



Commissioning and Servicing Commercial PV Systems with SunSpec Rapid Shutdown

SUNNY TRIPOWER CORE1-US (STP 33-US-41 / STP 50-US-41 / STP 62-US-41) /

SUNNY TRIPOWER X-US (STP 20-US-50 / STP 25-US-50 / STP 30-US-50)

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1 Requirements for PV Systems with Rapid Shutdown

Section 690.12, "Rapid Shutdown of PV Systems on Buildings" of the National Electrical Code, defines requirements for rooftop PV systems to reduce shock hazard to emergency responders, such as firefighters. When exposed to sunlight, PV modules remain energized even when not delivering power to the utility grid or the loads. Rapid shutdown provides a method for emergency responders to de-energize the entire PV system to levels that reduce potential shock hazard, thereby allowing emergency responders to work safely around the PV array.

Section 690.12 "Rapid Shutdown of PV System on Buildings" of the National Electrical Code defines requirements for reducing shock hazard from conductors within the boundary of the PV modules. One method of complying with requirements for reducing shock hazard within the PV array is to install module-level shutdown devices to reduce voltage within the PV array to 80 volts or less.

According to section 690.12(C), *Initiation Device* of the National Electrical Code, a device is required to initiate rapid shutdown of the PV system at a readily accessible location. For PV systems on commercial or industrial buildings with multiple inverters located on the rooftop, the initiator device is typically a service disconnect or main PV system disconnect located at ground level where it will be readily accessible to emergency responders arriving to the site.

QUALIFIED PERSON

Installation, commissioning, servicing and maintenance of SMA inverters must only be performed by electrically qualified persons according to the manual for SMA inverters and the other devices in the system.

The rapid shutdown requirements of the National Electrical Code 690.12 are not intended to provide assurance of de-energization of sub-section of the PV system when disconnecting, servicing or performing maintenance operations on individual inverters or sub-arrays of the PV system.

When installing, commissioning, servicing or performing maintenance operations on PV systems with rapid shutdown, it is important to follow the same safe work practices as with any electrical system, such as those described in NFPA 70E, *Standard for Electrical Safety in the Workplace*.

2 SMA Inverters and SunSpec Rapid Shutdown

The SMA inverters of the Sunny Tripower CORE1-US and Sunny Tripower X-US types have been certified according to standard UL 1741 "Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources" and are listed as PV Rapid Shutdown Equipment (PVRSE) to discharge the voltage on DC input and AC output conductors to levels required by the National Electrical Code 690.12. The inverters are additionally certified to support module-level shutdown for reducing shock hazard within a PV array with compatible module-level rapid shutdown devices that are compliant with the *SunSpec Communication Signal for Rapid Shutdown Functional Specification*. A list of compatible rapid shutdown devices is provided in the technical information "SunSpec Certified Rapid Shutdown Devices".

The inverters include an integrated SunSpec-compliant signal generator, which when activated sends a "permission to operate" signal over the DC conductors to rapid shutdown receiver devices integrated with the modules in the PV array. SunSpec-compliant rapid shutdown receiver devices prevent the energy from the connected module(s) from passing to the string conductors unless and until the SunSpec signal is received.

When the inverters are disconnected from AC grid voltage the inverters will initiate shutdown operation and stop transmitting the SunSpec signal on the DC conductors. When not receiving the SunSpec signal, the receiver devices will disconnect the PV modules from the string conductors thereby reducing the voltage on any conductor within the PV array to 80 volts or less as required by the National Electrical Code 690.12(B)(2)(2).

When re-starting following a rapid shutdown initiation, the inverters check the DC voltage on connected PV strings prior to transmitting the SunSpec signal. If the voltage is greater than 30 VDC on any PV input, the inverter will issue the event message 9034 to notify the system operator that the PV array was not fully de-energized as expected. Unless explained by known circumstances, the PV system must be inspected to ensure that all module-level rapid shutdown devices are properly installed and functioning.

3 Recommendation to Update Firmware

SMA Solar Technology AG recommends updating all installed inverters to the latest firmware version, and in particular that the update of inverters installed with SunSpec rapid shutdown devices (RSD) be prioritized.

With this firmware version, inverters set to SunSpec rapid shutdown operation mode will always transmit the SunSpec "permission to operate" signal while the inverter is in operation. This will prevent inverters from operating with only partially energized PV strings when the event 9034 occurs on startup due to cross-talk of the SunSpec signal from other inverters in the same system. Event 9034 may still occur when an inverter is started while other inverters in the same system are already in operation. These events are warnings only and will not affect subsequent inverter operation.

4 Commissioning PV Systems with SunSpec Rapid Shutdown

4.1 Information on Commissioning

Installing and commissioning of commercial PV systems with multiple inverters is often accomplished by completing installation on sub-sections of the PV system, and performing electrical tests and partial system startup to verify installation has been completed correctly in preparation for full system commissioning. For systems with SunSpec rapid shutdown module-level devices, there are some specific considerations for taking PV string electrical measurements and preparing inverters for operation and system commissioning.

4.2 Measuring the PV string open-circuit voltage

Measuring open circuit voltage (VOC) of a PV string is a common means of verifying string continuity and the expected number of modules in each string. For PV strings with SunSpec-compliant module-level rapid shutdown devices, modules are disconnected from string conductors whenever the SunSpec "permission to operate" signal is not being received. It is therefore not possible to directly measure module or string voltage unless the PV string is energized by transmitting the SunSpec signal to the rapid shutdown receiver devices.

However, SunSpec-compliant rapid shutdown receiver devices will have a standby voltage of approximately 1 VDC per device when the PV modules are illuminated and the SunSpec signal is not being received. When measured without transmitting the SunSpec signal, the open circuit voltage of a PV string should be equal to the number of module-level rapid shutdown devices (**NOTICE** note: not the number of modules where multi-module devices are used), multiplied by the standby voltage of each device. Refer to the module-level device documentation for the standby voltage level of that specific device.

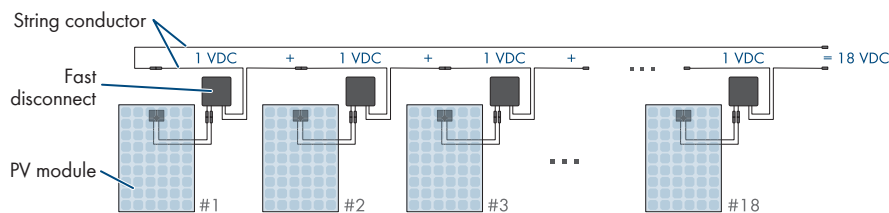


Figure 1: Example of expected open circuit voltage (VOC) for PV string with SunSpec rapid shutdown devices installed

4.3 PV String I-V Curve Measurements

Installation procedures and contracted scopes of work for installation and maintenance of PV systems sometimes include taking I-V curve measurements to confirm the current and voltage characteristics of each PV string. Measuring I-V curve characteristics on PV strings with SunSpec-compliant module-level rapid shutdown devices, however, is not possible unless the SunSpec "permission to operate" signal is transmitted to the module-level receiver devices to energize the PV string as if in operation.

The Sunny Tripower CORE1-US includes an I-V curve diagnosis function as of firmware version 3.12.21.R and the Sunny Tripower X-US as of firmware version 06.03.xx.R which performs an I-V curve trace on each DC input while the inverter is in operation. Results of the I-V curve measurements can be saved to PDF and exported for documentation purposes. The curve diagnostic function of the inverter can be used to measure and document I-V curve characteristics during commissioning and operational verification, or during periodic service and maintenance operations. For further information on this function of the inverter see the Technical Information "I-V and P-V diagnostics function: Using the inverter to determine the generator's characteristic curve to detect faults in PV modules".

4.4 Initial Inverter Startup and Operational Verification

In PV systems with multiple inverters and SunSpec rapid shutdown, when starting individual inverters or sub-groups of inverters to confirm inverter operation and complete configuration in preparation for full system commissioning, all other inverters should first be shut down by being disconnected from AC grid voltage.

1. Ensure the DC and AC disconnects of all inverters are in the open (OFF) position.
2. If starting a sub-group of inverters, ensure that there is a common means of disconnect from AC grid voltage, such as a main circuit breaker in an AC sub-panel, and ensure that this disconnect is in the open (OFF) position.

3. Ensure that the main PV system disconnect is in the closed (ON) position.
4. Switch the DC and AC disconnects on the inverter(s) to be started to the closed (ON) position.
5. If starting a sub-group of inverters, switch the common means of AC disconnect to the closed (ON) position.
6. After completing initial inverter operational verification and configuration, turn off the started inverter(s) by returning the inverter DC and AC disconnects to the open (OFF) position before attempting to start any other inverters.

If other inverters remain in operation prior to starting an inverter or sub-group of inverters, it is possible that some portions of the PV module connected to the inverter(s) being started will be energized prior to startup due to inductive coupling – or cross-talk – of the SunSpec signal from inverters that are already in operation onto the DC conductors of the inverter(s) being started. In this case the inverter(s) may issue warning event message "Error in rapid shutdown system" (event ID 9034) when starting up.

4.5 System Commissioning Startup

In PV systems with multiple inverters and SunSpec rapid shutdown, attempting to start up inverters one at a time may result in some inverters issuing warning event message 9034 when starting up.

1. Ensure the main PV system disconnect or other PV system rapid shutdown initiator device is in the open (OFF) position to disconnect all inverters from AC grid voltage.
2. Ensure that all inverter output circuit breakers and main circuit breakers in any PV sub-panels are in the closed (ON) position.
3. Switch the DC and AC disconnects of all inverters to the closed (ON) position.
4. Switch the main PV system disconnect or PV system rapid shutdown initiator device to the closed (ON) position to connect the PV system to AC grid voltage and begin operation.

5 Performing witness testing for rapid shutdown compliance

For some installations it may be required to demonstrate rapid shutdown compliance to the authority having jurisdiction (AHJ) or other project stakeholders. Where such witness testing of an installed system is required, compliance with the National Electrical Code 690.12 rapid shutdown requirements should be demonstrated by initiation of a PV system shutdown from the designated system rapid shutdown initiation device.

1. With PV system in operation, switch the main PV system disconnect or PV system rapid shutdown initiator device to the open (OFF) position to disconnect the PV system from AC grid voltage and initiate a system rapid shutdown.
2. Verify system shutdown via system monitoring interfaces and/or direct measurements.
3. Re-start system by switching the main PV system disconnect or PV system rapid shutdown initiator device to the closed (ON) position.

Disconnecting an individual inverter or sub-group of inverters from AC grid voltage while other inverters remain in operation may result in some portions of the PV array connected to the disconnected inverter(s) remaining energized. This does not indicate that the PV system is not compliant with the requirements for rapid shutdown of the National Electrical Code 690.12. The rapid shutdown requirements of the National Electrical Code 690.12 are not intended to provide assurance of de-energization of sub-sections of the PV system. It is not expected or intended that emergency responders would need to de-energize only portions of a PV system on a building while leaving other portions energized and operational.

6 Service and Maintenance Operations with SunSpec Rapid Shutdown

Servicing and maintenance of a PV system may require shutting down an inverter or sub-group of inverters for troubleshooting and maintenance operations either on the inverter(s) or in the sub-array attached to the inverter(s). When an inverter is disconnected from AC grid voltage, the inverter will interpret this as a rapid shutdown initiation and will stop transmitting the SunSpec rapid shutdown signal. It is possible, however, that after disconnecting an inverter or sub-group of inverters from AC grid voltage some portions of the PV array connected to those inverters may remain energized due to inductive coupling – or cross-talk – of the SunSpec signal from inverters that remain in operation onto the string conductors of the disconnected inverters.

QUALIFIED PERSON

When servicing or performing maintenance operations on PV systems with rapid shutdown, the PV module and conductors should be treated as potentially energized regardless of the operational status of the connected inverter(s). Always follow safe work practices when working with any PV or electrical system, such as those described in NFPA 70E, *Standard for Electrical Safety in the Workplace*.

When re-starting an inverter following service or maintenance activities while other inverters have remained in operation, it is possible that the voltage on some connected PV strings will be greater than 30 VDC. In this case the inverter will issue event message 9034.

7 Frequently Asked Questions

7.1 Will PV systems with SunSpec rapid shutdown re-start fully following a grid outage?

A grid outage will result in all inverters in the PV system being disconnected from AC grid voltage. The inverters will interpret this as a rapid shutdown initiation and will perform shutdown operation including stopping transmission of the SunSpec "permission to operate" signal. When grid voltage is restored all inverters will re-start and return to operation without need for further intervention.

7.2 Is rapid shutdown initiated by any other inverter events such as insulation (ground) faults or PV arcfaults?

Inverter rapid shutdown is only initiated when the inverter is disconnected from AC grid voltage. And even if an inverter is disconnected from AC grid voltage, it is possible that some portions of the PV array connected to the disconnected inverter may remain energized if other inverters in the PV system remain in operation. When investigating PV system faults, the PV array and conductors should be treated as potentially energized regardless of the operational status of the connected inverter. Always follow safe work practices when working with any PV or electrical system, such as those described in NFPA 70E, *Standard for Electrical Safety in the Workplace*.

7.3 What does event 9034 "Error in rapid shutdown system" mean?

With SunSpec rapid shutdown mode activated, during inverter startup the inverter measures DC voltage on its PV inputs prior to initiating transmission of the SunSpec "permission to operate" signal. If the inverter measures greater than 30 VDC on any PV inputs, the inverter will issue warning event message 9034 to indicate that DC voltage in excess of 30 VDC was detected prior to transmission of the SunSpec signal.

DC voltage in excess of 30 VDC prior to transmission of the SunSpec signal is commonly caused by inductive coupling – or cross-talk – of the SunSpec signal from inverters that are already in operation onto the string conductors of the inverter being started. If cross-talk is not suspected, event 9034 may also be an indication that some rapid shutdown devices in the array were not installed or are not operating correctly.

7.4 Why are PV strings not fully energized while the inverter is in operation, or why does inverter operate at reduced power?

This is an indication that the inverter is operating without transmitting the SunSpec "permission to operate" signal. Ensure that the inverter has been updated to the latest firmware and that SunSpec rapid shutdown mode has been activated.