SEL-FT50/SEL-FR12 Fault Transmitter and Receiver System

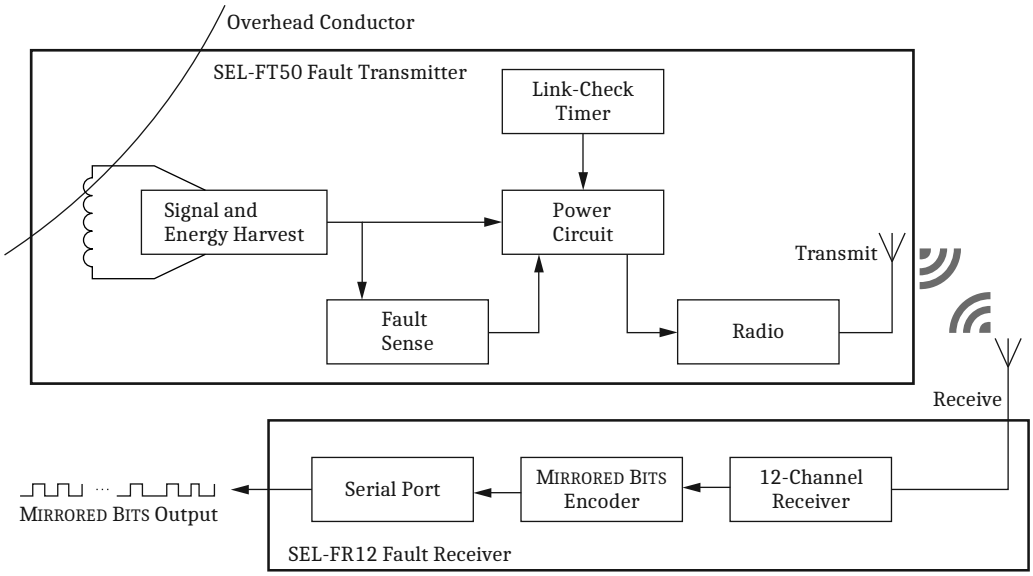
Accelerate Tripping, Speed Up Restoration, and Improve Safety on Distribution Feeders

Major Features and Benefits

The SEL-FT50/SEL-FR12 Fault Transmitter and Receiver System speeds up distribution-protection schemes by detecting and transmitting distribution feeder fault information to recloser controls or relays. Install the SEL-FT50 Fault Transmitters on laterals, branches, and the main line to broadcast fault status to one or more SEL-FR12 Fault Receivers. The SEL-FR12 communicates the fault data through MIRRORED BITS® communications to a relay or recloser control within 6 ms.

- **Real-Time Distribution Fault Detection.** Identify the faulted line segment with fault detection and low-latency communication while a fault is still active; for use in protection schemes.
- **Enhanced Protection.** Make real-time changes to the protection strategy based on information from the faulted distribution-line segment.
- **Improved Selectivity.** Trip a main feeder or branch recloser only when necessary. Avoid unnecessary entire-feeder outages.
- **Customized Reclosing Strategies.** Block or enable reclosing for specific line segments.
- **Improved Power Quality, Reduced System Stress, Limited Equipment Damage, and Enhanced Safety.** Leverage faulted feeder status to better coordinate between protective elements, leading to faster trip times.
- **Easy Operation.** Configure the fault transmitters and receiver without additional software.
- **No Batteries.** Power the SEL-FT50 directly from the line because batteries are not necessary.
- **Easy Installation.** Install the SEL-FT50 on live lines by using familiar line tools and techniques.
- **Flexible Integration.** Install the SEL-FT50/SEL-FR12 system in an existing relay protection system.

Functional Overview



The SEL-FT50/SEL-FR12 system consists of as many as twelve SEL-FT50 Fault Transmitters and one SEL-FR12 Fault Receiver. The SEL-FT50 is mounted on distribution conductors with voltages as high as 38 kV. The SEL-FR12 is mounted in a recloser control cabinet or in a substation control house.

When one or more SEL-FT50 Fault Transmitters detect a fault, they send a wireless signal to the SEL-FR12. The SEL-FR12 transfers the received signal to the recloser control or relay via MIRRORED BITS communications in as little as 6 ms. The recloser control uses the fault information to make protection or relay decisions.

To monitor the health of the system, the SEL-FT50 Fault Transmitters periodically send communication link-check messages to the SEL-FR12 to indicate their status.

System Overview

Figure 1 provides an overview of the SEL-FT50/SEL-FR12 system and illustrates how to apply it across a distribution power system.

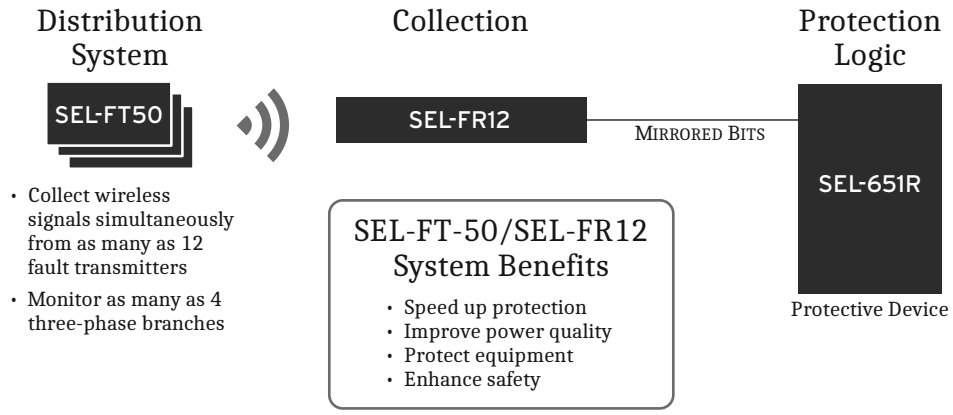


Figure 1 SEL-FT50/SEL-FR12 System

The SEL-FT50/SEL-FR12 system components are easy to use, and they contain many powerful and innovative features. Use programmable logic in the SEL-651R or in connected relays to incorporate the new protection capabilities and achieve the benefits shown in *Figure 1*.

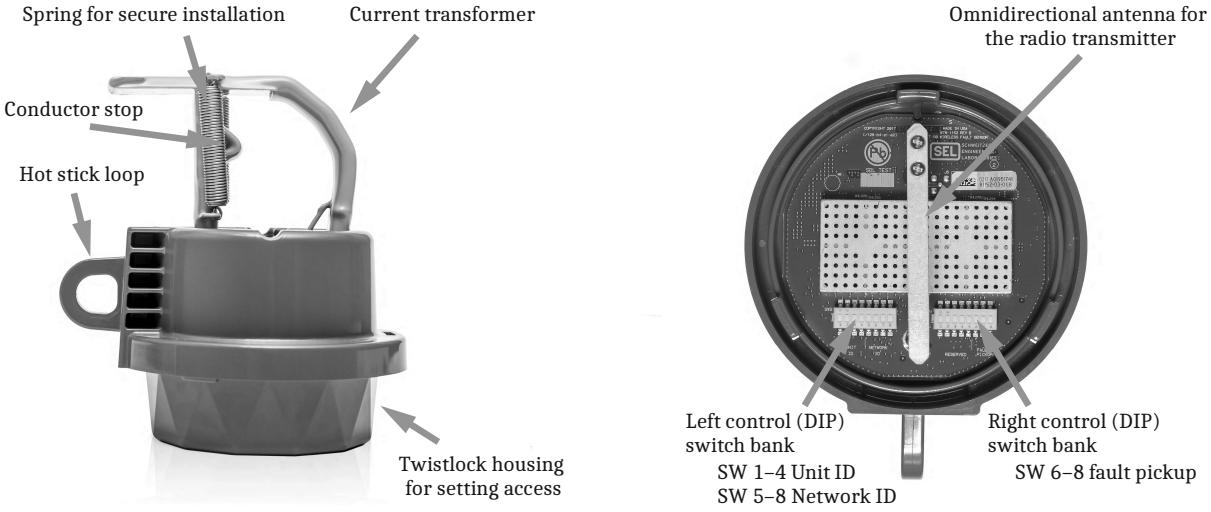


Figure 2 SEL-FT50 Overview

Each SEL-FT50 mounts onto and monitors the line current on one phase. When a fault occurs, the SEL-FT50 transmits a high-speed wireless signal to influence protection decisions. Control (DIP) switches inside the transmitter allow easy selection of unit and Network IDs. No batteries are needed because the SEL-FT50 is powered by the line current.

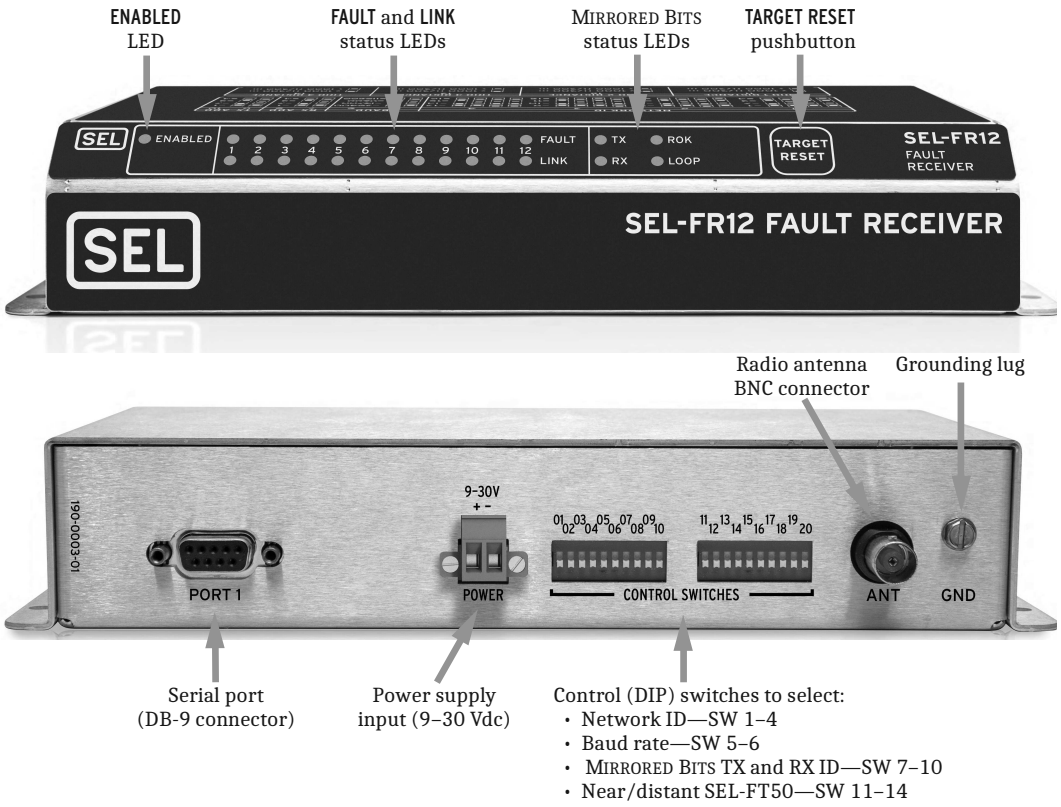


Figure 3 SEL-FR12 Overview

The SEL-FR12 collects wireless signals simultaneously from as many as 12 SEL-FT50 Fault Transmitters (enough for 4 three-phase installations). The SEL-FR12 reports faults to a relay or recloser control in less than 6 ms via MIRRORED BITS. The SEL-FR12 HMI contains 29 LEDs and 1 pushbutton, as shown in *Figure 3*.

- The **ENABLED** LED illuminates green when the SEL-FR12 is turned on and operational.
- The 12 **FAULT** LEDs (red, one per Unit ID) illuminate after the SEL-FR12 receives a Fault message from the associated SEL-FT50. These LEDs have a latching behavior so that once set, they remain on until reset by the **TARGET RESET** pushbutton or via MIRRORED BITS command.
- The 12 **LINK** LEDs (green, one per Unit ID) have a tristate operation:
  - **LINK** LEDs are initially off when the SEL-FR12 is turned on or after it receives a clear link status command via MIRRORED BITS.
  - **LINK** LEDs illuminate when the SEL-FR12 receives consecutive Link messages or one Fault message from the associated SEL-FT50. These LEDs have a delayed dropout behavior. Once illuminated, they remain illuminated as long as Link signals are periodically received.
  - **LINK** LEDs begin to flash after one minute elapses without receipt of a Link message for the associated Unit ID. When Link or Fault signals resume, the **LINK** LED stops flashing and stays illuminated once again.

- The **ROK**, **TX**, **RX** (green), and **LOOP** (red) LEDs indicate MIRRORED BITS status and activity. The **ROK** LED illuminates when MIRRORED BITS data exchange is successful.
- The **TARGET RESET** pushbutton resets the **FAULT** LEDs. Press and hold the pushbutton to illuminate all HMI LEDs (lamp test function).

Table 1 Target and Status LED Definitions

LED (Color)	Off	Flashing	On	Reset Methods
FAULT (red) target	No fault signal has been received from the corresponding Unit ID since the last reset.	Not applicable.	The SEL-FR12 received a fault signal from the corresponding Unit ID since the last reset.	Manual—resets via the **TARGET RESET** pushbutton. Remote—resets via MIRRORED BITS.
LINK (green) status	The SEL-FR12 has not detected an SEL-FT50 with the corresponding Unit ID since initialization. This learning feature keeps unused **LINK** LEDs turned off.	The SEL-FR12 is not presently receiving signals from the previously learned Unit ID, indicating that an SEL-FT50 is not harvesting energy during low-current conditions or an outage.	The SEL-FR12 has received signals from the corresponding Unit ID within the last minute, indicating that the SEL-FT50 is receiving minimum radio link active current.	Automatic—learning mode resets automatically after the SEL-FR12 turns on. Remote—resets via MIRRORED BITS.

Application Examples

Collect Fault Information From Remote Branches

A traditional recloser control or substation circuit breaker must be coordinated with the other protective devices on a distribution feeder, including fuses on downstream line segments. On the sample feeder in *Figure 4*, the recloser control or substation relay cannot distinguish one segment from another.

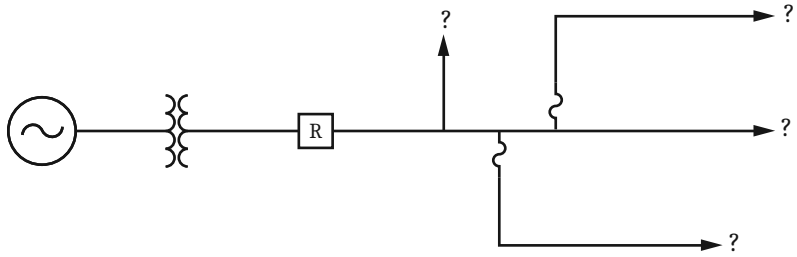


Figure 4 Typical Recloser Visibility

The SEL-FT50/SEL-FR12 system offers increased visibility to a recloser control by providing fault status from locations as far away as two miles. *Figure 5* illustrates how this allows the recloser control to see faults on individual branches, including locations where it is not economically feasible to install a relay or recloser. Each SEL-FT50 label in *Figure 5* represents three SEL-FT50 Fault Transmitters, one per phase.

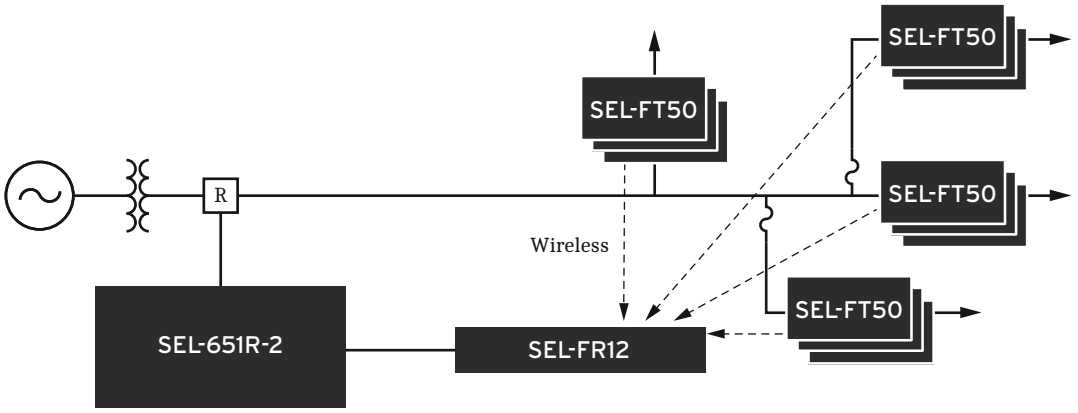


Figure 5 Recloser Communication With Fault Transmitters

Each SEL-FT50 monitors line current and instantly transmits a wireless signal when an overcurrent (fault) condition occurs. The companion SEL-FR12 receives and aggregates fault data from as many as 12 SEL-FT50 Fault Transmitters. Upon detecting a fault indication signal, the SEL-FR12 communicates the fault information to the host SEL-651R recloser control, or other SEL protective relay, by using MIRRORED BITS communications.

The SEL-FT50/SEL-FR12 system allows the protective relay or recloser control to make intelligent decisions by using high-speed fault information from remote locations.

Improve Fuse Coordination

In a radial distribution system, there are two main schemes that control fuse coordination: fuse-saving and fuse-blowing (also called trip-saving). Each of these schemes has shortcomings that you can address with the SEL-FT50/SEL-FR12 system.

Figure 6 gives a representation of a typical time-overcurrent coordination graph.

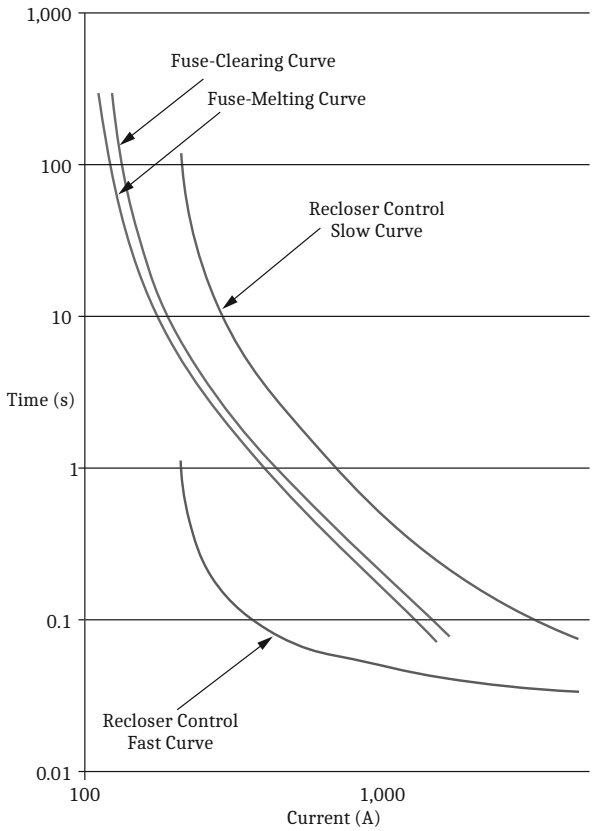


Figure 6 Example Time-Overcurrent Element Coordination

Fuse-Blowing Scheme Shortcomings

For a radial distribution system, the goal of the fuse-blowing scheme is to minimize the number of customers exposed to an interruption. The scheme accomplishes this by allowing a fuse to clear a given fault. The recloser only trips for faults that are not protected by a fuse. This scheme is sometimes called a trip-saving or fuse-blowing scheme because the recloser only trips when absolutely necessary.

Refer to *Figure 6* for the recloser control time-overcurrent element slow curve (shown in red). This curve must coordinate with the highest-rated fuse size present on the system, which is shown in green. An intentional coordination margin allows for prefault load and variances in fuse construction.

For faults on sections of the feeder that are not fuse-protected, the recloser must still implement this intentional coordination margin. The recloser control cannot determine which downstream branch the fault is on and assumes that the fault will be cleared by a fuse. *Figure 7* shows an example of a main line feeder and a fused lateral without a fuse. For a fault on the main line, the recloser control will wait before using the slow curve to clear the fault (see *Figure 6*). For a fault on the main line, the recloser control delays tripping unnecessarily because there is no fuse present.

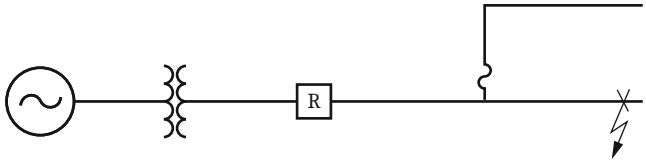
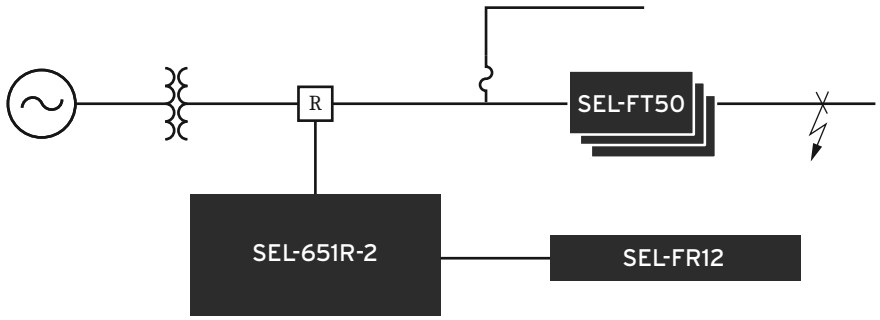


Figure 7 Fault on Unfused Tap

Improve Fuse-Blowing Schemes With the Fault Transmitter and Receiver System

With the SEL-FT50/SEL-FR12 system installed as shown in *Figure 8*, the recloser control receives an indication whenever a fault is on the unfused branch. With this information, if a fault occurs on the unfused line section, the recloser control can trip instantaneously instead of waiting for the fuse delay.

In *Figure 8*, the unfused tap is monitored by a set of SEL-FT50 Fault Transmitters (one for each phase), one SEL-FR12, and one SEL-651R. The SEL-FR12 is connected to the SEL-651R via a serial port.



When the fault is on the unfused branch, the recloser trips without fuse-coordination delay.

Figure 8 SEL-FT50 on Unfused Tap

When using the SEL-FT50/SEL-FR12 system, the SEL-651R knows when a fault occurs on the unfused tap because one or more of the SEL-FT50 Fault Transmitters detect the fault current and send the fault status to the SEL-FR12, which then conveys the information to the recloser control.

The SEL-651R settings replace or modify the curve behavior while the fault is happening. In the example fault shown in *Figure 8*, the recloser control enables the recloser control fast curve (see *Figure 6*). Compare this to when a fault is on the same unfused line section but the recloser control does not know it. The recloser trips after a delay. Based on the coordination curves in *Figure 6*, for a 1000 A fault, using the SEL-FT50/SEL-FR12 system to trip on the fast curve instead of the slow curve reduces the fault clearing time by 400 ms.

Fuse-Saving Combined With Fuse-Blowing Schemes

The fundamental choice in distribution-line protection is between fuse-saving and fuse-blowing. For a given fault, designers either favor blowing fuses and disrupting as few customers as possible, or tripping the recloser and interrupting the fault without blowing any fuses. Each method has its advantages, but the protection planner has to pick one or the other.

Using the SEL-FT50/SEL-FR12 system, design smart protection that switches from fuse-saving to fuse-blowing, or vice versa without interruption. You get the fuse-saving or fuse-blowing benefits you want while eliminating any drawbacks.

The following two example applications show how a single protective zone using the SEL-FT50/SEL-FR12 system allows both fuse-saving and fuse-blowing schemes in service.

Example 1: Switchover Without Interruption From a Fuse-Blowing Scheme to a Fuse-Saving Scheme

In this switchover scheme, utilities have the option to tailor protection for specific line segments with different characteristics. If the SEL-FT50 declares that a fault is present on a candidate line section, the scheme enables fuse-saving while the fault is in progress. For other faulted line segments, the fuse-blowing scheme works as intended.

Example 2: Switchover Without Interruption From a Fuse-Saving Scheme to a Fuse-Blowing Scheme

In this switchover scheme, the SEL-FT50/SEL-FR12 system is used to indicate which line section contains a fault. However, the fuse-saving scheme is the default operating mode. When the SEL-FT50 declares that a fault is present on a candidate line section, the scheme enables fuse-blowing while the fault is in progress. For other faulted line segments, the fuse-saving scheme works as intended.

Improve Feeder Cable First-Span Protection

The SEL-FT50/SEL-FR12 system improves first-span feeder cable protection. Feeder cables are often used for substation egress, eliminating overhead line clutter and improving working safety. These feeder cables radiate from a substation, continuing for a few feet to one mile. These cables are usually terminated on a riser pole and then connected to the overhead conductors.

To protect cable sections, some utilities use instantaneous overcurrent elements with pickup levels set to cover the entire cable length, plus some margin that overreaches onto a portion of the overhead line. In these applications, a high-current fault causes an instantaneous trip with no reclosing permitted.

While this approach protects equipment, it also often causes an unnecessary permanent outage when the fault is on the portion of the overhead line where available fault levels are still very high. The majority of overhead faults are caused by temporary events and are far more likely to occur than underground faults. By not reclosing for close-in overhead faults, the entire feeder suffers a permanent outage that could have been avoided.

To improve the first-span feeder cable protection, use a set of three SEL-FT50 Fault Transmitters to monitor the first span of overhead line, as shown in *Figure 9*. When an overhead fault occurs, the relay instantaneous element trips the recloser or feeder breaker, but reclosing is allowed when the SEL-FT50 signals that the fault is on the overhead portion of the feeder. This simple modification of an existing scheme improves system availability. This application extends to any line that transitions between overhead and underground lines. Knowing whether a fault is on an overhead or underground section of a feeder helps when coordinating reclosing and protection schemes.

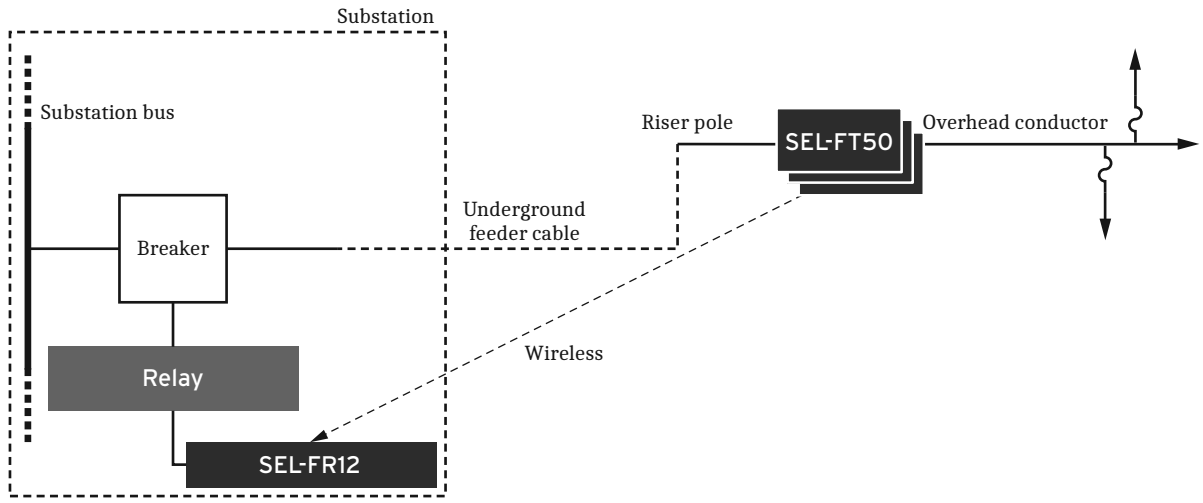


Figure 9 Feeder Cable Egress Protection With Enhancements

Tripping the Right Recloser Faster

You can protect a distribution feeder with multiple reclosers. In a radial system, to optimize selectivity, users want the recloser closest to the fault to operate for that fault. For this reason, reclosers at the end of the distribution line are set to trip first and the close-in reclosers are set to delay their tripping.

Figure 10 shows a fault in Zone R1. In a conventional protection design, assuming the reclosers use a fuse-blowing scheme, R1 clears this fault, but only after it gives Zones R2, R3, and R4 a chance to operate. This situation results in a long fault duration that stresses the system and impacts the power quality on other substation loads.

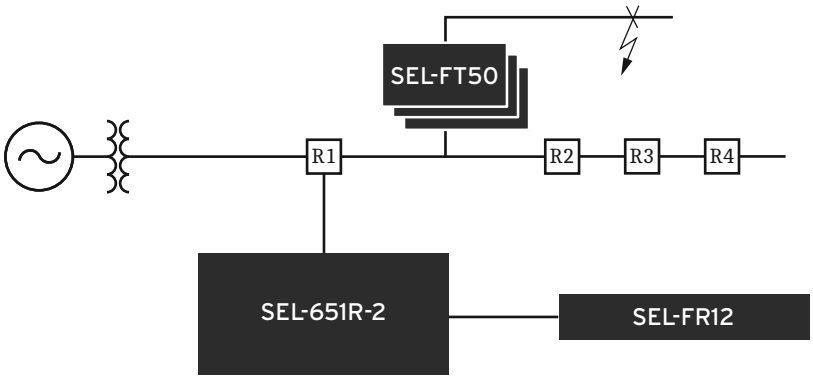


Figure 10 Radial Distribution Line With Multiple Reclosers

Fix this problem by using an SEL-FT50/SEL-FR12 system. In *Figure 10*, the SEL-FT50 detects the fault and immediately transmits the information to the SEL-FR12, which then sends this information to the recloser control at R1. Because R1 knows that the fault is in its zone, it trips without waiting for the downstream reclosers, avoiding the unnecessary coordination delay.

Safety Information

Regulatory Information

⚠CAUTION
Although the power level is low, concentrated energy from a directional antenna may pose a health hazard. Do not allow users to come closer than 23 cm (9 in) to the transmitter when it is operating.

⚠DANGER
Install fault transmitters and sensors in accordance with normal safe operating procedures. These instructions are not intended to replace or supersede existing safety or operating requirements. Only trained qualified personnel with knowledge of high voltage safety should install or operate fault transmitters.

The SEL-FT50 is approved for use only with specific output power configurations that have been tested and approved. Modifications to the SEL-FT50, the SEL-FR12, the antenna system, and the power output that have not been explicitly specified by the manufacturer are not permitted and may render the radio noncompliant with applicable regulatory authorities. The radio equipment described in this manual emits radio frequency energy. Professional installation is required.

This equipment has been tested and found to comply with the limits for Class A digital devices, pursuant to FCC Part 15 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 radiates radio frequency energy, and if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communication. Operation of this equipment in a residential environment is likely to cause harmful interference, in which case the user will be required to correct the interference at his/her own expense.

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.	Le présent appareil est conforme aux CNR d'Industrie Canada applicables aux appareils radio exempts de licence. L'exploitation est autorisée aux deux conditions suivantes : (1) l'appareil ne doit pas produire de brouillage ; (2) l'utilisateur de l'appareil doit accepter tout brouillage radioélectrique subi, même si le brouillage est susceptible d'en compromettre le fonctionnement.

Dangers, Warnings, and Cautions

This manual uses three kinds of hazard statements, defined as follows:

⚠DANGER
Indicates an imminently hazardous situation that, if not avoided, **will** result in death or serious injury.

⚠WARNING
Indicates a potentially hazardous situation that, if not avoided, **could** result in death or serious injury.

⚠CAUTION
Indicates a potentially hazardous situation that, if not avoided, **may** result in minor or moderate injury or equipment damage.

Safety Symbols

The following symbols apply to this device.

	**⚠CAUTION** Refer to accompanying documents.	**⚠ATTENTION** Se reporter à la documentation.
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Instruction manual	Manuel d'instructions

Safety Marks

The following statements apply to this device.

⚠DANGER Disconnect or de-energize all external connections before opening this device. Contact with hazardous voltages and currents inside this device can cause electrical shock resulting in injury or death.	**⚠DANGER** Débrancher tous les raccordements externes avant d'ouvrir cet appareil. Tout contact avec des tensions ou courants internes à l'appareil peut causer un choc électrique pouvant entraîner des blessures ou la mort.
⚠DANGER Contact with instrument terminals can cause electrical shock that can result in injury or death.	**⚠DANGER** Tout contact avec les bornes de l'appareil peut causer un choc électrique pouvant entraîner des blessuers ou la mort.
⚠WARNING Use of this equipment in a manner other than specified in this manual can impair operator safety safeguards provided by this equipment.	**⚠AVERTISSEMENT** L'utilisation de cet appareil suivant des procédures différentes de celles indiquées dans ce manuel peut désarmer les dispositifs de protection d'opérateur normalement actifs sur cet équipement.
⚠WARNING Have only qualified personnel service this equipment. If you are not qualified to service this equipment, you can injure yourself or others, or cause equipment damage.	**⚠AVERTISSEMENT** Seules des personnes qualifiées peuvent travailler sur cet appareil. Si vous n'êtes pas qualifiés pour ce travail, vous pourriez vous blesser avec d'autres personnes ou endommager l'équipement.

⚠WARNING Do not perform any procedures or adjustments that this instruction manual does not describe.	**⚠AVERTISSEMENT** Ne pas appliquer une procédure ou un ajustement qui n'est pas décrit explicitement dans ce manuel d'instruction.
⚠CAUTION Equipment components are sensitive to electrostatic discharge (ESD). Undetectable permanent damage can result if you do not use proper ESD procedures. Ground yourself, your work surface, and this equipment before removing any cover from this equipment. If your facility is not equipped to work with these components, contact SEL about returning this device and related SEL equipment for service.	**⚠ATTENTION** Les composants de cet équipement sont sensibles aux décharges électrostatiques (DES). Des dommages permanents non-décelables peuvent résulter de l'absence de précautions contre les DES. Raccordez-vous correctement à la terre, ainsi que la surface de travail et l'appareil avant d'en retirer un panneau. Si vous n'êtes pas équipés pour travailler avec ce type de composants, contacter SEL afin de retourner l'appareil pour un service en usine.

System Installation

SEL-FR12

The SEL-FR12 uses two 10-position control (DIP) switches to set the wireless network identification (Network ID) of the associated SEL-FT50 Fault Transmitters, the baud rate and addresses for the MIRRORED BITS serial communications port, and the separate receiver gain values for the SEL-FT50 Fault Transmitters.

The control (DIP) switch assignments are listed on the SEL-FR12 enclosure. The switch positions are labeled 1 through 20, but only 1 through 14 are used.

Physical Installation

Install the SEL-FR12 first for easier commissioning when you install the SEL-FT50 Fault Transmitters.

For simplest installation, place the SEL-FR12 inside the recloser control cabinet, powered by the 12 Vdc auxiliary power supply of the SEL-651R. However, it can be installed with any device that communicates through MIRRORED BITS. The SEL-FR12 must be connected to an antenna that is outside the recloser control cabinet and can connect to a coaxial cable run with proper grounding and lightning protection devices. The antenna is typically mounted higher up on the pole in a safe location. The appropriate antenna type is site-specific. Perform a path study before choosing the antenna.

The SEL-FR12 serial port connects to one of the serial ports of the SEL-651R that are configured for SEL MIRRORED BITS communications. This connection allows the SEL-FR12 to share the received fault with the recloser control. The programmable logic of the recloser control is configured to incorporate the received data as part of the protection or control decisions.

Installation details differ slightly for SEL-FR12 Fault Receivers placed in substations.

Refer to the *SEL Radios Accessories Guide* on the SEL website for a complete list of radio accessories offered by SEL.

Mounting the SEL-FR12

Use the accessory kit hardware to mount the SEL-FR12 in the recloser control cabinet. When ordered as an accessory to the SEL-651R, the unit comes pre-installed without wiring as part of the cabinet.

Chassis Ground and Power Connection

Connect the rear-panel grounding terminal (labeled with the ground symbol) to a rack frame ground or main station ground for proper safety and

performance. Use 4 mm^2 (12 AWG) or heavier wire of less than 2 meters (6.6 feet) for this connection. Make the ground connection before making the power connections.

Connect the power harness to a fused 12 V auxiliary power supply terminal on the SEL-651R, paying attention to polarity.

If possible, turn on the SEL-FR12 and verify that the **ENABLED** LED illuminates. Turn it off before continuing.

Connect the Serial Port

Use a short cable, such as the SEL-C272, to connect the serial output of the SEL-FR12 to the recloser control or relay serial port that has been configured for MIRRORED BITS operation.

Turn on the SEL-FR12 and verify that the **ROK** LED illuminates. If **ROK** does not assert, check the SEL-FR12 MIRRORED BITS Speed and Address switches and compare them with the MIRRORED BITS port settings of the host device. Turn it off before continuing.

Feed Lines

The feed line used with the antenna is important. Use coaxial cables that have low attenuation and are rated for outdoor use. Keep the feed line as short as possible to minimize signal loss between the radio and antenna. RG8X or LMR-400 coaxial cables are preferred. If longer lengths or less cable loss is desired for the radio link, then you can use a larger cable, such as a 7/8-inch HELIAX. *Table 2* lists the signal losses for the indicated lengths of each cable type.

Table 2 Length vs. Loss in Coaxial Cables at 900 MHz

Cable Type	Characteristic Impedance	3.05 Meters (10 Feet)	12.24 Meters (50 Feet)	30.48 Meters (100 Feet)	91.44 Meters (300 Feet)
RG-8X (SEL-C964, SEL-C975)	50 Ω	0.70 dB	3.50 dB	7.0 dB	Unacceptable loss
LMR-400 (SEL-C966, SEL-C968)	50 Ω	0.39 dB	1.95 dB	3.90 dB	Unacceptable loss
7/8-inch HELIAX (SEL-C978)	50 Ω	Do not use	0.64 dB	1.28 dB	3.84 dB

Antenna System Ground

Antenna system grounding is not included in the scope of this manual. Please consult a radio systems engineer or other professional for advice on ground-system design, and read AG2014-36, *Radio System Lightning Protection Best Practices*, which can be found on the SEL website. A well-designed system will minimize equipment damage and risk of electric shock to personnel.

Setting Network ID

To enable multiple wireless fault transmitter and fault receiver systems to operate in close proximity, both the SEL-FT50 and SEL-FR12 feature a Network ID selection (1–16). See *Figure 11* for an example of two networks.

The SEL-FR12 will only receive transmissions from SEL-FT50 Fault Transmitters that match its Network ID.

Each SEL-FT50 contain configuration switches to select one of sixteen network identification numbers. The SEL-FR12 also has Network ID

configuration switches and will only accept received SEL-FT50 messages that have a matching Network ID.

For example, if three distribution feeders emanate from one substation, each with their own SEL-FT50/SEL-FR12 system, these systems operate independently if they have unique Network IDs.

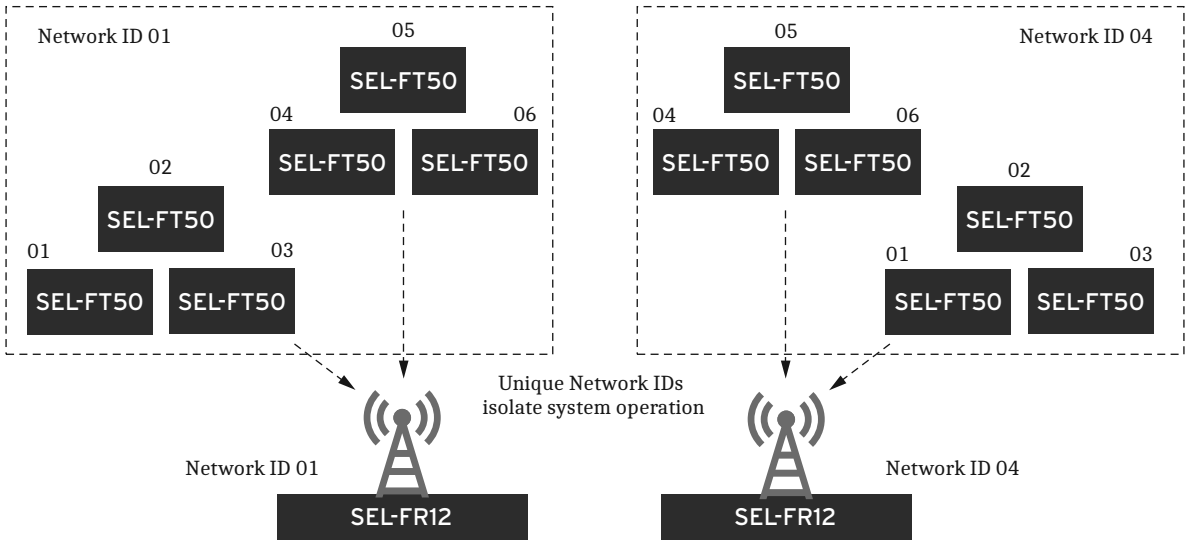


Figure 11 Two-Network Example

Once you have determined the Network ID to be used, set control switches to the appropriate positions, as shown in *Figure 12*.

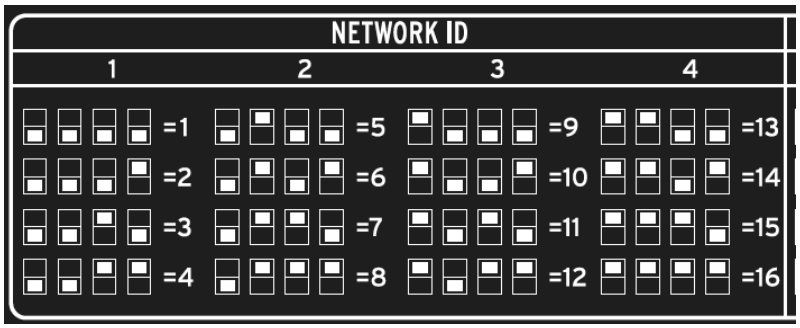


Figure 12 Network ID Switch Selection

Serial Port Settings

Configure the desired serial port baud rate through use of the control switch positions.

For best performance, choose the highest speed that matches the available MIRRORED BITS speed on the connected device.

Set the transmit address (**TX_ADD**) of the SEL-FR12 to match the receive address of the connected device. Set the receive address (**RX_ADD**) of the SEL-FR12 to match the receive transmit of the connected device. *Figure 13* outlines the control switch settings. Do not set the TX and RX addresses of each device to the same number because the SEL-FR12 detects a loopback condition when it receives its own transmit address in the MIRRORED BITS message. When the SEL-FR12 detects loopback, the **LOOP** LED illuminates and the **ROK** LED extinguishes.

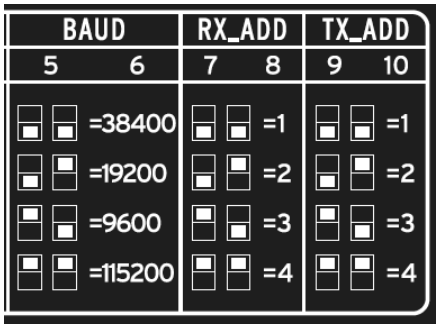


Figure 13 Serial Port Settings Selection

Setting Near/Distant SEL-FT50

For three-phase installations, the SEL-FT50 Fault Transmitters are installed in groups of three, and the received signal strength from all members of a trio is identical. The received signal strength between multiple trios is usually different because of path differences. To accommodate the range of reception signal strengths, an attenuation setting is provided for each trio. See *Table 3* for trio assignments.

Table 3 Trio Assignments

Node (Three-Phase)	Unit ID Assignments at Each Location	Trio Number
1	1, 2, 3	1
2	4, 5, 6	2
3	7, 8, 9	3
4	10, 11, 12	4

NOTE: There is no transmitter power adjustment selection in the SEL-FT50.

The appropriate attenuation setting for each trio is based on the distance between the trio and the SEL-FR12.

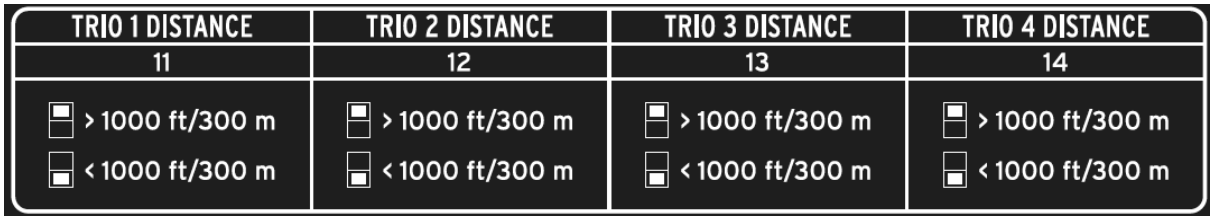


Figure 14 Trio Attenuation Switch Selection

Connecting the SEL-FR12 to Other SEL Devices

The SEL-FR12 uses the MB8 MIRRORED BITS protocol. The following examples give sample configurations for SEL devices that operate with the SEL-FR12. For each of these examples, select BAUD = 38400, RX_ADD = 2, and TX_ADD = 1 on the SEL-FR12. Only the minimum settings required are shown. Consult the appropriate instruction manual to ensure proper settings for your particular MIRRORED BITS application.

SEL-351, SEL-751 Relays, SEL-351R, and SEL-651R Recloser Controls

PROTO = MB8A*
SPEED = 38400
TXID = 2
RXID = 1

* = MB8A or MB8B may be used

SEL-451 Relay

PROTO= MBA*
SPEED = 38400
MBT = N
TX_ID = 2
TX MODE = P
STOPBIT = 2
RX_ID = 1
MBNUM = 8

* = MBA or MBB may be used

SEL-2505/SEL-2506 Remote I/O Module

SPEED = 38400
RX_ADD = 1
TX_ADD = 2

Mirrored Bits Interface and Messages

The SEL-FR12 communicates with a host device (protective relay or recloser control) through use of SEL Mirrored Bits communications. The connection requires one serial port on the host device. The SEL-FR12 supports four port speeds: 9.6, 19.2, 38.4, and 115.2 kbps. By default, the messages have the formats listed in *Table 4*.

Table 4 Default Command Set–SEL-FR12 Mirrored Bits Data Message Contents

Required SEL-651R Transmit Mirrored Bits (SELogic Equations) for Default Mode							
TMB1	TMB2	TMB3	TMB4	TMB5	TMB6	TMB7	TMB8
0	0	0	0	0	0	Clear link state in SEL-FR12	Target reset on SEL-FR12 HMI
SEL-651R Received Mirrored Bits (Relay Word bits)							
RMB1	RMB2	RMB3	RMB4	RMB5	RMB6	RMB	RMB8
Trio 1 FAULT	Trio 2 FAULT	Trio 3 FAULT	Trio 4 FAULT	Trio 1 LINK	Trio 2 LINK	Trio 3 LINK	Trio 4 LINK

The default command set is ideal for applications where SEL-FT50 Fault Transmitters are installed in trios and individual unit information is not needed. For other applications, the SEL-FR12 supports two additional Mirrored Bits command sets.

The command sets listed in *Table 6* and *Table 7* provide conditional responses. Program the SEL-651R logic to evaluate the expression RMB1 OR RMB2. When true, the remaining bits RMB3–RMB8 contain FAULT data; otherwise, they contain LINK data.

Table 5 defines the Trio FAULT and Trio LINK bits.

The TMB1–TMB6 entries in *Table 6* and *Table 7* indicate the required TMB states to select the Default Set or Command Set 2 or 3. Any other bit combinations force the SEL-FR12 to return all zeros and cause it to ignore TMB7 and TMB8 commands.

Table 5 Definition of FAULT and LINK Bits

Bit Label	Definition
LINK *u*	*u* = Unit ID 1–12 SEL-FR12 is receiving messages from SEL-FT50 Fault Transmitters. Asserts whenever SEL-FR12 LINK LED *u* is solidly illuminated.
Trio 1 LINK	Logical AND of the link status from the installed SEL-FT50 Fault Transmitters with Unit IDs 1, 2, and 3
Trio 2 LINK	Logical AND of the link status from the installed SEL-FT50 Fault Transmitters with Unit IDs 4, 5, and 6
Trio 3 LINK	Logical AND of the link status from the installed SEL-FT50 Fault Transmitters with Unit IDs 7, 8, and 9
Trio 4 LINK	Logical AND of the link status from the installed SEL-FT50 Fault Transmitters with Unit IDs 10, 11, and 12
FAULT *u*	*u* = Unit ID 1–12 Asserts for 116 ms when the SEL-FR12 receives a fault message from the SEL-FT50 and deasserts thereafter; this bit is not latched (this differs from the SEL-FR12 **FAULT** LEDs, which are latched until reset).
Trio 1 FAULT	Logical OR of the fault state from Unit IDs 1, 2, and 3
Trio 2 FAULT	Logical OR of the fault state from Unit IDs 4, 5, and 6
Trio 3 FAULT	Logical OR of the fault state from Unit IDs 7, 8, and 9
Trio 4 FAULT	Logical OR of the fault state from Unit IDs 10, 11, and 12

The Trio 1 LINK, Trio 2 LINK, Trio 3 LINK, and Trip 4 LINK bit logic ignores SEL-FT50 Fault Transmitters that have not been installed or detected. For example, if SEL-FT50 Fault Transmitters with Unit IDs 4 and 5 are installed, but there is no Unit ID 6, LINK 6 never asserts. The equation for the Trio 2 LINK is reduced to LINK 4 AND LINK 5.

Table 6 Detailed Command Set 2—SEL-FR12 MIRRORED BITS Data Message Contents

Required SEL-651R Transmit MIRRORED BITS (SELOGIC Equations) for Detailed Command Set (2)							
TMB1	TMB2	TMB3	TMB4	TMB5	TMB6	TMB7	TMB8
0	0	1	0	0	0	Clear link state in SEL-FR12	Target reset on SEL-FR12 HMI
SEL-651R Received MIRRORED BITS (Relay Word bits)							
RMB1	RMB2	RMB3	RMB4	RMB5	RMB6	RMB7	RMB8
Response During Normal Conditions (No Fault on Trio 1 or Trio 2)							
Trio 1 FAULT = 0	Trio 2 FAULT = 0	LINK 1	LINK 2	LINK 3	LINK 4	LINK 5	LINK 6
Response During FAULT Indication (One or Both Trio 1 FAULT, Trio 2 FAULT Asserted)							
Trio 1 FAULT	Trio 2 FAULT	FAULT 1	FAULT 2	FAULT 3	FAULT 4	FAULT 5	FAULT 6

Table 7 Detailed Command Set 3—SEL-FR12 MIRRORED BITS Data Message Contents

Required SEL-651R Transmit MIRRORED BITS (SELOGIC Equations) for Detailed Command Set (2)							
TMB1	TMB2	TMB3	TMB4	TMB5	TMB6	TMB7	TMB8
0	0	1	1	0	0	Clear link state in SEL-FR12	Target reset on SEL-FR12 HMI
SEL-651R Received MIRRORED BITS (Relay Word bits)							
RMB1	RMB2	RMB3	RMB4	RMB5	RMB6	RMB7	RMB8
Response During Normal Conditions (No Fault on Trio 3 or Trio 4)							
Trio 3 FAULT = 0	Trio 4 FAULT = 0	LINK 7	LINK 8	LINK 9	LINK 10	LINK 11	LINK 12
Response During FAULT Indication (One or Both Trio 3 FAULT, Trio 4 FAULT Asserted)							
Trio 3 FAULT	Trio 4 FAULT	FAULT 7	FAULT 8	FAULT 9	FAULT 10	FAULT 11	FAULT 12

Access 12 Individual LINK and FAULT Bits

Command Set 2 provides the individual status of Unit IDs 1–6 and Command Set 3 provides it for Unit IDs 7–12. However, there is no command set that provides all 12 individual status points at one time.

For applications that require more than six individual LINK *u* or FAULT *u* bits, set the SEL-651R to alternately request Command Set 2 and Command Set 3. Achieve this by operating TMB4 from a SELOGIC timer, changing state automatically (refer to the top sections of *Table 6* and *Table 7*). Configure further SELOGIC to qualify and decode the RMB data, and store the result in the appropriate SELOGIC variables for use in control functions or for system logging in the Sequential Events Recorder.

Temporarily Disable SEL-FR12 MIRRORED BITS Responses

For commissioning purposes, it may be necessary to disable the MIRRORED BITS data that the SEL-FR12 is transmitting. In the SEL-651R, set TMB1–TMB8 = 0, with the exception of setting TMB4 = 1. This has no effect on the SEL-FR12 front-panel LED operation.

SEL-FT50

Settings and Configuration

The SEL-FT50 uses two internal eight-position switch banks to configure the Unit ID, the Network ID, and the Fault Pickup current level.

To begin, open the SEL-FT50 by twisting the bottom counter-clockwise. On the inside of the device, you will see the two banks of switches. The switch positions are labeled 1 through 8 on each of the two switch banks. The switch selections are outlined on a label on the interior of the device, as shown in *Figure 15*.

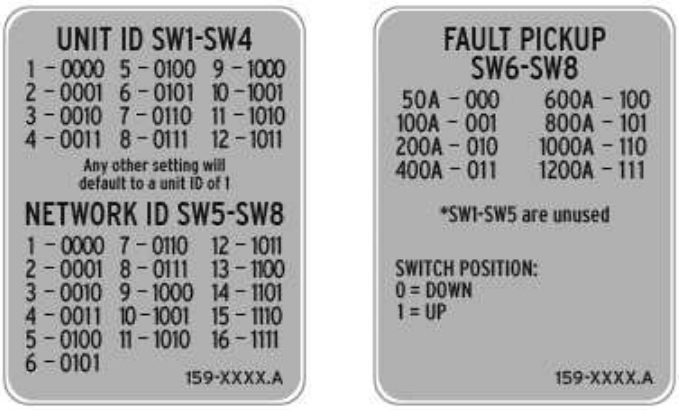


Figure 15 Switch Selections Labels

Setting the Unit ID

The SEL-FR12 Fault Receiver receives wireless signals from as many as 12 SEL-FT50 Fault Transmitters on the same network, defined by the Network ID selection in the SEL-FT50/SEL-FR12 system.

To allow the SEL-FR12 to distinguish which fault transmitter has sent a message, each SEL-FT50 transmits a Unit ID field as part of the message (the Unit ID is a number from 1 to 12).

The following lists the requirements when planning the Unit IDs to use in a system:

- Unit IDs cannot be duplicated on the network.
- Not all Unit IDs need to be present.
- Unit IDs should be grouped in three-phase locations as trios (see *Table 3*).
- Single-phase and two-phase applications are possible in specific situations.
- Unit IDs should be marked on the system record for later installation and commissioning work.
- Each SEL-FT50 Unit ID is configurable and is selected by the Unit ID control switches inside the housing.

Setting the Network ID

Configure your SEL-FT50 Fault Transmitters to communicate on the same network as your SEL-FR12 by giving both devices the same Network ID. Devices with different Network IDs cannot communicate.

Setting Fault Pickup

The topic of power system coordination is outside the scope of this guide. An overcurrent element must supervise SEL-FT50 data when used in trip decisions or other operations affecting protection. Choose an SEL-FT50 Fault Pickup to be at or below the upstream protective device (e.g., recloser control) supervising the overcurrent pickup setting (expressed in primary amperes).

Because the SEL-FT50 measurement accuracy is not as accurate as a relay, take care when choosing your fault pickup settings. The measurement accuracy for each trip threshold is spelled out in the specifications section.

Follow the guidelines in the following table to ensure the right pickup levels while avoiding false pickups.

Table 8 Fault Pickup Accuracy Considerations

Fault Pickup Level	Host Relay Pickup Setting	Load Behind FT50
50A	> 75A	< 25A
100A	> 130A	< 70A
200A	> 260A	< 140A
400A	> 480A	< 320A
600A	> 720A	< 480A
800A	> 960A	< 640A
1000A	> 1200A	< 800A
1200A	> 1440A	< 960A

NOTE: The SEL-FT50 current measurement circuitry is not as precise as a protective relay overcurrent element. Refer to *Specifications on page 25* for fault pickup accuracy, response characteristics, and device ratings.

This selection method guarantees that the SEL-FT50 picks up for any fault that the protective device element can see. This setting method will perform well in locations where fault current is much higher than load current.

The protection planner must consider the load current range on the distribution system at each node, combined with the SEL-FT50 accuracy rating at currents below the fault pickup. High load current levels may result in false assertion of the SEL-FT50 fault detector. In most cases, this is acceptable because the supervising overcurrent element will not assert. However, the more frequent a load condition is mistaken for a fault, and the longer each instance persists, the higher the chance of the SEL-FT50 missing an actual fault. To avoid this situation, consider selecting the SEL-FT50 Fault Pickup setting to be one step higher.

Field Installation

Wireless Considerations

Radio Path. Spread-spectrum radios operating in the 900-MHz band are limited by line-of-sight. Obstructions in the line-of-sight will impact the performance of the radio, because the strongest radio signal is communicated directly along the radio line-of-sight. The line-of-sight between two antennas is shaped like an ellipse (called the Fresnel zone). The point exactly halfway between the two antennas is the widest part of the ellipse, as shown in *Figure 16*. At 900 MHz and 304.8 m (1000 ft) apart, the Fresnel zone is 4.9 m (16 ft) in diameter. At 32 km (20 mi) apart, it is 51.8 m (170 ft) in diameter. Anything within the Fresnel zone will obstruct and reduce signal strength and availability (the ground, buildings, vegetation, etc.). *Table 9* depicts the maximum Fresnel zone diameter and path loss for some typical path distances.

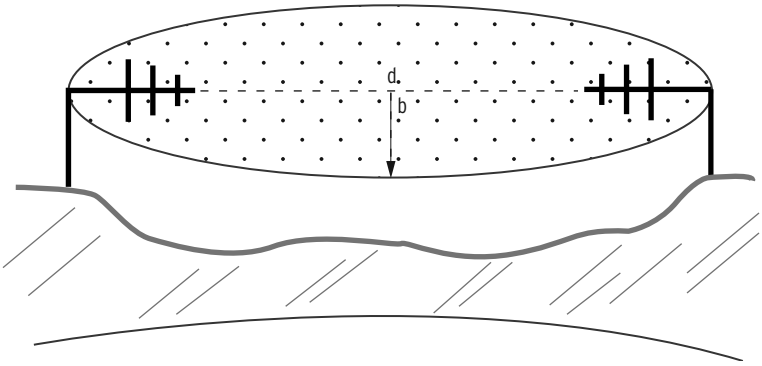


Figure 16 Fresnel Zone

The formula used to calculate the widest distance of the Fresnel zone is as follows:

$$b = 17.32\sqrt{d/(4f)}$$

where:

b = radius of the Fresnel zone in meters
d = distance between transmitter and receiver in kilometers
f = frequency transmitted in GHz

Table 9 900-MHz Fresnel Zone Radius

Distance Between Antennas (d)	Fresnel Zone Radius (b)	Free-Space Loss (dB)
304.8 m (1000 ft)	4.9 m (16 ft)	81
1.6 km (1 mi)	11.6 m (38 ft)	96
8 km (5 mi)	25.9 m (85 ft)	110
16 km (10 mi)	36.6 m (120 ft)	116

Obstructions in the Fresnel zone may also cause multipath interference because of reflective or refractive signals that may arrive at the receiver out of phase with the desired signal. The Fresnel zone should be at least 60 percent clear of obstructions for reliable radio communications. Large objects outside the Fresnel zone can also cause reflections that can affect reliable radio operation.

Fade Margin. The fade margin determines the allowable signal loss between the transmitter and receiver. The fade margin is a function of system gains (transmitter power, receiver sensitivity, and antenna gain) and system losses (free-space loss, losses because of Earth's curvature, and coaxial cable loss). Variations in temperature and humidity of the atmosphere along with elevation cause the signals to bend more or bend less, resulting in fading at the receiver. The longer the path, the more likely deep fades will occur, requiring a greater fade margin. The formula to calculate free-space loss is shown below.

$$Free\text{-}Space\ Loss = 92.4 + 20\log(f) + 20\log(d)\ dB$$

where:

f = frequency in GHz
d = distance in km

Regional conditions also impact the probability of signal fade. Generally, mountainous terrain is more favorable, while tropical areas and those near large bodies of water are less favorable. Perform a site survey before installing the SEL-FT50 Fault Transmitters to obtain the fade margin. A fade margin of 10 dB yields adequate performance for noncritical communications links

while a fade margin of 15 dB yields good radio performance for critical communications links.

Site Survey. A line-of-sight path provides the most reliable transmission in all cases. As the distance increases, the need for a clear path becomes more critical in creating a reliable, available radio link. If you have a clear line-of-sight to the other location without obstructions to the Fresnel zone (see *Radio Path on page 20*) then a path study is generally not needed. Longer distances may require a path study, a visual path inspection, and a spectrum analysis of the area to give a good indication of how high the antenna needs to be and how good the radio link will be.

Radio Interference. The SEL-FT50 shares frequency spectrum with other services and FCC Part 15 (unlicensed) devices in ITU Region 2 (North, Central, and South America). Error-free communication may not be achievable in a given location and some level of interference should be expected. For a given fault, the SEL-FT50 sends four consecutive messages. This mitigates the effect of radio interference by increasing the odds that a fault indication will be communicated successfully during situations with poor channel conditions.

Physical Installation

Install the SEL-FT50 on a distribution line by using an industry-standard hot stick.

Step 1. Use a hot stick to grasp the hook eye on the side of the SEL-FT50, and place the device on the line so that the opening hangs over the line.

Figure 17 Positioning the SEL-FT50

Step 2. Apply slight downward and sideways pressure until the device is closed around the line.

The spring mechanism should be pushed in, so that it wraps around the line.

Figure 18 SEL-FT50 Installation Position

Step 3. Apply slight upward pressure until the device is secured around the line as shown in *Figure 19*.

Figure 19 SEL-FT50 Secure on the Line

Step 4. Use the hot stick to adjust the transmitter orientation so that it is directly vertical. This is important to ensure the best propagation characteristics for the internal antenna.

Dimensions

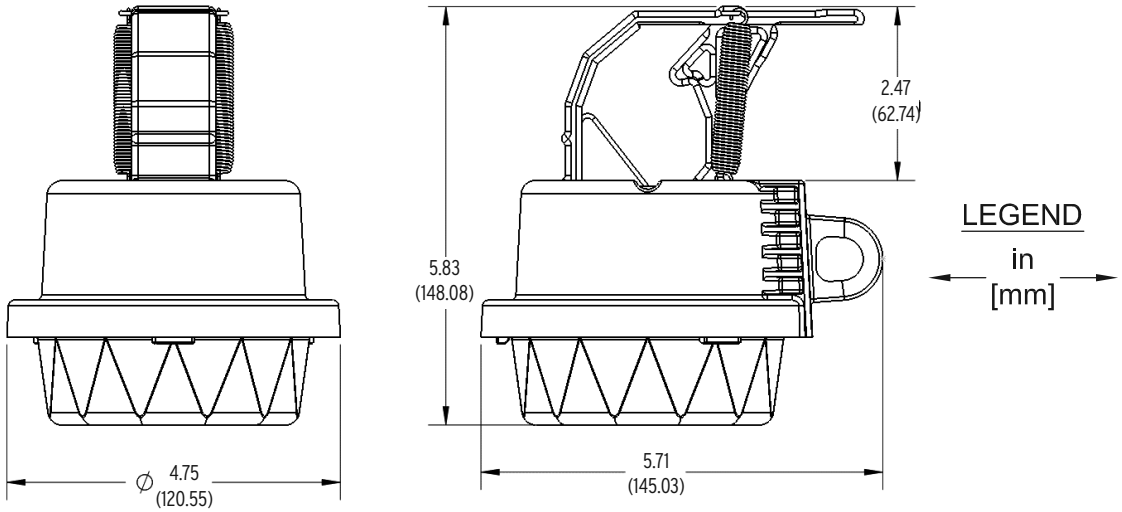


Figure 20 SEL-FT50 Dimensions

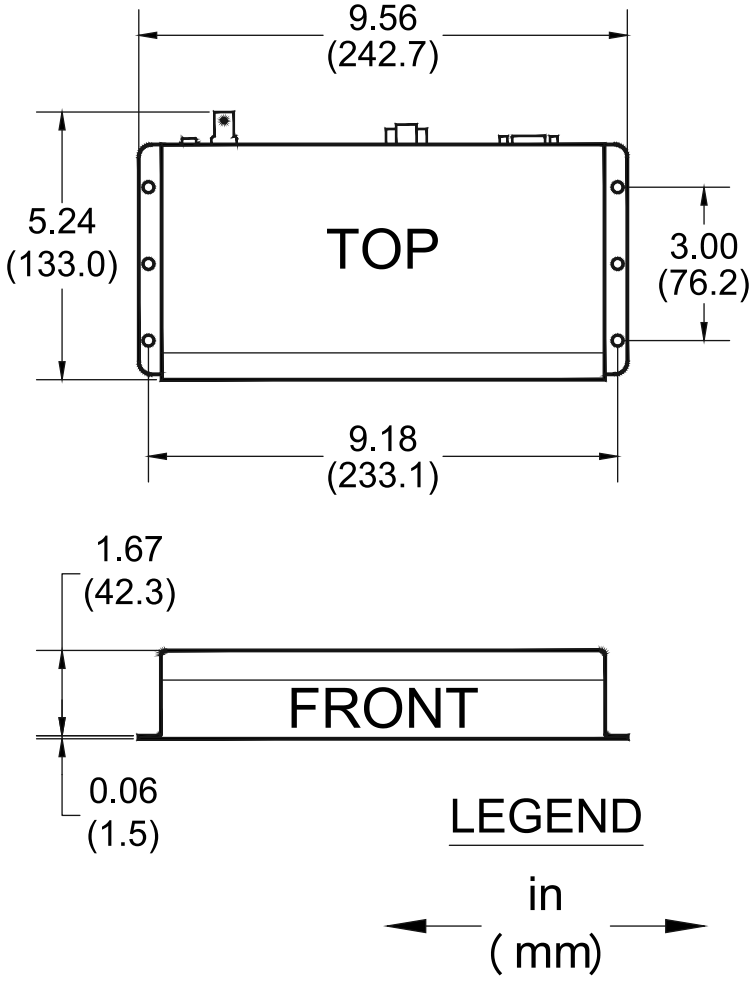


Figure 21 SEL-FR12 Dimensions

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system.

General

Operating Temperature

–40° to +85°C (–40° to +185°F)

Storage Temperature

–40° to +85°C (–40° to +185°F)

Operating Environment

Pollution Degree:	2
Relative Humidity:	5–95%, noncondensing
Maximum Altitude:	2000 m

Ingress Protection (SEL-FT50)

IP67

Clamp Range (SEL-FT50)

7.6 mm to 27.9 mm (0.3 in to 1.1 in)

Dimensions

SEL-FT50:	145 mm diameter x 148 mm height (5.71 in. diameter x 5.83 in. height)
SEL-FR12:	44 mm x 243 mm x 117 mm (1.73 in x 9.57 in x 4.61 in)

Weight

SEL-FT50:	0.6 kg (1.3 lb)

System

Power System Frequency Range

45–65 Hz

Current Pickup Level

Note: Units are individually configurable.

50, 100, 200, 400, 600, 800, 1000, 1200 A

Fault Detection Accuracy

50 A Threshold:	50%
100 A, 200 A Threshold:	30%
400 A Threshold and Above:	20%

Maximum Voltage

38 kV (L-L)

Power

SEL-FT50 Minimum Radio Link Active Current

15 A

SEL-FR12 Power Requirements

Voltage:	9–30 Vdc
Power Consumption:	< 2 W

Radio System

Frequency Band

902–928 MHz ISM band

SEL-FT50

TX Power:	700 mW (28 dBm)

SEL-FR12

Number of Channels:	12
Antenna Connector:	BNC, 50 Ω
RX Sensitivity:	–100 dBm at 1% error rate
Serial Protocol:	MIRRORED BITS communications
Serial Port:	9600, 19200, 38400, 115200 bps

Modulation

FSK

Typical Range

4 miles with 20 dB of interference/fade margin

Appendix A: Manual Versions

Instruction Manual

The date code at the bottom of each page of this manual reflects the creation or revision date.

Table 10 lists the instruction manual versions and revision descriptions. The most recent instruction manual version is listed first.

Table 10 Instruction Manual Revision History

Date Code	Summary of Revisions
20170317	➤ Initial version.

Appendix B: Two Branch Application

Two Branch Application

This application has two three-phase branches, A and B, as shown in *Figure 22*. Branch B has a fuse and uses a fuse-blowing scheme, while Branch A does not. When a fault occurs on Branch A, the recloser operates to clear the fault. In traditional protection schemes, those without the SEL-FT50/SEL-FR12 system, the time-inverse overcurrent curves of the SEL-651R recloser control are set above the fuse-clearing curve, resulting in longer tripping times for faults on Branch A. Use the SEL-FT50/SEL-FR12 system to improve this protection scheme.

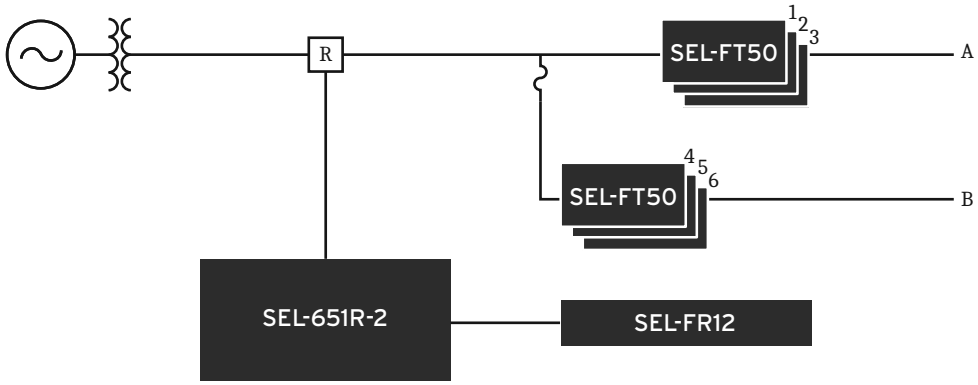


Figure 22 SEL-FT50/SEL-FR12 System Protection Scheme

Insert a set of three SEL-FT50 Fault Transmitters on each branch, one per phase. The SEL-FR12 connects to the SEL-651R with an SEL-C272 serial cable. In this example, the load current of Branch A is 200 A, and the load current of Branch B is 100 A. The 51 element pickup of the SEL-651R is set above 200 percent of the load current. In this example, the fuse size is 140 T, the SEL-651R 51 element pickup is 550 A, and the settings from *Table 11* apply.

Table 11 Settings for the SEL-FT50 Fault Transmitters

SEL-FT50	Branch	Unit ID Control (DIP) Switch Positions	Network ID Control (DIP) Switch Positions	Pickup Threshold Control (DIP) Switch Positions
1	A	1—(0000)	3—(0010)	400 A—(011)
2	A	2—(0001)	3—(0010)	400 A—(011)
3	A	3—(0010)	3—(0010)	400 A—(011)
4	B	4—(0011)	3—(0010)	200 A—(010)
5	B	5—(0100)	3—(0010)	200 A—(010)
6	B	6—(0101)	3—(0010)	200 A—(010)

This settings example uses Network ID = 3, and the fault current pickup threshold is set above the load current and below the pickup.

The Network ID of the SEL-FR12 matches the Network ID of the SEL-FT50 Fault Transmitters. *Table 12* assumes that the distances of the SEL-FT50 Fault Transmitters are farther than 300 m (1000 ft). See *Table 13* for the settings of the SEL-651R and *Table 14* for the SEL-651R transmit MIRRORED BITS settings.

Table 12 Settings for the SEL-FR12

Network ID	BAUD	RX_ADD	TX_ADD	Trio 1 Distance	Trio 2 Distance	Trio 3 Distance	Trio 4 Distance
3—(0010)	38400	1	2	> 300 m (1000 ft)	> 300 m (1000 ft)	> 300 m (1000 ft)	> 300 m (1000 ft)

Table 13 SEL-651R Settings

PROTO	SPEED	TXID	RXID
MB8A or MB8B	38400	1	2

Table 14 SEL-651R Transmit MIRRORED BITS Settings

TMB1A	TMB2A	TMB3A	TMB4A	TMB5A	TMB6A	TMB7A	TMB8A	Comments
0	0	0	0	0	0	0	TRGTR	The **TARGET RESET** pushbutton of the SEL-651R resets the latched **FAULT** LEDs of the SEL-FR12.

With these settings, Branch B operates using a fuse-blowing scheme where the fuse clears faults on the branch, while Branch A operates separately, tripping much faster because the protection does not wait for a fuse-coordination delay.

SCHWEITZER ENGINEERING LABORATORIES, INC.
2350 NE Hopkins Court • Pullman, WA 99163-5603 U.S.A.
Tel: +1.509.332.1890 • Fax: +1.509.332.7990
selinc.com • info@selinc.com

PMFR12-01