Rapid Shutdown

by Brian Mehalic

Section 690.12 of the *National Electrical Code (NEC)*, which was first introduced in 2014, governs rapid shutdown (RS) of PV systems on buildings. For the 2017 edition, this section has been expanded and clarified, including defining RS initiation devices. (See "New Rapid Shutdown Solutions" in this issue for more information on strategies and products to meet new RS requirements.)

Where RS Applies

Section 690.12 only applies to PV systems in or on buildings—ground- or pole-mounted systems are not subject to these requirements so long as none of the system circuits "touch" a building. An exception is when a building's sole purpose is to house PV system equipment; then RS does not apply.

Wiring from the PV and within the PV array to the PV system disconnect is subject to 690.12—see the system schematics in Figure 690.1(b) for specific configurations on page 47 of this issue. This is an example of how clearly defining the location of the PV system disconnect adds clarity throughout Article 690. For instance, this shows that an energy-storage system in an AC-coupled multimode system is not part of the PV system, and thus not subject to RS.

Newly defined in the 2017 edition, the PV array boundary is described as 1 foot in *all* directions from the outer edges of the PV array. Section 690.12(B)(1) applies to PV system circuits *outside* of the array boundary, as well as to circuit conductors more than 3 feet from the point of entry into the building; 690.12(B)(2) covers circuits *inside* of the array boundary. While the RS voltage limit is higher inside the array boundary, the requirement to control PV system conductors inside the array boundary has in practice necessitated module-level RS, which has tremendous implications on system design and component selection.

RS is not a disconnect requirement—rather, it resides in Part II of Article 690, "Circuit Requirements." As such, a variety of products—some of which may be disconnects—can be used and must be listed for the purpose per Section 690.12(D). However, this requirement for listing does not include disconnects, circuit breakers, or control switches that are used to initiate rapid shutdown.

Controlled Conductors

Outside of the array boundary, conductors must be limited to 30 volts within 30 seconds of RS initiation. This is not tremendously different than the 2014 *NEC* requirement, though the distance from the array to where the conductors must be controlled has decreased due to the definition of the array boundary only being 1 foot.

Prior to the 2017 *NEC*, there was no requirement for controlling voltage inside the array boundary; now there is, and three options exist, though not all of them are practical or possible. (Note that this requirement does not go into effect until January 1, 2019, or immediately upon adoption of the 2017 *NEC*, if the jurisdiction adopts it after that date.)

To meet the RS requirement inside the array boundary (or for conductors inside the boundary and not more than 3 feet from the point of penetration into the building; for example, running parallel to the roof, inside the building, and underneath and within 1 foot of the array), the most common approach is to limit conductors to no more than 80 V within 30 seconds of RS initiation, as described in 690.12(B)(2)(2). In most cases, this voltage level equals "module-level" shutdown—the open-circuit voltage of two 60-cell PV modules in series will likely exceed 80 V at the expected low temperatures in many locations; two 72-cell modules definitely will. Module-level power electronics (MLPEs), such as DC-to-DC converters, microinverters, or additional module-level devices specifically designed for RS, will be used to meet this requirement.

Another option— 690.12(B)(2)(3)—is an allowance for PV arrays without exposed wiring methods or conductive parts that are installed more than 8 feet from grounded parts or ground. Since shock hazards are minimized by the nature of the system design, these types of arrays do not have to comply with RS inside the array boundary. While some types of building-integrated PV systems may fall under this allowance, they must still meet the 690.12(B)(1) requirements that apply outside of the array boundary.

Some PV arrays may be listed or field-labeled as being an "RS" PV array, thus meeting the requirement as specified in 690.12(B)(2)(1). However, standards for RS PV arrays have not been completed, and by the time a standard is fully developed, it is likely that it will be written to meet 2020 *NEC* RS requirements in the form of UL3741, "Standard for Safety for Photovoltaic Hazard Control."

Initiation Devices

Section 690.12(C) is new and provides three options for the RS initiation device or devices. Regardless of the type of device, its "off" position must equate to RS having been initiated. For one- and two-family dwellings, the device (or devices) must be outside the building and readily accessible.

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One option for an initiation device is the service-disconnecting means, which will meet requirements for most load-side-connected interactive PV systems without energy storage. Shutting off power to the building shuts off the inverter and also causes associated, listed RS equipment—such as a contactor combiner and/or MLPEs—to open or otherwise operate, meeting the requirements for controlling conductors inside and outside the array boundary. When possible, this is the preferred initiation device, since first responders will already be using the service disconnect to isolate the building from utility power and this single switch can perform both functions.

The PV system-disconnecting means can also be used as the RS initiation device; this is a typical configuration for supply-side-connected PV systems that do not have energy storage. Connected to the primary source of power between the utility meter and the main service disconnect, a supply-side-connected PV system will not be impacted by shutting off the main service disconnect. Disconnecting means and overcurrent protection are required to interconnect on the supply side, and this device—either a fused disconnect or a circuit breaker—can double as the RS initiator.

The third option for initiation devices is a readily accessible switch that clearly indicates "on" and "off" (with "off" equaling RS initiation). As described in the Informational Note to 690.12(C)(3), this strategy could be employed for multimode systems, since a loss of utility power—and the system switching from interactive to stand-alone mode—is an expected operating condition and a strategy for initiating RS based on a loss of grid power would not work. Note that the PV system disconnect could still be the initiation device for multimode systems, and either of these options—meaning the PV system disconnect or an accessible on/off switch—could also be used for stand-alone systems.

Section 690.12(C) allows for multiple switches—up to six—per service, so long as the switch(es) act as the initiation devices for *all* of the PV systems on that service that are required to have RS. (Having two separate PV systems—which could mean a total of 12 switches—would not be allowed on a single service.)

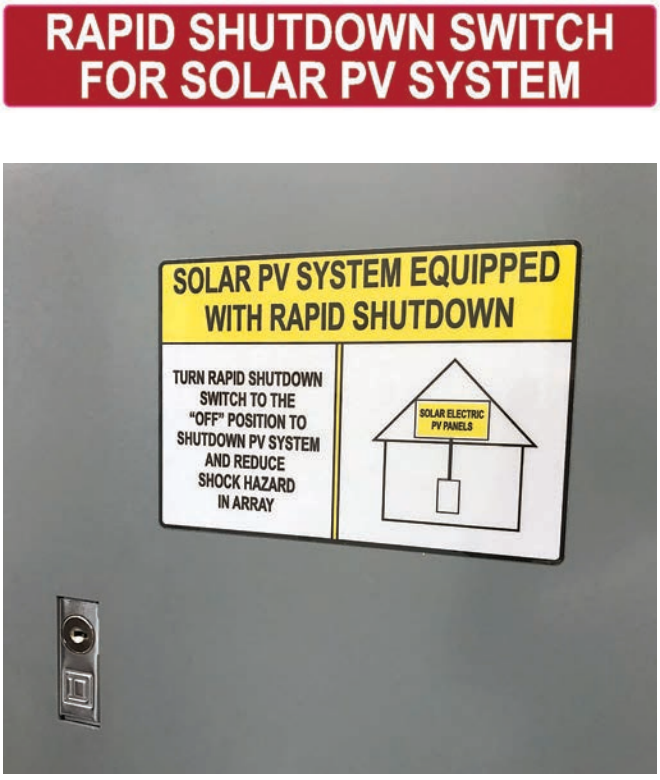
Labeling

Marking requirements for buildings with PV systems —which must have RS—and for the associated initiation device(s) are found in Section 690.56(C).

The initiation device, referred to as the "rapid shutdown switch" in 690.56(C)(3), must be labeled as such. As is the case with other labels primarily intended for first responders, there are specific requirements: all capital letters, white letters on red, and with a minimum letter height of 3/8 inches. The label must either be on the switch or no more than 3 feet from it.

After January 1, 2019, there will only be one other label required for RS; until then, there are two, which distinguish between systems that have RS only outside the array boundary [see Figure 690.56(C)(1)(b)] and those that meet the 690.12(B)(2) requirement for inside the boundary [Figure 690.56(C)(1)(a)]. Because of the enhanced safety offered by controlling conductors both inside and outside of the array boundary, the label indicating "module-level" RS has a requirement for black text on a yellow background. The increased hazard associated with RS only outside the array boundary is indicated by the requirement for white lettering on a red background, as well as different wording indicating that "conductors within the array remain energized in sunlight." As with the label for the RS switch, font sizes are specified for both labels.

Finally, because there could be a case where there are two systems on a building with different RS requirements—for example, if a system is installed in 2019 on a building that has an existing system from 2014 or a pre-2014 system where no RS was required, 690.56(C)(2) provides details on labeling, including a requirement to delineate which arrays will remain energized inside the array boundary.



Courtesy HellermannTyton (2)

Top: The required label at the RS switch. Bottom: This label must be located no more than 3 feet from the service-disconnecting means. These labels comply with *NEC* Section 690.56(C)(1) requirements for PV systems with rapid shutdown both inside and outside the array boundary. In jurisdictions that have adopted the 2017 *NEC*, this will be the only type of RS allowed after January 1, 2019.