input, advanced SELOGIC, and IEEE C37.118-compliant synchrophasor protocol to provide real-time measurement data.
- **Additional Optional Features.** Select from a wide offering of other optional features, including IEC 61850, DNP3 serial and LAN/WAN, Modbus TCP/IP, Simple Network Time Protocol (SNTP), ten internal RTDs, expanded digital/analog I/O, additional EIA-232 or EIA-485 communications ports, and single or dual, copper-wire or fiber-optic Ethernet ports.

Overview



- Sequential Events Recorder
- Event Reports and Load Profile
- SEL ASCII, Modbus® RTU, Ethernet*, Modbus TCP*, IEC 61850*, DNP3 LAN/WAN*, DNP3 Serial*, SNTP*, Telnet*, FTP*, and DeviceNet Communications*
- Event Messenger Compatible
- Front-Panel Tricolor LED Programmable Targets
- Two Inputs and Three Outputs Standard
- I/O Expansion*—Additional Contact Inputs, Contact Outputs, Analog Inputs, Analog Outputs, and RTD Inputs
- ST® Fiber-Optic Communications Port
- Single or Dual Ethernet, Copper or Fiber-Optic Communications Port*
- Battery-Backed Clock, IRIG-B Time-Synchronization
- Instantaneous Metering
- Eight Programmable Front Pushbuttons and Tricolor LED Indicators
- Advanced SELogic® Control Equations
- 32 Programmable Display Messages
- Station Battery Monitor*
- Breaker Wear Monitoring
- Synchrophasor Protocol (IEEE C37.118)
- Arc-Flash Protection*
- Peak Demand, Demand Metering
- Aurora Mitigation Islanding Detection (81RF Element)
- Load Encroachment
- High-Impedance Fault Detection*
- Fault Locator
- Directional Protection*

*Optional

Figure 1 Functional Diagram

Applications

Figure 2 shows some typical protection applications for the SEL-751. You can use the SEL-751 directional and non-directional overcurrent functions to protect virtually any power system circuit or device including lines, feeders, transformers, capacitor banks, reactors, and generators. Over- and underfrequency, over- and undervoltage, and synchronism-check elements are well suited for applications at distributed generation sites. Directional power elements make the relay suitable for utility and customer interface protection in applications with customer generation.

You can use powerful SELOGIC control equations in all SEL-751 models for custom protection and control applications. SEL application guides and technical support personnel are available to help with unique applications.

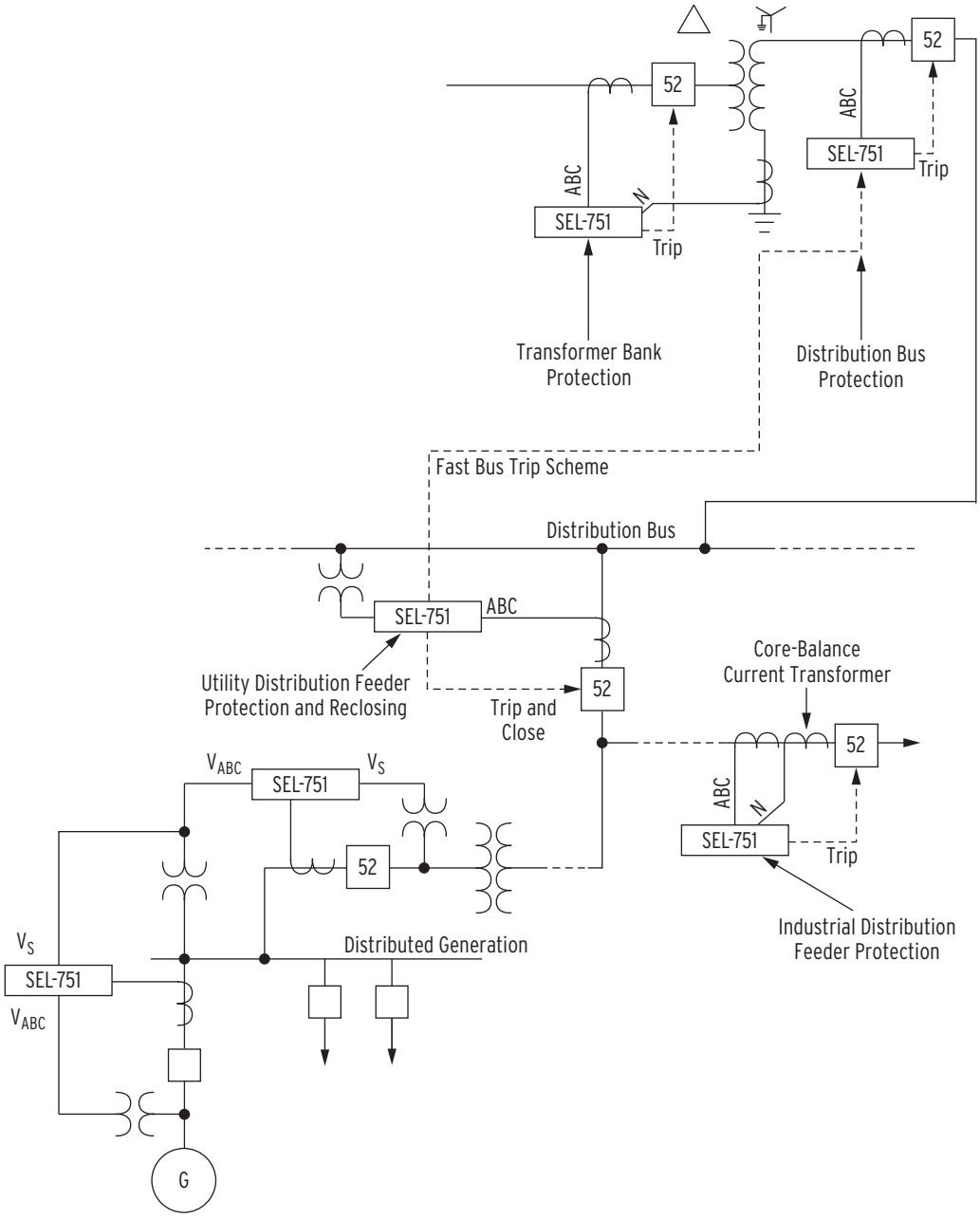


Figure 2 SEL-751 Feeder Protection Relay Applied Throughout the Power System

Protection Features

Overcurrent Elements

The SEL-751 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 1* lists the curves available in the SEL-751.

The SEL-751 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.

Table 1 Inverse-Time Overcurrent Curves

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

Overcurrent Elements for Phase Fault Detection

The SEL-751 relay 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 load while retaining sensitivity to higher magnitude three-phase faults.

On extremely heavily loaded feeders, SEL-751 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 3* 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.

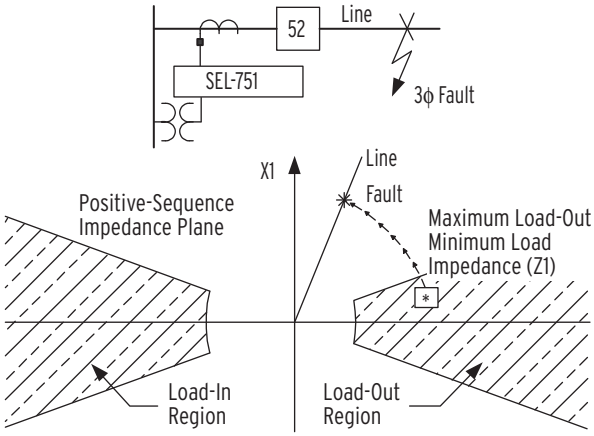


Figure 3 Load Encroachment Characteristics

Directional Elements Increase Sensitivity and Security

Phase and ground directional elements come standard in an SEL-751 with the directional control option. An automatic setting mode (EDIR = AUTO) 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.

Overcurrent Elements for Ground Fault Detection

Residual-ground (IG) and neutral (IN) overcurrent elements detect ground faults. Use optoisolated inputs or the internal ground directional element to control these elements and increase security. Best Choice Ground Directional Element logic in an SEL-751 with the directional control option selects whatever negative-sequence impedance, zero-sequence impedance, and zero-sequence current polarizing techniques provide optimal directional ground element control.

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 4*. You only need to make a global setting (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-751 model meets all your distribution protection needs, regardless of available three-phase voltages.

In addition, the SEL-751 supports single voltage input. For customers with a single PT input, the SEL-751 will assume balanced voltage input for all protection and metering functions.

Loss-of-Potential Logic

The SEL-751 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), 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 the optional recloser control.

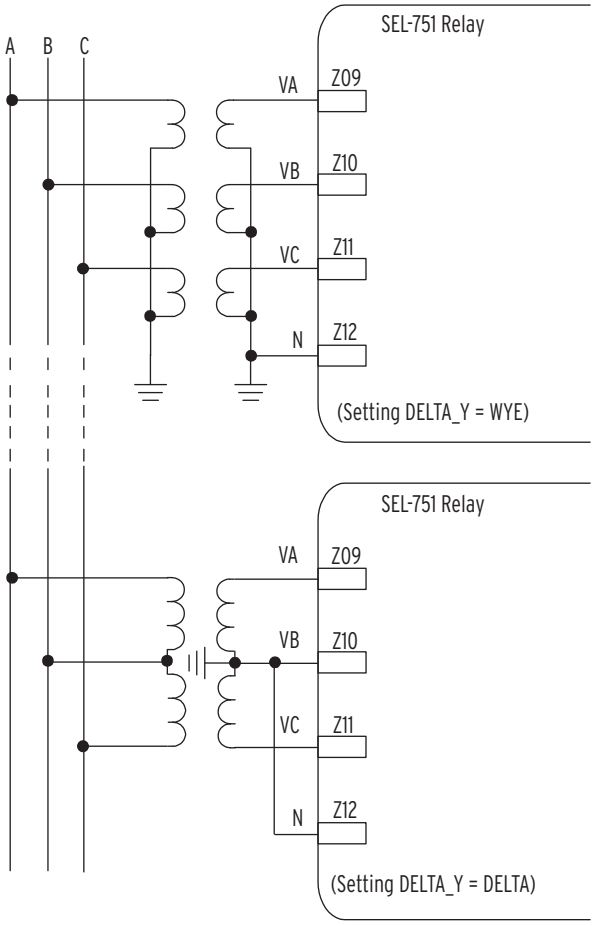


Figure 4 Connect Wye or Open-Delta Voltage to SEL-751 Three-Phase Voltage Inputs

Voltage and Frequency Elements for Extra Protection and Control

Over- and Undervoltage Elements

Phase-to-ground, phase-to-phase, negative-sequence, and residual overvoltage (59) and phase-to-ground or phase-to-phase undervoltage (27) elements in the SEL-751 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).

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-751 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, for example, when there is a sudden imbalance between generation and load. They 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 above or below nominal frequency.

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 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 5*) based on the frequency deviation from nominal frequency (DF = FREQ – FNOM) and the rate-of-change of frequency (DF3C) to detect islanding conditions.

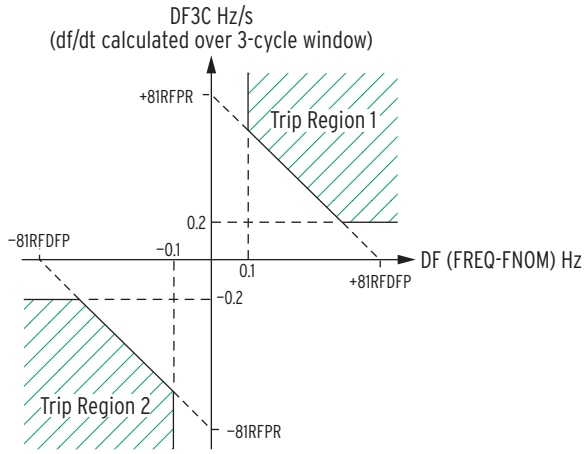


Figure 5 81RF Characteristic Power Element Protection

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.

Power Element Protection

The SEL-751 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 SEL-751 with Arc Sense Technology™ (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 prefault 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 much as 20 minutes of high-impedance fault activity in 2-cycle resolution compressed ASCII format and it stores a summary of HIF activity that you can access through the use of ASCII commands.

Arc-Flash Protection

An arcing short circuit or a ground fault in low or medium voltage switchgear can cause very serious equipment damage and personal injury. They can also cause 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-751 relay adds four-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-751.

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 (over a second fiber-optic cable). If the relay optical receiver does not detect this light, the relay declares a malfunction and alarms. *Figure 6* (top) shows a diagram for the point sensor application.

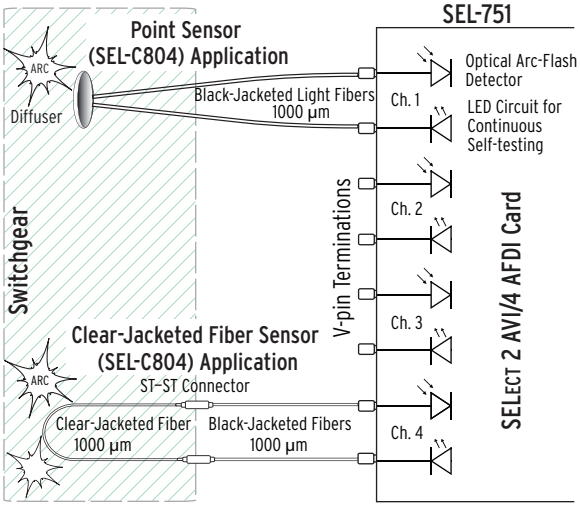


Figure 6 SEL-751 Arc-Flash Detection System

Clear-Jacketed Fiber Sensor Application

A second option for 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 6* (bottom) shows a diagram for the clear-jacketed fiber sensor application.

The SEL-751 AFD system provides four 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 avoid serious damage or personal 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-751 is equipped with either an optional 10 RTD input expansion card or an external SEL-2600 RTD Module with as many as 12 RTD inputs, you can program as many as 12 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 C, provides 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)

Additional Ordering Options

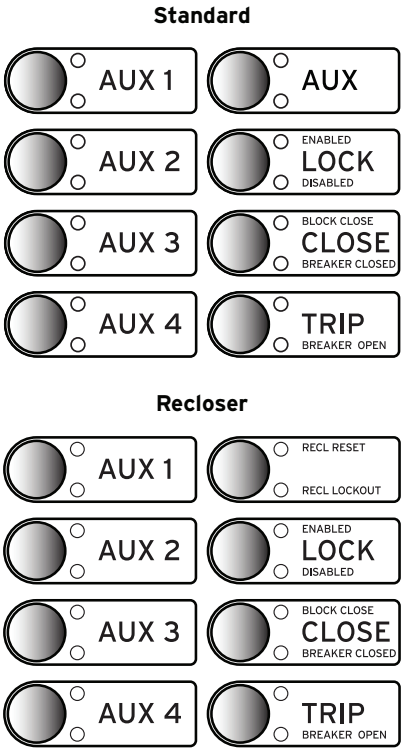
You can order the following options for any SEL-751 model (see the Model Option Table for details).

- Single or dual, copper or fiber-optic Ethernet port(s), Modbus TCP, SNTP, DNP3 serial and DNP3 LAN/WAN, FTP, Telnet
- IEC 61850
- DeviceNet
- EIA-232 or EIA-485 communications
- Additional EIA-232 or EIA-485 port
- Analog I/O (4 AI/4 AO, 8 AI)
- Digital I/O (4 DI/4 DO, 8 DI, 8 DO, 3 DI/4 DO/1 AO, 4 DI/3 DO)
- Vsync, Vbat voltage input, and four arc-flash detection inputs card (SELECT 2 AVI/4 AFDI) for synchronism-check, dc station battery monitor, and arc-flash protection applications.
- Ten RTDs
- Conformal coating for chemically harsh and high moisture environments
- Firmware options including the following:
  - Recloser Control
  - Directional control
  - Arc-Sense technology for high-impedance fault detection (HIF)

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 7*). You can set the SER to track operator controls. You can also change operator control functions using SELOGIC control equations. The following operator control descriptions are for factory-set logic.



Note: All text can be changed with the configurable labels.

Figure 7 Operator Controls for Standard and Optional Reclosing Models

In the standard SEL-751, you can program the top right operator control and its corresponding two LEDs. When the SEL-751 is ordered with optional reclosing, the two LEDs are programmed to give the status of the reclosing. The two LEDs, **RECL RESET** and **RECL LOCKOUT**, indicate whether the recloser is in the Reset or Lockout state.

The **LOCK** operator control blocks selected functions. Press it for at least three seconds to engage or disengage the lock function. While locked in position, the following operator controls cannot change state if pressed, **TRIP** and **CLOSE**.

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

Programmable Autoreclosing

When ordered with optional reclosing, the SEL-751 can autoreclose a circuit breaker as many as four times before lockout. Use SELOGIC control equations to program the SEL-751 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-duty 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 (**Reset** and **Lockout**) track the reclosing state.

Relay and Logic Settings Software

ACSELERATOR QuickSet Software simplifies settings and provides analysis support for the SEL-751. With ACSELERATOR QuickSet you have several ways to create and manage relay settings:

- ➤ 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 ACSELERATOR QuickSet you can verify settings and analyze events; and analyze power system events with the integrated waveform and harmonic analysis tools.

Use the following features of ACSELERATOR QuickSet to monitor, commission, and test the SEL-751.

- The PC interface remotely retrieves power system data.
- The human-machine interface (HMI) monitors meter data, Relay Word bits, and output contacts status during testing. The control window allows resetting of metering quantities, arc-flash sensor testing and diagnostics, and other control functions.

Metering and Monitoring

The SEL-751 provides extensive metering capabilities. See *Specifications on page 23* for metering and power measurement accuracies. As shown in *Table 2*, metered quantities include phase voltages and currents; sequence voltages and currents; power, frequency, and energy; and maximum/minimum logging of selected quantities. The relay reports all metered quantities in primary quantities (current in A primary and voltage in V primary).

Load Profile

The SEL-751 features a programmable Load Profile (LDP) recorder that records as many as 17 metering quantities into nonvolatile memory at fixed time intervals. The LDP saves several days to several weeks of the most recent data depending on the LDP settings (4000 intervals total).

Table 2 Metering Capabilities

Quantities[a]	Description
Currents IA, IB, IC, IN, IG	Input currents, residual ground current (IG = 3I0 = IA + IB + IC)
Voltages VA, VB, VC	Wye-connected voltage inputs
Voltages VAB, VBC, VCA	Delta-connected voltage inputs
Voltage VS	Synchronism-check voltage input
Power $kW_{A,B,C,3P}$ $kVAR_{A,B,C,3P}$ $kVA_{A,B,C,3P}$	Single and three-phase kilowatts, kilovars, and kilovolt-amps
Energy MWh3P, MVARh3P-IN, MVARh3P-OUT, MVAh3P	Three-phase megawatt hours, megavar-hours, and megavolt-amp-hours
Power Factor $PF_{A,B,C,3P}$	Single and three-phase power factor (leading or lagging)
Sequence I1, 3I2, 3I0, V1, 3V2, 3V0	Positive-, negative-, and zero-sequence currents and voltages
Frequency, FREQ, FREQS (Hz)	Instantaneous relay frequency, synchronism-check voltage frequency
Voltage VDC	Station battery voltage
Light Intensity (%) LS1–LS4	Arc-flash light inputs in percentage of full scale
AIx01–AIx08	Analog Inputs
MV01–MV32	Math Variables
RA001–RA128	Remote Analogs
RTD1–RTD12	RTD temperature measurement (degrees C)

Types of Metering		
Instantaneous	RMS	Max/Min
Math Variables	Synchrophasors	Energy
Demand and Peak Demand	Analog Inputs	Thermal
Light	Remote Analogs	HIF (High-Impedance Fault)

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

Synchrophasor Measurements

Use IEEE C37.118-2005 protocol to send synchrophasor data to such SEL synchrophasor applications as the SEL-3373 Station Phasor Data Concentrator (PDC), the SEL-5073 SYNCHROWAVE® PDC, the SEL-3378 Synchrophasor Vector Processor (SVP), the SEL-3530 Real-Time Automation Controller (RTAC), and the SEL SYNCHROWAVE® software suite.

The SEL-3373 Station PDC and the SEL-5073 SYNCHROWAVE PDC correlate data from multiple SEL-751 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-751 synchrophasors is selectable with a range of 1–60 messages per second. This flexibility is important for efficient use of communication capacity.

The SEL-751 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 the low-cost SEL-751 in any application that otherwise would require purchasing a separate dedicated phasor measurement unit (PMU).

Use the SEL-751 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 then state estimation is no longer necessary. The system state is directly measured.

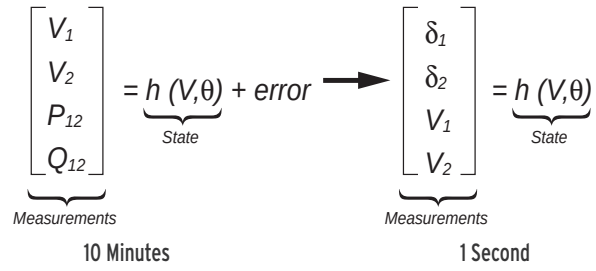


Figure 8 Synchrophasor Measurements Turn State Estimation Into State Measurement

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.

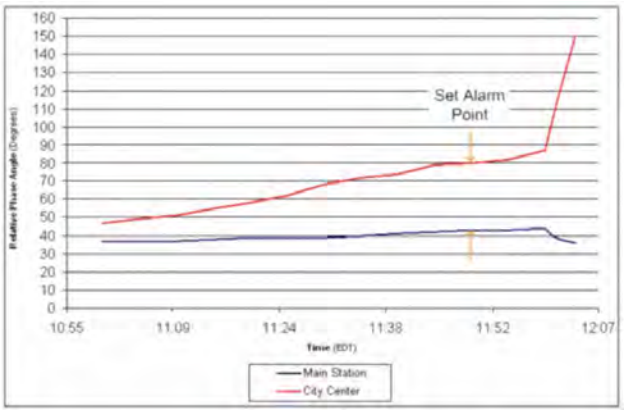


Figure 9 Visualization of Phase Angle Measurements Across a Power System

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

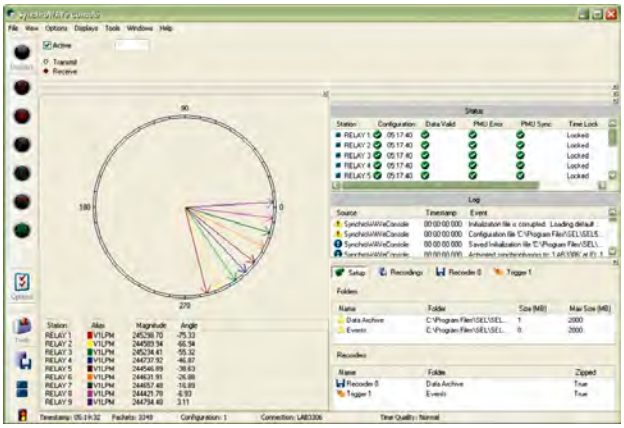


Figure 10 SEL-5078 SYNCHROWAVE Console Real-Time, Wide-Area Visualization Tool

Event Reporting

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 and filtered or raw analog data).

The relay stores as many as 10 of the most recent 64-cycle or as many as 44 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
- ➤ Unfiltered or filtered analog
- ➤ ASCII or Compressed ASCII

The relay SER feature stores the latest 1024 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.

The IRIG-B time-code input synchronizes the SEL-751 internal clock time to within ±1 µs of the time-source input. Convenient sources for this time code are the SEL-2401 Satellite-Synchronized Clock, the SEL Communications Processor, or the SEL Real Time Automation Controller (RTAC) (via Serial Port 2 or 3 on the SEL-751). For time accuracy specifications for metering, synchrophasors, and events, see *Specifications*.

Substation Battery Monitor

The SEL-751 relays 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-751 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 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-751 breaker monitor feature compares this input data to the measure (unfiltered) ac current at the time of trip and the number of close-to-open operations.

Every time the breaker trips, it integrates the measured current information. When the result of this integration exceeds the breaker wear curve threshold (see *Figure 11*) the relay alarms via output contact, communications port, or front-panel display. This kind of information allows timely and economical scheduling of breaker maintenance.

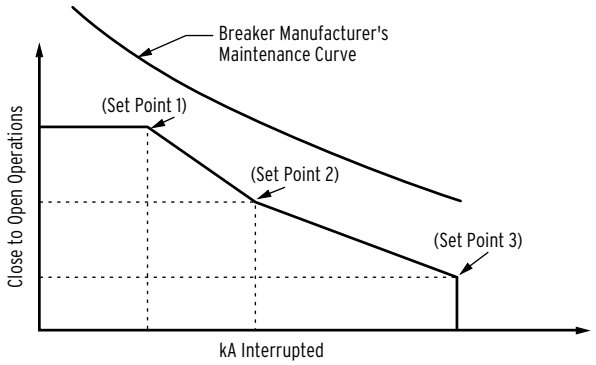


Figure 11 Breaker Contact Wear Curve and Settings

Fault Locator

The SEL-751 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 prefault 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.

Automation

Flexible Control Logic and Integration Features

The SEL-751 is equipped with as many as four independently operated serial ports: one EIA-232 port on the front, one EIA-232 or EIA-485 port on the rear, and one fiber-optic port. Additionally, the SEL-751 has one EIA-232 or EIA-485 port option card. Optionally, the relay supports single or dual, and 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. Establish communication by connecting computers, modems, protocol converters, printers, an SEL real-time automation controller (RTAC), SEL Communications Processor, SEL computing platform, SCADA serial port, and/or RTUs for local or remote communication. Refer to *Table 3* for a list of communications protocols available in the SEL-751.

Table 3 Communications Protocols

Type	Description
Simple ASCII	Plain language commands for human and simple machine communications. Use for metering, setting, self-test status, event reporting, and other functions.
Compressed ASCII	Comma-delimited ASCII data reports. Allows external devices to obtain relay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended Fast Meter and Fast Operate	Binary protocol for machine-to-machine communications. Quickly updates SEL communications processors, RTUs, and other substation devices with metering information, relay element, I/O status, time-tags, open and close commands, and summary event reports. Data are checksum protected. Binary and ASCII protocols operate simultaneously over the same communications lines so control operator metering information is not lost while a technician is transferring an event report.
Fast SER Protocol	Provides SER events to an automated data collection system.
Modbus	Serial- or Ethernet-based Modbus with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and setting groups.
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.
IEC 61850	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-compliant synchrophasors for system state, response, and control capabilities.
Event Messenger	The SEL-3010 allows users to receive alerts sent directly to their cell phone. Alerts can be triggered through relay events and can include quantities measured by the relay.
DeviceNet	Allows for connection to a DeviceNet network for access to metering data, protection elements, contact I/O, targets, and setting groups.
SNTP	Ethernet-based protocol that provides time synchronization of the relay.

Apply an SEL communications processor as the hub of a star network, with point-to-point fiber or copper connection between the hub and the SEL-751 (see *Figure 12*).

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.

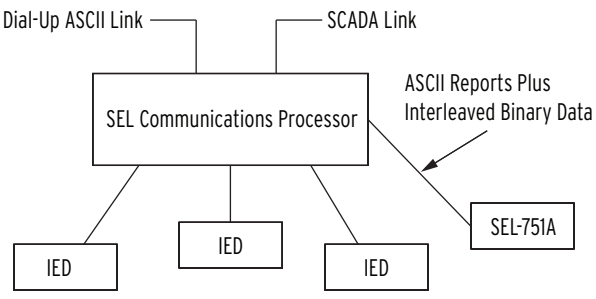


Figure 12 Example Communication System

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-751 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. Eliminate 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 32 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 32 general purpose SELOGIC control equation timers. Each timer has independent time-delay pickup and dropout settings. Program each timer input with any desired element (e.g., time qualify a current element). Assign the timer output to trip logic, transfer trip communications, or other control scheme logic.
- **Eliminates settings changes**. Selectable setting groups make the SEL-751 ideal for applications requiring frequent setting changes and for adapting the protection to changing system conditions.

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

Switching setting groups switches logic and relay element settings. You can 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 Protocol 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-751 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

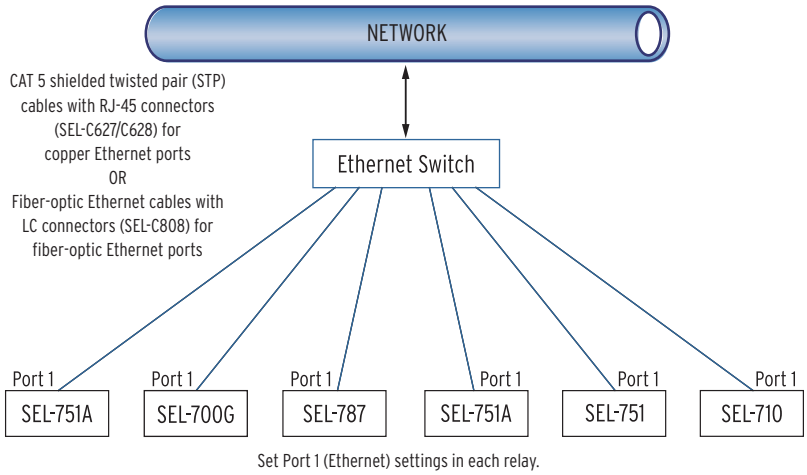


Figure 13 Simple Ethernet Network Configuration

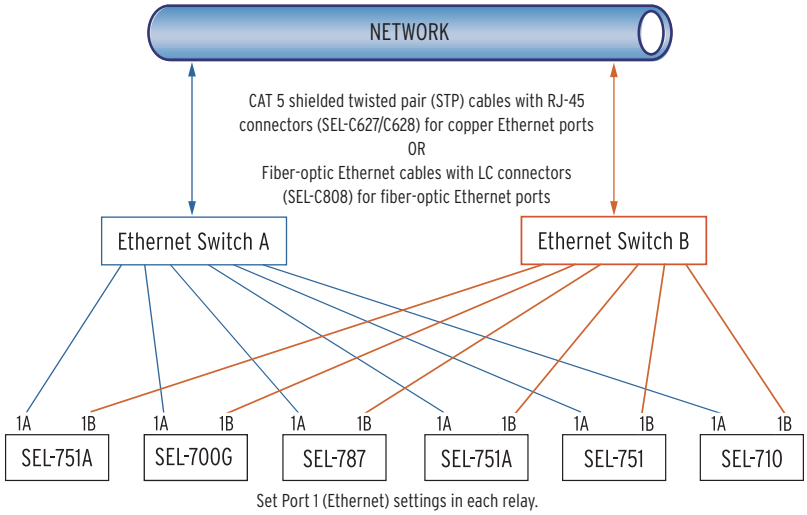


Figure 14 Simple Ethernet Network Configuration With Dual Redundant Connections (Failover Mode)

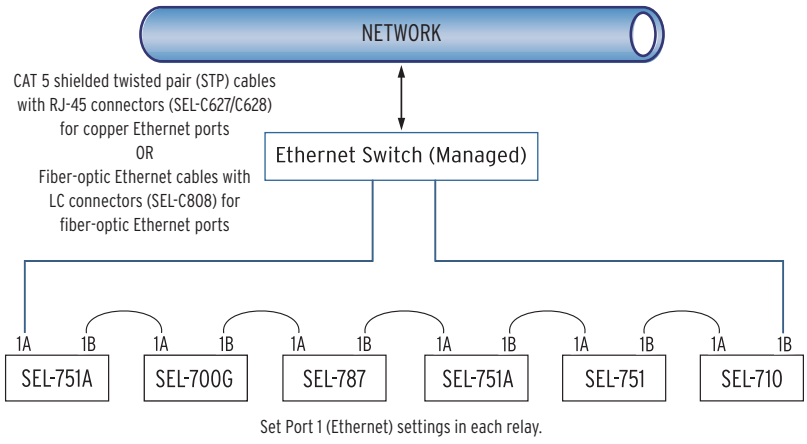


Figure 15 Simple Ethernet Network Configuration With Ring Structure (Switched Mode)

Additional Features

MIRRORED BITS Relay-to-Relay Communications

The SEL-patented MIRRORED BITS communications technology provides bidirectional relay-to-relay digital communications. MIRRORED BITS can operate independently on as many as two EIA-232 rear serial ports and one fiber-optic rear serial port on a single SEL-751.

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 16*). 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.

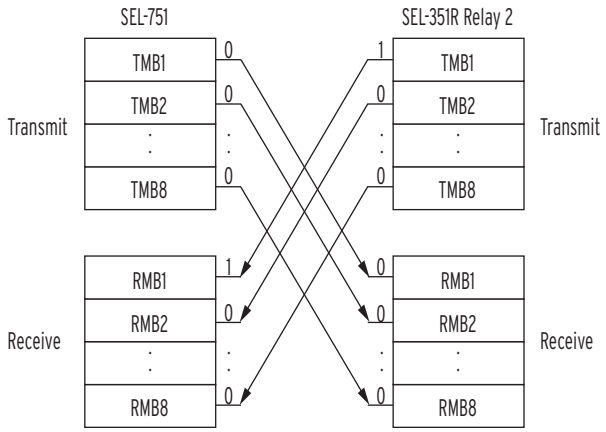


Figure 16 MIRRORED BITS Transmit and Receive Bits

Status and Trip Target LEDs

The SEL-751 includes 24 status and trip target tri-color 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 18*. 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-751, when used with the SEL-3010 Event Messenger, can allow 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 can allow the user to receive voice messages on any phone for alerts to transition of any Relay Word bits in the relay.

Verbal notification of breaker openings, fuse failures, RTD alarms, etc. can now be sent directly to your cell phone through the use of your SEL-751 and 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-751.

Configurable Labels

Use the configurable labels to relabel the operator controls and LEDs to suit the installation requirements. This feature includes preprinted labels (with factory default text), blank label media, and a Microsoft® Word template on CD-ROM. This allows quick, professional-looking labels for the SEL-751. Labels may also be customized without the use of a PC by writing the new label on the blank stock provided.

The ability to customize the control and indication features allows specific utility or industry procedures to be implemented without the need for adhesive labels. All of the figures in this data sheet show the factory default labels of the SEL-751, including the standard model shown in *Figure 18*.

Guideform Specification

Feeder protection shall be provided by a microprocessor-based relay equipped with the following protection, monitoring, control, automation, and reporting functions. Self-checking functions shall be included. Specific requirements are as follows.

Protection and Control

- Phase, residual, and negative-sequence overcurrent elements (50P/50G/50Q) with optional directional control
- Phase, residual, and negative-sequence inverse time-overcurrent elements (51P/51G/51Q) with optional directional control
- Neutral overcurrent and inverse time-overcurrent elements (50N, 51N)
- Breaker/contactor failure
- Autoreclosing control (79)
- Arc-flash detection and arc-flash overcurrent (50PAF, 50NAF)
- Over- and undervoltage (59, 59G, 59Q, 27)
- Directional power elements (32)
- Power factor (55)
- Over- and underfrequency (81)
- Rate-of-change of frequency (81R)
- Loss-of-potential (60)
- Synchronism check (25)
- Fast rate-of-change of frequency (81RF) for Aurora mitigation
- High-impedance fault detection: The relay shall include high-impedance fault detection algorithms capable of detecting HIF signatures without being affected by loads and other system operation conditions. The relay shall make high-impedance fault summary, history, and event information available.
- Fault locator: The relay shall include a fault-locating algorithm to calculate fault location without communications channels, special instrument transformers, or prefault information.
- Synchrophasors: The relay shall include operation as a phasor measurement unit (PMU) according to the IEEE C37.118–2005 Standard for Synchrophasors for Power Systems.
- Adaptive phase overcurrent elements: The relay shall incorporate adaptive phase overcurrent elements that perform reliably in the presence of current transformer saturation, dc offset, and off-frequency harmonics.

Temperature Inputs

Availability of as many as 12 RTD inputs in an external module (SEL-2600 with ST® connectors option) or 10 RTD inputs with an internal card, which, when included, shall have the following features:

- Optical fiber transmission of RTD temperatures (using SEL-2600) to relay: range > 1000 m
- Separately field-selected RTD types: Pt100, Ni100, Ni120, or Cu10
- Noise immunity (50 Hz and higher) on RTD inputs as much as 1.4 Vac_{peak}
- One contact input (with SEL-2600)

Automation

- 32 local control logic points, 32 remote control logic points, 32 latching logic points, 32 counters, 32 math variables, 32 logic variables, and 32 timers
- SELOGIC® control equations with Boolean and math equations capability for logic and control

Communications/Integration

- ASCII, Modbus® RTU, DeviceNet™, Event Messenger, MIRRORED BITS®, SNTP, Telnet, FTP, Modbus® TCP, DNP3 serial and LAN/WAN, IEEE C37.118 (synchrophasor data), and IEC 61850 protocols
- One front-panel EIA-232 port and one rear-panel EIA-232 or EIA-485 port, one ST fiber-optic serial port, and an optional single or dual, copper or fiber-optic Ethernet port(s)
- Capability for an additional rear-panel EIA-232 or EIA-485 port
- Windows®-based PC software for setting, report retrieval, metering, HMI, and control.

Front-Panel Visualization

- The front panel shall be capable of displaying measured values, calculated values, I/O status, device status, and configuration parameters on a front-panel LCD display.
- The display shall have a rotating capability to display custom messages and data. 32 display messages shall be provided.
- The front panel shall also have a minimum of 6 user-programmable LEDs and 8 user-programmable pushbutton controls with 16 programmable LEDs.

Monitoring and Reporting

- Load-profile monitoring: Provide periodic snap-shot (selectable rate from every 5 to 60 minutes) of as many as 17 selectable analog quantities.
- Metering: The relay shall include metering capabilities for real-time current, voltage, power, energy qualities, and demand and peak demand current and power values. RTD temperature metering, synchrophasor data metering, and minimum/ maximum metering shall also be included. The arc-flash protection shall include light metering.
- Event summaries: Fault type and trip data, including time of tripping
- Event reports: 15-cycle length (as many as 44 reports) or 64-cycle length (as many as 10 reports) with a 4 or 32 samples/cycle resolution
- SER: As many as 1024 time-tagged, most recent input, output, and element transitions
- Data stored in nonvolatile, Flash memory
- Station battery monitor with two levels of detection
- Breaker wear monitoring
- Event report with arc-flash light input
- High-impedance fault event reports

Hardware

- Operating temperature range of –40° to +85°C
- Power supply input operating voltage range of 24/48 Vdc, 125/250 Vdc, or 120/240 Vac
- Demodulated IRIG-B time-synchronization input capability
- Optional 10 internal RTD inputs or 12 external RTD inputs
- 5 A or 1 A, ac current inputs IA, IB, IC, and IN
- 300 V maximum, 3 ac voltage inputs, synchronism-check voltage input, station battery voltage input, and arc-flash detection (AFD) inputs
- Flexible, configurable I/O, including digital I/O and analog I/O
- Electromechanical or optional fast hybrid (high-speed, high-current interruption) digital outputs
- Optoisolated digital inputs
- Jumper-selectable current (as high as ±20 mA range) or voltage (as high as ±10 V range) analog inputs
- Jumper-selectable current (as high as ±20 mA range) or voltage (as high as ±10 V range) analog outputs
- Relay front panel shall meet the requirements of NEMA 12/IP65

Service and Support

- Reliability: The vendor shall supply the actual mean time between failures (MTBF) for the device upon request.
- Manufacturer: The device shall be manufactured in the U.S.A.
- Conformal Coating: The device shall have optional conformal coating to protect the circuit boards from harsh environments.
- Warranty: The device shall include a ten-year, no-questions-asked warranty for all material and workmanship defects. In addition, the warranty shall cover accidental, customer-induced damage.

Wiring Diagrams

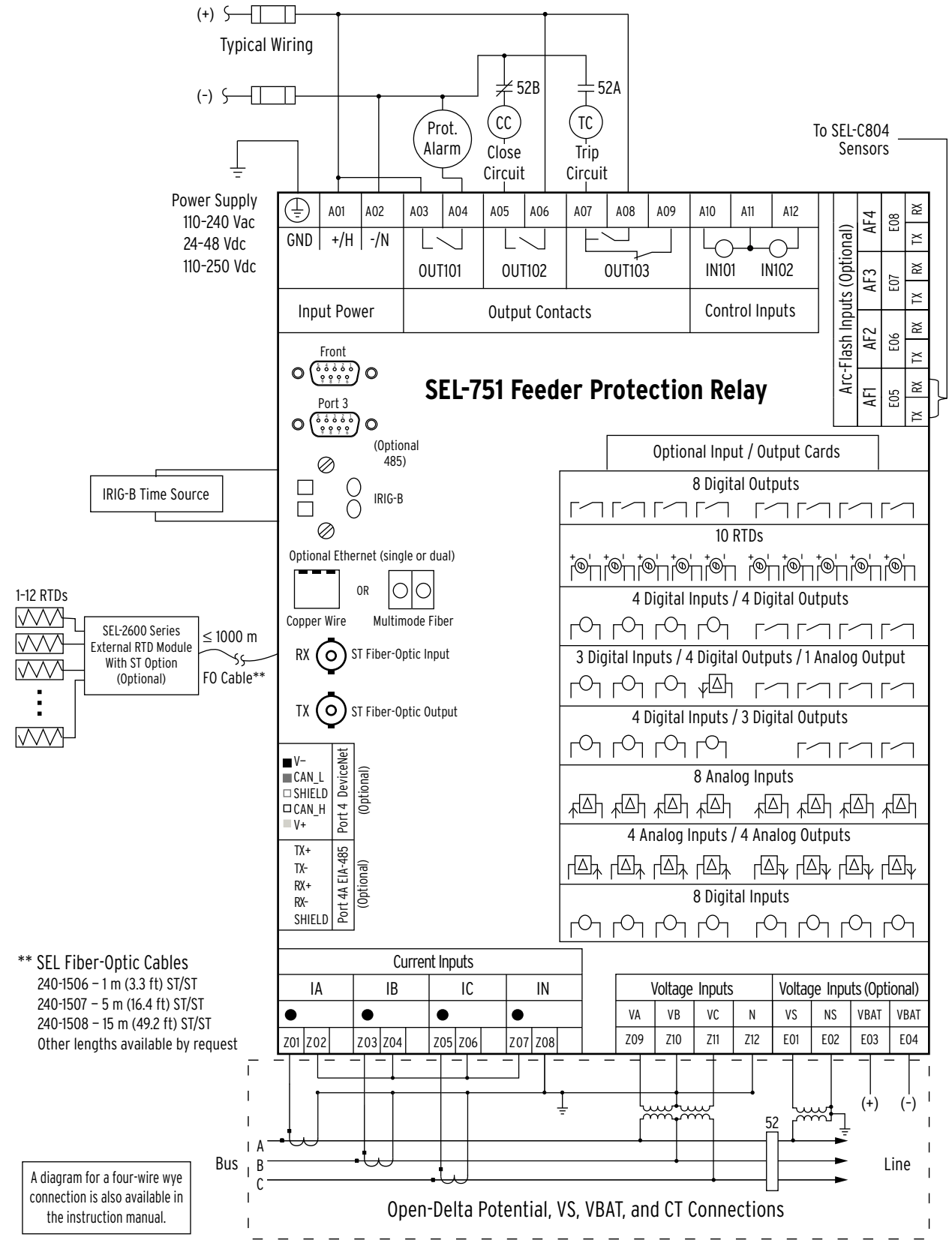


Figure 17 Wiring Diagram SEL-751

Panel Diagrams

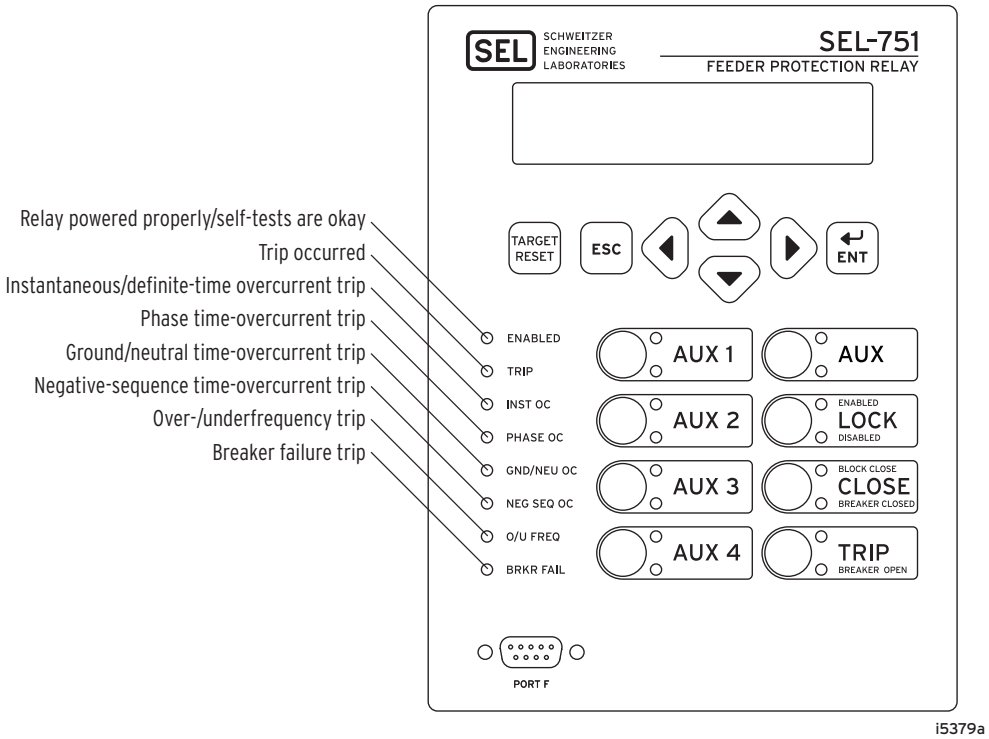
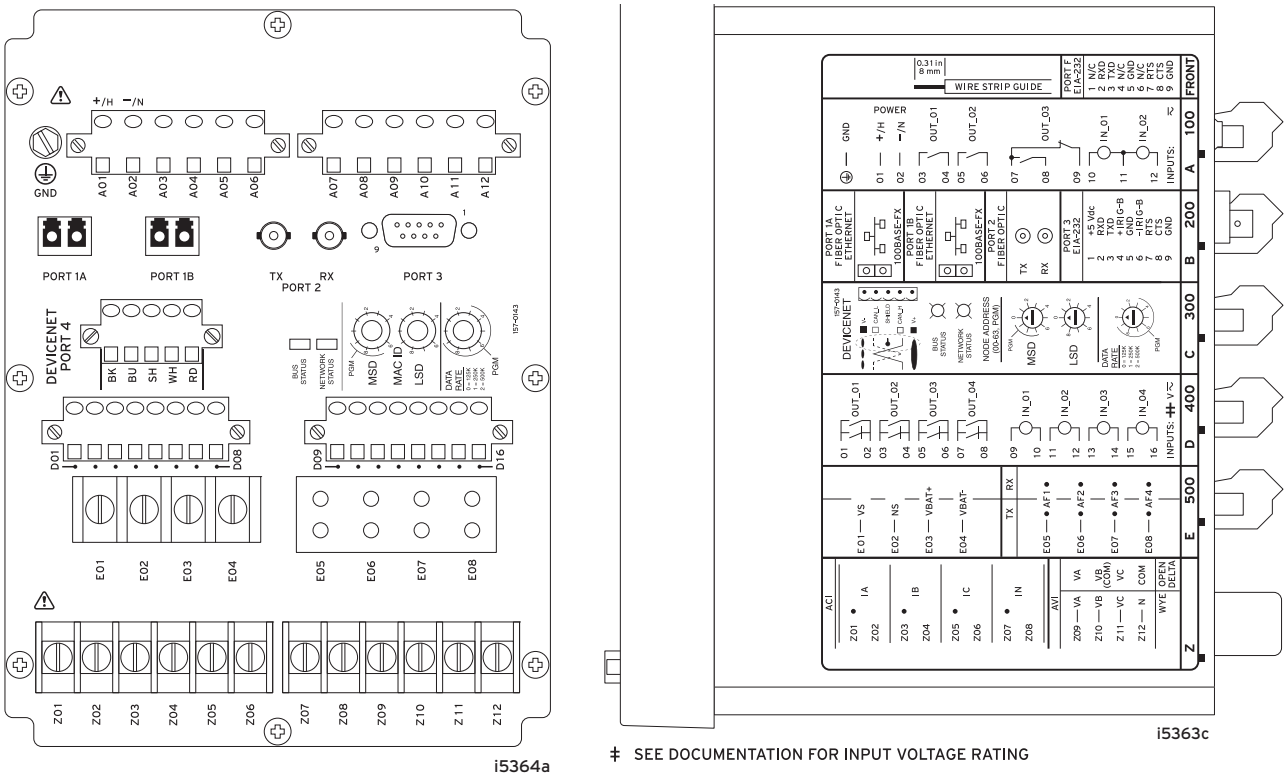
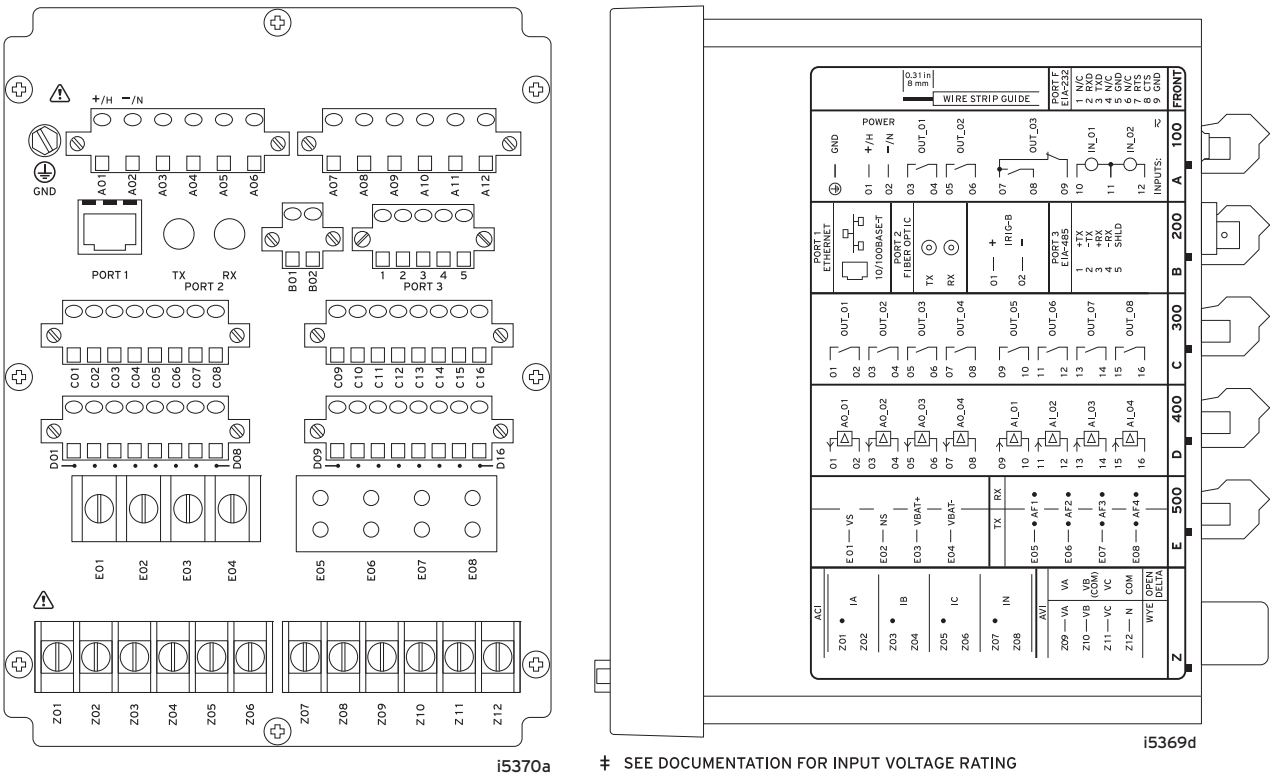


Figure 18 Front Panel With Default Configurable Labels in Base Relay



(A) Rear-Panel Layout (B) Side-Panel Input and Output Designations

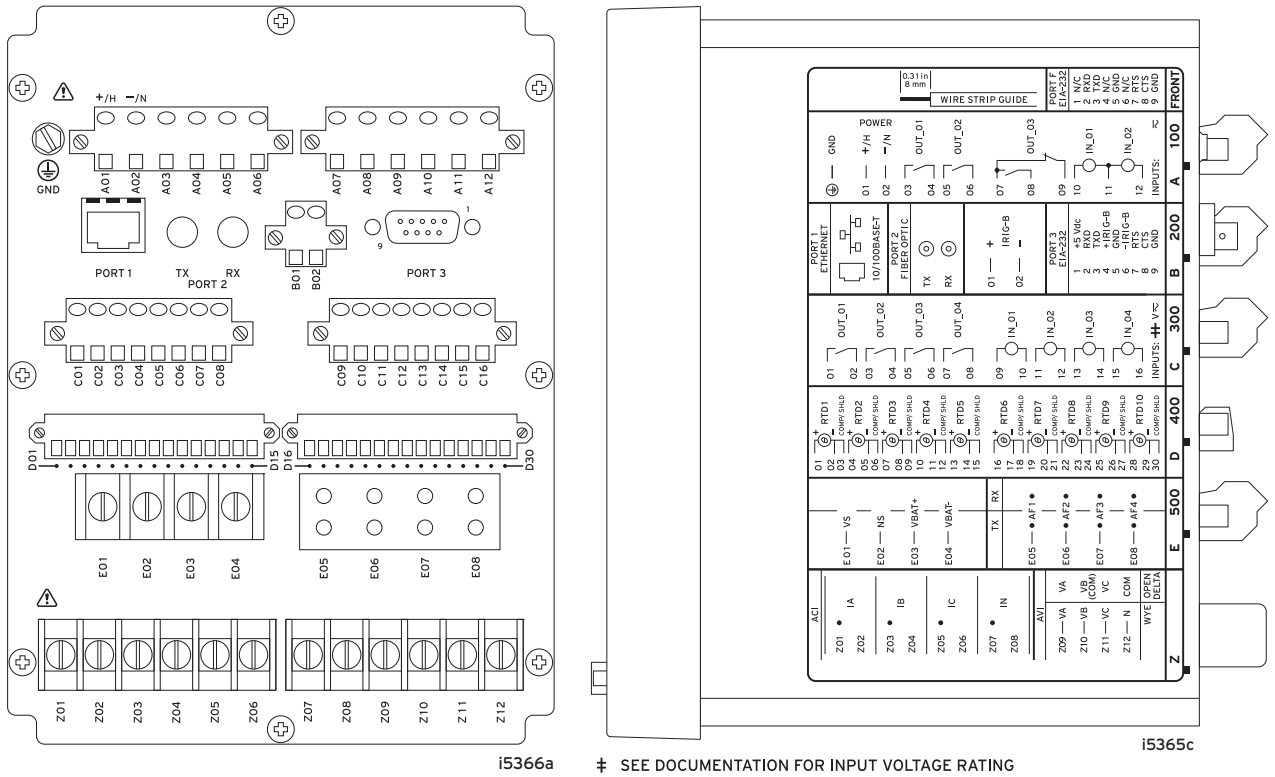
Figure 19 Dual Fiber Ethernet With 2 AVI/ 4 AFDI Voltage Option With Arc-Flash Detector Inputs, DeviceNet Card, and Fast Hybrid 4 DI/4 DO Card (Relay MOT 751501AA3CA70850830)



(A) Rear-Panel Layout

(B) Side-Panel Input and Output Designations

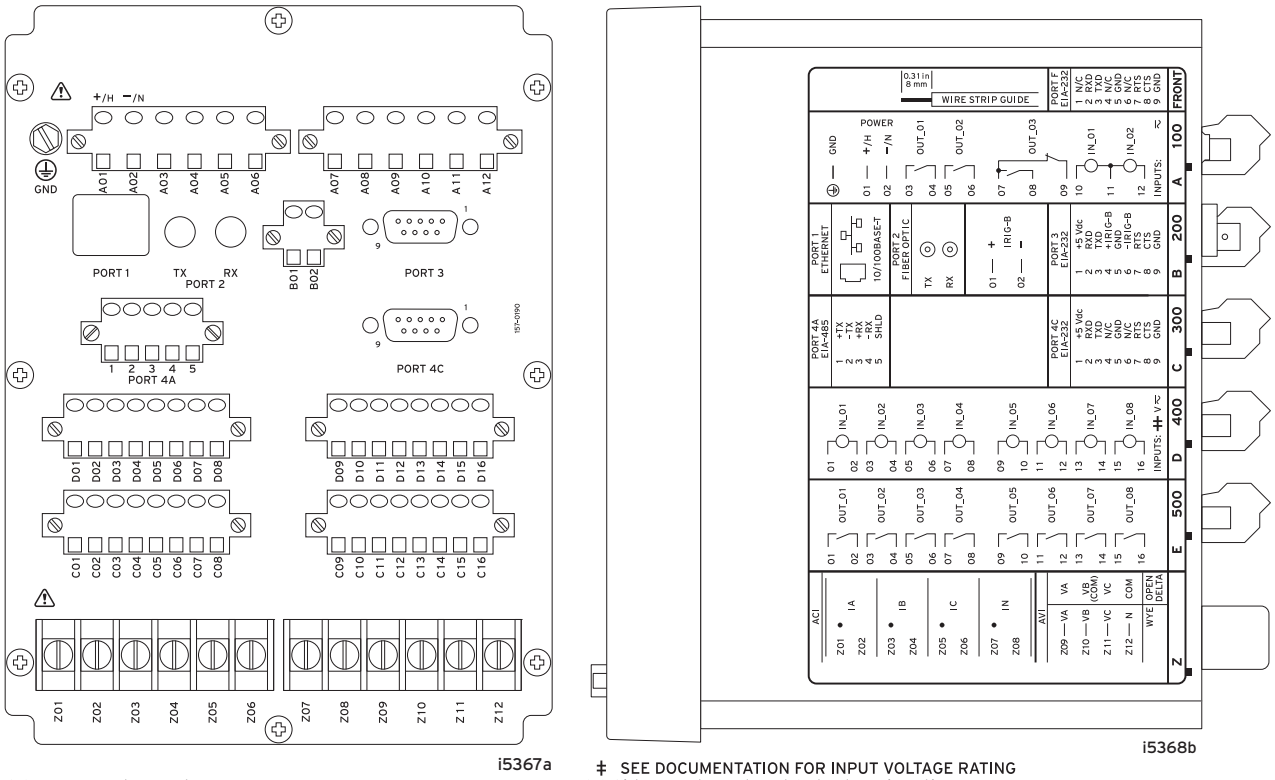
Figure 20 Single Copper Ethernet, EIA-485 Communication, 8 DO (Form-A) Card, 4 AI/4AO Card, and 2 AVI/4 AFDI Voltage Option With Arc-Flash Detector Inputs (Relay MOT 751201A2A6X70810320)



(A) Rear-Panel Layout

(B) Side-Panel Input and Output Designations

Figure 21 Single Copper Ethernet With EIA-232 Communication, RTD Card, 4 DI/4 DO Card and 2 AVI/4 AFDI Voltage Option Card With Arc-Flash Detector Inputs (Relay MOT 751501A1A9X70850230)



(A) Rear-Panel Layout

(B) Side-Panel Input and Output Designations

Figure 22 No Ethernet, EIA-232 Serial Communications, EIA-232/EIA-485 Communications Card, 8 DI Card and 8 DO Card (Form-A) (Relay MOT 751401AA03A2A850000)

Relay Dimensions

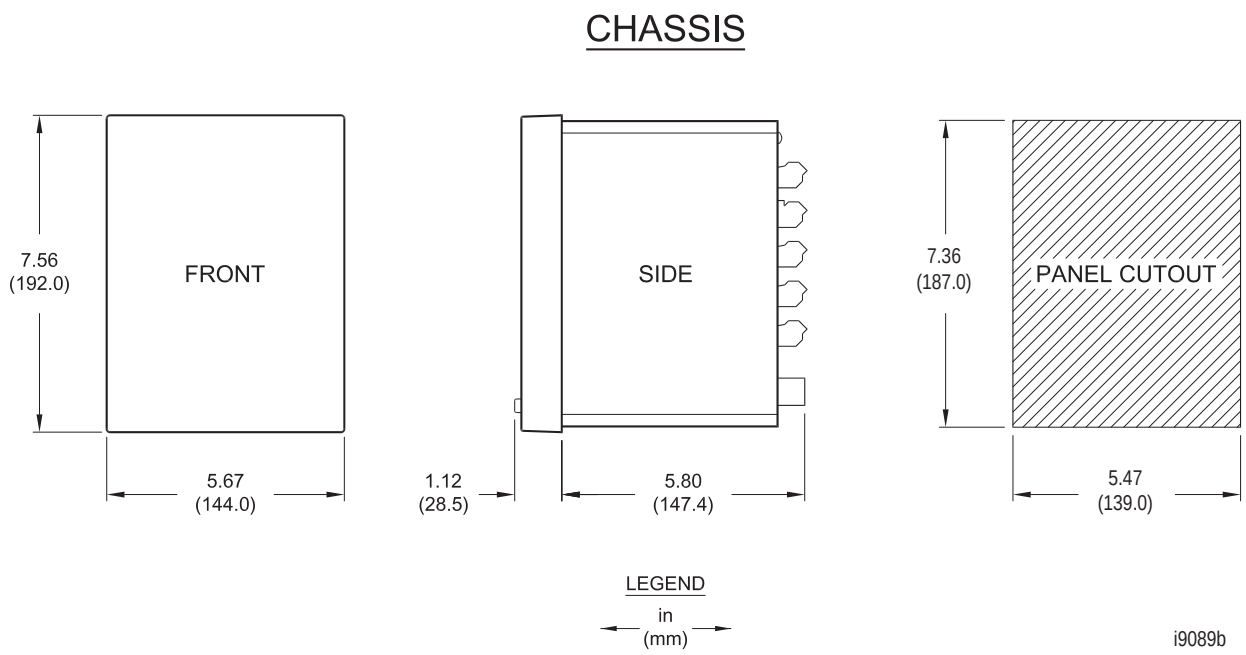


Figure 23 SEL-751 Dimensions for Rack- and Panel-Mount Models

Specifications

General

AC Current Input

Phase and Neutral Currents

I_{NOM} = 1 A or 5 A secondary, depending on model.

I_{NOM} = 5 A

Continuous Rating:	15 A, linear to 100 A symmetrical
1 Second Thermal:	500 A
Burden (per phase):	< 0.1 VA

I_{NOM} = 1 A

Continuous Rating:	3 A, linear to 20 A symmetrical
1 Second Thermal:	100 A
Burden (per phase):	< 0.01 VA
Measurement Category:	II

AC Voltage Inputs

V_{NOM} (L-L) Setting Range:	20–250 V (if DELTA_Y := DELTA) 20–440 V (if DELTA_Y := WYE)
Rated Continuous Voltage:	300 Vac
10 Second Thermal:	600 Vac
Burden:	< 0.1 VA
Input Impedance:	4 MΩ differential (phase-phase) 7 MΩ common mode (phase-chassis)

Power Supply

125/250 Vdc or 120/240 Vac

Rated Supply Voltage:	110–240 Vac, 50/60 Hz 110–250 Vdc
Input Voltage Range:	85–264 Vac 85–300 Vdc
Power Consumption:	< 40 VA (ac) < 20 W (dc)
Interruptions:	50 ms @ 125 Vac/Vdc 100 ms @ 250 Vac/Vdc

24/48 Vdc

Rated Supply Voltage:	24–48 Vdc
Input Voltage Range:	19.2–60.0 Vdc
Power Consumption:	<20 W (dc)
Interruptions:	10 ms @ 24 Vdc 50 ms @ 48 Vdc

Output Contacts

General

OUT103 is Form C Trip output, all other outputs are Form A, except for the SELECT 4 DI / 3 DO card, which supports one Form-B and two Form-C outputs and SELECT 8DO card, which supports Form-A and Form-B outputs.

Mechanical Durability:	100,000 no load operations
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
Thermal:	50 A for 1 s
Contact Protection:	360 Vdc, 40 J MOV protection across open contacts

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

24 Vdc	.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
Utilization Category:	AC-15 (control of electromagnetic loads > 72 VA)
Contact Rating Designation:	B300 (B = 5 A, 300 = rated insulation voltage)
Voltage Protection Across Open Contacts:	270 Vac, 40 J
Rated Operational Current (I_e):	3 A @ 120 Vac 1.5 A @ 240 Vac
Conventional Enclosed Thermal Current (I_{the}) Rating:	5 A
Rated Frequency:	50/60 ±5 Hz
Electrical Durability Make VA Rating:	3600 VA, cos ϕ = 0.3
Electrical Durability Break VA Rating:	360 VA, cos ϕ = 0.3

UL/CSA Digital Output Contact Temperature Derating for Operating at Elevated Temperatures

Digital Output Cards Installed	Operating Ambient	Maximum Value of Current (I_{the})	Duty Factor
1–3	less than or equal to 60°C	5.0 A	Continuous
1–3	between 60°C and 70°C	2.5 A	Continuous

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

Make:	30 A
Carry:	6 A continuous carry at 70°C 4 A continuous carry at 85°C
1 s Rating:	50 A
Open State Leakage Current:	< 100 µA
MOV Protection (maximum voltage):	250 Vac/330 Vdc
Pickup Time:	< 50 µs, resistive load
Dropout Time:	< 8 ms, resistive load

Break Capacity (10000 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

Note: Per IEC 60255-23:1994, using the simplified method of assessment.

Note: Make rating per IEEE C37.90-1989.

Optoisolated Control Inputs

When Used With DC Control Signals

250 V:	ON for 200–312.5 Vdc OFF below 150 Vdc
220 V:	ON for 176–275 Vdc OFF below 132 Vdc
125 V:	ON for 100–156.2 Vdc OFF below 75 Vdc
110 V:	ON for 88–137.5 Vdc OFF below 66 Vdc
48 V:	ON for 38.4–60 Vdc OFF below 28.8 Vdc
24 V:	ON for 15–30 Vdc OFF for <5 Vdc

When Used With AC Control Signals

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)

	1A0	**4A0**
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
Simple Network Time Protocol (SNTP) Accuracy Internal Clock:	±5 ms
Unsychronized 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 (RJ-45 connector)
Single/Dual 100BASE-FX (LC connector)

Multimode Fiber-Optic Port

Location:	Front Panel
Data Speed:	300–38400 bps

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 Mb
Typical Fiber Attenuation:	–2 dB/Km

Port 2 Serial

Wavelength:	820 nm
Optical Connector Type:	ST
Fiber Type:	Multimode
Link Budget:	8 dB
Typical TX Power:	–16 dBm

RX Min. Sensitivity:	–24 dBm
Fiber Size:	62.5/125 µm
Approximate Range:	~1 Km
Data Rate:	5 Mb
Typical Fiber Attenuation:	–4 dB/Km

Channels 1-4 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 dB/m
Black-Jacketed Fiber Typical Loss:	–0.17 dB/m
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 dB/m
Clear-Jacketed Fiber Typical Loss:	–0.17 dB/m
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
Option 2:	DeviceNet communications card

Communications Protocols

SEL, Modbus, DNP3, FTP, TCP/IP, Telnet, SNTP, IEC 61850, MIRRORED BITS, EVMSG, C37.118 (synchrophasors) and DeviceNet.

Operating Temperature

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

Note: Not applicable to UL applications.

Note: LCD contrast is impaired for temperatures below –20°C and above 70°C.

DeviceNet Communications Card Rating:	+60°C (140°F) maximum

Operating Environment

Pollution Degree:	2
Overvoltage Category:	II
Atmospheric Pressure:	80–110 kPa
Relative Humidity:	5–95%, noncondensing
Maximum Altitude:	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 lbs)

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:	0.225 Nm (1.6 in-lb)
Maximum:	0.25 Nm (2.2 in-lb)

Type Tests

Environmental Tests

Enclosure Protection:	IEC 60529:2001 + CRDG:2003 IP65 enclosed in panel IP20 for terminals IP54 rated terminal dust protection assembly (SEL Part #915900170). 10°C temperature derating applies to the temperature specifications of the relay.
Vibration Resistance:	IEC 60068-2-6:2007 3 G, 10–150 Hz IEC 60255-21-1:1988, Class 1 IEC 60255-21-3:1993, Class 2
Shock Resistance:	IEC 60255-21-2:1988, Class 1
Cold:	IEC 60068-2-1:2007 –40°C, 16 hours
Damp Heat, Steady State:	IEC 60068-2-78:2001 40°C, 93% relative humidity, 4 days
Damp Heat, Cyclic:	IEC 60068-2-30:2005 25–55°C, 6 cycles, 95% relative humidity
Dry Heat:	IEC 60068-2-2:2007 85°C, 16 hours

Dielectric Strength and Impulse Tests

Dielectric (HiPot):	IEC 60255-5:2000 IEEE C37.90-2005 2.5 kVac on current inputs, ac voltage inputs, contact I/O 2.0 kVac on analog inputs 1.0 kVac on analog outputs 2.83 kVdc on power supply
Impulse:	IEC 60255-5:2000; C37.90 2005 0.5 J, 4.7 kV on power supply, contact I/O, ac current and voltage inputs 0.5 J, 530 V on analog outputs

RFI and Interference Tests

EMC Immunity

Electrostatic Discharge Immunity:	IEC 61000-4-2:2008 IEC 60255-22-2:2008 Severity Level 4 8 kV contact discharge 15 kV air discharge
Radiated RF Immunity:	IEC 61000-4-3:2010 IEC 60255-22-3:2007 10 V/m IEEE C37.90.2-2004 35 V/m
Digital Radio Telephone RF Immunity:	ENV 50204:1995
Fast Transient, Burst Immunity:	IEC 61000-4-4:2011 IEC 60255-22-4:2008 4 kV @ 5.0 kHz 2 kV @ 5.0 kHz for comm. ports
Surge Immunity:	IEC 61000-4-5:2005 IEC 60255-22-5:2008 2 kV line-to-line 4 kV line-to-earth
Surge Withstand Capability Immunity:	IEC 60255-22-1:2007 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
Conducted RF Immunity:	IEC 61000-4-6:2008 IEC 60255-22-6: 2001 10 Vrms
Magnetic Field Immunity:	IEC 61000-4-8:2009 1000 A/m for 3 seconds 100 A/m for 1 minute IEC 61000-4-9: 2001 1000 A/m
Power Supply Immunity:	IEC 60255-11:2008

EMC Emissions

Conducted Emissions:	EN 55011:1998, Class A IEC 60255-25:2000
Radiated Emissions:	EN 55011:1998, Class A IEC 60255-25:2000

Electromagnetic Compatibility

Product Specific:	EN 50263:1999

Certifications

ISO 9001:	This product was designed and manufactured under an ISO 9001 certified quality management system.
UL, cUL*:	Protective Relay Category NRGU, NRGU7 per UL 508, C22.2 No. 14

* 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.

CE:	CE Mark–EMC Directive Low Voltage Directive IEC 61010-1:2001 IEC 60947-1 IEC 60947-4-1 IEC 60947-5-1

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)
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.

Oscillography

Length:	15 or 64 cycles
Sampling Rate:	16 samples per cycle unfiltered 4 samples per cycle filtered
Trigger:	Programmable with Boolean expression
Format:	ASCII and Compressed ASCII
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):	5 ms

Relay Elements

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

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:	±3% ±0.02 • I_{NOM} A secondary (Steady State) ±5% ±0.02 • I_{NOM} A secondary (Transient) ±6% ±0.02 • I_{NOM} A secondary (Transient for 50Q)
Time Delay:	0.00–400.00 seconds, 0.01 seconds steps 0.1–400.0 seconds, 0.1 second steps (50Q)
Pickup/Dropout Time:	<1.5 cycles

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 ±0.02 • I_{NOM} A secondary (Steady State pickup)
Pickup/Dropout Time:	2–5 ms/1 cycle

Arc-Flash Time-Overlight (TOL1–TOL4)

Pickup Setting Range, % of Full Scale:	3.0–20.0% (Point Sensor) 0.6–4.0% (Fiber Sensor)
Pickup/Dropout Time:	2–5 ms/1 cycle

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

Pickup Setting Range, A Secondary:	
5 A models:	0.50–16.00 A, 0.01 A steps 0.25–16.00 A, 0.01 A steps (51N)
1 A models:	0.10–3.20 A, 0.01 A steps 0.05–16.00 A, 0.01 A steps (51N)
Accuracy:	±5% of setting ±0.02 • I_{NOM} A secondary (Steady State pickup)
Time Dial	
US:	0.50–15.00, 0.01 steps
IEC:	0.05–1.50, 0.01 steps
Accuracy:	±1.5 cycles, ±4% between 2 and 30 multiples of pickup (within rated range of current)

Undervoltage (27P, 27PP, 27S)

Setting Range:	OFF, 2.00–300.00 V (Phase elements, phase-phase elements with delta inputs or synchronism voltage input) OFF, 2.00–520.00 V (Phase-phase elements with wye inputs)
Accuracy:	±1% of setting ±0.5 V
Time Delay:	0.00–120.00 seconds, 0.01 second steps
Pickup/Dropout Time:	<1.5 cycles

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

Setting Range:	OFF, 2.00–300.00 V (Phase elements, phase-phase elements with delta inputs or synchronism voltage input) OFF, 2.00–520.00 V (Phase-Phase elements with wye inputs)
Accuracy:	±1% of setting ±0.5 V
Time Delay:	0.00–120.00 seconds, 0.01 second steps
Pickup/Dropout Time:	<1.5 cycles

Power Elements (32)

Instantaneous/Definite Time, 3 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) and ±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) and ±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 • 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 • I_{NOM}) with current tracking
Time Delay:	0.00–240.00 seconds, 0.01 second steps
Pickup/Dropout Time:	< 4 cycles

Rate-of-Change of Frequency (81R)

Setting Range:	Off, 0.10–15.00 Hz/sec
Accuracy:	±100 mHz/s, ±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% ±0.5 volts (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

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

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 ±2 Vdc

Timers

Setting Range:	Various
Accuracy:	±0.5% of setting ±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 ohm 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 Trip/Alarm Time Delay:	Approx. 6 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, unless otherwise noted.

Phase Currents:	±1% of reading, ±1° (±2.5° at 0.2–0.5 A for relays with I_{NOM} = 1 A)
3-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)
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

3-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
3-Phase Average Line-to-Ground Voltages:	±1% of reading for voltages within 24–264 V
Voltage Imbalance (%):	±2% of reading
V1 Positive-Sequence Voltage:	±2% of reading for voltages within 24–264 V
3V2 Negative-Sequence Voltage:	±2% of reading for voltages within 24–264 V
Real 3-Phase Power (kW):	±3% of reading for 0.10 < pf < 1.00
Reactive 3-Phase Power (kVAR):	±3% of reading for 0.00 < pf < 0.90
Apparent 3-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 non-volatile 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 Data Rate in Messages per Second

IEEE C37.118 Protocol:	60 (nominal 60 Hz system) 50 (nominal 50 Hz system)
IEEE C37.118 Accuracy:	Level 1 at maximum message rate when phasor has the same frequency as phase A voltage
Current Range:	(0.4–2) • I_{NOM} (I_{NOM} = 1 A or 5 A)
Frequency Range:	±5 Hz of nominal (50 or 60 Hz)
Voltage Range:	24 V–264 V
Phase Angle Range:	–179.99° to 180°

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