WSO-11

Wireless Sensor for Overhead Lines

Instruction Manual

20171010

SCHWEITZER ENGINEERING LABORATORIES, INC.

PMWS011-01

PMWSO11-01

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Preface

Overview

The WSO-11 Instruction Manual describes how to install, operate, and troubleshoot the WSO-11 Wireless Sensor for Overhead Lines.

An overview of each manual section and topics follows:

Preface. Describes the manual organization and conventions used to present information.

Section 1: Introduction and Specifications. Introduces WSO-11 features and lists the specifications.

Section 2: Installation. Describes radio activation and installation procedures for the WSO-11.

Section 3: Features. Describes the features and basic functionality of the WSO-11.

Section 4: Parameters and Settings. Describes the various WSO-11 settings and parameters that can be configured via over-the-air (OTA) updates.

Section 5: Maintenance. Describes the maintenance required over the product life of the WSO-11.

Section 6: Testing and Troubleshooting. Describes how to test and troubleshoot the WSO-11 in the field.

Appendix A: Firmware and Manual Versions. Lists the firmware and manual revision dates and describes the modifications.

Appendix B: Acronym List. Lists common abbreviations and terms used in the WSO-11 Instruction Manual.

Safety Information

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

Safety Symbols

The following symbols are often marked on SEL products.

	**CAUTION** Refer to accompanying documents.	**ATTENTION** Se reporter à la documentation.
	Earth (ground)	Terre
	Protective earth (ground)	Terre de protection
	Direct current	Courant continu
	Alternating current	Courant alternatif
	Both direct and alternating current	Courant continu et alternatif
	Instruction manual	Manuel d'instructions

Safety Marks

The following statements apply to this device.

Other Safety Marks

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.

General Information

Examples

This instruction manual uses several example illustrations and instructions to explain how to effectively operate the WSO-11. These examples are for demonstration purposes only; the firmware identification information or settings values included in these examples may not necessarily match those in the current version of your WSO-11.

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SEL trademarks appearing in this manual are shown in the following table.

AutoRANGER®

Technical Assistance

We appreciate your interest in SEL products and services. If you have questions or comments, please contact us at:

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Section 1
Introduction and Specifications

WSO-11 Product Overview

The WSO-11 wireless overhead sensor is a faulted circuit indicator (FCI) for distribution lines that measures and stores load information while monitoring a distribution line for loss-of-current and fault events. The sensor transmits packets over the On-Ramp Wireless RPMA® (Random Phase Multiple Access) Network, providing a secure and reliable communications link. The data on this network can be used for parsing and analysis, helping to reduce the time necessary to locate faults. Other features of the WSO-11 include its ability to monitor and report load current, trip threshold, and battery voltage, as well as the history of outages and events. The sensor transmits this information in a status update packet at a user-defined update interval. It also reports by exception any user-defined events, such as permanent faults, to the wireless network.

The WSO-11 employs SEL AutoRANGER technology to automatically select a trip threshold based on the monitored load current. This eliminates the need to specify a trip threshold at the time of ordering. A lithium cell with a 20-year shelf life provides sensor power, and materials in sensor construction are appropriate for a long service life in the harsh environment of an overhead power-line application.

Figure 1.1 WSO-11 Faulted Circuit Indicator

WSO-11 Physical Characteristics

The molded plastic housing material of the WSO-11 consists of an ultraviolet (UV)-stabilized polycarbonate resin suitable for outdoor applications. A spring-loaded stainless steel clamp is used to secure the device to overhead conductors. The housing features an ultrasonically welded lens containing a mechanical flag display and a hookeye for installation with a standard hot stick.

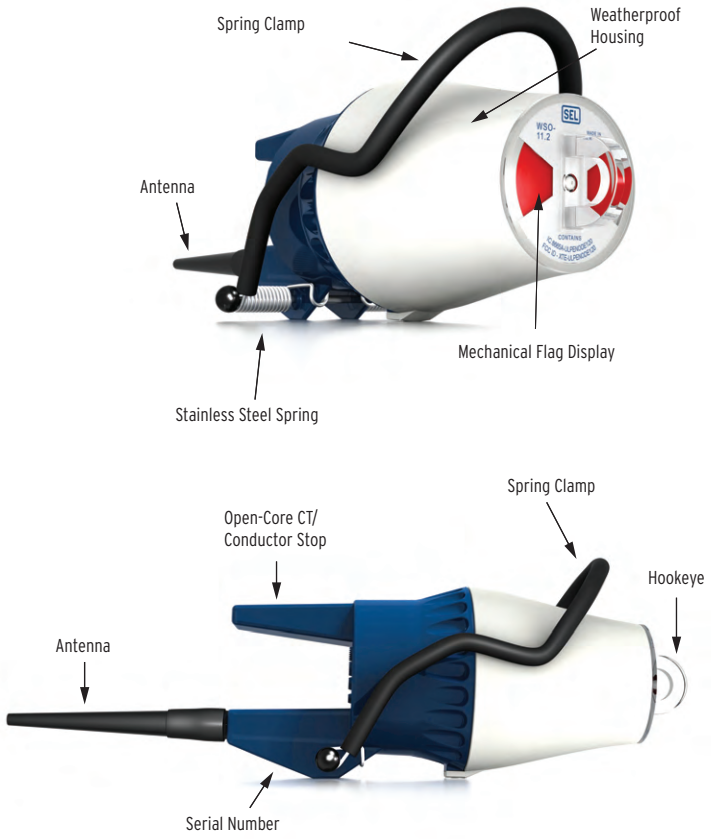

Figure 1.2 WSO-11 Physical Characteristics

Specifications

Compliance

Designed and manufactured under an ISO 9001 certified quality management system

General

Maximum Nominal System Voltage (L-L):	34.5 kV
Nominal Inrush Restraint Response Time:	75 ms
Outer Diameter Mounting Range:	4.1–38.1 mm (0.16–1.50 in)
Power:	High-capacity lithium battery with a 20-year shelf life

Fault Detection

Trip Threshold Range:	50–1200 A
Trip Threshold Accuracy (at 0.75" conductor diameter):	±30%
Maximum Fault Current:	25 kA
Nominal Trip Response Time:	24 ms (default)

Load Measurement

Current Range:	0–600 A
Current Measurement Accuracy (at 0.75" conductor diameter):	±25% (5–600 A)

Temperature

Operating:	–40° to +85°C (–40° to +185°F)
Storage:	–40° to +85°C (–40° to +185°F)

Weight

728 g (1.6 lb)

Radio

Operating Frequency:	2.4 GHz ISM band
Report Status Update:	24 hours (default)
Network:	On-Ramp Wireless RPMA Network Infrastructure

Regulatory

Federal Communications Commission:	FCC Part 15, Subpart B (Unintentional Radiators)
Industry Canada:	ICES-003, Issue 5, Class B (Unintentional Radiators)

Type Tests

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

Electromagnetic Compatibility Immunity

Radiated Electromagnetic Field Immunity:	IEEE C37.90.2-2004 Severity Level: 20 V/m

Environmental

Temperature Cycling:	IEEE 495-2007 Test 4.4.1; 2 hours at –40°, +20°, and +85°C, 5 cycles
Rain:	MIL 810G 506.5, Procedure 1 Rain and Blowing Rain

Vibration

Vibration Resistance:	IEC 60255-21-1:1988 Class 2 Endurance Class 2 Response IEEE 495-2007 Test 4.4.6
Shock Resistance:	IEC 60255-21-2:1988 Class 1 Shock Withstand Class 2 Shock Response Class 1 Bump Withstand IEEE 495-2007 Test 4.4.6
Seismic:	IEC 60255-21-3:1993 Class 2 Quake Response IEEE 495-2007 Test 4.4.6

Regulatory Compliance

The radio module has been designed to meet the following standard: FCC-CFR Part 15.247 Radio Frequency Devices, Subparts A-General and B-Unintentional Radiators (testing is done at module level for Modular Approval).

FCC ID: XTE-ULPENODE120 or XTE-ULPD100
IC: 8655A-ULPENODE120 or 8655A-ULPD100

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions:

- This device may not cause harmful interference.
- This device must accept any interference received, including interference that may cause undesired operation.

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Section 2
Installation

Diagram and Dimensions

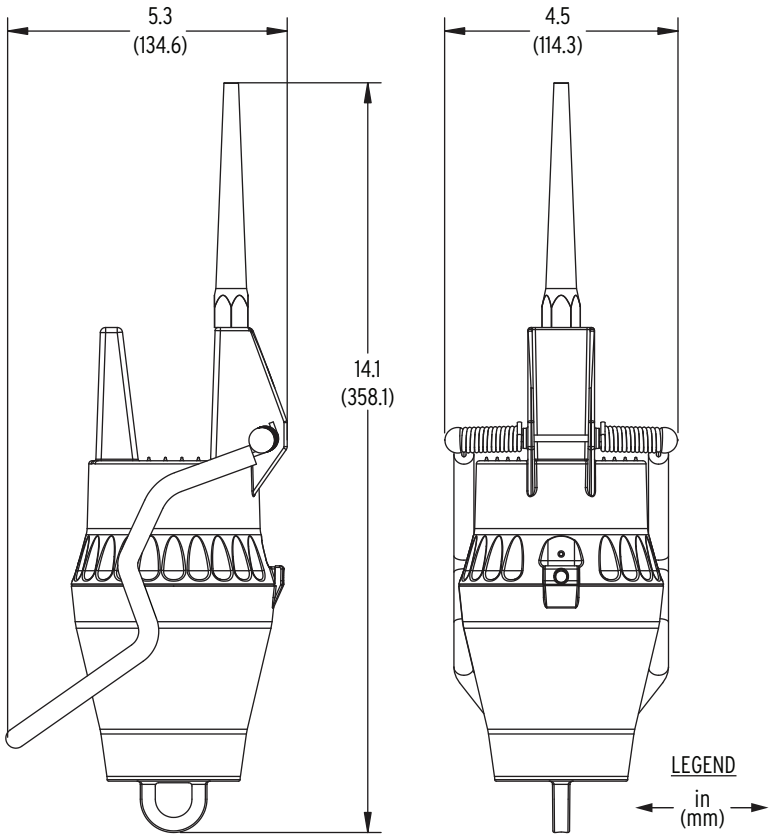

Figure 2.1 WSO-11 Dimension Drawing

Safety

⚠CAUTION
Install fault indicators 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 indicators and sensors.

Read and understand all instructions in their entirety before installing the WSO-11.

WSO-11 Radio Activation

CRSRTT Magnet Tool

CAUTION
Keep WSO-11 units away from permanent magnets, except for the magnet tool when used according to the following directions.

NOTE: Activating the radio of a WSO-11 device without connection to the On-Ramp Wireless RPMA® (Random Phase Multiple Access) Network coverage will reduce product battery life.

The CRSRTT magnet tool (SEL part number CRSRTT; see *Figure 2.2*) is used to activate and deactivate the integrated radio for wireless communication and manually reset the WSO-11 sensor. Remove the protective shorting bar before using the magnet tool, and replace the shorting bar after use.

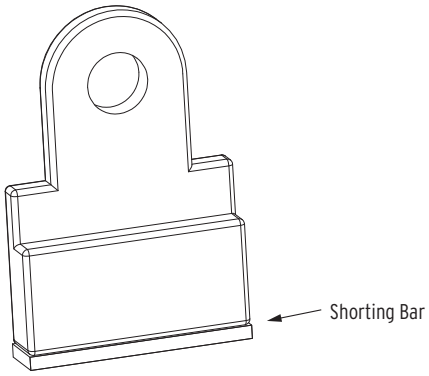

Figure 2.2 CRSRTT Magnet Tool

Radio Activation/ Deactivation

Step 1. Remove the shorting bar from the magnet tool.

Step 2. Use caution not to place the magnet tool near the mechanical flag display. Hold the exposed magnet over the **ACTIVATE** label (illustrated in *Figure 2.3*) on the WSO-11 for a minimum of ten seconds. (The mechanical flag display may move as a result of the magnetic field created by the magnet tool. Do not confuse this motion of the flag display assembly with reset or trip signals from the control circuitry).

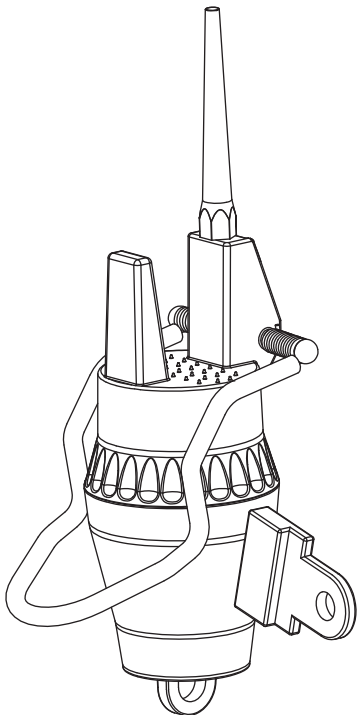

Figure 2.3 Radio Activation

NOTE: For end device configuration on the network gateway, contact On-Ramp Wireless. You must complete associated network settings prior to installing a WSO-11 device.

Step 3. Upon your removal of the magnet tool, the unit changes the state of the flag display to indicate proper application of the magnet tool. A tripped display (red flag visible) indicates radio activation. A reset display (red flag not visible) indicates deactivation of the radio.

You can activate or deactivate the unit with the display in either the tripped (red flag visible) or reset (red flag not visible) position. The final state of the display, five seconds after the removal of the magnet tool, indicates the state of the radio. A final display state of tripped indicates an activated radio, while a reset state indicates that the radio is deactivated. The flag may change state twice (if necessary) to indicate proper application of the magnet tool and the state of the radio.

Step 4. Replace the shorting bar on the magnet tool for storage.

WSO-11 Installation

Mounting Considerations

⚠CAUTION
Do not attempt to slide the WSO-11 along the conductor to move its position. To reposition the WSO-11, remove the sensor from the line and reinstall it at the correct location.

To reduce hazards associated with the unit falling from the line because of excessive vertical oscillation, do not install the WSO-11 sensor mid-span, over roadways, etc. Vertical oscillation of the overhead conductor occurs mainly because of wind, with the greatest amplitude in the center between two poles. Placement of the WSO-11 closer to the pole significantly reduces exposure of the WSO-11 to vertical oscillation.

To ensure optimal WSO-11 function, install the WSO-11 with spacings according to *Figure 2.4*.

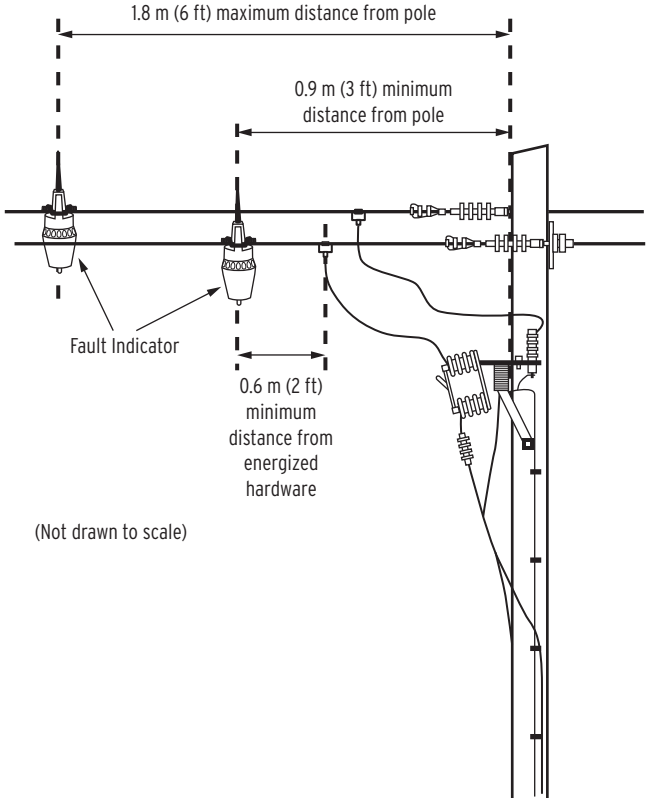

Figure 2.4 Spacing Requirements

Installation

⚠CAUTION
Do not handle or grasp the WSO-11 by the integral antenna. Doing so can damage the antenna or the antenna seal.

The WSO-11 sensor is intended for use on overhead conductors. For AutoRANGE mode, the WSO-11 requires a continuous load current greater than or equal to the Current Detection Hysteresis Threshold parameter (I_{HYS}). The I_{HYS} default value is 5 A (rms) when the sensor is installed on a conductor with an outside diameter of 0.75". In Low-Current mode, the WSO-11 will arm after being unarmed for the duration of the user-defined time period Low-Current Enter (T_{LC_ENTER}).

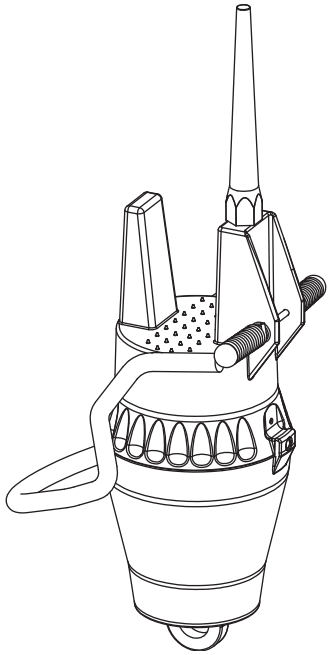

Figure 2.5 WSO-11 Installation

Step 1. Use a hot stick to grasp the hookeye on the face of the wireless sensor (see *Figure 2.6*).

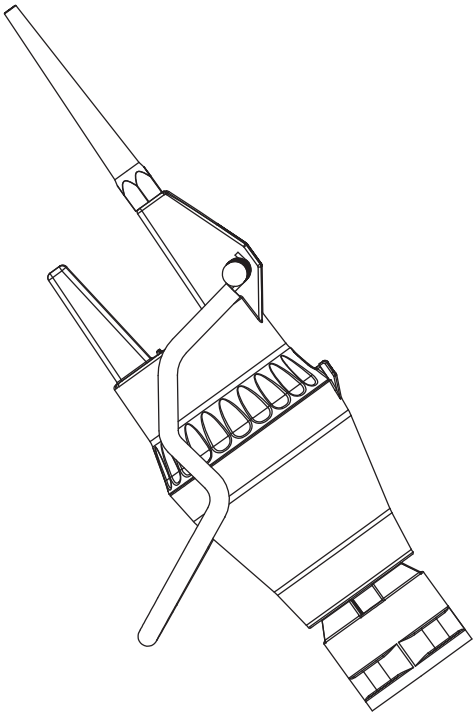

Figure 2.6 Installation Step 1

Step 2. Position the WSO-11 so that the end of its spring clamp fits behind the conductor (see *Figure 2.7*).

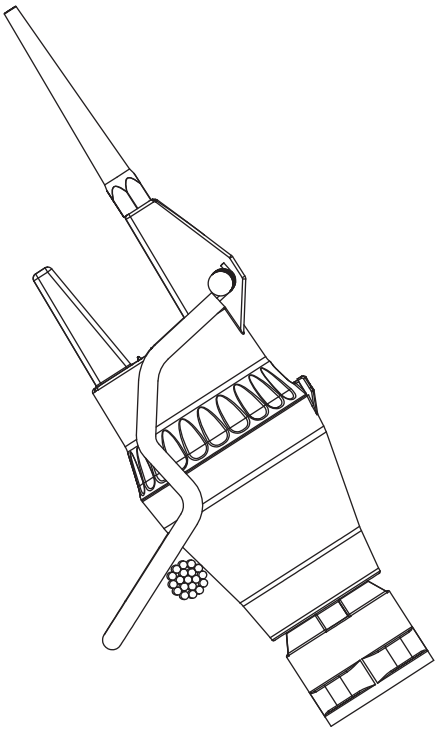

Figure 2.7 Installation Step 2

Step 3. Apply force on the spring clamp by pulling downward on the WSO-11 (see *Figure 2.8*).

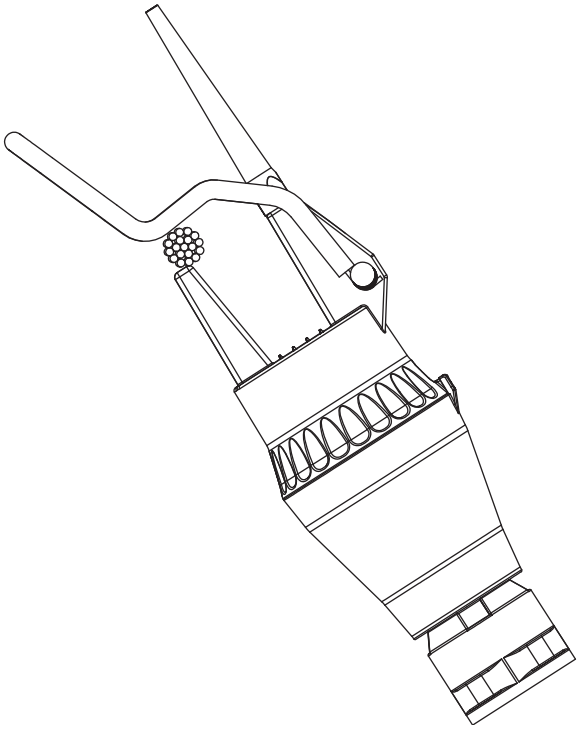

Figure 2.8 Installation Step 3

Step 4. Slide the wireless sensor onto the conductor. Position the conductor between the conductor stop and the spring clamp (see *Figure 2.9*).

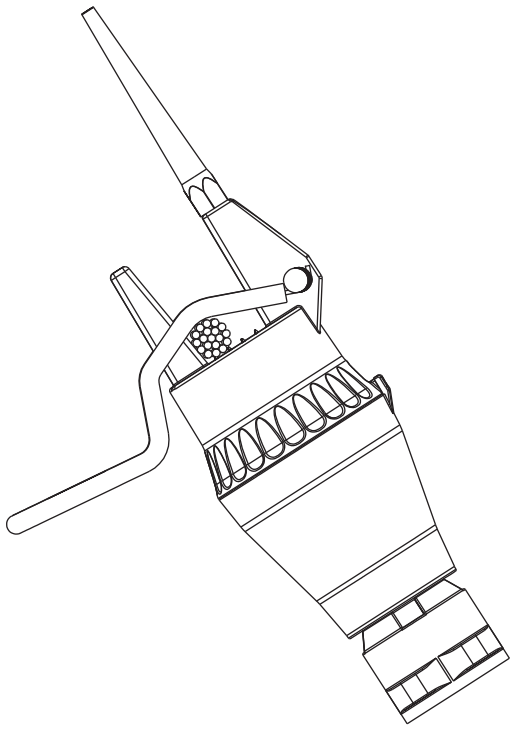

Figure 2.9 Installation Step 4

Step 5. Release the hot stick from the WSO-11 hookeye (see *Figure 2.10*).

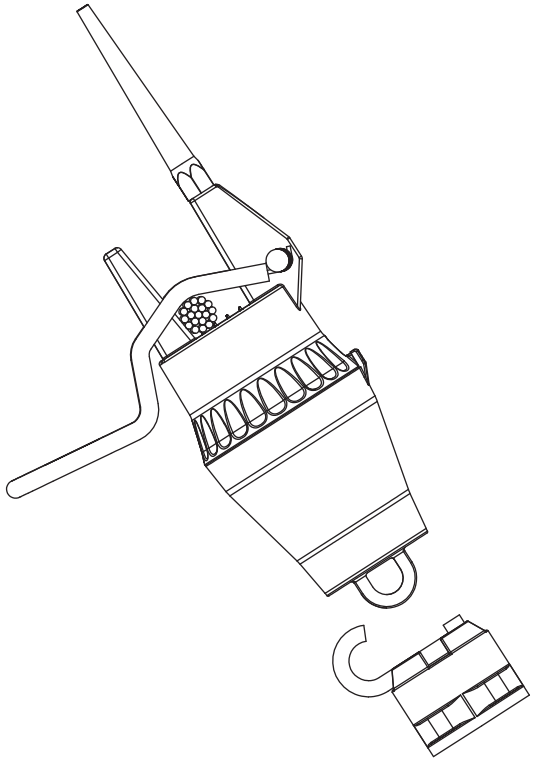

Figure 2.10 Installation Step 5

Step 6. Position the unit so that the hookeye points towards the ground (see *Figure 2.11*).

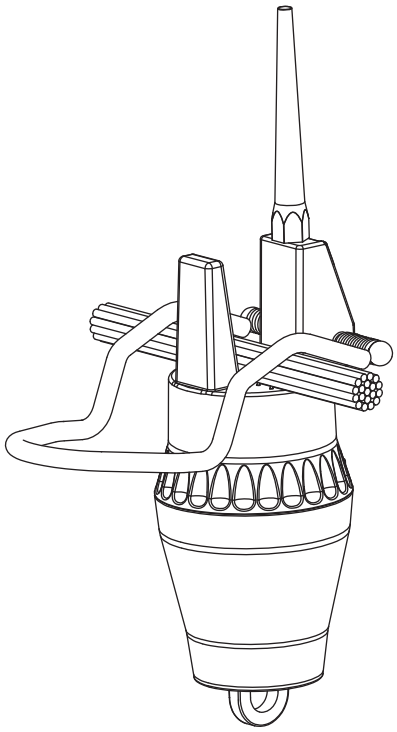

Figure 2.11 Installation Step 6

The WSO-11 generates an exception deployment packet (by default) after it joins the RPMA® (Random Phase Multiple Access) Network. It generates an exception restoration packet (by default) when it arms for event detection. In addition to the exception packets, the unit resets the mechanical flag display (red flag not visible) to indicate that the device has joined the network, is armed, and is ready to detect events.

Removal

Step 1. Use a hot stick to grasp the hookeye on the face of the wireless sensor (see *Figure 2.12*).

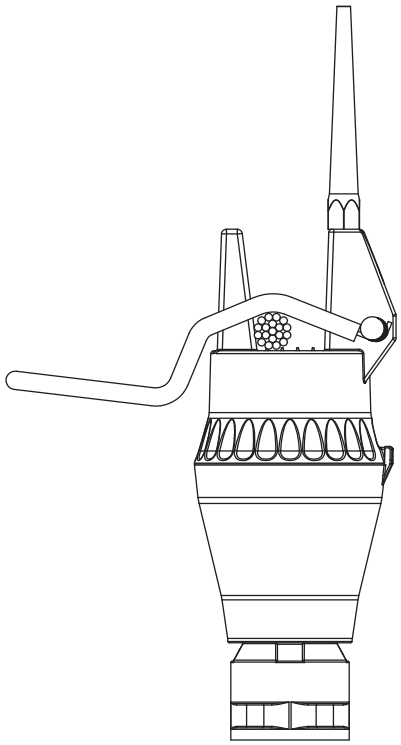

Figure 2.12 Removal Step 1

Step 2. Pull downward on the hot stick until high resistance is felt (see *Figure 2.13*).

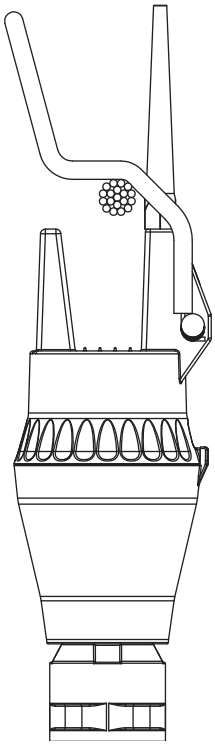

Figure 2.13 Removal Step 2

Step 3. Rotate the WSO-11 until the unit is removed from the conductor (see *Figure 2.14* and *Figure 2.15*).

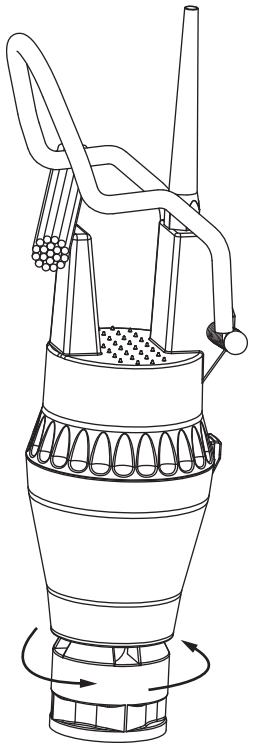

Figure 2.14 Removal Step 3 Part I

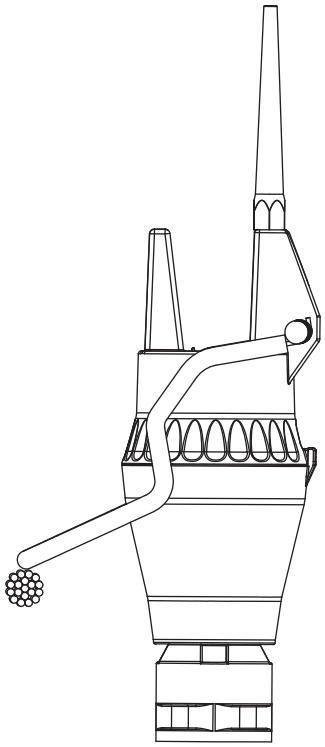

Figure 2.15 Removal Step 3 Part II

Step 4. Deactivate the internal radio. See *Radio Activation/ Deactivation* for the radio deactivation procedure.

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Section 3
Features

Overview

This section includes the following:

- *Basic Functionality*
  - *User Interface*
  - *Over-the-Air (OTA) Functionality*
- *AutoRANGE Mode*
  - *Device Arming*
  - *AutoRANGE Logic*
  - *Loss-of-Current Detection*
  - *Fault Detection*
  - *Load Pickup Event*
  - *Dynamic Delayed Trip*
  - *Backfeed Restraint*
  - *Load Data*
- *Low-Current Mode*
  - *Entering Low-Current Mode*
  - *Low-Current Fault Detection*
  - *Reset*
  - *Exiting Low-Current Mode*
- *Data Packet Types*
  - *Periodic Packets*
  - *Exception Packets*
- *Time Stamps*
- *Radio*
- *System Self Diagnostics*

Basic Functionality

User Interface

Display

The mechanical flag display on the WSO-11 provides indication of multiple device conditions: the state of the radio (on/off), the radio's connectivity to the On-Ramp Wireless RPMA® (Random Phase Multiple Access) Network, and indication of various events (tripped/reset). The mechanical flag display will always display a permanent fault event, but can also be configured to indicate other system events. The mechanical flag display can also be configured to remain tripped for a user-defined time or can be reset upon the restoration of current. See *Flag Reset Type*, *Flag Timed Reset*, and *Flag Indication on page 4.4* for more information about setting the mechanical flag behavior.

Figure 3.1 Mechanical Flag Display (Tripped)

Figure 3.2 Mechanical Flag Display (Not Tripped/Reset)

The On-Ramp Wireless Total View application can provide a web-based human-machine interface (HMI) to display sensor data outlined in this manual.

Product Identification

To aid product tracking and field deployment, each sensor housing is pin-stamped with product identification information as shown in *Figure 3.3*. The MAC address, used to designate each data packet to a particular unit, is a subset of the product serial number.

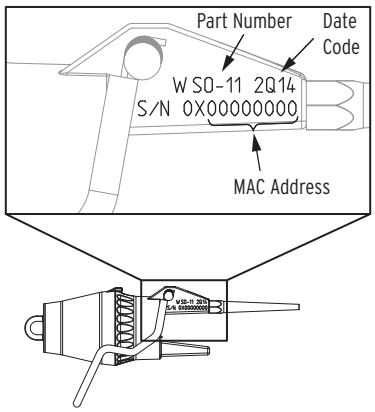

Figure 3.3 Product Identification Information

Over-the-Air (OTA) Functionality

NOTE: All OTA firmware updates and setting changes intended for the WSO-11 will impact battery performance.

NOTE: Firmware updates intended for other products on the RPMA Network or for other versions of the WSO-11 are invalid. Invalid firmware updates are not downloaded, and they have no effect on battery life.

NOTE: After a hardware restart or reset command, the WSO-11 will be unarmed in AutoRANGE mode. See Device Arming and Entering Low-Current Mode for details on device arming following an OTA update.

You can use built-in over-the-air (OTA) functionality to reprogram WSO-11 devices in the field. The ability to reprogram devices in the field is crucial for large deployments of wireless fault indicators.

The WSO-11 accepts a new firmware image or settings change when it becomes available from the RPMA Network. The device first validates the new firmware and then uses the new firmware image to reprogram the unit.

The WSO-11 remains fully operational during OTA downloading and during the reprogramming process. After it reprograms to a new firmware image, the device performs a hardware restart and then is momentarily unarmed in AutoRANGE mode. The unit must rejoin the network and rearm; see *Device Arming* or *Entering Low-Current Mode* for details. The device sends a deployment packet (by default) after it rejoins the network and sends a restoration packet (by default) after it becomes armed in either AutoRANGE or Low-Current mode.

If necessary, you can send a reset command to a particular WSO-11 without resetting every unit installed on the network. You can perform a device reset via a downlink command from the web-based HMI display. You can also reset the integrated radio separately from the WSO-11 via a downlink command. Contact On-Ramp Wireless for details on performing reset commands for WSO-11 devices connected to the RPMA Network.

See *Section 4: Parameters and Settings* for information on the WSO-11 parameters you can set using OTA updates.

Upgrade Firmware

NOTE: Failure to download a compatible configuration file before a firmware upgrade attempt will cause a device outage.

Contact SEL for a new firmware image or a new configuration file. Contact the On-Ramp Wireless for detailed instructions on how to perform over-the-air firmware upgrades or settings changes to deployed devices.

Install a configuration file compatible with the new firmware image prior to upgrading the WSO-11 firmware. This prepares the WSO-11 to receive the new settings and is necessary for proper WSO-11 operation with the new firmware. The WSO-11 devices will disable the radio and drop off the network if new firmware is installed without a compatible configuration file.

AutoRANGE Mode

The WSO-11 uses AutoRANGER trip logic to detect faults on circuits with greater than 5 A load current while operating in AutoRANGE mode. While in Low-Current mode, functionality will vary (see *Low-Current Mode* for details).

Device Arming

NOTE: If the WSO-11 is not armed prior to a system event, it will not detect or report that event.

The WSO-11 must be armed prior to a system event to detect and report that event. The WSO-11 arms in AutoRANGE mode when it detects load current greater than the Current Detection Hysteresis Threshold (I_{HYS}) for longer than the System Detection Period (T_{SYS}). If the WSO-11 does not detect load current greater than I_{HYS}, it remains unarmed in AutoRANGE mode.

Figure 3.4 shows a sample load current (I_{LOAD}) profile (in rms) that results in the WSO-11 arming itself in AutoRANGE mode following a permanent outage. The WSO-11 will be armed at the end of T_{SYS}. It will also transmit a Restoration packet at the end of T_{SYS} if the Restoration Packet Exception parameter is enabled. See *Restoration Packet* for details on the restoration exception packets. See *Restoration Exception on page 4.2* for details on configuring the Restoration Exception parameter.

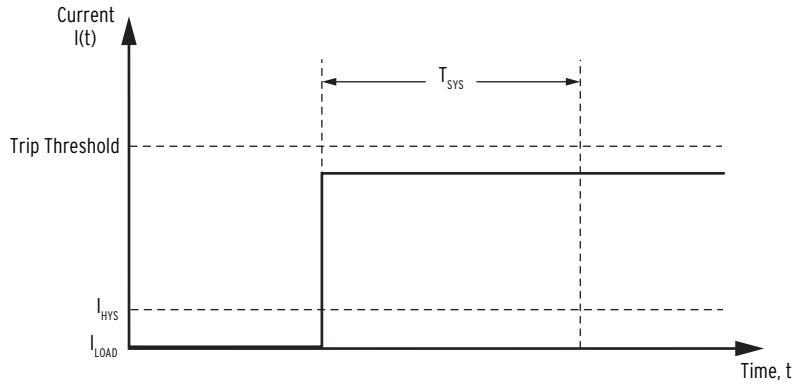

Figure 3.4 Device Arming in AutoRANGE Mode

For momentary outages (momentary faults, momentary LOC, disturbance, load pickup) the device will rearm in AutoRANGE mode at the end of the Momentary Fault Timeout (T_{FLT}) or Momentary LOC Timeout (T_{LOC}).

AutoRANGE Logic

The WSO-11 has eight distinct autoranging trip thresholds: 50 A, 100 A, 200 A, 400 A, 600 A, 800 A, 1000 A, and 1200 A. The unit automatically selects, or autoranges, to one of these eight trip thresholds according to the load current it measures. Each trip threshold has an associated load current range, as shown in *Table 3.1*.

Table 3.1 Trip Thresholds for Measured Load Current Ranges

Trip Threshold (A)	$I_{LOAD,min}$ (A)	$I_{LOAD,max}$ (A)
50	5	25
100	16.1	50
200	34.5	100
400	73.9	200
600	158.5	300
800	247.6	400
1000	339.7	500
1200	434.2	600

The WSO-11 measures system load current every 30 seconds (autoranging period—T_{AR}). According to this measurement, the unit either remains at its existing trip threshold or autoranges to a different trip threshold. This feature enables the WSO-11 to handle variable loads including seasonal and time-of-day fluctuations, simplifying specification, application, and stocking. *Table 3.1* lists the measured load current (I_{LOAD}) minimum and maximum values associated with the WSO-11 trip threshold. *Figure 3.5* graphically represents *Table 3.1*.

The period between load current measurements and trip threshold adjustments is T_{AR} = 30 seconds. If the trip threshold increases as a result of a transient load current, it readjusts with the next measurement 30 seconds later.

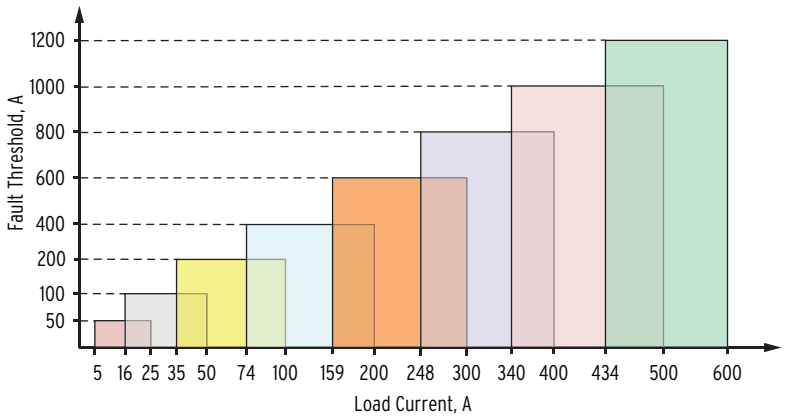

Figure 3.5 Self-Configured Trip Threshold as a Function of Load Current

The load current ranges overlap for each trip threshold. This provides hysteresis to the autoranging algorithm and prevents the WSO-11 from oscillating between trip thresholds. (If the load current ranges did not overlap, normal fluctuations in load current would cause the WSO-11 to oscillate between two trip thresholds.)

Figure 3.6 illustrates how overlapping load current cutoffs for adjacent trip thresholds stabilize the trip threshold, allowing the WSO-11 to select a single trip threshold.

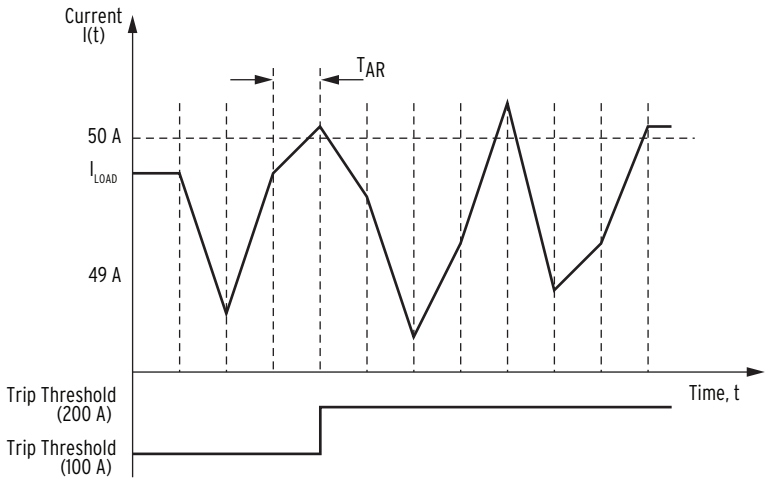

Figure 3.6 Stable Autoranging Algorithm

Loss-of-Current Detection

The WSO-11 will detect a loss of current (LOC) when the measured current falls below the hardware-defined Minimum Current Detection Threshold (I_{MIN}). The I_{MIN} threshold has a typical value of 3 A but will vary depending on cable diameter and temperature. The I_{MIN} threshold will range from 1 A to 5 A.

Permanent LOC

The WSO-11 uses the user-defined time delay parameter Momentary LOC Timeout (T_{LOC}) to distinguish between a momentary LOC and permanent LOC event. See *Section 4: Parameters and Settings* for information on setting the T_{LOC} timing parameter.

To register an LOC, the WSO-11 must be armed prior to the LOC condition. See *Device Arming* for details on arming.

Once armed, the WSO-11 detects an LOC when there is a system protection operation. When the load current decreases to less than the Minimum Current Detection Threshold (I_{MIN}) for longer than 75 ms (nominal), the WSO-11 registers an operation of the primary system protection. This will start the T_{LOC} timer.

If load current is below I_{MIN} when the T_{LOC} timer expires, the WSO-11 registers a permanent LOC event.

The WSO-11 then generates (by default) an exception report for a permanent LOC and increments the cumulative permanent LOC counter.

Reporting permanent LOC events by exception can be disabled if desired. See *Permanent LOC Exception on page 4.3* for details on disabling this parameter.

Figure 3.7 shows a sample load current (I_{LOAD}) profile (in rms) that results in the WSO-11 registering a permanent LOC event at the end of T_{LOC}.

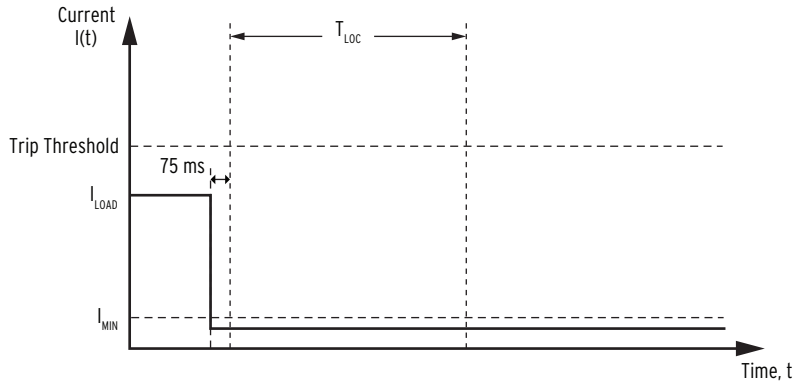

Figure 3.7 Permanent LOC Example

Momentary LOC

The WSO-11 uses the user-defined time delay parameter Momentary LOC Timeout (T_{LOC}) to distinguish between a momentary LOC and permanent LOC event. See *Section 4: Parameters and Settings* for information on setting the T_{LOC} timing parameter.

To register an LOC, the WSO-11 must be armed prior to the LOC condition. See *Device Arming* for details on arming.

Once armed, an LOC will be detected when there is a system protection operation. When the load current decreases to less than the Minimum Current Detection Threshold (I_{MIN}) for longer than 75 ms (nominal), the WSO-11 registers an operation of the primary system protection. This will start the T_{LOC} timer.

If load current above I_{MIN} is detected when the T_{LOC} timer expires, the WSO-11 registers a momentary LOC event.

The WSO-11 does not generate (by default) an exception report for a momentary LOC, but it increments the momentary LOC counter for appearance in the next periodic report.

Reporting momentary LOC events by exception can be enabled if desired. See *Momentary LOC Exception on page 4.3* for details on enabling this parameter.

Figure 3.8 shows a sample load current (I_{LOAD}) profile (in rms) that results in the WSO-11 registering a momentary LOC event at the end of T_{LOC}.

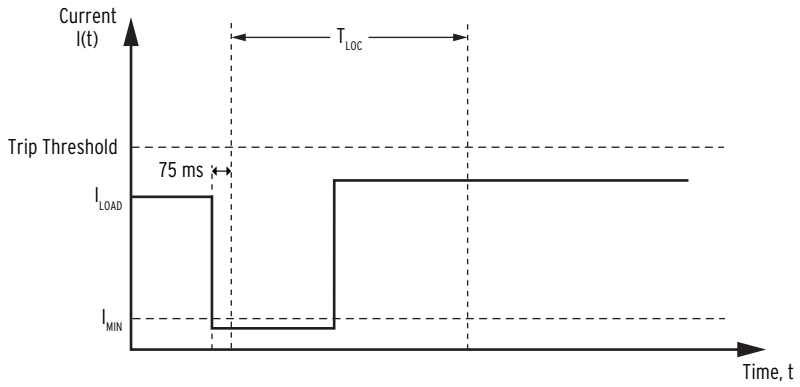

Figure 3.8 Momentary LOC Example

Inrush Restraint

A fault indicator applied on a circuit that uses a reclosing scheme should be able to distinguish between fault events and system energization inrush currents occurring during reclose attempts. Otherwise, the reclosing operations could falsely trip indicators installed on non-faulted line sections.

Any time measured system current drops below the Minimum Current Detection Threshold (I_{MIN}) for 75 ms (nominal), the WSO-11 enters into inrush restraint (IR) mode. The LOC detection timing parameter of 75 ms is a hardware-defined nominal setting that cannot be configured.

For permanent outages that exceed the Momentary Fault Timeout (T_{FLT}) or the Momentary LOC Timeout (T_{LOC}), the WSO-11 will remain in IR mode until current is restored and it rearms. The WSO-11 will not respond to any events until it has rearmed at the end of the System Detection Period (T_{SYS}). See *Device Arming* for details on the device arming requirements.

For permanent outages, the total time the WSO-11 is in IR mode is the entire outage duration plus T_{SYS}.

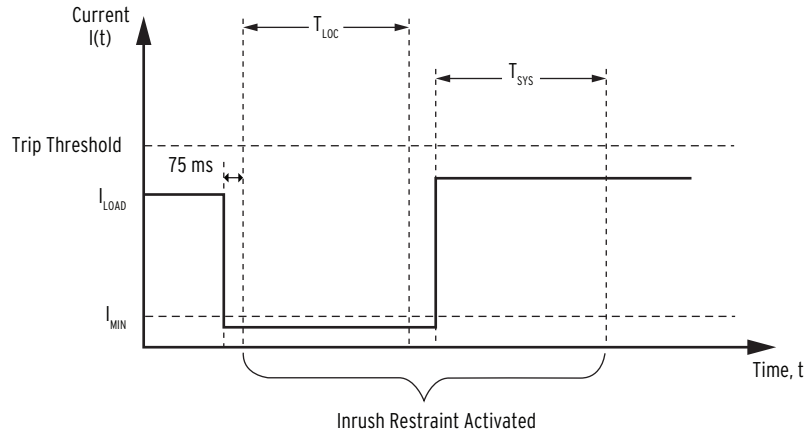

Figure 3.9 Permanent LOC Inrush Restraint Example

Figure 3.9 shows an example of a permanent loss-of-current event followed by a system restoration. The region labeled Inrush Restraint Activated indicates the time the WSO-11 will be in IR mode. Notice that the IR mode activates 75 ms after current drops below the I_{MIN} threshold. The inrush current resulting from system energization could exceed the trip threshold, but the WSO-11 will not register a fault event because it is in IR mode.

For momentary outages in which power is restored (load current is greater than I_{MIN}) prior to the T_{FLT} or the T_{LOC} timeout, the WSO-11 will be in IR mode only for the T_{FLT} or T_{LOC} period. At the end of the T_{FLT} or T_{LOC} period, the device will rearm.

The WSO-11 will be in IR mode for the T_{FLT} or T_{LOC} period for momentary LOC, momentary fault, disturbance, and load pickup events.

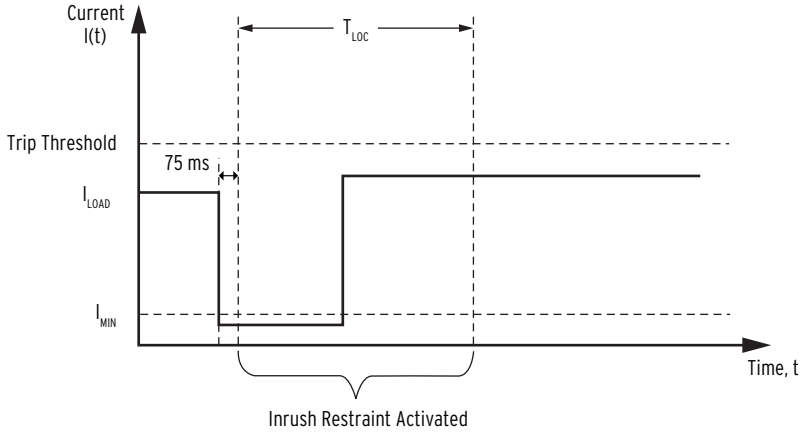

Figure 3.10 Momentary LOC Inrush Restraint Example

Figure 3.10 shows an example of a momentary loss-of-current event followed by a successful reclose. The region labeled Inrush Restraint Activated indicates the time the WSO-11 will be in IR mode. Notice that the IR mode activates 75 ms after current drops below the I_{MIN} threshold. The inrush current resulting from reclosing could exceed the trip threshold, but the WSO-11 will not register a fault event because it is in IR mode.

In *Figure 3.10*, I_{LOAD} is restored before time T_{LOC}, so the WSO-11 does not generate an exception report (by default). It does, however, increment the momentary LOC counter for appearance in the next periodic report.

Fault Detection

There are two requirements for the WSO-11 to indicate a fault condition. First, the fault current magnitude must exceed the self-configured trip threshold. Second, the current must exceed the trip threshold for the defined Dynamic Delayed Trip (DDT) (see *Dynamic Delayed Trip*), or number of half-cycles for each trip threshold. The WSO-11 will count each half-cycle that is above the trip threshold within 20 ms of the previous registered half-cycle above the trip threshold. If the WSO-11 does not detect current above the trip threshold within 20 ms of the previous half-cycle, then the DDT counter is reset.

If you have enabled the DDT parameter, the device indicates a fault if any trip threshold met the delay trip criterion and processed a fault event. If you have disabled DDT behavior, the unit only indicates a fault if the presently set trip threshold delay trip criterion was met.

The WSO-11 reports the highest trip threshold exceeded by the fault current in the exception packet for a permanent fault, momentary fault, or disturbance. The WSO-11 only transmits exception packets if the parameter for that event type is enabled. See *Section 4: Parameters and Settings* for details on configuring exception packets.

Permanent Fault

The WSO-11 uses the user-defined time delay parameter Momentary Fault Timeout (T_{FLT}) to distinguish between disturbance events, momentary faults, and permanent faults. See *Momentary Fault Timeout (T_{FLT}) on page 4.1* for information on setting the T_{FLT} timing parameter.

To register a fault and prevent false tripping because of inrush currents, the WSO-11 must be armed prior to the fault condition. See *Device Arming* for details on arming.

Once armed, the WSO-11 must detect fault current in excess of the self-configured trip threshold setting for a period longer than the DDT setting of that trip threshold. This will start the T_{FLT} timer.

To validate a fault event, the WSO-11 monitors for a system protection operation. The WSO-11 registers a system protection operation when there is a loss of current. When the current drops below the Minimum Current Detection Threshold (I_{MIN}) for longer than 75 ms (nominal), the WSO-11 registers an operation of the primary system protection.

If a valid loss of current is detected during the T_{FLT} time period, and load current is below I_{MIN} when the T_{FLT} timer expires, the WSO-11 registers a permanent fault event.

The WSO-11 then generates (by default) an exception report for a permanent fault and increments the cumulative permanent fault counter.

Reporting permanent fault events by exception can be disabled if desired. See *Permanent Fault Exception on page 4.3* for details on disabling this parameter.

Figure 3.11 shows a sample load current (I_{LOAD}) profile (in rms) that results in the WSO-11 registering a permanent fault event at the end of T_{FLT}.

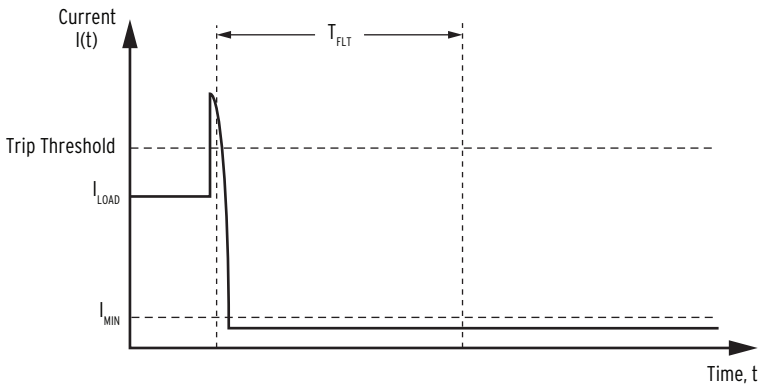

Figure 3.11 Permanent Fault Example

Momentary Fault

The WSO-11 uses the user-defined time delay parameter Momentary Fault Timeout (T_{FLT}) to distinguish between disturbance events, momentary faults, and permanent faults. See *Momentary Fault Timeout (T_{FLT}) on page 4.1* for information on setting the T_{FLT} timing parameter.

To register a fault and prevent false tripping because of inrush currents, the WSO-11 must be armed prior to the fault condition. See *Device Arming* for details on arming.

Once armed, the WSO-11 must detect fault current in excess of the self-configured trip threshold setting for a period longer than the DDT setting of that trip threshold. This will start the T_{FLT} timer.

To validate a fault event, the WSO-11 monitors for a system protection operation. The WSO-11 then registers a system protection operation when there is a loss of current. When the current drops below the Minimum Current Detection Threshold (I_{MIN}) for longer than 75 ms (nominal), the WSO-11 registers an operation of the primary system protection.

If a valid loss of current is detected during the T_{FLT} time period, and load current above I_{MIN} is detected when the T_{FLT} timer expires, the WSO-11 registers a momentary fault event.

The WSO-11 does not generate (by default) an exception report for a momentary fault, but it increments the momentary fault counter for appearance in the next periodic report.

Reporting momentary fault events by exception can be enabled if desired. See *Momentary Fault Exception on page 4.3* for more details on enabling this parameter.

Figure 3.12 shows a sample load current (I_{LOAD}) profile (in rms) that results in the WSO-11 registering a momentary fault event.

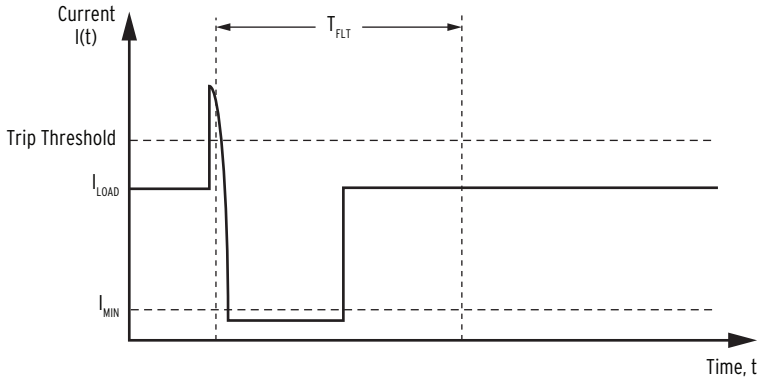

Figure 3.12 Momentary Fault Example

Disturbance Event

In addition to its ability to distinguish between a momentary and permanent fault, the WSO-11 can also recognize a disturbance event. The WSO-11 registers a disturbance when it detects an increase in current exceeding the trip threshold, but does not detect a corresponding system protection operation or load pickup event.

To register a fault and prevent false tripping because of inrush currents, the WSO-11 must be armed prior to the fault condition. See *Device Arming* for details on arming.

Once armed, the WSO-11 must detect fault current exceeding the self-configured trip threshold setting for a period longer than the Dynamic Delayed Trip (DDT) setting of that trip threshold. This will start the T_{FLT} timer.

To validate a fault event, the WSO-11 monitors for a system protection operation (i.e., a loss of current). If no valid loss of current is detected during the T_{FLT} time period, and no load pickup event is detected at the end of T_{FLT}, the WSO-11 registers a disturbance event.

The WSO-11 does not generate (by default) an exception report for a disturbance, but it increments the disturbance counter for indication in the next periodic report.

Reporting disturbance events by exception can be enabled if desired. See *Disturbance Exception on page 4.3* for details on enabling this parameter.

Figure 3.13 shows a sample load current (I_{LOAD}) profile (in rms) that results in the WSO-11 registering a disturbance event.

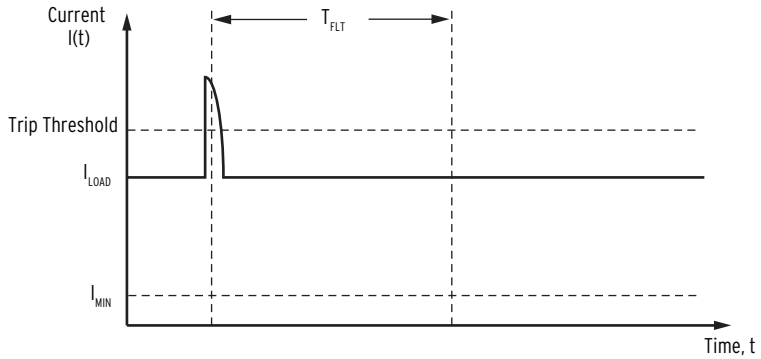

Figure 3.13 Disturbance Event Example

Load Pickup Event

Increase in load resulting from reconfiguration or sections of the electrical distribution system becoming energized can cause the load current to exceed the self-configured trip threshold. The WSO-11 can distinguish between a fault event and a load pickup (LPU) event.

At the next Update Interval (T_{UI}), the WSO-11 reports the total number of LPU events during the given T_{UI}.

To register a fault and prevent false tripping because of inrush currents, the WSO-11 must be armed prior to the fault condition. See *Device Arming* for details on arming.

A load pickup event (see *Figure 3.14*) occurs when load current exceeds the trip threshold, the WSO-11 detects no loss of current, and a new higher sustained load is established before time parameter Momentary Fault Timeout (T_{FLT}) expires.

In *Figure 3.14*, at the end of time period T_{FLT}, the WSO-11 reconfigures a new trip threshold based on the newly established load (see *Table 3.1*).

The WSO-11 does not generate (by default) an exception report for an LPU, but it increments the LPU counter for indication in the next periodic report.

Reporting load pickup events by exception can be enabled if desired. See *Load Pickup Exception on page 4.3* for details on enabling this parameter.

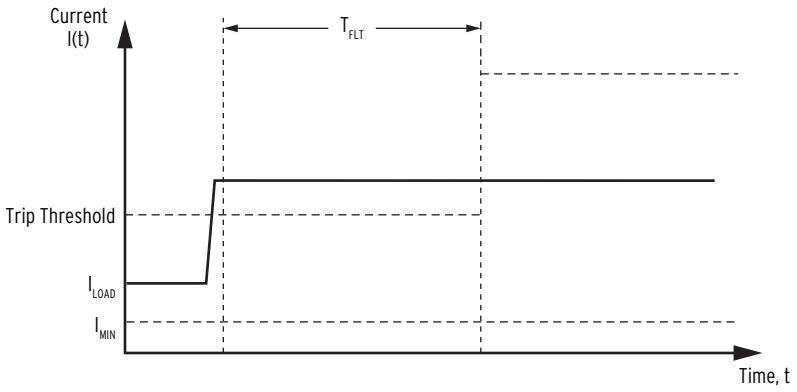

Figure 3.14 Load Pickup Example

The WSO-11 will not respond to events during the T_{FLT} period because it is in inrush restraint (IR) mode (see *Inrush Restraint* for details on IR mode). At the end of the T_{FLT} period, the device will exit IR mode and rearm.

Dynamic Delayed Trip

To detect faults, the WSO-11 trip response time must be faster than the total clear time of system protection. The WSO-11 offers Dynamic Delayed Trip (DDT), which supports configurable trip response times for each individual trip threshold. This feature allows you to create customized WSO-11 trip response curves to coordinate with system protection schemes. See *Dynamic Delayed Trip (DDT) on page 4.2* for details on setting the DDT parameter.

The default trip response time for all trip thresholds is 1.5 cycles (24 ms at 60 Hz). This setting was selected as the default to fit most applications; it ensures that the WSO-11 detects events before any system protection element operates. However, certain system conditions or various protection schemes can cause the WSO-11 to operate in a manner other than intended. Applying a customized DDT helps prevent the WSO-11 from falsely indicating fault conditions because of short bursts of high current that might occur normally, but which do not indicate a fault. You can set the period of sustained fault current before the WSO-11 indicates a fault to vary with the magnitude of the trip threshold. The combination of automatic trip threshold selection and DDT allows integration of the WSO-11 into almost any circuit protection scheme.

Figure 3.15 shows the default trip response times for the WSO-11. Notice that the response times of each trip threshold are all equal and provide a faster response time than the system protection curve. This ensures that the WSO-11 detects events before the protection operates. In some cases, however, this can also lead to undesired operations if the system exhibits transient events that the system protection has not registered and which may not be considered faults.

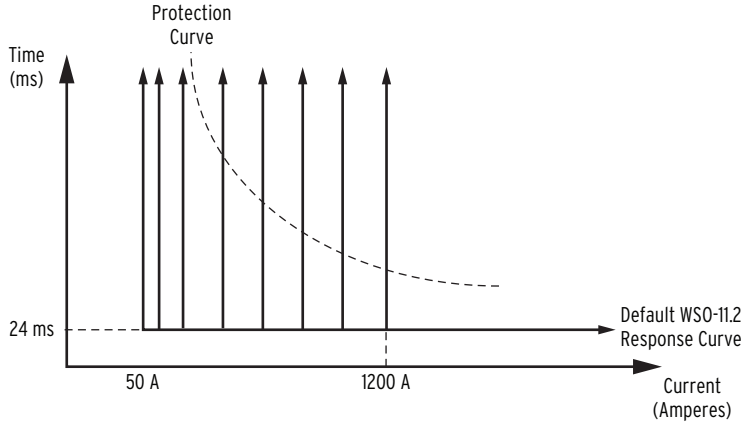

Figure 3.15 Default WSO-11 Response Curve

Figure 3.16 shows the same protection curve as in *Figure 3.15*, but it includes a coordinated WSO-11 response curve. The response time of each trip threshold is customized to produce a response curve that coordinates with the protection scheme.

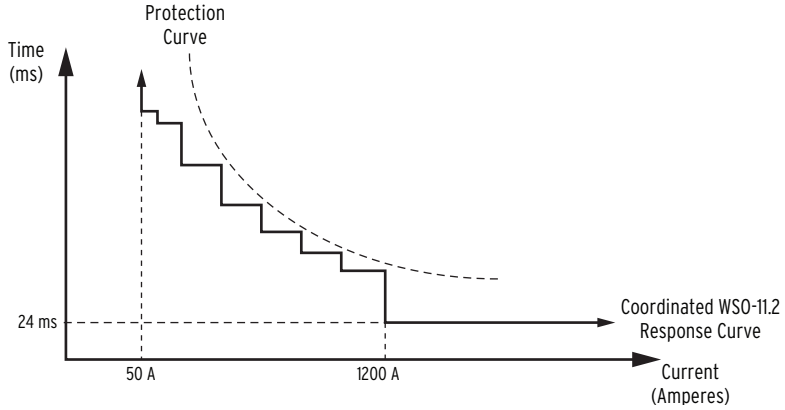

Figure 3.16 Coordinated WSO-11 Response Curve

Backfeed Restraint

Backfeed current can emanate from many sources on a distribution circuit. These can include stored-energy devices, inductive coupling to adjacent phases or circuits, and residual current flow during single phasing. Depending on the magnitude and duration, backfeed can cause the WSO-11 to falsely trip or reset, leading to confusion in the field.

The WSO-11 uses the System Detection Period (T_{SYS}) and Current Detection Hysteresis Threshold (I_{HYS}) to reduce false tripping or resetting because of backfeed conditions on the system.

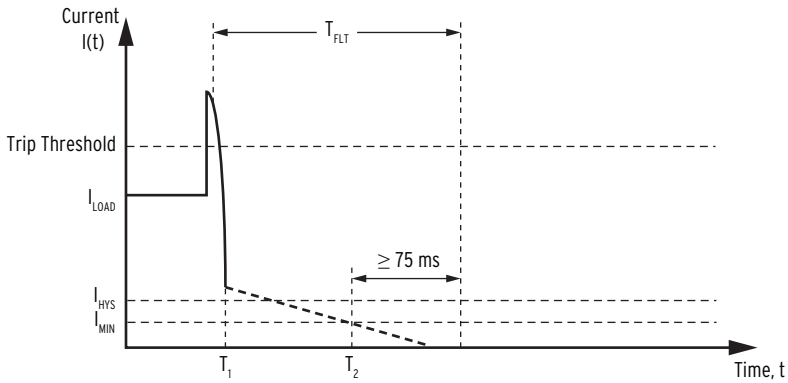

Figure 3.17 Backfeed Current After a Fault

Figure 3.17 shows an example of backfeed resulting from a motor winding down after a fault event. At time T_1, the backfeed current contribution becomes greater than the load current. To register a fault event, after the fault current exceeds the trip threshold, the WSO-11 must detect a loss of current before timing parameter Momentary Fault Timeout (T_{FLT}) expires; this is shown in *Figure 3.17* at time T_2. For the WSO-11 to register a loss of current, current must remain below I_{MIN} for at least 75 ms (nominal). Time T_{FLT} should be longer than any backfeed contribution to ensure fault events are not missed because of backfeed current.

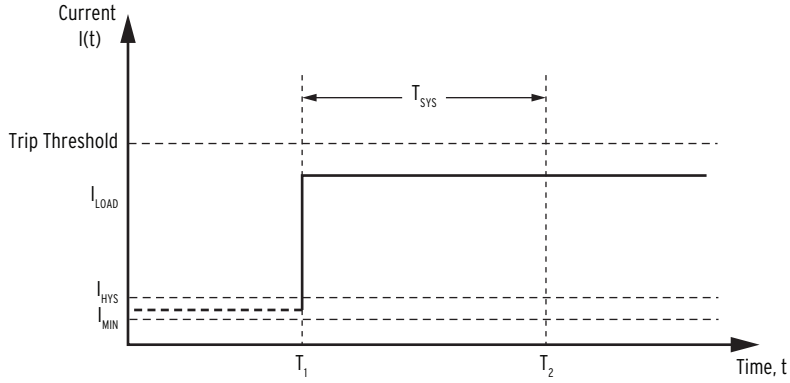

Figure 3.18 Backfeed Current

The WSO-11 is designed to automatically reset upon restoration of sustained load current exceeding the I_{HYS} setting. *Figure 3.18* shows a circuit with backfeed current present before system energization. The WSO-11 will not reset falsely as a result of backfeed current as long as this current does not exceed the I_{HYS} setting for time T_{SYS}. Therefore, ensure that you set the I_{HYS} parameter to a value greater than the maximum backfeed contribution (see *Figure 3.18*). The sensor will remain unarmed until it has detected load current exceeding I_{HYS} for time T_{SYS} (shown at T_2).

See *Section 4: Parameters and Settings* for information on setting the I_{HYS} and T_{SYS} parameters.

Load Data

The WSO-11 reports load data over the previous Update Interval (T_{UI}), either by averaging load data or reporting the highest peak load measurement. The WSO-11 sends 24 load data values (one per statistic interval) every T_{UI}. The total T_{UI} is divided into 24 statistic intervals (T_{SI}), each of equal length.

$$\text{Statistic Interval}(T_{SI}) = \frac{\text{Update Interval}(T_{UI})}{24} \quad \textbf{Equation 3.1}$$

The WSO-11 reports load data, either mean load or rolling average peak load, in rms values.

The WSO-11 reports load data in tenths of an ampere for both mean load and rolling average peak load.

See *Section 4: Parameters and Settings* for details about setting the Load Reporting and Update Interval parameters.

The WSO-11 takes a load measurement once every 30 seconds while load current exceeds the Current Detection Hysteresis Threshold (I_{HYS}). See *Current Detection Hysteresis Threshold (I_{HYS}) on page 4.2* for details on setting the I_{HYS} parameter.

Rolling Average Peak Load

You can use rolling average peak load for planning purposes to identify and monitor areas of stress on the system. While you are using rolling average peak load, the WSO-11 uses a mathematical rolling average window and reports the highest rolling average over the given statistic interval (T_{SI}).

At the end of the statistic interval, the WSO-11 reports the maximum calculated rolling average as the rolling average peak load. The WSO-11 provides one rolling average peak load measurement for each statistic interval in every update interval.

The WSO-11 calculates a mathematical rolling average every 30 seconds based on three consecutive load measurements taken every 30 seconds. It then calculates the moving average by adding the present load measurement and the previous two (three total) measurements and dividing by three. The rolling average response as a function of the unit input current is shown in *Figure 3.19*.

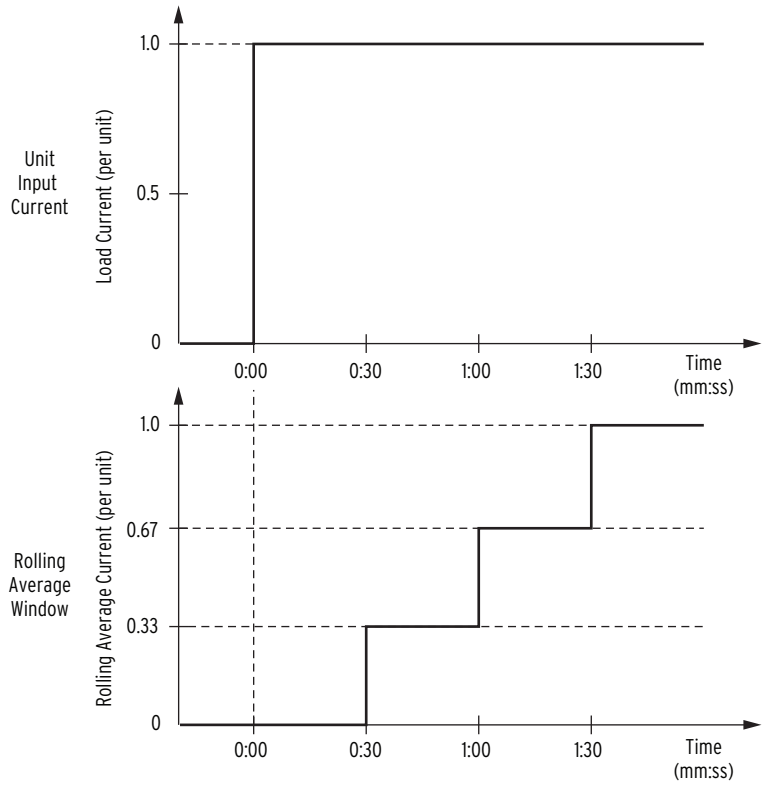

Figure 3.19 Response of Rolling Average to a Step Input

Time = 0:00

Presume that the load current has been at zero for at least three measurements (at –1:00, –0:30, and 0:00) before Time = 0:00. The three 30-second intervals in the sliding time window at Time = 0:00 each have a measurement equal to zero.

Rolling average current at Time = 0:00 $= \frac{0.0}{3} = 0.0$ per unit.

Time = 0:30

The three 30-second intervals in the sliding time window at Time = 0:30 each correspond to the 30-second measurements in *Table 3.2*.

Table 3.2 Rolling Average Peak Load Example, Time = 0:30

Time 0:30	Corresponding 30-Second Intervals
0.0 per unit	–0:30
0.0 per unit	0:00
1.0 per unit	0:30
1.0 per unit	

Rolling average current at Time = 0:30 $= \frac{1.0}{3} = 0.33$ per unit.

Time = 1:00

The three 30-second intervals in the sliding time window at Time = 1:00 each correspond to the 30-second measurements in *Table 3.3*.

Table 3.3 Rolling Average Peak Load Example, Time = 1:00

Time 1:00	Corresponding 30-Second Intervals
0.0 per unit	0:00
1.0 per unit	0:30
1.0 per unit	1:00
2.0 per unit	

Rolling average current at Time = 1:00 $= \frac{2.0}{3} = 0.67$ per unit.

Time = 1:30

The three 30-second intervals in the sliding time window at Time = 1:30 each correspond to the 30-second measurements in *Table 3.4*.

Table 3.4 Rolling Average Peak Load Example, Time = 1:30

Time 1:30	Corresponding 30-Second Intervals
1.0 per unit	0:30
1.0 per unit	1:00
1.0 per unit	1:30
3.0 per unit	

Rolling average current at Time = 1:30 $= \frac{3.0}{3} = 1.0$ per unit.

Mean Load

When you set load reporting to mean load, the WSO-11 averages all load measurements over a given statistic interval and provides one average load measurement for each statistic interval in every update interval.

Low-Current Mode

The WSO-11 can detect faults on lightly loaded circuits while operating in Low-Current mode. The following features are suspended while the sensor is armed in Low-Current mode: load monitoring, inrush restraint, and restoration reset. The WSO-11 cannot distinguish between fault types in Low-Current mode, and will report all fault events (including momentary faults and disturbances) as permanent faults. The sensor continues to send periodic update packets at every update interval. The WSO-11 can only enter Low-Current mode when the Low-Current Enable parameter is set to TRUE. See *Section 4: Parameters and Settings* for information on setting the Low-Current Enable parameter.

While in Low-Current mode, the WSO-11 stops using the AutoRANGER trip logic, and instead uses a configurable fixed trip threshold.

Entering Low-Current Mode

NOTE: The Low-Current Enable parameter must be set to **TRUE** to allow the WSO-11 to enter Low-Current mode. See Low-Current Enable on page 4.4 for details.

Set the Low-Current Enable parameter to TRUE to allow the WSO-11 to enter Low-Current Mode. The WSO-11 enters Low-Current mode after remaining unarmed in AutoRANGE mode for the user-defined time period Low-Current Enter (T_{LC_ENTER}; 48 hours by default). The delay from the T_{LC_ENTER} timer prevents the WSO-11 from entering Low-Current mode during an extended outage. See *Section 4: Parameters and Settings* for information on setting the Low-Current Enter parameter.

Figure 3.20 shows a sample load profile that results in the WSO-11 entering Low-Current mode. At time T_1, the T_{LC_ENTER} timer begins; when the timer expires and load current is still below I_{HYS} (at time T_2), the WSO-11 enters and arms in Low-Current mode. The WSO-11 stops the T_{LC_ENTER} timer when it arms for normal operation.

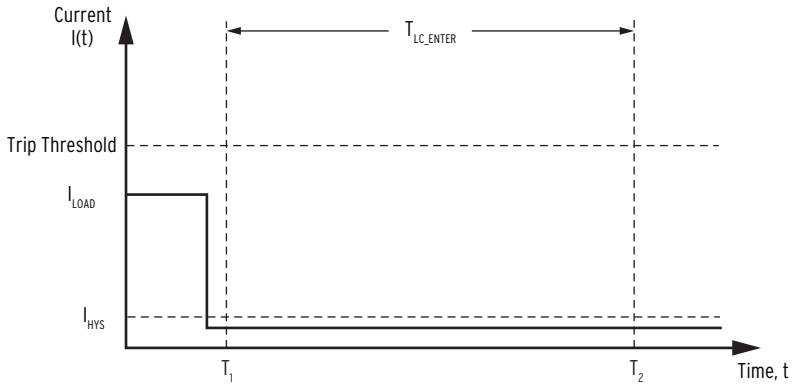

Figure 3.20 Device Arming in Low-Current Mode

The WSO-11 generates and transmits an exception restoration packet and resets the mechanical flag display when it enters Low-Current mode (at time T_2 in *Figure 3.20*). Each transmitted packet indicates when the sensor is (or is not) in Low-Current mode.

Reporting restoration packets by exception can be disabled if desired. See *Restoration Exception on page 4.2* for details on disabling this parameter.

Low-Current Fault Detection

The WSO-11 detects and reports overcurrent events while armed in Low-Current mode. The sensor reports all faults (including momentary faults and disturbances) as permanent faults while in Low-Current mode.

The WSO-11 uses the user-defined Low-Current Trip Threshold and Low-Current Delay Trip (T_{LC_DT}) parameters to determine the fault condition while in Low-Current mode. The Low-Current Trip Threshold is a fixed value; it does not adjust to changes in load current. Coordinate the Low-Current Threshold and T_{LC_DT} parameters with system protection settings to ensure the WSO-11 trips before the protection system clears the fault. Set the Low-Current Trip Threshold above load current and inrush current to prevent false tripping. See *Section 4: Parameters and Settings* for details on configuring these parameters.

The WSO-11 registers a fault event when it detects current exceeding the Low-Current Trip Threshold for a period longer than the T_{LC_DT} time period. *Figure 3.21* shows a sample load current (I_{LOAD}) profile (in rms) that results in the WSO-11 registering a fault in Low-Current mode.

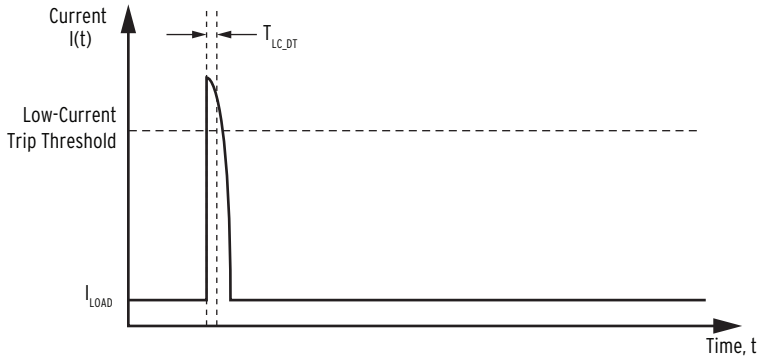

Figure 3.21 Low-Current Fault Detection

After detecting a fault, the WSO-11 increments the permanent fault counter, trips the mechanical flag display, and generates an exception permanent fault packet. The WSO-11 unarms after detecting a fault.

Reporting permanent fault events by exception can be disabled if desired. See *Permanent Fault Exception on page 4.3* for details on disabling this parameter.

Reset

The WSO-11 operates as a timed reset device while in Low-Current mode. After detecting a fault in Low-Current mode, the WSO-11 remains tripped and unarmed for a user-defined reset period (Low-Current Reset—T_{LC_RESET}). See *Section 4: Parameters and Settings* for information on configuring the Low-Current Reset parameter. *Figure 3.22* shows the period required for the WSO-11 to reset after detecting a fault in Low-Current mode.

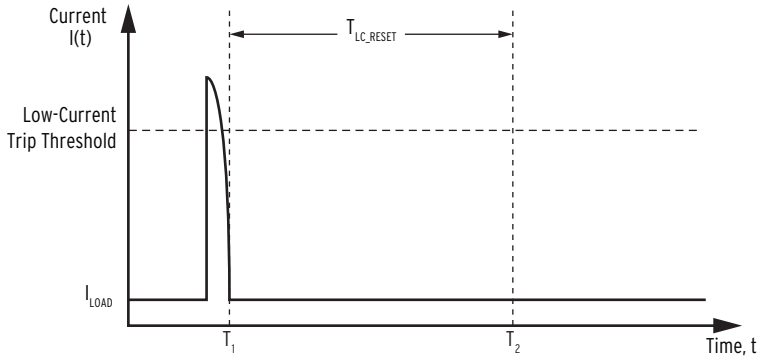

Figure 3.22 Low-Current Reset

At the end of the Low-Current Reset period (at T_2 in *Figure 3.22*), the WSO-11 resets the mechanical flag display, generates an exception restoration packet, and arms to detect future fault events.

Reporting restoration packets by exception can be disabled if desired. See *Restoration Exception on page 4.2* for details on disabling this parameter.

Exiting Low-Current Mode

The user-defined Low-Current Hysteresis (I_{LC_HYS}) and Low-Current Exit Timeout (T_{LC_EXIT}) parameters determine when the WSO-11 rearms in AutoRANGE mode. See *Section 4: Parameters and Settings* for information on configuring these parameters.

Load current must be detected and remain above I_{LC_HYS} for the duration of the T_{LC_EXIT} period. At the end of T_{LC_EXIT} (48 hours by default), the WSO-11 exits Low-Current mode and arms in AutoRANGE mode. *Figure 3.23* shows a sample load current (I_{LOAD}) profile (in rms) that results in the WSO-11 exiting Low-Current mode.

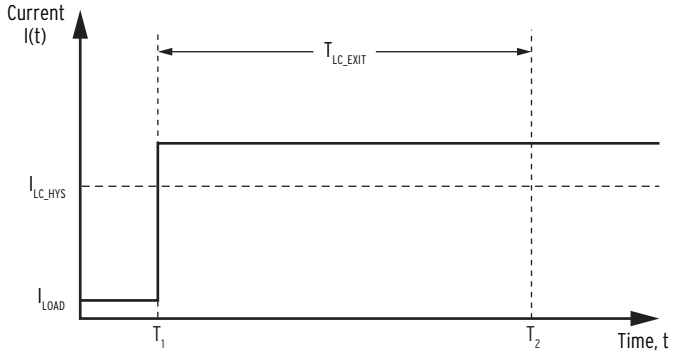

Figure 3.23 Exiting Low-Current Mode

The WSO-11 sends an exception restoration packet when it arms itself in AutoRANGE mode. Reporting restoration packets by exception can be disabled if desired. See *Restoration Exception on page 4.2* for details on disabling this parameter.

Data Packet Types

The WSO-11 measures and collects various sensor data and transmits this information to the RPMA Network in the form of data packets. This section outlines the different types of data packets the WSO-11 generates.

You can use the On-Ramp Wireless Total View web-based HMI to display WSO-11 data. Contact On-Ramp Wireless for details on the latest version of the web-based HMI display.

Periodic Packets

A periodic packet is a regularly scheduled update that the WSO-11 generates once every Update Interval (T_{UI}). The periodic packet includes device ID, current firmware version, load data, device flags, battery statistics, and momentary and permanent counters.

Exception Packets

An exception packet is an unscheduled report resulting from some system event.

Any of the exception packets listed below can be enabled or disabled. See *Section 4: Parameters and Settings* for details on configuring exception packets.

Deployment Packet

When the Deployment Exception parameter is enabled, the WSO-11 generates an exception deployment packet after each of the following instances:

- The WSO-11 joins the RPMA Network for the first time.
- The WSO-11 resets after receiving a downlink reset command.
- The WSO-11 resets after successfully reprogramming an OTA firmware upgrade or setting change.

Exception deployment packets are enabled by default.

Restoration Packet

The WSO-11 generates an exception restoration packet after it clears a permanent fault or permanent LOC condition and the Restoration Exception parameter is enabled. A restoration packet indicates that the device is armed and ready to detect future events. See *Device Arming* and *Entering Low-Current Mode* for details on arming requirements.

Exception restoration packets are enabled by default.

Permanent Fault Packet

The WSO-11 generates an exception permanent fault packet after it detects a permanent fault condition and the Permanent Fault Exception parameter is enabled. See *Permanent Fault* for details on permanent fault detection.

Exception permanent fault packets are enabled by default.

Permanent LOC Packet

The WSO-11 generates an exception permanent LOC packet after it detects a permanent loss-of-current condition and the Permanent LOC Exception parameter is enabled. See *Permanent LOC* for details on permanent loss-of-current detection.

Exception permanent LOC packets are enabled by default.

Momentary Fault Packet

NOTE: By default, the WSO-11 will not send an exception packet for a momentary fault event.

The WSO-11 generates an exception momentary fault packet after it detects a momentary fault condition and the Momentary Fault Exception parameter is enabled. See *Momentary Fault* for details on momentary fault detection.

Exception momentary fault packets are disabled by default.

Momentary LOC Packet

NOTE: By default, the WSO-11 will not send an exception packet for a momentary LOC event.

The WSO-11 generates an exception momentary LOC packet after it detects a momentary LOC condition and the Momentary LOC Exception parameter is enabled. See *Momentary LOC* for details on momentary fault detection.

Exception momentary LOC packets are disabled by default.

Disturbance Packet

NOTE: By default, the WSO-11 will not send an exception packet for a disturbance event.

The WSO-11 generates an exception disturbance packet after it detects a disturbance condition and the Disturbance Exception parameter is enabled. See *Disturbance Event* for details on momentary fault detection.

Exception disturbance packets are disabled by default.

Load Pickup Packet

NOTE: By default, the WSO-11 will not send an exception packet for a load pickup event.

The WSO-11 generates an exception packet after it detects a load pickup condition and the Load Pickup Exception parameter is enabled. See *Load Pickup Event* for details on load pickup detection.

Exception load pickup packets are disabled by default.

Time Stamps

NOTE: Time synchronization comes from the RPMA Network, which determines the time-stamp accuracy. Contact On-Ramp Wireless for details on the time synchronization accuracy.

The WSO-11 will time-stamp every transmitted packet so that the data packets can be correlated to system events. The WSO-11 will either time-stamp the packet at the time of the event or when the packet is transmitted, depending on the type of packet.

The WSO-11 will time-stamp packets when they are generated for the following packet types:

- Periodic Packet
- Deployment Packet

The WSO-11 will time-stamp packets when the event occurred for the following exception packet types:

- Restoration Packet
- Permanent Fault Packet
- Permanent LOC Packet
- Momentary Fault Packet
- Momentary LOC Packet
- Disturbance Packet
- Load Pickup Packet

Radio

The WSO-11 includes an integrated On-Ramp Wireless RPMA Radio. Each radio on the RPMA Network communicates in a star topology to an above-ground RPMA Access Point. Each RPMA Access Point can support thousands of nodes in a star topology.

The RPMA Network uses direct-sequence spread spectrum (DSSS) and operates in the license-free 2.4 GHz ISM band.

The WSO-11 typical maximum transmitting range from endpoint installation location to the nearest access point is dependent on propagation environment (e.g., terrain) and installation location.

Contact On-Ramp Wireless for further details regarding the RPMA Network and RPMA Access Point.

System Self Diagnostics

The WSO-11 performs self-tests regularly to ensure the hardware is functioning and operating as intended. If a diagnostic test fails, the corresponding flag is asserted and will be indicated on the next transmitted packet.

Low Battery Flag

The WSO-11 monitors the internal battery voltage every 10 minutes and displays the average voltage in millivolts (mV) in every periodic report.

If the average voltage drops below 2.9 V, the WSO-11 asserts the low battery flag.

If the average voltage rises above 3.0 V, the WSO-11 will clear the low battery flag.

After the low battery flag is asserted, the estimated worst case remaining radio transmissions pending RF performance left in the battery cell is as follows:

- 8–9 transmissions at +25°C (+77°F) (typical)
- 5 transmissions at +85°C (+185°F) (worst case)

NOTE: In very cold environments, low ambient temperatures could cause the measured voltage to drop below 2.9 V, resulting in the low battery flag being set. When the ambient temperature rises, the WSO-11 clears the low battery flag if it was asserted because of environmental conditions and not as a result of battery capacity.

Flash Error Flag

The WSO-11 performs regular self-test checks on the Flash memory of the controller and asserts the Flash error flag if it detects any memory errors.

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Section 4
Parameters and Settings

Overview

NOTE: All OTA updates will affect battery life.

You can use an over-the-air (OTA) update to change parameters and settings. This means that you can upgrade or reconfigure deployed devices in the field while they are still in service. OTA updates can apply to all WSO-11 devices on the network, or a downlink message can be used to target individual devices. All OTA updates affect battery life. Smaller updates, such as setting changes, have less of an effect on battery life than larger updates, such as firmware upgrades.

Any parameter or setting changes to field devices will require a new configuration file provided by SEL. Please contact SEL to review all required changes and generate a new configuration file for an OTA update or downlink message.

Any parameter or setting changes that are different from the default configuration can be downloaded OTA to field devices or can be factory configured prior to delivery. Please contact SEL prior to ordering to have devices configured at the factory.

Configurable Parameters

Update Interval (T_{UI})

NOTE: SEL does not recommend setting T_{UI} to a value of less than 6 hours. Any changes to T_{UI} will affect battery life.

The Update Interval designates the time between each periodic packet. The default value is 24 hours.

You can set the T_{UI} on a per-unit basis through the On-Ramp Wireless element management system (EMS). Changes to the T_{UI} will affect battery life. New T_{UI} changes take effect after the transmission of the next packet.

Changing the T_{UI} consequently changes the statistic interval (T_{SI}). See *Load Data on page 3.15* for details on statistic interval.

Momentary Fault Timeout (T_{FLT})

The Momentary Fault Timeout (T_{FLT}) parameter defines the time difference between a permanent and momentary fault. See *Fault Detection on page 3.9* for details on fault detection. T_{FLT} is set in 15-second increments. The minimum value for the parameter is 15 seconds, and the maximum value is 60 minutes.

The default value is 5 minutes.

Momentary LOC Timeout (T_{LOC})

The Momentary LOC Timeout (T_{LOC}) parameter defines the time difference between a permanent and momentary LOC. See *Loss-of-Current Detection on page 3.6* for details on loss-of-current detection. T_{LOC} is set in 15-second increments. The minimum value for the parameter is 15 seconds, and the maximum value is 60 minutes.

The default value is 3 minutes.

Dynamic Delayed Trip (DDT)

NOTE: When setting a unique DDT curve, ensure that each threshold has a less than or equal to DDT setting than the DDT setting of the next lower trip threshold.

The Dynamic Delayed Trip (DDT) parameter defines the trip response time for each specific trip threshold. You can set each trip threshold with a different trip response time. See *Dynamic Delayed Trip on page 3.13* for details on using DDT. DDT is set in half-cycles. The minimum value for the parameter is 1 half-cycle, and the maximum value is 255 half-cycles.

The default value is 3 half-cycles (24.9 ms at 60 Hz) for all trip thresholds.

DDT Enable

The DDT Enable parameter defines whether the DDT feature is turned on. If DDT Enable is FALSE, the device only registers a fault event according to the criterion of the presently selected fault threshold.

The default value is TRUE (DDT is enabled).

Load Reporting

The Load Reporting parameter defines whether the reported load data are in a rolling average peak load or mean load format. See *Load Data on page 3.15* for more details on load data measurements.

The default value is TRUE (rolling average peak load enabled).

Current Detection Hysteresis Threshold (I_{HYS})

The Current Detection Hysteresis Threshold or I_{HYS} parameter defines the minimum current activation level. I_{HYS} is set in tenths of an ampere. The minimum value is 5 A, and the maximum value is 600 A.

The default value is 5 A.

The I_{HYS} parameter is the minimum current activation level measured by the WSO-11 when it is installed on a conductor with a 0.75" outside diameter. Installing the WSO-11 on a wider or narrower conductor affects the measured current level. The minimum current activation level (I_{HYS}) can therefore vary from actual load current.

System Detection Period (T_{SYS})

The System Detection Period (T_{SYS}) parameter defines the duration of time for which the load current must exceed I_{HYS} before the device arms. T_{SYS} is set in 5-second increments. The minimum value is 5 seconds, and the maximum value is 90 hours.

The default value is 5 minutes.

Deployment Exception

The Deployment Exception parameter determines whether the unit will send an exception packet after initial product deployment. See *Deployment Packet on page 3.20* for details on the deployment exception packets. If Deployment Exception is TRUE, the WSO-11 will transmit an exception packet for initial product deployment.

The default value is TRUE (initial deployment will be transmitted by exception).

Restoration Exception

The Restoration Exception parameter determines whether the unit will send an exception packet after restoration of current. See *Device Arming on page 3.4* for details on restoration of current. See *Restoration Packet on page 3.21* for details on the restoration exception packets. If Restoration Exception is TRUE, the WSO-11 will transmit an exception packet after current is restored and the device arms.

The default value is TRUE (current restoration will be transmitted by exception).

Permanent Fault Exception

The Permanent Fault Exception parameter determines whether the unit will send an exception packet after a permanent fault event. See *Permanent Fault on page 3.9* for details on permanent fault detection. See *Permanent Fault Packet on page 3.21* for details on the permanent fault exception packets. If Permanent Fault Exception is TRUE, the WSO-11 will transmit an exception packet for all permanent fault events.

The default value is TRUE (permanent fault events will be transmitted by exception).

Permanent LOC Exception

The Permanent LOC Exception parameter determines whether the unit will send an exception packet after a permanent LOC event. See *Permanent LOC on page 3.6* for details on permanent LOC detection. See *Permanent LOC Packet on page 3.21* for details on the permanent LOC exception packets. If Permanent LOC Exception is TRUE, the WSO-11 will transmit an exception packet for all permanent LOC events.

The default value is TRUE (permanent LOC events will be transmitted by exception).

Momentary Fault Exception

The Momentary Fault Exception parameter determines whether the unit will send an exception packet after a momentary fault event. See *Momentary Fault on page 3.10* for details on momentary fault detection. See *Momentary Fault Packet on page 3.21* for details on the momentary fault exception packets. If Momentary Fault Exception is TRUE, the WSO-11 will transmit an exception packet for all momentary fault events.

The default value is FALSE (momentary fault events will not be transmitted by exception).

Momentary LOC Exception

The Momentary LOC Exception parameter determines whether the unit will send an exception packet after a momentary LOC event. See *Momentary LOC on page 3.7* for details on momentary LOC detection. See *Momentary LOC Packet on page 3.21* for details on the momentary LOC exception packets. If Momentary LOC Exception is TRUE, the WSO-11 will transmit an exception packet for all momentary LOC events.

The default value is FALSE (momentary LOC events will not be transmitted by exception).

Disturbance Exception

The Disturbance Exception parameter determines whether the unit will send an exception packet after a disturbance event. See *Disturbance Event on page 3.11* for details on disturbance detection. See *Disturbance Packet on page 3.21* for details on the disturbance exception packets. If Disturbance Exception is TRUE, the WSO-11 will transmit an exception packet for all disturbance events.

The default value is FALSE (disturbance events will not be transmitted by exception).

Load Pickup Exception

The Load Pickup Exception parameter determines whether the unit will send an exception packet after a load pickup event. See *Load Pickup Event on page 3.12* for details on load pickup detection. See *Load Pickup Packet on*

page 3.21 for details on the load pickup exception packets. If Load Pickup Exception is TRUE, the WSO-11 will transmit an exception packet for all load pickup events.

The default value is FALSE (load pickup events will not be transmitted by exception).

Flag Reset Type

NOTE: The Low-Current Reset (T_{LC_RESET}) parameter defines the WSO-11 reset behavior for Low-Current mode.

The Flag Reset Type parameter determines whether the mechanical flag display will reset on system current restoration or have a timed reset.

When Flag Reset Type parameter is set to CURRENT, the mechanical flag will reset after current is restored above Current Detection Hysteresis (I_{HYS}) for greater than the System Detection Period (T_{SYS}).

When the Flag Reset Type parameter is set to TIME**,** the mechanical flag will remain tripped for a user-defined time period (Flag Timed Reset) before resetting. The mechanical flag will trip for all events configured by the Flag Indication parameter, and will only reset after time Flag Timed Reset has expired and current has been restored.

The default value is CURRENT (flag will reset on current restoration).

Flag Timed Reset

NOTE: If the Flag Reset Type parameter is set to CURRENT, the Flag Timed Reset parameter is ignored.

The Flag Timed Reset parameter determines the duration for which the mechanical flag will remain tripped if Flag Reset Type is set to TIME. When using this parameter, the mechanical flag will only reset after time Flag Timed Reset has expired and current has been restored. The Flag Timed Reset parameter is set in 15-second increments. The minimum value for the parameter is 30 seconds, and the maximum value is 10 days.

The default value is 4 hours.

Flag Indication

NOTE: When the Flag Reset Type parameter is configured to TIME, any fault indication event will trip the mechanical flag display for the Flag Timed Reset time period.

NOTE: If the Flag Reset Type parameter is configured to CURRENT, the Flag Indication parameter can only be configured for permanent LOC events. The mechanical flag display will always respond to permanent fault events.

The Flag Indication parameter determines what types of events the mechanical flag display will indicate for. The mechanical flag display will always indicate for a permanent fault but can be configured to indicate additional events.

Flag Indication can be set to any combination of the following:

- Permanent LOC
- Momentary Faults
- Momentary LOC
- Disturbance
- Load Pickup

Low-Current Enable

The Low-Current Enable parameter determines whether the product can enter Low-Current mode when applied to a lightly loaded circuit. If the parameter is set to TRUE, Low-Current mode is enabled.

The default value is FALSE (Low-Current mode is disabled).

Low-Current Trip Threshold

NOTE: The Low-Current Trip Threshold parameter is ignored when the Low-Current Enable parameter is set to FALSE.

The Low-Current Trip Threshold defines the trip threshold (in amperes) used in Low-Current mode. The parameter can be set to 50 A, 100 A, 200 A, 400 A, 800 A, 1000 A, or 1200 A.

The default value is 50 A.

Low-Current Delay Trip (T_{LC_DT})

NOTE: The Low-Current Trip Delay parameter is ignored when the Low-Current Enable parameter is set to FALSE.

The Low-Current Delay Trip (T_{LC_DT}) parameter defines the trip response time for the Low-Current Trip Threshold. The Low-Current Delay Trip parameter is set in half-cycles. The minimum value for the parameter is 1 half-cycle, and the maximum value is 255 half-cycles.

The default value is 3 half-cycles (24.9 ms at 60 Hz).

Low-Current Reset (T_{LC_RESET})

NOTE: The Low-Current Reset parameter is ignored when the Low-Current Enable parameter is set to FALSE.

The Low-Current Reset (T_{LC_RESET}) parameter determines the duration for which the WSO-11 remains tripped after a fault in Low-Current mode. The Low-Current Reset parameter is set in 15-minute increments. The minimum value for the parameter is 15 minutes, and the maximum value is 48 hours.

The default value is 8 hours.

Low-Current Enter Timeout (T_{LC_ENTER})

NOTE: The Low-Current Enter Timeout parameter is ignored when the Low-Current Enable parameter is set to FALSE.

The Low-Current Enter Timeout (T_{LC_ENTER}) parameter determines the duration for which the WSO-11 remains unarmed before it enters Low-Current mode. The Low-Current Enter Timeout parameter is set in 1-hour increments. The minimum value for the parameter is 1 hour, and the maximum value is 10 days.

The default value is 48 hours.

Low-Current Exit Timeout (T_{LC_EXIT})

NOTE: The Low-Current Exit Timeout parameter is ignored when the Low-Current Enable parameter is set to FALSE.

The Low-Current Exit Timeout (T_{LC_EXIT}) parameter determines the duration for which current measurements must remain above Low-Current Exit Hysteresis (I_{LC_HYS}) before the WSO-11 exits Low-Current operation. The Low-Current Exit Timeout parameter is set in 1-hour increments. The minimum value for the parameter is 1 hour, and the maximum value is 10 days.

The default value is 48 hours.

Low-Current Exit Hysteresis (I_{LC_HYS})

NOTE: The Low-Current Exit Hysteresis parameter is ignored when the Low-Current Enable parameter is set to FALSE.

The Low-Current Exit Hysteresis (I_{LC_EXIT}) parameter determines the load current required to exit Low-Current mode. The Low-Current Exit Hysteresis parameter is set in 1-ampere increments. The minimum value for the parameter is 5 A, and the maximum value is 250 A.

The default value is 15 A.

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Section 5
Maintenance

The WSO-11 is designed to be as maintenance free as possible, minimizing your total cost of ownership.

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.

⚠WARNING
Batteries should always be handled with care and only by trained personnel. Failure to comply with safety procedures of the battery manufacturer could result in serious

NOTE: The battery manufacturer MSDS information is subject to change without notice. MSDS information should be stored in such a manner that it is accessible to utility personnel during a safety related event. The MSDS should be updated periodically to ensure the most current and accurate information.

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.

The WSO-11 contains two battery packs, each of which consists of a lithium battery and a hybrid layer capacitor (HLC):

- Lithium cell

  Primary (non-rechargeable) lithium metal battery models; MSDS No.-TLP-100, 3_6V based PP (Revision-C). August 2009. <www.tadiranbat.com>.

  "Lithium Technical Notice." Guidelines for Disposal of Lithium Cells and Batteries. May 2008. <www.tadiranbat.com>.

- Hybrid Layer Capacitor

  HLC primary (non-rechargeable) lithium cells; MSDS No. HLC-01 (Rev. G). April 2010. <www.tadiranbat.com>.

Battery Replacement

The WSO-11 comes with a pre-installed high-capacity non-rechargeable lithium cell with a 20-year shelf life. For a single periodic packet every 24 hours and 44 exception packets annually, estimated battery life is in excess of 14 years.

Contact SEL for instructions on battery replacement procedures.

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Section 6
Testing and Troubleshooting

Testing

You can use the Mini Current Loop (see *Figure 6.1*) to test WSO-11 units by simulating permanent faults and permanent LOC conditions. When energized, a nominal magnetic field equivalent to approximately 10 A continuously circulates through the loop. When the integral pushbutton plunger is depressed, an equivalent magnetic field of approximately 1000 A is produced and will trip appropriate faulted circuit indicators.

The Mini Current Loop is sold separately (SEL part number: MCL120). Consult the factory for details and assistance with use of a Mini Current Loop for testing WSO-11 units.

Figure 6.1 Mini Current Loop

Troubleshooting

For help in troubleshooting WSO-11 units, *Table 6.1* lists causes and responses to possible issues. Contact the SEL Fault Indicator and Sensor Division for technical assistance.

Table 6.1 Troubleshooting

Issue	Cause	Response
WSO-11 unit fails to join the RPMA Network	Radio is not activated	Follow the radio activation procedure and verify that the radio has been activated
	Node ID is not in the element management system (EMS)	Confirm the WSO-11 Node ID is in the EMS
	Installation location is not within the network coverage area	Confirm with On-Ramp Wireless that the installation location has sufficient network strength
WSO-11 unit has dropped off the RPMA Network and has not rejoined	Unit is on the fringe of the network coverage area	Confirm with On-Ramp Wireless that the installation location has sufficient network strength
	Battery is depleted	Contact SEL for battery replacement options
WSO-11 unit has dropped off the RPMA Network and rejoins	Unit is in an unreliable network coverage area	Confirm with On-Ramp Wireless that the installation location has sufficient network strength
WSO-11 unit reports low battery flag	WSO-11 battery has dropped below minimum voltage threshold	Contact SEL for battery replacement options
	Extremely low ambient temperature	Flag will be cleared when ambient temperature increases
WSO-11 does not report fault events when expected	Fault exception reporting is not configured	Enable exception report for the desired event types
	WSO-11 is not properly coordinated with protection scheme	Set DDT settings to coordinate WSO-11 with protection scheme—consult SEL
WSO-11 unit transmits exception packet unexpectedly	Exception packets are enabled for a particular event type	Disable exception reports for the desired event types
Flag display does not rotate	Battery depleted	Contact SEL for battery replacement options
Unit has become separated from overhead line	Unit is installed more than six feet away from the pole	Move the unit within the recommended installation range noted in *Mounting Considerations on page 2.3*
Mechanical flag does not reset at time T_{SYS} after installation	Insufficient load current	The WSO-11 must be installed on circuits with load current greater than I_{HYS}
	Installation location is not within the network coverage area	Confirm with On-Ramp Wireless that the installation location has sufficient network strength

Technical Assistance

Obtain technical assistance from the following:

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
Internet: selinc.com
Email: info@selinc.com

Appendix A
Firmware and Manual Versions

Firmware

Determine Firmware Version

You can see the firmware version presently running on your WSO-11 in the On-Ramp Wireless web-based HMI display. Every data packet the WSO-11 transmits includes information about the firmware version presently running on the device.

Firmware Revision History

Table A.1 list the firmware versions, a description of modifications, and the manual date code that corresponds to firmware versions. The most recent firmware version is listed first.

Table A.1 Firmware Revision History (Sheet 1 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
SEL-WSO-11-3.8	➤ Addressed issue which in firmware 3.7 caused the WSO-11 to fail rejoining the RPMA network after a radio reset.	20160818
SEL-WSO-11-3.7	➤ Added Low-Current mode functionality. ➤ Modified the firmware to reset the state of the WSO-11 and reset all of the device counters after a manual reset. In all previous firmware, the WSO-11 would preserve the state of the device and the counters after a manual reset.	20150813
SEL-WSO-11-3.6	➤ Addressed issue which in previous firmware caused the WSO-11 to improperly set the Flash Error Flag after a successful over-the-air firmware download. ➤ Resolved an issue in which the radio was disabled following a successful over-the-air firmware download when valid user configuration settings were not downloaded prior to the firmware upgrade.	20150421
SEL-WSO-11.2-3.5	➤ Corrected product behavior during a high magnitude fault stimulus of extended duration that caused hardware failure. NOTE: This issue has only manifested in a testing environment and has not been observed in the field. ➤ Corrected erroneous detection of current in low battery state. NOTE: This issue has only manifested in a testing environment and has not been observed in the field. ➤ Corrected erroneous product reset that could occur following a repeated fault stimulus with a duration between 1 ms and the configured delay trip setting. NOTE: This issue will only manifest after more than 30 stimuli in less than 30 seconds. ➤ Prevented the product from becoming unarmed after a momentary event with low post-event load currents (below 5 A but greater than 3 A). NOTE: This issue has only manifested in a testing environment and has not been observed in the field. ➤ Added Deployment Exception parameter to trigger exception packet for deployment events.	20140717

Table A.1 Firmware Revision History (Sheet 2 of 2)

Firmware Identification (FID) Number	Summary of Revisions	Manual Date Code
	➤ Added Restoration Exception parameter to trigger exception packet for restoration events. ➤ Added Permanent Fault Exception parameter to trigger exception packet for permanent fault events. ➤ Added Permanent LOC Exception parameter to trigger exception packet for permanent LOC events. ➤ Added Momentary Fault Exception parameter to trigger exception packet for momentary fault events. ➤ Added Momentary LOC Exception parameter to trigger exception packet for momentary LOC events. ➤ Added Disturbance Exception parameter to trigger exception packet for disturbance events. ➤ Added Load Pick Up Exception parameter to trigger exception packet for load pick up events. ➤ Added Flag Reset Type parameter to reset mechanical flag display on current or time. ➤ Added Flag Timed Reset parameter to set the amount of time for the mechanical flag display to reset. ➤ Added Flag Indication parameter to define the event types the mechanical flag display will respond to. ➤ Enhanced packet time stamping.	
SEL-WSO-11.2-3.4	➤ Added over-the-air (OTA) firmware download functionality. ➤ Added OTA log retrieval functionality. ➤ Added downlink configuration settings update functionality. ➤ Added OTA FCI setting retrieval functionality. ➤ Added OTA radio reset downlink command. ➤ Corrected momentary loss-of-current bug relating to pre-outage sub 1 ms transients.	20130722
SEL-WSO-11.2-3.0	Initial second generation build. ➤ Bootloader initial release. ➤ Application Initial release. ➤ Added peak measurement mode. ➤ Added statistic interval in data packet. ➤ Insert measured battery voltage in transmitted data. ➤ Added deployment and restoration reset packets.	N/A
SEL-WSO-11.2-2.0	➤ Enhanced stability in the loss-of-current detection algorithm relating to noncontinuous fault events prior to an outage.	N/A
SEL-WSO-11.2-1.0	➤ Initial version.	N/A

Instruction Manual

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

Table A.2 lists the instruction manual release dates and a description of modifications. The most recent instruction manual revisions are listed at the top.

Table A.2 Instruction Manual Revision History (Sheet 1 of 2)

Revision Date	Summary of Revisions
20171010	Section 5 ➤ Updated *Battery Safety.*
20160818	Section 4 ➤ Updated *Momentary LOC Timeout (T_{LOC})* parameter. Appendix A ➤ Updated for firmware version SEL-WSO-11-3.8.
20150813	Section 1 ➤ Updated *Specifications*. Section 2 ➤ Updated *WSO-11 Radio Activation*. ➤ Updated *WSO-11 Installation*. ➤ Updated *Figure 2.4: Spacing Requirements*. Section 3 ➤ Updated *Basic Functionality.* ➤ Added *AutoRANGE Mode*. ➤ Added *Low-Current Mode*. ➤ Updated *Radio*. Section 4 ➤ Added *Low-Current Enable* parameter. ➤ Added *Low-Current Trip Threshold* parameter. ➤ Added *Low-Current Delay Trip* parameter. ➤ Added *Low-Current Reset* parameter. ➤ Added *Low-Current Enter Timeout* parameter. ➤ Added *Low-Current Exit Timeout* parameter. ➤ Added *Low-Current Exit Hysteresis* parameter. Section 6 ➤ Updated *Table 6.1: Troubleshooting*. Appendix A ➤ Updated for firmware version SEL-WSO-11-3.7.
20150421	Preface ➤ Updated *Safety Information*. Section 2 ➤ Updated *Figure 2.4: Spacing Requirements*. Section 3 ➤ Added *Product Identification*. ➤ Updated *Figure 3.3: Product Identification Information*. Appendix A ➤ Updated for firmware version 3.6.

Table A.2 Instruction Manual Revision History (Sheet 2 of 2)

Revision Date	Summary of Revisions
20141125	Updated product images. **Section 3** ➤ Added *Upgrade Firmware* section under *Over-the-Air (OTA) Functionality.*
20140717	Updated product images. **Section 1** ➤ Updated accuracy data. **Section 3** ➤ Updated *Display* section with the new mechanical flag behavior. ➤ Removed Trip Threshold equations. ➤ Removed Oscillating Trip Threshold with No Hysteresis example. ➤ Added *Device Arming* section. ➤ Removed fault detection diagrams. ➤ Added *Momentary Fault Packet*, *Momentary LOC Packet*, *Disturbance Packet*, and *Load Pick Up Packet* to *Packet Types*. ➤ Added *Time Stamps* section. **Section 4** ➤ Removed *Autorange Enable* parameter. ➤ Removed *Default Trip Threshold* parameter. ➤ Added *Deployment Exception* parameter. ➤ Added *Restoration Exception* parameter. ➤ Added *Permanent Fault Exception* parameter. ➤ Added *Permanent LOC Exception* parameter. ➤ Added *Momentary Fault Exception* parameter. ➤ Added *Momentary LOC Exception* parameter. ➤ Added *Disturbance Exception* parameter. ➤ Added *Load Pick Up Exception* parameter. ➤ Added *Flag Reset Type* parameter. ➤ Added *Flag Indication* parameter. **Section 6** ➤ Revised *Table 6.1: Troubleshooting.*
20130722	➤ Initial version.

Appendix B
Acronym List

DSSS	Direct-Sequence Spread Spectrum
DDT	Dynamic Delayed Trip
EMS	Element Management System
FCI	Faulted Circuit Indicator
HLC	Hybrid Layer Capacitor
HMI	Human-Machine Interface
IR	Inrush Restraint
LOC	Loss of Current
MSDS	Material Safety Data Sheet
OTA	Over the Air
RF	Radio Frequency
RPMA	Random Phase Multiple Access
WSO	Wireless Sensor for Overhead Lines

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