

# SEL-411L

Advanced Line Differential Protection, Automation, and Control System

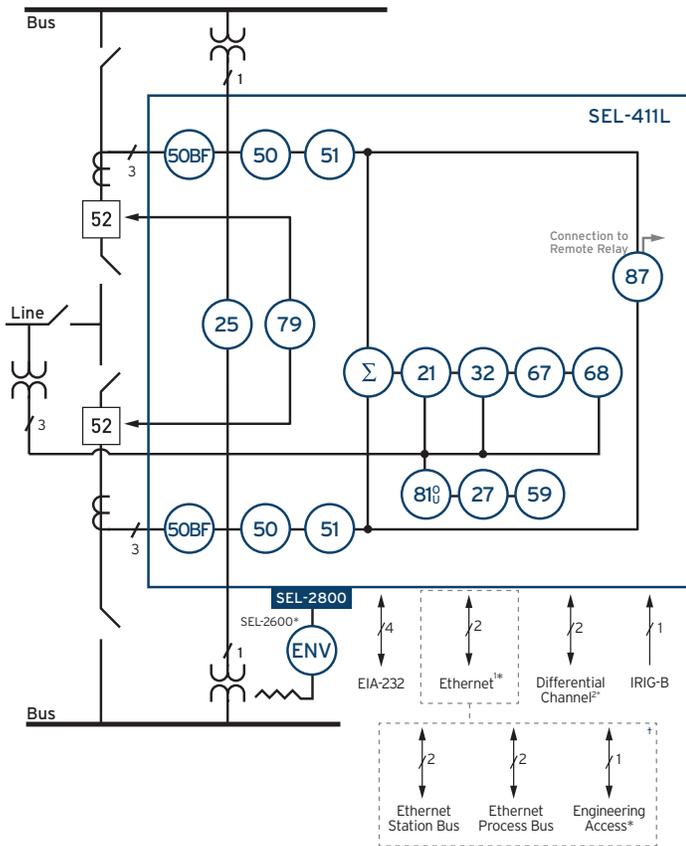


## Combine subcycle line protection with traveling-wave fault locating

- Minimize damage and repairs on transmission lines with subcycle differential and distance protection.
- Reduce the time and effort to find faults when dispatching line crews based on traveling-wave fault locating, accurate to within one tower span.
- Use comprehensive communications protocols and advanced automation functions to allow customization for different applications.
- Transform the way you modernize your substation with SEL Time-Domain Link (TiDL®) and Sampled Values (SV) technologies.



# Functional Overview



## ANSI Numbers/Acronyms and Functions

21	Phase and Ground Distance
25	Synchronism Check
27	Undervoltage
32	Directional Power
50	Overcurrent
50BF	Dual Breaker Failure Overcurrent
51	Time Overcurrent
59	Overvoltage
67	Directional Overcurrent
68	Out-of-Step Block/Trip
79	Single-/Three-Pole Reclosing
81 (O,U)	Over-/Underfrequency
87	Current Differential

## Additional Functions

85 RIO	SEL MIRRORRED BITS <sup>®</sup> Communications
BCD	Broken Conductor Detection
BRM	Breaker Wear Monitor
DFR	Event Reports
ENV	SEL-2600 RTD Module*
HMI	Operator Interface
LDE	Load Encroachment
LGC	Expanded SELogic <sup>®</sup> Control Equations
FL	Fault Locator (Impedance, Traveling-Wave*)
MET	High-Accuracy Metering
PMU	Synchrophasors
SBM	Station Battery Monitor
SER	Sequential Events Recorder
SIP	Software-Invertible Polarities
SV	IEC 61850-9-2 Samples Valued Technology* <sup>†</sup>
THM	IEC 60255-Compliant Thermal Model
TiDL	Time-Domain Link Technology* <sup>†</sup>

<sup>1</sup>Copper or fiber-optic    <sup>2</sup>Serial or Ethernet    \*Optional feature

<sup>†</sup>TiDL and SV relays receive current and voltage values from remote merging units.

# Key Features

## Line Current Differential, Distance, and Directional Overcurrent Protection

Apply subcycle single- or three-pole line protection for up to four terminal lines, even with two breakers per terminal, using the SEL-411L Advanced Line Differential Protection, Automation, and Control System. The 87L function allows protection for transmission lines with up to four terminals. Five zones of phase and ground distance elements provide subcycle operation and superior security. 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 like POTT, DCB, and DCUB or for instantaneous or time-step backup protection. Meet specific application needs while reducing protection system costs by stocking one line protective relay that uses a combination of differential, distance, and overcurrent elements.

## Fault Locating

Find faults fast with traveling-wave fault locating in the SEL-411L-1, and reduce maintenance expenses by sending crews directly to the tower nearest to the fault. At the same time, ensure dependability with single- and multi-ended impedance-based fault-locating methods.

## Broken Conductor Detection

Detect conductor breaks in subtransmission or transmission overhead lines using the broken conductor detection function. This function can prevent a shunt fault that could occur from a falling conductor and blocks the autoreclose attempts on to a permanent fault. It also provides location of the conductor break to aid in restoring the power line.

## Automation and Communication

Improve station integration and reduce costs with the free-form SELogic editor in the SEL-411L. Custom SELogic control equations offer the flexibility to tailor the relay to your particular application. Program control equations for each control output based on data received from primary equipment or other devices, and use communications protocols to send status and control signals to other protection system devices using serial or Ethernet protocols. Integrate the SEL-411L into a larger system using communication protocols, including the following:

- MIRRORED BITS communications
- DNP3 LAN/WAN
- IEC 61850 Edition 2.1
- Parallel Redundancy Protocol (PRP)
- IEEE 1588 Precision Time Protocol Version 2 (PTPv2)
- Simple Network Time Protocol (SNTP)

## Digital Secondary System Technologies

Modernize your substation by applying SEL TiDL technology or SEL SV technology, both digital secondary system solutions. Replace copper wires with fiber-optic cables to increase safety, reduce costs associated with using copper wires, and limit the impact of electromagnetic interference.

TiDL is a simple and secure point-to-point solution that is easy to implement, with no external time source or network engineering required. SEL-TMU TiDL Merging Units placed in the yard digitize signals and transmit them over fiber-optic cables to the SEL-411L-2 TiDL relay in the control house.

SEL SV technology combines protection in the merging unit with the flexibility of Ethernet networking and IEC 61850 compliance. SEL SV merging units (or other IEC 61850-9-2 SV-compliant units) digitize signals and transmit them via Ethernet over fiber-optic cables to an SEL-411L-2 SV relay in the control house.

# Product Overview—SEL-411L

EIA-232 front serial port is quick and convenient for system setup and local access.

Front-panel display allows operators to control and view the status of disconnects and breakers.

24 programmable target LEDs with user-configurable labels alert operators in the substation to faulted phases, the relay's status, and element operation.

Programmable operator pushbuttons with user-configurable labels allow front-panel customization.



User-selectable mimic screens show the system configuration in one-line diagram format.

Easy-to-use keypad aids simple navigation.

Choose from a vertical or horizontal, panel-mount or rack-mount chassis and different size options.

Three EIA-232 serial ports for MIRRORING BITS communications, SCADA, and engineering access provide flexibility to communicate with other devices and control systems. The ports include demodulated IRIG-B for precise-time input.

Choose either fiber or copper connections for one or two 87L communications channels.

Communications protocols include FTP, Telnet, synchrophasors, DNP3 LAN/WAN, PRP, IEEE 1588 PTPv2,\*\* and IEC 61850 Edition 2.1.\*



Six current and six voltage analog inputs support protection for substations with dual-breaker schemes.

The power supply allows different options: 24–48 Vdc; 48–125 Vdc or 110–120 Vac; or 125–250 Vdc or 120–240 Vac.

\*Optional feature

\*\*A five-port Ethernet communications card option (shown) supports PTPv2 on Ports 5A, 5B, 5C, and 5D. A four-port Ethernet communications card option supports PTPv2 on 5A and 5B.

# Applications

## High-Speed Differential Protection on Up to Four Terminals

The SEL-411L provides subcycle single- or three-pole line current differential protection along with reliable backup distance protection for your transmission lines. The patented generalized Alpha Plane technology combined with overcurrent supervision, external fault detection, optional charging current compensation, and disturbance detection logic enables the 87L function to operate with exceptional security and sensitivity. The SEL-411L supports data exchange over a serial network or a dedicated Ethernet network to provide line current differential protection for transmission lines with as many as four terminals, even with two breakers per terminal.

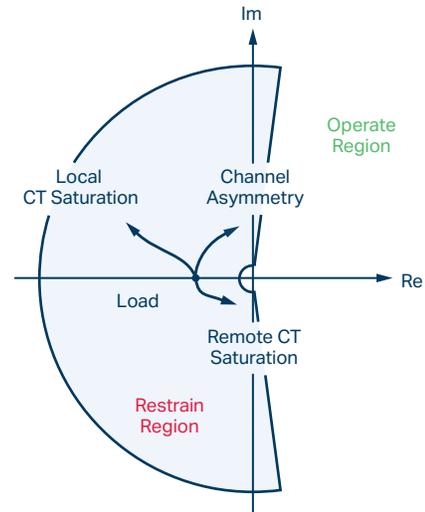
## Flexible 87L Data Channel Selection for Common Communications Configurations

Choose the 87L communications channel option that fits your application needs. Distance limitations may apply to fiber-optic communications. Please see the product documentation for specific limits. Options include:

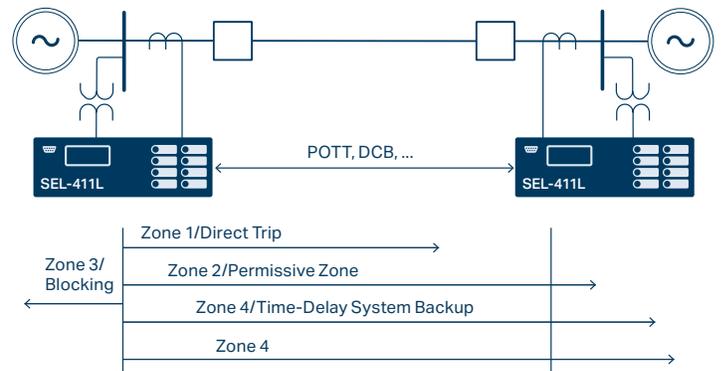
- Isolated EIA-422
- Isolated ITU-T G.703
- 850 nm or 1,300 nm fiber, IEEE C37.94 encoding
- 1,300 nm single-mode or multimode fiber
- 1,550 nm single-mode fiber
- Ethernet (10/100BASE-T, 100BASE-FX, or 100/1000BASE SFP connections)

## Five Forward and Reverse Zones for Reliable Distance Protection

The SEL-411L has reliable distance protection with five zones of phase and ground (mho and quadrilateral) distance elements. The coupling capacitor voltage transformer (CCVT) transient overreach logic optimizes performance and enhances Zone 1 distance element security. The Best Choice Ground Directional Element<sup>®</sup> selects the best element to use (32I, 32Q, or 32V) to supervise the distance elements for ground faults without user settings. In addition, with full pilot scheme settings, it is easy to integrate the SEL-411L into your existing distance protection schemes. Choose from POTT, DCUB, PUTT, DCB, and DTT schemes.



Accommodate channel asymmetry and CT saturation with Alpha Plane restrain and operate regions.



# Device Functions

## Out-of-Step Blocking and Tripping

During power swings, the relay automatically selects either out-of-step blocking or tripping. Out-of-step blocking enhances your security by blocking distance elements during stable swing conditions. During unstable power swing conditions, out-of-step tripping maintains generation load balance. The SEL-411L provides both conventional out-of-step logic using dual blinders and zero-setting out-of-step logic that simplifies implementation.

## Line-Charging Current Compensation

Built-in charging compensation improves the sensitivity and speed of differential protection for long extra-high-voltage lines or cables. The SEL-411L uses an adaptive algorithm based on voltages measured in the differential scheme to provide accurate compensation. In the event of a loss-of-potential condition, the relay uses automatic fallback logic to keep the differential scheme secure.

## Series Compensation Line Logic

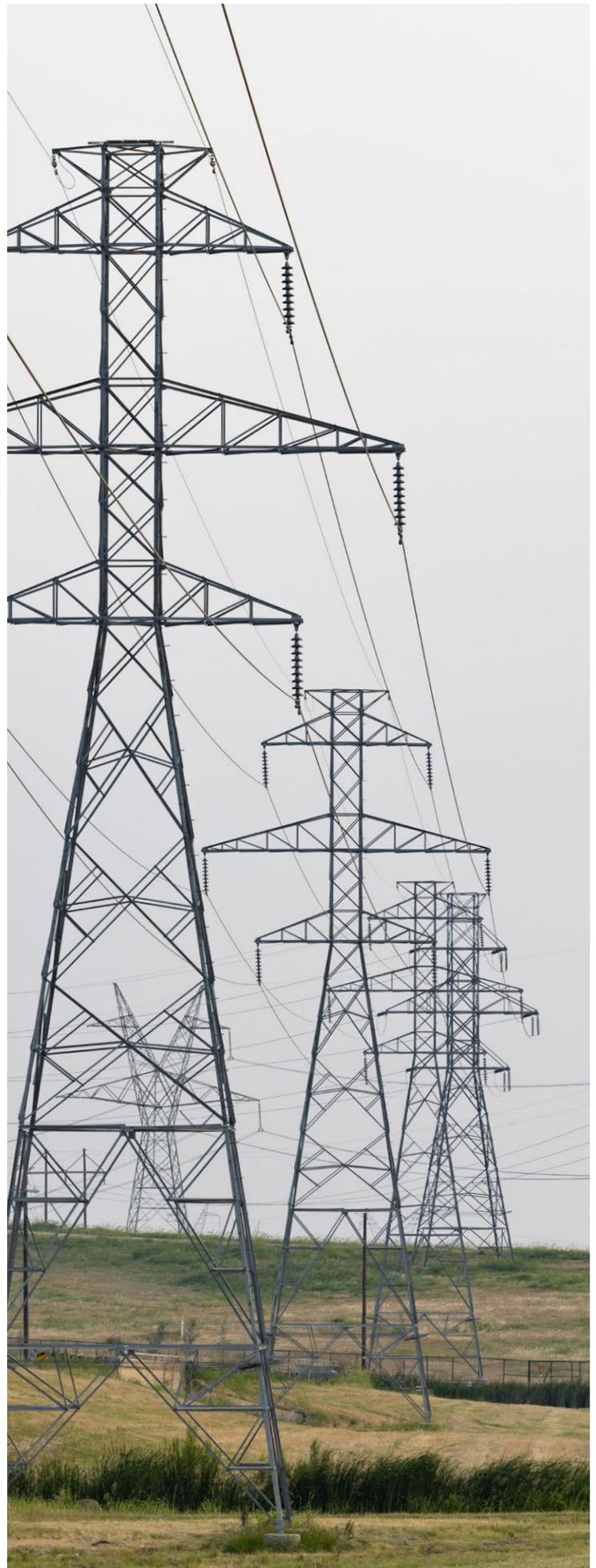
The optional series compensation logic detects when a fault is beyond a series capacitor and prevents Zone 1 overreach on series-compensated lines. This provides secure protection for your power system, resulting in higher power transfers and reliable service to customers.

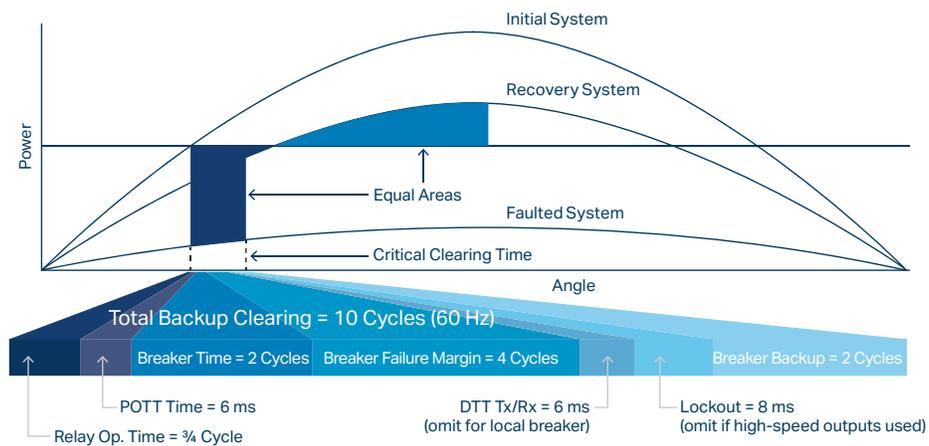
## Compensation for In-Line Transformers

By providing complete protection for the combined line and transformer, the SEL-411L simplifies protection schemes and reduces equipment costs. The relay compensates for vector group, ratio, and zero-sequence current to protect transmission lines with in-line transformer applications. You can use harmonic blocking, restraint, or both for stabilization under magnetizing inrush conditions.

## Bay Control, Reclosing, and Breaker Failure Detection

Increase flexibility for different station configurations with complete bay control, reclosing, and breaker failure protection. For double-breaker arrangements, the SEL-411L monitors the current for each breaker. The relay can also monitor the circuit breaker performance, including average and last tripping times, motor run times, and contact interrupting duty.



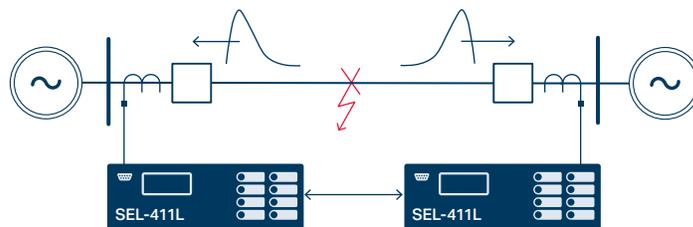


### Open-Phase Pole Detection Logic

The SEL-411L provides high-speed breaker failure protection by applying fast open-phase detection logic. This logic detects an open phase in less than one cycle, leading to shorter breaker failure margin times. By combining high-speed tripping with shorter breaker failure margin times, the relay helps improve the power transfer capability while maintaining stability.

### Thermal Overload Protection

Use the three independent IEC 60255-149 thermal elements to activate a control action, issue an alarm, or trip when the conductor temperature is high as a result of adverse operating conditions. The optional SEL-2600 RTD Module can provide ambient temperature measurements.



### Traveling-Wave Fault Locating

Traveling-wave fault locating provides greater accuracy and lets you send your line crew to the nearest tower or span to quickly address the problem. Using GPS clocks and the 87L communications channel already in your system, the relay automatically calculates the fault location using the double-ended method. In systems without a communications channel, use the traveling-wave event data to calculate an accurate fault location by hand or with SEL-5601-2 SYNCHROWAVE<sup>®</sup> Event Software. Traveling-wave fault locating is the best method for series-compensated and parallel transmission line configurations. You will get precise results regardless of the line configuration or fault impedance.

## Broken Conductor Detection

Detect broken conductors on 33 kV or greater overhead lines. The broken conductor detection function in the SEL-411L uses line-charging current magnitudes to reliably identify conductor breaks in lines before they convert into shunt faults. The detection function identifies complete breaks on a single conductor. The detection logic can be configured to alarm or to issue a trip command to the breaker when a broken conductor condition is detected.



SEL-5078-2 SYNCHROWAVE Central Software provides visualization and analysis of power system operating conditions.

## Synchrophasor Monitoring and Recording

To significantly improve your system's performance, SEL offers complete synchrophasor solutions, including hardware, communications, viewing and analysis software, data collection, and data archiving. The SEL-411L provides real-time system state measurement with time-synchronized voltages and currents in the IEEE C37.118-2011 standard format. In addition, SEL-5078-2 SYNCHROWAVE Central Software or third-party software allows you to view and analyze system phase angles, load oscillations, voltage profiles, and other critical system information.

# SEL TiDL Process Bus Solutions

SEL Time-Domain Link (TiDL) technology is a protection-centered digital secondary system solution engineered with simplicity in mind. This technology minimizes cybersecurity risks and network engineering by using point-to-point communications and a nonroutable protocol. A TiDL-based solution does not require an external time reference.

## Simple Architecture

SEL-TMU devices are placed in the yard close to the primary equipment and digitize discrete I/O signals and analog data, such as voltages and currents. These data are then transported over fiber-optic cables to an SEL-411L-2 TiDL relay in the control house. The point-to-point architecture simplifies implementation and drives overall maintenance and maintenance costs down.

## Data-Sharing Capabilities

Each SEL-TMU can be paired with up to four SEL-400 series TiDL relays. This data-sharing capability allows design flexibility, and point-to-point connections simplify system expansion.

## Built-In Data Synchronization

TiDL relays measure the path delay between the relay and the merging unit on each connected port to align current and voltage measurements acquired from different merging units. This eliminates the need for external time sources, such as GPS clocks, for synchronization. All data from the SEL-TMU devices are synchronized with each other regardless of the number of units connected to the SEL-411L-2 relay or the length of the fiber.

## Strong Cybersecurity Posture

The dedicated, deterministic TiDL system helps secure mission-critical systems. The isolated point-to-point connections and the absence of switches and routers reduce the electronic security perimeter and limit attack points. This security-minded architecture prevents remote access, and its simplicity eliminates the need for managing port access.

## Minimal Training Required

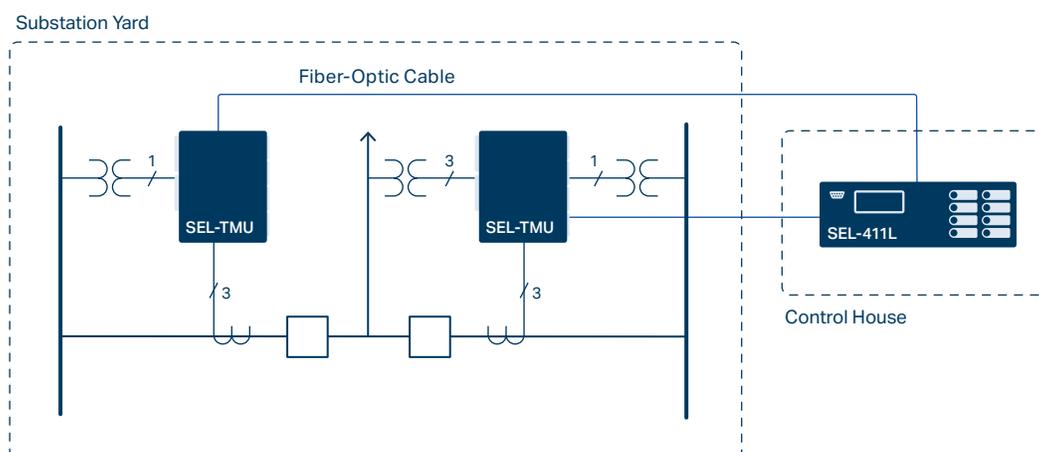
The relay settings for the SEL-411L-2 TiDL relay are the same as those in all popular SEL-400 series models, providing consistency and simplicity. You can use the same protection schemes and applications for complete line protection.

## Flexible Communications Options

The SEL-411L can be configured with a five-port Ethernet card supporting PRP or failover functionality to increase system availability. Use PTPv2 on process bus or station bus ports to provide time synchronization.

This card also features dedicated ports and IP addresses for station bus and engineering access networks to provide selective access control.

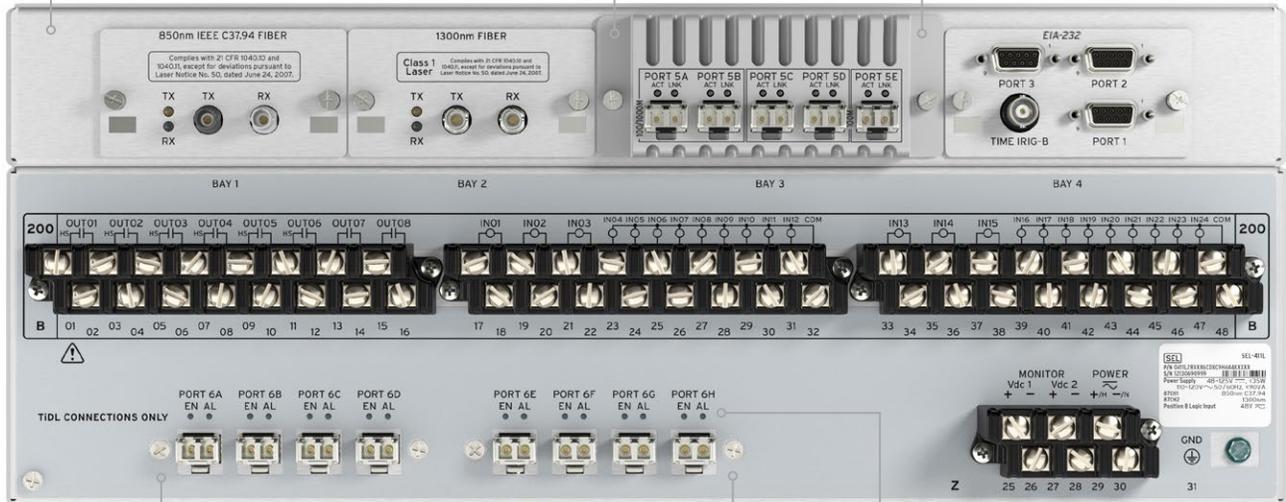
Use small form-factor pluggable (SFP) transceivers on process bus, station bus, and engineering access ports. Single- and multimode communications options provide increased flexibility.



# SEL-411L-2 With TiDL Technology

4U chassis with horizontal mounting options (panel or rack) accommodates your application needs.

Select a five-port Ethernet card for dedicated station bus and engineering access ports.



Eight SFP ports allow the TiDL relay to connect with eight remote SEL-TMU devices and to receive remote analog and digital data.

LEDs for viewing the connection status to an SEL-TMU on a per-port basis.

# SEL SV-Based Process Bus Solutions

SEL Sampled Values (SV)-based solutions are communications-centric, network-based solutions that combine protection in the merging unit with the flexibility of IEC 61850-9-2.

## Networked Architecture

The SEL-411L-2 SV relay (subscriber) in the control house receives digital analog signals from SV merging units (publishers) in the yard via a fiber-based Ethernet network. SEL SV-based solutions allow you to create a flexible Ethernet-based network using tools such as software-defined networks or VLANs. You can use SEL software-defined networking (SDN) switches to provide centralized traffic engineering and improve Ethernet performance. SEL SDN switches act as transparent PTP clocks that support the IEEE C37.238-2011 power system profile, ensuring submicrosecond time synchronization of the end devices.

## Merging Units With Built-In Protection

Some SEL relays can be used as SV merging units. Apply the SEL-401 Protection, Automation, and Control Merging Unit for overcurrent and breaker failure protection and the SEL-421 Protection, Automation, and Control Merging Unit for complete line protection, including five zones of subcycle mho and quadrilateral distance elements. If IEC 61850 network communications are lost, the SEL merging units provide backup standalone protection.

## Interoperability

SEL-411L-2 SV relays and other SEL SV devices are implemented with IEC 61850-9-2 based on the UCA 61850-9-2LE guideline. You can use them with primary equipment that generates SV streams or with other manufacturers' SV units.

## Advanced Network Monitoring and Diagnostic Tools

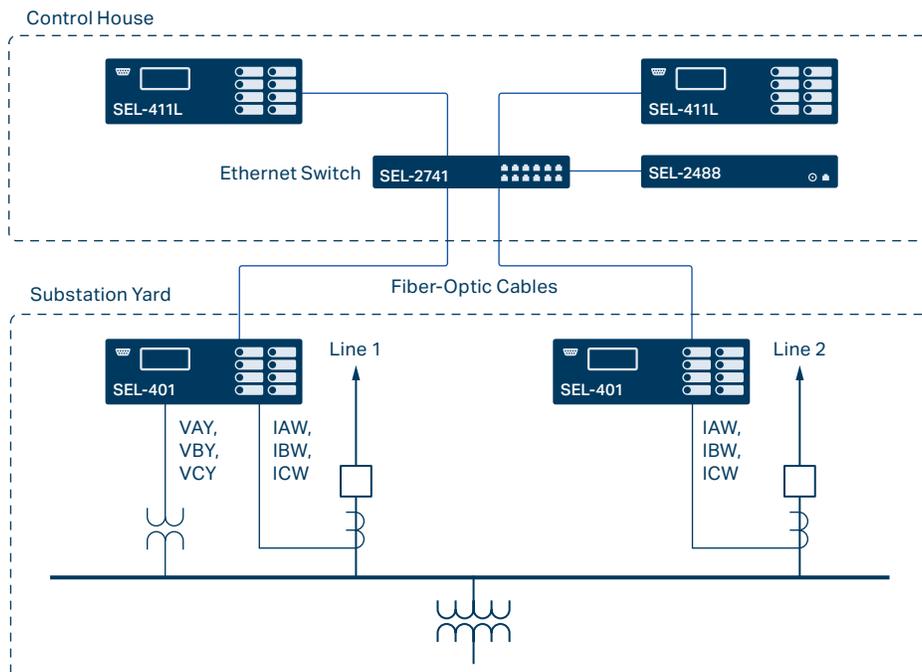
The SEL-411L-2 SV relay provides advanced network monitoring and diagnostic tools through standard IEC 61850 logical nodes. Additional diagnostic information and statistics are available through COM SV, GOO, ETH, and COM PRP commands, which aid in troubleshooting. The TEST SV command allows you to check the network connectivity as well as the CT and PT ratios between publisher and subscriber devices.

## Flexible Communications Options

The SEL-411L can be configured with a five-port Ethernet card supporting PRP or failover functionality to increase system availability. Use PTPv2 on process bus or station bus ports to provide time synchronization.

This card also features dedicated ports and IP addresses for station bus and engineering access networks to provide selective access control.

Use SFP transceivers on process bus, station bus, and engineering access ports. Single- and multimode communications options provide increased flexibility. All ports support 100 Mbps SFPs, and process bus ports also support 1 Gbps SFPs.



# SEL-411L-2 With SV Technology

Select a five-port Ethernet card for dedicated process bus, station bus, and engineering access ports.

Choose either fiber or copper connections for one or two 87L communications channels.

Choose an SFP transceiver to match application requirements. Process bus ports support 100 Mbps and 1 Gbps connections. Station bus and engineering access support 100 Mbps connections. Select single- or multimode fiber.

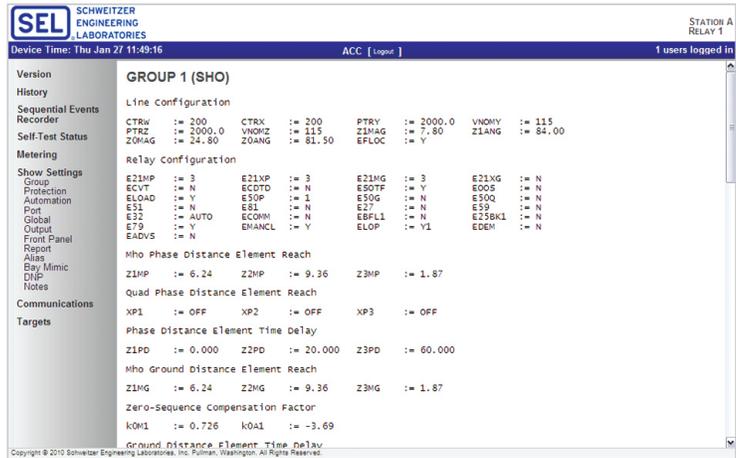


4U chassis with horizontal mounting options (panel or rack) accommodates your application needs.

# Accessibility and Communications

## Built-In Web Server

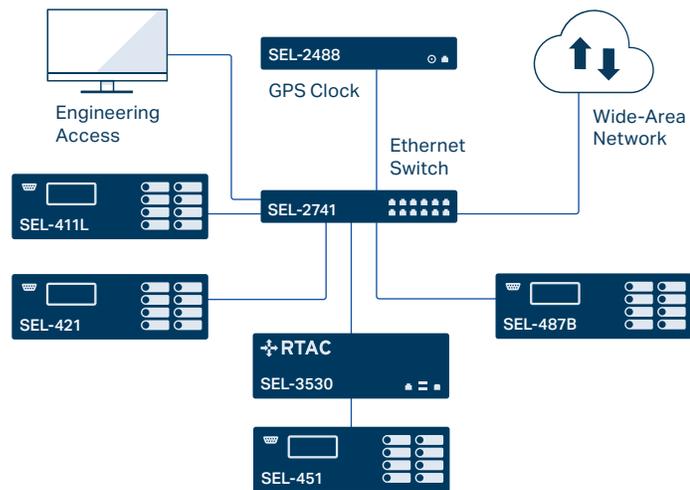
Use the optional Ethernet card to access basic SEL-411L information on a standard Ethernet network with the built-in web server. View the relay status, Sequential Events Recorder (SER) data, metering information, and settings. For increased security, obtaining web server access requires a relay password and the information is limited to a read-only view.



A built-in web server provides easy access to settings, relay status, metering, and event data.

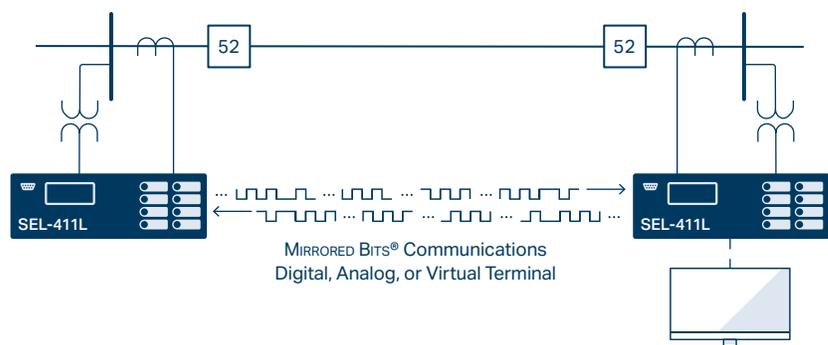
## Ethernet-Based Communications

An Ethernet communications card enables you to communicate using a variety of protocols, including FTP, HTTP, DNP3, PTPv2, PRP, Telnet, synchrophasors, and IEC 61850 Edition 2.1. Select between copper, fiber, or a combination of port types.



## MIRRORED BITS Communications

This field-proven technology provides simple and powerful bidirectional digital communications between devices. MIRRORED BITS communications can transmit/receive information between upstream relays and downstream recloser controls to enhance coordination and generate faster tripping for downstream faults.

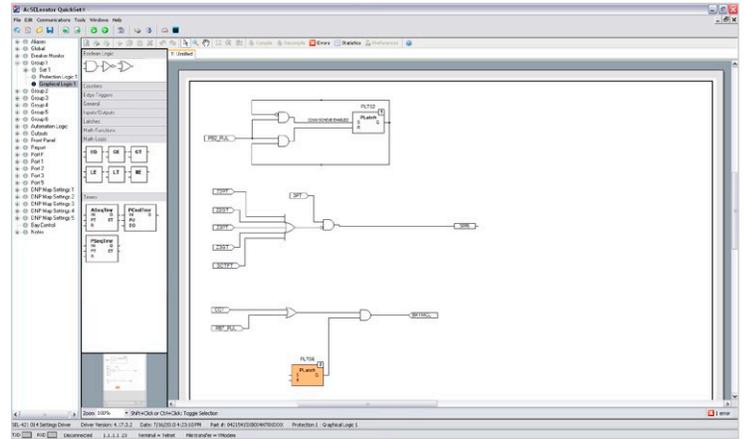


# Setting and Commissioning Software

## Graphical Logic Editor (GLE)

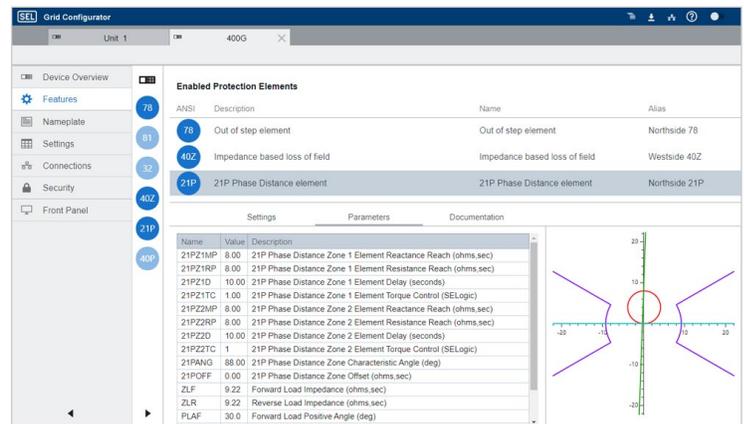
ACSELERATOR QuickSet® SEL-5030 Software allows engineers and technicians to quickly create, manage, and deploy settings for SEL power system devices. With the GLE, you can view SELogic control equations graphically and document settings files for easier validation and commissioning. You can also convert existing SELogic control equations to easy-to-read diagrams and save diagrams with QuickSet settings.

The GLE capability in QuickSet makes it easy to design new SELogic control equations with the convenient diagram navigation tool, drag-and-drop interface, function block diagrams, and automatic layout function. You can manage your control diagrams with a full element palette. The GLE aids in reducing design errors and reducing the time and expense of commissioning relays.



## Configuration Software

Included only with the TiDL and SV relays, SEL Grid Configurator is a software tool that allows engineers and technicians to quickly create, manage, and deploy settings for SEL power system devices. It features a modern interface designed for ease of use, with powerful protection visualization and comprehensive reporting to reduce device deployment complexity.



# SEL-411L Specifications

General			
<b>AC Current Inputs</b> (6 total)	5 A nominal 1 A nominal	<b>TiDL Ports</b>	Fiber-optic ports: 8 Range: ~2 km Data rate: 100 Mbps Protocol: SEL T-Protocol
<b>AC Voltage Inputs</b> (6 total)	0–300 V <sub>L-N</sub> operational	<b>SV Ports</b>	Subscriber: As many as 7 SV data streams Data rate: 4.8 kHz for 60 Hz system, 4 kHz for 50 Hz system Protocol: IEC 61850-9-2
<b>Communications Protocols</b>	FTP, Telnet, SEL ASCII, SEL Fast Message, synchrophasors, DNP3, PRP, PTPv2, and IEC 61850 Edition 2.1 (Reference rear render for PTP implementation requirements.)	<b>Precise-Time Input</b>	Demodulated IRIG-B time input and PTPv2
<b>Traveling-Wave Fault Locating</b> (SEL-411L-1 only)	Type: Double-ended method Accuracy: ±25 m for step change in current applied simultaneously to both relays	<b>Processing</b>	AC voltage and current inputs: 8,000 samples per second Protection and control processing: 8 times per power system cycle
<b>Communications Ports</b>	<b>Serial Ports</b> One front-panel and three rear-panel EIA-232 serial ports 300–57,600 bps <b>Four-Port Ethernet Card</b> Four 10/100BASE-T twisted-pair network ports, or Four 100BASE-FX fiber-optic network ports, or Two 10/100BASE-T twisted-pair network ports and two 100BASE-FX fiber-optic network ports <b>Five-Port Ethernet Card</b> Two 100/1000BASE SFP ports Three 100BASE SFP ports	<b>Power Supply</b>	24–48 Vdc 48–125 Vdc or 110–120 Vac 125–250 Vdc or 120–240 Vac
		<b>Operating Temperature</b>	–40° to +85°C (–40° to +185°F)

## SCHWEITZER ENGINEERING LABORATORIES

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