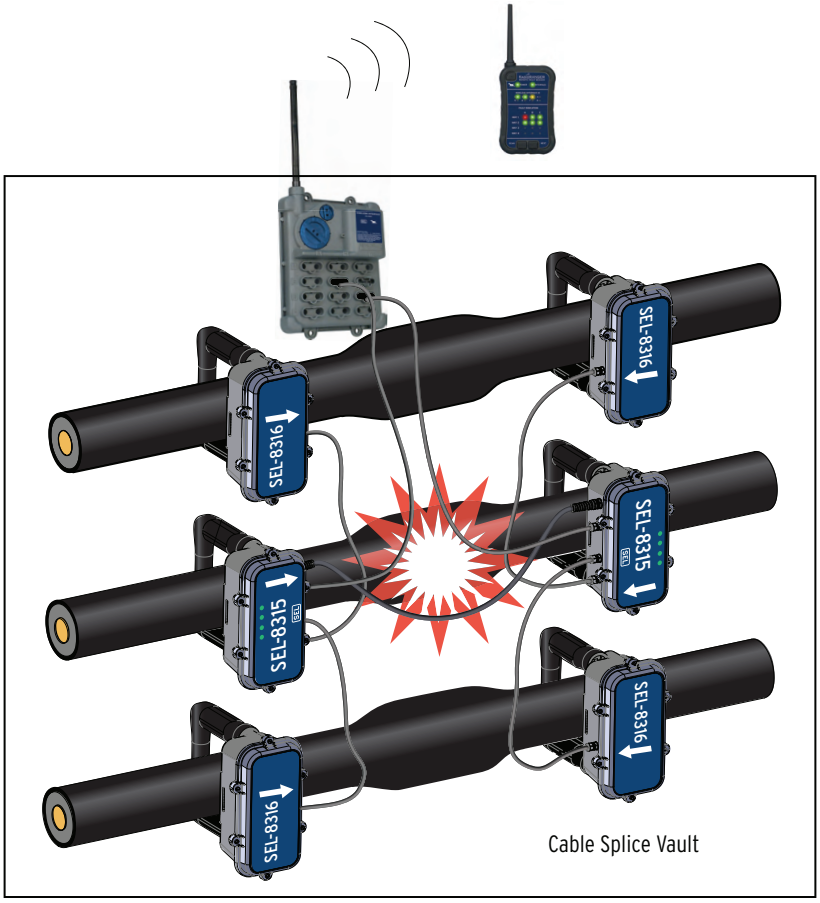
SEL-8315 Phase Comparison Faulted Circuit Indicator (PC FCI)



Features and Benefits

- **Locates Faulted Cable Sections Quickly**. Locate cable failures by using easy-to-install Phase Comparison Faulted Circuit Indicators (PC FCIs).
- **Designed and Tested for Harsh Environments.** The PC FCIs are submersible to depths as great as 15 feet of water and can operate in extreme temperatures.
- **Self-Powered.** No external power source.
- **Compatible With Existing RadioRANGER® Installations.** The PC FCIs plug into the RadioRANGER SEL-8300 Wireless Interface and report to the interface any out-of-phase condition. You can then use the RadioRANGER SEL-8310 Remote Fault Reader to remotely read the status of the cable.

Phase Comparison Faulted Circuit Indicator Theory of Operation

The PC FCI, used to monitor a three-phase section of cable, consists of the following elements:

- Two PC FCI control electronics (SEL-8315)
- Four split-core CTs (SEL-8316)

Figure 1 provides an overview of the PC FCI components at one end of the monitored cable section. The other end of the monitored cable has a duplicate set of sensors.

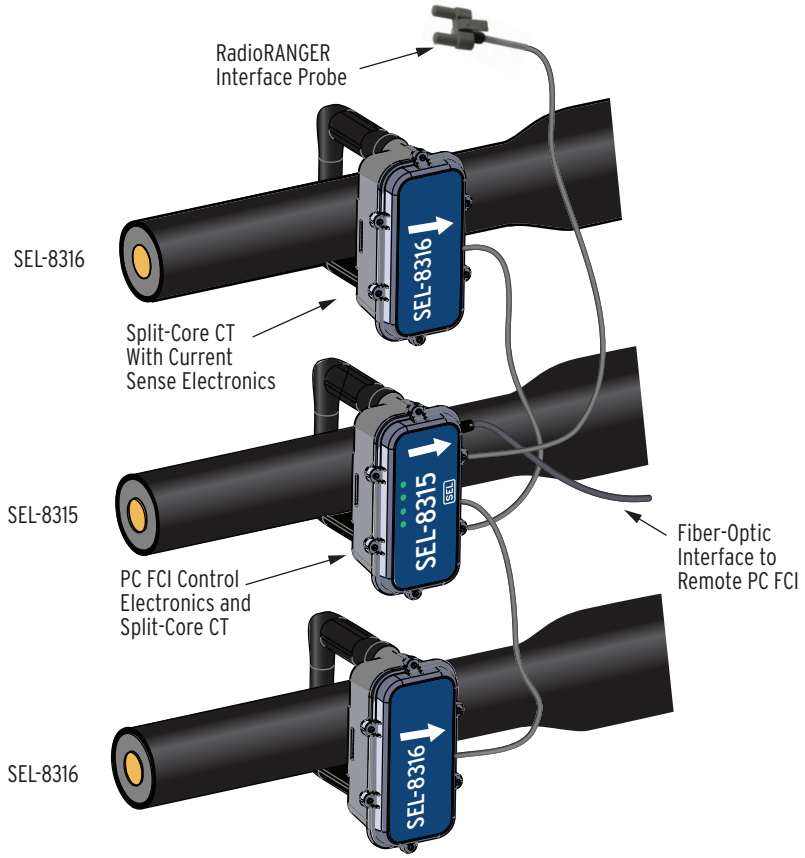


Figure 1 Phase Comparison Faulted Circuit Indicator Components

PC FCI Control Electronics

Figure 2 SEL-8315 PC FCI Control Electronics

The SEL-8315 PC FCI control electronics measure current flowing through the cable to which it is attached and from adjacent cables, to which the SEL-8316 split-core CTs are attached. Two SEL-8315 control electronics are connected together by a fiber-optic cable and exchange three-phase power system information. Local SEL-8315 PC FCI control electronics determine the phase polarity for each cable, and then transmits the phase polarity information for each cable, via the fiber-optic cable, to the remote SEL-8315 PC FCI control electronics. The SEL-8315 PC FCI control electronics at both cable ends then compare the local and remote polarities of each cable to determine if the currents are in-phase, i.e., a no-fault condition, or out-of-phase, i.e., a fault condition.

Figure 3 depicts the SEL-8315 PC FCI phase comparison concept. The blue blocks represent the positive polarity of the current waveform. The yellow blocks represent the negative polarity of the current waveform. Under normal conditions, positive and negative polarities of the power system waveform will be aligned in time. Under fault conditions, however, there is a current phase reversal at one end of the monitored cable. In the fault condition, the positive and negative measurements will be out-of-phase when the SEL-8315 PC FCI compares the local and remote measurements, i.e., blue and yellow blocks in *Figure 3* are out of phase, indicating a fault condition.

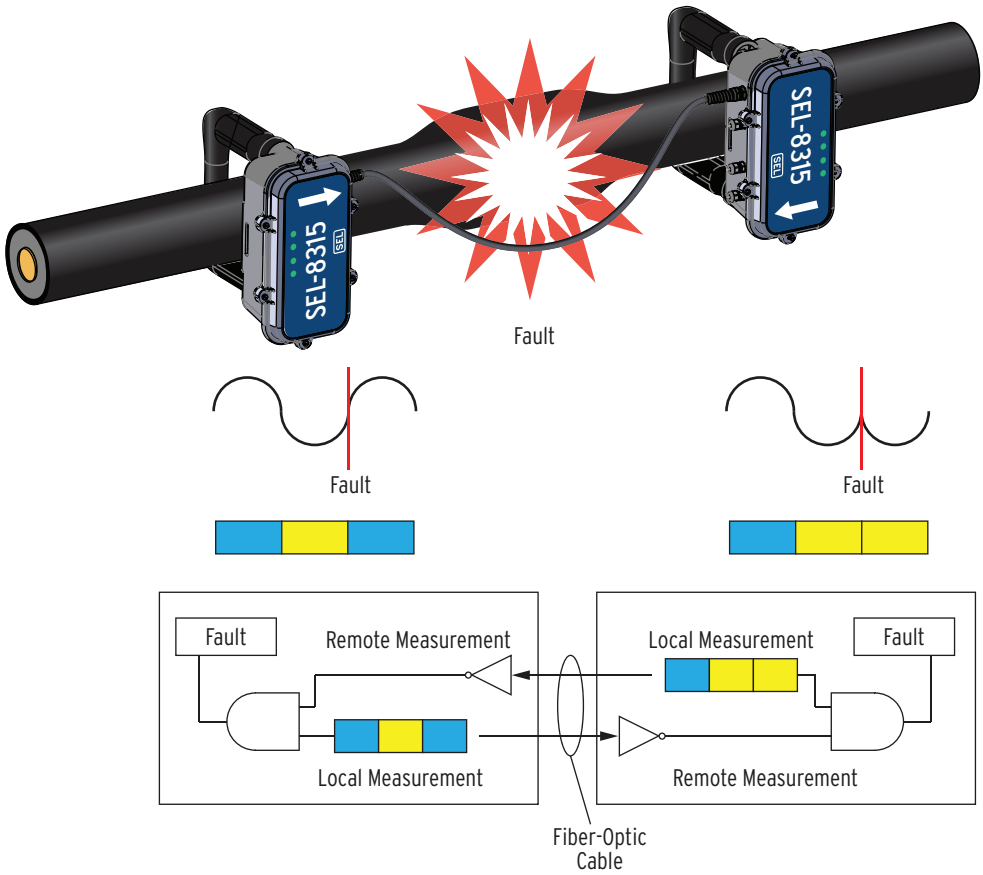


Figure 3 Phase Comparison Principle

NOTE: The SEL-8300 and SEL-8310 are not included as part of the SEL-8315 system.

The RadioRANGER interface probe connects the SEL-8315 PC FCI control to the SEL-8300 wireless interface. When the SEL-8315 PC FCI detects an out-of-phase condition, it sends a pulse from each SEL-8315 unit to the wireless interface. The wireless interface latches the faulted phase condition. When the SEL-8310 Remote Fault Reader interrogates the wireless interface, the wireless interface reports the faulted phase information.

Figure 4 SEL-8310 Interrogating SEL-8315

The SEL-8315 has four status indicators consisting of two LEDs each, one green and one amber (see *Figure 5*). The RX indicator shows the fiber-optic communication status. The A, B, and C indicators show the status of the individual phases. When a fault is detected, the PC FCI turns on the amber status indicator corresponding to the faulted cable. When power goes down, the amber indicator corresponding to the faulted cable blinks at a rate of approximately one pulse every four seconds (see *Table 1*).

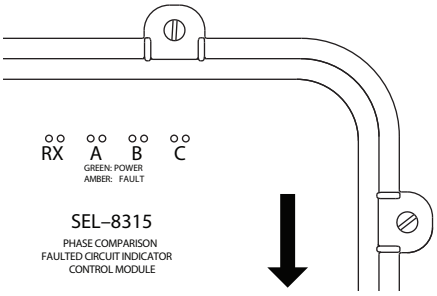


Figure 5 Status Indicator LEDs

Table 1 PC FCI LED Indicators

Indicator	LED Color	Behavior
RX	Green	On when unit is receiving data from the remote PC FCI
	Amber	On when unit is not receiving data from remote PC FCI
A	Green	On when current is detected on Phase A
	Amber	On or blinking when a fault is detected on Phase A
B	Green	On when current is detected on Phase B
	Amber	On or blinking when a fault is detected on Phase B
C	Green	On when current is detected on Phase C
	Amber	On or blinking when a fault is detected on Phase C

Split-Core Current Sensor

Figure 6 PC FCI Split-Core Sensor

The SEL-8316 split-core CTs provide a scaled-down version of the current in the monitored cable. The output of the CTs provide both the monitored current phase and the power to operate the PC FCI control electronics.

Applications

The PC FCI is designed to detect solid dielectric cable failures. Solid dielectric cables, such as cross-linked polyethylene (XLPE), are predominate in underground transmission cables from 69 to 230 kV. Construction of these systems typically consists of concrete-encased duct banks. Cable runs are limited to a maximum of 2,000 feet to allow for manageable cable spool size and to prevent installers from damaging the cable when they pull it through a conduit. Cable splices are required to connect cable sections and are done in underground splice vaults.

Figure 7 Underground Splice Vault

Excluding physical damage resulting from excavations, underground splice failure is the leading source of cable failures. Protective equipment is typically placed at substations but not in the splice vaults. When faults occur at the splice, they can result in a sustained outage until troubleshooters can determine the faulted cable section. Historically, troubleshooters have performed comprehensive visible inspections in each splice vault. The inspection process can be extensive if the vault is in a hard-to-reach location such as a busy intersection. The PC FCI and RadioRANGER system identifies faulted cable sections and provides a simple RF interface to notify a troubleshooter of the fault location without physically entering the vault.

Intra-Vault Cable Fault Detection

Figure 8 shows an application that uses PC FCIs at the entrance and exit of a vault. The PC FCI zone-of-monitoring is the cable section within the vault, and it will detect an out-of-phase condition within the vault. The troubleshooter identifies the fault location by using the RadioRANGER Remote Fault Reader at each vault location to determine if the fault condition is present.

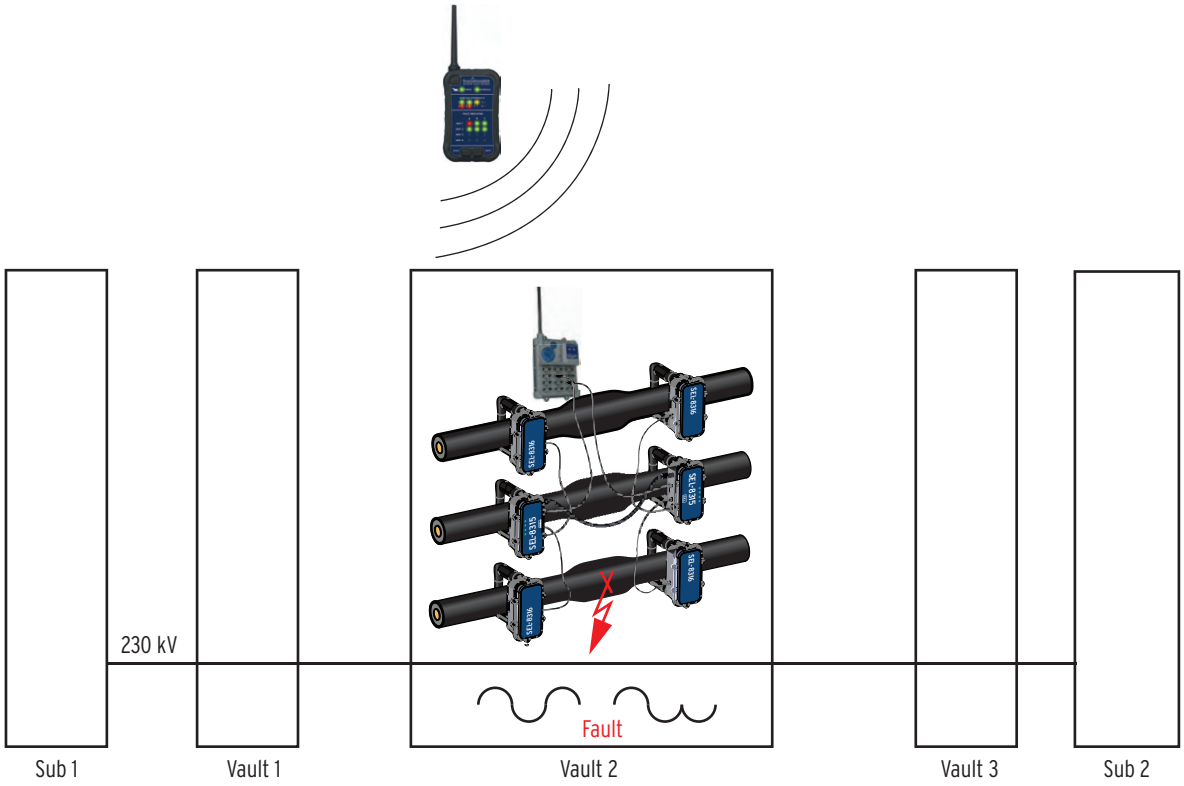


Figure 8 Intra-Vault PC FCI Application

Installation

The PC FCI components necessary to monitor a cable section consist of the following.

Qty	Item
2	SEL-8315 PC FCI Control Electronics Module ①
4	SEL-8316 Split-Core CT ②
1	SEL-8300 Wireless Interface Module[a] ③
1	SEL-8310 Remote Fault Reader[a] ④
1	Fiber-Optic Cable ⑤
1	CT release tool ⑥
14	Cable tie ⑦
14	Hose clamp
1	Instruction manual
2	ESD strap ⑧

a. The SEL-8300 and SEL-8310 are sold separately from the PC FCI system.

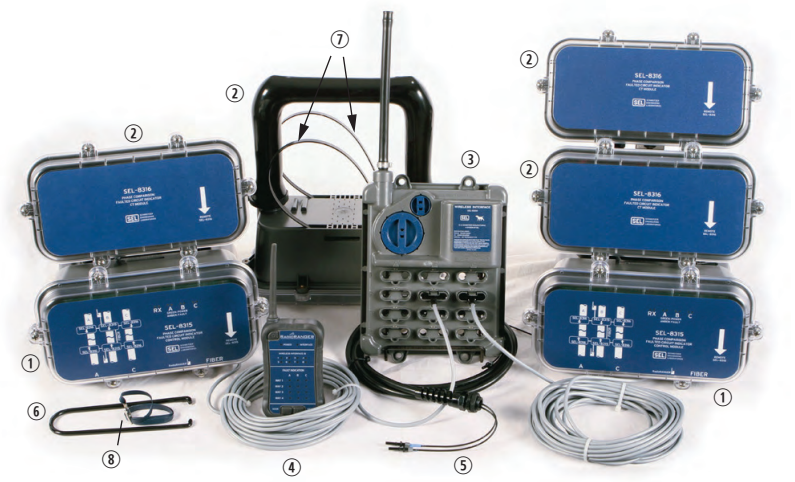


Figure 9 PC FCI Package Components

Installation Overview

Consider the following factors when determining where to mount the PC FCI system.

- The phase comparison control and CT modules should be placed between the cable splice connection and the ground conductor pull back. CTs should be installed at a location where primary current flow can be monitored and such that the ground return path of the faulted current does not cancel the primary current.
- Each control and CT module must have its corresponding control and CT module's protected area section arrows pointing toward each other (see *Figure 17*).

Step 1. Install the SEL-8316 CT modules on A-phase.

Figure 10 Release Tool for PC FCI

a. To disassemble the U portion of the CT module from the base, position the provided CT release tool as shown in *Figure 11*.

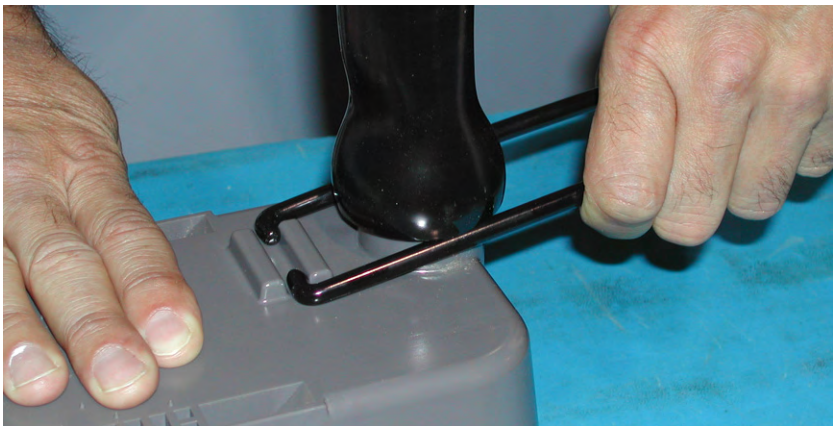


Figure 11 Position Release Tool

b. Squeeze tool and pry upwards to slide the core away from the housing.

c. Repeat on the other side.

d. Hold the core and housing and pull apart, being careful not to bend the steel core.

e. Place the U portion of the CT around the cable and reattach the base, ensuring that the arrow points toward the cable section to be monitored and that the CT is fully seated to the base.

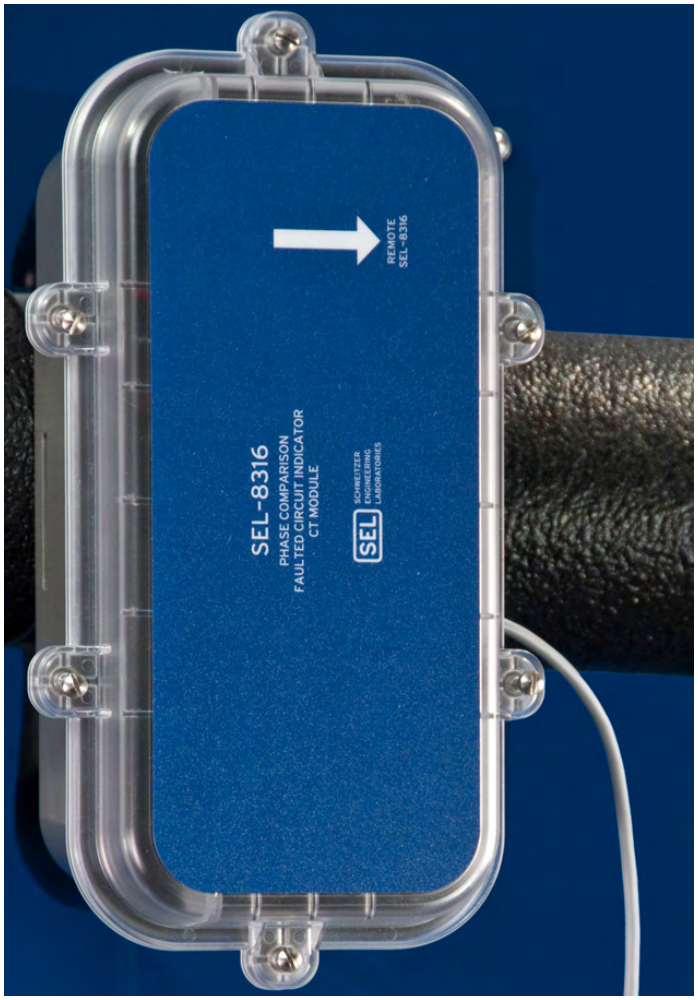


Figure 12 CT Module With Arrow Pointing Toward Cable Splice

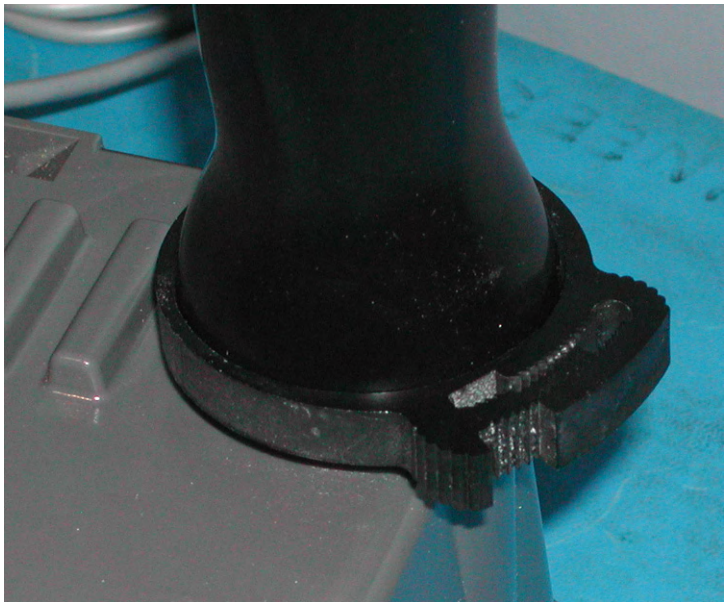
NOTE: Do not close zip ties before fastening to the cable. Once closed, ties cannot be opened again.

f. Fasten the base and CT to the cable by using two zip ties (HD plastic zip ties included); place one in front and one in back.

Figure 13 HD Plastic Zip Ties

Figure 14 Hose Clamp for PC FCI

g. Position the two plastic hose clamps to secure the CT top to the base.



h. Use CHANNELLOCK®-type pliers or a similar tool to tighten the hose clamps.

Figure 15 CT Module Installed on Phase Conductor

i. Repeat *Step a* through *Step g* for the C-phase.

NOTE: Ensure that the arrow points into the zone of detection.

Step 2. Install the SEL-8315 control electronics module on the B-phase conductor by the same method as *Step 1*. Be sure that the arrow is pointing toward the zone of detection. *Figure 16* shows the installation of half of the PC FCI system.

Figure 16 Control and CT Modules Installed on Left Half of Three-Phase Conductors

NOTE: Ensure that the arrow points into the zone of detection.

Step 3. Repeat *Step 1* and *Step 2* to install the other half of the PC FCI units on the other end of the monitored cable section.

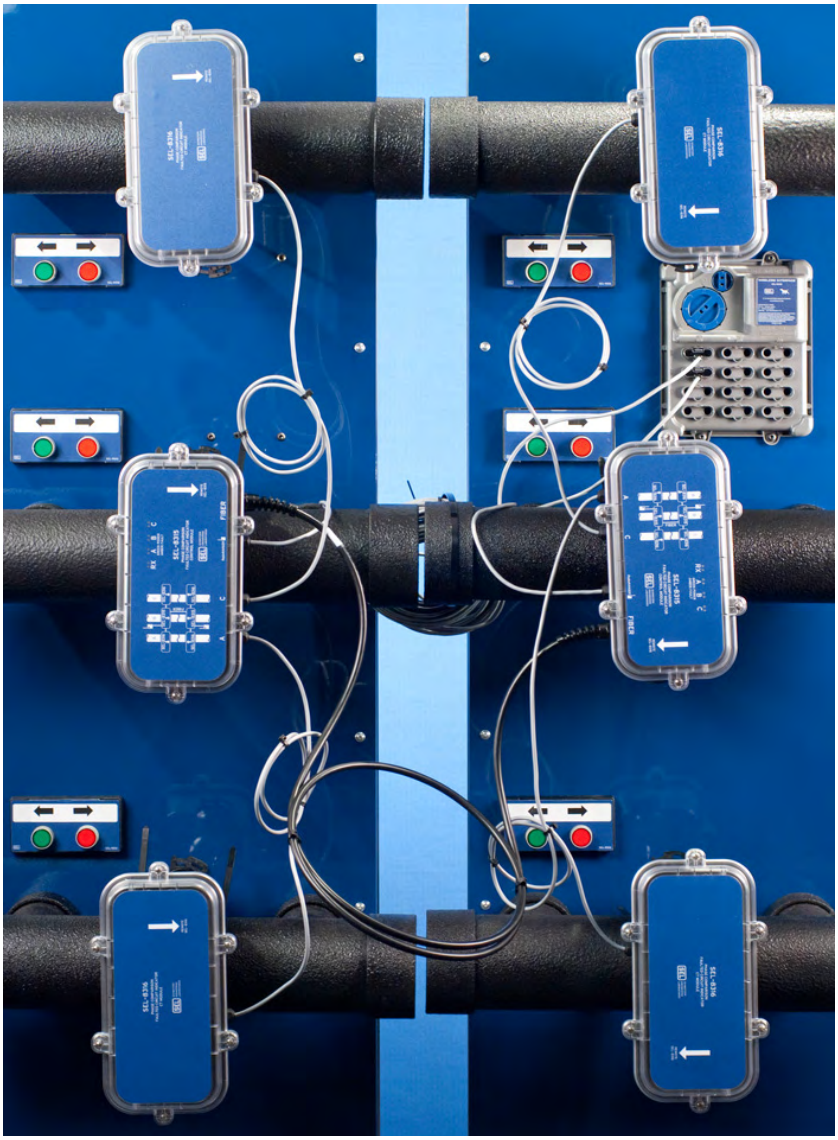


Figure 17 Assembled Control and CT Modules on the Phase Conductor

Step 4. Remove the top cover from both SEL-8315 units in preparation for A-phase, C-phase, and fiber-optic cable connection.

Step 5. Put on the supplied ESD wrist strap and connect it to the printed circuit board **ESD STRAP** connector as shown in *Figure 18*.

Step 6. On the SEL-8315, remove the A-phase locking nut and route the cable through the A-phase hole.

Step 7. Install the locking nut and torque it to 1.69 Nm–2.26 Nm (15–20 in-lb).

Step 8. Repeat *Step 6*–*Step 7* for C-phase.

Step 9. Connect the SEL-8316 A-phase terminal lugs to the A-phase terminal block on the SEL-8315 control module.

Step 10. Repeat *Step 9* for the C-phase SEL-8316.

Step 11. Repeat *Step 9* and *Step 10* for the other side of the PC FCI system to connect the A- and C-phase SEL-8316 to the SEL-8315.

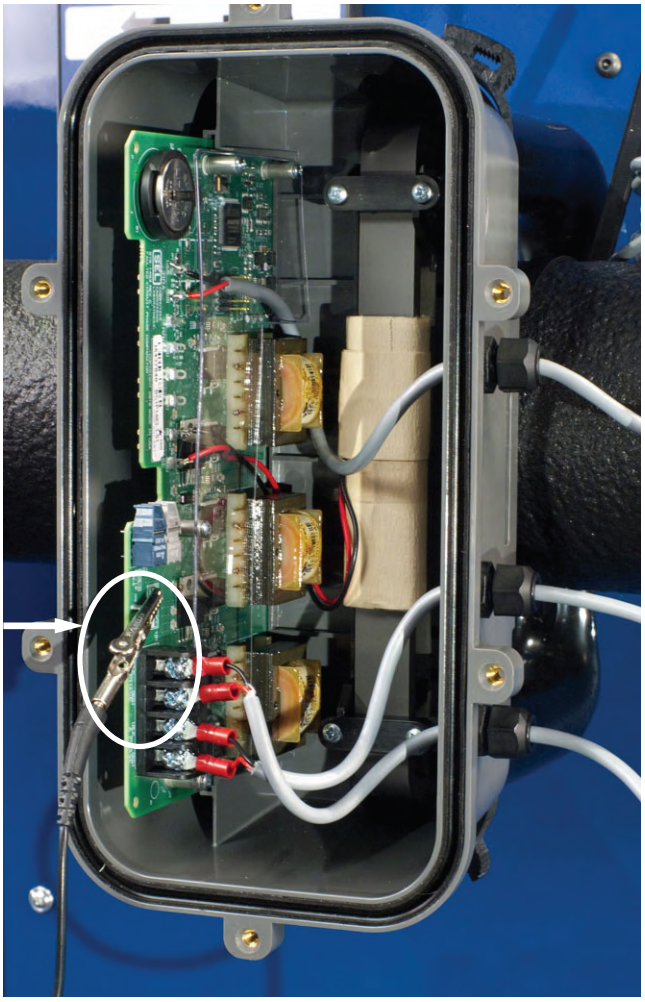


Figure 18 Control Module With Cover Removed

Step 12. On the SEL-8315 units, remove the fiber-optic locking nut and route the fiber-optic cable through the hole.

Step 13. Install the locking nut and torque it to 4.5 Nm–5 Nm (40–45 in-lb).

Step 14. Plug the fiber-optic cable into the receptacle. For multimode short-haul, use *Step a*. For multimode long-haul, use *Step b*.

a. For multimode short-haul, plug the fiber cable end with the blue marker into the blue fiber receptacle, and the unmarked fiber cable into the gray receptacle, as shown in *Figure 19*.

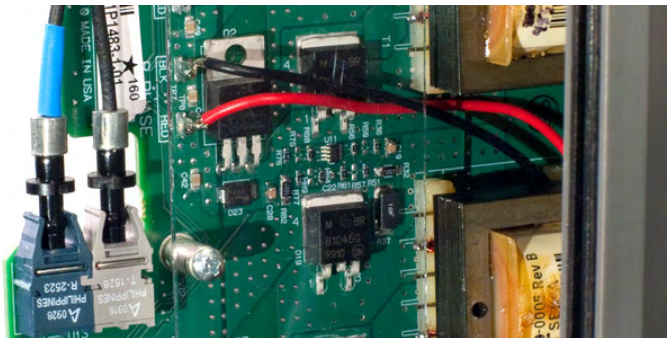


Figure 19 Proper Fiber-Optic Cable Installation, Multimode Short-Haul

b. For multimode long-haul, plug the fiber cable end with the blue marker into the gray fiber receptacle, and the unmarked fiber cable into the black receptacle, as shown in *Figure 20*.

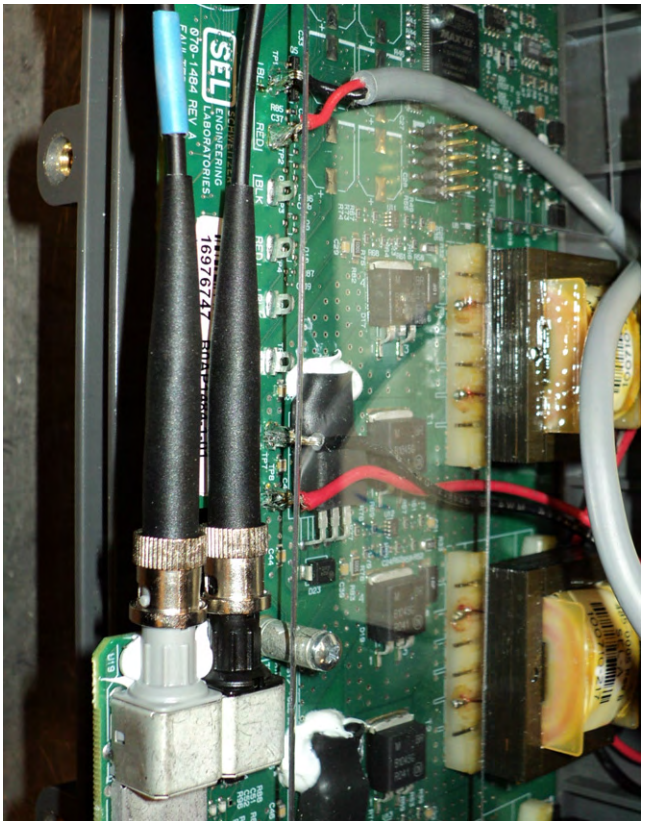


Figure 20 Proper Fiber-Optic Cable Installation, Multimode Long-Haul

Step 15. Use the same method from *Step 12* through *Step 14* to install the fiber-optic cable in the second SEL-8315.

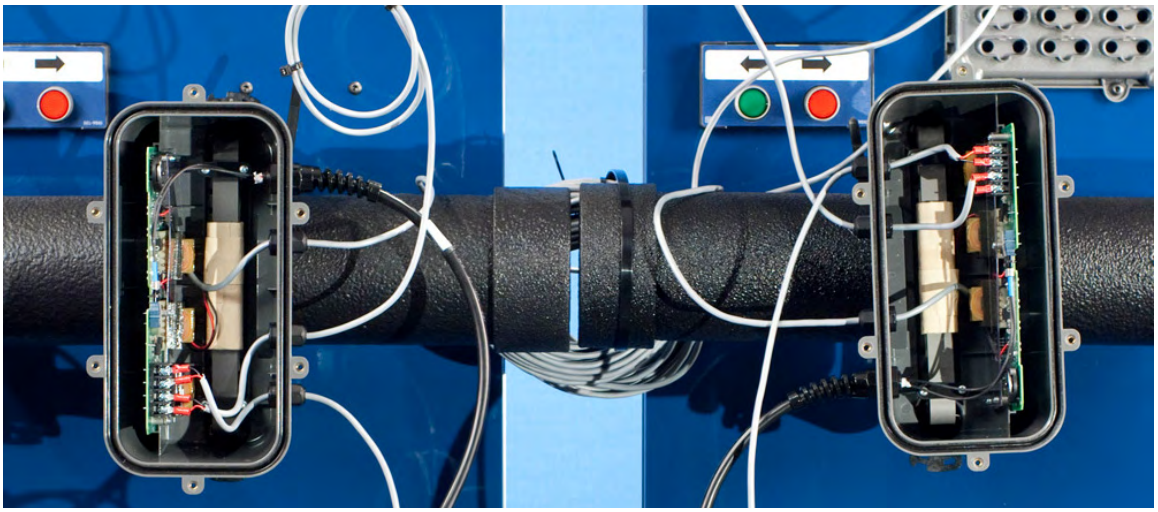


Figure 21 Fiber-Optic Cable Between the Control Modules

Step 16. Disconnect the ESD strap and replace the top cover on both SEL-8315 units. Lightly tighten all the cover screws, then torque to 1 Nm (9 in-lb) in a criss-cross pattern.

Step 17. Plug the RadioRANGER probes from the SEL-8315 units into the RadioRANGER SEL-8300 Wireless Interface, as shown in *Figure 22*. Probes can be inserted in any phase or way location desired. PC FCI information will be displayed on the SEL-8310 Remote Fault Reader consistent with the locations selected on the SEL-8300 Wireless Interface.

Step 18. Turn on the SEL-8300 Wireless Interface, and use the large dial to select a wireless ID number.

Step 19. Turn on the SEL-8310 Remote Fault Reader, and hold the SEL-8310 between four to thirty feet from the SEL-8300 Wireless Interface. Press the scan button to verify that the system correctly reports the status of the PC FCI. See the RadioRANGER Instruction Manual for more details on the wireless fault indication system.

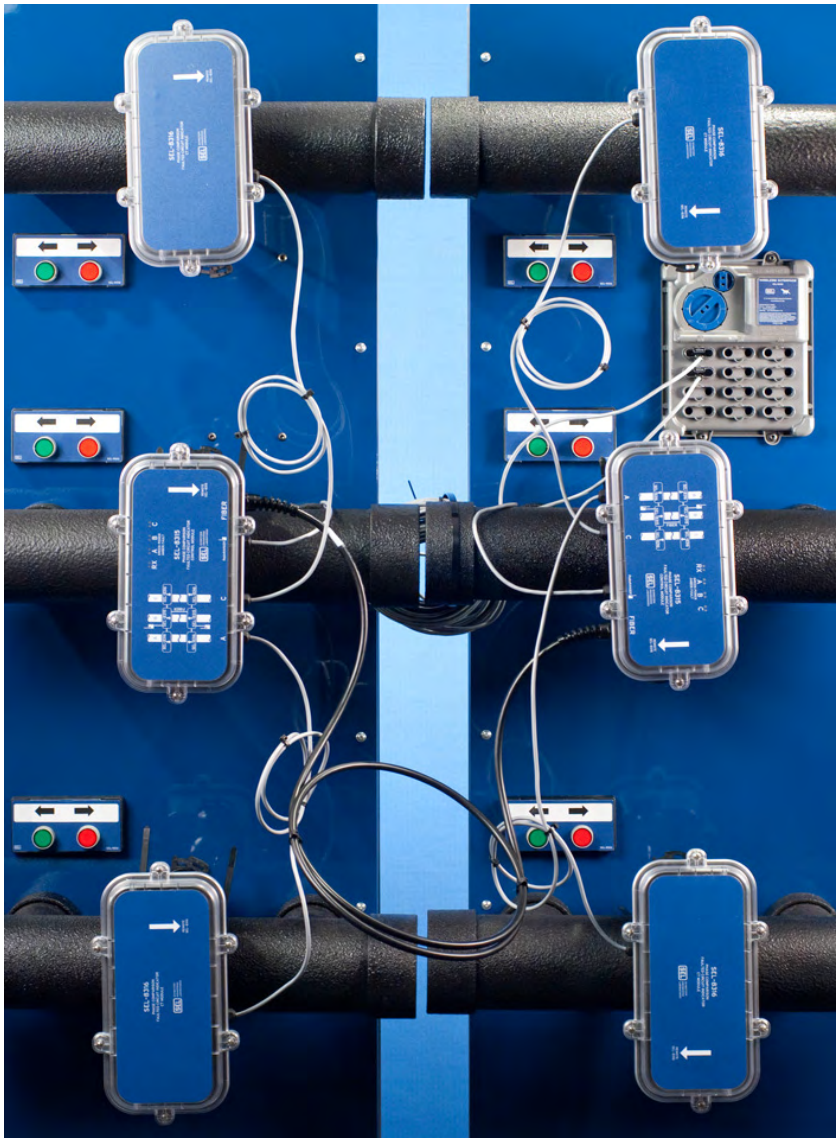


Figure 22 Reassembled Phase Comparison System With Control Module Plugged Into the Wireless Interface Module

Dimensions

PC FCI CONTROL ELECTRONICS SEL-8315

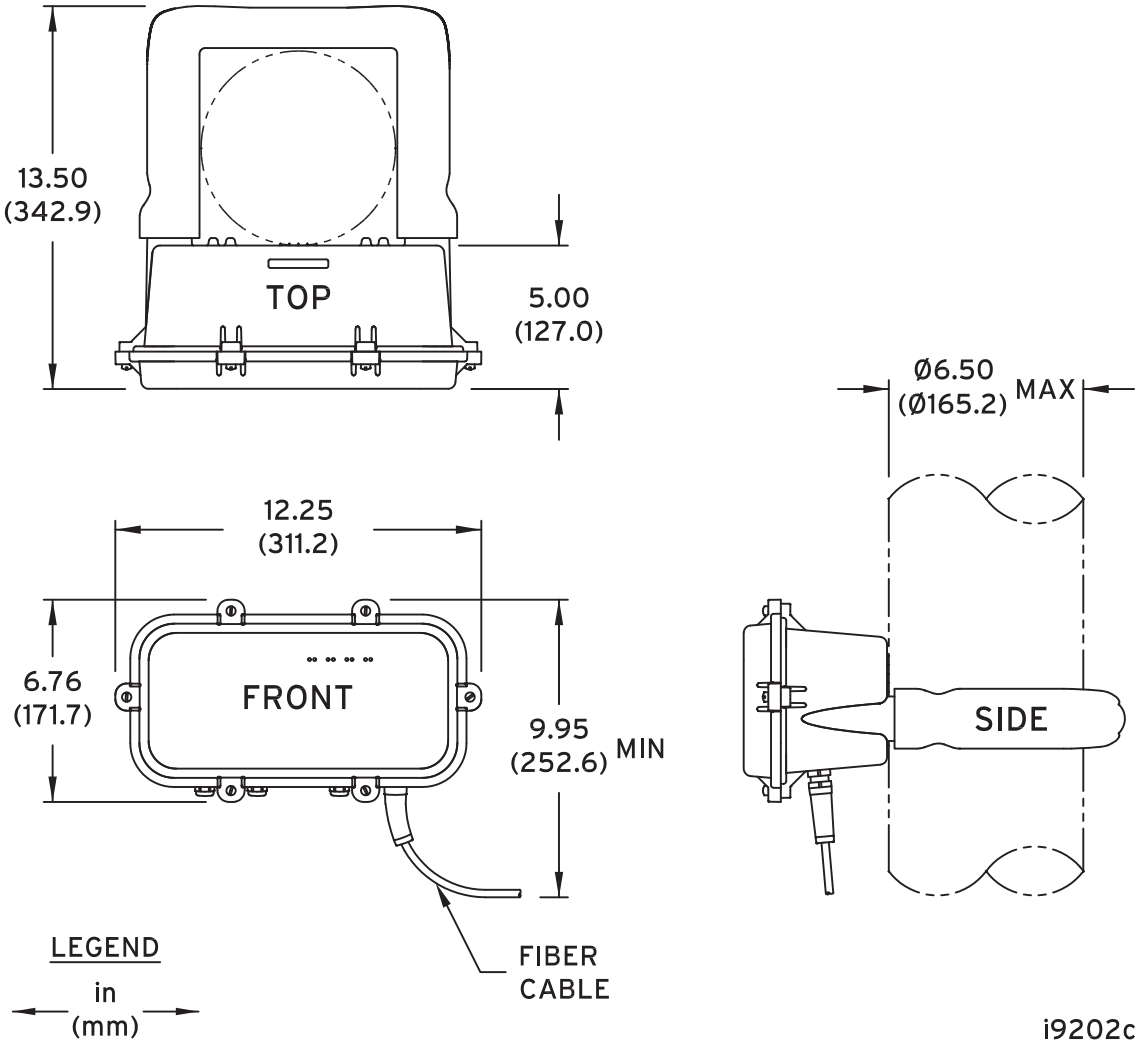


Figure 23 SEL-8315 Control Electronics Module Dimensions

PC FCI SPLIT-CORE SENSOR SEL-8316

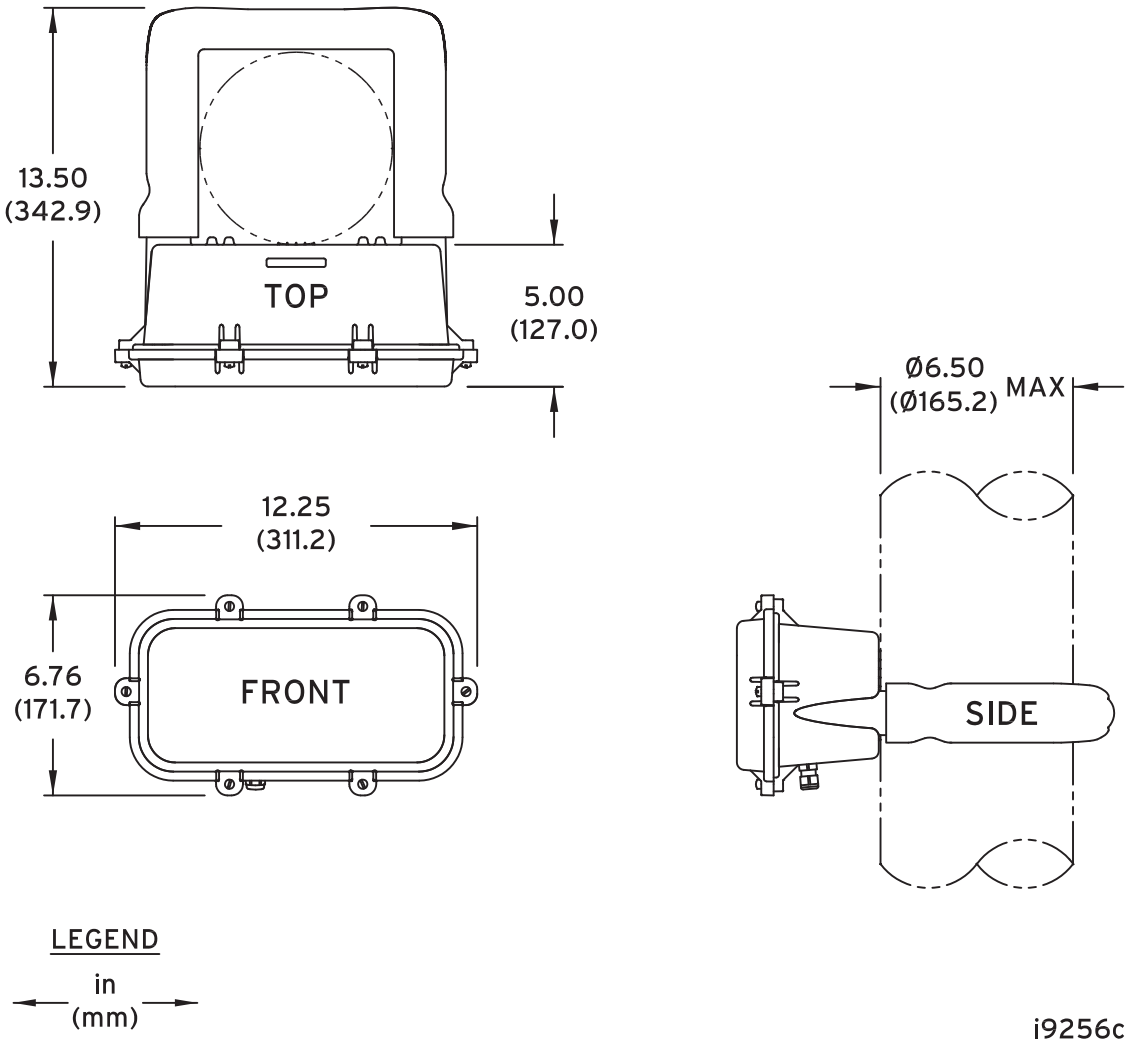


Figure 24 SEL-8316 Split-Core Sensor Module Dimensions

Battery Safety

⚠CAUTION
This product is shipped with or contains a lithium metal cell. Lithium metal cells and batteries may present a risk of fire or explosion. Do not short circuit, recharge, puncture, incinerate, crush, drop, disassemble, immerse, or incorrectly install lithium metal cells or batteries. Do not expose lithium metal cells or batteries to temperatures that are above the declared operating temperature range of this product. This product must be disposed of in accordance with all applicable rules, laws, and regulations, such as EPA's Universal Waste Rule, the EU Batteries Directive and other local rules.

This product is shipped with or contains a lithium metal cell. Lithium metal cells are often classified as dangerous goods by dangerous goods shipment regulations. These regulations along with your package carrier specify the packaging and labeling to be used, along with the information to be provided when shipping dangerous goods. This product must be transported in accordance with all applicable rules, laws, and regulations, such as the rules published by the Pipeline and Hazardous Materials Safety Administration; the International Civil Aviation Organization; the International Air Transport Association; the Maritime Dangerous Goods Code; the UN Model Regulations on the Transport of Dangerous Goods and rules for inland, waterways, road and rail transportation, and others. Please consult any applicable regulations and your package carrier for proper handling of this product.

Specifications

General

Phase Comparison Control Electronics

The FCI system can be powered by any one phase sensor, i.e., the Control Electronics unit or Split-Core CT unit, in a three-phase set.

Operation Ranges

Minimum Operating Current:	150 A (Note: Any phase measuring more than 150 A will power the three-phase set)
Maximum Continuous Operating Current:	2000 A
Maximum Fault Current:	40 kA, symmetrical, 6 cycles

Fault Detection Time

Pre-Fault Current <150 A

150 A to 200 A Fault:	35 ms max, <25 ms typical
200 A to 800 A Fault:	30 ms max, <16 ms typical
800 A Fault or Greater:	15 ms max, <8 ms typical

Pre-Fault Current >150 A for >30 ms

150 A or Greater:	15 ms max, <7 ms typical

Fault Detection Reset

The FCI automatically resets when the following conditions persist for one second:

Current is detected on any one phase.
No fault is detected on any phase.

Fiber Optics

Multimode Short-Haul

Transmission Distance:	250 m
Cable Type:	Multimode: 200 µm
Connector Type:	V-pin

Multimode Long-Haul

Transmission Distance:	3100 m
Cable Type:	Multimode: 62.5 µm
Connector Type:	ST

Physical Characteristics

PC FCI Control Electronics Module

Control Module Width:	16.9 cm (6.67 in)
Control Module Height:	31.06 cm (12.23 in)
Control Module Depth:	32.49 cm (12.79 in)
Weight:	8 lbs

PC FCI Split-Core CT Module

CT Module Width:	17.17 cm (6.76 in)
CT Module Height:	31.06 cm (12.23 in)
CT Module Depth:	32.49 cm (12.79 in)
Weight:	7 lbs

RadioRANGER System Compatibility

SEL-8300 Wireless Interface
SEL-8310 Remote Fault Reader

Type Tests

Environmental Tests

Temperature Cycling:	IEEE 495-2007 Test 4.4.1; -40° to 85 C, 5 cycles
Trip Current:	IEEE 495-2007 Test 4.4.9; –40°, 20°, and 85°C
Reset:	IEEE 495-2007 Test 4.4.10; –40°, 20°, and 85°C
Water Submersion:	IEEE 495-2007 Test 4.4.2; Submerged 15 ft, 5°, 25°, and 70°C

Electrostatic Discharge Test

ESD:	IEC 61000-4-2:2003 Level 4

RFI and Interference Tests

Radiated, Radio Frequency, Electromagnetic Field Immunity (RFI):	IEC 61000-4-3-2008 10 V/m
Immunity to Conducted Disturbance, Induced by Radio Frequency Fields:	IEC 61000-4-6 (2006) 10 V

High-Current Tests

Short-Time Current:	IEEE 495-2007 Test 4.4.7; 10 kA X/R = 6
Effect of Current from Adjacent Conductors:	IEEE 495-2007 Test 4.4.8; 25 kA X/R = 20, Conductor 18 inches from FCI

Vibration and Shock Tests

Shock and Bump:	IEC 255-21-2 (T) Class 1 (Bump Test, Shock Withstand), Class 2 (Shock Response)
Sinusoidal Vibration:	IEC 255-21-1 (T) Class 1 (Vibration Endurance), Class 2 (Vibration Response)

Other Mechanical Tests

Electric Cord Pull-Out:	IEEE 495-2007 Test 4.4.5; 30 lbs, 1 hour
Salt Fog:	IEEE 495-2007 Test 4.4.4; 5% solution, 96 hour exposure
Submersion/Water Resistance:	Submersible to 4.57 m (15 ft)

Notes

⚠WARNING
Operator safety may be impaired if the device is used in a manner not specified by SEL.

⚠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.

⚠CAUTION
There is danger of explosion if the battery is incorrectly replaced. Replace only with Ray-O-Vac® no. BR2335 or equivalent recommended by manufacturer. Dispose of used batteries according to the manufacturer's instructions.

⚠CAUTION
Class 1 LASER Product. This product uses visible or invisible LASERs based on model option. Looking into optical connections, fiber ends, or bulkhead connections can result in hazardous radiation exposure.

⚠AVERTISSEMENT
La sécurité de l'opérateur peut être compromise si l'appareil est utilisé d'une façon non indiquée par SEL.

⚠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.

⚠ATTENTION
Il y a un danger d'explosion si la pile électrique n'est pas correctement remplacée. Utiliser exclusivement Ray-O-Vac® No. BR2335 ou un équivalent recommandé par le fabricant. Se débarrasser des piles usagées suivant les instructions du fabricant.

⚠ATTENTION
Produit LASER de Classe 1. Ce produit utilise des LASERS visibles ou invisibles dépendant des options du modèle. Regarder vers les connecteurs optiques, les extrémités des fibres ou les connecteurs de cloison peut entraîner une exposition à des rayonnements dangereux.

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This product is covered by the standard SEL 10-year warranty. For warranty details, visit selinc.com or contact your customer service representative.

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