SEL-421-7 Protection, Automation, and Control System

Protection, Automation, and Control System With Sampled Values or TiDL Technology
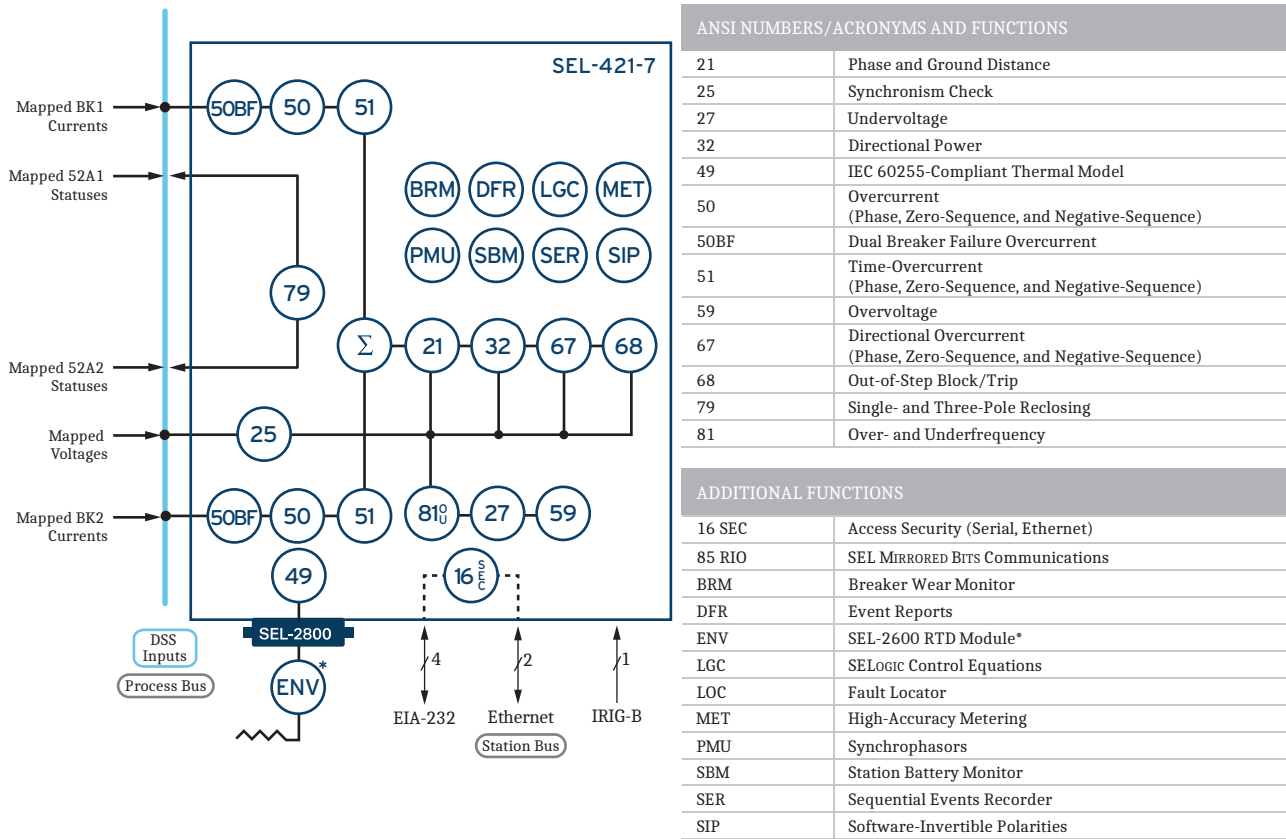

Key Features and Benefits

The SEL-421-7 Protection, Automation, and Control System With Sampled Values or TiDL Technology combines high-speed distance and directional protection with complete control for a two-breaker bay.

➤ **Complete Distance Protection.** You can apply as many as five zones of phase and ground distance and directional overcurrent elements. Select mho or quadrilateral characteristics for any phase or ground distance element. Use the optional high-speed distance elements and series-compensation logic to optimize protection for critical lines or series-compensated lines. Patented coupling capacitor voltage transformer (CCVT) transient overreach logic enhances the security of Zone 1 distance elements. Best Choice Ground Directional Element® logic optimizes directional element performance and eliminates the need for many directional settings. Apply the distance and directional elements in communications-based protection schemes such as POTT, DCB, and DCUB, or for instantaneous or time-step backup protection.

➤ **Power Swing Blocking and Out-of-Step Tripping.** You can select power swing blocking of distance elements for stable power swings or out-of-step tripping for unstable power swings. Zero-setting, out-of-step detection logic is available, eliminating the need for settings and power system studies.

➤ **Switch-Onto-Fault.** Disconnect status inputs and voltage elements can enable high-speed protection.

➤ **Synchronism Check.** Synchronism check can prevent circuit breakers from closing if the corresponding phases across the open circuit breaker are excessively out of phase, magnitude, or frequency. The synchronism-check function has a user-selectable synchronizing voltage source and incorporates slip frequency, two levels of maximum angle difference, and breaker close time into the closing decision.

➤ **Reclosing Control.** You can incorporate programmable single-pole or three-pole trip and reclose of one or two breakers into an integrated substation control system. Synchronism and voltage checks from multiple sources provide complete bay control.

➤ **Fault Locator.** Utilities can efficiently dispatch line crews to quickly isolate line problems and restore service faster.

➤ **Dual CT Input.** You can combine currents within the relay from two sets of CTs for protection functions or keep them separately available for monitoring and station integration applications.

➤ **Primary Potential Redundancy.** Multiple voltage inputs to the relay provide primary voltage input redundancy. Upon loss-of-potential (LOP) detection, the relay can use inputs from an electrically equivalent source connected to the relay. Protection remains in service without compromising security.

➤ **Comprehensive Metering.** The built-in, high-accuracy metering functions can improve feeder loading. Use watt and VAR measurements to optimize feeder operation. Minimize equipment needs with full metering capabilities, including: rms, maximum/minimum, demand/peak, energy, and instantaneous values.

➤ **Auxiliary Trip/Close Pushbuttons.** These optional pushbuttons are electrically isolated from the rest of the relay. They function independently from the relay and do not need relay power.

➤ **Bay Control.** The relay provides bay control functionality with status indication and control for disconnect switches. The relay features control for as many as two breakers and status indication of as many as three breakers. Numerous predefined user-selectable mimic displays are available; the selected mimic appears on the front-panel screen in one-line diagram format. The one-line diagram includes user-configurable labels for disconnect switches, breakers, bay name, and display for as many as six analog quantities. The relay features SELOGIC programmable local control supervision of breaker and disconnect switch operations.

➤ **Breaker Failure.** High-speed (less than one cycle) open-pole detection logic reduces coordination times for critical breaker failure applications. Apply the relay to supply breaker failure protection for all supported breakers. Logic for breaker failure retrip and initiation of transfer tripping is included.

➤ **IEC 60255-149 Compliant Thermal Model.** The relay can provide a configurable thermal model for the protection of a wide variety of devices. This function can activate a control action or issue an alarm or trip when equipment overheats as a result of adverse operation conditions. A separate resistance temperature detector (RTD) module is required for this application.

➤ **Ethernet Access.** The optional Ethernet card grants access to all relay functions. Use IEC 61850 Manufacturing Message Specification (MMS) or DNP3 protocol directly to interconnect with automation systems. You can also connect to DNP3 networks through a communications processor. Use File Transfer Protocol (FTP) for high-speed data collection. Connect to substation or corporate LANs to transmit synchrophasors by using TCP or UDP internet protocols.

➤ **Serial Data Communication.** The relay can communicate serial data through SEL ASCII, SEL Fast Message, SEL Fast Operate, MIRRORED BITS®, and DNP3 protocols. Synchrophasor data are provided in either SEL Fast Message or IEEE C37.118 format.

➤ **Automation.** The enhanced automation features include programmable elements for local control, remote control, protection latching, and automation latching. Local metering on the large front-panel LCD eliminates the need for separate panel meters. Serial and Ethernet links efficiently transmit key information, including metering data, protection element and control I/O status, synchrophasor data, IEC 61850 Edition 2 GOOSE messages, Sequential Events Recorder (SER) reports, breaker monitoring, relay summary event reports, and time synchronization. Apply expanded SELOGIC® control equations with math and comparison functions in control applications. Incorporate as many as 1000 lines of automation logic to accelerate and improve control actions.

➤ **Synchrophasors.** You can make informed load dispatch decisions based on actual real-time phasor measurements from relays across your power system. Record streaming synchrophasor data from the relay for system-wide disturbance recording. Control the power system by using local and remote synchrophasor data.

➤ **Breaker and Battery Monitoring.** You can schedule breaker maintenance when accumulated breaker duty (independently monitored for each pole) indicates possible excess contact wear. The relay records electrical and mechanical operating times for both the last operation and the average of operations since function reset. Alarm contacts provide notification of substation battery voltage problems (as many as two independent battery monitors in some SEL-400 series relays) even if voltage is low only during trip or close operations.

➤ **Digital Secondary Systems (DSS) Technologies.** You can order the relay as either an SV subscriber or a TiDL relay. DSS capable relays receive current and voltage information that is published by remote merging units instead of standard PT and CT inputs. DSS technologies reduce copper cable lengths and associated installation labor costs and improve the overall safety of the substation.

➤ **IEC 61850-9-2LE SV Subscriber.** The SV subscriber can subscribe to current and voltage information that is published by as many as seven remote SV merging units that are compliant with the IEC 61850-9-2LE guideline.

➤ **TiDL Relay.** The TiDL relay can receive current and voltage information from as many as eight SEL-TMUs (TiDL Merging Units) over direct point-to-point fiber-optic connections. The TiDL relay automatically synchronizes data collection, alleviating the need or impact of an external clock on protection.

➤ **Selective Protection Disabling.** The subscriber or TiDL relay provides selective disabling of protection functions by using hard-coded logic or available torque-control equations in case of a loss of communications between your merging unit and relay that results in the loss of relevant analog data.

➤ **Current Summation.** The relay can combine multiple SV stream currents to simplify external wiring.

➤ **Six Independent Settings Groups.** The relay includes group logic to adjust settings for different operating conditions, such as station maintenance, seasonal operations, emergency contingencies, loading, source changes, and adjacent relay settings changes. Select the active group settings by control input, command, or other programmable conditions.

➤ **Software-Invertible Polarities.** Inverting individual or grouped CT and PT polarities allows you to account for field wiring or zones of protection changes. CEV files and all metering and protection logic use the inverted polarities, whereas COMTRADE event reports do not use inverted polarities but rather record signals as applied to the relay.

➤ **Parallel Redundancy Protocol (PRP).** PRP provides seamless recovery from any single Ethernet network failure. The Ethernet network and all traffic are fully duplicated with both copies operating in parallel.

➤ **IEC 61850 Operating Modes.** The relay supports IEC 61850 standard operating modes such as Test, Blocked, On, and Off.

➤ **IEEE 1588, Precision Time Protocol (PTP).** PTP provides high-accuracy timing over an Ethernet network.

➤ **Digital Relay-to-Relay Communications.** MIRRORED BITS communications can monitor internal element conditions between bays within a station, or between stations, using SEL fiber-optic transceivers. Send digital, analog, and virtual terminal data over the same MIRRORED BITS channel.

➤ **Sequential Events Recorder (SER).** The SER records the last 1000 events, including setting changes, startups, and selectable logic elements.

➤ **Oscillography and Event Reporting.** The relay records voltages, currents, and internal logic points at a sampling rate as fast as 8 kHz. Offline phasor and harmonic-analysis features allow investigation of bay and system performance. Time-tag binary COMTRADE event reports with high-accuracy time stamping for accuracy better than 10 µs.

➤ **Digitally Signed Upgrades.** The relay supports upgrading the relay firmware with a digitally signed upgrade file. The digitally signed portion of the upgrade file helps ensure firmware and device authenticity after it is sent over a serial or Ethernet connection.

➤ **Increased Security.** The relay divides control and settings into seven relay access levels; the relay has separate breaker, protection, automation, and output access levels, among others. Set unique passwords for each access level.

➤ **Rules-Based Settings Editor.** You can communicate with and set the relay by using an ASCII terminal or use Grid Configurator to configure the relay and analyze fault records with relay element response. Use as many as 200 aliases to rename any digital or analog quantity in the relay.

Functional Overview

Four-port Ethernet card ordering option depicted.

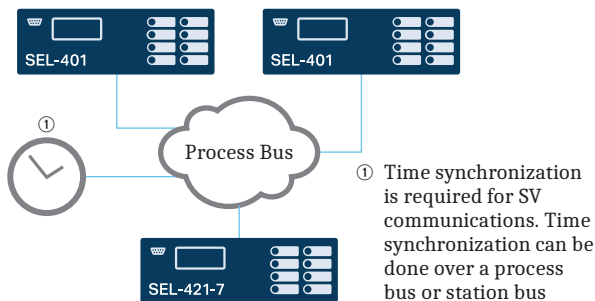| ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
21	Phase and Ground Distance
25	Synchronism Check
27	Undervoltage
32	Directional Power
49	IEC 60255-Compliant Thermal Model
50	Overcurrent (Phase, Zero-Sequence, and Negative-Sequence)
50BF	Dual Breaker Failure Overcurrent
51	Time-Overcurrent (Phase, Zero-Sequence, and Negative-Sequence)
59	Overvoltage
67	Directional Overcurrent (Phase, Zero-Sequence, and Negative-Sequence)
68	Out-of-Step Block/Trip
79	Single- and Three-Pole Reclosing
81	Over- and Underfrequency

ADDITIONAL FUNCTIONS	
16 SEC	Access Security (Serial, Ethernet)
85 RIO	SEL Mirrored Bits Communications
BRM	Breaker Wear Monitor
DFR	Event Reports
ENV	SEL-2600 RTD Module*
LGC	SELogic Control Equations
LOC	Fault Locator
MET	High-Accuracy Metering
PMU	Synchrophasors
SBM	Station Battery Monitor
SER	Sequential Events Recorder
SIP	Software-Invertible Polarities

* Optional Feature
Note: Both copper and fiber-optic Ethernet ports are available.

Figure 1   SEL-421-7 SV Subscriber or TiDL Relay Functional Overview
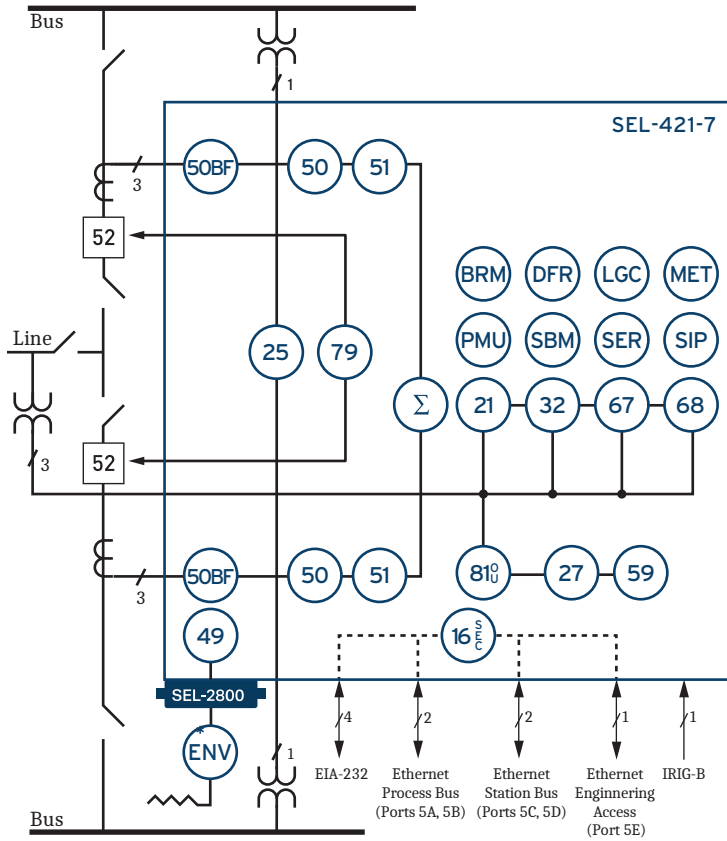
Five-port Ethernet card ordering option depicted.

Figure 2   SEL-421-7 SV Publisher Functional Overview

ANSI NUMBERS/ACRONYMS AND FUNCTIONS	
21	Phase and Ground Distance
25	Synchronism Check
27	Undervoltage
32	Directional Power
49	IEC 60255-Compliant Thermal Model
50	Overcurrent (Phase, Zero-Sequence, and Negative-Sequence)
50BF	Dual Breaker Failure Overcurrent
51	Time-Overcurrent (Phase, Zero-Sequence, and Negative-Sequence)
59	Overvoltage
67	Directional Overcurrent (Phase, Zero-Sequence, and Negative-Sequence)
68	Out-of-Step Block/Trip
79	Single- and Three-Pole Reclosing
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16 SEC	Access Security (Serial, Ethernet)
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MET	High-Accuracy Metering
PMU	Synchrophasors
SBM	Station Battery Monitor
SER	Sequential Events Recorder
SIP	Software-Invertible Polarities

* Optional Feature
Note: Both copper and fiber-optic Ethernet ports are available.

SV

The SEL-421-7 SV Subscriber subscribes to data streams that are published from a merging unit, such as the SEL-421-7 SV Publisher or SEL-401 Protection, Automation, and Control Merging Unit. The SEL-421-7 SV Publisher provides full backup protection while the SEL-401 can provide basic phase overcurrent and breaker failure protection in the absence of communication. Using the process bus, the SEL-421-7 SV Publisher or SEL-401 can provide voltage and current information to multiple relays that subscribe to SV streams (see *Figure 1* and *Figure 2*). The data are synchronized using Precision Time Protocol (PTP).

① Time synchronization is required for SV communications. Time synchronization can be done over a process bus or station bus

Figure 3   SV Network

TiDL

The SEL-421-7 TiDL relay receives and automatically synchronizes data streams from connected and commissioned SEL-TMUs. The TiDL technology does not require an external time source for local relay protection functions.
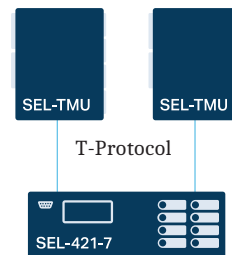
Figure 4   SEL TiDL System

Protection Features

Complete Distance Protection

The SEL-421-7 simultaneously measures as many as five zones of phase and ground mho distance protection plus five zones of phase and ground quadrilateral distance protection. You can apply these distance elements, together with optional high-speed distance elements, in communications-assisted and step-distance protection schemes. You can use expanded SELOGIC control equations to tailor the relay further to your particular application.

The relay includes LOP detection, load encroachment, and CCVT transient detection logic for enhanced security.

Optional series-compensated line logic can also be added to prevent overreach of the Zone 1 distance element, resulting from the series capacitor transient response.

Each of the distance elements has a specific reach setting. The ground distance elements include three zero-sequence compensation factor settings (k01, k0R, and k0F) to calculate ground fault impedance accurately. Setting k01 uses positive-sequence quantities to adjust zero-sequence transmission line impedance for accurate measurement. Settings k0F and k0R account for forward and reverse zero-sequence mutual coupling between parallel transmission lines.

Figure 5 shows the performance times of the high-speed and standard distance elements for a range of faults, locations, and source impedance ratios (SIR).

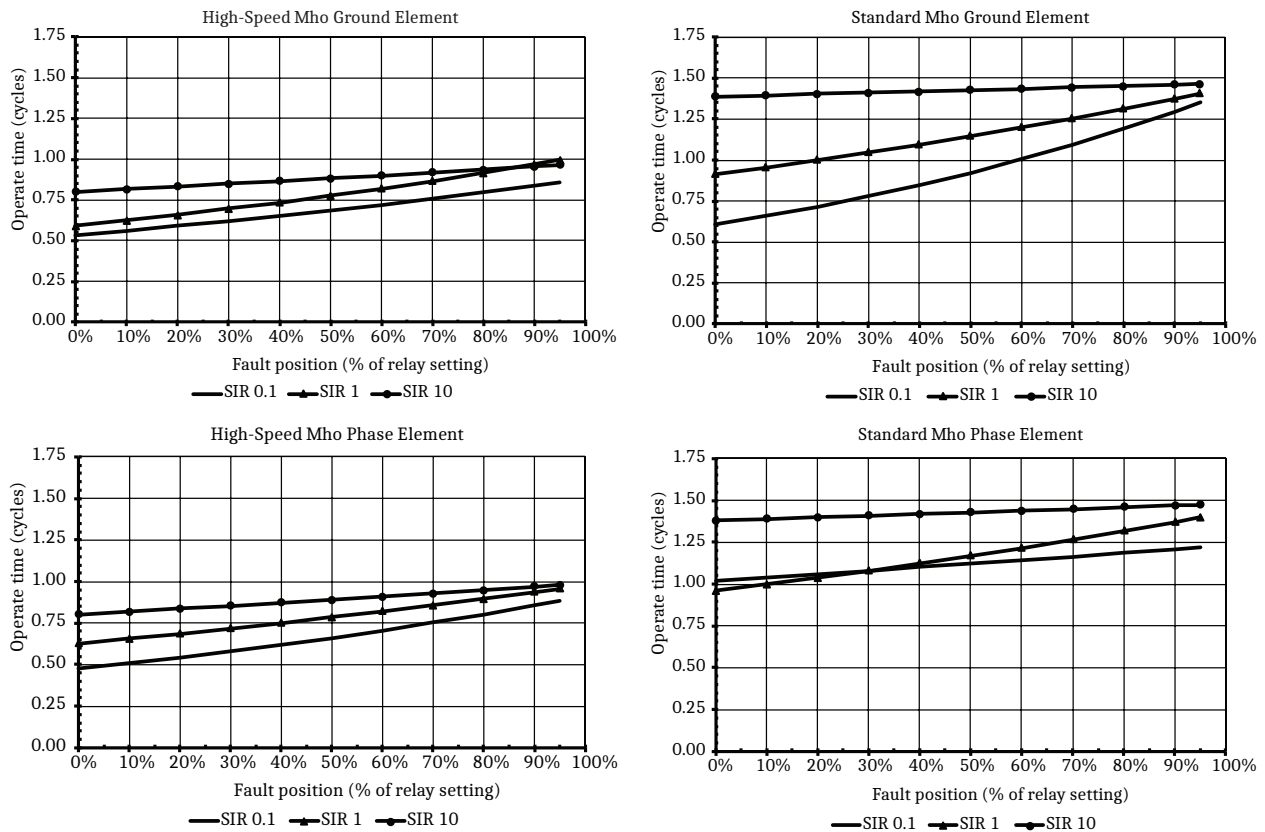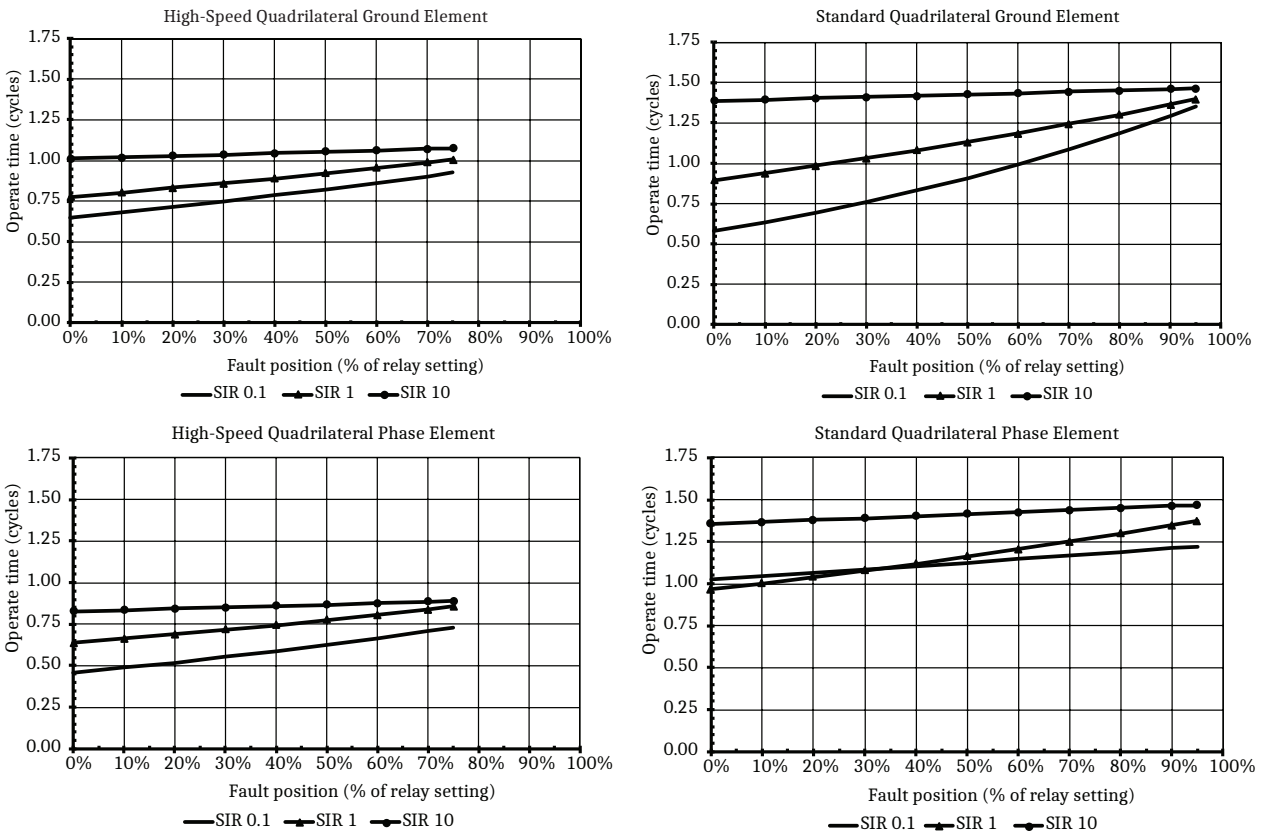## Subcycle Tripping Times Using Optional High-Speed Elements

Figure 5   Distance Zone 1 Median Operating Time for Varying Fault Locations and Different SIRs

High-Speed Quadrilateral Ground Element
— SIR 0.1   — SIR 1   — SIR 10

Standard Quadrilateral Ground Element
— SIR 0.1   — SIR 1   — SIR 10

High-Speed Quadrilateral Phase Element
— SIR 0.1   — SIR 1   — SIR 10

Standard Quadrilateral Phase Element
— SIR 0.1   — SIR 1   — SIR 10

Figure 5   Distance Zone 1 Median Operating Time for Varying Fault Locations and Different SIRs (Continued)

Mho Distance Elements

The SEL-421-7 uses mho characteristics for phase and ground distance protection. Two zones are fixed in the forward direction, and the remaining three zones can be set for either forward or reverse. All mho elements use positive-sequence memory polarization that expands the operating characteristic in proportion to the source impedance (*Figure 6*). This provides dependable, secure operation for close-in faults.
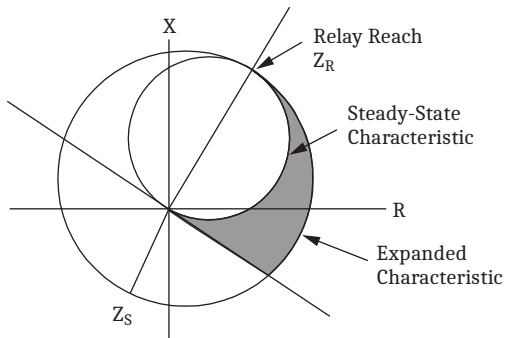
Figure 6   Mho Characteristic

As an optional addition to the standard distance elements, there are three zones (either three forward, or two forward and one reverse) of high-speed distance elements. These high-speed elements use voltage and current phasors derived

from a fast half-cycle filter to provide subcycle tripping times. Settings are automatically associated with the standard element zone reach, requiring no additional settings.

Quadrilateral Distance Elements

The SEL-421-7 provides five zones of quadrilateral phase and ground distance characteristics for improved fault and arc resistance coverage and reach-limiting action on short lines. The top line of the quadrilateral characteristic automatically tilts with load flow to avoid under- and overreaching. Available settings prevent overreaching of the quadrilateral characteristic from nonhomogeneous fault current components. You can use the mho and quadrilateral distance elements separately or concurrently.

Out-of-Step Detection

The relay provides two different algorithms for out-of-step detection. One of the two schemes may be selected by the user.

The zero-setting method requires no power system studies or any settings (other than enabling). Using local voltage measurements (see *Figure 7*) to closely approximate the swing center voltage (SCV) allows the relay to use the rate-of-change of SCV to quantify the power swing condition.

The second algorithm is a conventional out-of-step detection that provides timers and blinders that are set outside any of the distance element reach settings. A power swing is declared when an impedance locus travels through the blinders slower than a preset time.
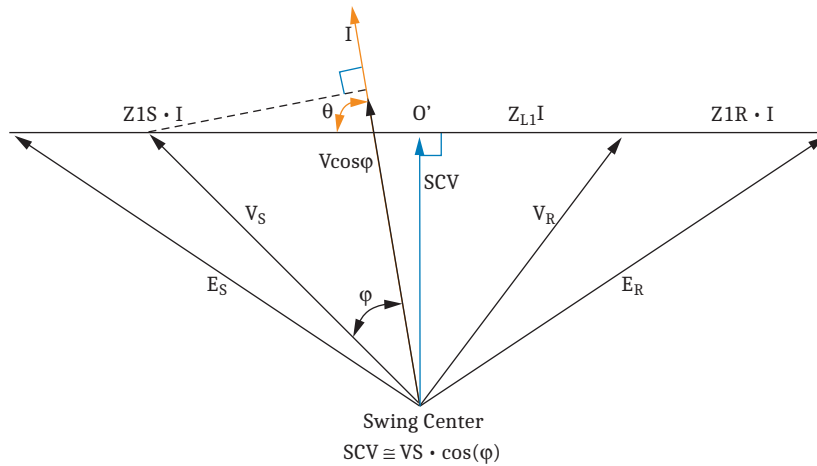
Figure 7   Applying VS to Approximate the Swing Center Voltage Provides an Accurate Local Quantity to Detect Power Swings

Directional Elements

The SEL-421-7 includes a number of directional elements for supervision of overcurrent elements and distance elements. The negative-sequence directional element uses the same patented principle proven in the SEL-321. This directional element can be applied in virtually any application, regardless of the amount of negative-sequence voltage available at the relay location.

The following three directional elements working together provide directional control for the ground overcurrent elements:

➤ Negative-sequence voltage-polarized directional element

➤ Zero-sequence voltage-polarized directional element

➤ Zero-sequence current-polarized directional element

Our patented Best Choice Ground Directional Element selects the best ground directional element for the system conditions and simplifies directional element settings. (You can override this automatic setting feature for special applications.)

Communications-Assisted Tripping Schemes

Use MIRRORED BITS communications with SEL fiber-optic transceivers for 3–6 ms relay-to-relay transmission time. Among the schemes supported are the following:

➤ Permissive overreaching transfer tripping (POTT) for two- or three-terminal lines

➤ Directional comparison unblocking (DCUB) for two- or three-terminal lines

➤ Directional comparison blocking (DCB)

Use the SELOGIC control equation TRCOMM to program specific elements, combinations of elements, inputs, etc., to perform communications scheme tripping and other scheme functions. The logic readily accommodates the following conditions:

➤ Current reversals

➤ Breaker open at one terminal

➤ Weak-infeed conditions at one terminal

➤ Switch-onto-fault conditions

Step-distance and time-overcurrent protection provide reliable backup operation should the communications channel be lost.

Combined Current for Protection Flexibility

For traditional relays, when protecting a line fed from two breakers, such as a breaker-and-a-half system or double-breaker system, you must parallel the CTs before connecting these inputs to the relay. The relay accepts two separate CT inputs (these CTs can be a different ratio) and combines these currents mathematically. This allows collecting separate current metering and breaker monitor information for each breaker and breaker failure functions on a per-breaker basis. Breaker diagnostic reports from the SEL-421 provide you comparative breaker information that you can use for advanced, proactive troubleshooting.

Multifunction Recloser With Flexible Applications

The SEL-421-7 includes both single-pole and three-pole trip and reclose functions, for either one or two breakers (*Figure 8*). Synchronism check is included for breaker control. Synchronizing and polarizing voltage inputs are fully programmable with dead line/dead bus closing logic as well as zero-closing-angle logic to minimize system stress upon reclosing. Program as many as two single-pole reclose attempts and four three-pole reclose attempts as well as combined single-/three-pole reclosing sequences. Select leader and follower breakers directly, or use a SELOGIC control equation to determine reclosing order based on system conditions. Coupled with independent-pole-operating circuit breakers, this reclosing system gives maximum flexibility for present system conditions and for future requirements.
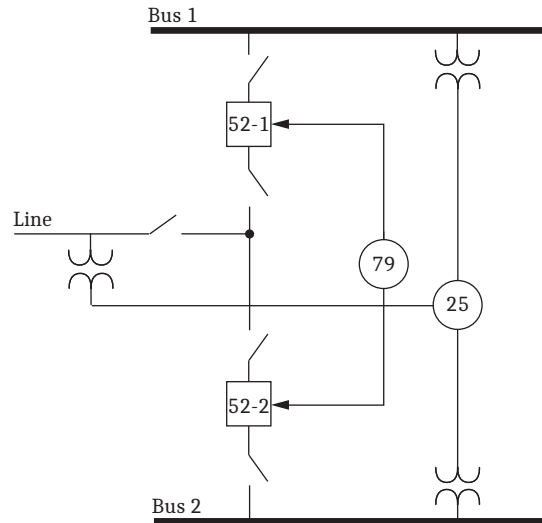

Figure 8   Two-Breaker Reclosing With Synchronism Check

Additional Features

Front-Panel Display

The LCD shows event, metering, setting, and relay self-test status information. The target LEDs display relay target information as described in *Figure 9*.

The LCD is controlled by the navigation pushbuttons (*Figure 10*), automatic messages the relay generates, and user-programmed analog and digital display points. The rotating display scrolls through alarm points, display points, and metering screens. If none are active, the relay scrolls through displays of the fundamental and rms metering screens. Each display remains for a user-programmed time (1–15 s) before the display continues scrolling. Any message generated by the relay because of an alarm condition takes precedence over the rotating display.

Figure 9 and *Figure 10* show close-up views of the front panel of the SEL-421. The front panel includes a 128 x 128 pixel, 3" x 3" LCD screen; LED target indicators; and pushbuttons with indicating LEDs for local control functions. The asserted and deasserted colors for the LEDs are programmable. Configure any of the direct-acting pushbuttons to navigate directly to any HMI menu item. Quickly view events, alarm points, display points, or the SER.
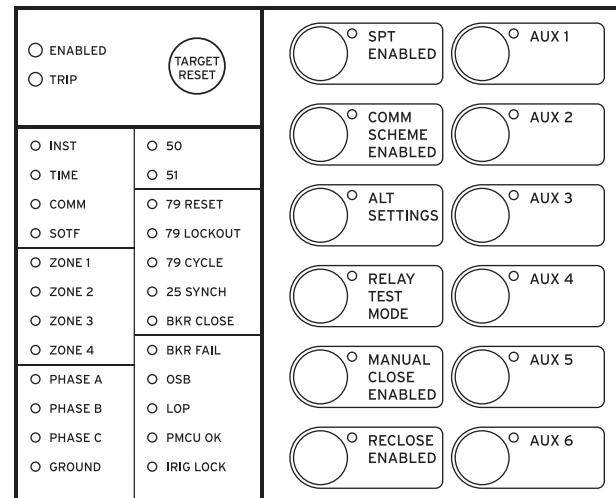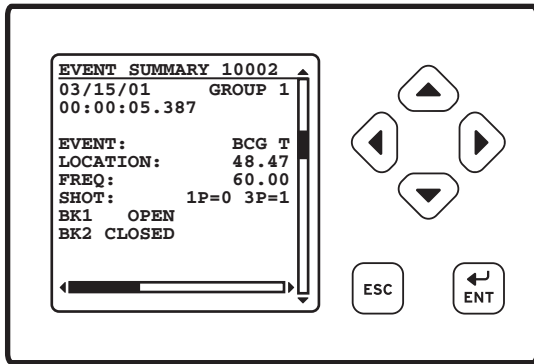

Figure 9   Factory-Default Status and Trip Target LEDs (12 Pushbutton, 24 Target LED Option)

Figure 10   Factory-Default Front-Panel Display and Pushbuttons

Bay Control

The SEL-421-7 provides dynamic bay one-line diagrams on the front-panel screen with disconnect and breaker control. You can download the Grid Configurator interface from selinc.com to obtain additional user-selectable bay types. The bay control can control as many as ten disconnects and two breakers, depending on the one-line diagram selected. Certain one-line diagrams provide status for as many as three breakers and five disconnect switches. Operate disconnects and breakers with ASCII commands, SELOGIC control equations, Fast Operate Messages, and from the one-line diagram. The one-line diagram includes user-configurable apparatus labels and as many as six user-definable analog quantities.

One-Line Bay Diagrams

The SEL-421-7 offers a variety of preconfigured one-line diagrams for common bus configurations. Once you select a one-line diagram, you can customize the names for all of the breakers, disconnect switches, and buses. Most one-line diagrams contain analog display points. You can set these display points to any of the available analog quantities with labels, units, and scaling. The SEL-421-7 updates these values along with the breakers and switch position in real time to give instant status and complete control of a bay. The following diagrams demonstrate some of the preconfigured bay arrangements available in the SEL-421-7.

Programmable interlocks help prevent operators from incorrectly opening or closing switches or breakers. The SEL-421-7 not only prevents the operator from making an incorrect control decision, but can notify and/or alarm upon initiation of an incorrect operation.

Circuit Breaker Operations From the Front Panel

Figure 11–Figure 14 are examples of some of the selectable one-line diagrams in the SEL-421-7. Select the one-line diagram from the Bay settings. Additional settings for defining labels and analog quantities are also found in the Bay settings. One-line diagrams are composed of the following:
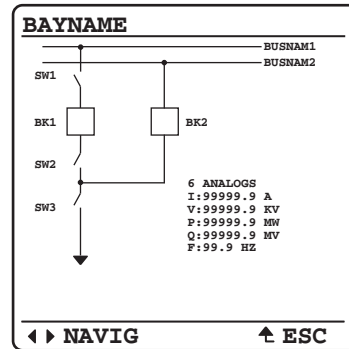
➤ Bay names and bay labels

➤ Busbar and busbar labels

➤ Breaker and breaker labels

➤ Disconnect switches and disconnect switch labels

➤ Analog display points
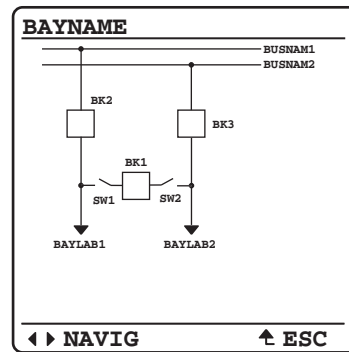
Figure 11   Breaker-and-a-Half
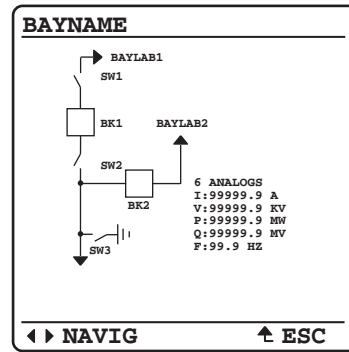
Figure 12   Ring Bus With Ground Switch
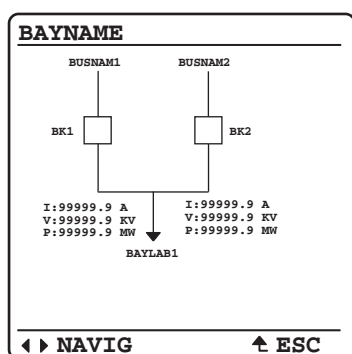

Figure 13   Double Bus/Double Breaker

Figure 14   Source Transfer Bus

Figure 15 shows the breaker control screens available when the **ENT** pushbutton is pressed with the circuit breaker highlighted as shown in *Figure 15(a)*.
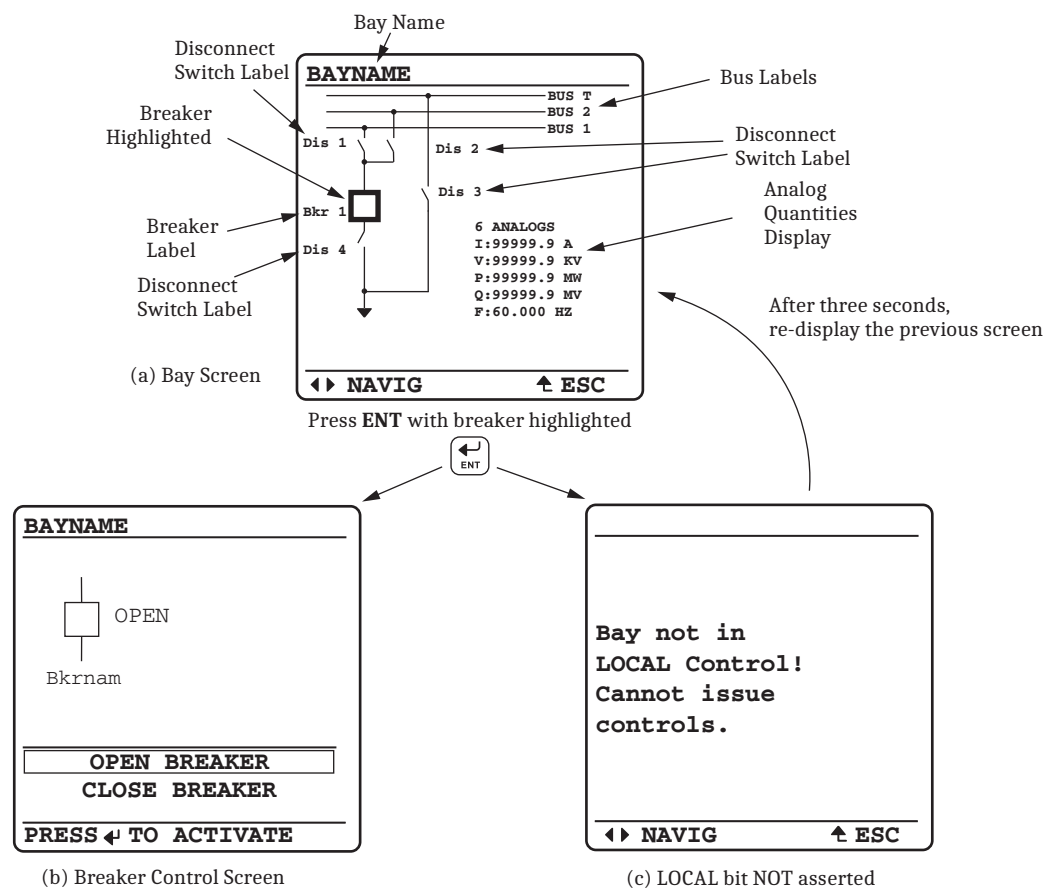

Figure 15   Screens for Circuit Breaker Selection

Rack-Type Breakers Mosaics

The SEL-421-7 supports the display of rack-type (also referred to as truck-type) circuit breakers. The rack-type breakers have three positions: racked out, test, and racked in. When in the test or racked-in positions, the breaker can be displayed as open or closed. When racked out, no breaker open/close display are available. The rack-type breakers are a display-only functionality and do not impact any circuit breaker control capabilities.

Status and Trip Target LEDs

The SEL-421-7 includes programmable status and trip target LEDs, as well as programmable direct-action control pushbuttons on the front panel. *Figure 9* and *Figure 10* show these targets.

The SEL-421-7 features a versatile front panel that you can customize to fit your needs. Use SELOGIC control equations and slide-in configurable front-panel labels to change the function and identification of target LEDs and operator control pushbuttons and LEDs. The blank

slide-in label set is included with the SEL-421-7. You can use templates supplied with the relay or hand label supplied blank labels and print label sets from a printer.

Alarm Points

You can display messages on the SEL-421-7 front-panel LCD that indicate alarm conditions in the power system. The relay uses alarm points to place these messages on the LCD.

Figure 16 shows a sample alarm points screen. The relay can display as many as 66 alarm points. The relay automatically displays new alarm points while in manual-scrolling mode and in autoscrolling mode. You can configure the alarm points message and trigger it either immediately by using inputs, communications, or conditionally by using powerful SELOGIC control equations. The asterisk next to the alarm point indicates an active alarm. Use the front-panel navigation pushbuttons to clear inactive alarms.

```
ALARM POINTS
─────────────────────
*Unauthorized Access
*Xfmr Fan Failed
*Xfmr Heat Overload




─────────────────────
Press ↵ to acknldge
```
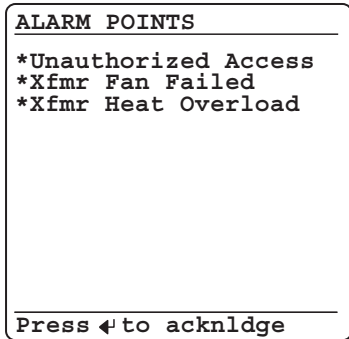
Figure 16   Sample Alarm Points Screen

Advanced Display Points

Create custom screens showing metering values, special text messages, or a mix of analog and status information. *Figure 17* shows an example of how display points can be used to show circuit breaker information and current metering. As many as 96 display points can be created. All display points occupy only one line on the display at all times. The height of the line is programmable as either single or double as shown in *Figure 17*. These screens become part of the autoscrolling display when the front panel times out.
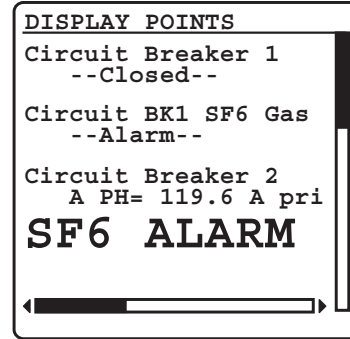
```
DISPLAY POINTS
─────────────────────
Circuit Breaker 1
    --Closed--

Circuit BK1 SF6 Gas
    --Alarm--

Circuit Breaker 2
    A PH= 119.6 A pri
SF6 ALARM

◄████████          ►
```

Figure 17   Sample Display Points Screen

Communications Features

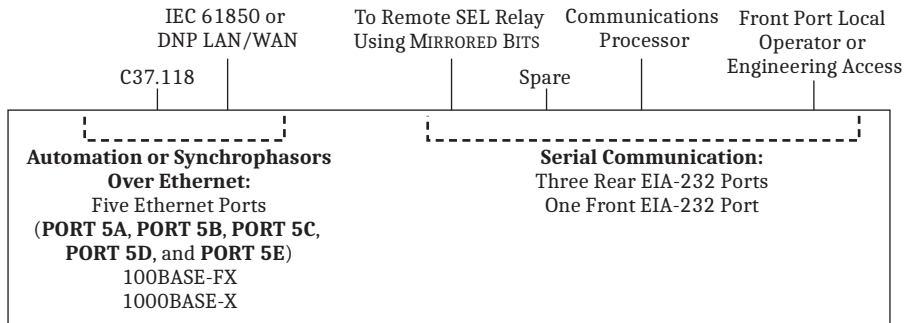See *Specifications on page 23* for specific supported protocols.

Figure 18   System Functional Overview

The relay offers the following communications features:

➤ Four independent EIA-232 serial ports.

➤ Access to event history, relay status, and meter information from the communications ports.

➤ Password-controlled settings management and automation features.

➤ SCADA interface capability, including FTP, IEC 61850, DNP3 LAN/WAN (via Ethernet), and DNP3 (via serial port). The relay does not require special communications software. You only need ASCII terminals, printing terminals, or a computer supplied with terminal emulation and a serial communications port.

➤ Synchrophasor data at 60 message-per-second data format.

Ethernet Card

The Ethernet card has five small form-factor pluggable (SFP) ports.[a] **PORT 5A** and **PORT 5B** are reserved for the process bus network. **PORT 5C** and **PORT 5D** are reserved for the station bus network. The process and station bus networks support PRP and fast failover redundancy modes. **PORT 5E** operates on an isolated network with a unique IP address making it ideal for engineering and data access. All ports support 100 Mbps speeds. **PORT 5A** and **PORT 5B** also support 1 Gbps speeds to satisfy potentially large traffic requirements on the process bus. The process bus, station bus, and engineering access networks use separate MAC addresses and are logically delineated, including in the Configured IED Description (CID) file.[b]

Use popular Telnet applications for easy terminal communications with SEL relays and other devices. Transfer data at high speeds for fast file uploads. The Ethernet card communicates using FTP applications for easy and fast file transfers.

Communicate with SCADA by DNP3 and other substation IEDs by using IEC 61850 Manufacturing Message Specification (MMS) and GOOSE messaging.

Choose Ethernet connection media options for primary and standby connections:

➤ 10/100BASE-T twisted pair network[c]

➤ 100BASE FX fiber-optic network

➤ 1000BASE-X fiber-optic network[d]

---

[a] SFP transceivers are not included with the card and must be ordered separately. See selinc.com/products/sfp for a list of compatible SFP transceivers.

[b] This paragraph describes the five-port Ethernet card ordering option. It does not apply to the four-port Ethernet card ordering option.

[c] Four-port Ethernet card ordering option only.

[d] Gigabit speeds are only available on **PORT 5A** and **PORT 5B** of the five-port Ethernet card ordering option.

Telnet and FTP

Use Telnet to access relay settings, metering, and event reports remotely by using the ASCII interface. Use FTP to transfer settings files to and from the relay via the high-speed Ethernet port.

DNP3 LAN/WAN

DNP3 LAN/WAN provides the relay with DNP3 Level 2 Outstation functionality over Ethernet. Configure DNP3 data maps for use with specific DNP3 masters.

PTP

The Ethernet card provides the ability for the relay to accept IEEE 1588 PTPv2 for data time synchronization. PTP support includes the Default, Power System, and Power Utility Automation Profiles. When connected directly to a grandmaster clock providing PTP at 1-second synchronization intervals, the relay can be synchronized to an accuracy of ±100 ns in the PTP time scale.
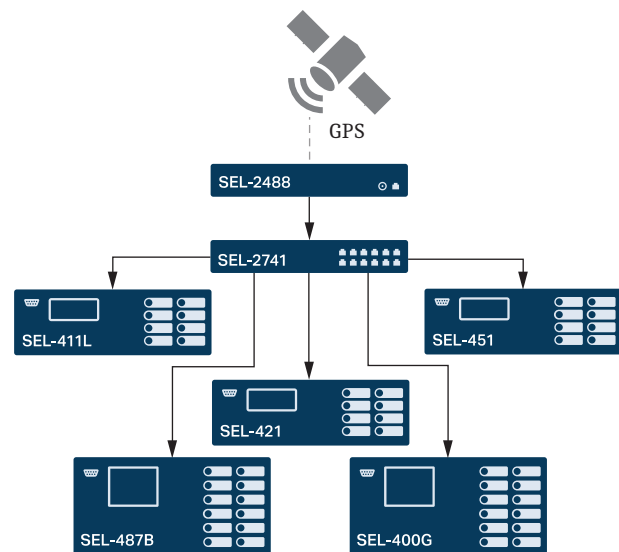

Figure 19   Example PTP Network

SNTP Time Synchronization

Use SNTP to synchronize relays to as little as ±1 ms with no time source delay. Use SNTP as a primary time source, or as a backup to a higher accuracy time input to the relay.

PRP

Use PRP to provide seamless recovery from any single Ethernet network failure, in accordance with IEC 62439-3. The Ethernet network and all traffic are fully duplicated with both copies operating in parallel.

HTTP Web Server

The relay can serve read-only webpages displaying certain settings, metering, and status reports. The web server also allows quick and secure firmware upgrades over Ethernet. As many as four users can access the embedded HTTP server simultaneously.

IEC 61850 Ethernet Communications

IEC 61850 Ethernet-based communication protocols provide interoperability between intelligent devices within the substation. Standardized logical nodes allow interconnection of intelligent devices from different manufacturers for monitoring and control of the substation.

Eliminate system RTUs by streaming monitor and control information from the intelligent devices directly to remote SCADA client devices.

You can order the relay with IEC 61850 protocol for relay monitor and control functions, including:

➤ As many as 128 incoming GOOSE messages. You can use the incoming GOOSE messages to control as many as 256 control bits in the relay with <3 ms latency from device to device depending on network design. These messages provide binary control inputs to the relay for high-speed control functions and monitoring.

➤ As many as eight outgoing GOOSE messages. Configure outgoing GOOSE messages for Boolean or analog data such as high-speed control and monitoring of external breakers, switches, and other devices. Boolean data are provided with <3 ms latency from device to device depending on network design.

➤ IEC 61850 Data Server. The relay equipped with embedded IEC 61850 Ethernet protocol provides data according to predefined logical node objects. Each relay supports as many as seven unbuffered MMS report client associations. Relevant Relay Word bits are available within the logical node data, so status of relay elements, inputs, outputs, or SELOGIC control equations can be monitored.

➤ As many as 256 virtual bits. Configure the virtual bits within GOOSE messaging to represent a variety of Boolean values available within the relay. These bits that the relay receives are available for use in SELOGIC control equations.

➤ As many as 64 remote analog outputs. Assign the remote analog outputs to virtually any analog quantity available in the relay. You can also use SELOGIC math variables to develop custom analog quantities for assignment as remote analog outputs. Remote

analog outputs that use GOOSE messages provide peer-to-peer transmission of analog data. Each relay can receive as many as 256 remote analog inputs and use those inputs as analog quantities within SELOGIC control equations.

➤ IEC 61850 standard operating modes. The relay supports Test, Blocked, On, and Off. The relay also supports Simulation mode for added flexibility.

MMS File Services

This service of IEC 61850 MMS provides support for file transfers completely within an MMS session. All relay files that can be transferred via FTP can also be transferred via MMS file services.

MMS Authentication

When enabled via a setting in the Configured IED Description (CID) file, the relay requires authentication from any client requesting to initiate an MMS session.

Architect Software

Use ACSELERATOR Architect SEL-5032 Software to manage the IEC 61850 configuration for devices on the network. This Windows-based software provides easy-to-use displays for identifying and binding IEC 61850 network data among logical nodes that use IEC 61850-compliant CID files. Architect uses CID files to describe the data available in each relay.

Serial Communications
MIRRORED BITS Communications

The SEL patented MIRRORED BITS technology provides bidirectional relay-to-relay digital communication.

Figure 20 shows two relays with SEL-2815 Fiber-Optic Transceivers that use MIRRORED BITS communications. MIRRORED BITS communications can operate simultaneously on any two serial ports. This bidirectional digital communication creates additional outputs (transmitted MIRRORED BITS) and additional inputs (received MIRRORED BITS) for each serial port operating in the MIRRORED BITS communications mode.

Communicated information can include digital, analog, and virtual terminal data. Virtual terminal allows operator access to remote relays through the local relay. You can use this MIRRORED BITS protocol to transfer information between stations to enhance coordination and achieve faster tripping.
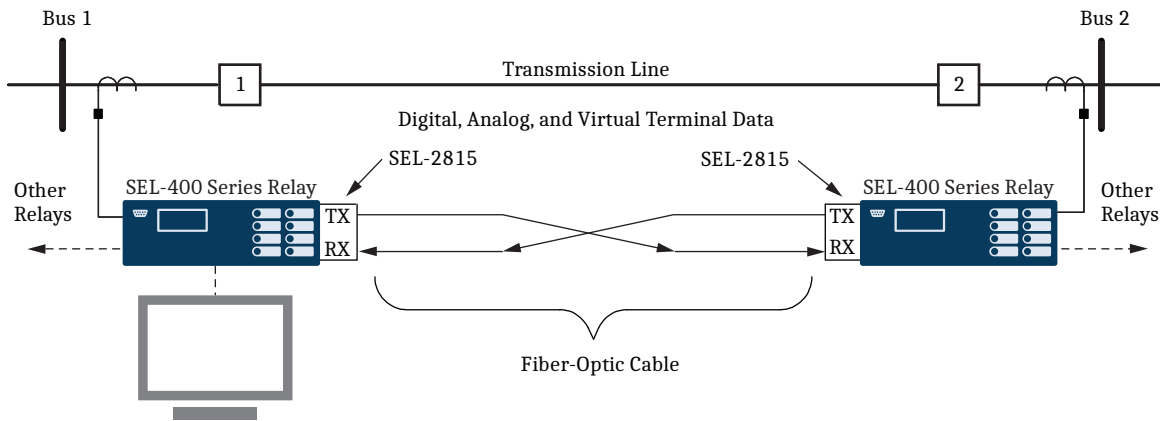
Figure 20   Integral Communication Provides Secure Protection, Monitoring, and Control as Well as Terminal Access to Both Relays Through One Connection

Open Communications Protocols

The relay does not require special communications software. ASCII terminals, printing terminals, or a computer supplied with terminal emulation and a serial communications port are all that is required. *Table 1* lists a brief description of the terminal protocols.

Table 1   Open Communications Protocol

Type	Description
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 bay data in an appropriate format for direct import into spreadsheets and database programs. Data are checksum protected.
Extended Fast Meter, Fast Operate, and Fast SER	Binary protocol for machine-to-machine communications. Quickly updates communications processors, RTUs, and other substation devices with metering information, bay 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 that control operator metering information is not lost while a technician is transferring an event report.
Ymodem	Support for reading event, settings, and oscillography files.
Optional DNP3 Level 2 Outstation	DNP with point remapping. Includes access to metering data, protection elements, contact I/O, targets, SER, relay summary event reports, and settings groups.
IEEE C37.118	Phasor measurement protocol.
MIRRORED BITS	SEL protocol for exchanging digital and analog information among SEL relays and for use as low-speed terminal connection.
IEC 61850	Ethernet-based international standard for interoperability between intelligent devices in a substation.
PRP	PRP provides redundant Ethernet network capabilities for seamless operation in the event of loss to one network.
SNTP	Ethernet-based SNTP for time synchronization among relays.
FTP and Telnet	Use Telnet to establish a terminal-to-relay connection over Ethernet. Use FTP to move files in and out of the relay over Ethernet.

Automation

Flexible Control Logic and Integration Features

Use the control logic to perform the following:

➤ Replace traditional panel control switches

➤ Eliminate remote terminal unit (RTU)-to-bay wiring

➤ Replace traditional latching relays

➤ Replace traditional indicating panel lights

Eliminate traditional panel control switches with 64 local control points. Set, clear, or pulse local control points with the front-panel pushbuttons and display. Program the local control points to implement your control scheme via SELOGIC control equations. Use the local control points for such functions as trip testing, enabling/disabling reclosing, and tripping/closing circuit breakers.

Eliminate RTU-to-bay wiring with 64 remote control points per relay. Set, clear, or pulse remote control points via serial port commands. Incorporate the remote control points into your control scheme via SELOGIC control equations. Use remote control points for SCADA-type control operations (e.g., trip, close, settings group selection).

Replace traditional latching relays for such functions as remote control enable with 64 latching control points. Program latch set and latch reset conditions with SELOGIC control equations. Set or reset the latch control points via

control inputs, remote control points, local control points, or any programmable logic condition. The relay retains the states of the latch control points after turning on following a power interruption.

Replace traditional indicating panel lights and switches with as many as 24 latching target LEDs and as many as 12 programmable pushbuttons with LEDs. Define custom messages (i.e., BREAKER OPEN, BREAKER CLOSED, RECLOSER ENABLED) to report power system or relay conditions on the large format LCD. Control displayed messages with SELOGIC control equations by driving the LCD via any logic point in the relay.

SELOGIC Control Equations With Expanded Capabilities and Aliases

Expanded SELOGIC control equations put relay logic in the hands of the engineer. Assign inputs to suit your application, logically combine selected bay elements for various control functions, and assign outputs to your logic functions.

Programming SELOGIC control equations consists of combining relay elements, inputs, and outputs with SELOGIC control equation operators (*Table 2*). Any element in the Relay Word can be used in these equations. For complex or unique applications, these expanded SELOGIC functions allow superior flexibility.

Table 2   SELOGIC Control Equation Operators

Operator Type	Operators	Comments
Boolean	AND, OR, NOT	Allows combination of measuring units.
Edge Detection	F_TRIG, R_TRIG	Operates at the change of state of an internal function.
Comparison	>, >=, =, <=, <, < >	
Arithmetic	+, –, *, /	Uses traditional math functions for analog quantities in an easily programmable equation.
Numerical	ABS, SIN, COS, LN, EXP, SQRT, LOG	
Precedence Control	( )	Allows multiple and nested sets of parentheses.
Comment	#, (* *)	Provides for easy documentation of control and protection logic.

Use the relay alias capability to assign more meaningful names to analog and Boolean quantities. This improves the readability of customized programming. Use as many as 200 aliases to rename any digital or analog quantity. The following is an example of possible applications of SELOGIC control equations that use aliases.

```
=>>SET T <Enter>
 1: PMV01,THETA
```

(assign the alias "THETA" to math variable PMV01)

```
 2: PMV02,TAN
```

(assign the alias "TAN" to math variable PMV02)

```
=>>SET L <Enter>
 1: # CALCULATE THE TANGENT OF THETA
 2: TAN:=SIN(THETA)/COS(THETA)
```

(use the aliases in an equation)

Add programmable control functions to your relay and automation systems. New functions and capabilities enable using analog values in conditional logic statements. The following are examples of possible applications of SELOGIC control equations with expanded capabilities.

➤ Emulate a motor-driven reclose timer, including stall, reset, and drive-to-lockout conditions.

➤ Scale analog values for SCADA retrieval.

➤ Initiate remedial action sequence based on load flow before fault conditions.

➤ Interlock breakers and disconnect switches.

➤ Restrict breaker tripping in excessive duty situations without additional relays.

➤ Hold momentary change-of-state conditions for SCADA polling.

Metering and Monitoring

Access a range of useful information in the relay with the metering function. Metered quantities include fundamental primary and secondary current and voltage magnitudes and angles for each terminal. RMS voltage and current metering is also provided. Fundamental phase and real and reactive power, per-phase voltage magnitude, angle, and frequency are displayed in the metering report for applications that use the relay voltage inputs.

Table 3   Metering Capabilities

Capabilities	Description
Instantaneous Quantities	
Voltages $V_{A, B, C}$ (Y), $V_{A, B, C}$ (Z), $V\phi\phi$, 3V0, V1, 3V2	0–300 V with phase quantities for each of the six voltage sources available as separate quantities.
Currents $I_{A, B, C}$ (W), $I_{A, B, C}$ (X), I_AL, I_BL, I_CL, (combined currents), IGL, I1L, 3I2L (combined currents)	Phase quantities for each of the two current sources available as separate quantities or combined as line quantities.
Differential Metering	
Currents $I_{A, B, C}$, I1, $3I_2$, $3I_0$	Local terminal/all Remote Terminals
Differential Current $I_{A, B, C}$, I1, $3I_2$, $3I_0$	Local terminal/all Remote terminals

Alpha Plane
    k
    alpha
	Alpha plane ratio
	Alpha plane angle

Power/Energy Metering Quantities	
MW, MWh, MVAR, MVARh, MVA, PF, single-phase and three-phase	Available for each input set and as combined quantities for the line.
Demand/Peak Demand Metering	
$I_{A, B, C}$, $3I_2$, $3I_0$	Thermal or rolling interval demand and peak demand.
MW, MVAR, MVA, single-phase	Thermal or rolling interval demand and peak demand.
MW, MVAR, MVA, three-phase	Thermal or rolling interval demand and peak demand.
Synchrophasors	
Voltages (Primary Magnitude, Angle) $V_{A, B, C}$ (Y), $V_{A, B, C}$ (Z)	Primary phase quantities (kV) for each of the six voltage sources available.
Currents $I_{A, B, C}$ (W), $I_{A, B, C}$ (X)	Primary phase quantities (A) for each of the six voltage sources available.

Frequency
    FREQ
    dF/dT
	Frequency (Hz) as measured by frequency source potential inputs.
	Rate-of-change in frequency (Hz/s).

Event Reporting and SER

Event reports and SER features simplify post-fault analysis and help improve your understanding of both simple and complex protective scheme operations. These features also aid in testing and troubleshooting relay settings and protective schemes.

Oscillography and Event Reporting

In response to a user-selected internal or external trigger, the voltage, current, and element status information contained in each event report confirms relay, scheme, and system performance for every fault. The relay provides sampling rates as fast as 8 kHz for analog quantities in a COMTRADE file format, as well as eight-sample-per-cycle and four-sample-per-cycle event reports. The relay stores as much as 3 seconds of 8 kHz event data. The relay supports inclusion of user-configurable analogs in the events. Reports are stored in nonvolatile memory. Relay settings operational in the relay at the time of the event are appended to each event report.

Each relay provides event reports for analysis with software such as SEL-5601-2 SYNCHROWAVE® Event Software. With SYNCHROWAVE Event, you can display events from several relays to make the fault analysis easier and more meaningful. Because the different relays time-stamp the events with values from their individual clocks, be sure to time synchronize the relay with an IRIG-B clock input or PTP source to use this feature.

Event Summary

Each time the relay generates a standard event report, it also generates a corresponding event summary. This is a concise description of an event that includes the following information:

➤ Relay/terminal identification
➤ Event date and time
➤ Event type
➤ Event number
➤ Time source
➤ Active settings group
➤ Targets asserted during the fault
➤ Current magnitudes and angles for each terminal
➤ Pre-fault and fault calculated zero- and negative-sequence currents
➤ Voltage magnitudes and angles
➤ Terminals tripped for this fault
➤ Recloser shot count at time of trigger (if applicable)
➤ Fault location (if applicable)
➤ Breaker status (open/close)

With an appropriate setting, the relay sends an event summary in ASCII text automatically to one or more serial ports each time an event report is triggered.

SV Reporting

The SV Subscriber includes a comprehensive report of the SV communication stream. The ASCII command **COM SV** displays statistics information from the sample values stream to aid in troubleshooting.

SER

Use this feature to gain a broad perspective of relay element operation. Items that trigger an SER entry are selectable and can include as many as 250 monitoring points, such as I/O change-of-state and element pickup/dropout. The relay SER stores the latest 1000 events.

Analog Signal Profiling

The relay provides analog signal profiling for as many as 20 analog quantities. Select any analog quantity measured or calculated by the relay for analog signal profiling. You can select signal sampling rates of 1, 5, 15, 30, and 60 minutes through settings. The analog signal profile report provides a comma-separated variable (CSV) list that you can load into any spreadsheet or database for analysis and graphical display.

SELOGIC enable/disable functions can start and stop signal profiling based on Boolean or analog comparison conditions.

Substation Battery Monitor for DC Quality Assurance

The relay measures and reports the substation battery voltage for up to two battery systems. The SEL-411L, SEL-421, SEL-451 support two battery monitors while the SEL-487B, SEL-487E, and SEL-487V support one. Each battery monitor supports programmable threshold comparators and associated logic provides alarm and control for batteries and chargers. The relay also provides dual ground detection. Monitor dc system status alarms with an SEL communications processor and trigger messages, telephone calls, or other actions.

The measured dc voltage is reported in the METER display via serial port communications, on the LCD, and in the event report. Use the event report data to see an oscillographic display of the battery voltage. Monitor the substation battery voltage drops during trip, close, and other control operations.

Breaker Contact Wear Monitoring

Circuit breakers experience mechanical and electrical wear during each operation. Effective scheduling of breaker maintenance takes into account the manufacturer's published data of contact wear versus interruption levels and operation count.

➤ Every time the breaker trips, the relay integrates interrupted current. When the result of this integration exceeds the threshold set by the breaker wear curve (*Figure 21*), the relay can alarm via an output contact or the optional front-panel display. With this information, you can schedule breaker maintenance in a timely, economical fashion.

➤ The relay monitors last and average mechanical and electrical interruption time per pole. You can easily determine if operating time is increasing beyond reasonable tolerance and then schedule proactive breaker maintenance. You can activate an alarm point if operation time exceeds a preset value.

The relay also monitors breaker motor run time, pole discrepancy, and breaker inactivity.
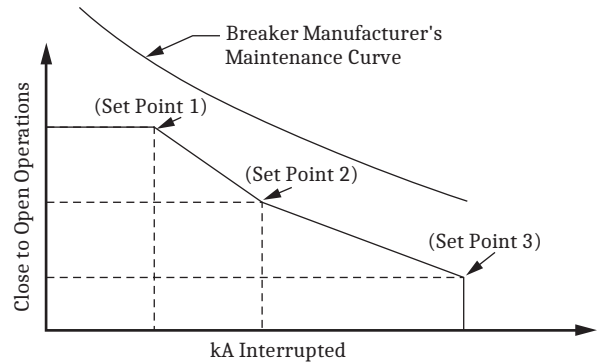
Figure 21 Breaker Contact Wear Curve and Settings

Diagrams and Dimensions
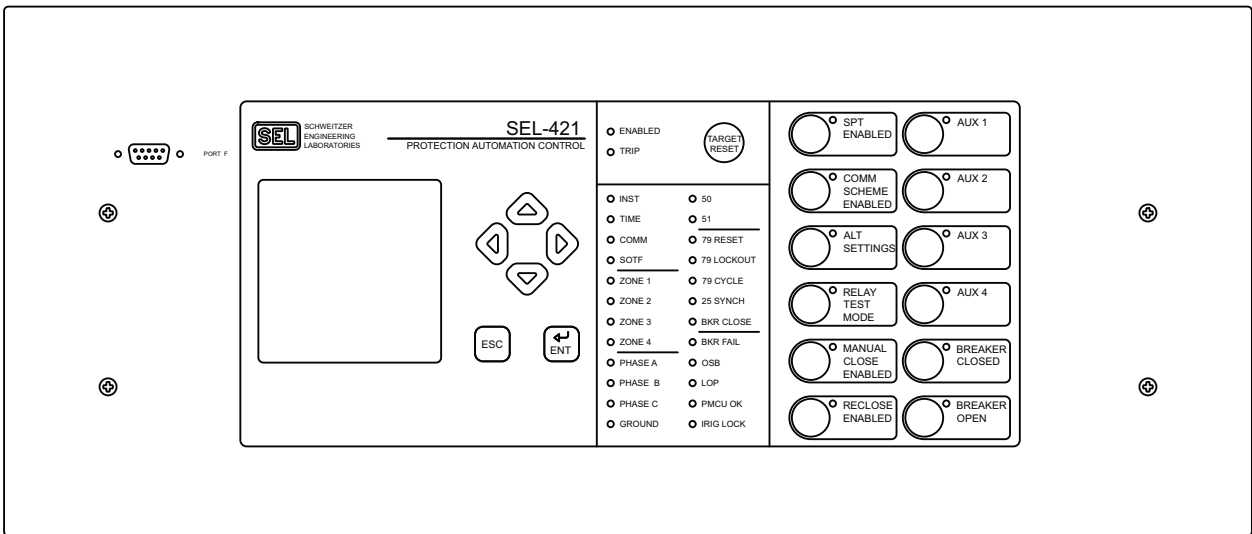
i7285a

Figure 22 4U Front Panel, Panel-Mount Option
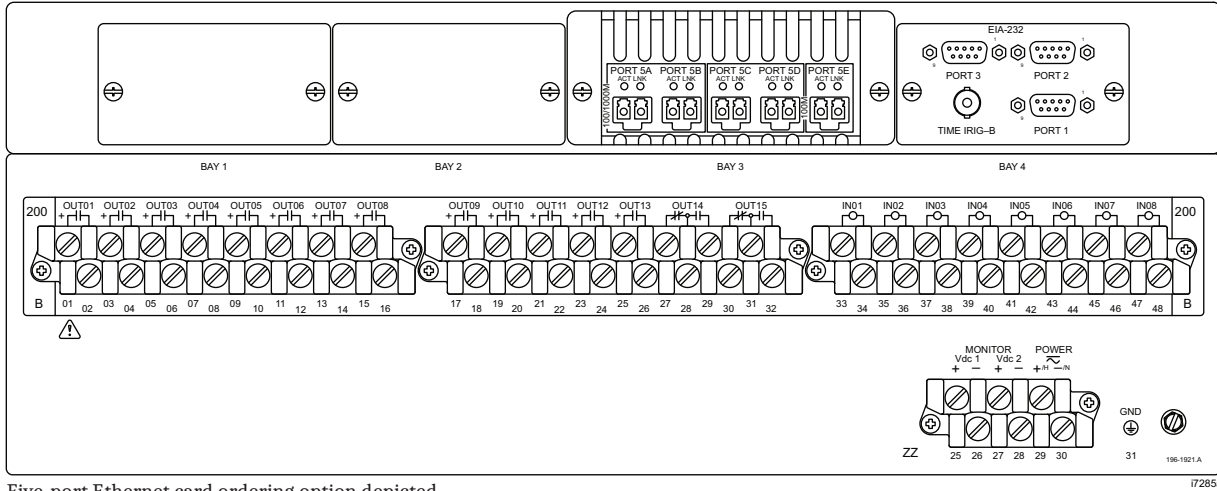
Five-port Ethernet card ordering option depicted.

Figure 23   SEL-421-7 SV Subscriber 4U Rear Panel, INT7 (200 Slot) Interface Board
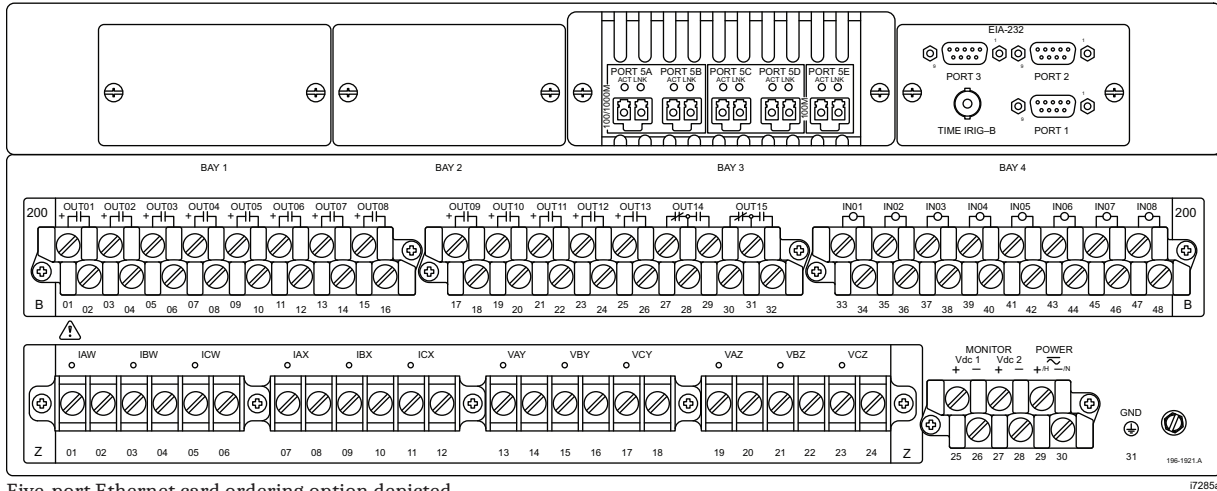
Five-port Ethernet card ordering option depicted.

Figure 24   SEL-421-7 SV Publisher 4U Rear Panel, INT7 (200 Slot) Interface Board
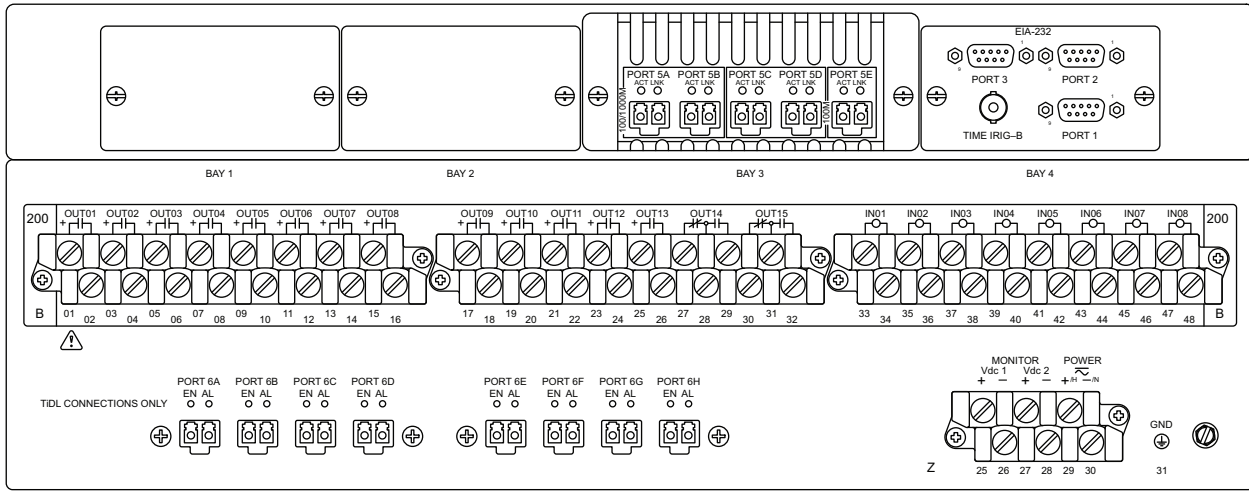
Five-port Ethernet card ordering option depicted.

Figure 25   SEL-421-7 TiDL 4U Rear Panel

RACK-MOUNT CHASSIS

PANEL-MOUNT CHASSIS

DIMENSION	ONE I/O BOARD (4U)	TWO I/O BOARD (5U)	THREE I/O BOARD (6U)
A	6.97 (177.0)	8.72 (221.5)	10.47 (265.9)
B	4.00 (101.6)	5.75 (146.0)	7.50 (190.5)
C	8.40 (213.4)	10.15 (257.8)	11.90 (302.3)
D	6.85 (174.0)	8.60 (218.4)	10.35 (262.9)
E	N/A	N/A	3.00 (76.2)

*ADD 0.30 (7.6) FOR CONNECTORIZED RELAYS
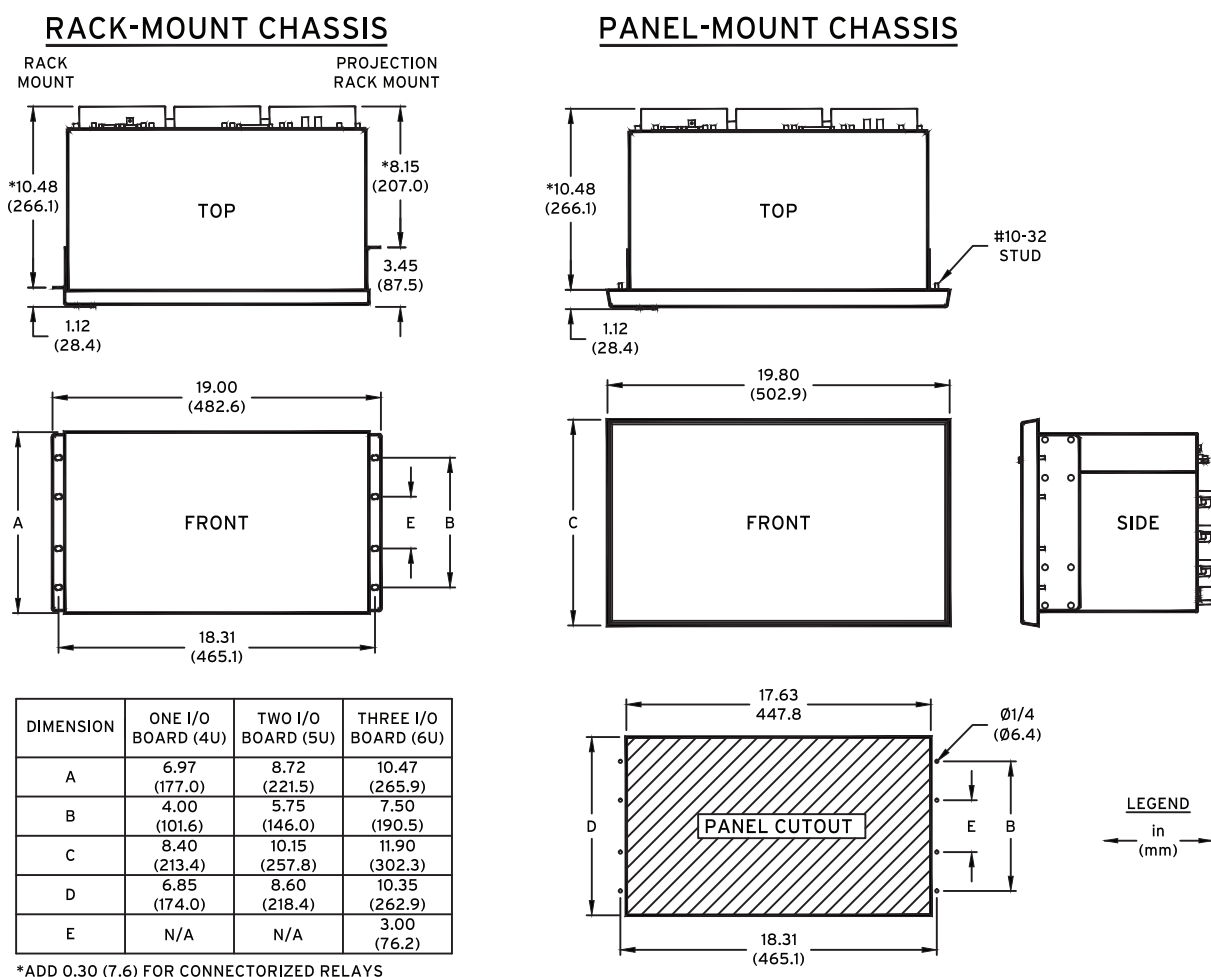
Figure 26   SEL-421-7 Dimensions for Rack- and Panel-Mount Models

Models and Options

Consider the following options when ordering and configuring the SEL-421-7.

➤ DSS connector type

➢ IEC 61850-9-2LE-compliant SV publisher relay

➢ IEC 61850-9-2LE-compliant SV subscriber relay

➢ SEL TiDL relay with T-Protocol

➤ Chassis size

➢ (U is one rack unit—1.75 in or 44.45 mm)

➢ SEL-421-7 SV Subscriber or TiDL relay supports 4U only

➢ SEL-421-7 SV Publisher supports 4U, 5U, and 6U

Table 4   Interface Board Information (Sheet 1 of 2)

Board Name	Inputs	Description	Outputs	Description
INT2	8	Optoisolated, independent, level-sensitive	13	Standard Form A
			2	Standard Form C
INT4	18	Two sets of 9 common optoisolated, level-sensitive	6	High-speed, high-current interrupting, Form A
	6	Optoisolated, independent, level-sensitive	2	Standard Form A
INT7	8	Optoisolated, independent, level-sensitive	13	High-current interrupting, Form A
			2	Standard Form C

Table 4   Interface Board Information (Sheet 2 of 2)

Board Name	Inputs	Description	Outputs	Description
INT8	8	Optoisolated, independent, level-sensitive	8	High-speed, high-current interrupting, Form A
INTD	18	Two sets of 9 common optoisolated, level-sensitive	8	Standard Form A
	6	Optoisolated, independent, level-sensitive		

➤ Chassis orientation and type
  ➢ Horizontal rack mount
  ➢ Horizontal panel mount
  ➢ Vertical rack mount
  ➢ Vertical panel mount
➤ Power supply
  ➢ 24–48 Vdc
  ➢ 48–125 Vdc or 110–120 Vac
  ➢ 125–250 Vdc or 110–240 Vac
➤ Secondary inputs
  ➢ 1 A nominal or 5 A nominal CT inputs
  ➢ 300 V phase-to-neutral wye configuration PT inputs
➤ Ethernet card options
  ➢ Four-port Ethernet card with port combinations of:
    ➢ Four copper (10BASE-T/100BASE-TX)
    ➢ Four fiber (100BASE-FX)
    ➢ Two copper (10BASE-T/100BASE-TX) and two fiber (100BASE-FX)
  ➢ Five-port Ethernet card with SFP ports (100BASE-FX and 1000BASE-X)[e]

➤ Communications protocols
  ➢ Complete group of protocols (SEL ASCII, SEL Compressed ASCII, SEL Settings File Transfer, SEL Fast Meter, SEL Fast Operate, SEL Fast SER, resistance temperature detector (RTD), enhanced Mirrored Bits Communications), DNP3, and Synchrophasors (SEL Fast Message and IEEE C37.118 format)

NOTE: The SEL-421-7 can be ordered with either SV publication or SV subscription.
  ➢ Above protocols plus IEC 61850 Edition 2
➤ Connector type (publisher only)
  ➢ Screw-terminal block inputs
  ➢ Connectorized

Contact the SEL factory or your local Technical Service Center for particular part number and ordering information (see *Technical Support on page 3.22*). You can also view the latest part number and ordering information on the SEL website at selinc.com.

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[e] All ports support 100 Mbps speeds. **PORT 5A** and **PORT 5B** also support 1 Gbps speeds.

Specifications

Note: If your SEL-421-7 TiDL uses DSS, relay operating times are delayed. For SV applications, operating times are delayed by the configured channel delay, CH_DLY. See *SV Network Delays on page 17.25 in the SEL-400 Series Relays Instruction Manual* for more details. For TiDL applications, the operating times are delayed by a fixed 1 millisecond. Use caution when setting relay coordination to account for this added delay.

Note: The metering and protection element accuracies specified for the SEL-421-7 TiDL are valid only when using SEL merging units. For SV applications, third-party SV publisher devices are supported but hardware accuracies and analog filtering need to be considered to determine the effect on SEL-421-7 SV Subscriber performance.

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

FCC Compliance Statement

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.

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

CE Mark

RCM Mark

General

AC Analog Inputs

Sampling Rate:	8 kHz

AC Current Input (Secondary Circuit)

Current Range Rating (With DC Offset at X/R = 10, 1.5 Cycles)

1 A Nominal:	0.1–18.2 A
5 A Nominal:	0.5–91 A

Continuous Thermal Rating

1 A Nominal:	3 A
	4 A (+55°C)
5 A Nominal:	15 A
	20 A (+55°C)

Saturation Current (Linear) Rating

1 A Nominal:	20 A
5 A Nominal:	100 A

A/D Current Limit (Peak)

1 A Nominal:	49.5 A
5 A Nominal:	247.5 A

Note: Signal clipping can occur beyond this limit.

One-Second Thermal Rating

1 A Nominal:	100 A
5 A Nominal:	500 A

One-Cycle Thermal Rating

1 A Nominal:	250 A peak
5 A Nominal:	1250 A peak

Burden Rating

1 A Nominal:	≤0.1 VA @ 1 A
5 A Nominal:	≤0.5 VA @ 5 A

AC Voltage Inputs

Three-phase, four-wire (wye) connections are supported.

Rated Voltage Range:	55–250 V_{LN}
Operational Voltage Range:	0–300 V_{LN}

Ten-Second Thermal Rating:	600 Vac
Burden:	≤0.1 VA @ 125 V

Frequency and Rotation

Nominal Frequency Rating:	50 ± 5 Hz
	60 ± 5 Hz
Phase Rotation:	ABC or ACB
Frequency Tracking Range:	40–65 Hz
	<40 Hz = 40 Hz
	>65 Hz = 65 Hz
Default Slew Rate:	15 Hz/s

Power Supply

24-48 Vdc

Rated Voltage:	24–48 Vdc
Operational Voltage Range:	18–60 Vdc
Vdc Input Ripple:	15% per IEC 60255-26:2013
Interruption:	20 ms at 24 Vdc, 100 ms at 48 Vdc per IEC 60255-26:2013

Burden

SV Relay:	<35 W
TiDL Relay:	<40 W

48-125 Vdc or 110-120 Vac

Rated Voltage:	48–125 Vdc, 110–120 Vac
Operational Voltage Range:	38–140 Vdc
	85–140 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-26:2013
Interruption:	14 ms at 48 Vdc, 160 ms at 125 Vdc per IEC 60255-26:2013

Burden

SV Relay:	<35 W, <90 VA
TiDL Relay	<40 W, <90 VA

125-250 Vdc or 110-240 Vac

Rated Voltage:	125–250 Vdc, 110–240 Vac
Operational Voltage Range:	85–300 Vdc
	85–264 Vac
Rated Frequency:	50/60 Hz
Operational Frequency Range:	30–120 Hz
Vdc Input Ripple:	15% per IEC 60255-26:2013
Interruption:	46 ms at 125 Vdc, 250 ms at 250 Vdc per IEC 60255-26:2013

Burden

SV Relay:	<35 W, <90 VA
TiDL Relay:	<40 W, <90 VA

Control Outputs

Note: IEEE C37.90-2005 and IEC 60255-27:2013

Update Rate:	1/8 cycle
Make (Short Duration Contact Current):	30 Adc
	1,000 operations at 250 Vdc
	2,000 operations at 125 Vdc
Limiting Making Capacity:	1000 W at 250 Vdc (L/R = 40 ms)
Mechanical Endurance:	10,000 operations

Standard

Rated Voltage:	24–250 Vdc 110–240 Vrms
Operational Voltage Range:	0–300 Vdc 0–264 Vrms
Operating Time:	Pickup ≤6 ms (resistive load) Dropout ≤6 ms (resistive load)
Short-Time Thermal Withstand:	50 A for 1 s
Continuous Contact Current:	6 A at 70°C 4 A at 85°C
Contact Protection:	MOV protection across open contacts 264 Vrms continuous voltage 300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance:	10,000 operations 10 operations in 4 seconds, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break L/R = 40 ms (DC) PF = 0.4 (AC)
24 Vdc	0.75 Adc	0.75 Adc
48 Vdc	0.63 Adc	0.63 Adc
125 Vdc	0.30 Adc	0.30 Adc
250 Vdc	0.20 Adc	0.20 Adc
110 Vrms	0.30 Arms	0.30 Arms
240 Vrms	0.20 Arms	0.20 Arms

Hybrid (High-Current Interrupting)

Rated Voltage:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time:	Pickup ≤6 ms (resistive load) Dropout ≤6 ms (resistive load)
Short-Time Thermal Withstand:	50 Adc for 1 s
Continuous Contact Current:	6 Adc at 70°C 4 Adc at 85°C
Contact Protection:	MOV protection across open contacts 300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance:	10,000 operations 4 operations in 1 second, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break
24 Vdc	10 Adc	10 Adc (L/R = 40 ms)
48 Vdc	10 Adc	10 Adc (L/R = 40 ms)
125 Vdc	10 Adc	10 Adc (L/R = 40 ms)
250 Vdc	10 Adc	10 Adc (L/R = 20 ms)

Note: Do not use hybrid control outputs to switch ac control signals.

Fast Hybrid (High-Speed High-Current Interrupting)

Rated Voltage:	24–250 Vdc
Operational Voltage Range:	0–300 Vdc
Operating Time:	Pickup ≤10 μs (resistive load) Dropout ≤8 ms (resistive load)
Short-Time Thermal Withstand:	50 Adc for 1 s
Continuous Contact Current:	6 Adc at 70°C 4 Adc at 85°C
Contact Protection:	MOV protection across open contacts 300 Vdc continuous voltage
Limiting Breaking Capacity/Electrical Endurance:	10,000 operations 4 operations in 1 second, followed by 2 minutes idle

Rated Voltage	Resistive Break	Inductive Break
24 Vdc	10 Adc	10 Adc (L/R = 40 ms)
48 Vdc	10 Adc	10 Adc (L/R = 40 ms)
125 Vdc	10 Adc	10 Adc (L/R = 40 ms)
250 Vdc	10 Adc	10 Adc (L/R = 20 ms)

Note: Do not use hybrid control outputs to switch ac control signals.

Control Inputs

Optoisolated (For Use With AC or DC Signals)

Main Board:	No I/O
INT2, INT7, and INT8 Interface Board:	8 inputs with no shared terminals
INT4 and INTD Interface Board:	6 inputs with no shared terminals 18 inputs with shared terminals (2 groups of 9 inputs with each group sharing one terminal)
Voltage Options:	24, 48, 110, 125, 220, 250 V
Current Draw:	<5 mA at nominal voltage <8 mA for 110 V option
Sampling Rate:	2 kHz

DC Thresholds (Dropout thresholds indicate level-sensitive option)

24 Vdc:	Pickup 19.2–30.0 Vdc; Dropout <14.4 Vdc
48 Vdc:	Pickup 38.4–60.0 Vdc; Dropout <28.8 Vdc
110 Vdc:	Pickup 88.0–132.0 Vdc; Dropout <66.0 Vdc
125 Vdc:	Pickup 105–150 Vdc; Dropout <75 Vdc
220 Vdc:	Pickup 176–264 Vdc; Dropout <132 Vdc
250 Vdc:	Pickup 200–300 Vdc; Dropout <150 Vdc

AC Thresholds (Ratings met only when recommended control input settings are used)

24 Vac:	Pickup 16.4–30.0 Vac rms; Dropout <10.1 Vac rms
48 Vac:	Pickup 32.8–60.0 Vac rms; Dropout <20.3 Vac rms
110 Vac:	Pickup 75.1–132.0 Vac rms; Dropout <46.6 Vac rms
125 Vac:	Pickup 89.6–150.0 Vac rms; Dropout <53.0 Vac rms
220 Vac:	Pickup 150.3–264.0 Vac rms; Dropout <93.2 Vac rms
250 Vac:	Pickup 170.6–300 Vac rms; Dropout <106 Vac rms
Current Drawn:	<5 mA at nominal voltage <8 mA for 110 V option
Sampling Rate:	2 kHz

Communications Ports

EIA-232:	1 front and 3 rear
Serial Data Speed:	300–57600 bps

Ethernet Card Slot for the Four-Port Ethernet Card

Ordering Option:	10/100BASE-T
Connector Type:	RJ45

Ordering Options: 100BASE-FX fiber-optic Ethernet

Mode: Multi

Wavelength (nm): 1300

Source: LED

Connector Type: LC

Min. TX Pwr. (dBm): –19

Max. TX Pwr. (dBm): –14

RX Sens. (dBm): –32

Sys. Gain (dB): 13

Ethernet Card Slot for the Five-Port Ethernet Card

Ordering Option: 100BASE-FX fiber-optic Ethernet SFP transceiver

Part Number: 8103-01 or 8109-01

Mode: Multi

Wavelength (nm): 1310

Source: LED

Connector Type: LC

Min. TX Pwr. (dBm): –24

Max. TX Pwr. (dBm): –14

Min. RX Sens. (dBm): –31

Max. RX Sens. (dBm): –12

Approximate Range: 2 km

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Ordering Option: 1000BASE-LX fiber-optic Ethernet SFP transceiver

Part Number: 8130-01, 8130-02, 8130-03, or 8130-04

Mode: Single

Wavelength (nm): 1310

Source: LED

Connector Type: LC

	Part Number			
	8130-01	8130-02	8130-03	8130-04
Min. TX Pwr. (dBm)	–9.5	–6	–5	–2
Max. TX Pwr. (dBm)	–3	–1	0	3
Min. RX Sens. (dBm)	–21	–22	–24	–24
Max. RX Sens. (dBm)	–3	–3	–3	–3
Approximate Range (km)	10	20	30	40

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Ordering Option: 1000BASE-XD fiber-optic Ethernet SFP transceiver

Part Number: 8130-05

Mode: Single

Wavelength (nm): 1550

Source: LED

Connector Type: LC

Min. TX Pwr. (dBm): –5

Max. TX Pwr. (dBm): 0

Min. RX Sens. (dBm): –24

Max. RX Sens. (dBm): –3

Approximate Range: 50 km

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Ordering Option: 1000BASE-ZX fiber-optic Ethernet SFP transceiver

Part Number: 8130-06, 8130-08, or 8130-10

Mode: Single

Wavelength (nm): 1550

Source: LED

Connector Type: LC

	Part Number		
	8130-06	8130-08	8130-10
Min. TX Pwr. (dBm)	0	1	5
Max. TX Pwr. (dBm)	5	5	8
Min. RX Sens. (dBm)	–24	–36	–36
Max. RX Sens. (dBm)	–3	–10	–10
Approximate Range (km)	80	160	200

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Ordering Option: 1000BASE-SX fiber-optic Ethernet SFP transceiver

Part Number: 8131-01

Mode: Multi

Wavelength (nm): 850

Source: LED

Connector Type: LC

Min. TX Pwr. (dBm): –9

Max. TX Pwr. (dBm): –2.5

Min. RX Sens. (dBm): –18

Max. RX Sens. (dBm): 0

Approximate Range: 300 m for 62.5/125 μm; 550 m for 50/125 μm

Transceiver Internal Temperature Accuracy: ±3.0°C

Transmitter Average Optical Power Accuracy: ±3.0 dB

Received Average Optical Input Power Accuracy: ±3.0 dB

Optional TiDL Communication Ports

Number of Ports: 8

Protocol: T-Protocol

Supported SFP
Transceivers: 8103-01 or 8109-01

Note: For SFP Transceiver specification, see *Ethernet Card Slot for the Five-Port Ethernet Card on page 25*.

Time Inputs

IRIG-B Input−Serial PORT 1

Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operating Voltage Range:	0–8 Vdc
Logic High Threshold:	≥2.8 Vdc
Logic Low Threshold:	≤0.8 Vdc
Input Impedance:	2.5 kΩ

IRIG-B Input−BNC Connector

Input:	Demodulated IRIG-B
Rated I/O Voltage:	5 Vdc
Operating Voltage Range:	0–8 Vdc
Logic High Threshold:	≥2.2 Vdc
Logic Low Threshold:	≤0.8 Vdc
Input Impedance:	>1 kΩ
Rated Insulation Voltage	150 Vdc

PTP

Input:	IEEE 1588 PTPv2
Profiles:	Default, C37.238-2011 (Power Profile), IEC/IEEE 61850-9-3-2016 (Power Utility Automation Profile)
Synchronization Accuracy:	±100 ns @ 1-second synchronization intervals when communicating directly with master clock

Operating Temperature

–40° to +85°C (–40° to +185°F)

Note: LCD contrast impaired for temperatures below –20° and above +70°C. Stated temperature ranges not applicable to UL applications.

Humidity

5% to 95% without condensation

Weight (Maximum)

SV Publisher

4U Rack Unit:	10.2 kg (22.5 lb)
5U Rack Unit:	11.8 kg (26 lb)
6U Rack Unit:	13.5 kg (30 lb)

SV Subscriber

4U Rack Unit:	6.57 kg (14.47 lb)

TiDL Relay

4U Rack Unit:	6.74 kg (14.87 lb)

Terminal Connections

Rear Screw-Terminal Tightening Torque, #8 Ring Lug

Minimum:	1.0 Nm (9 in-lb)
Maximum:	2.0 Nm (18 in-lb)

User terminals and stranded copper wire should have a minimum temperature rating of 105°C. Ring terminals are recommended.

Wire Sizes and Insulation

Wire sizes for grounding (earthing), current, voltage, and contact connections are dictated by the terminal blocks andYou can use the following table as a guide in selecting wire sizes: expected load currents.

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 (5.3 mm^2)
Potential (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 (5.3 mm^2)
Other Connection	18 AWG (0.8 mm^2)	10 AWG (5.3 mm^2)

Type Tests

Installation Requirements

Overvoltage Category:	2
Pollution Degree:	2

Safety

Product Standards	IEC 60255-27:2013 IEEE C37.90-2005 21 CFR 1040.10
Dielectric Strength:	IEC 60255-27:2013, Section 10.6.4.3 2.5 kVac, 50/60 Hz for 1 min: Analog Inputs, Contact Outputs, Digital Inputs 3.6 kVac for 1 min: Power Supply, Battery Monitors 2.5 kVac for 1 min: IRIG-B 1.1 kVac for 1 min: Ethernet
Impulse Withstand:	IEC 60255-27:2013, Section 10.6.4.2 IEEE C37.90-2005 Common Mode: ±1.0 kV: Ethernet ±2.5 kV: IRIG-B ±5.0 kV: All other ports Differential Mode: 0 kV: Analog Inputs, Ethernet, IRIG-B, Digital Inputs ±5.0 kV: Standard Contact Outputs, Power Supply Battery Monitors +5.0 kV: Hybrid Contact Outputs
Insulation Resistance:	IEC 60255-27:2013, Section 10.6.4.4 >100 MΩ @ 500 Vdc
Protective Bonding:	IEC 60255-27:2013, Section 10.6.4.5.2 <0.1 Ω @ 12 Vdc, 30 A for 1 min
Ingress Protection:	IEC 60529:2001 + CRGD:2003 IEC 60255-27:2013 IP30 for front and rear panel IP10 for rear terminals with installation of ring lug IP40 for front panel with installation of serial port cover
Max Temperature of Parts and Materials:	IEC 60255-27:2013, Section 7.3
Flammability of Insulating Materials:	IEC 60255-27:2013, Section 7.6 Compliant

Electromagnetic (EMC) Immunity

Product Standards:	IEC 60255-26:2013 IEC 60255-27:2013 IEEE C37.90-2005
Surge Withstand Capability (SWC):	IEC 61000-4-18:2006 + A:2010 IEEE C37.90.1-2012 Slow Damped Oscillatory, Common and Differential Mode: ±1.0 kV ±2.5 kV Fast Transient, Common and Differential Mode: ±4.0 kV

Electrostatic Discharge (ESD):	IEC 61000-4-2:2008 IEEE C37.90.3-2001 Contact: ±8 kV Air Discharge: ±15 kV
Radiated RF Immunity:	IEEE C37.90.2-2004 IEC 61000-4-3:2006 + A1:2007 + A2:2010 20 V/m (>35 V/m, 80% AM, 1 kHz) Sweep: 80 MHz to 1 GHz Spot: 80, 160, 450, 900 MHz 10 V/m (>15 V/m, 80% AM, 1 kHz) Sweep: 80 MHz to 1 GHz Sweep: 1.4 GHz to 2.7 GHz Spot: 80, 160, 380, 450, 900, 1850, 2150 MHz
Electrical Fast Transient Burst (EFTB):	IEC 61000-4-4:2012 Zone A: ±2 kV: Communication ports ±4 kV: All other ports
Surge Immunity:	IEC 61000-4-5:2005 Zone A: ±2 kV$_{L-L}$ ±4 kV$_{L-E}$ ±4 kV: Communication Ports **Note:** Cables connected to IRIG-B ports shall be less than 10 m in length for Zone A compliance. Zone B: ±2 kV: Communication Ports
Conducted Immunity:	IEC 61000-4-6:2013 20 V/m; (>35 V/m, 80% AM, 1 kHz) Sweep: 150 kHz–80 MHz Spot: 27, 68 MHz
Power Frequency Immunity (DC Inputs):	IEC 61000-4-16:2015 Zone A: Differential: 150 V$_{RMS}$ Common Mode: 300 V$_{RMS}$
Power Frequency Magnetic Field:	IEC 61000-4-8:2009 Level 5: 100 A/m; ≥60 Seconds; 50/60 Hz 1000 A/m 1 to 3 Seconds; 50/60 Hz **Note:** 50G1P ≥0.05 (ESS = N, 1, 2) 50G1P ≥0.1 (ESS = 3, 4)
Power Supply Immunity:	IEC 61000-4-11:2004 IEC 61000-4-17:1999/A1:2001/A2:2008 IEC 61000-4-29:2000 AC Dips & Interruptions Ripple on DC Power Input DC Dips & Interruptions Gradual Shutdown/Startup (DC only) Discharge of Capacitors Slow Ramp Down/Up Reverse Polarity (DC only)
Damped Oscillatory Magnetic Field:	IEC 61000-4-10:2016 Level 5: 100 A/m

EMC Compatibility

Product Standards:	IEC 60255-26:2013
Emissions:	IEC 60255-26:2013, Section 7.1 Class A 47 CFR Part 15B Class A Canada ICES-001 (A) / NMB-001 (A)

Environmental

Product Standards:	IEC 60255-27:2013
Cold, Operational:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Cold, Storage:	IEC 60068-2-1:2007 Test Ad: 16 hours at –40°C
Dry Heat, Operational:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Dry Heat, Storage:	IEC 60068-2-2:2007 Test Bd: 16 hours at +85°C
Damp Heat, Cyclic:	IEC 60068-2-30:2005 Test Db: +25 °C to +55 °C, 6 cycles (12 + 12-hour cycle), 95% RH
Damp Heat, Steady State:	IEC 60068-2-78:2013 Severity: 93% RH, +40 °C, 10 days
Vibration Resistance:	EC 60255-21-1:1988 Class 2 Endurance, Class 2 Response
Shock Resistance:	IEC 60255-21-2:1988 Class 1 Shock Withstand, Class 1 Bump Withstand, Class 2 Shock Response
Seismic:	IEC 60255-21-3:1993 Class 2 Quake Response

Event Reports

High-Resolution Data

Rate:	8000 samples/second 4000 samples/second 2000 samples/second 1000 samples/second
Output Format:	Binary COMTRADE

Note: Per IEEE C37.111-1999 and IEEE C37.111-2013, *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems.*

Event Reports

Storage:	35 quarter-second events or 24 half-second events
Maximum Duration:	Five records of 24 seconds each of 4000 samples/second

Event Summary

Storage:	100 summaries

Breaker History

Storage:	128 histories

Sequential Events Recorder (SER)

Storage:	1000 entries
Trigger Elements:	250 relay elements
Resolution:	0.5 ms for contact inputs 1/8 cycle for all elements

Processing Specifications

AC Voltage and Current Inputs

8000 samples per second, 3 dB low-pass analog filter cut-off frequency of 3000 Hz.

Digital Filtering

Full-cycle cosine and half-cycle Fourier filters after low-pass analog and digital filtering.

Protection and Control Processing

8 times per power system cycle.
Reclosing logic runs once per power system cycle.

Control Points

64 remote bits
64 local control bits
32 latch bits in protection logic
32 latch bits in automation logic

Relay Element Pickup Ranges and Accuracies

Mho Phase Distance Elements

Zones 1–5 Impedance Reach

  Setting Range

    5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps

    1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

  Sensitivity

    5 A Model: 0.5 A_{P-P} secondary

    1 A Model: 0.1 A_{P-P} secondary
(Minimum sensitivity is controlled by the pickup of the supervising phase-to-phase overcurrent elements for each zone.)

  Accuracy (Steady State): ± 3% of setting at line angle for SIR (source-to-line impedance ratio) <30 ±5% of setting at line angle for 30 ≤ SIR≤ 60

  Zone 1 Transient Overreach: <5% of setting plus steady-state accuracy

  Operating Time: See *Figure 5*.

Quadrilateral Phase Distance Elements

Zones 1–5 Impedance Reach

  Quadrilateral Reactance Reach

    5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps

    1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

  Quadrilateral Resistance Reach

    Zones 1, 2, and 3

      5 A Model: OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps

      1 A Model: OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps

    Zones 4 and 5

      5 A Model: OFF, 0.05 to 150 Ω secondary, 0.01 Ω steps

      1 A Model: OFF, 0.25 to 750 Ω secondary, 0.01 Ω steps

  Sensitivity

    5 A Model: 0.5 A secondary

    1 A Model: 0.1 A secondary

  Accuracy (Steady State): ±3% of setting at line angle for SIR < 30 ±5% of setting at line angle for 30 ≤ SIR≤ 60

  Transient Overreach: <5% of setting *plus* steady-state accuracy

  Operating Time: See *Figure 5*.

Mho Ground Distance Elements

Zones 1–5 Impedance Reach

  Mho Element Reach

    5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps

    1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

  Sensitivity

    5 A Model: 0.5 A secondary

    1 A Model: 0.1 A secondary
(Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)

  Accuracy (Steady State): ±3% of setting at line angle for SIR <30 ±5% of setting at line angle for 30 ≤ SIR≤ 60

  Zone 1 Transient Overreach: <5% of setting *plus* steady-state accuracy

  Operating Time: See *Figure 5*.

Quadrilateral Ground Distance Elements

Zones 1–5 Impedance Reach

  Quadrilateral Reactance Reach

    5 A Model: OFF, 0.05 to 64 Ω secondary, 0.01 Ω steps

    1 A Model: OFF, 0.25 to 320 Ω secondary, 0.01 Ω steps

  Quadrilateral Resistance Reach

    Zones 1, 2, and 3

      5 A Model: OFF, 0.05 to 50 Ω secondary, 0.01 Ω steps

      1 A Model: OFF, 0.25 to 250 Ω secondary, 0.01 Ω steps

    Zones 4 and 5

      5 A Model: OFF, 0.05 to 150 Ω secondary, 0.01 Ω steps

      1 A Model: OFF, 0.25 to 750 Ω secondary, 0.01 Ω steps

  Sensitivity

    5 A Model: 0.5 A secondary

    1 A Model: 0.1 A secondary
(Minimum sensitivity is controlled by the pickup of the supervising phase and residual overcurrent elements for each zone.)

  Accuracy (Steady State): ±3% of setting at line angle for SIR <30 ±5% of setting at line angle for 30 ≤ SIR≤ 60

  Transient Overreach: <5% of setting plus steady-state accuracy

  Operating Time: See *Figure 5*.

Instantaneous/Definite-Time Overcurrent Elements

Phase, Residual Ground, and Negative-Sequence

  Pickup Range

    5 A Model: OFF, 0.25–100.00 A secondary, 0.01 A steps

    1 A Model: OFF, 0.05–20.00 A secondary, 0.01 A steps

  Accuracy (Steady State)

    5 A Model: ±0.05 A plus ±3% of setting

    1 A Model: ±0.01 A plus ±3% of setting

  Transient Overreach: <5% of pickup

  Time Delay: 0.00–16000.00 cycles, 0.125 cycle steps

  Timer Accuracy: ±0.125 cycle plus ±0.1% of setting

  Maximum Operating Time: 1.5 cycles

High-Speed Directional Overcurrent Elements

Ground and Phase

  Pickup Range

    5 A Model: OFF, 0.25–100 A secondary, 0.01 A steps

    1 A Model: Off, 0.05–20 A secondary, 0.01 A steps

  Transient Overreach: 5% of pickup

  Maximum Operating Time: 0.75 cycles

Time-Overcurrent Elements

  Pickup Range

    5 A Model: 0.25–16.00 A secondary, 0.01 A steps

    1 A Model: 0.05–3.20 A secondary, 0.01 A steps

  Accuracy (Steady State)

    5 A Model: ±0.05 A plus ±3% of setting

    1 A Model: ±0.01 A plus ±3% of setting

  Time-Dial Range

    US: 0.50–15.00, 0.01 steps

    IEC: 0.05–1.00, 0.01 steps

Curve Timing Accuracy: ±1.50 cycles plus ±4% of curve time (for current between 2 and 30 multiples of pickup)

Reset: 1 power cycle or Electromechanical Reset Emulation time

Ground Directional Elements

Neg.-Seq. Directional Impedance Threshold (Z2F, Z2R)

5 A Model: –64 to 64 Ω

1 A Model: –320 to 320 Ω

Zero-Seq. Directional Impedance Threshold (Z0F, Z0R)

5 A Model: –64 to 64 Ω

1 A Model: –320 to 320 Ω

Supervisory Overcurrent Pickup 50FP, 50RP

5 A Model: 0.25 to 5.00 A 3I0 secondary
0.25 to 5.00 A 3I2 secondary

1 A Model: 0.05 to 1.00 A 3I0 secondary
0.05 to 1.00 A 3I2 secondary

Directional Power Elements

Pickup Range

5 A Model: –20000.00 to 20000 VA, 0.01 VA steps

1 A Model: –4000.00 to 4000 VA, 0.01 VA steps

Accuracy (Steady State):   ±5 VA plus ±3% of setting at nominal frequency and voltage

Time-Delay: 0.00–16000.00 cycles, 0.25 cycle steps

Timer Accuracy: ±0.25 cycle plus ±0.1% of setting

Undervoltage and Overvoltage Elements

Pickup Ranges

Phase Elements: 2–300 V secondary, 0.01 V steps

Phase-to-Phase Elements: 4–520.0 V secondary, 0.01 V steps

Accuracy (Steady State):   ±0.5 V plus ±5% of setting

Transient Overreach: <5% of pickup

Underfrequency and Overfrequency Elements

Pickup Range: 40.01–69.99 Hz, 0.01 Hz steps

Accuracy, Steady State Plus Transient: ±0.005 Hz for frequencies between 40.00 and 70.00 Hz

Maximum Pickup/Dropout Time: 3.0 cycles

Time-Delay Range: 0.04–400.0 s, 0.01 s increments

Time-Delay Accuracy: ±0.1% ± 0.0042 s

Pickup Range, Undervoltage Blocking: 20–200 V_{LN} (Wye)

Pickup Accuracy, Undervoltage Blocking: ±2% ± 0.5 V

Optional RTD Elements
(Models Compatible With SEL-2600 RTD Module)

12 RTD Inputs Via SEL-2600 RTD Module and SEL-2800 Fiber-Optic Transceiver

Monitor Ambient or Other Temperatures

PT 100, NI 100, NI 120, and CU 10 RTD-Types Supported, Field Selectable

As long as 500 m Fiber-Optic Cable to SEL-2600 RTD Module

Breaker Failure Instantaneous Overcurrent

Setting Range

5 A Model: 0.50–50.0 A, 0.01 A steps

1 A Model: 0.10–10.0 A, 0.01 A steps

Accuracy

5 A Model: ±0.05 A plus ± 3% of setting

1 A Model: ±0.01 A plus ± 3% of setting

Transient Overreach: <5% of setting

Maximum Pickup Time: 1.5 cycles

Maximum Reset Time: 1 cycle

Timers Setting Range: 0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*)
0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)

Time Delay Accuracy: 0.125 cycle plus ±0.1% of setting

Synchronism-Check Elements

Slip Frequency Pickup Range: 0.005–0.500 Hz, 0.001 Hz steps

Slip Frequency Pickup Accuracy: ±0.0025 Hz plus ±2% of setting

Close Angle Range: 3°–80°, 1° steps

Close Angle Accuracy: ±3°

Load-Encroachment Detection

Setting Range

5 A Model: 0.05–64 Ω secondary, 0.01 Ω steps

1 A Model: 0.25–320 Ω secondary, 0.01 Ω steps

Forward Load Angle: –90° to +90°

Reverse Load Angle: +90° to +270°

Accuracy

Impedance Measurement: ±3%

Angle Measurement: ±2°

Out-of-Step Elements

Blinders (R1) Parallel to the Line Angle

5 A Model: 0.05 to 70 Ω secondary
–0.05 to –70 Ω secondary

1 A Model: 0.25 to 350 Ω secondary
–0.25 to –350 Ω secondary

Blinders (X1) Perpendicular to the Line Angle

5 A Model: 0.05 to 96 Ω secondary
–0.05 to –96 Ω secondary

1 A Model: 0.25 to 480 Ω secondary
–0.25 to –480 Ω secondary

Accuracy (Steady State):   ±3% of setting for SIR < 30
±5% of setting for 30 ≤ SIR ≤ 60

Transient Overreach: <5% of setting

Positive-Sequence Overcurrent Supervision

Setting Range

5 A Model: 1.0–100.0 A, 0.01 A steps

1 A Model: 0.2–20.0 A, 0.01 A steps

Accuracy

5 A Model: ±3% of setting plus ±0.05 A

1 A Model: ±3% of setting plus ±0.01 A

Transient Overreach: <5% of setting

Bay Control

Breakers: 2 (control), 3rd indication

Disconnects (Isolators):   10 (maximum)

Timers Setting Range: 1–99999 cycles, 1-cycle steps

Time-Delay Accuracy: ±0.1% of setting, ±0.125 cycle

Timer Specifications

Setting Ranges

Breaker Failure: 0–6000 cycles, 0.125 cycle steps (All but BFIDO*n*, BFISP*n*)
0–1000 cycles, 0.125 cycle steps (BFIDO*n*, BFISP*n*)

Communications-
Assisted Tripping Schemes: 0.000–16000 cycles, 0.125 cycle steps

Out-of-Step Timers

  OSBD, OSTD: 0.500–8000 cycles, 0.125 cycle steps

  UBD: 0.500–120 cycles, 0.125 cycle steps

Pole-Open Timer: 0.000–60 cycles, 0.125 cycle steps

Recloser: 1–99999 cycles, 1 cycle steps

Switch-Onto-Fault

  CLOEND, 52AEND: OFF, 0.000–16000 cycles, 0.125 cycle steps

  SOTFD: 0.50–16000 cycles, 0.125 cycle steps

Synchronism-Check Timers

  TCLSBK1, TCLSBK2: 1.00–30.00 cycles, 0.25 cycle steps

Zone Time Delay: 0.000–16000 cycles, 0.125 cycle steps

Station DC Battery System Monitor Specifications

Rated Voltage: 24–250 Vdc

Operational Voltage Range: 0–300 Vdc

Sampling Rate: DC1: 2 kHz
DC2: 1 kHz

Processing Rate: 1/8 cycle

Operating Time: Less than 1.5 cycles (all elements except ac ripple)
Less than 1.5 seconds (ac ripple element)

Setting Range

  15–300 Vdc, 1 Vdc steps (all elements except ac ripple)

  1–300 Vac, 1 Vac steps (ac ripple element)

Accuracy

  Pickup Accuracy: $\pm3\% \pm 2$ Vdc (all elements except ac ripple)
$\pm10\% \pm 2$ Vac (ac ripple element)

Metering Accuracy

All metering accuracy is at 20°C, and nominal frequency unless otherwise noted.

Currents

Phase Current Magnitude

  5 A Model: $\pm0.2\%$ plus ± 4 mA (2.5–15 A sec)

  1 A Model: $\pm0.2\%$ plus ± 0.8 mA (0.5–3 A sec)

Phase Current Angle

  All Models: $\pm0.2°$ in the current range $0.5 \cdot I_{NOM}$ to $3.0 \cdot I_{NOM}$

Sequence Currents Magnitude

  5 A Model: $\pm0.3\%$ plus ± 4 mA (2.5–15 A sec)

  1 A Model: $\pm0.3\%$ plus ± 0.8 mA (0.5–3 A sec)

Sequence Current Angle

  All Models: $\pm 0.3°$ in the current range $0.5 \cdot I_{NOM}$ to $3.0 \cdot I_{NOM}$

Voltages

Phase and Phase-to-Phase
Voltage Magnitude: $\pm 0.1\%$ (33.5–300 V_{L-N})

Phase and Phase-to-Phase
Angle: $\pm0.5°$ (33.5–300 V_{L-N})

Sequence Voltage
Magnitude: $\pm0.1\%$ (33.5–300 V_{L-N})

Sequence Voltage Angle: $\pm0.5°$ (33.5–300 V_{L-N})

Frequency (Input 40–65 Hz)

Accuracy: ±0.01 Hz

Power

MW (P), Per Phase (Wye), 3φ (Wye or Delta) Per Terminal

$\pm1\%$ (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
$\pm0.7\%$ (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)

MVA (S), Per Phase (Wye), 3φ (Wye or Delta) Per Terminal

$\pm1\%$ (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
$\pm0.7\%$ (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)

PF, Per Phase (Wye), 3φ (Wye or Delta) Per Terminal

$\pm1\%$ (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
$\pm0.7\%$ (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)

Energy

MWh (P), Per Phase (Wye), 3φ (Wye or Delta)

$\pm1\%$ (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (1φ)
$\pm0.7\%$ (0.1–1.2) • I_{NOM}, 33.5–300 Vac, PF = 1, 0.5 lead, lag (3φ)

Synchrophasors

Number of Synchrophasor
Data Streams: 5

Number of Synchrophasors
for Each Stream: 15 phase synchrophasors
(6 voltage and 9 currents)
5 positive-sequence synchrophasors
(2 voltage and 3 currents)

Number of User Analogs
for Each Stream: 16 (any analog quantity)

Number of User Digitals for
Each Stream: 64 (any Relay Word bit)

Synchrophasor Protocol: IEEE C37.118-2005,
SEL Fast Message (Legacy)

Synchrophasor Data Rate: As many as 60 messages per second

Synchrophasor Accuracy:

  Voltage Accuracy: $\pm1\%$ Total Vector Error (TVE)
Range 30–150 V, f_{NOM} ±5 Hz

  Current Accuracy: $\pm1\%$ Total Vector Error (TVE)
Range (0.1–20) • I_{NOM} A, f_{NOM} ±5 Hz

Synchrophasor Data
Recording: Records as much as 120 s
IEEE C37.232-2011 File Naming
Convention

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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