A person designated as a qualified person shall possess the skills and knowledge related to the construction and operation of the electrical equipment and installation and shall have received documented safety training on the hazards involved. Documentation of their qualifications shall be on file with the office of the establishment in charge of the completed installation.

(3) Effective safeguards acceptable to the authority having jurisdiction are established and maintained.

The integrated electrical systems commonly used in large and complex industrial processes are designed, installed, and operated under stringent on-site engineering supervision. The control equipment, including overcurrent devices, is located so that it is accessible to qualified personnel, but that location might not meet and is not required to meet the conditions described in the Article 100 definition of readily accessible. Locating overcurrent devices and their associated disconnecting means so that it is not readily accessible to unqualified personnel is one of the preventative measures used to help maintain continuity of operation.

For some industrial processes, the sudden loss of electrical power to vital equipment is an unacceptable level of risk, and an orderly shutdown procedure is necessary to prevent severe equipment damage, injury to personnel, or, in some extreme cases, catastrophic failure. Orderly shutdown is commonly employed in nuclear power–generating facilities, paper mills, and other areas with hazardous processes.

**685.3 Application of Other Articles**

The articles/sections in Table 685.3 apply to particular cases of installation of conductors and equipment, where there are orderly shutdown requirements that are in addition to those of this article or are modifications of them.

**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.
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690.1 Scope

The provisions of this article apply to solar photovoltaic (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 photovoltaic 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.

The use of photovoltaic (PV) systems as utility-interactive or stand-alone power-supply systems has steadily increased as the technology and availability of PV equipment have evolved. Also, recently passed legislation that provides financial incentives to end users has resulted in the burgeoning use of these systems in residential, commercial, institutional, and industrial settings. The requirements of Article 690 cover the use of stand-alone and utility-interactive PV systems. Utility-interactive photovoltaic systems are subject to the requirements for interconnected electric power production sources contained in Article 705.

Exhibit 690.1 shows a custom-designed home with a PV electrical system. The integrated array of glass panels on the roof generates electricity directly from the sun using PV modules.

690.2 Definitions

Alternating-Current (ac) Module (Alternating-Current Photovoltaic Module). A complete, environmentally protected unit consisting of solar cells, optics, inverter, and other components, exclusive of tracker, designed to generate ac power when exposed to sunlight.

An ac PV module consists of a single integrated mechanical unit. Because there is no accessible, field-installed dc wiring in this single unit, the dc PV source-circuit requirements in
690.2 Article 690 • Solar Photovoltaic (PV) Systems

**FIGURE 690.1(B) Identification of Solar Photovoltaic System Components in Common System Configurations.**

**Interactive system**

- Photovoltaic source circuits
- Inverter input circuit
- Inverter output circuit
- Electric production and distribution network connection

**Hybrid system**

- Wind, engine-generator, micro-hydro-electric, and other power sources
- Energy storage, charge controller, and system control
- Inverter input circuit
- Inverter output circuit
- dc loads
- Inverter

**Stand-alone system**

- Photovoltaic output circuit
- Charge controller
- Inverter input circuit
- Inverter output circuit
- Main supply equipment for ac loads
- Energy storage
- Inverter

**Notes:**
1. These diagrams are intended to be a means of identification for photovoltaic system components, circuits, and connections.
2. Disconnecting means and overcurrent protection required by Article 690 are not shown.
3. System grounding and equipment grounding are not shown. See Article 690, Part V.
4. Custom designs occur in each configuration, and some components are optional.

**EXHIBIT 690.2** An array composed of multiple modules or panels installed on a support structure and foundation. (Courtesy of NECA)

Blocking diodes are not required by this Code, although the instructions or labels supplied with the PV module may require them. Blocking diodes are not overcurrent devices and may not be substituted for any overcurrent device required by this Code.

**Building Integrated Photovoltaics.** Photovoltaic cells, devices, modules, or modular materials that are integrated into the outer surface or structure of a building and serve as the outer protective surface of that building.

**Charge Controller.** Equipment that controls dc voltage or dc current, or both, used to charge a battery.

**Diversion Charge Controller.** Equipment that regulates the charging process of a battery by diverting power from energy storage to direct-current or alternating-current loads or to an interconnected utility service.

**Electrical Production and Distribution Network.** A power production, distribution, and utilization system, such as a utility system and connected loads, that is external to and not controlled by the photovoltaic power system.

**Hybrid System.** A system comprised of multiple power sources. These power sources may include photovoltaic, wind, micro-hydro generators, engine-driven generators, and others, but do not include electrical production and distribution network systems. Energy storage systems, such as batteries, do not constitute a power source for the purpose of this definition.

**Interactive System.** A solar photovoltaic system that operates in parallel with and may deliver power to an electrical

---

**Array.** A mechanically integrated assembly of modules or panels with a support structure and foundation, tracker, and other components, as required, to form a direct-current power-producing unit.

A rooftop photovoltaic array is illustrated in Exhibit 690.2.

**Bipolar Photovoltaic Array.** A photovoltaic array that has two outputs, each having opposite polarity to a common reference point or center tap.

**Blocking Diode.** A diode used to block reverse flow of current into a photovoltaic source circuit.
production and distribution network. For the purpose of this
definition, an energy storage subsystem of a solar photovoltaic
system, such as a battery, is not another electrical pro-
duction source.

**Inverter.** Equipment that is used to change voltage level or
waveform, or both, of electrical energy. Commonly, an in-
verter [also known as a power conditioning unit (PCU) or
power conversion system (PCS)] is a device that changes dc
input to an ac output. Inverters may also function as battery
chargers that use alternating current from another source
and convert it into direct current for charging batteries.

**Inverter Input Circuit.** Conductors between the inverter
and the battery in stand-alone systems or the conductors be-
tween the inverter and the photovoltaic output circuits for
electrical production and distribution network.

**Inverter Output Circuit.** Conductors between the inverter
and an ac panelboard for stand-alone systems or the conduc-
tors between the inverter and the service equipment or an-
other electric power production source, such as a utility, for
electrical production and distribution network.

**Module.** A complete, environmentally protected unit con-
sisting of solar cells, optics, and other components, exclu-
sive of tracker, designed to generate dc power when exposed
to sunlight.

**Monopole Subarray.** A PV subarray that has two conduc-
tors in the output circuit, one positive (+) and one nega-
tive (−). Two monopole PV subarrays are used to form a
bipolar PV array.

**Panel.** A collection of modules mechanically fastened to-
gether, wired, and designed to provide a field-installable
unit.

**Photovoltaic Output Circuit.** Circuit conductors between
the photovoltaic source circuit(s) and the inverter or dc utili-
zation equipment.

**Photovoltaic Power Source.** An array or aggregate of ar-
rays that generates dc power at system voltage and current.

**Photovoltaic Source Circuit.** Circuits between modules
and from modules to the common connection point(s) of the
dc system.

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

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

**Solar Photovoltaic System.** The total components and
subsystems that, in combination, convert solar energy
into electric energy suitable for connection to a utilization
load.

**Stand-Alone System.** A solar photovoltaic system that
supplies power independently of an electrical production
and distribution network.

The simplified circuit schematics in Exhibits 690.3 through
690.6 demonstrate the use of various components in a PV sys-
tem. Specific requirements for overcurrent protection, discon-
necting means, and grounding are covered in other sections of
Article 690 and should not be assumed based on these draw-
ings. Instructions for, or labels on the PV module might re-
quire additional overcurrent devices that may not be shown.

**Subarray.** An electrical subset of a PV array.

### 690.3 Other Articles

Wherever the requirements of other articles of this Code and
Article 690 differ, the requirements of Article 690 shall
apply and, if the system is operated in parallel with a pri-
mary source(s) of electricity, the requirements in 705.14,
705.16, 705.32, and 705.143 shall apply.

**Exception:** Solar photovoltaic systems, equipment, or wir-
ing installed in a hazardous (classified) location shall also
comply with the applicable portions of Articles 500 through
516.

### 690.4 Installation

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

**(B) Identification and Grouping.** Photovoltaic source cir-
cuits 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, or branch circuits of
other non-PV systems, unless the conductors of the different
systems are separated by a partition. Photovoltaic system
conductors shall be identified and grouped as required by
690.4(B)(1) through (4). The means of identification shall
be permitted by separate color coding, marking tape, tag-
ging, or other approved means.

Section 690.4(B) does not permit the alternating-current
branch-circuit conductors that supply an exterior luminaire
installed near a roof-mounted PV array to share the same
raceway or cable with the conductors of PV source circuits
or PV output circuits.
Conductors directly related to a specific PV system, such as those in dc and ac output power circuits, may be contained in the same raceway as PV source and output conductors, providing they meet the requirements of 690.4(B) (1) through (B)(4) and 300.3(C).

(1) Photovoltaic Source Circuits. Photovoltaic source circuits shall be identified at all points of termination, connection, and splices.

(2) Photovoltaic Output and Inverter Circuits. The conductors of PV output circuits and inverter input and output circuits shall 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 is not 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 wire ties or similar means at least once, and then shall 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.

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

In general, 690.4(C) requires that a jumper be installed between a module terminal or lead and the connection point to the grounded PV source-circuit conductor. That way, a module can be removed without interrupting the grounded conductor to other PV source circuits. If interrupted, such conductors, although identified as grounded, would be operating at the system potential with respect to ground, and a shock hazard could result. The reverse-current protection requirement on nearly all PV modules (as indicated by the fuse requirement labeled on the back of each module) generally dictates that each module or string of modules have a series overcurrent device and become a source circuit.
(D) **Equipment.** Inverters, motor generators, photovoltaic modules, photovoltaic panels, ac photovoltaic modules, source-circuit combiners, and charge controllers intended for use in photovoltaic power systems shall be identified and listed for the application.

Section 690.4(D) requires equipment used in PV systems to be listed for the application. Equipment listed for marine, mobile, telecommunications, or other applications may not be suitable for installation in permanent PV power systems complying with this Code.

(E) **Wiring and Connections.** The equipment and systems in 690.4(A) through (D) and all associated wiring and interconnections shall be installed only by qualified persons.

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

(F) **Circuit Routing.** Photovoltaic source and PV output conductors, in and out of conduit, and inside of a building or structure, shall be routed along building structural members such as beams, rafters, trusses, and columns where the location of those structural members can be determined by observation. Where circuits are imbedded 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.

The general requirement covering the location of the photovoltaic disconnecting means in 690.14(C)(1) specifies that it be located nearest to the point where the PV circuit conductors enter a building or structure. The distance between the array and the disconnecting means is not limited by the Code. The PV circuit conductors between the photovoltaic power source and the PV disconnecting means are energized whenever the source is producing power. Because of this potential exposure to energized conductors, a marking is required to warn roofers, other tradespersons, or first responders of the location of energized PV conductors where PV source or output circuits are “imbedded” or concealed by the roofing material. This requirement does not apply to conductors installed in areas of the
(G) Bipolar Photovoltaic Systems. Where the sum, without consideration of polarity, of the PV system voltages of the two monopole subarrays exceeds the rating of the conductors and connected equipment, monopole subarrays in a bipolar PV system shall be physically separated, and the electrical output circuits from each monopole subarray shall be installed in separate raceways until connected to the inverter. The disconnecting means and overcurrent protective devices for each monopole subarray output shall be in separate enclosures. All conductors from each separate monopole subarray shall be routed in the same raceway.

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.

(H) Multiple Inverters. A PV system shall be permitted to have multiple utility-interactive 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 location of all ac and dc PV system disconnecting means in the building.

Exception: A directory shall not be required where all inverters and PV dc disconnecting means are grouped at the main service disconnecting means.

690.5 Ground-Fault Protection

Grounded dc photovoltaic arrays shall be provided with dc ground-fault protection meeting the requirements of 690.5(A) through (C) to reduce fire hazards. Ungrounded dc photovoltaic arrays shall comply with 690.35.

Exception No. 1: Ground-mounted or pole-mounted photovoltaic arrays with not more than two paralleled source cir-
Solar Photovoltaic (PV) Systems

EXHIBIT 690.6 Simplified circuit schematic of a rooftop grid-connected system.

Ground-fault detection and interruption for the direct-current portions of PV systems should not be confused with the requirements for alternating-current circuit GFCI protection, as defined in Article 100. A GFCI is intended for the protection of personnel in single-phase ac systems. The ac GFCI functions to open the ungrounded conductor when a 5-mA fault current is detected. In contrast, devices meeting the requirements of 690.5 are intended to prevent fires in dc PV circuits due to ground faults.

(A) Ground-Fault Detection and Interruption. The ground-fault protection device or system shall be capable of detecting a ground-fault current, interrupting the flow of fault current, and providing an indication of the fault.

Automatically opening the grounded conductor of the faulted circuit 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.

Typical ground-fault protection devices meeting the requirements of 690.5(A) operate by opening the main dc bonding jumper. They sense dc ground faults anywhere on the dc system and may be mounted anywhere in that system. They are usually installed inside the utility-interactive inverters or in the dc power center in stand-alone PV systems. Ground-fault protection accomplished through the opening of the grounded conductor also has to incorporate disconnecting means to automatically open all conductors of the faulted circuit.

(B) Isolating Faulted Circuits. The faulted circuits shall be isolated by one of the two following methods:

1. The ungrounded conductors of the faulted circuit shall be automatically disconnected.
2. The inverter or charge controller fed by the faulted circuit shall automatically cease to supply power to output circuits.

Exception No. 2: Photovoltaic arrays installed at other than dwelling units shall be permitted without ground-fault protection if each equipment grounding conductor is sized in accordance with 690.45.
Typical ground-fault protection devices operating in PV systems (48-volt nominal and below) automatically disconnect the ungrounded conductor with a circuit breaker mechanically linked to a ground-fault-sensing circuit breaker. Equipment operating above 48 volts nominal usually automatically shuts off the connected equipment to meet this requirement when a ground fault is sensed.

(C) Labels and Markings. A warning label shall appear on the utility-interactive inverter or be applied by the installer near the ground-fault indicator at a visible location, stating the following:

**WARNING**
ELECTRIC SHOCK HAZARD
IF A GROUND FAULT IS INDICATED,
NORMALLY GROUNDED CONDUCTORS MAY BE UNGROUNDED AND ENERGIZED

When the photovoltaic system also has batteries, the same warning shall also be applied by the installer in a visible location at the batteries.

Many types of ground-fault detection and interruption equipment break the negative-to-ground bond to interrupt the fault currents, and the now ungrounded PV negative conductor generally is at open-circuit voltage below the ground reference (e.g., −400 volts).

690.6 Alternating-Current (ac) Modules

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

(B) Inverter Output Circuit. The output of an ac module shall be considered an inverter output circuit.

(C) Disconnecting Means. A single disconnecting means, in accordance with 690.15 and 690.17, shall be permitted for the combined ac output of one or more ac modules. Additionally, each ac module in a multiple ac module system shall be provided with a connector, bolted, or terminal-type disconnecting means.

Alternating-current PV modules, as utility-interactive devices, are designed to produce ac power only when they are connected to an external source of ac power at the correct voltage and frequency. A single disconnecting means re- moves the external source and turns off all ac PV modules connected to that disconnecting device.

(D) Ground-Fault Detection. Alternating-current module systems shall be permitted to use a single detection device to detect only ac ground faults and to disable the array by removing ac power to the ac module(s).

The detection device permitted by 690.6(D) is a fire prevention device and is not intended to be a shock prevention device. Existing GFCI and equipment ground-fault protection devices are generally not listed for backfeeding and are not suitable for meeting this requirement.

(E) Overcurrent Protection. The output circuits of ac modules shall be permitted to have overcurrent protection and conductor sizing in accordance with 240.5(B)(2).

II. Circuit Requirements

690.7 Maximum Voltage

(A) Maximum Photovoltaic System Voltage. In a dc photovoltaic source circuit or output circuit, the maximum photovoltaic system voltage for that circuit shall be calculated as the sum of the rated open-circuit voltage of the series-connected photovoltaic modules corrected for the lowest expected ambient temperature. For crystalline and multicrystalline silicon modules, the rated open-circuit voltage shall be multiplied by the correction factor provided in Table 690.7. This voltage shall be used to determine the voltage rating of cables, disconnects, overcurrent devices, and other equipment. Where the lowest expected ambient temperature is below −40°C (−40°F), or where other than crystalline or multicrystalline silicon photovoltaic modules are used, the system voltage adjustment shall be made in accordance with the manufacturer’s instructions.

When open-circuit voltage temperature coefficients are supplied in the instructions for listed PV modules, they shall be used to calculate the maximum photovoltaic system voltage as required by 110.3(B) instead of using Table 690.7.

Informational Note: One source for statistically valid, lowest-expected, ambient temperature design data for various locations is the Extreme Annual Mean Minimum Design Dry Bulb Temperature found in the ASHRAE Handbook — Fundamentals. These temperature data can be used to calculate maximum voltage using the manufacturer’s temperature coefficients relative to the rating temperature of 25°C.

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 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 potential (both open circuit and operating) of a PV power source increases with decreasing temperature. The installer should note the temperature conditions under 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 should be used to adjust the maximum open-circuit voltage of the crystalline system before conductors, overcurrent devices, and switchgear are selected.

The temperature adjustment requirement is also included in the instructions provided with listed PV modules and is established at a fixed 125 percent, regardless of temperature. Table 690.7 supersedes the fixed 125 percent where the lowest temperature is above −40°C.

Where a listed PV module includes open-circuit voltage temperature coefficients in the installation instructions, these temperature coefficients provide a more accurate maximum system voltage and are required to be used instead of applying Table 690.7. The NEC does not require temperature coefficient information to be included in the installation instructions.

Bipolar PV systems (with positive and negative voltages) must use the sum of the absolute values of the open-circuit voltages to determine the rated open-circuit system voltage. For 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 960 volts. This voltage should be multiplied by a temperature-dependent factor from Table 690.7, yielding a system design voltage of up to 1200 volts. The system design voltage should be used in the selection of cables and other equipment. Also, see the definition of photovoltaic system voltage in 690.2. Certain methods of connecting bipolar PV arrays meeting the requirements of 690.7(E) may have different requirements for calculating the maximum system voltage.

### TABLE 690.7 Voltage Correction Factors for Crystalline and Multicrystalline Silicon Modules

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

A significant difference exists between the rated open-circuit voltage and the operating voltage in PV dc circuits. For the PV system to perform its intended function, rated dc open-circuit voltages of up to 600 volts may be present.

(D) Circuits over 150 Volts to Ground. In one- and two-family dwellings, live parts in photovoltaic source circuits and photovoltaic output circuits over 150 volts to ground shall not be accessible to other than qualified persons while energized.

Informational Note: See 110.27 for guarding of live parts, and 210.6 for voltage to ground and between conductors.

Where dc circuitry over 150 volts to ground is present in one- and two-family dwellings, additional protection for unqualified persons may be needed. Protection may be in the form of conduit, a closed cabinet, or an enclosure that requires the use of tools to open it and that permits entry only by qualified persons.

(E) Bipolar Source and Output Circuits. For 2-wire circuits connected to bipolar systems, the maximum system voltage shall be the highest voltage between the conductors.
of the 2-wire circuit if all of the following conditions apply:

(1) One conductor of each circuit of a bipolar subarray is solidly grounded.

*Exception: The operation of ground-fault or arc-fault devices (abnormal operation) shall be permitted to interrupt this connection to ground when the entire bipolar array becomes two distinct arrays isolated from each other and the utilization equipment.*

(2) Each circuit is connected to a separate subarray.

(3) The equipment is clearly marked with a label as follows:

**WARNING**

*BIPOLAR PHOTOVOLTAIC ARRAY.*

**DISCONNECTION OF NEUTRAL OR GROUNDED CONDUCTORS MAY RESULT IN OVERVOLTAGE ON ARRAY OR INVERTER.*

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)(4).

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.

The use of the array short-circuit current allows for proper sizing of conductors to handle the current generated during extended periods of operation under a short-circuit current operating point.

The 125 percent factor is required by 690.8(A)(1) because PV modules, PV source circuits, and PV output circuits can deliver output currents higher than the rated short-circuit currents for more than 3 hours near solar noon. This requirement is duplicated in the instructions provided with each listed module, but this factor only needs to be applied once. A second 125 percent factor is required by 690.8(B).

PV modules in hot climates operate at temperatures of 60°C to 80°C due to solar heating. Conductors with insulation types rated at least 90°C should be used, and these conductors should have the ampacity corrected in accordance with Table 310.15(B)(16) or Table 310.15(B)(17).

**(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.

Both stand-alone and utility-interactive inverters are power-limited devices. Output circuits connected to these devices are sized on the continuous rated outputs of these devices and are not based on load calculations or reduced-size PV arrays or battery banks, if any. Some inverters may have specifications listing sustained maximum output currents, and the higher of this number or the rated output should be used.

**(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.

Stand-alone inverters are nearly constant-output voltage devices. As the input battery voltage decreases, the input battery current increases to maintain a constant ac output power. The input current for such inverters is calculated by taking the rated full-power output of the inverter in watts and dividing it by the lowest operating battery voltage and then by the rated efficiency of the inverter under those operating conditions.

For example, the input current for a 4000-watt, 24-volt inverter that is 85 percent efficient at 22 volts can be calculated as follows:

\[
\text{Ampere input} = \frac{\text{watt output}}{\text{voltage} \times \text{efficiency}}
\]

\[
= \frac{4000 \text{ W}}{22 \text{ V} \times 0.85} = 214 \text{ A}
\]

Ripple currents might be present in the dc-input circuits of single-phase, stand-alone inverters. These ripple currents might cause nuisance operation of overcurrent devices at continuous high inverter outputs. In such cases, the measured maximum true rms (root mean square) value of the total (ac + dc) input current, which will be greater than the average current calculated here, should be used to determine conductor sizes and overcurrent device ratings.

**(B) Ampacity and Overcurrent Device Ratings.** Photovoltaic system currents shall be considered to be continuous.

**(1) Overcurrent Devices.** Overcurrent devices, where required, shall be rated as required by 690.8(B)(1)(a) through (1)(d).

(a) To carry 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.

The exception to 690.8(B)(1)(a) permits use at the full rating of assemblies, such as panelboards, incorporating overcurrent devices listed for continuous operation at 100 percent of the rating.

#### (b) Terminal temperature limits shall be in accordance with 110.3(B) and 110.14(C).

#### (c) Where operated at temperatures greater than 40°C (104°F), the manufacturer’s temperature correction factors shall apply.

#### (d) The rating or setting of overcurrent devices shall be permitted in accordance with 240.4(B), (C), and (D).

### Conductor Ampacity

#### (a) One hundred and twenty-five percent of the maximum currents calculated in 690.8(A) without any additional correction factors for conditions of use.

#### (b) The maximum currents calculated in 690.8(A) after conditions of use have been applied.

#### (c) The conductor selected, after application of conditions of use, shall be protected by the overcurrent protective device, where required.

### Systems with Multiple Direct-Current Voltages

For a photovoltaic 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.

### 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 fuse plus 125 percent of the short-circuit current from the other parallel-connected modules.

Normally, labeling 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 may allow the use of one overcurrent device to provide reverse-current protection for two modules or strings of modules and overcurrent protection for the conductors. The PV module manufacturer should be contacted for specific information.

### 690.9 Overcurrent Protection

#### (A) Circuits and Equipment

Photovoltaic source circuit, photovoltaic output circuit, inverter output circuit, and storage battery circuit conductors and equipment shall be protected in accordance with the requirements of Article 240. Circuits connected to more than one electrical source shall have overcurrent devices located so as to provide overcurrent protection from all sources.

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 or the maximum overcurrent protective device size specified on the PV module nameplate.

Informational Note: Possible backfeed of current from any source of supply, including a supply through an inverter into the photovoltaic output circuit and photovoltaic source circuits, is a consideration in determining whether adequate overcurrent protection from all sources is provided for conductors and modules.

In the circuits illustrated in Exhibits 690.3, 690.4, 690.5, and 690.6, the PV source-circuit overcurrent devices are required to be rated so that the source-circuit conductors are protected in accordance with Article 240 and so that the overcurrent device ratings do not exceed the maximum overcurrent device rating marked on the modules. Possible backfeed currents from the other PV source circuits, other supply sources through the inverter, and storage-battery circuits, if any, have to be considered.

Blocking diodes (possibly required by the module manufacturer for specific applications) can lose their blocking ability because of overtemperature conditions or internal breakdown. Therefore, overcurrent protection has to be considered with a condition of shorted blocking diodes if they are used in the circuit.

In typical one- and two-family dwelling unit utility-interactive PV systems, overcurrent devices may only be required in the dc PV source or output circuits where there are more than two strings of PC modules connected in parallel.

At the inverter or battery/charge controller end of the PV output circuit, the need for overcurrent protection has to
be considered with respect to the maximum backfeed fault current available from other sources.

(B) 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 utility-interactive inverter output, not less than the rated continuous output current of the inverter, shall be permitted without overcurrent protection from the inverter.

(C) Photovoltaic Source Circuits. Branch-circuit or supplementary-type overcurrent devices shall be permitted to provide overcurrent protection in photovoltaic source circuits. The overcurrent devices shall be accessible but shall not be required to be readily accessible.

Standard values of supplementary overcurrent devices allowed by this section shall be in one ampere size increments, starting at one ampere up to and including 15 amperes. Higher standard values above 15 amperes for supplementary overcurrent devices shall be based on the standard sizes provided in 240.6(A).

If the overcurrent protection of PV source circuits is considered supplementary overcurrent protection, use of overcurrent devices with ratings other than those suitable for branch-circuit protection is permitted. The use of such devices permits module protection closer to the specified ratings required on the labels attached to listed modules. It is anticipated that only qualified service personnel will replace or reset overcurrent devices in PV source circuits. Consequently, ready access to the user need not be provided. These supplementary overcurrent devices must be listed for dc operation and have appropriate voltage and current ratings.

Overcurrent devices used to protect modules or module interconnections may be installed in enclosures mounted outdoors in locations exposed to direct sunlight that may subject the overcurrent devices to operating temperatures higher than 40°C. Appropriate derating instructions are available from the overcurrent device manufacturer.

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

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 these dc systems, are not suitable for use in permanently wired residential or commercial electrical power systems meeting the requirements of the Code.

(E) Series Overcurrent Protection. In PV source circuits, a single overcurrent protection device shall be permitted to protect the PV modules and the interconnecting conductors.

The single overcurrent device (when required) may provide both the reverse-current protection required for the series-connected PV modules and the overcurrent protection required for the interconnecting conductors.

690.10 Stand-Alone Systems

The premises wiring system shall be adequate to meet the requirements of this Code for a similar installation connected to a service. The wiring on the supply side of the building or structure disconnecting means shall comply with this Code except as modified by 690.10(A) through (E).

(A) Inverter Output. The ac output from a stand-alone inverter(s) shall be permitted to supply ac power to the building or structure disconnecting means at current levels less than the calculated load connected to that disconnect. The inverter output rating or the rating of an alternate energy source shall be equal to or greater than the load posed by the largest single utilization equipment connected to the system. Calculated general lighting loads shall not be considered as a single load.

A stand-alone residential or commercial PV installation may have an ac output and be connected to a building wired in full compliance with all articles of this Code. Even though such an installation may have service-entrance equipment rated at 100 or 200 amperes at 120/240 volts, the PV source is not required to provide either the full current rating or the dual voltages of the service equipment. While safety requirements dictate full compliance with the ac wiring sections of the Code, a PV installation is usually designed so that the actual ac demands on the system are sized to the output rating of the PV system. The inverter output is required by 690.10(A) to have sufficient capacity to power the largest single piece of utilization equipment to be supplied by the PV system, but the inverter output does not have to be sized for the potential multiple loads to be simultaneously
connected to it. Lighting loads are managed by the user based on the available energy from the PV system.

(B) Sizing and Protection. The circuit conductors between the inverter output and the building or structure disconnecting means shall be sized based on the output rating of the inverter. These conductors shall be protected from overcurrents in accordance with Article 240. The overcurrent protection shall be located at the output of the inverter.

(C) Single 120-Volt Supply. The inverter output of a stand-alone solar photovoltaic system shall be permitted to supply 120 volts to single-phase, 3-wire, 120/240-volt service equipment or distribution panels where there are no 240-volt outlets and where there are no multiwire branch circuits. In all installations, the rating of the overcurrent device connected to the output of the inverter shall be less than the rating of the neutral bus in the service equipment. This equipment shall be marked with the following words or equivalent:

WARNING
SINGLE 120-VOLT SUPPLY. DO NOT CONNECT MULTIWIRE BRANCH CIRCUITS!

Multiwire branch circuits are common in one- and two-family dwelling units. When connected to a normal 120/240-volt ac service, the currents in the neutral conductors of these multiwire branch circuits (typically 14-3 AWG) subtract or are, at most, no larger than the rating of the branch-circuit overcurrent device. When these electrical systems are connected to a single 120-volt PV power system inverter by paralleling the two ungrounded conductors in the service-entrance load center, the currents in the neutral conductor for each multiwire branch circuit add rather than subtract. The currents in the neutral conductor may be as high as twice the rating of the branch-circuit overcurrent device. With this configuration, neutral conductor overloading is possible.

(D) Energy Storage or Backup Power System Requirements. Energy storage or backup power supplies are not required.

Stand-alone PV systems may be operated without energy storage or backup power. The systems are tailored to meet the load requirements.

(E) Back-fed Circuit Breakers. Plug-in type back-fed circuit breakers connected to a stand-alone inverter output in either stand-alone or utility-interactive systems shall be secured in accordance with 408.36(D). Circuit breakers that are marked “line” and “load” shall not be backfed.

690.11 Arc-Fault Circuit Protection (Direct Current)

Photovoltaic systems with dc source circuits, dc output circuits, or both, on or penetrating a building operating at a PV system maximum system voltage of 80 volts or greater, shall be protected by a listed (dc) arc-fault circuit interrupter, PV type, or other system components listed to provide equivalent protection. The PV arc-fault protection means shall comply with the following requirements:

1. 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 dc PV source and output circuits.
2. The system shall disable or disconnect one of the following:
   a. Inverters or charge controllers connected to the fault circuit when the fault is detected
   b. System components within the arcing circuit
3. The system shall require that the disabled or disconnected equipment be manually restarted.
4. The system shall have an annunciator that provides a visual indication that the circuit interrupter has operated. This indication shall not reset automatically.

To mitigate fire initiation hazards associated with arcing type faults occurring in dc source circuits and dc output circuits, 690.11 requires arc-fault circuit protection for PV systems. The requirement applies only where the conductors are installed on or in a building. The arc-fault protection device used to meet this requirement must be listed for dc and for use in photovoltaic systems. Listed components that provide protection equivalent to arc-fault protection are also permitted by this requirement.

III. Disconnecting Means

690.13 All Conductors

Means shall be provided to disconnect all current-carrying dc conductors of a photovoltaic system from all other conductors in a building or other structure. 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
690.14 Additional Provisions

Photovoltaic disconnecting means shall comply with 690.14(A) through (D).

(A) Disconnecting Means. The disconnecting means shall not be required to be suitable as service equipment and shall comply with 690.17.

(B) Equipment. Equipment such as photovoltaic source circuit isolating switches, overcurrent devices, and blocking diodes shall be permitted on the photovoltaic side of the photovoltaic disconnecting means.

(C) Requirements for Disconnecting Means. Means shall be provided to disconnect all conductors in a building or other structure from the photovoltaic system conductors.

In general, equipment that needs servicing must be disconnected from sources of supply. In a PV system, however, some equipment, as indicated, is permitted to be located on the PV power source side of the disconnecting means. See Exhibit 690.7. Servicing the exempted equipment might require disabling all or portions of the array, as explained in the commentary following 690.18.

A disconnecting means located in each PV source circuit or located physically at each PV module location is not required. Unlike load circuits (e.g., rooftop air conditioners), PV source-circuit conductors may be energized at any time from the PV modules. A centrally located disconnect meeting the requirements of 690.14(C)(1) near the inverter or batteries serves to disconnect the PV source circuits from the other portions of the electric power system.

(1) Location. The photovoltaic disconnecting means shall be installed at a readily accessible location either on the outside of a building or structure or inside nearest the point of entrance of the system conductors.

Exception: Installations that comply with 690.31(E) shall be permitted to have the disconnecting means located remote from the point of entry of the system conductors.

The photovoltaic system disconnecting means shall not be installed in bathrooms.

These requirements generally prohibit long runs of PV source and output circuits inside a building before reaching the required PV disconnect. A short conductor run through a wall at the point of first penetration to reach a disconnect mounted inside the building is allowed. Section 690.31(E) permits these circuits to be run inside a building when installed in metal conduit from the point of entrance to the system disconnecting means.

(2) Marking. Each photovoltaic system disconnecting means shall be permanently marked to identify it as a photovoltaic system disconnect.

(3) Suitable for Use. Each photovoltaic system disconnecting means shall be suitable for the prevailing conditions. Equipment installed in hazardous (classified) locations shall comply with the requirements of Articles 500 through 517.

(4) Maximum Number of Disconnects. The photovoltaic system disconnecting means shall consist of not more than six
switches or six circuit breakers mounted in a single enclosure, in a group of separate enclosures, or in or on a switchboard.

(5) Grouping. The photovoltaic system disconnecting means shall be grouped with other disconnecting means for the system to comply with 690.14(C)(4). A photovoltaic disconnecting means shall not be required at the photovoltaic module or array location.

Where a building has multiples sources of power, such as the utility, the PV array, backup generator, and wind system, no more than six disconnects for each source of power to the building, are allowed, and the disconnects for each source are required to be grouped together. However, a PV system may be considered a source of supply separate from a utility source under certain conditions (see 230.2), and each source may have up to six grouped disconnecting means as permitted by 230.72.

(D) 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. These installations shall comply with (1) through (4):

(1) A direct-current photovoltaic disconnecting means shall be mounted within sight of or in the inverter.

(2) An alternating-current disconnecting means shall be mounted within sight of or in the inverter.

This section permits the utility-interactive inverter to be installed in a location that is not readily accessible, so the requirements in 690.14(D)(1) and (D)(2) provide for dc and ac disconnecting means at the inverter location to facilitate servicing of the inverter.

(3) The alternating-current output conductors from the inverter and an additional alternating-current disconnecting means for the inverter shall comply with 690.14(C)(1).

The disconnect required by 690.14(C)(1) allows the inverter(s) and the circuit to it (them) to be de-energized from a readily accessible location.

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

690.16 Fuses

Switches, pullouts, or similar devices that have suitable ratings may serve as means to disconnect fuses from all sources of supply.

(A) Disconnecting Means. Disconnecting means shall be provided to disconnect a fuse from all sources of supply if the fuse is energized from both directions. Such a fuse in a photovoltaic source circuit shall be capable of being disconnected independently of fuses in other photovoltaic source circuits.

(B) Fuse Servicing. Disconnecting means shall be installed on PV output circuits where overcurrent devices (fuses) must be serviced that cannot be isolated from energized circuits. The disconnecting means shall be within sight of, and accessible to, the location of the fuse or integral with fuse holder and shall comply with 690.17. Where the disconnecting means are located more than 1.8 m (6 ft) from the overcurrent device, a directory showing the location of each disconnect shall be installed at the overcurrent device location.

Non-load-break-rated disconnecting means shall be marked “Do not open under load.”

690.17 Switch or Circuit Breaker

The disconnecting means for ungrounded conductors shall consist of a manually operable switch(es) or circuit breaker(s) complying with all of the following requirements:

(1) Located where readily accessible

(2) Externally operable without exposing the operator to contact with live parts

(3) Plainly indicating whether in the open or closed position

(4) Having an interrupting rating sufficient for the nominal circuit voltage and the 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. The sign shall be clearly legible and have the following words or equivalent:
IV. Wiring Methods

690.31 Methods Permitted

(A) Wiring Systems. All raceway and cable wiring methods included in this Code and other wiring systems and fittings specifically intended and identified for use on photovoltaic arrays shall be permitted. Where wiring devices with integral enclosures are used, sufficient length of cable shall be provided to facilitate replacement.

Where photovoltaic source and output circuits operating at maximum system voltages greater than 30 volts are installed in readily accessible locations, circuit conductors shall be installed in a raceway.

Most PV modules do not have provisions for attaching raceways. These circuits may have to be made “not readily accessible” by use of physical barriers such as wire screening.

Informational Note: Photovoltaic modules operate at elevated temperatures when exposed to high ambient temperatures and to bright sunlight. These temperatures may 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) Single-Conductor Cable. 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 photovoltaic source circuits for photovoltaic module interconnections within the photovoltaic array.

Exception: Raceways shall be used when required by 690.31(A).

Informational Note: Photovoltaic (PV) wire [also photovoltaic (PV) cable] has a nonstandard outer diameter. Conduit fill may be calculated using Table 1 of Chapter 9.

Most PV modules are designed for a direct series connection by using factory-installed leads and connectors. To accommodate such a direct series connection without the waste of one or more conductors in a multiconductor cable, use of a single-conductor Type USE-2 cable and single-conductor cable listed and labeled for PV applications is permitted in PV source circuits. Long runs of separated conductors (with loop inductance and distributed capacitance) and the resulting long time constants in dc circuits may result in improper operation of overcurrent devices. It is suggested that, wherever possible, both positive and negative conductors of each circuit and the equipment grounding conductor be routed as close together as possible to minimize the circuit time constant. The smaller loop resulting from the close routing also decreases induced currents from nearby lightning strikes. Because PV modules may operate at high temperatures and are installed in outdoor, exposed locations, the use of high-temperature, wet-rated conductors such as USE-2, THWN-2, or RHW-2 is advisable. See 310.15(B)(3)(c) for requirements on the ampacities of conductors in circular raceways 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.”

(C) Flexible Cords and Cables. Flexible cords and cables, where used to connect the moving parts of tracking PV modules, 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. For ambient temperatures exceeding 30°C (86°F), the ampacities shall be derated by the appropriate factors given in Table 690.31(C).
(D) 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 690.8. Section 310.15 shall be used to determine the cable ampacity adjustment and correction factors.

Because the smaller cables permitted by 690.31(D) are not normally marked with standard Code-recognized markings (e.g., USE-2), the PV module manufacturer or installer should verify that these cables are listed and labeled for PV use, thereby indicating 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.

(E) Direct-Current Photovoltaic Source and Output Circuits Inside a Building. Where dc photovoltaic source or output circuits from a building-integrated or other photovoltaic system 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 690.14(A), (B), and (D). The wiring methods shall comply with the additional installation requirements in (1) through (4).

The use of metallic raceways, Type MC metal-clad cable, or metal enclosures inside a building provides 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 690.5.

(1) Beneath Roofs. Wiring methods shall not be installed within 25 cm (10 in.) of the roof decking or sheathing except where directly below the roof surface covered by PV modules and associated equipment. Circuits shall be run perpendicular to the roof penetration point to support a minimum of 25 cm (10 in.) below the roof decking.

Informational Note: The 25 cm (10 in.) requirement is to prevent accidental damage from saws used by fire fighters for roof ventilation during a structure fire.

(2) Flexible Wiring Methods. Where flexible metal conduit (FMC) smaller than metric designator 21 (trade size $\frac{3}{4}$) 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.

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

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<th>75°C (167°F)</th>
<th>90°C (194°F)</th>
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</table>
Article 690 - Solar Photovoltaic (PV) Systems

(4) Marking and Labeling Methods and Locations. The labels or markings shall be visible after installation. Photovoltaic 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.

The objective of the requirements contained in 690.31(E)(1) through (4) 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 exposes personnel to shock hazards and the building to further damage resulting from the ignition of combustible members due to arcing from damaged conductors.

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

Flexible, fine-stranded cables recognized in Table 310.104(A) have numerous, very fine strands and can be used only with specially tested, listed, and identified terminations. The terminals, connectors, and crimp-on lugs found on most electrical equipment used in PV systems are not suitable for use with these types of cables. The requirements for these fine-stranded conductors are covered in 110.14.

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 fault-current withstand, and shall be capable of resisting the effects of the environment in which they are used.

690.33 Connectors

The connectors permitted by Article 690 shall comply with 690.33(A) through (E).

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

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

(C) Type. The connectors shall be of the latching or locking type. Connectors that are readily accessible and that are used in circuits operating at over 30 volts, nominal, maximum system voltage for dc circuits, or 30 volts for ac circuits, shall require a tool for opening.

(D) Grounding Member. The grounding member shall be the first to make and the last to break contact with the mating connector.

(E) Interruption of Circuit. Connectors shall be either (1) or (2):

1. Be rated for interrupting current without hazard to the operator.
2. Be a type that requires the use of a tool to open and marked “Do Not Disconnect Under Load” or “Not for Current Interrupting.”

The two options provided for connectors in this requirement provide for safe disconnection of circuit connectors either by being able to be opened under load or by having a warning indicating that disconnection prior to opening the connector is necessary. Connectors that can be opened or disconnected using only the hands are not acceptable.

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.

690.35 Ungrounded Photovoltaic Power Systems

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

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

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

(C) Ground-Fault Protection. All photovoltaic source and output circuits shall be provided with a ground-
fault protection device or system that complies with (1) through (3):

1. Detects a ground fault.
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.

**D** The photovoltaic source conductors shall consist of the following:

1. Nonmetallic jacketed multiconductor cables
2. Conductors installed in raceways, or
3. Conductors listed and identified as Photovoltaic (PV) Wire installed as exposed, single conductors.

Three options for PV source output circuits are provided by 690.35(D). All cables and conductors installed outdoors and exposed to direct sunlight and wet conditions have to be suitable for these conditions, and such suitability is verified by the cables and conductors being listed. Conductors inside raceways installed in wet locations are required to be identified or listed as suitable for this environmental condition. See 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. Although not required as a general rule, these conductors can be installed in a raceway at the discretion of the installer.

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

**F** The photovoltaic 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.

PV dc circuits operate in outdoor environments and are expected to be energized for many years. Aging of the conductors, dust and dirt infiltration, and moisture and water intrusion create leakage paths from the conductors to ground. These high-resistance leakage paths can result in leakage current values less than those detected by the required ground-fault detection device, but they can cause any ungrounded conductor to become a potential shock hazard with respect to ground.

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

Many types of PV equipment are designed to operate only on grounded systems. Equipment to be used on ungrounded systems must be tested and evaluated for such use.

### V. Grounding

**690.41 System Grounding**

For a photovoltaic power source, one conductor of a 2-wire system with a photovoltaic system voltage over 50 volts and the reference (center tap) conductor of a bipolar system shall be solidly grounded or shall use other methods that accomplish equivalent system protection in accordance with 250.4(A) and that utilize equipment listed and identified for the use.

**Exception:** Systems complying with 690.35.

Low-voltage systems that are not grounded are required by 690.41 to be solidly grounded, having overcurrent protection in each of the ungrounded conductors, as required by 240.21. Other methods that employ available equipment may be used to achieve objectives contained in 250.4(A), thereby providing protection for the PV power source circuits equivalent to solid grounding.

**690.42 Point of System Grounding Connection**

The dc circuit grounding connection shall be made at any single point on the photovoltaic output circuit.

Informational Note: Locating the grounding connection point as close as practicable to the photovoltaic source better protects the system from voltage surges due to lightning.

**Exception:** Systems with a 690.5 ground-fault protection device shall be permitted to have the required grounded conductor-to-ground bond made by the ground-fault protection device. This bond, where internal to the ground-fault equipment, shall not be duplicated with an external connection.

If other than solid grounding is utilized, as permitted by 690.41, the connections should be made in accordance with
the markings found on the equipment or in the installation instructions.

Stand-alone PV systems might require the grounding connection point to be located close to the high-current conductors associated with the battery and the inverter.

PV systems requiring ground-fault protection devices (see 690.5) are permitted to have the single-point grounding connection made inside the ground-fault protection equipment or inside the utility-interactive inverter and additional external bonding connections are not permitted. Connections are to be made in accordance with markings on the equipment or in the installation instructions.

690.43 Equipment Grounding

Equipment grounding conductors and devices shall comply with 690.43(A) through (F).

(A) Equipment Grounding Required. Exposed non-current-carrying metal parts of PV module frames, electrical equipment, and conductor enclosures shall be grounded in accordance with 250.134 or 250.136(A), regardless of voltage.

Equipment grounding is required even in low-voltage (12- and 24-volt) systems not otherwise required to have a system ground. A grounding electrode must be added to an ungrounded system to accommodate the equipment grounds.

(B) Equipment Grounding Conductor Required. An equipment grounding conductor between a PV array and other equipment shall be required in accordance with 250.110.

(C) Structure as Equipment Grounding Conductor. Devices listed and identified for grounding the metallic frames of PV modules or other equipment shall be permitted to bond the exposed metal surfaces or other equipment to mounting structures. Metallic mounting structures, other than building steel, used for grounding purposes shall be identified as equipment-grounding conductors or shall have identified bonding jumpers or devices connected between the separate metallic sections and shall be bonded to the grounding system.

(D) Photovoltaic Mounting Systems and Devices. Devices and systems used for mounting PV modules that are also used to provide grounding of the module frames shall be identified for the purpose of grounding PV modules.

(E) Adjacent Modules. Devices identified and listed for bonding the metallic frames of PV modules shall be permit-
tion for equipment grounding conductors in photovoltaic systems that are not provided with ground-fault protection is related to size and withstand capability of the equipment grounding conductor, rather than overcurrent device operation.

690.46 Array Equipment Grounding Conductors

Equipment grounding conductors for photovoltaic modules smaller than 6 AWG shall comply with 250.120(C).

690.47 Grounding Electrode System

(A) Alternating-Current Systems. If installing an ac system, a grounding electrode system shall be provided in accordance with 250.50 through 250.60. The grounding electrode conductor shall be installed in accordance with 250.64.

(B) Direct-Current Systems. If installing a dc system, a grounding electrode system shall be provided in accordance with 250.166 for grounded systems or 250.169 for ungrounded systems. The grounding electrode conductor shall be installed in accordance with 250.64.

A common dc grounding-electrode conductor shall be permitted to serve multiple inverters. The size of the common grounding electrode and the tap conductors shall be in accordance with 250.166. The tap conductors shall be connected to the common grounding-electrode conductor by exothermic welding or with connectors listed as grounding and bonding equipment in such a manner that the common grounding electrode conductor remains without a splice or joint.

(C) Systems with Alternating-Current and Direct-Current Grounding Requirements. Photovoltaic systems having dc circuits and ac circuits with no direct connection between the dc grounded conductor and ac grounded conductor shall have a dc grounding system. The dc grounding system shall be bonded to the ac grounding system by one of the methods in (1), (2), or (3).

This section shall not apply to ac PV modules.

When using the methods of (C)(2) or (C)(3), the existing ac grounding electrode system shall meet the applicable requirements of Article 250, Part III.

Informational Note No. 1: ANSI/UL 1741, Standard for Inverters, Converters, and Controllers for Use in Independent Power Systems, requires that any inverter or charge controller that has a bonding jumper between the grounded dc conductor and the grounding system connection point have that point marked as a grounding electrode conductor (GEC) connection point. In PV inverters, the terminals for the dc equipment grounding conductors and the terminals for ac equipment grounding conductors are generally connected to, or electrically in common with, a grounding busbar that has a marked dc GEC terminal.

Informational Note No. 2: For utility-interactive systems, the existing premises grounding system serves as the ac grounding system.

(1) Separate Direct-Current Grounding Electrode System Bonded to the Alternating-Current Grounding Electrode System. A separate dc grounding electrode or system shall be installed, and it shall be bonded directly to the ac grounding electrode system. The size of any bonding jumper(s) between the ac and dc systems shall be based on the larger size of the existing ac grounding electrode conductor or the size of the dc grounding electrode conductor specified by 250.166. The dc grounding electrode conductor(s) or the bonding jumpers to the ac grounding electrode system shall not be used as a substitute for any required ac equipment grounding conductors.

(2) Common Direct-Current and Alternating-Current Grounding Electrode. A dc grounding electrode conductor of the size specified by 250.166 shall be run from the marked dc grounding electrode connection point to the ac grounding electrode. Where an ac grounding electrode is not accessible, the dc grounding electrode conductor shall be connected to the ac grounding electrode conductor in accordance with 250.64(C)(1). This dc grounding electrode conductor shall not be used as a substitute for any required ac equipment grounding conductors.

(3) Combined Direct-Current Grounding Electrode Conductor and Alternating-Current Equipment Grounding Conductor. An unspliced, or irreversibly spliced, combined grounding conductor shall be run from the marked dc grounding electrode conductor connection point along with the ac circuit conductors to the grounding busbar in the associated ac equipment. This combined grounding conductor shall be the larger of the sizes specified by 250.122 or 250.166 and shall be installed in accordance with 250.64(E).

Inverters used in PV power systems usually contain a transformer that isolates the dc grounded circuit conductor from the ac grounded circuit conductor. Isolation necessitates that both a dc and an ac grounding system be installed. The two grounding systems are to be bonded together or have a common grounding electrode so that all ac and dc grounded circuit conductors and equipment grounding conductors have the same near-zero potential to earth.

The combined dc equipment grounding, dc system grounding, and ac equipment grounding required by this section establishes only one grounding circuit and connection for the entire PV system from the PV array to the ac point of connection. Under PV dc ground-fault conditions, an interruption of this single circuit may allow exposed
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690.48 Continuity of Equipment Grounding Systems
Where the removal of equipment disconnects the bonding connection between the grounding electrode conductor and exposed conducting surfaces in the photovoltaic source or output circuit equipment, a bonding jumper shall be installed while the equipment is removed.

PV source and output circuits are energized anytime the PV modules are exposed to light. The equipment grounding system is a primary line of defense against electric shocks and fires. In many PV systems, the main bonding jumper and the equipment grounding busbar are located in the inverter or a dc power center that may require removal for service. The continuity of the equipment grounding conductors should be maintained even when the equipment is removed.

690.49 Continuity of Photovoltaic Source and Output Circuit Grounded Conductors
Where the removal of the utility-interactive inverter or other equipment disconnects the bonding connection between the grounding electrode conductor and the photovoltaic source and/or photovoltaic output circuit grounded conductor, a bonding jumper shall be installed to maintain the system grounding while the inverter or other equipment is removed.

PV source and output circuits are energized anytime the PV modules are exposed to light. The marked, grounded circuit conductors should always remain grounded because they may be energized daily and cannot be easily disconnected from the source. In many PV systems, the main bonding jumper is located in the inverter or a dc power center that may require removal for service. The continuity to ground of the grounded circuit conductors should be maintained even when the equipment is removed.

690.50 Equipment Bonding Jumpers
Equipment bonding jumpers, if used, shall comply with 250.120(C).

VI. Marking

690.51 Modules
Modules shall be marked with identification of terminals or leads as to polarity, maximum overcurrent device rating for module protection, and with the following ratings:

(1) Open-circuit voltage
(2) Operating voltage
(3) Maximum permissible system voltage
(4) Operating current
(5) Short-circuit current
(6) Maximum power

690.52 Alternating-Current Photovoltaic Modules
Alternating-current modules shall be marked with identification of terminals or leads and with identification of the following ratings:

(1) Nominal operating ac voltage
(2) Nominal operating ac frequency
(3) Maximum ac power
(4) Maximum ac current
(5) Maximum overcurrent device rating for ac module protection

690.53 Direct-Current Photovoltaic Power Source
A permanent label for the direct-current photovoltaic power source indicating items (1) through (5) shall be provided by the installer at the photovoltaic disconnecting means:

(1) Rated maximum power-point current
(2) Rated maximum power-point voltage
(3) Maximum system voltage

Informational Note to (3): See 690.7(A) for maximum photovoltaic system voltage.

(4) Short-circuit current

Informational Note to (4): See 690.8(A) for calculation of maximum circuit current.

(5) Maximum rated output current of the charge controller (if installed)

Informational Note: Reflecting systems used for irradiance enhancement may result in increased levels of output current and power.

After installation of PV arrays, it may be difficult to determine the system’s rated voltage and current. These ratings, along with the open-circuit voltage and short-circuit current, are necessary to size the remainder of the system components, as specified elsewhere in Article 690. Generally, the marking described in 690.53 is required to be provided by the installer. The rated values for the PV power source can be calculated by adding voltage ratings of series-connected modules and adding current ratings of parallel-connected modules or PV source circuits.

Some charge controllers have higher rated output currents than the input currents from the PV array. They reduce the screen's voltage.
the input voltage from the PV array while increasing the output to the battery.

With respect to the informational note, a deliberate increase in the level of irradiance by reflectors or the like can cause the power source to operate at levels above those recommended by the manufacturer. See 110.3.

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 Power Systems Employing Energy Storage
Photovoltaic power systems employing energy storage shall also be marked with the maximum operating voltage, including any equalization voltage and the polarity of the grounded circuit conductor.

690.56 Identification of Power Sources
(A) Facilities with Stand-Alone Systems. Any structure or building with a photovoltaic power system that is not connected to a utility service source and is a stand-alone system shall have a permanent plaque or directory installed on the exterior of the building or structure at a readily visible location acceptable to the authority having jurisdiction. The plaque or directory shall indicate the location of system disconnecting means and that the structure contains a stand-alone electrical power system.

(B) Facilities with Utility Services and PV Systems. Buildings or structures with both utility service and a photovoltaic system shall have a permanent plaque or directory providing the location of the service disconnecting means and the photovoltaic system disconnecting means if not located at the same location.

VII. Connection to Other Sources
690.57 Load Disconnect
A load disconnect that has multiple sources of power shall disconnect all sources when in the off position.

690.60 Identified Interactive Equipment
Only inverters and ac modules listed and identified as interactive shall be permitted in interactive systems.

690.61 Loss of Interactive System Power
An inverter or an ac module in an interactive solar photovoltaic system shall automatically de-energize its output to the connected electrical production and distribution network upon loss of voltage in that system and shall remain in that state until the electrical production and distribution network voltage has been restored.

A normally interactive solar photovoltaic system shall be permitted to operate as a stand-alone system to supply loads that have been disconnected from electrical production and distribution network sources.

The requirement of 690.61 prevents energizing of otherwise de-energized system conductors or output conductors of other off-site sources (e.g., an electrical utility) and is intended to prevent electric shock. This feature normally is provided as part of the utility-interactive inverter.

690.63 Unbalanced Interconnections
Unbalanced connections shall be in accordance with 705.100.

690.64 Point of Connection
Point of connection shall be in accordance with 705.12.

PV systems interconnected with other power production systems are also subject to the requirements of Article 705, including 705.12.

VIII. Storage Batteries
690.71 Installation
(A) General. Storage batteries in a solar photovoltaic system shall be installed in accordance with the provisions of Article 480. The interconnected battery cells shall be considered grounded where the photovoltaic power source is installed in accordance with 690.41.

(B) Dwellings.
(1) Operating Voltage. Storage batteries for dwellings shall have the cells connected so as to operate at less than 50 volts nominal. Lead-acid storage batteries for dwellings shall have no more than twenty-four 2-volt cells connected in series (48-volts nominal).

Exception: Where live parts are not accessible during routine battery maintenance, a battery system voltage in accordance with 690.7 shall be permitted.

(2) Guarding of Live Parts. Live parts of battery systems for dwellings shall be guarded to prevent accidental
At any voltage, a primary safety concern in battery systems is that a fault (e.g., a metal tool dropped onto a terminal) might cause a fire or an explosion. Guarded, as defined in Article 100, describes the best method to reduce this hazard.

(C) Current Limiting. A listed, current-limiting, overcurrent device shall be installed in each circuit adjacent to the batteries where the available short-circuit current from a battery or battery bank exceeds the interrupting or withstand ratings of other equipment in that circuit. The installation of current-limiting fuses shall comply with 690.16.

(D) Battery Nonconductive Cases and Conductive Racks. Flooded, vented, lead-acid batteries with more than twenty-four 2-volt cells connected in series (48 volts, nominal) shall not use conductive cases or shall not be installed in conductive cases. Conductive racks used to support the nonconductive cases shall be permitted where no rack material is located within 150 mm (6 in.) of the tops of the nonconductive cases.

This requirement shall not apply to any type of valve-regulated lead-acid (VRLA) battery or any other type of sealed batteries that may require steel cases for proper operation.

(E) Disconnection of Series Battery Circuits. Battery circuits subject to field servicing, where more than twenty-four 2-volt cells are connected in series (48 volts, nominal), shall have provisions to disconnect the series-connected strings into segments of 24 cells or less for maintenance by qualified persons. Non–load-break bolted or plug-in disconnects shall be permitted.

(F) Battery Maintenance Disconnecting Means. Battery installations, where there are more than twenty-four 2-volt cells connected in series (48 volts, nominal), shall have a disconnecting means, accessible only to qualified persons, that disconnects the grounded circuit conductor(s) in the battery electrical system for maintenance. This disconnecting means shall not disconnect the grounded circuit conductor(s) for the remainder of the photovoltaic electrical system. A non–load-break-rated switch shall be permitted to be used as the disconnecting means.

(G) Battery Systems of More Than 48 Volts. On photovoltaic systems where the battery system consists of more than twenty-four 2-volt cells connected in series (more than 48 volts, nominal), the battery system shall be permitted to operate with ungrounded conductors, provided the following conditions are met:

1. The photovoltaic array source and output circuits shall comply with 690.41.
2. The dc and ac load circuits shall be solidly grounded.
3. All main ungrounded battery input/output circuit conductors shall be provided with switched disconnects and overcurrent protection.
4. A ground-fault detector and indicator shall be installed to monitor for ground faults in the battery bank.

690.72 Charge Control

(A) General. Equipment shall be provided to control the charging process of the battery. Charge control shall not be required where the design of the photovoltaic source circuit is matched to the voltage rating and charge current requirements of the interconnected battery cells and 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.

All adjusting means for control of the charging process shall be accessible only to qualified persons.

Informational Note: Certain battery types such as valve-regulated lead acid or nickel cadmium can experience thermal failure when overcharged.

(B) Diversion Charge Controller.

1. Sole Means of Regulating Charging. A photovoltaic power system employing a diversion charge controller as the sole means of regulating the charging of a battery shall be equipped with a second independent means to prevent overcharging of the battery.

2. Circuits with Direct-Current Diversion Charge Controller and Diversion Load. Circuits containing a dc diversion charge controller and a dc diversion load shall comply with the following:

1. The current rating of the diversion load shall be less than or equal to the current rating of the diversion load charge controller. The voltage rating of the diversion load shall be greater than the maximum battery voltage. The power rating of the diversion load shall be at least 150 percent of the power rating of the photovoltaic array.
Diversion loads are typically rated by the current that they will draw at some rated voltage. If the rated current of the diversion load exceeds the current rating of the diversion load controller, the controller may not function properly.

(2) The conductor ampacity and the rating of the overcurrent device for this circuit shall be at least 150 percent of the maximum current rating of the diversion charge controller.

If any portion of a diversion charge control system fails, the batteries may be overcharged and can create a potentially hazardous condition. Requiring a second, independent charge control method (usually a series regulator) and robust diversion controller circuits will minimize the potential problems.

(3) PV Systems Using Utility-Interactive Inverters. Photovoltaic power systems using utility-interactive inverters to control battery state-of-charge by diverting excess power into the utility system shall comply with (1) and (2):

(1) These systems shall not be required to comply with 690.72(B)(2). The charge regulation circuits used shall comply with the requirements of 690.8.

(2) These systems shall have a second, independent means of controlling the battery charging process for use when the utility is not present or when the primary charge controller fails or is disabled.

(C) Buck/Boost Direct-Current Converters. When buck/boost charge controllers and other dc power converters that increase or decrease the output current or output voltage with respect to the input current or input voltage are installed, the requirements shall comply with 690.72(C)(1) and (C)(2).

(1) The ampacity of the conductors in output circuits shall be based on the maximum rated continuous output current of the charge controller or converter for the selected output voltage range.

(2) The voltage rating of the output circuits shall be based on the maximum voltage output of the charge controller or converter for the selected output voltage range.

Flexible, fine-stranded cables shall be terminated only with terminals, lugs, devices, or connectors in accordance with 110.14(A).

Battery plates and terminals are sometimes constructed of relatively soft lead and lead alloys encased in plastics that are sealed with asphalt. Large-size, low-stranding stiff copper conductors attached to these components may cause them to be distorted. The use of flexible cables (see Article 400) may reduce the possibility of such distortions. Listed cables with the appropriate physical and chemical-resistant properties should be used. Welding and “battery” cables are not allowed or described in the Code for this use. Flexible “building wire”–type cables (Chapter 3) are also available and suitable for this use. Terminals intended for connection of stranded conductors using other than Class B and C stranding are required to be listed and marked for this use. Flexible, fine-stranded battery connection cables cannot be connected to terminals identified for use with conductors using the larger strands of conductors using Class B and C stranding. See the commentary on 690.31(F).

IX. Systems over 600 Volts

690.80 General
Solar photovoltaic systems with a maximum system voltage over 600 volts dc shall comply with Article 490 and other requirements applicable to installations rated over 600 volts.

690.85 Definitions
For the purposes of Part IX of this article, the voltages used to determine cable and equipment ratings are as follows.

Battery Circuits. In battery circuits, the highest voltage experienced under charging or equalizing conditions.

Photovoltaic Circuits. In dc photovoltaic source circuits and photovoltaic output circuits, the maximum system voltage.

ARTICLE 692
Fuel Cell Systems

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