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# Photovoltaic Energy System Code Requirements

The Code requirements for PV systems are in the following codes, which are in effect statewide.

The National Electrical Code NFPA 70- 2020

The NFPA 1 Fire Code NFPA 1 – 2018

The International Residential Code - 2015

The International Building Code - 2015

The NFPA codes can be seen on the NFPA website (www.nfpa.org).

The International codes can be seen on The International Code Council website (www.iccsafe.org).

Excerpts from the applicable code are attached.

Some PV systems have storage batteries associated with them. See Article 706 of The Electrical Code and Chapter 52 of NFPA 1 for the code requirements for storage batteries, associated with PV systems, or otherwise.

All PV systems and battery storage systems must be designed and installed per the applicable codes and equipment manufacturer's instructions.

If you have questions or need further information, let us know.

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## **Photovoltaic Building Code Requirements; Note all references to the International Fire Code (IFC) mean NFPA-1 version 2018**

# IRC 2015

**R324.3 Photovoltaic systems.**

Photovoltaic systems shall be designed and installed in accordance with Sections R324.3.1 through R324.6.1 and NFPA 70. Inverters shall be *listed* and *labeled* in accordance with UL 1741. Systems connected to the utility grid shall use inverters listed for utility interaction.

❖ Section R324.3 requires that solar photovoltaic energy systems comply with Sections R324.3.1 through R324.6.1 and NFPA 70. NFPA 70 is the National Electrical Code®.

Section R324.3 also requires that inverters for photovoltaic solar energy systems be listed and labeled in accordance with UL 1741 and that, where systems are connected to the utility grid, the inverters be listed for that purpose.

The ever-increasing demand for alternative power sources brings with it new hazards to confront emergency responders. Among the most popular of these alternative energy sources are solar photovoltaic (PV) power systems. A number of United States electric utility power suppliers offer incentives for the installation of PV systems on buildings because such systems offer the property owners the ability to generate their own electricity and, in many cases, sell excess electricity back to the utility provider. Such an arrangement is a benefit to the utility provider because it reduces their power generation demand, which in turn can control the rates that commercial and residential customers pay. Demand for PV power systems has increased by several orders of magnitude in the past decade. According to the U.S. Energy Information Administration, approximately 21,200 PV cells and modules were shipped domestically in 1999; by 2008, the number shipped was over 524,200. As the number of PV power systems increases, economy of scale will continue to reduce the system's costs, making them more common on commercial and residential buildings.

PV systems are designed to convert light energy into direct current (DC) electricity. They have no moving parts and do not contain fluids. The light-to-electricity conversion begins at the PV cell, which is commonly a semiconductor device that generates electricity when exposed to light. To be effective, PV cells are assembled into PV modules, which are then assembled into PV panels. The panels are assembled onto a frame or a flexible substrate, which then can be affixed to the roof of buildings to create a PV array. The PV arrays and its modules are wired together and generally operate as a series electrical circuit. PV arrays are required by NFPA 70 to have a fuse or other means of branch circuit protection to prevent them from being overloaded. While not required, a PV array is commonly equipped with a blocking diode. A blocking diode is analogous to a check valve in a piping system because it limits the direction the electrons can travel. The blocking diode prevents electrical current from one power supply from finding entry into another. In PV systems, the blocking diode protects each individual PV panel if other panels fail and prevents the withdrawal of electricity from the system during the nighttime.

The greatest danger facing emergency responders operating in proximity to solar energy collection systems is the lack of knowledge needed to operate safely around these systems. Some of the potential hazards associated with PV systems are tripping hazards and/or falls for fire fighters operating on the roof and the potential for earlier roof collapse due to the added dead load and electric shock. The provisions of Sections R324.3 through R324.6.1 were based on similar provisions in the IFC and were developed to provide for the proper installation of PV systems and to address the potential hazards to fire fighters.

**R324.3.1 Equipment listings.**

Photovoltaic panels and modules shall be listed and labeled in accordance with UL 1703.

❖ Photovoltaic panels and modules must be listed and labeled by an approved agency to show that they comply with applicable national standards. The label is the primary, if not the only, assurance to the installer, the inspector and the end user that a similar appliance has been tested and evaluated by an approved agency and performed safely and efficiently when installed and operated in accordance with its listing. Photovoltaic panels and modules must be listed and labeled to UL 1703, which is a referenced standard for flat plate photovoltaic modules and panels with a system voltage of 1,000 or less

**R324.4 Rooftop-mounted photovoltaic systems.**
Rooftop-mounted photovoltaic panel systems installed on or above the roof covering shall be designed and installed in accordance with Section R909.
❖ For photovoltaic panel systems that are mounted directly to rooftops, Section R324.3.1 requires compliance with the structural and installation requirements of Section 909. Section 909 applies specifically to roof-top-mounted photovoltaic panel systems. Photovoltaic panel systems are defined in Section R202.

**R324.4.1 Roof live load.**

Roof structures that provide support for photovoltaic panel systems shall be designed for applicable roof live load. The design of roof structures need not include roof live load in the areas covered by photovoltaic panel systems. Portions of roof structures not covered by photovoltaic panels shall be designed for roof live load. Roof structures that provide support for photovoltaic panel systems shall be designed for live load, $L_R$, for the load case where the photovoltaic panel system is not present.

❖ This section addresses live loads for photovoltaic (PV) panel systems (see the definition of "Photovoltaic panel system") and indicates where and how such loads must be considered. Note that the loads imposed by PV panel systems are dead loads, not live loads. This section does not address dead loads. This section addresses roof live loads in two cases as follows:

Case 1, areas of roofs that are covered by PV panels: Roof live load is not required to be considered or modeled in these areas because the assumption is that no one will be walking on top of the panels or on the roof area covered by the panels.

Case 2, areas of roofs that are not covered by PV panels: The code-prescribed roof live load is required to be considered in the same manner that they typically would in conditions where photovoltaic panels are not present.

**R324.5 Building-integrated photovoltaic systems.**

Building-integrated photovoltaic systems that serve as roof coverings shall be designed and installed in accordance with Section R905.

❖ Building-integrated photovoltaic product is defined in Section R202 as a building product that is part of the building envelope and incorporates photovoltaic modules. Building integrated photovoltaic systems must be designed and installed in accordance with Section 905. Section R202 also defines "Photovoltaic module."

**R324.5.1 Photovoltaic shingles.**

Photovoltaic shingles shall comply with Section R905.16.

❖ Where photovoltaic collectors also function as shingle roof coverings, they must comply with Section R905.16, which specifically addresses photovoltaic shingles, and its subsections. Section R202 defines "Photovoltaic shingles" and "Photovoltaic module." Photovoltaic shingles are roof coverings that include photovoltaic modules and resemble conventional shingles. Photovoltaic modules are environmentally protected units that include solar cells, optics and components, other than a tracker, that generate electrical power from sunlight.

**R324.6 Ground-mounted photovoltaic systems.**

Ground-mounted photovoltaic systems shall be designed and installed in accordance with Section R301.

❖ Photovoltaic systems that are mounted on the ground must meet the structural design provisions of Section R301.

**R324.6.1 Fire separation distances.**

Ground-mounted photovoltaic systems shall be subject to the *fire separation distance* requirements determined by the local *jurisdiction*.

❖ The code does not contain specific requirements for ground-mounted photovoltaic systems based on fire separation distance. Instead, the code defaults to the local jurisdiction for guidance on this subject.

**R909.1 General.**

The installation of photovoltaic panel systems that are mounted on or above the roof covering shall comply with this section, Section R324 and NFPA 70.

❖ Rooftop-mounted photovoltaic (PV) panel systems can be mounted on or above the roof covering. The PV panel system must comply with Section R909, the applicable portions of Section R324 and NFPA 70 and the manufacturer's installation instructions. PV panel systems installed on or above the roof covering must be securely fastened to the roof/rafter system. Often, solar collector systems are installed with manufactured metal mounting brackets that can be attached to the roofing system or wood blocking, or with sleepers using lag bolts or other secure mounting systems. The manufacturer's mounting specifications must be followed so that the panels are properly mounted. This is especially important in areas with high wind loads. Also, the weight of the collector system must be checked to confirm that the roof structure is designed to meet the increased load. Roof penetrations must be sealed during and after installation of the PV panel systems. At a minimum, there will be roof penetrations for the electrical conduits connecting to the panels. PV panel systems mounted above the roof covering will require penetrations into the rafter system or blocking to attach the collectors to the roof, and care must be taken to seal the penetrations

**R909.2 Structural requirements.**

Rooftop-mounted photovoltaic panel systems shall be designed to structurally support the system and withstand applicable gravity loads in accordance with Chapter 3. The roof upon which these systems are installed shall be designed and constructed to support the loads imposed by such systems in accordance with Chapter 8.

❖ See the commentary to Section R909.1

**R909.3 Installation.**

Rooftop-mounted photovoltaic systems shall be installed in accordance with the manufacturer's instructions. Roof penetrations shall be flashed and sealed in accordance with this chapter.

❖ See the commentary to Section R909.1

# IBC 2015

**[BF]1505.8 Building-integrated photovoltaic products.**

*Building-integrated photovoltaic products* installed as the roof covering shall be tested, *listed* and *labeled* for fire classification in accordance with Section 1505.1.

❖ This section requires photovoltaic products integrated into the envelope as a roof covering to comply with UL 790 or ASTM E108.

**[BF]1505.9 Photovoltaic panels and modules.**

Rooftop-mounted *photovoltaic panel systems* shall be tested, *listed* and identified with a fire classification in accordance with UL 1703. The fire classification shall comply with Table 1505.1 based on the type of construction of the building.

❖ This section recognizes that stand-off rack-mounted photovoltaic panels and modules are better tested in accordance with UL 1703 rather than UL 790 or ASTM E108. It also clarifies that the fire classification listed for the photovoltaic panels and modules must be consistent with the fire classification requirement for the roof covering.

**[BS]1510.7Photovoltaic panels and modules.**

Rooftop-mounted *photovoltaic panels* and *modules* shall be designed in accordance with this section.

❖ Rooftop-mounted photovoltaic panels and modules need to comply with building code requirements similar to other rooftop structures.

**[BS]1510.7.1 Wind resistance.**

Rooftop-mounted *photovoltaic panels* and *modules* shall be designed for component and cladding wind loads in accordance with Chapter 16 using an effective wind area based on the dimensions of a single unit frame.

❖ This section clarifies that rooftop-mounted photovoltaic panels and modules need to resist component and cladding wind loads and specifies that a single unit must be used to establish the effective wind area.

**[BS]1510.7.2 Fire classification.**

Rooftop-mounted *photovoltaic panels* and *modules* shall have the fire classification in accordance with Section 1505.9.

❖ The minimum requirements set forth here are intended for the rooftop-mounted photovoltaic panels and modules to comply with the same minimum requirements as the underlying roof assembly.

**[BS]1510.7.3 Installation.**

Rooftop-mounted *photovoltaic panels* and *modules* shall be installed in accordance with the manufacturer's instructions.

❖ Rooftop-mounted photovoltaic panels and modules need to be installed in accordance with the manufacturer's instructions.

**[BS]1510.7.4 Photovoltaic panels and modules.**

Rooftop-mounted *photovoltaic panels* and *modules* shall be *listed* and labeled in accordance with UL 1703 and shall be installed in accordance with the manufacturer's instructions.

❖ This section addresses the safety of photovoltaic panels and modules by requiring these products to comply with UL 1703 and to be installed in accordance with the manufacturer's instructions. UL 1703 is a standard used to investigate photovoltaic modules and panels and includes construction and performance requirements that address potential safety hazards.

**1607.12.5 Photovoltaic panel systems.**

Roof structures that provide support for *photovoltaic panel systems* shall be designed in accordance with Sections 1607.12.5.1 through 1607.12.5.4, as applicable.

❖ Photovoltaic (PV) panel systems, also known as "solar panels," are required to be designed to resist the live loads in this section.

**1607.12.5.1 Roof live load.**

Roof surfaces to be covered by solar photovoltaic panels or modules shall be designed for the roof live load, $L_r$, assuming that the photovoltaic panels or modules are not present. The roof photovoltaic live load in areas covered by solar photovoltaic panels or modules shall be in addition to the panel loading unless the area covered by each solar photovoltaic panel or module is inaccessible. Areas where the clear space between the panels and the rooftop is not more than 24 inches (610 mm) shall be considered inaccessible. Roof surfaces not covered by photovoltaic panels shall be designed for the roof live load.

❖ PV panels can affect where live loads occur or are placed on the roof. The intent is for two design conditions to be checked: 1. Assuming that the panels are not present; and 2. Assuming that the panels are present. The first analysis addresses cases where panels are anticipated to be installed but for some reason end up being omitted, or where the panels are initially installed but are removed at some point in the building's life. In the second analysis, live load may be omitted in areas where the clear space under the panels is 24 inches (710 mm) or less, which is considered inaccessible. Live load should be applied to all accessible areas, including roof surfaces not covered by panels.

**1607.12.5.2 Photovoltaic panels or modules.**

The structure of a roof that supports solar photovoltaic panels or modules shall be designed to accommodate the full solar photovoltaic panels or modules and ballast dead load, including concentrated loads from support frames in combination with the loads from Section 1607.12.5.1 and other applicable loads. Where applicable, snow drift loads created by the photovoltaic panels or modules shall be included.

❖ The effects of concentrated loads from the support frames, including ballast, must be considered. If the panels will tend to cause snow drifts, these loads shall be considered as well.

**1607.12.5.3 Photovoltaic panels or modules installed as an independent structure.**

Solar photovoltaic panels or modules that are independent structures and do not have accessible/occupied space underneath are not required to accommodate a roof photovoltaic live load, provided the area under the structure is restricted to keep the public away. All other loads and combinations in accordance with Section 1605 shall be accommodated.

Solar photovoltaic panels or modules that are designed to be the roof, span to structural supports and have accessible/occupied space underneath shall have the panels or modules and all supporting structures designed to support a roof photovoltaic live load, as defined in Section 1607.12.5.1 in combination with other applicable loads. Solar photovoltaic panels or modules in this application are not permitted to be classified as "not accessible" in accordance with Section 1607.12.5.1.

❖ PV panels that are designed as part of an independent ground-supported structure are not required to be designed for roof live loads if the space under them is inaccessible. PV panels that are designed to act as a roofing over an occupied space (e.g., panels that form a carport roof) must be designed for roof live loads.

**1607.12.5.4 Ballasted photovoltaic panel systems.**

Roof structures that provide support for ballasted *photovoltaic panel systems* shall be designed, or analyzed, in accordance with Section 1604.4; checked in accordance with Section 1604.3.6 for deflections; and checked in accordance with Section 1611 for ponding.

❖ Although the design of all roof members is required to consider deflection and ponding, as are all roof members that support unballasted PV panels, given the weight of typical ballasted PV systems it was believed appropriate to reinforce the fact that roof members supporting such systems must be analyzed for deflection and ponding as well as meet minimum capacity requirements.

**3111.1 General.**

Photovoltaic panels and modules shall comply with the requirements of this code and the *International Fire Code*.

❖ Photovoltaic arrays are increasing in popularity as an alternative energy source. These arrays, which cannot be shut down and retain electrical charges, pose unique hazards to fire fighters operating on roofs with arrays or nearby circuits. This section references the IFC, which provides general requirements to allow for increased safety of fire fighters working near the arrays.

**3111.1.1 Rooftop-mounted photovoltaic panels and modules.**

Photovoltaic panels and modules installed on a roof or as an integral part of a roof assembly shall comply with the requirements of Chapter 15 and the *International Fire Code*.

❖ This section notes that the requirements for rooftop mounted solar photovoltaic panels are found in Chapter 15. More specifically. Section 1505.8. Building integrated photovoltaic products, Section 1509.9, Photovoltaic panels and modules. Section 1507.17, Photovoltaic shingles and Section 1512, Photovoltaic panels and modules. must be addressed.

**11.9.2** The emergency command center shall be separated from the remainder of the building by a fire barrier having a fire resistance rating of not less than 1 hour.

**11.9.3** New emergency command center rooms shall be a minimum of 200 ft$^2$ (19 m$^2$) with a minimum dimension of 10 ft (3050 mm).

*N* **11.9.3.1** Existing emergency command center rooms shall be maintained with the minimum square footage and dimensions previously approved by the AHJ.

**11.9.4** The following shall be provided in the emergency command center:

(1) The fire department communication unit
(2) A telephone for fire department use with controlled access to the public telephone system
(3) Schematic building plans indicating the typical floor plan and detailing the building core means of egress, fire protection systems, fire-fighting equipment, and fire department access
(4) Work table
(5) If applicable, hazardous material management plans for the building

**11.9.5** Where otherwise required, the following devices or functions shall be provided within the emergency command center:

(1) The emergency voice/alarm communication system unit
(2) Fire detection and alarm system annunciator unit
(3) Annunciator visually indicating the location of the elevators and whether they are operational
(4) Status indicators and controls for air-handling systems
(5) Controls for unlocking stairway doors simultaneously
(6) Sprinkler valve and waterflow detector display panels
(7) Emergency and standby power status indicators
(8) Fire pump status indicators
(9) Generator supervision devices and manual start and transfer features
(10) Public address system, where specifically required by other sections of this *Code*
(11) Controls required for smoke control

**11.9.6 Emergency Command Center Acceptance Testing.** Devices, equipment, components, and sequences shall be individually tested in accordance with appropriate standards and manufacturers' documented instructions.

**11.10* Two-Way Radio Communication Enhancement Systems.**

**11.10.1** In all new and existing buildings, minimum radio signal strength for fire department communications shall be maintained at a level determined by the AHJ.

**11.10.2** Where required by the AHJ, two-way radio communication enhancement systems shall comply with NFPA 1221.

**11.10.3** Where a two-way radio communication enhancement system is required and such system, components, or equipment has a negative impact on the normal operations of the facility at which it is installed, the AHJ shall have the authority to accept an automatically activated responder system.

Δ **11.11 Medical Gas and Vacuum Systems.** Medical gas and vacuum systems shall comply with NFPA 99.

**11.12 Photovoltaic Systems.**

**11.12.1** Photovoltaic systems shall be in accordance with Section 11.12 and *NFPA 70.*

**11.12.2 Building-Mounted Photovoltaic Installations.**

**11.12.2.1* Marking.** Photovoltaic systems shall be permanently marked as specified in this subsection.

*N* **11.12.2.1.1* Rapid Shutdown Marking.** Buildings with a PV system shall be provided with permanent labels as described in 11.12.2.1.1.1 through 11.12.2.1.1.7.

*N* **11.12.2.1.1.1 Rapid Shutdown Type.** The type of PV system rapid shutdown shall be labeled as described in 11.12.2.1.1.1.1 or 11.12.2.1.1.1.2.

*N* **11.12.2.1.1.1.1** For PV systems that shut down the array and conductors leaving the array:

EMERGENCY RESPONDER:
THIS SOLAR PV SYSTEM IS EQUIPPED
WITH RAPID SHUTDOWN

TURN RAPID SHUTDOWN SWITCH TO THE "OFF"
POSITION TO SHUT DOWN ENTIRE PV SYSTEM

*N* **11.12.2.1.1.1.2** For PV systems that only shut down conductors leaving the array:

EMERGENCY RESPONDER:
THIS SOLAR PV SYSTEM IS EQUIPPED
WITH RAPID SHUTDOWN

TURN RAPID SHUTDOWN SWITCH TO
THE "OFF" POSITION.
ONLY CONDUCTORS INSIDE BUILDING OR OFF THE
ROOF WILL SHUT DOWN

*N* **11.12.2.1.1.2** The label shall be reflective, with all letters capitalized and having a minimum height of ⅜ in. (9.5 mm), in white on a red background.

*N* **11.12.2.1.1.3** The label shall include a simple diagram of a building with a roof. Diagram sections in red shall signify sections of the PV system that are not shut down when the rapid shutdown switch is operated. Sections of the diagram in green shall signify sections of the PV system that are shut down when the rapid shutdown switch is operated.

*N* **11.12.2.1.1.4** The rapid shutdown label shall be located on or no more than 3 ft (1 m) from the service disconnecting means to which the PV systems are connected, and the label shall indicate the location of the rapid shutdown switch if it is not at the same location.

*N* **11.12.2.1.1.5 Buildings with More Than One Rapid Shutdown Type.** For buildings that have PV systems with both rapid shutdown types, or a rapid shutdown type and a PV system with no rapid shutdown, a detailed plan view diagram of the roof shall be provided showing each PV system and a dotted line around areas that remain energized after the rapid shutdown switch is operated.

*N* **11.12.2.1.1.6 Rapid Shutdown Switch.** The rapid shutdown switch shall have a label located on or no more than 3 ft (1 m) from the switch that includes the following words:

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

*N* **11.12.2.1.1.7** The label required by 11.12.2.1.1.6 shall be reflective, with all letters capitalized and having a minimum height of ⅜ in. (9.5 mm), in white on red background. [*70*:690.56(C)]

*N* **11.12.2.1.2** Each PV system disconnecting means shall be permanently marked to identify it as a PV system disconnect and shall indicate whether in the open or closed position. [*70*:690.13(B)]

*N* **11.12.2.1.3 Markings for Direct-Current Photovoltaic Source and Direct-Current Output Circuits on or Inside a Building.** The following wiring methods and enclosures that contain PV power source conductors shall be marked with the words WARNING: PHOTOVOLTAIC POWER SOURCE by means of permanently affixed labels or other approved permanent marking:

(1) Exposed raceways, cable trays, and other wiring methods
(2) Covers or enclosures of pull boxes and junction boxes
(3) Conduit bodies in which any of the available conduit openings are unused

[*70*:690.31(G)(3)]

*N* **11.12.2.1.3.1 Marking Locations and Methods.** The labels or markings shall be visible after installation. The labels shall be reflective and shall have all letters capitalized with a minimum height of ⅜ in. (9.5 mm) white on red background. PV power circuit labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 10 ft (3 m). Labels required by this section shall be suitable for the environment where they are installed. [*70*:690.31(G)(4)]

*N* **11.12.2.1.4 Secondary Power Source Markings.** A permanent plaque or directory, denoting all electric power sources on or in the premises, shall be installed at each service equipment location and at locations of all electric power production sources capable of being interconnected. [*70*:705.10]

*N* **11.12.2.1.5 Installer Information.** A label shall be installed adjacent to the main disconnect indicating the name and emergency telephone number of the company currently servicing the PV system.

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*N* **11.12.2.2 Roof Access.**

*N* **11.12.2.2.1 General.** Access and spacing requirements shall be required to provide emergency access to the roof, provide pathways to specific areas of the roof, provide for smoke ventilation opportunity areas, and to provide emergency egress from the roof. The AHJ shall be permitted to reduce or modify roof access based upon fire department ventilation procedures or alternative methods that ensure adequate fire department access, pathways, and smoke ventilation.

*N* **11.12.2.2.2 One- and Two-Family Dwellings and Townhouses.** Photovoltaic systems installed in one- and two-family dwellings and townhouses shall provide roof access in accordance with 11.12.2.2.2. Designation of ridges shall not apply to roofs with 2 in 12 or less pitch.

*N* **11.12.2.2.2.1 Pathways.** Not less than two 36 in. (914 mm) wide pathways on separate roof planes, from gutter to ridge, shall be provided on all buildings. One pathway shall be provided on the street or driveway side of the roof. For each roof plane with a PV array, a 36 in. (914 mm) wide pathway from gutter to ridge shall be provided on the same roof plane as the PV array, on an adjacent roof plane or straddling the same and adjacent roof planes. Pathways shall be located in areas with minimal obstructions such as vent pipes, conduit, or mechanical equipment.

*N* **11.12.2.2.2.2** For PV arrays occupying up to 33 percent of the plan view roof area, a minimum 18 in. (457 mm) pathway shall be provided on either side of a horizontal ridge. For PV arrays occupying more than 33 percent of the plan view roof area, a minimum of 36 in. (914 mm) pathway shall be provided on either side of a horizontal ridge.

*N* **11.12.2.2.3 Buildings Other Than One- and Two-Family Dwellings and Townhouses.** Photovoltaic systems installed on any building other than one- and two-family dwellings and townhouses shall provide roof access in accordance with 11.12.2.2.3. Where the AHJ determines that the roof configuration is similar to a one- and two-family dwelling or townhouse, the AHJ shall allow the roof access requirements of 11.12.2.2.2. Detached, nonhabitable structures including, but not limited to, parking shade structures, carports, solar trellises, and similar structures shall not be required to provide roof access.

*N* **11.12.2.2.3.1 Perimeter Pathways.** A minimum 4 ft (1219 mm) wide perimeter pathway shall be provided around the edges of the roof for buildings with a length or width of 250 ft (76.2 m) or less along either axis. A minimum 6 ft (1829 mm) wide perimeter pathway shall be provided around the edges of the roof for buildings having length or width greater than 250 ft (76.2 m) along either axis.

*N* **11.12.2.2.3.2 Other Pathways.** Pathways shall be over areas capable of supporting fire fighters accessing the roof and shall be provided between array sections as follows:

(1) Pathways shall be provided in a straight line 48 in. (1219 mm) or greater in width to all ventilation hatches, and roof standpipes.
(2) Pathways shall be provided 48 in. (1219 mm) or greater in width around roof access hatches with at least one 48 in. (1219 mm) or greater in width pathway to the parapet or roof edge.
(3) Pathways shall be provided at intervals no greater than 150 ft (46 m) throughout the length and width of the roof.

*N* **11.12.2.2.3.3 Smoke Ventilation.** A pathway shall be provided 48 in. (1219 mm) or greater in width bordering all sides of nongravity-operated smoke and heat vents. Ventilation options between array sections shall be one of the following:

(1) A pathway 96 in. (2438 mm) or greater in width
(2) A pathway 48 in. (1219 mm) or greater in width and bordering on existing roof skylights or gravity-operated dropout smoke and heat vents on not less than one side
(3) A pathway 48 in. (1219 mm) or greater in width and bordering 48 in. (1219 mm) by 96 in. (2438 mm) venting cutouts options every 20 ft (6096 mm)

*N* **11.12.2.2.3.4 Minimizing Obstructions in Pathways.** Pathways shall be located in areas with minimal obstructions such as vent pipes, conduit, or mechanical equipment to reduce trip hazards and maximize ventilation opportunities.

**11.12.3 Ground-Mounted Photovoltaic System Installations.** Ground-mounted photovoltaic systems shall be installed in accordance with 11.12.3.1 through 11.12.3.3.

**11.12.3.1* Clearances.** A clear area of 10 ft (3048 mm) around ground-mounted photovoltaic installations shall be provided.

**11.12.3.2* Vegetation Management Plan.** A vegetation management plan or noncombustible base acceptable to the AHJ shall be approved and maintained under and around the installation where required by the AHJ.

**11.12.3.3* Security Barriers.** Fencing, skirting, or other suitable security barriers shall be installed when required by the AHJ.

## Chapter 12 Features of Fire Protection

**12.1 General.** This chapter shall apply to new, existing, permanent, or temporary buildings.

**12.2* Construction.**

Δ **12.2.1*** Where required by this *Code*, a type of building construction shall comply with NFPA 220.

**12.2.2** Fire safety construction features for new and existing occupancies shall comply with this *Code* and the referenced edition of NFPA *101*.

**12.3 Fire-Resistive Materials and Construction.**

Δ **12.3.1** The design and construction of fire walls and fire barrier walls that are required to separate buildings or subdivide a building to prevent the spread of fire shall comply with Section 12.3 and NFPA 221.

**12.3.2* Quality Assurance for Penetrations and Joints.** In new buildings three stories or greater in height, a quality assurance program for the installation of devices and systems installed to protect penetration and joints shall be prepared and monitored by the RDP responsible for design. Inspections of firestop systems and fire-resistive joint systems shall be in accordance with 12.3.2.1 and 12.3.2.2.

**12.3.2.1** Inspection of firestop systems of the types tested in accordance with ASTM E814, *Standard Test Method for Fire Tests of Through-Penetration Fire Stops*, or /UL 1479, *Standard for Fire Tests of Through-Penetration Firestops*, shall be conducted in accordance with ASTM E2174, *Standard Practice for On-Site Inspection of Installed Fire Stops*. [*5000*:40.9.1]

**12.3.2.2** Inspection of fire-resistive joint systems of the types tested in accordance with ASTM E1966, *Standard Test Method for Fire-Resistive Joint Systems*, or UL 2079, *Standard for Tests for Fire Resistance of Buildings Joint Systems*, shall be conducted in accordance with ASTM E2393, *Standard Practice for On-Site Inspection of Installed Fire Resistive Joint Systems and Perimeter Fire Barriers*. [*5000*:40.9.2]

**12.3.3* Maintenance of Fire-Resistive Construction, Draft-Stop Partitions, and Roof Coverings.**

**12.3.3.1** Required fire-resistive construction, including fire barriers, fire walls, exterior walls due to location on property, fire-resistive requirements based on type of construction, draft-stop partitions, and roof coverings, shall be maintained and shall be properly repaired, restored, or replaced where damaged, altered, breached, penetrated, removed, or improperly installed.

**12.3.3.2** Where required, fire-rated gypsum wallboard walls or ceilings that are damaged to the extent that through openings exist, the damaged gypsum wallboard shall be replaced or returned to the required level of fire resistance using a listed repair system or using materials and methods equivalent to the original construction.

**12.3.3.3** Where readily accessible, required fire-resistance-rated assemblies in high-rise buildings shall be visually inspected for integrity at least once every 3 years.

**12.3.3.3.1** The person responsible for conducting the visual inspection shall demonstrate appropriate technical knowledge and experience in fire-resistance-rated design and construction acceptable to the AHJ.

**12.3.3.3.2** A written report prepared by the person responsible for conducting the visual inspection shall be submitted to the AHJ documenting the results of the visual inspection.

**12.4 Fire Doors and Other Opening Protectives.**

Δ **12.4.1*** The installation and maintenance of assemblies and devices used to protect openings in walls, floors, and ceilings against the spread of fire and smoke within, into, or out of buildings shall comply with Section 12.4 and NFPA 80. [**80**:1.1]

**12.4.2*** With the exception of fabric fire safety curtain assemblies, Section 12.4 addresses assemblies that have been subjected to standardized fire tests. *(See Chapter 20 of NFPA 80.)* [**80**:1.1.1]

**12.4.3*** Incinerator doors, record room doors, and vault doors are not covered in Section 12.4. [**80**:1.1.2]

**12.4.4*** Requirements for horizontally sliding, vertically sliding, and swinging doors as used in this *Code* do not apply to hoistway doors for elevators and dumbwaiters. [**80**:1.1.3]

**12.4.5*** Section 12.4 shall not cover fire resistance glazing materials and horizontally sliding accordion or folding assemblies fabricated for use as walls and tested as wall assemblies in accordance with ASTM E119, *Standard Test Methods for Fire Tests of Building Construction and Materials*, or ANSI/UL 263, *Standard for Fire Tests of Building Construction and Materials*. [**80**:1.1.4]

**12.4.6 Care and Maintenance of Fire Doors and Other Opening Protectives.**

**12.4.6.1** Subsection 12.4.6 shall cover the inspection, testing, and maintenance of fire doors, fire shutters, fire windows, and opening protectives other than fire dampers and fabric fire safety curtains. [**80**:5.1.1.1]

*N* **12.4.6.2** The requirements of Section 12.4 shall apply to new and existing installations. [**80**:5.1.1.2]

**12.4.6.3 Operability.**

**12.4.6.3.1** Doors, shutters, and windows shall be operable at all times. [**80**:5.1.2.1]

**12.4.6.3.2** Doors, shutters, and windows shall be kept closed and latched or arranged for automatic closing. [**80**:5.1.2.2]

*N* **12.4.6.3.3 Prevention of Door Blockage.**

*N* **12.4.6.3.3.1** Door openings and their surrounding areas shall be kept clear of anything that could obstruct or interfere with the free operation of the door. [**80**:5.1.2.3.2]

## Part II. Orderly Shutdown

**685.10 Location of Overcurrent Devices in or on Premises.** Location of overcurrent devices that are critical to integrated electrical systems shall be permitted to be accessible, with mounting heights permitted to ensure security from operation by unqualified personnel.

**685.12 Direct-Current System Grounding.** Two-wire dc circuits shall be permitted to be ungrounded.

**685.14 Ungrounded Control Circuits.** Where operational continuity is required, control circuits of 150 volts or less from separately derived systems shall be permitted to be ungrounded.

# ARTICLE 690 Solar Photovoltaic (PV) Systems

## Part I. General

Δ **690.1 Scope.** This article applies to solar PV systems, other than those covered by Article 691, including the array circuit(s), inverter(s), and controller(s) for such systems. The systems covered by this article include those interactive with other electric power production sources or stand-alone, or both. These PV systems may have ac or dc output for utilization.

Informational Note No. 1: See Informational Note Figure 690.1(a) and Informational Note Figure 690.1(b).

Informational Note No.2: Article 691 covers the installation of large-scale PV electric supply stations.

The use of photovoltaic (PV) systems as interactive or stand-alone power-supply systems has steadily increased as the technology of PV equipment has evolved and its availability has improved. The requirements of Article 690 cover the use of stand-alone and interactive PV systems. Interactive photovoltaic systems are also subject to the requirements for interconnected electric power production sources contained in Article 705.

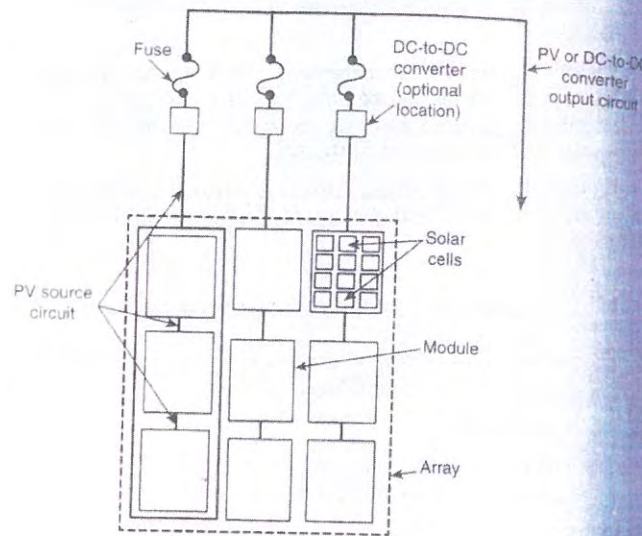
Exhibit 690.1 shows a typical installation of a PV array in a field.

**690.2 Definitions.** The definitions in this section shall apply only within this article.

*N* **AC Module System.** An assembly of ac modules, wiring methods, materials, and subassemblies that are evaluated, identified, and defined as a system.

Δ **Alternating-Current (ac) Module (Alternating-Current Photovoltaic Module).** A complete, environmentally protected unit consisting of solar cells, inverter, and other components, designed to produce ac power.

An ac PV module consists of a single integrated unit. Because there is no accessible, field-installed dc wiring in this single unit, the dc PV




Note:
(1) These diagrams are intended to be a means of identification for PV power source components, circuits, and connections that make up the PV power source.
(2) Custom PV power source designs occur, and some components are optional.

Δ *INFORMATIONAL NOTE FIGURE 690.1(a) Identification of PV Power Source Components.*

source-circuit requirements in the *NEC*® are not applicable to the dc wiring in an ac PV module.

**Array.** A mechanically and electrically integrated grouping of modules with support structure, including any attached system components such as inverter(s) or dc-to-dc converter(s) and attached associated wiring.

An array composed of multiple panels installed on a support structure is illustrated in Exhibit 690.2.

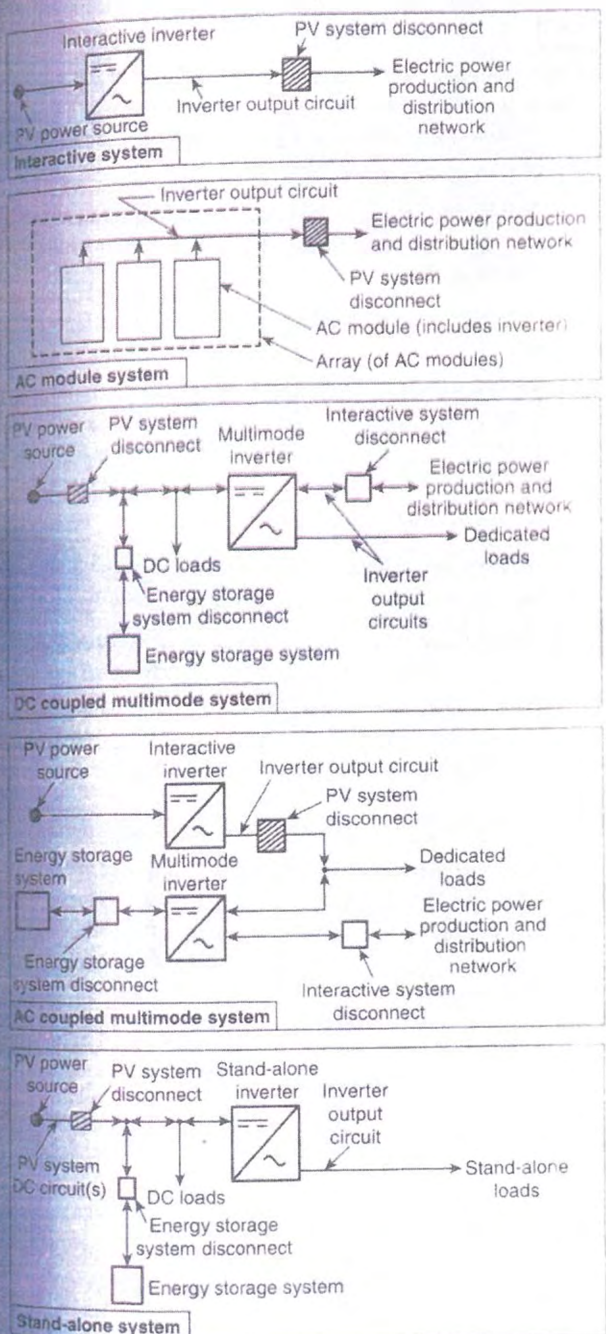
Δ **Bipolar Circuit.** A dc circuit that is comprised of two monopole circuits, each having an opposite polarity connected to a common reference point.

**DC-to-DC Converter Output Circuit.** The dc circuit conductors connected to the output of a dc combiner for dc-to-dc converter source circuits.

**DC-to-DC Converter Source Circuit.** Circuits between dc-to-dc converters and from dc-to-dc converters to the common connection point(s) of the dc system.

**Direct-Current (dc) Combiner.** An enclosure that includes devices used to connect two or more PV system dc circuits in parallel.

*N* **Electronic Power Converter.** A device that uses power electronics to convert one form of electrical power into another form of electrical power.




Note:
(1) These diagrams are intended to be a means of identification for PV system components, circuits, and connections.
(2) The PV system disconnect in these diagrams separates the PV system from all other systems.
(3) Not all disconnecting means required by Article 690, Part III are shown.
(4) System grounding and equipment grounding are not shown. See Article 690, Part V.
(5) Custom designs occur in each configuration, and some components are optional.

Δ *INFORMATIONAL NOTE FIGURE 690.1(b)*
*Identification of PV System Components in Common Configurations.*

**EXHIBIT 690.1** *A PV array. (Courtesy of Solar Design Associates, LLC)*

**EXHIBIT 690.2** *A PV array support structure that allows for continued use of the walkway. (Courtesy of Solar Design Associates, LLC)*

Informational Note: Examples of electronic power converters include, but are not limited to, inverters, dc-to-dc converters, and electronic charge controllers. These devices have limited current capabilities based on the device ratings at continuous rated power.

Δ **Grounded, Functionally.** A system that has an electrical ground reference for operational purposes that is not solidly grounded.

Informational Note: A functionally grounded system is often connected to ground through an electronic means internal to an inverter or charge controller that provides ground-fault protection. Examples of operational purposes for functionally grounded systems include ground-fault detection and performance-related issues for some power sources.

Δ **Module.** A complete, environmentally protected unit consisting of solar cells and other components designed to produce dc power.

Δ **Monopole Circuit.** An electrical subset of a PV system that has two conductors in the output circuit, one positive (+) and one negative (−).

**PV Output Circuit.** The dc circuit conductors from two or more connected PV source circuits to their point of termination.

**PV Source Circuit.** The dc circuit conductors between modules and from modules to dc combiners, electronic power converters, or a dc PV system disconnecting means.

**PV System DC Circuit.** Any dc conductor in PV source circuits, PV output circuits, dc-to-dc converter source circuits, and dc-to-dc converter output circuits.

**Solar Cell.** The basic PV device that generates electricity when exposed to light.

### 690.4 General Requirements.

**(A) Photovoltaic Systems.** Photovoltaic systems shall be permitted to supply a building or other structure in addition to any other electrical supply system(s).

**(B) Equipment.** Inverters, motor generators, PV modules, ac modules and ac module systems, dc combiners, dc-to-dc converters, rapid shutdown equipment, dc circuit controllers, and charge controllers intended for use in PV systems shall be listed or be evaluated for the application and have a field label applied.

The simplified circuit schematic in Exhibit 690.3 illustrates components in a PV system. Specific requirements for overcurrent protection, disconnecting means, and grounding are covered in other sections of Article 690 and should not be assumed based on this drawing. Instructions for or labels on the PV module might require additional overcurrent devices that are not shown.

Equipment listed for marine, mobile, telecommunications, or other applications might not be suitable for installation in permanent PV power systems.

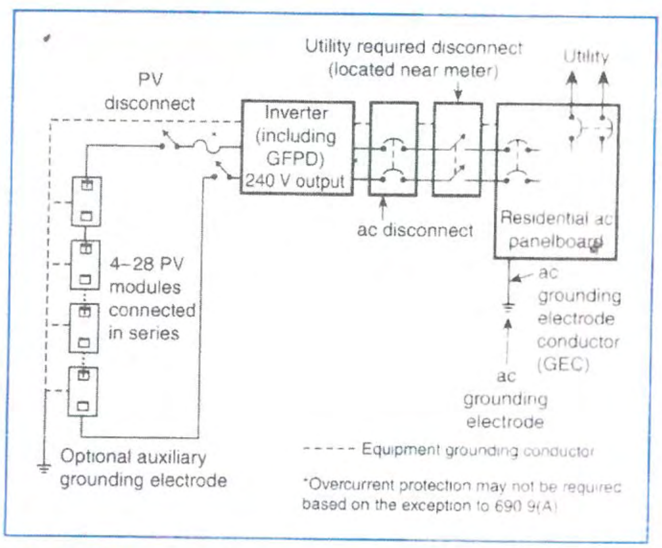



**EXHIBIT 690.3** *Simplified circuit schematic of a rooftop grid-connected system.*

**See also**

**NFPA 790,** Standard for Competency of Third-Party Field Evaluation Bodies, and **NFPA 791,** Recommended Practice and Procedures for Unlabeled Electrical Equipment Evaluation, for information on field evaluation of equipment

**(C) Qualified Personnel.** The installation of equipment and all associated wiring and interconnections shall be performed only by qualified persons.

Informational Note: See Article 100 for the definition of *qualified person*.

**(D) Multiple PV Systems.** Multiple PV systems shall be permitted to be installed in or on a single building or structure. Where the PV systems are remotely located from each other, a directory in accordance with 705.10 shall be provided at each PV system disconnecting means.

**(E) Locations Not Permitted.** PV system equipment and disconnecting means shall not be installed in bathrooms.

N **(F) Electronic Power Converters Mounted in Not Readily Accessible Locations.** Electronic power converters and their associated devices shall be permitted to be mounted on roofs or other exterior areas that are not readily accessible. Disconnecting means shall be installed in accordance with 690.15.

### 690.6 Alternating-Current (ac) Modules and Systems.

**(A) Photovoltaic Source Circuits.** The requirements of Article 690 pertaining to PV source circuits shall not apply to ac modules or ac module systems. The PV source circuit, conductors, and inverters shall be considered as internal components of an ac module or ac module system.

Δ **(B) Output Circuit.** The output of an ac module or ac module system shall be considered an inverter output circuit.

Pre-engineered ac module systems have components specified in their instructions that will interconnect multiple ac modules into a system with a single output circuit. The output circuit from such a system can be treated like an inverter output circuit just as a single ac module's output is. All dc and ac wiring up to the system termination point, as identified in its instructions, can be considered internal to the system. Considerations for ampacity, disconnection, and other requirements that generally apply to the interconnection of multiple ac modules are addressed in the pre-engineering of the system.

## Part II. Circuit Requirements

Δ **690.7 Maximum Voltage.** The maximum voltage of PV system dc circuits shall be the highest voltage between any two conductors of a circuit or any conductor and ground. The maximum voltage shall be used to determine the voltage and voltage to ground of circuits in the application of this *Code*. Maximum voltage shall be used for conductors, cables, equipment, working space, and other applications where voltage limits and ratings are used.

PV system dc circuits on or in buildings shall be permitted to have a maximum voltage no greater than 1000 volts. PV system dc circuits on or in one- and two-family dwellings shall be permitted to have a maximum voltage no greater than 600 volts. Where not located on or in buildings, listed dc PV equipment, rated at a maximum voltage no greater than 1500 volts, shall not be required to comply with Parts II and III of Article 490.

Δ **(A) Photovoltaic Source and Output Circuits.** In a dc PV source circuit or output circuit, the maximum PV system voltage for that circuit shall be calculated in accordance with one of the following methods:

(1) The sum of the PV module–rated open-circuit voltage of the series-connected modules corrected for the lowest expected ambient temperature using the open-circuit voltage temperature coefficients in accordance with the instructions included in the listing or labeling of the module

(2) For crystalline and multicrystalline silicon modules, the sum of the PV module–rated open-circuit voltage of the series-connected modules corrected for the lowest expected ambient temperature using the correction factors provided in Table 690.7(A)

(3) For PV systems with an inverter generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method maximum voltage calculation provided by a licensed professional electrical engineer

Informational Note No. 1: One source for lowest-expected, ambient temperature design data for various locations is the chapter titled "Extreme Annual Mean Minimum Design Dry Bulb Temperature" found in the *ASHRAE Handbook — Fundamentals*, 2017. These temperature data can be used to calculate maximum voltage.

Informational Note No. 2: One industry standard method for calculating maximum voltage of a PV system is published by Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*.

***TABLE 690.7(A)*** *Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules*

**Correction Factors for Ambient Temperatures Below 25°C (77°F). (Multiply the rated open-circuit voltage by the appropriate correction factor shown below.)**

| Ambient Temperature (°C) | Factor | Ambient Temperature (°F) |
|---|---|---|
| 24 to 20 | 1.02 | 76 to 68 |
| 19 to 15 | 1.04 | 67 to 59 |
| 14 to 10 | 1.06 | 58 to 50 |
| 9 to 5 | 1.08 | 49 to 41 |
| 4 to 0 | 1.10 | 40 to 32 |
| −1 to −5 | 1.12 | 31 to 23 |
| −6 to −10 | 1.14 | 22 to 14 |
| −11 to −15 | 1.16 | 13 to 5 |
| −16 to −20 | 1.18 | 4 to −4 |
| −21 to −25 | 1.20 | −5 to −13 |
| −26 to −30 | 1.21 | −14 to −22 |
| −31 to −35 | 1.23 | −23 to −31 |
| −36 to −40 | 1.25 | −32 to −40 |

A PV source is not a constant-voltage source, and the difference between the rated operating voltage determined under controlled laboratory conditions and the open-circuit voltage, adjusted for lowest expected ambient temperature, under field-installed conditions can be significant. Consequently, the higher-rated open-circuit voltage must be used to select circuit components with proper voltage ratings.

The voltage (both open circuit and operating) of a PV power source increases as the temperature decreases. The installer should note the temperature conditions for which the PV device was rated. If the anticipated lowest temperature at the installation site is lower than the rating condition (25°C), Table 690.7(A) must be used to adjust the maximum open-circuit voltage of crystalline systems before conductors, overcurrent devices, and switchgear are selected. For other than crystalline systems, see the manufacturer's instructions.

Where a listed PV module includes open-circuit voltage temperature coefficients in the installation instructions, the temperature coefficients provide a more accurate maximum system voltage than those from Table 690.7(A) and are required to be used instead of applying the table.

Bipolar PV systems (with positive and negative voltages) are required to be separated into two separate monopolar circuits; thus, the maximum circuit voltage is the maximum voltage of a single monopole.

**Application Example**

A system with open-circuit voltages of +480 volts and −480 volts with respect to ground would have a system open-circuit voltage of 480 volts even though the pole-to-pole maximum is 960 volts. This voltage should be multiplied by a temperature-dependent factor from Table 690.7(A), yielding a system design voltage of up to 600 volts since this is the maximum voltage to ground and the maximum voltage between the two wires of a single monopole permitted for one- and two-family dwellings. The system design voltage should be used in the selection of cables and other equipment. Certain bipolar PV arrays meeting the requirements of 690.7(C) might have different requirements for calculating the maximum system voltage.

**(B) DC-to-DC Converter Source and Output Circuits.** In a dc-to-dc converter source and output circuit, the maximum voltage shall be calculated in accordance with 690.7(B)(1) or (B)(2).

**(1) Single DC-to-DC Converter.** For circuits connected to the output of a single dc-to-dc converter, the maximum voltage shall be determined in accordance with the instructions included in the listing or labeling of the dc-to-dc converter. If the instructions do not provide a method to determine the maximum voltage, the maximum voltage shall be the maximum rated voltage output of the dc-to-dc converter.

Δ **(2) Two or More Series-Connected DC-to-DC Converters.** For circuits connected to the output of two or more series-connected dc-to-dc converters, the maximum voltage shall be determined in accordance with the instructions included in the listing or labeling of the dc-to-dc converter. If the instructions do not provide a method to determine the maximum voltage, the maximum voltage shall be the sum of the maximum rated voltage output of the dc-to-dc converters in series.

**(C) Bipolar Source and Output Circuits.** For monopole subarrays in bipolar systems, the maximum voltage shall be the highest voltage between the monopole subarray circuit conductors where one conductor of the monopole subarray circuit is connected to the functionally grounded reference. To prevent overvoltage in the event of a ground fault or arc fault, the monopole subarray circuits shall be isolated from ground.

### 690.8 Circuit Sizing and Current.

Δ **(A) Calculation of Maximum Circuit Current.** The maximum current for the specific circuit shall be calculated in accordance with one of the methods in 690.8(A)(1) or (A)(2).

*N* **(1) PV System Circuits.** The maximum current shall be calculated in accordance with 690.8(A)(1)(a) through (A)(1)(e).

(a) *Photovoltaic Source Circuit Currents.* The maximum current shall be as calculated in either of the following:

(1) The maximum current shall be the sum of the short-circuit current ratings of the PV modules connected in parallel multiplied by 125 percent.
(2) For PV systems with an inverter generating capacity of 100 kW or greater, a documented and stamped PV system design, using an industry standard method maximum current calculation provided by a licensed professional electrical engineer, shall be permitted. The calculated maximum current value shall be based on the highest 3-hour current average resulting from the simulated local irradiance on the PV array accounting for elevation and orientation. The current value used by this method shall not be less than 70 percent of the value calculated using 690.8(A)(1)(a)(1).

Informational Note: One industry standard method for calculating maximum current of a PV system is available from Sandia National Laboratories, reference SAND 2004-3535, *Photovoltaic Array Performance Model*. This model is used by the System Advisor Model simulation program provided by the National Renewable Energy Laboratory.

Method (1) uses the array short-circuit current, which allows for proper sizing of conductors to handle the current generated during periods of operation under a short-circuit condition.

The 125 percent factor is required because PV modules can deliver output currents higher than the rated short circuit currents for more than 3 hours near solar noon. Method (2) permits a licensed professional electrical engineer to perform simulations to establish the highest 3-hour current for a specific system.

(b) *Photovoltaic Output Circuit Currents.* The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1)(a).

(c) *DC-to-DC Converter Source Circuit Current.* The maximum current shall be the dc-to-dc converter continuous output current rating.

(d) *DC-to-DC Converter Output Circuit Current.* The maximum current shall be the sum of parallel connected dc-to-dc converter source circuit currents as calculated in 690.8(A)(1)(c).

(e) *Inverter Output Circuit Current.* The maximum current shall be the inverter continuous output current rating.

Both stand-alone and interactive inverters are power-limited devices. Output circuits connected to these devices are sized on the continuous-rated outputs of the inverter. Exhibit 690.4 shows an inverter label displaying the maximum output circuit current along with other necessary ratings.

*N* **(2) Circuits Connected to the Input of Electronic Power Converters.** Where a circuit is protected with an overcurrent device not exceeding the conductor ampacity, the maximum current shall be permitted to be the rated input current of the electronic power converter input to which it is connected.

Δ **(B) Conductor Ampacity.** Circuit conductors shall be sized to carry not less than the larger ampacity calculated in accordance with 690.8(B)(1) or (B)(2).

**(1) Without Adjustment and Correction Factors.** The maximum currents calculated in 690.8(A) multiplied by 125 percent without adjustment or correction factors.

*Exception: Circuits containing an assembly, together with its overcurrent device(s), that is listed for continuous operation*

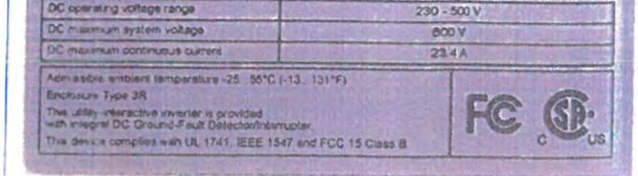


**EXHIBIT 690.4** *An interactive inverter label*

*at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.*

**(2) With Adjustment and Correction Factors.** The maximum currents calculated in 690.8(A) with adjustment and correction factors.

**(C) Systems with Multiple Direct-Current Voltages.** For a PV power source that has multiple output circuit voltages and employs a common-return conductor, the ampacity of the common-return conductor shall not be less than the sum of the ampere ratings of the overcurrent devices of the individual output circuits.

**(D) Sizing of Module Interconnection Conductors.** Where a single overcurrent device is used to protect a set of two or more parallel-connected module circuits, the ampacity of each of the module interconnection conductors shall not be less than the sum of the rating of the single overcurrent device plus 125 percent of the short-circuit current from the other parallel-connected modules.

Normally, labels or module instructions require reverse overcurrent protection for each module or string of modules. In some cases, modules with low-rated short-circuit currents and high values of the required series protective fuse could allow the use of one overcurrent device to provide reverse-current protection for multiple modules or strings of modules and overcurrent protection for the conductors. The PV module manufacturer should be contacted for specific information regarding allowable source circuit configurations.

### 690.9 Overcurrent Protection.

Δ **(A) Circuits and Equipment.** PV system dc circuit and inverter output conductors and equipment shall be protected against overcurrent. Circuits sized in accordance with 690.8(A)(2) are required to be protected against overcurrent with overcurrent protective devices. Each circuit shall be protected from overcurrent in accordance with 690.9(A)(1), (A)(2), or (A)(3).

N **(1) Circuits Where Overcurrent Protection Not Required.** Overcurrent protective devices shall not be required where both of the following conditions are met:

(1) The conductors have sufficient ampacity for the maximum circuit current.
(2) The currents from all sources do not exceed the maximum overcurrent protective device rating specified for the PV module or electronic power converter.

N **(2) Circuits Where Overcurrent Protection is Required on One End.** A circuit conductor connected at one end to a current-limited supply, where the conductor is rated for the maximum circuit current from that supply, and also connected to sources having an available maximum circuit current greater than the ampacity of the conductor, shall be protected from overcurrent at the point of connection to the higher current source.

Informational Note: Photovoltaic system dc circuits and electronic power converter outputs powered by these circuits are current-limited and in some cases do not need overcurrent protection. Where these circuits are connected to higher current sources, such as parallel-connected PV system dc circuits, energy storage systems, or a utility service, the overcurrent device is often installed at the higher current source end of the circuit conductor.

It may be possible for other PV source circuits, other supply sources through the inverter, and energy storage system circuits to supply current to source circuits in the event of a fault. An overcurrent device is required for each conductor at each connection point to limit the fault current on that conductor, unless the conductors are sized for the maximum available current. Where more than two strings of PV modules are connected in parallel, overcurrent devices might be required in the dc PV source or output circuits.

N **(3) Other Circuits.** Circuits that do not comply with 690.9(A)(1) or (A)(2) shall be protected with one of the following methods:

(1) Conductors not greater than 3 m (10 ft) in length and not in buildings, protected from overcurrent on one end
(2) Conductors not greater than 3 m (10 ft) in length and in buildings, protected from overcurrent on one end and in a raceway or metal clad cable
(3) Conductors protected from overcurrent on both ends
(4) Conductors not installed on or in buildings are permitted to be protected from overcurrent on one end of the circuit where the circuit complies with all of the following conditions:
   a. The conductors are installed in metal raceways or metal-clad cables, or installed in enclosed metal cable trays, or underground, or where directly entering pad-mounted enclosures.
   b. The conductors for each circuit terminate on one end at a single circuit breaker or a single set of fuses that limit the current to the ampacity of the conductors.
   c. The overcurrent device for the conductors is an integral part of a disconnecting means or shall be located within 3 m (10 ft) of conductor length of the disconnecting means.
   d. The disconnecting means for the conductors is installed outside of a building, or at a readily accessible location nearest the point of entrance of the conductors inside of a building, including installations complying with 230.6.

Section 690.9(A)(3) addresses circuits with sources of overcurrent on both ends with three protection options.

Section 690.9(A)(3)(1) permits short conductor lengths to be protected from overcurrent on one end. Short conductors are common where combiner boxes are installed next to inverters, and the language in this requirement will reduce the need for fuses on both ends of a short wire. The "tap rule" in 240.21(B) is an example of where the 10-foot length is used for feeder taps with remote overcurrent protection.

Section 690.9(A)(3)(2) permits conductors of 10 feet or less in buildings if they are in raceways or metal-clad cables, which is similar to the requirement in 240.21

Section 690.9(A)(3)(3) covers conductors in general with sources of overcurrent on both ends since they would require overcurrent protection on both ends as required by Article 240.

Section 690.9(A)(3)(4) covers longer runs with overcurrent on one end where the conductors are located outside of building. Since conductors in PV systems have very limited short-circuit current on at least one end of the conductor, overcurrent protection is typically located on one end of the circuit. With the language related to inputs to electronic conversion devices, many dc circuits will be required to have overcurrent protection on both ends of the circuit where on buildings and where greater than 10 feet in length, in accordance with 690.9(A)(3)(1)

Δ **(B) Device Ratings.** Overcurrent devices used in PV system dc circuits shall be listed for use in PV systems. Electronic devices that are listed to prevent backfeed current in PV system dc circuits shall be permitted to prevent overcurrent of conductors on the PV array side of the device. Overcurrent devices, where required, shall be rated in accordance with one of the following and permitted to be rounded up to the next higher standard size in accordance with 240.4(B):

(1) Not less than 125 percent of the maximum currents calculated in 690.8(A).
(2) An assembly, together with its overcurrent device(s), that is listed for continuous operation at 100 percent of its rating shall be permitted to be used at 100 percent of its rating.

Informational Note: Some electronic devices prevent backfeed current, which in some cases is the only source of overcurrent in PV system dc circuits.

Because these circuits are subject to environmental stresses, the overcurrent devices for the dc circuits are required to be specifically listed for use in PV systems. The overcurrent devices can be either supplemental or branch-circuit devices. Direct-current fault currents are considerably harder to interrupt than ac faults. Overcurrent devices marked or listed only for ac use should not be used in dc circuits. Automotive- and marine-type fuses, although used in dc systems, might not have the proper ratings for use in PV systems.

Δ **(C) Source and Output Circuits.** A single overcurrent protective device, where required, shall be permitted to protect the PV modules, dc-to-dc converters, and conductors of each source circuit or the conductors of each output circuit. Where single overcurrent protection devices are used to protect source or output circuits, all overcurrent devices shall be placed in the same polarity for all circuits within a PV system. The overcurrent devices shall be accessible but shall not be required to be readily accessible.

Informational Note: Due to improved ground-fault protection required in PV systems by 690.41(B), a single overcurrent protective device in either the positive or negative conductors of a PV system in combination with this ground-fault protection provides adequate overcurrent protection.

**(D) Power Transformers.** Overcurrent protection for a transformer with a source(s) on each side shall be provided in accordance with 450.3 by considering first one side of the transformer, then the other side of the transformer, as the primary.

*Exception: A power transformer with a current rating on the side connected toward the interactive inverter output, not less than the rated continuous output current of the inverter, shall be permitted without overcurrent protection from the inverter.*

**690.10 Stand-Alone Systems.** The wiring system connected to a stand-alone system shall be installed in accordance with 710.15.

Exhibit 690.5 shows the controller and energy storage components of a stand-alone system.

**See also**

**Article 706** for permanently installed energy storage systems
**Article 710** for stand-alone systems

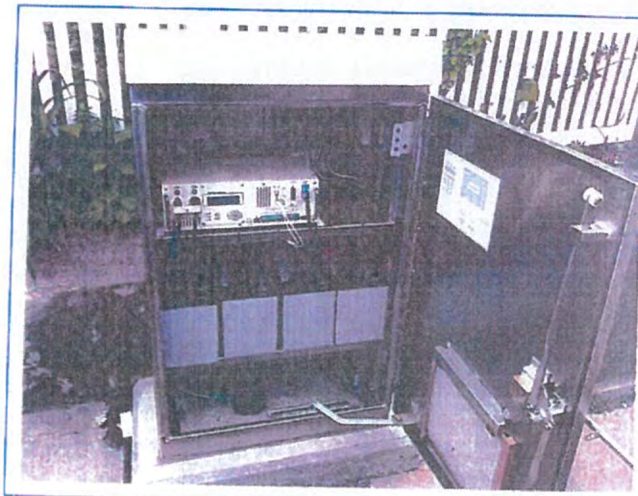


*EXHIBIT 690.5 Stand-alone system components. (Courtesy of Solar Design Associates, LLC)*

Δ **690.11 Arc-Fault Circuit Protection (Direct Current).** Photovoltaic systems with PV system dc circuits operating at 80 volts dc or greater between any two conductors shall be protected by a listed PV arc-fault circuit interrupter or other system components listed to provide equivalent protection. The system shall detect and interrupt arcing faults resulting from a failure in the intended continuity of a conductor, connection, module, or other system component in the PV system dc circuits.

Informational Note: Annex A includes the reference for the *Photovoltaic DC Arc-Fault Circuit Protection* product standard.

*Exception: For PV systems not installed on or in buildings, PV output circuits and dc-to-dc converter output circuits that* *are installed in metallic raceways or metal-clad cables, or installed in enclosed metallic cable trays, or are underground shall be permitted without arc-fault circuit protection. Detached structures whose sole purpose is to house PV system equipment shall not be considered buildings according to this exception.*

The arc-fault protective device used to meet this requirement must be listed for dc use and listed for use in PV systems. Listed components that provide protection equivalent to arc-fault protection also are permitted by this requirement. The exception allows PV output circuits on ground-mounted PV systems, meeting the requirements, and those installed in metal raceway and metal clad cables, to be installed without arc-fault protection.

**690.12 Rapid Shutdown of PV Systems on Buildings.** PV system circuits installed on or in buildings shall include a rapid shutdown function to reduce shock hazard for firefighters in accordance with 690.12(A) through (D).

*Exception: Ground-mounted PV system circuits that enter buildings, of which the sole purpose is to house PV system equipment, shall not be required to comply with 690.12.*

Fire fighters must contend with elements of a PV system that remain energized after the service disconnect is opened. This rapid shutdown requirement reduces the potential for shock within 30 seconds of activation of shutdown. Methods and designs for achieving proper rapid shutdown are not addressed by the *NEC* but instead are addressed in the product standards for this type of equipment.

**(A) Controlled Conductors.** Requirements for controlled conductors shall apply to the following:

(1) PV system dc circuits
(2) Inverter output circuits originating from inverters located within the array boundary

Informational Note: The rapid shutdown function reduces the risk of electrical shock that dc circuits in a PV system could pose for firefighters. The ac output conductors from PV systems that include inverters will either be de-energized after shutdown initiation or will remain energized by other sources such as a utility service. To prevent PV arrays with attached inverters from having energized ac conductors within the PV array(s), those circuits are also specifically controlled after shutdown initiation.

**(B) Controlled Limits.** The use of the term *array boundary* in this section is defined as 305 mm (1 ft) from the array in all directions. Controlled conductors outside the array boundary shall comply with 690.12(B)(1) and inside the array boundary shall comply with 690.12(B)(2).

**(1) Outside the Array Boundary.** Controlled conductors located outside the boundary or more than 1 m (3 ft) from the point of entry inside a building shall be limited to not more than 30 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.

Δ **(2) Inside the Array Boundary.** The PV system shall comply with one of the following:

(1) A PV hazard control system listed for the purpose shall be installed in accordance with the instructions included with the listing or field labeling. Where a hazard control system requires initiation to transition to a controlled state, the rapid shutdown initiation device required in 690.12(C) shall perform this initiation.

Informational Note: A listed or field-labeled hazard PV control system is comprised of either an individual piece of equipment that fulfills the necessary functions or multiple pieces of equipment coordinated to perform the functions as described in the installation instructions to reduce the risk of electric shock hazard within a damaged PV array for fire fighters. See UL 3741, *Photovoltaic Hazard Control*.

(2) Controlled conductors located inside the boundary shall be limited to not more than 80 volts within 30 seconds of rapid shutdown initiation. Voltage shall be measured between any two conductors and between any conductor and ground.
(3) PV arrays shall have no exposed wiring methods or conductive parts and be installed more than 2.5 m (8 ft) from exposed grounded conductive parts or ground.

Exhibit 690.6 illustrates the array boundary and the controlled conductors and limits.

Δ **(C) Initiation Device.** The initiation device(s) shall initiate the rapid shutdown function of the PV system. The device's "off" position shall indicate that the rapid shutdown function has been initiated for all PV systems connected to that device. For one-family and two-family dwellings an initiation device(s) shall be located at a readily accessible location outside the building.

For a single PV system, the rapid shutdown initiation shall occur by the operation of any single initiation device. Devices shall consist of at least one or more of the following:

(1) Service disconnecting means
(2) PV system disconnecting means
(3) Readily accessible switch that plainly indicates whether it is in the "off" or "on" position

Informational Note: Examples of where an initiation device that complies with 690.12(C)(3) would be used is where a PV system is connected to an optional standby or stand-alone system.

Where multiple PV systems are installed with rapid shutdown functions on a single service, the initiation device(s) shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. These initiation device(s) shall initiate the rapid shutdown of all PV systems with rapid shutdown functions on that service.

Multiple rapid shutdown initiating devices are permitted, as long as each initiating device is capable of initiating shutdown.

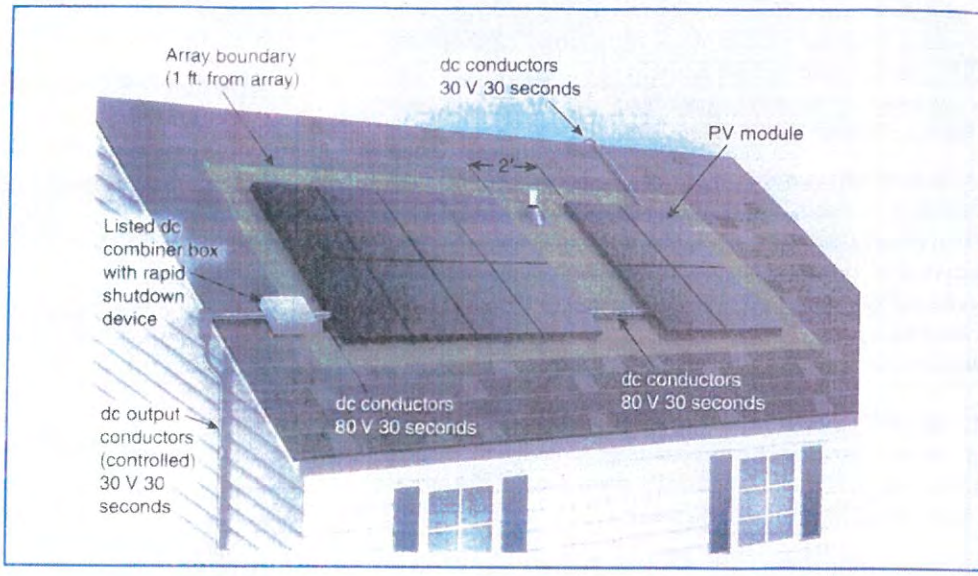



***EXHIBIT 690.6*** *Controlled conductors and limits.*

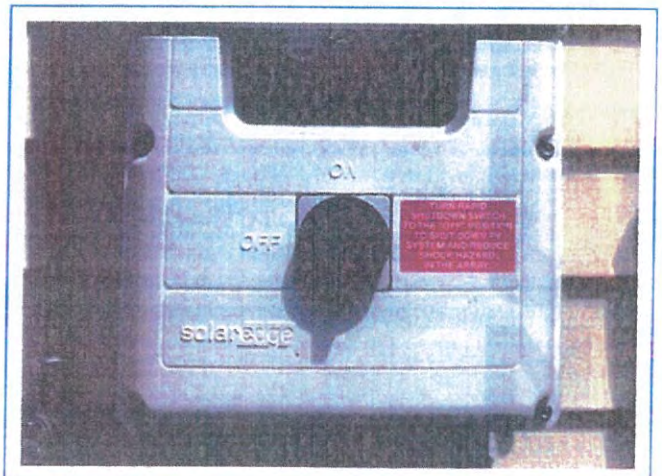



***EXHIBIT 690.7*** *Rapid shutdown device.*

Δ **(D) Equipment.** Equipment that performs the rapid shutdown functions, other than initiation devices such as listed disconnect switches, circuit breakers, or control switches, shall be listed for providing rapid shutdown protection.

Exhibit 690.7 shows a typical rapid shutdown device.

## Part III. Disconnecting Means

**690.13 Photovoltaic System Disconnecting Means.** Means shall be provided to disconnect the PV system from all wiring systems including power systems, energy storage systems, and utilization equipment and its associated premises wiring.

**(A) Location.** The PV system disconnecting means shall be installed at a readily accessible location. Where disconnecting means of systems above 30 V are readily accessible to unqualified persons, any enclosure door or hinged cover that exposes live parts when open shall be locked or require a tool to open.

Informational Note: PV systems installed in accordance with 690.12 address the concerns related to energized conductors entering a building.

The readily accessible disconnect is permitted to be inside or outside the building. See Figure 690.1(b) for PV disconnect locations within the system. The PV system disconnect in these diagrams separates the PV system from all other systems. Locating the disconnect in a readily accessible location is still required where the installation would require a lock or tool to prevent access to the interior of the disconnecting means.

**(B) Marking.** Each PV system disconnecting means shall plainly indicate whether in the open (off) or closed (on) position and be permanently marked "PV SYSTEM DISCONNECT" or equivalent. Additional markings shall be permitted based upon the specific system configuration. For PV system disconnecting means where the line and load terminals may be energized in the open position, the device shall be marked with the following words or equivalent:

WARNING
ELECTRIC SHOCK HAZARD
TERMINALS ON THE LINE AND LOAD SIDES
MAY BE ENERGIZED IN THE OPEN POSITION

The warning sign(s) or label(s) shall comply with 110.21(B).

**(C) Maximum Number of Disconnects.** Each PV system disconnecting means shall consist of not more than six switches or six sets of circuit breakers, or a combination of not more than six switches and sets of circuit breakers, mounted in a single enclosure, or in a group of separate enclosures. A single PV system disconnecting means shall be permitted for the combined ac output of one or more inverters or ac modules in an interactive system.

Informational Note: This requirement does not limit the number of PV systems connected to a service as permitted in 690.4(D). This requirement allows up to six disconnecting means to disconnect a single PV system. For PV systems where all power is converted through interactive inverters, a dedicated circuit breaker, in 705.12(B)(1), is an example of a single PV system disconnecting means.

If a building has multiple sources of power, such as the utility, a PV system, a backup generator, and a wind system, no more than six disconnects for each source of power to the building are permitted. However, this does not require the disconnects for all the sources to be grouped together.

Interactive ac PV modules are designed to produce power only if they are connected to an external power source at the correct voltage and frequency. A single disconnecting means removes the external source and turns off the output of all ac PV modules connected to that disconnecting device.

**(D) Ratings.** The PV system disconnecting means shall have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals of the PV system disconnect.

The required rating of the PV system disconnecting means is different depending on whether it is connected to the line side or the load side of the service.

**(E) Type of Disconnect.** The PV system disconnecting means shall simultaneously disconnect the PV system conductors that are not solidly grounded from all conductors of other wiring systems. The PV system disconnecting means or its remote operating device or the enclosure providing access to the disconnecting means shall be capable of being locked in accordance with 110.25. The PV system disconnecting means shall be one of the following:

(1) A manually operable switch or circuit breaker
(2) A connector meeting the requirements of 690.33(D)(1) or (D)(3)
(3) A pull-out switch with the required interrupting rating
(4) A remote-controlled switch or circuit breaker that is operable locally and opens automatically when control power is interrupted
(5) A device listed or approved for the intended application

Informational Note: Circuit breakers marked "line" and "load" may not be suitable for backfeed or reverse current.

Exhibit 690.8 shows an ac PV system disconnect.

Δ **690.15 Disconnecting Means for Isolating Photovoltaic Equipment.** Disconnecting means of the type required in 690.15(D) shall be provided to disconnect ac PV modules, fuses, dc-to-dc converters, inverters, and charge controllers from all conductors that are not solidly grounded.


*EXHIBIT 690.8* PV system disconnect.

**(A) Location.** Isolating devices or equipment disconnecting means shall be installed in circuits connected to equipment at a location within the equipment, or within sight and within 3 m (10 ft) of the equipment. An equipment disconnecting means shall be permitted to be remote from the equipment where the equipment disconnecting means can be remotely operated from within 3 m (10 ft) of the equipment. Where disconnecting means of equipment operating above 30 volts are readily accessible to unqualified persons, any enclosure door or hinged cover that exposes live parts when open shall be locked or require a tool to open.

Δ **(B) Isolating Device.** An isolating device shall not be required to have an interrupting rating. Where an isolating device is not rated for interrupting the circuit current, it shall be marked "Do Not Disconnect Under Load" or "Not for Current Interrupting." An isolating device shall not be required to simultaneously disconnect all current-carrying conductors of a circuit. The isolating device shall be one of the following:

(1) A mating connector meeting the requirements of 690.33 and listed and identified for use with specific equipment
(2) A finger-safe fuse holder
(3) An isolating device that requires a tool to place the device in the open (off) position
(4) An isolating device listed for the intended application

Δ **(C) Equipment Disconnecting Means.** Equipment disconnecting means shall have ratings sufficient for the maximum circuit current, available fault current, and voltage that is available at the terminals. Equipment disconnecting means shall simultaneously disconnect all current-carrying conductors that are not solidly grounded to the circuit to which it is connected. Equipment disconnecting means shall be externally operable without exposing the operator to contact with energized parts and shall indicate whether in the open (off) or closed (on) position. Where not within sight or not within 3 m (10 ft) of the equipment, the disconnecting means or its remote operating device or the enclosure providing access to the disconnecting means shall be capable of being locked in accordance with 110.25. Equipment disconnecting means, where used, shall be one of the types in 690.13(E)(1) through (E)(5).

Equipment disconnecting means, other than those complying with 690.33, shall be marked in accordance with the warning in 690.13(B) if the line and load terminals can be energized in the open position.

Informational Note: A common installation practice is to terminate PV source-side dc conductors in the same manner that utility source-side ac conductors are generally connected on the line side of a disconnecting means. This practice is more likely to de-energize load-side terminals, blades, and fuses when the disconnect is in the open position and no energized sources are connected to the load side of the disconnect.

N **(D) Type of Disconnecting Means.** Where disconnects are required to isolate equipment, the disconnecting means shall be one of the following applicable types:

(1) An equipment disconnecting means in accordance with 690.15(C) shall be required to isolate dc circuits with a maximum circuit current over 30 amperes.
(2) An isolating device in accordance with 690.15(B) shall be permitted for circuits other than those covered by 690.15(D)(1).

## Part IV. Wiring Methods and Materials

### 690.31 Wiring Methods.

**(A) Wiring Systems.** All raceway and cable wiring methods included in this *Code*, other wiring systems and fittings specifically listed for use in PV arrays, and wiring as part of a listed system shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

Where PV source and output circuits operating at voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be guarded or installed in Type MC cable or in raceway. The ampacity of 105°C (221°F) and 125°C (257°F) conductors shall be permitted to be determined by Table 690.31(A)(b). For ambient temperatures greater than 30°C (86°F), the ampacities of these conductors shall be corrected in accordance with Table 690.31(A)(a).

All cables and conductors installed outdoors and exposed to direct sunlight and wet conditions must be suitable for such conditions. Conductors inside raceways installed in wet locations are required to be identified or listed as suitable for wet locations.

**See also**

**310.10(C)** for the requirements on conductors installed in wet locations

Open, single conductors are permitted where listed and identified as "Photovoltaic Wire," "Photovoltaic Cable," "PV Wire," or "PV Cable." These conductors are evaluated for use where exposed to direct sunlight and wet conditions.

Most PV modules do not have means for attaching raceways. These circuits might have to be made "not readily accessible" by use of physical barriers such as wire plastic or metal guards.

Informational Note: See 110.14(C) for conductor temperature limitations due to termination provisions.

Δ *TABLE 690.31(A)(a) Correction Factors*

| Ambient Temperature (°C) | Temperature Rating of Conductor: 105°C (221°F) | Temperature Rating of Conductor: 125°C (257°F) | Ambient Temperature (°F) |
|---|---|---|---|
| 30 | 1 | 1 | 86 |
| 31–35 | 0.97 | 0.97 | 87–95 |
| 36–40 | 0.93 | 0.95 | 96–104 |
| 41–45 | 0.89 | 0.92 | 105–113 |
| 46–50 | 0.86 | 0.89 | 114–122 |
| 51–55 | 0.82 | 0.86 | 123–131 |
| 56–60 | 0.77 | 0.83 | 132–140 |
| 61–65 | 0.73 | 0.79 | 141–149 |
| 66–70 | 0.68 | 0.76 | 150–158 |
| 71–75 | 0.63 | 0.73 | 159–167 |
| 76–80 | 0.58 | 0.69 | 168–176 |
| 81–85 | 0.52 | 0.65 | 177–185 |
| 86–90 | 0.45 | 0.61 | 186–194 |
| 91–95 | 0.37 | 0.56 | 195–203 |
| 96–100 | 0.26 | 0.51 | 204–212 |
| 101–105 | — | 0.46 | 213–221 |
| 106–110 | — | 0.4 | 222–230 |
| 111–115 | — | 0.32 | 231–239 |
| 116–120 | — | 0.23 | 240–248 |

N *TABLE 690.31(A)(b) Ampacities of Insulated Conductors Rated Up To and Including 2000 Volts, 105°C Through 125°C (221°F Through 257°F), Not More Than Three Current-Carrying Conductors in Raceway, Cable, or Earth (Directly Buried), Based on Ambient Temperature of 30°C (86°F)*

| AWG | Types: PVC, CPE, XLPE 105°C | Types: XLPE, EPDM 125°C |
|---|---|---|
| 18 | 15 | 16 |
| 16 | 19 | 20 |
| 14 | 29 | 31 |
| 12 | 36 | 39 |
| 10 | 46 | 50 |
| 8 | 64 | 69 |
| 6 | 81 | 87 |
| 4 | 109 | 118 |
| 3 | 129 | 139 |
| 2 | 143 | 154 |
| 1 | 168 | 181 |
| 1/0 | 193 | 208 |
| 2/0 | 229 | 247 |
| 3/0 | 263 | 284 |
| 4/0 | 301 | 325 |

Δ **(B) Identification and Grouping.** PV system dc circuits and Class 1 remote control, signaling, and power-limited circuits of a PV system shall be permitted to occupy the same equipment wiring enclosure, cable, or raceway. PV system dc circuits shall not occupy the same equipment wiring enclosure, cable, or raceway as other non-PV systems, or inverter output circuits, unless the PV system dc circuits are separated from other circuits by a barrier or partition. PV system circuit conductors shall be identified and grouped as required by 690.31(B)(1) and (B)(2).

*Exception: PV system dc circuits utilizing multiconductor jacketed cable or metal-clad cable assemblies or listed wiring harnesses identified for the application shall be permitted to occupy the same wiring method as inverter output circuits and other non-PV systems. All conductors, harnesses, or assemblies shall have an insulation rating equal to at least the maximum circuit voltage applied to any conductor within the enclosure, cable, or raceway.*

AC branch-circuit conductors that supply an exterior luminaire installed near a roof-mounted PV array are examples of conductors that must not share the same raceway or cable with PV source or output circuit conductors. Conductors of different systems are permitted in the same cable tray where separated from the PV source or output circuit conductors by a barrier or a partition of a material compatible with the cable tray. *Barrier* is a more generic term than *partition* and would allow approved methods to keep these circuits from direct contact with each other. The exception permits dc multiconductor jacketed cable or metal-clad cable assemblies, listed for the application, to be installed with inverter output circuits and other non-PV system conductors.

DC conductors directly related to a specific PV system are permitted in the same raceway as PV source and output conductors, provided they are grouped and identified and meet the separation requirements of 300.3(C).

Δ **(1) Identification.** PV system dc circuit conductors shall be identified at all termination, connection, and splice points by color coding, marking tape, tagging, or other approved means. Conductors relying on other than color coding for polarity identification shall be identified by an approved permanent marking means such as labeling, sleeving, or shrink-tubing that is suitable for the conductor size. The permanent marking means for nonsolidly grounded positive conductors shall include imprinted plus signs (+) or the word POSITIVE or POS durably marked on insulation of a color other than green, white, or gray. The permanent marking means for nonsolidly grounded negative conductors shall include imprinted negative signs (−) or the word NEGATIVE or NEG durably marked on insulation of a color other than green, white, gray, or red. Only solidly grounded PV system dc circuit conductors shall be marked in accordance with 200.6.

*Exception: Where the identification of the conductors is evident by spacing or arrangement, further identification shall not be required.*

**(2) Grouping.** Where the conductors of more than one PV system occupy the same junction box or raceway with a removable cover(s), the PV system conductors of each system shall be grouped separately by cable ties or similar means at least once and shall then be grouped at intervals not to exceed 1.8 m (6 ft).

*Exception: The requirement for grouping shall not apply if the circuit enters from a cable or raceway unique to the circuit that makes the grouping obvious.*

Δ **(C) Cables.** Type PV wire or cable and Type distributed generation (DG) cable shall be listed.

Informational Note: See UL 4703, *Standard for Photovoltaic Wire*, for PV wire and UL 3003, *Distributed Generation Cables*, for DG cable.

*N* **(1) Single-Conductor Cable.** Single-conductor cable in exposed outdoor locations in PV system dc circuits within the PV array shall be permitted to be one of the following:

(1) PV wire or cable
(2) Single-conductor cable marked sunlight resistant and Type USE-2 and Type RHW-2

Exposed cables shall be supported and secured at intervals not to exceed 600 mm (24 in.) by cable ties, straps, hangers, or similar fittings listed and identified for securement and support in outdoor locations. PV wire or cable shall be permitted in all locations where RHW-2 is permitted.

*Exception: PV systems meeting the requirements of 691.4 shall be permitted to have support and securement intervals as defined in the engineered design.*

Most PV modules are designed for a direct series connection by using factory-installed leads and connectors. To accommodate such a connection, use of a single-conductor PV wire or cable or Type USE-2 cable and single-conductor cable listed for PV applications is permitted in PV source circuits. Type USE-2 cables must be marked RHW-2 and sunlight resistant. Cables connected to PV modules are exposed to sunlight, which can result in ultraviolet degradation of the insulation.

Extremely long runs of separated conductors (with loop inductance and distributed capacitance) and the resulting long-time constants in dc circuits can result in improper operation of overcurrent devices. Running both positive and negative conductors of each circuit and the EGC as close together as possible also decreases induced currents from nearby lightning strikes. Because PV modules might operate at high temperatures and are installed in outdoor, exposed locations, the use of high-temperature conductors rated for wet locations, such as USE-2, or RHW-2, is often necessary. See 310.15(B)(2) for requirements on the ampacities of conductors in raceways or cables installed on rooftops exposed to sunlight. Single conductor cables listed and labeled for use in PV applications will be identified as "PV Wire," "PV Cable," "Photovoltaic Wire," or "Photovoltaic Cable."

*N* **(2) Cable Tray.** Single-conductor PV wire or cable of all sizes or distributed generation (DG) cable of all sizes, with or without a cable tray rating, shall be permitted in cable trays installed in outdoor locations, provided that the cables are supported at intervals not to exceed 300 mm (12 in.) and secured at intervals not to exceed 1.4 m (4½ ft).

Informational Note: PV wire and cable and DG cable have a nonstandard outer diameter. Table 1 of Chapter 9 contains the allowable percent of cross section of conduit and tubing for conductors and cables.

**(3) Multiconductor Jacketed Cables.** Where part of a listed PV assembly, multiconductor jacketed cables shall be installed in accordance with the included instructions. Where not part of a listed assembly, or where not otherwise covered in this Code, multiconductor jacketed cables, including DG cable, shall be installed in accordance with the product listing and shall be permitted in PV systems. These cables shall be installed in accordance with the following:

(1) In raceways, where on or in buildings other than rooftops
(2) Where not in raceways, in accordance with the following:
   a. Marked sunlight resistant in exposed outdoor locations
   b. Protected or guarded, where subject to physical damage
   c. Closely follow the surface of support structures
   d. Secured at intervals not exceeding 1.8 m (6 ft)
   e. Secured within 600 mm (24 in.) of mating connectors or entering enclosures
   f. Marked direct burial, where buried in the earth

**(4) Flexible Cords and Cables Connected to Tracking PV Arrays.** Flexible cords and flexible cables, where connected to moving parts of tracking PV arrays, shall comply with Article 400 and shall be of a type identified as a hard service cord or portable power cable; they shall be suitable for extra-hard usage, listed for outdoor use, water resistant, and sunlight resistant. Allowable ampacities shall be in accordance with 400.5. Stranded copper PV wire shall be permitted to be connected to moving parts of tracking PV arrays in accordance with the minimum number of strands specified in Table 690.31(C)(4).

***TABLE 690.31(C)(4)*** *Minimum PV Wire Strands*

| PV Wire AWG | Minimum Strands |
|---|---|
| 18 | 17 |
| 16–10 | 19 |
| 8–4 | 49 |
| 2 | 130 |
| 1 AWG–1000 MCM | 259 |

*N* **(5) Flexible, Fine-Stranded Cables.** Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14.

Section 110.14 requires connectors and terminals for conductors more finely stranded than Class B and Class C stranding as shown in Chapter 9, Table 10, to be identified for the specific conductor class or classes.

**(6) Small-Conductor Cables.** Single-conductor cables listed for outdoor use that are sunlight resistant and moisture resistant in sizes 16 AWG and 18 AWG shall be permitted for module interconnections where such cables meet the ampacity requirements of 400.5. Section 310.14 shall be used to determine the cable ampacity adjustment and correction factors.

Because the smaller cables might not be marked with standard code-recognized markings (such as USE-2), the PV module manufacturer or installer should verify that these cables are listed and labeled for PV use, which would indicate that they have the necessary sunlight and moisture resistance and are suitable for exposed, outdoor use.

In accordance with 200.6(A), grounded conductors that are smaller than 6 AWG and used in PV source circuits are permitted to be marked at the time of installation with a white marking at all terminations. Only solidly grounded PV systems are allowed to have white markings.

Δ **(D) Direct-Current Circuits on or in Buildings.** Where inside buildings, PV system dc circuits that exceed 30 volts or 8 amperes shall be contained in metal raceways, in Type MC metal-clad cable that complies with 250.118(10), or in metal enclosures.

*Exception: PV hazard control systems installed in accordance with 690.12(B)(2)(1) shall be permitted to be provided with or listed for use with nonmetallic enclosure(s), nonmetallic raceway(s), and cables other than Type MC metal-clad cable(s), at the point of penetration of the surface of the building to the PV hazard control actuator.*

Wiring methods on or in buildings shall comply with the additional installation requirements in 690.31(D)(1) and (D)(2).

The use of metal raceways, Type MC cable, or metal enclosures inside a building provides additional physical protection for these circuits. Metal raceways also provide additional fire resistance should faults develop in the cable, and they provide an additional ground-fault detection path for the ground-fault protection device required by 690.41(B).

**(1) Flexible Wiring Methods.** Where flexible metal conduit (FMC) smaller than metric designator 21 (trade size ¾) or Type MC cable smaller than 25 mm (1 in.) in diameter containing PV power circuit conductors is installed across ceilings or floor joists, the raceway or cable shall be protected by substantial guard strips that are at least as high as the raceway or cable. Where run exposed, other than within 1.8 m (6 ft) of their connection to equipment, these wiring methods shall closely follow the building surface or be protected from physical damage by an approved means.

Δ **(2) Marking and Labeling Required.** Unless located and arranged so the purpose is evident, the following wiring methods and enclosures that contain PV system dc circuit conductors shall be marked with the wording PHOTOVOLTAIC POWER SOURCE or SOLAR PV DC CIRCUIT by means of permanently affixed labels or other approved permanent marking:

(1) Exposed raceways, cable trays, and other wiring methods
(2) Covers or enclosures of pull boxes and junction boxes
(3) Conduit bodies in which any of the available conduit openings are unused

The labels or markings shall be visible after installation. All letters shall be capitalized and shall be a minimum height of 9.5 mm (⅜ in.) in white on a red background. Labels shall appear on every section of the wiring system that is separated by enclosures, walls, partitions, ceilings, or floors. Spacing between labels or markings, or between a label and a marking, shall not be more than 3 m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.

The objective of the requirements contained in 690.31(D)(2) is to protect persons from inadvertently damaging PV source and output circuit conductors. Where the location of the PV circuit conductors is not obvious, fire fighters, other first responders, and maintenance personnel could be exposed to shock hazards. Ventilating roofs containing PV source or output circuits by cutting the membrane with saws could expose personnel to shock hazards and the building to further damage resulting from the ignition of combustible members due to arcing from damaged conductors.

**(E) Bipolar Photovoltaic Systems.** Where the sum, without consideration of polarity, of the voltages of the two monopole circuits exceeds the rating of the conductors and connected equipment, monopole circuits in a bipolar PV system shall be physically separated, and the electrical output circuits from each monopole circuit shall be installed in separate raceways until connected to the inverter. The disconnecting means and overcurrent protective devices for each monopole circuit output shall be in separate enclosures. All conductors from each separate monopole circuit shall be routed in the same raceway. Solidly grounded bipolar PV systems shall be clearly marked with a permanent, legible warning notice indicating that the disconnection of the grounded conductor(s) may result in overvoltage on the equipment.

*Exception: Listed switchgear rated for the maximum voltage between circuits and containing a physical barrier separating the disconnecting means for each monopole circuit shall be permitted to be used instead of disconnecting means in separate enclosures.*

N **(F) Wiring Methods and Mounting Systems.** Roof-mounted PV array mounting systems shall be permitted to be held in place with an approved means other than those required by 110.13 and shall utilize wiring methods that allow any expected movement of the array.

Informational Note: Expected movement of unattached PV arrays is often included in structural calculations.

**690.32 Component Interconnections.** Fittings and connectors that are intended to be concealed at the time of on-site assembly, where listed for such use, shall be permitted for on-site interconnection of modules or other array components. Such fittings and connectors shall be equal to the wiring method employed in insulation, temperature rise, and short-circuit current rating, and shall be capable of resisting the effects of the environment in which they are used.

**690.33 Mating Connectors.** Mating connectors, other than connectors covered by 690.32, shall comply with 690.33(A) through (D).

**(A) Configuration.** The mating connectors shall be polarized and shall have a configuration that is noninterchangeable with receptacles in other electrical systems on the premises.

**(B) Guarding.** The mating connectors shall be constructed and installed so as to guard against inadvertent contact with live parts by persons.

**(C) Type.** The mating connectors shall be of the latching or locking type. Mating connectors that are readily accessible and that are used in circuits operating at over 30 volts dc or 15 volts ac shall require a tool for opening. Where mating connectors are not of the identical type and brand, they shall be listed and identified for intermatability, as described in the manufacturer's instructions.

The requirements for intermatability refer to the connection of two different brands or types of mating connectors that can be installed together only where they have been listed and identified for this use. The term *intermatability* is used in UL 6703, *Connectors for Use in Photovoltaic Systems*.

Δ **(D) Interruption of Circuit.** Mating connectors shall be one of the following:

(1) Rated for interrupting current without hazard to the operator
(2) A type that requires the use of a tool to open and marked "Do Not Disconnect Under Load" or "Not for Current Interrupting"
(3) Supplied as part of listed equipment and used in accordance with instructions provided with the listed connected equipment

Informational Note: Some listed equipment, such as microinverters, are evaluated to make use of mating connectors as disconnect devices even though the mating connectors are marked as "Do Not Disconnect Under Load" or "Not for Current Interrupting."

The three options for connectors in this requirement provide for safe disconnection of circuit connectors either by allowing them to be opened under load or by requiring a warning indicating that load disconnection is necessary prior to opening the connector. Connectors that are not rated for disconnection under load cannot be opened or disconnected without the use of a tool. Connectors that are included as part of the listing of listed equipment also are permitted.

**690.34 Access to Boxes.** Junction, pull, and outlet boxes located behind modules or panels shall be so installed that the wiring contained in them can be rendered accessible directly or by displacement of a module(s) or panel(s) secured by removable fasteners and connected by a flexible wiring system.

## Part V. Grounding and Bonding

**690.41 System Grounding.**

Δ **(A) PV System Grounding Configurations.** One or more of the following system configurations shall be employed:

(1) 2-wire PV arrays with one functionally grounded conductor
(2) Bipolar PV arrays according to 690.7(C) with a functional ground reference (center tap)
(3) PV arrays not isolated from the grounded inverter output circuit
(4) Ungrounded PV arrays
(5) Solidly grounded PV arrays as permitted in 690.41(B)
(6) PV systems that use other methods that accomplish equivalent system protection in accordance with 250.4(A) with equipment listed and identified for the use

Δ **(B) Ground-Fault Protection.** PV system dc circuits that exceed 30 volts or 8 amperes shall be provided with dc ground-fault protection meeting the requirements of 690.41(B)(1) and (B)(2) to reduce fire hazards.

Solidly grounded PV source circuits with not more than two modules in parallel and not on or in buildings shall be permitted without ground-fault protection.

Informational Note: Not all inverters, charge controllers, or dc-to-dc converters include ground-fault protection. Equipment that does not have ground-fault protection often includes the following statement in the manual: "Warning: This unit is not provided with a GFDI device."

**(1) Ground-Fault Detection.** The ground-fault protection device or system shall detect ground fault(s) in the PV system dc circuit conductors, including any functional grounded conductors, and be listed for providing PV ground-fault protection. For dc-to-dc converters not listed as providing ground-fault protection, where required, listed ground fault protection equipment identified for the combination of the dc-to-dc converter and ground-fault protection device shall be installed to protect the circuit.

Informational Note: Some dc-to-dc converters without integral ground-fault protection on their input (source) side can prevent other ground-fault protection equipment from properly functioning on portions of PV system dc circuits.

Ground-fault detection and interruption for the dc portions of PV systems should not be confused with the requirements for ac circuit GFCI protection. (See the definition of *ground fault protection of equipment* in Article 100.) A GFCI is intended for the protection of personnel in single-phase and some three-phase ac systems. The ac GFCI functions to open the ungrounded conductor when a 5-milliampere fault current is detected. In contrast, devices meeting this requirement are intended to prevent fires in dc PV circuits due to ground faults.

The addition of some dc-to-dc converters into PV circuits could defeat or otherwise negatively affect ground-fault protection of the circuit. Either ground-fault protection must be provided by the converter, or the equipment providing ground-fault protection must be identified as being compatible to provide ground-fault protection.

Δ **(2) Faulted Circuits.** The faulted circuits shall be controlled by one of the following methods:

(1) The current-carrying conductors of the faulted circuit shall be automatically disconnected.
(2) The device providing ground-fault protection fed by the faulted circuit shall automatically cease to supply power to output circuits and interrupt the faulted PV system dc circuits from the ground reference in a functionally grounded system.

*N* **(3) Indication of Faults.** Ground-fault protection equipment shall provide indication of ground faults at a readily accessible location.

Informational Note: Examples of indication include, but are not limited to, the following: remote indicator light, display, monitor, signal to a monitored alarm system, or receipt of notification by web-based services.

**690.42 Point of System Grounding Connection.** Systems with a ground-fault protective device in accordance with 690.41(B) shall have any current-carrying conductor-to-ground connection made by the ground-fault protective device. For solidly grounded PV systems, the dc circuit grounding connection shall be made at any single point on the PV output circuit.

Δ **690.43 Equipment Grounding and Bonding.** Exposed non-current-carrying metal parts of PV module frames, electrical equipment, and conductor enclosures of PV systems shall be connected to an equipment grounding conductor in accordance with 250.134 or 250.136, regardless of voltage. Equipment grounding conductors and devices shall comply with 690.43(A) through (D).

**(A) Photovoltaic Module Mounting Systems and Devices.** Devices and systems used for mounting PV modules that are also used for bonding module frames shall be listed, labeled, and identified for bonding PV modules. Devices that mount adjacent PV modules shall be permitted to bond adjacent PV modules.

**(B) Equipment Secured to Grounded Metal Supports.** Devices listed, labeled, and identified for bonding and grounding the metal parts of PV systems shall be permitted to bond the equipment to grounded metal supports. Metallic support structures shall have identified bonding jumpers connected between separate metallic sections or shall be identified for equipment bonding and shall be connected to the equipment grounding conductor.

Δ **(C) With Circuit Conductors.** Equipment grounding conductors for the PV array and support structure where installed shall be contained within the same raceway or cable or otherwise run with the PV system conductors where those circuit conductors leave the vicinity of the PV array.

N **(D) Bonding for Over 250 Volts.** The bonding requirements contained in 250.97 shall apply only to solidly grounded PV system circuits operating over 250 volts to ground.

Δ **690.45 Size of Equipment Grounding Conductors.** Equipment grounding conductors for PV system circuits shall be sized in accordance with 250.122. Where no overcurrent protective device is used in the circuit, an assumed overcurrent device rated in accordance with 690.9(B) shall be used when applying Table 250.122.

Increases in equipment grounding conductor size to address voltage drop considerations shall not be required.

**690.47 Grounding Electrode System.**

Δ **(A) Buildings or Structures Supporting a PV System.** A building or structure(s) supporting a PV system shall utilize a grounding electrode system installed in accordance with Part III of Article 250.

PV array equipment grounding conductors shall be connected to a grounding electrode system in accordance with Part VII of Article 250. This connection shall be in addition to any other equipment grounding conductor requirements in 690.43(C). The PV array equipment grounding conductors shall be sized in accordance with 690.45. For specific PV system grounding configurations permitted in 690.41(A), one of the following conditions shall apply:

(1) For PV systems that are not solidly grounded, the equipment grounding conductor for the output of the PV system, where connected to associated distribution equipment connected to a grounding electrode system, shall be permitted to be the only connection to ground for the system.
(2) For solidly grounded PV systems, as permitted in 690.41(A)(5), the grounded conductor shall be connected to a grounding electrode system by means of a grounding electrode conductor sized in accordance with 250.166.

Informational Note: Most PV systems are functionally grounded systems rather than solidly grounded systems as defined in this *Code*. For functionally grounded PV systems with an interactive inverter output, the ac equipment grounding conductor is connected to associated grounded ac distribution equipment. This connection is most often the connection to ground for ground-fault protection and equipment grounding of the PV array.

Δ **(B) Grounding Electrodes and Grounding Electrode Conductors.** Additional grounding electrodes shall be permitted to be installed in accordance with 250.52 and 250.54. Grounding electrodes shall be permitted to be connected directly to the PV module frame(s) or support structure. A grounding electrode conductor shall be sized according to 250.66. A support structure for a ground-mounted PV array shall be permitted to be considered a grounding electrode if it meets the requirements of 250.52. PV arrays mounted to buildings shall be permitted to use the metal structural frame of the building if the requirements of 250.68(C)(2) are met.

## Part VI. Marking

Δ **690.51 Modules and AC Modules.** Modules and ac modules shall be marked in accordance with their listing.

Δ **690.53 DC PV Circuits.** A permanent readily visible label indicating the highest maximum dc voltage in a PV system, calculated in accordance with 690.7, shall be provided by the installer at one of the following locations:

(1) DC PV system disconnecting means
(2) PV system electronic power conversion equipment
(3) Distribution equipment associated with the PV system

**690.54 Interactive System Point of Interconnection.** All interactive system(s) points of interconnection with other sources shall be marked at an accessible location at the disconnecting means as a power source and with the rated ac output current and the nominal operating ac voltage.

**690.55 Photovoltaic Systems Connected to Energy Storage Systems.** The PV system output circuit conductors shall be marked to indicate the polarity where connected to energy storage systems.

**690.56 Identification of Power Sources.**

Δ **(A) Facilities with Stand-Alone Systems.** Plaques or directories shall be installed in accordance with 710.10.

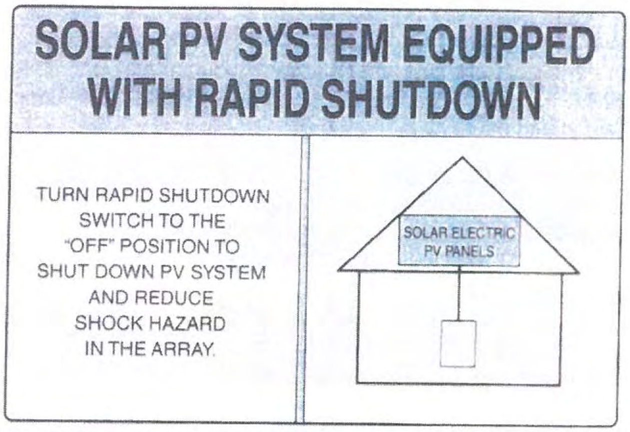
**(B) Facilities with Utility Services and Photovoltaic Systems.** Plaques or directories shall be installed in accordance with 705.10 and 712.10, as required.

**(C) Buildings with Rapid Shutdown.** Buildings with PV systems shall have a permanent label located at each service equipment location to which the PV systems are connected or at an approved readily visible location and shall indicate the location of rapid shutdown initiation devices. The label shall include a simple diagram of a building with a roof and shall include the following words:

SOLAR PV SYSTEM IS EQUIPPED
WITH RAPID SHUTDOWN.
TURN RAPID SHUTDOWN SWITCH
TO THE "OFF" POSITION TO
SHUT DOWN PV SYSTEM AND
REDUCE SHOCK HAZARD IN ARRAY.

The title "SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN" shall utilize capitalized characters with a minimum height of 9.5 mm (3⁄8 in.) in black on yellow background, and the remaining characters shall be capitalized with a minimum height of 4.8 mm (3⁄16 in.) in black on white background.

Informational Note: See Informational Note Figure 690.56(C).




*INFORMATIONAL NOTE FIGURE 690.56(C) Label for Roof-Mounted PV Systems with Rapid Shutdown.*

Δ **(1) Buildings with More Than One Rapid Shutdown Type.** For buildings that have PV systems with more than one rapid shutdown type or PV systems with no rapid shutdown, a detailed plan view diagram of the roof shall be provided showing each different PV system with a dotted line around areas that remain energized after rapid shutdown is initiated.

Δ **(2) Rapid Shutdown Switch.** A rapid shutdown switch shall have a label that includes the following wording located on or no more than 1 m (3 ft) from the switch:

RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

The label shall be reflective, with all letters capitalized and having a minimum height of 9.5 mm (3⁄8 in.) in white on red background.

## Part VII. Connection to Other Sources

**690.59 Connection to Other Sources.** PV systems connected to other sources shall be installed in accordance with Parts I and II of Article 705 and Article 712.

The requirements for inverters in 705.40 prevent energizing of otherwise de-energized system conductors or output conductors of other off-site sources (such as an electrical utility) and are intended to prevent electric shock. The ability to automatically de-energize output upon loss of voltage is normally a feature of the interactive inverter.

## Part VIII. Energy Storage Systems

**690.71 General.** An energy storage system connected to a PV system shall be installed in accordance with Article 706.

Circuits between a PV system and an energy storage device are bidirectional, since a supply source is present on both ends of the circuit. Many energy storage devices are capable of significant short-circuit currents. Therefore, overcurrent protection is needed for circuits connected to these devices.

**See also**

**706.15** for disconnecting means requirements
**706.31** for overcurrent protection requirements

**690.72 Self-Regulated PV Charge Control.** The PV source circuit shall be considered to comply with the requirements of 706.33 if:

(1) The PV source circuit is matched to the voltage rating and charge current requirements of the interconnected battery cells and,
(2) The maximum charging current multiplied by 1 hour is less than 3 percent of the rated battery capacity expressed in ampere-hours or as recommended by the battery manufacturer

# ARTICLE 691 Large-Scale Photovoltaic (PV) Electric Supply Stations

**691.1 Scope.** This article covers the installation of large-scale PV electric supply stations with an inverter generating capacity of no less than 5000 kW, and not under exclusive utility control.

Informational Note No. 1: Facilities covered by this article have specific design and safety features unique to large-scale PV facilities and are operated for the sole purpose of providing electric supply to a system operated by a regulated utility for the transfer of electric energy.

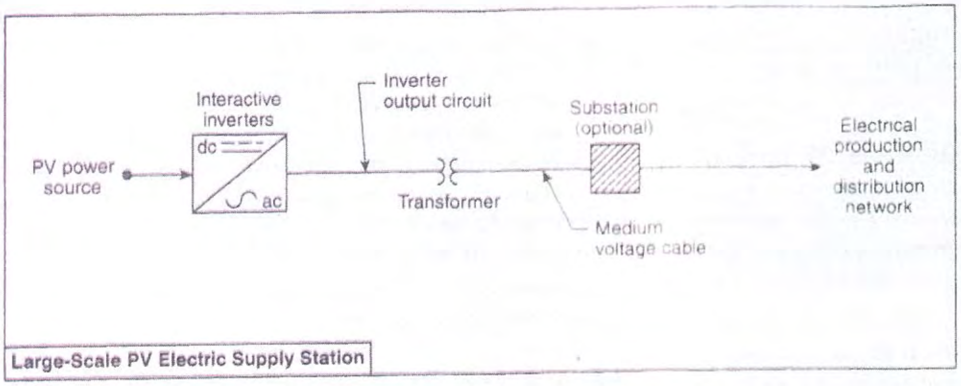
Informational Note No. 2: Section 90.2(B)(5) includes information about utility-owned properties not covered under this *Code*. For additional information on electric supply stations, see ANSI/IEEE C2-2017, *National Electrical Safety Code*.

Informational Note No. 3: See Informational Note Figure 691.1.

The systems covered by this article are a minimum size of 5 megawatts. One large solar farm in the United States has an output of 550 megawatts. The larger solar farms can cover an area of several square miles. Because they are not installed on buildings, the installation requirements for Article 691 differ from those of Article 690, which is primarily aimed at installation on buildings.

**691.2 Definitions.** The definitions in this section shall apply only within this article.

**Electric Supply Stations.** Locations containing the generating stations and substations, including their associated generator, storage battery, transformer, and switchgear areas.




Notes:
(1) Custom designs occur in each configuration, and some components are optional.
(2) The drawing is for informational purposes only and is not representative of all potential configurations.

**N** *INFORMATIONAL NOTE FIGURE 691.1 Identification of Large-Scale PV Electric Supply Station Components.*

**Generating Station.** A plant wherein electric energy is produced by conversion from some other form of energy (e.g., chemical, nuclear, solar, wind, mechanical, or hydraulic) by means of suitable apparatus.

**691.4 Special Requirements for Large-Scale PV Electric Supply Stations.** Large-scale PV electric supply stations shall be accessible only to authorized personnel and comply with the following:

(1) Electrical circuits and equipment shall be maintained and operated only by qualified personnel.

Informational Note: Refer to *NFPA 70E-2018, Standard for Electrical Safety in the Workplace*, for electrical safety requirements.

(2) Access to PV electric supply stations shall be restricted by fencing or other adequate means in accordance with 110.31. Field-applied hazard markings shall be applied in accordance with 110.21(B).
(3) The connection between the PV electric supply station and the system operated by a utility for the transfer of electrical energy shall be through medium- or high-voltage switch gear, substation, switch yard, or similar methods whose sole purpose shall be to safely and effectively interconnect the two systems.
(4) The electrical loads within the PV electric supply station shall only be used to power auxiliary equipment for the generation of the PV power.
(5) Large-scale PV electric supply stations shall not be installed on buildings.

Large-scale PV systems are required to be accessible to qualified personnel only. Section 691.9 requires an engineered design installation to have documented procedures and means of isolation of equipment.

Δ **691.5 Equipment.** All electrical equipment shall be approved for installation by one of the following:

(1) Listing and labeling
(2) Be evaluated for the application and have a field label applied
(3) Where products complying with 691.5(1) or (2) are not available, by engineering review validating that the electrical equipment is evaluated and tested to relevant standards or industry practice

**691.6 Engineered Design.** Documentation of the electrical portion of the engineered design of the electric supply station shall be stamped and provided upon request of the AHJ. Additional stamped independent engineering reports detailing compliance of the design with applicable electrical standards and industry practice shall be provided upon request of the AHJ. The independent engineer shall be a licensed professional electrical engineer retained by the system owner or installer. This documentation shall include details of conformance of the design with Article 690, and any alternative methods to Article 690, or other articles of this *Code*.

**691.7 Conformance of Construction to Engineered Design.** Documentation that the construction of the electric supply station conforms to the electrical engineered design shall be provided upon request of the AHJ. Additional stamped independent engineering reports detailing the construction conforms with this *Code*, applicable standards and industry practice shall be provided upon request of the AHJ. The independent engineer shall be a licensed professional electrical engineer retained by the system owner or installer. This documentation, where requested, shall be available prior to commercial operation of the station.

**691.8 Direct Current Operating Voltage.** For large-scale PV electric supply stations, calculations shall be included in the documentation required in 691.6.

**691.9 Disconnecting Means for Isolating Photovoltaic Equipment.** Isolating devices shall not be required within sight of equipment and shall be permitted to be located remotely from equipment. The engineered design required by 691.6 shall document disconnection procedures and means of isolating equipment.

Informational Note: For information on electrical system maintenance, see NFPA 70B-2019, *Recommended Practice for Electrical Equipment Maintenance.* For information on written procedures and conditions of maintenance, including lockout/tagout procedures, see NFPA *70E*-2018.

Buildings whose sole purpose is to house and protect supply station equipment shall not be required to comply with 690.12. Written standard operating procedures shall be available at the site detailing necessary shutdown procedures in the event of an emergency.

**691.10 Arc-Fault Mitigation.** PV systems that do not comply with the requirements of 690.11 shall include details of fire mitigation plans to address dc arc-faults in the documentation required in 691.6.

**691.11 Fence Bonding and Grounding.** Fence grounding requirements and details shall be included in the documentation required in 691.6.

Informational Note: See 250.194 for fence bonding and grounding requirements enclosing substation portions of an electric supply station. Grounding requirements for other portions of electric supply station fencing are assessed based on the presence of overhead conductors, proximity to generation and distribution equipment, and associated step and touch potential.

# ARTICLE 692 Fuel Cell Systems

## Part I. General

**692.1 Scope.** This article applies to the installation of fuel cell systems.

Informational Note: Some fuel cell systems can be interactive with other electrical power production sources, are stand-alone, or both. Some fuel cell systems are connected to electric energy storage systems such as batteries. Fuel cell systems can have ac output(s), dc output(s), or both for utilization.

The rising demand for electric power has led to the development of power sources that are viable alternatives to, or can be interconnected with, electric utility distribution systems. Article 692 covers the installation of on-premises electrical supply systems in which the power is derived from an electrochemical system that consumes fuel to generate an electric current.

The principle of operation is that direct current is generated through a chemical reaction in which hydrogen rich fuel such as natural gas, LP-Gas, or hydrogen is consumed. The consumption of the fuel gas is via an electrochemical process, as opposed to internal combustion prime movers, which consume fuel using a combustion process. A power inverter converts the dc to ac. The installation requirements of Article 692 allow power derived from fuel cells to be safely delivered into residential and light commercial occupancies as the sole source of electric power or as an integrated source with a utility or other power source.

**692.2 Definitions.** The following definition(s) shall apply only within this article.

**Fuel Cell Output Circuit.** The conductors used to connect the fuel cell system to its electrical point of delivery.

Informational Note: In the case of sites that have series- or parallel-connected multiple units, the term *output circuit* also refers to the conductors used to electrically interconnect the fuel cell system(s).

**692.4 Installation.**

**(A) Fuel Cell System.** A fuel cell system shall be permitted to supply a building or other structure in addition to any service(s) of another electricity supply system(s).

**(B) Identification of Power Sources.** Fuel cell systems shall be identified according to 692.4(B)(1) through (B)(3).

N (1) **Interconnected AC Systems.** Plaques or directories shall be installed in accordance with 705.10.

N (2) **DC Microgrid Systems.** Plaques or directories shall be installed in accordance with 712.10.

N (3) **Stand-Alone Systems.** Plaques or directories shall be installed in accordance with 710.10.

**(C) System Installation.** Fuel cell systems including all associated wiring and interconnections shall be installed by only qualified persons.

Informational Note: See Article 100 for the definition of *qualified person.*

**692.6 Listing Requirement.** The fuel cell system shall be approved for the application in accordance with one of the following:

(1) Be listed for the application
(2) Be evaluated for the application and have a field label applied

## Part II. Circuit Requirements

**692.8 Circuit Sizing and Current.**

**(A) Nameplate Rated Circuit Current.** The nameplate(s) rated circuit current shall be the rated current indicated on the fuel cell nameplate(s).

**(B) Conductor Ampacity and Overcurrent Device Ratings.** The ampacity of the feeder circuit conductors from the fuel cell system(s) to the premises wiring system shall not be less than the greater of (1) nameplate(s) rated circuit current or (2) the rating of the fuel cell system(s) overcurrent protective device(s).

**(C) Ampacity of Grounded or Neutral Conductor.** If an interactive single-phase, 2-wire fuel cell output(s) is connected to the grounded or neutral conductor and a single ungrounded conductor of a 3-wire system or of a 3-phase, 4-wire, wye-connected system, the maximum unbalanced neutral load current plus the fuel cell system(s) output rating shall not exceed the ampacity of the grounded or neutral conductor.

**692.9 Overcurrent Protection.**

**(A) Circuits and Equipment.** If the fuel cell system is provided with overcurrent protection sufficient to protect the circuit conductors that supply the load, additional circuit overcurrent devices shall not be required. Equipment and conductors connected to more than one electrical source shall be protected.

**(B) Accessibility.** Overcurrent devices shall be readily accessible.

## Part III. Disconnecting Means

**692.13 All Conductors.** Means shall be provided to disconnect all current-carrying conductors of a fuel cell system power source from all other conductors in a building or other structure.

**692.17 Switch or Circuit Breaker.** The disconnecting means for ungrounded conductors shall consist of readily accessible, manually operable switch(es) or circuit breaker(s).

Where all terminals of the disconnecting means may be energized in the open position, a warning sign shall be mounted on or adjacent to the disconnecting means. The sign shall be clearly legible and shall have the following words or equivalent:

DANGER
ELECTRIC SHOCK HAZARD.
DO NOT TOUCH TERMINALS.
TERMINALS ON BOTH THE LINE AND
LOAD SIDES MAY BE ENERGIZED
IN THE OPEN POSITION.

The danger sign(s) or label(s) shall comply with 110.21(B).

## Part IV. Wiring Methods

**692.31 Wiring Systems.** All raceway and cable wiring methods included in Chapter 3 of this *Code* and other wiring systems and fittings specifically intended and identified for use with fuel cell systems shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

## Part V. Grounding

**692.41 System Grounding.**

**(A) AC Systems.** Grounding of ac systems shall be in accordance with 250.20, and with 250.30 for stand-alone systems.

**(B) DC Systems.** Grounding of dc systems shall be in accordance with 250.160.

**(C) Systems with Alternating-Current and Direct-Current Grounding Requirements.** When fuel cell power systems have both alternating-current (ac) and direct-current (dc) grounding requirements, the dc grounding system shall be bonded to the ac grounding system. The bonding conductor shall be sized according to 692.45. A single common grounding electrode and grounding bar may be used for both systems, in which case the common grounding electrode conductor shall be sized to meet the requirements of both 250.66 (ac) and 250.166 (dc).

**692.44 Equipment Grounding Conductor.** A separate equipment grounding conductor shall be installed.

**692.45 Size of Equipment Grounding Conductor.** The equipment grounding conductor shall be sized in accordance with 250.122.

**692.47 Grounding Electrode System.** Any auxiliary grounding electrode(s) required by the manufacturer shall be connected to the equipment grounding conductor specified in 250.118.

## Part VI. Marking

**692.53 Fuel Cell Power Sources.** A marking specifying the fuel cell system, output voltage, output power rating, and continuous output current rating shall be provided at the disconnecting means for the fuel cell power source at an accessible location on the site.

**692.54 Fuel Shut-Off.** The location of the manual fuel shut-off valve shall be marked at the location of the primary disconnecting means of the building or circuits supplied.

**692.56 Stored Energy.** A fuel cell system that stores electrical energy shall require the following warning sign, or equivalent, at the location of the service disconnecting means of the premises:

WARNING
FUEL CELL POWER SYSTEM CONTAINS
ELECTRICAL ENERGY STORAGE DEVICES.

The warning sign(s) or label(s) shall comply with 110.21(B).

## Part VII. Connection to Other Circuits

**692.59 Transfer Switch.** A transfer switch shall be required in non–grid-interactive systems that use utility grid backup. The transfer switch shall maintain isolation between the electrical production and distribution network and the fuel cell system.