SEL-411L
Advanced Line Differential Protection, Automation, and Control System

Combine subcycle line protection with traveling-wave fault locating

• Subcycle differential and distance protection minimizes damage and expensive repairs on transmission lines.
• Traveling-wave fault locating pinpoints faults within one tower span.
• Comprehensive communications protocols and advanced automation functions 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
- **85 RIO**: SEL MIRRORED BITS® Communications
- **87**: Current Differential
- **DFR**: Event Reports
- **ENV**: SEL-2600 RTD Module
- **HMI**: Operator Interface
- **LGC**: Expanded SELOGIC® Control Equations
- **MET**: High-Accuracy Metering
- **PMU**: Synchrophasors
- **SER**: Sequential Events Recorder

**Additional Functions**

- **BRM**: Breaker Wear Monitor
- **LDE**: Load Encroachment
- **LOC**: Fault Locator
- **SBM**: Station Battery Monitor
- **SIP**: Software-Invertible Polarities
- **SV**: IEC 61850-9-2 Sampled Values Technology
- **THM**: IEC 60255-Compliant Thermal Model
- **TiDL**: Time-Domain Link Technology

'Copper or Fiber-optic  
'Serial or Ethernet  
'*Optional feature

†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 current differential 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. Five zones of phase and ground distance elements as well as directional overcurrent elements provide subcycle operation and superior security. You can invert individual or grouped CT or PT polarities to account for field wiring or protection zone changes. By stocking one line protection relay that uses a combination of differential, distance, and overcurrent elements, you can meet specific application needs while reducing protection system costs.

Comprehensive Monitoring
Implement advanced 87L channel monitoring functions to validate 87L channel health and enhance trip security. You can also incorporate IEEE C37.118 synchrophasor measurements into wide-area protection and control systems. High-accuracy time correlation improves event report analysis.

High-Accuracy Fault Locating
Find faults fast with optional traveling-wave fault locating in the SEL-411L-1. This reduces maintenance expenses because you can send crews directly to the tower nearest to the fault. You also have the option to implement single- and double-ended impedance-based fault-locating methods in parallel with traveling-wave fault locating.

Advanced Automation and Communication
Reduce total project construction and operation costs by integrating four-shot recloser and relay logic to automate operations. Serial or Ethernet communications improve station integration. You can choose from a variety of available protocols, including:

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

Digital Secondary System Technologies
Modernize your substation by applying SEL TiDL technology or SEL SV technology. Both of these 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 combines protection in the merging unit with the flexibility of IEC 61850-9-2 to increase power system reliability. 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-0/-1 Relay

- 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.
- User-selectable mimic screens show the system configuration in one-line diagram format.
- 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.
- Easy-to-use keypad aids simple navigation.
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.*

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

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

Three EIA-232 serial ports for Mirrored 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.

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

**For PTPv2 implementation, Ports 5A and 5B must be used for engineering access and SCADA.
Applications

Line Current Differential Protection
The SEL-411L provides subcycle single- or three-pole line current differential protection along with reliable backup distance protection for your critical 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
Choose the 87L communications channel option that fits your application needs:

- Isolated EIA-422
- Isolated ITU-T G.703
- 850 nm (2 km limit) or 1,300 nm (15 km limit) fiber, IEEE C37.94 encoding
- 1,300 nm single-mode (80 km limit) or multimode (30 km limit) fiber
- 1,550 nm single-mode fiber (80 km limit)
- Ethernet (10/100BASE-T or 100BASE-FX connections)

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® eliminates the need for multiple 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, DCB, PUTT, DCB, and DTT schemes.

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 SEL-2600 RTD Module can provide ambient temperature measurements.
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.

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 blenders and zero-settings out-of-step logic that simplifies the implementation.

Multiterminal Transmission Lines
Protect transmission lines with up to four terminals, even for breaker-and-a-half bus configurations or other two-breaker schemes with dual CT and PT inputs. The unique fault-locating algorithm uses information from all terminals to identify the faulted branch on multiterminal transmission lines. This allows you to dispatch line crews more efficiently so that line problems are quickly isolated and power is restored to customers faster.

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.

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.
Traveling-Wave Fault Locating
Optional 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. With the GPS clocks and communications channel already in your system, the relay automatically calculates the fault location. Without a communications channel, the relay still measures and records the traveling-wave event. Using the traveling-wave event data, you can calculate an accurate fault location by hand or with SEL-5601-2 SYNCHRO WAVE® 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.

High-Speed Breaker Failure for Two Breakers
The SEL-411L applies fast open-phase detection logic to detect 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.
Synchrophasors
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 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.

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 can monitor the current for each breaker separately or combine the currents for protection purposes. The relay can also monitor the circuit breaker performance, including average and last tripping times, motor run times, and contact interrupting duty.
TiDL Technology

TiDL technology is a protection-centered digital secondary system solution engineered with simplicity in mind. This technology requires no external time source, has strong cybersecurity, and is easy to implement, with no network engineering required.

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. With this point-to-point architecture, implementation is simple and requires zero network engineering.

Data-SharingCapabilities
Each SEL-TMU can be paired with up to four SEL-400 series TiDL relays. This data-sharing capability gives you flexibility on how to best design protection for your system and makes installations more economical by reducing the device count. In addition, the point-to-point connections make expanding easy.

Built-In Time Synchronization
TiDL maintains relative time; therefore, it does not rely on an external time reference for protection. 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.
SEL-411L-2 With TiDL Technology

Eight 100 Mbps fiber-optic ports allow the TiDL relay to connect with eight remote SEL-TMU devices and to receive remote analog and digital data.

LEDs indicate the connection status to an SEL-TMU TiDL Merging Unit on a per-port basis.

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

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

SEL SV technology is a communications-centric, network-based solution that combines 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 digitized analog signals from an SV merging unit (publisher) in the yard via a fiber-based Ethernet network. SEL SV technology allows you to create a flexible Ethernet-based point-to-multipoint network using tools such as software-defined networks or VLANs to fit your application needs. You can use the SEL-2740S Software-Defined Network Switch to provide centralized traffic engineering and improve Ethernet performance. The switch acts as a transparent Precision Time Protocol clock that supports the IEEE C37.238 power system profile, ensuring submicrosecond time synchronization of the end devices.

Merging Units With Built-In Protection
In an SEL SV solution, the SEL-401 Protection, Automation, and Control Merging Unit provides overcurrent and breaker failure protection and the SEL-421 Protection, Automation, and Control Merging Unit provides 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 and the UCA 61850-9-2LE guideline. You can use them with primary equipment that generates SV streams or with other manufacturers’ SV units.

Unique Testing and Troubleshooting Tools
The COM SV command in SEL merging units provides you with information about your SV configuration, including warning and error codes that detail why an SEL-411L-2 SV relay rejected an SV stream, which aids troubleshooting. The TEST SV command allows you to check the network connectivity and the CT and PT ratios between publisher and subscriber devices.
SEL-411L-2 With SV Technology

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

Select fiber-optic, copper, or mixed Ethernet with separate ports for SV data and engineering access.

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

Built-In Web Server
Access basic SEL-411L information on a standard Ethernet network with the built-in web server. From there you can 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.

Ethernet-Based Communications
The Ethernet ports enable you to communicate using a variety of protocols, including FTP, DNP3, MMS, PTPv2, and IEC 61850 Edition 2. By using failover, switched mode, or PRP, you can increase your system’s reliability. For PTPv2 implementation, Ports 5A and 5B must be used for engineering access and SCADA.

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

Simplify the SEL-411L Configuration Process With the Graphical Logic Editor (GLE)

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 your AcSELERator QuickSet® SEL-5030 Software 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.

Next-Generation Configuration Software

Included with the TiDL and SV relays, SEL Grid Configurator is a new 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

<table>
<thead>
<tr>
<th>AC Current Inputs</th>
<th>5 A nominal</th>
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<tbody>
<tr>
<td></td>
<td>1 A nominal</td>
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<tr>
<th>AC Voltage Inputs</th>
<th>300 V&lt;sub&gt;L-N&lt;/sub&gt; continuous</th>
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</table>

| Serial            | 3 rear-panel and 1 front-panel EIA-232 serial ports; SEL ASCII commands, SEL Fast Messages, DNP3, IEEE C37.118 synchrophasors |

| Ethernet          | Communications protocols include FTP, Telnet, synchrophasors, DNP3 LAN/WAN, PRP, PTPv2, and IEC 61850 Edition 2 (optional). For PTPv2 implementation, Ports 5A and 5B must be used for engineering access and SCADA. Choose from the following port options: Four 10/100BASE-T twisted-pair network ports Four 100BASE-FX fiber-optic network ports Two 10/100BASE-T twisted-pair network ports and two 100BASE-FX fiber-optic network ports |

| Traveling-Wave Fault Locating | Type: Double-ended method |
|                               | Accuracy: ±25 m for step change in current applied simultaneously to both relays |

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<tr>
<th>TiDL Ports</th>
<th>Fiber-optic ports: 8</th>
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<tbody>
<tr>
<td></td>
<td>Range: ~2 km</td>
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<tr>
<td></td>
<td>Data rate: 100 Mbps</td>
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<td></td>
<td>Protocol: SEL T-Protocol</td>
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<tr>
<th>SV Ports</th>
<th>Subscriber: As many as 7 SV data streams</th>
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<tr>
<td></td>
<td>Data rate: 4.8 kHz for 60 Hz system, 4 kHz for 50 Hz system</td>
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<tr>
<td></td>
<td>Protocol: IEC 61850-9-2</td>
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| Precise-Time Input | Demodulated IRIG-B time input and PTPv2 |

| Synchrophasors | IEEE C37.118 Standard |
|               | Up to 50 messages per second (50 Hz system) |
|               | Up to 60 messages per second (60 Hz system) |
|               | UDP Multicast Capability |
|               | SEL Fast Message Protocol |
|               | Up to 10 messages per second (50 Hz system) |
|               | Up to 20 messages per second (60 Hz system) |

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<tr>
<th>Processing</th>
<th>AC voltage and current inputs: 8,000 samples per second</th>
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<tr>
<td></td>
<td>Protection and control processing: 8 times per power system cycle</td>
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| Power Supply | 24–48 Vdc |
|             | 48–125 Vdc or 110–120 Vac |
|             | 125–250 Vdc or 120–240 Vac |

| Operating Temperature | −40° to +85°C (~−40° to +185°F) |