**ARTICLES 690-690.691**
**Solar Photovoltaic (PV) Systems**

## I. General

**690.1 Scope.** The provisions of this article apply to solar PV electrical energy systems, including the array circuit(s), inverter(s), and controller(s) for such systems. [See Figure 690.1(a) and Figure 690.1(b).] Solar PV systems covered by this article may be interactive with other electrical power production sources or stand-alone, with or without electrical energy storage such as batteries. These systems may have ac or dc output for utilization.

### 690.2 Definitions.

**DC-to-DC Converter.**
A device installed in the PV source circuit or PV output circuit that can provide an output dc voltage and current at a higher or lower value than the input dc voltage and current.

**Direct-Current (dc) Combiner.**
A device used in the PV source and PV output circuits to combine two or more dc circuit inputs and provide one dc circuit output.

**Multimode Inverter.**
Equipment having the capabilities of both the utility-interactive inverter and the stand-alone inverter.

**Photovoltaic System Voltage.**
The direct current (dc) voltage of any PV source or PV output circuit. For multiwire installations, the PV system voltage is the highest voltage between any two dc conductors.

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

**Stand-Alone System.**

A solar PV system that supplies power independently of an electrical production and distribution network.

**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, PV panels, ac PV modules, dc combiners, dc-to-dc converters, and charge controllers intended for use in PV power systems shall be listed for the PV application.

**(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 Inverters.**
A PV system is permitted to have multiple inverters installed in or on a single building or structure. Where the inverters are remotely located from each other, a directory in accordance with 705.10 shall be installed at each dc PV system disconnecting means, at each ac disconnecting means, and at the main service disconnecting means showing the locations of all ac and dc PV system disconnecting means in the building.

**690.5 Ground-Fault Protection.**

**(A) Ground-Fault Detection and Interruption.**
The ground fault protection device or system shall:
(1) Be capable of detecting a ground fault in the PV array dc current-carrying conductors and components, including any intentionally grounded conductors,
(2) Interrupt the flow of fault current
(3) Provide an indication of the fault, and
(4) Be listed for providing PV ground-fault protection

Automatically opening the grounded conductor for measurement purposes or to interrupt the ground-fault current path shall be permitted. If a grounded conductor is opened to interrupt the ground-fault current path, all conductors of the faulted circuit shall be automatically and simultaneously opened. Manual operation of the main PV dc disconnect shall not activate the ground-fault protection device or result in grounded conductors becoming ungrounded.

**690.8 Circuit Sizing and Current.**

**(A) Calculation of Maximum Circuit Current.**

The maximum current for the specific circuit shall be calculated in accordance with 690.8(A)(1) through (A)(5).

*Informational Note: Where the requirements of 690.8(A)(1) and (B)(1) are both applied, the resulting multiplication factor is 156 percent.*

**(1) Photovoltaic Source Circuit Currents.**

The maximum current shall be the sum of parallel module rated short-circuit currents multiplied by 125 percent.

**(2) Photovoltaic Output Circuit Currents.**

The maximum current shall be the sum of parallel source circuit maximum currents as calculated in 690.8(A)(1).

**(3) Inverter Output Circuit Current.**

The maximum current shall be the inverter continuous output current rating.

**(4) Stand-Alone Inverter Input Circuit Current.**

The maximum current shall be the stand-alone continuous inverter input current rating when the inverter is producing rated power at the lowest input voltage.

**(5) DC-to-DC Converter Output Current.**

The maximum current shall be the dc-to-dc converter continuous output current rating.

**(B) Conductor Ampacity.**
PV system currents shall be considered to be continuous. Circuit conductors shall be sized to carry not less than the larger of 690.8(B)(1) or (2).

**(1)** One hundred and twenty-five percent of the maximum currents calculated in 690.8(A) before the application of adjustment and correction factors.

*Exception: Circuits containing 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.*

**(2)** The maximum currents calculated in 690.8(A) after the application of 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.

**690.9 Overcurrent Protection.**
**(A) Circuits and Equipment.**
PV source circuit, PV output circuit, inverter output circuit, and storage battery circuit conductors and equipment shall be protected in accordance with the requirements of Article 240. Protection devices for PV source circuits and PV output circuits shall be in accordance with the requirements of 690.9(B) through (E). Circuits, either ac or dc, connected to current-limited supplies (e.g., PV modules, ac output of utility-interactive inverters), and also connected to sources having significantly higher current availability (e.g., parallel strings of modules, utility power), shall be protected at the source from overcurrent.

(E). Circuits, either ac or dc, connected to current-limited supplies (e.g., PV modules, ac output of utility-interactive inverters), and also connected to sources having significantly higher current availability (e.g., parallel strings of modules, utility power), shall be protected at the source from overcurrent.

*Exception: An overcurrent device shall not be required for PV modules or PV source circuit conductors sized in accordance with 690.8(B) where one of the following applies:*
*(a) There are no external sources such as parallel connected source circuits, batteries, or backfeed from inverters.*
*(b) The short-circuit currents from all sources do not exceed the ampacity of the conductors and the maximum overcurrent protective device size rating specified on the PV module nameplate.*

**(B) Overcurrent Device Ratings.**
Overcurrent device ratings shall be not less than 125 percent of the maximum currents calculated in 690.8(A).

*Exception: Circuits containing 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.*

**(C) Direct-Current Rating.**
Overcurrent devices, either fuses or circuit breakers, used in any dc portion of a PV power system shall be listed and shall have the appropriate voltage, current, and interrupt ratings.

**(D) Photovoltaic Source and Output Circuits.**
Listed PV overcurrent devices are required to provide overcurrent protection in PV source and output circuits. The overcurrent devices shall be accessible but shall not be required to be readily accessible.

**(E) Series Overcurrent Protection.**
In grounded PV source circuits, a single overcurrent protection device, where required, shall be permitted to protect the PV modules and the interconnecting conductors. In ungrounded PV source circuits complying with 690.35, an overcurrent protection device, where required, shall be installed in each ungrounded circuit conductor and shall be permitted to protect the PV modules and the interconnecting cables.

**690.12 Rapid Shutdown of PV Systems on Buildings.**
PV system circuits installed on or in buildings must include a rapid shutdown function that controls specific conductors in accordance with 690.12(1) through (5) as follows.

(1) Requirements for controlled conductors shall apply only to PV system conductors of more than 1.5 m (5 ft) in length inside a building, or more than 3 m (10 ft) from a PV array.

(2) Controlled conductors are to be limited to not more than 30 volts and 240 volt-amperes within 10 seconds of rapid shutdown initiation.

(3) Voltage and power shall be measured between any two conductors and between any conductor and ground.

(4) The rapid shutdown initiation methods shall be labeled in accordance with 690.56(B).

(5) Equipment that performs the rapid shutdown shall be listed and identified.

**690.13 Building or Other Structure Supplied by a Photovoltaic System.**
Means shall be provided to disconnect all ungrounded dc conductors of a PV system from all other conductors in a building or other structure.

**690.15 Disconnection of Photovoltaic Equipment.**
Means shall be provided to disconnect equipment, such as inverters, batteries, and charge controllers, from all ungrounded conductors of all sources. If the equipment is energized from more than one source, the disconnecting means shall be grouped and identified. A single disconnecting means in accordance with 690.17 shall be permitted for the combined ac output of one or more inverters or ac modules in an interactive system.

**(A) Utility-Interactive Inverters Mounted in Not Readily Accessible Locations.**
Utility-interactive inverters shall be permitted to be mounted on roofs or other exterior areas that are not readily accessible and shall comply with 690.15(A)(1) through (4):

(1) A dc PV disconnecting means shall be mounted within sight of or in each inverter.

(2) An ac disconnecting means shall be mounted within sight of or in each inverter.

(3) The ac output conductors from the inverter and an additional ac disconnecting means for the inverter shall comply with 690.13(A).

(4) A plaque shall be installed in accordance with 705.10.

**(B) Equipment.**
Equipment such as PV source circuit isolating switches, overcurrent devices, dc-to-dc converters, and blocking diodes shall be permitted on the PV side of the PV disconnecting means.

**(C) Direct-Current Combiner Disconnects.** The dc output of dc combiners mounted on roofs of dwellings or other buildings shall have a load break disconnecting means located in the combiner or within 1.8 m (6 ft) of the combiner. The disconnecting means shall be permitted to be remotely controlled but shall be manually operable locally when control power is not available.

**690.17 Disconnect Type.**

**(A) Manually Operable.**
The disconnecting means for ungrounded PV conductors shall consist of a manually operable switch(es) or circuit breaker(s). The disconnecting means shall be permitted to be power operable with provisions for manual operation in the event of a power-supply failure. The disconnecting means shall be one of the following listed devices:

(1) A PV industrial control switch marked for use in PV systems

(2) A PV molded-case circuit breaker marked for use in PV systems

(3) A PV molded-case switch marked for use in PV systems

(4) A PV enclosed switch marked for use in PV systems

(5) A PV open-type switch marked for use in PV systems

(6) A dc-rated molded-case circuit breaker suitable for backfeed operation

(7) A dc-rated molded-case switch suitable for backfeed operation

(8) A dc-rated enclosed switch

(9) A dc-rated open-type switch

(10) A dc-rated rated low-voltage power circuit breaker Informational Note: Devices marked with “line” and “load” are not suitable for backfeed or reverse current.

**(B) Simultaneous Opening of Poles.**
The PV disconnecting means shall simultaneously disconnect all ungrounded supply conductors.

**(C) Externally Operable and Indicating.** The PV disconnecting means shall be externally operable without exposing the operator to contact with live parts and shall indicate whether in the open or closed position.

**(D) Disconnection of Grounded Conductor.**
A switch, circuit breaker, or other device shall not be installed in a grounded conductor if operation of that switch, circuit breaker, or other device leaves the marked, grounded conductor in an ungrounded and energized state.

*Exception No. 1: A switch or circuit breaker that is part of a ground-fault detection system required by 690.5, or that is part of an arc-fault detection/interruption system required by 690.11, shall be permitted to open the grounded conductor when that switch or circuit breaker is automatically opened as a normal function of the device in responding to ground faults.*

*Exception No. 2: A disconnecting switch shall be permitted in a grounded conductor if all of the following conditions are met:*

*(1) The switch is used only for PV array maintenance.*

*(2) The switch is accessible only by qualified persons.*

*(3) The switch is rated for the maximum dc voltage and current that could be present during any operation, including ground-fault conditions.*

**(E) Interrupting Rating.**
The building or structure disconnecting means shall have an interrupting rating sufficient for the maximum circuit voltage and current that is available at the line terminals of the equipment. 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.

**690.31 Methods Permitted.**
**(A) Wiring Systems.**
All raceway and cable wiring methods included in this *Code*, other wiring systems and fittings specifically listed for use on 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 maximum system voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be guarded or installed in a raceway.
Informational Note: Photovoltaic modules operate at elevated temperatures when exposed to high ambient temperatures and to bright sunlight. These

temperatures routinely exceed 70°C (158°F) in many locations. Module interconnection conductors are available with insulation rated for wet locations and a temperature rating of 90°C (194°F) or greater.

**(B) Identification and Grouping.**
PV source circuits and PV output circuits shall not be contained in the same raceway, cable tray, cable, outlet box, junction box, or similar fitting as conductors, feeders, branch circuits of other non-PV systems, or inverter output circuits, unless the conductors of the different systems are separated by a partition. PV system conductors shall be identified and grouped as required by 690.31(B)(1) through (4). The means of identification shall be permitted by separate color coding, marking tape, tagging, or other approved means.

**(1) PV Source Circuits.** PV source circuits must be identified at all points of termination, connection, and splices.

**(2) PV Output and Inverter Circuits.**
The conductors of PV output circuits and inverter input and output circuits must be identified at all points of termination, connection, and splices.

**(3) Conductors of Multiple Systems.**
Where the conductors of more than one PV system occupy the same junction box, raceway, or equipment, the conductors of each system shall be identified at all termination, connection, and splice points.

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

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

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

**(C) Single-Conductor Cable.**

(1) **General.** Single-conductor cable Type USE-2, and single-conductor cable listed and labeled as photovoltaic (PV) wire shall be permitted in exposed outdoor locations in PV source circuits for PV module interconnections within the PV array.

(2) **Cable Tray.**
PV source circuits and PV output circuits using single-conductor cable listed and labeled as photovoltaic (PV) wire of all sizes, with or without a cable tray marking/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 (4.5 ft).

Informational Note: Photovoltaic wire and PV cable have a nonstandard outer diameter. See Table 1 of Chapter 9 for conduit fill calculations.

**(D) Multiconductor Cable.**
Multiconductor cable Type TC-ER or Type USE-2 shall be permitted in outdoor locations in PV inverter output circuits where used with utility interactive inverters mounted in locations that are not readily accessible. The cable must be secured at intervals not exceeding 1.8 m (6 ft). Equipment grounding for the utilization equipment shall be provided by an equipment grounding conductor within the cable.

**(G) Direct-Current Photovoltaic Source and Direct- Current Output Circuits on or Inside a Building.**
Where dc PV source or dc PV output circuits from building integrated systems or other PV systems are run inside a building or structure, they shall be contained in metal raceways, Type MC metal-clad cable that complies with 250.118(10), or metal enclosures from the point of penetration of the surface of the building or structure to the first readily accessible disconnecting means. The disconnecting means shall comply with 690.13(B) and (C) and 690.15(A) and (B). The wiring methods shall comply with the additional installation requirements in 690.31(G)(1) through (4).

**(1) Embedded in Building Surfaces.**
Where circuits are embedded in built-up, laminate, or membrane roofing materials in roof areas not covered by PV modules and associated equipment, the location of circuits shall be clearly marked using a marking protocol that is approved as being suitable for continuous exposure to sunlight and weather.

**(3) Marking and Labeling Required.**
The following wiring methods and enclosures that contain PV power source conductors shall be marked with the wording: 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

**(4) Marking and Labeling Methods and Locations.**
The labels or markings shall be visible after installation. The labels shall be reflective, and all letters shall be capitalized and shall be a minimum height of 9.5 mm (3/8 in.) in white on a 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 3 m (10 ft). Labels required by this section shall be suitable for the environment where they are installed.

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

**(I) Bipolar Photovoltaic Systems.**
Where the sum, without consideration of polarity, of the PV system voltages of the two monopole sub-arrays exceeds the rating of the conductors and connected equipment, monopole sub-arrays in a bipolar PV system shall be physically separated, and the electrical output circuits from each monopole sub-array shall be installed in separate raceways until connected to the inverter. The disconnecting means and overcurrent protective devices for

each monopole sub-array output shall be in separate enclosures. All conductors from each separate monopole subarray shall be routed in the same raceway.
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 subarray shall be permitted to be used instead of disconnecting means in separate enclosures.*

**(J) Module Connection Arrangement.**
The connection to a module or panel shall be arranged so that removal of a module or panel from a PV source circuit does not interrupt a grounded conductor connection to other PV source circuits.

**690.35 Ungrounded Photovoltaic Power Systems.**
Photovoltaic power systems shall be permitted to operate with ungrounded PV source and output circuits where the system complies with 690.35(A) through (G).

**(A) Disconnects.**
All PV source and output circuit conductors
shall have disconnects complying with 690, Part III.

**(B) Overcurrent Protection.**
All PV source and output circuit conductors shall have overcurrent protection complying with 690.9.

**(C) Ground-Fault Protection.**
All PV source and output circuits shall be provided with a ground-fault protection device or system that complies with 690.35(1) through (4):

(1) Detects ground fault(s) in the PV array dc currentcarrying conductors and components

(2) Indicates that a ground fault has occurred

(3) Automatically disconnects all conductors or causes the inverter or charge controller connected to the faulted circuit to automatically cease supplying power to output circuits

(4) Is listed for providing PV ground-fault protection

**(D) Conductors.**
The PV source conductors shall consist of the following:

(1) Metallic or nonmetallic jacketed multi-conductor cables

(2) Conductors installed in raceways

(3) Conductors listed and identified as PV wire installed as exposed, single conductors, or

(4) Conductors that are direct-buried and identified for direct-burial use

**(E) Battery Systems.**
The PV power system direct-current circuits shall be permitted to be used with ungrounded battery systems complying with 690.71(G).

**(F) Marking.**
The PV power source shall be labeled with the following warning at each junction box, combiner box, disconnect, and device where energized, ungrounded circuits may be exposed during service:

WARNING

ELECTRIC SHOCK HAZARD. THE DC CONDUCTORS OF THIS PHOTOVOLTAIC SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED.

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

**(G) Equipment.**
The inverters or charge controllers used in systems with ungrounded PV source and output circuits shall be listed for the purpose.

**690.41 System Grounding.**
Photovoltaic systems shall comply with one of the following:

(1) Ungrounded systems shall comply with 690.35.

(2) Grounded two-wire systems shall have one conductor grounded or be impedance grounded, and the system shall comply with 690.5.

(3) Grounded bipolar systems shall have the reference (center tap) conductor grounded or be impedance grounded, and the system shall comply with 690.5.

(4) Other methods that accomplish equivalent system protection in accordance with 250.4(A) with equipment listed and identified for the use shall be permitted to be used.

**690.45 Size of Equipment Grounding Conductors.**
Equipment grounding conductors for PV source and PV output circuits shall be sized in accordance with 250.122. Where no overcurrent protective device is used in the circuit, an assumed overcurrent device rated at the PV maximum circuit current shall be used when applying Table 250.122. Increases in equipment grounding conductor size to address voltage drop considerations are not required. An equipment grounding conductor shall not be smaller than 14 AWG.

**690.46 Array Equipment Grounding Conductors.**
For PV modules, equipment grounding conductors smaller than 6 AWG shall comply with 250.120(C). Where installed in raceways, equipment grounding conductors and grounding electrode conductors not larger than 6 AWG shall be permitted to be solid.

**690.47 Grounding Electrode System.**

**(B) Direct-Current Systems.**

An ac equipment grounding system shall be permitted to be used for equipment grounding of inverters and other equipment and for the ground-fault detection reference for ungrounded PV systems.

**(3) Combined Direct-Current Grounding Electrode Conductor and Alternating-Current Equipment Grounding Conductor.**

For ungrounded systems, this conductor shall be sized in accordance with 250.122 and shall not be required to be larger than the largest ungrounded phase conductor.

**(D) Additional Auxiliary Electrodes for Array Grounding.**
A grounding electrode shall be installed in accordance with 250.52 and 250.54 at the location of all ground- and pole-mounted PV arrays and as close as practicable to the location of roof-mounted PV arrays. The electrodes shall be connected directly to the array frame(s) or structure. The dc grounding electrode conductor shall be sized according to 250.166. Additional electrodes are not permitted to be used as a substitute for equipment bonding or equipment grounding conductor requirements. The structure of a ground- or pole-mounted PV array shall be permitted to be considered a grounding electrode if it meets the requirements of 250.52. Roof-mounted PV arrays shall be permitted to use the metal frame of a building or structure if the requirements of 250.52(A)(2) are met.

*Exception No. 1: An array grounding electrode(s) shall not be required where the load served by the array is integral with the array.*

*Exception No. 2: An additional array grounding electrode( s) shall not be required if located within 1.8 m (6 ft) of the premises wiring electrode.*

**690.56 Identification of Power Sources.**

**(C) Facilities with Rapid Shutdown.**
Buildings or structures with both utility service and a PV system, complying with 690.12, shall have a permanent plaque or directory including the following wording:

PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN

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

## VIII. Storage Batteries

### 690.71 Installation.

**(H) Disconnects and Overcurrent Protection.**

Where energy storage device input and output terminals are more than 1.5 m (5 ft) from connected equipment, or where the circuits from these terminals pass through a wall or partition, the installation shall comply with the following:

(1) A disconnecting means and overcurrent protection shall be provided at the energy storage device end of the circuit. Fused disconnecting means or circuit breakers shall be permitted to be used.

(2) Where fused disconnecting means are used, the line terminals of the disconnecting means shall be connected toward the energy storage device terminals.

(3) Overcurrent devices or disconnecting means shall not be installed in energy storage device enclosures where explosive atmospheres can exist.

(4) A second disconnecting means located at the connected equipment shall be installed where the disconnecting means required by 690.71(H)(1) is not within sight of the connected equipment.

(5) Where the energy storage device disconnecting means is not within sight of the PV system ac and dc disconnecting means, placards or directories shall be installed at the locations of all disconnecting means indicating the location of all disconnecting means.

## IX. Systems over 1000 Volts

### 690.80 General.

Solar PV systems with a maximum system voltage over 1000 volts dc shall comply with Article 490 and other requirements applicable to installations rated over 1000 volts.

**690.81 Listing.**
Products listed for PV systems shall be permitted to be used and installed in accordance with their listing. PV wire that is listed for direct burial at voltages above 600 volts, but not exceeding 2000 volts, shall be installed in accordance with Table 300.50, column 1.

## X. Electric Vehicle Charging

**690.90 General.**
Photovoltaic systems used directly to charge electric vehicles shall comply with Article 625 in addition to the requirements of this article.

**690.91 Charging Equipment.**
Electric vehicle couplers shall comply with 625.10. Personnel protection systems in accordance with 625.22 and automatic de-energization of cables in accordance with 625.19 are not required for PV systems with maximum system voltages of less than 80 volts dc.