Solar PV System Permitting and Inspection

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Photovoltaic System Basics

I-V Curve

I-V Curve with Power

Inspecting PV Systems for Code-Compliance
Current varies with irradiance

Voltage varies with temperature

Differences Between PV and Conventional Electrical Systems

- PV systems have *dc circuits* that require special design and equipment.
- PV systems can have *multiple energy sources*, and special disconnects are required to isolate components.
- Energy flows in PV systems may be *bi-directional*.
- Utility-Interactive PV systems require an interface with the ac utility-grid and special considerations must be adopted. (utility must be involved-hence utility training)

*Expedited Permit Process for Small-Scale PV Systems*

Revised Version Recently Updated:

www.solarabcs.org/permitting
Required Information for Permit

- Site plan showing location of major components on the property. This drawing need not be exactly to scale, but it should represent relative location of components at site (see supplied example site plan). PV arrays on dwellings with a 3’ perimeter space at ridge and sides do not need fire service approval.
- Electrical diagram showing PV array configuration, wiring system, overcurrent protection, inverter, disconnects, required signs, and ac connection to building (see supplied standard electrical diagram).
- Specification sheets and installation manuals (if available) for all manufactured components including, but not limited to, PV modules, inverter(s), combiner box, disconnects, and mounting system.

Step 1: Structural Review of PV Array Mounting System

- Is the array to be mounted on a defined, permitted roof structure? Yes/No (structure designed for local conditions)
- If No due to non-compliant roof or ground mount, submit completed worksheet for roof structure WKS1.

WKS1

1. Roof construction: Rafters Trusses
2. Describe site-built rafter or site-built truss system.
   a. Rafter Size: ___ x ___ inches
   b. Rafter Spacing: ________ inches
   c. Maximum unsupported span: _____ feet, _____ inches
   d. Are the rafters over-spanned? (see the IRC span tables in B.2.) Yes No
   e. If Yes, complete the rest of this section.

B.2 Span Tables

- A framing plan is required only if the combined weight of the PV array exceeds 5 pounds per square foot (PSF) or the existing rafters are over-spanned. The following span tables from the 2009 International Residential Code (IRC) can be used to determine if the rafters are over-spanned. For installations in jurisdictions using different span tables, follow the local tables.
Inspecting PV Systems for Code-Compliance

Roof Information:

- Is the roofing type lightweight (Yes = composition, lightweight masonry, metal, etc...)?
  - If No, submit completed worksheet for roof structure WKS1.
- Does the roof have a single roof covering? Yes/No
  - If No, submit completed worksheet for roof structure WKS1.
- Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk).

Mounting System Information:

- The mounting structure is an engineered product designed to mount PV modules? Yes/No
  - If No, provide details of structural attachment certified by a design professional.
- For manufactured mounting systems, fill out information on the mounting system below:
Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)

- In order for a PV system to be considered for an expedited permit process, the following must apply:
  1. PV modules, utility-interactive inverters, and combiner boxes are identified for use in PV systems.
  2. The PV array is composed of 4 series strings or less.
  3. The inverter has a continuous power output 13,440 Watts or less.
  4. The ac interconnection point is on the load side of service disconnecting means (690.64(B), 705.12(D)).
  5. One of the electrical diagrams (E1.1, E1.1a, E1.1b, E1.1c) can be used to accurately represent the PV system.
One-line Diagram

- Should have sufficient detail to call out the electrical components, the wire types and sizes, number of conductors, and conduit type and size where needed.
- Should include information about PV modules and inverter(s).
- Should include information about utility disconnecting means (required by many utilities).
## ASHRAE Temperature Data

<table>
<thead>
<tr>
<th>State</th>
<th>Low Temperature</th>
<th>High Temperature</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>LA</td>
<td>-15°C</td>
<td>35°C</td>
<td>-2°C</td>
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<tr>
<td>CA</td>
<td>-10°C</td>
<td>40°C</td>
<td>-5°C</td>
</tr>
<tr>
<td>TN</td>
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<tr>
<td>TX</td>
<td>-10°C</td>
<td>45°C</td>
<td>-5°C</td>
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### Conductors Sizing Chart for Hottest U.S. Climate

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>100% Duty</th>
<th>50% Duty</th>
<th>10% Duty</th>
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<tbody>
<tr>
<td>1/0 AWG</td>
<td>75 A</td>
<td>37.5 A</td>
<td>18.75 A</td>
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<tr>
<td>2/0 AWG</td>
<td>100 A</td>
<td>50 A</td>
<td>25 A</td>
</tr>
<tr>
<td>4/0 AWG</td>
<td>150 A</td>
<td>75 A</td>
<td>37.5 A</td>
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</table>

### Maximum Conductor Size in Raceway

<table>
<thead>
<tr>
<th>Conductor Size</th>
<th>100% Duty</th>
<th>50% Duty</th>
<th>10% Duty</th>
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<tr>
<td>1/0 AWG</td>
<td>75 A</td>
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<tr>
<td>4/0 AWG</td>
<td>150 A</td>
<td>75 A</td>
<td>37.5 A</td>
</tr>
</tbody>
</table>

### Inspecting PV Systems for Code-Compliance

1. **Maximum System Voltage [NEC 690.7]**
   - Inspect the maximum voltage based on the appropriate value on Table 690.7 in the NEC, and then multiplying that value by the number of modules in a string.
2. **ASHRAE Temperature Data**
   - Use the data provided in the table for low and high temperatures.
3. **Conductor Sizing Chart**
   - Use the chart to determine the appropriate conductor size for the application.

### FORT COLLINS (SATRS)

- **Elevation**: 1523 ft
- **High Temp**: 74°F
- **Distance above roof**: 32 ft
- **Extreme**: 90°F
TABLE OF NEC 690.64(B) AC INTERCONNECTION OPTIONS

<table>
<thead>
<tr>
<th>Maximum Inverter Current</th>
<th>Required Inverter OCSP Size</th>
<th>Minimum Conductor Size in Conduit</th>
<th>Minimum Busbar/Main Branch Combination (Radius/Amperes/Max Area)</th>
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<tbody>
<tr>
<td>64 Amps</td>
<td>60 Amps</td>
<td>4 AWG</td>
<td>40/400, 20/150</td>
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<td>56 Amps</td>
<td>70 Amps</td>
<td>4 AWG</td>
<td>22/200, 20/226</td>
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<td>48 Amps</td>
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<td>6 AWG</td>
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<td>50 Amps</td>
<td>8 AWG</td>
<td>125/100, 16/126</td>
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<td>35 Amps</td>
<td>45 Amps</td>
<td>8 AWG</td>
<td>20/250</td>
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<td>33 Amps</td>
<td>40 Amps</td>
<td>8 AWG</td>
<td>20/200</td>
</tr>
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<td>24 Amps</td>
<td>30 Amps</td>
<td>10 AWG</td>
<td>12/150</td>
</tr>
<tr>
<td>16 Amps</td>
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<td>12 AWG</td>
<td>10/200</td>
</tr>
<tr>
<td>10 Amps</td>
<td>15 Amps</td>
<td>14 AWG</td>
<td>8/100</td>
</tr>
</tbody>
</table>

NOTES FOR ELECTRICAL DIAGRAM FOR EXAMPLE 1 - STANDARD STRING INVERTER SYSTEM

Diagram for Example 1 - Standard String Inverter System
Inspecting PV Systems for Code-Compliance
Section 1. Field Inspection

Checklist for Array:

- a) Array matches plans
- b) Wire Management
- c) Module and Array Grounding
- d) Electrical enclosures on Roof Accessible and Connections Suitable for the Environment
- e) Array Fastened and Sealed According To Attachment Detail
- f) Conductor Ratings and Sizes

Inspection Checklist for Array:

a) Array Matches Plans

- PV module model number matches plans and spec sheets
- Get a digital photo of module label, if possible

Typical PV Module Label
Common Installation Mistakes with Array Modules and Configurations

• 1. Changing the array wiring layout without changing the submitted electrical diagram.
• 2. Changing the module type or manufacturer as a result of supply issues.
• 3. Exceeding the inverter or module voltage due to improper array design.
• 4. Putting too few modules in series for proper operation of the inverter during high summer array temperatures.

The most important safety issue is proper support and protection of conductors.

Inspection Checklist for Array:

b) Wire Management

Proper Installation of Exterior Cables

• NEC 338.10(B)(4)(b) states how USE-2 is to be installed in exterior locations.
• PV Wire/Cable should follow the same installation methods as USE-2.
• Section 338.10 refers the installer on to Article 334.30 (NM Cable) for support methods
Proper Installation of Exterior Cables—Article 334.30

- 1. Secured by staples, cable ties, straps, hangers, or similar fittings at intervals that do not exceed 4.5 feet
- 2. Secured within 12 inches of each box, cabinet, conduit body, or other termination
- 3. Sections protected from physical damage by raceway shall not be required to be secured within the raceway
- 4. Cable shall closely follow the surface of the building finish or of running boards ((NEC 334.15)—the analogous installation for USE-2 in PV arrays is for the conductors to follow support rails or module extrusions)
- 5. Protected from physical damage by raceway when necessary

Wire Management—Proper

Wire Management—Support?

Common Installation Mistakes with Wire Management

- 1. Not enough supports to properly control cable.
- 2. Conductors touching roof or other abrasive surfaces exposing them to physical damage.
- 3. Conductors not supported within 12 inches of boxes or fittings.
- 4. Not supporting raceways at proper intervals.
- 5. Multiple cables entering a single conductor cable gland (aka cord grip)
- 6. Not following support members with conductors.
Proper cable glands into Combiner Box

Common Installation Mistakes with Wire Management—cont.
- 7. Pulling cable ties too tight or leaving them too loose.
- 8. Not fully engaging plug connectors.
- 9. Bending conductors too close to connectors.
- 10. Bending USE-2 cable tighter than allowable bending radius.
- 11. Plug connectors on non-locking connectors not fully engaged

Wire Management count the bad ideas

Wire Management —wire bending radius
Module bonding and grounding methods

- 1. Some modules are designed to be grounded using a stainless-steel thread-forming screw threaded into the module frame holding the EGC at a grounding symbol. An isolating washer, such as a stainless cup washer is often used to isolate the copper conductor from the aluminum frame to prevent galvanic corrosion.
- 2. Some modules can be grounded to their mounting structures with stainless steel star washers placed between the module and the support structure. This creates an electrical bond while isolating the aluminum frame from dissimilar materials such as galvanized steel. The EGC is attached to an electrically continuous support member with a properly installed grounding lug.
Module bonding and grounding methods—cont.

- 3. Some modules can be grounded by properly installing a properly rated lay-in lug to the either the grounding point on the module, or any unused mounting hole. The EGC is run through this lay-in lug to bond the modules together.

- 4. For specific module mounting products (e.g. UniRac, ProSolar, DPW, etc.), there exists listed grounding clips to bond typical aluminum framed modules to the mounting structure. Only the proper clip can be used with each mounting structure. This allows the EGC to be connected to the electrically continuous rail. This method is consistent the NEC 690.43 and NEC 250.136.

- 5. Some modules can be grounded together using serrated clips that hold the module to the support structure and electrically bond with the module. One lug on any module can ground a whole row.
Common Installation Mistakes with Module and Array Grounding

1. Not installing a grounding conductor on the array at all.
2. Using cad-plated Tek screws to fasten ground wires or lugs to modules.
3. Using indoor-rated grounding lugs on PV modules and support structures.
4. Not protecting EGCs smaller than 6 AWG from physical damage.
5. Allowing copper EGC to come in contact with the aluminum rails and module frames.
6. Assuming that simply bolting aluminum frames to support structures provides effective grounding.

Grounding Hardware and Components

- Indoor lug and Tek screw
- Stainless hardware looks like new
- Galvanized washer showing galvanic corrosion with aluminum contact

Improper Connections

- Wire twisted together, wrapped in tape, and in the sun
- Dry wirenut and not in a j-box
Ratings and locations of Disconnects

NEMA 3R disconnect on sloped roof designed for vertical mounting only

Black cover to shield improperly installed switch only served to make switch invisible

Common Installation Mistakes with Electrical Boxes, Conduit Bodies, and Disconnecting Means

- 1. Installing disconnects rated for vertical installation in a non-vertical application.
- 2. Installing improperly rated fuses in source combiners and fused disconnects.
- 3. Covering boxes or conduit bodies making them nearly inaccessible for service.
- 4. Not following manufacturer’s directions for wiring disconnect for 600 Vdc ratings.
- 5. Installing dry wire nuts in wet locations and inside boxes that get wet routinely.
- 6. Using improper fittings to bring conductors into exterior boxes.

Ratings and locations of Combiner Boxes

NEMA 4 Combiner Box with disconnect built-in. Designed for horizontal or vertical mounting

Many disconnects like these require the ungrounded conductor to be broken twice in series to get the 600 Vdc rating

Incorrect Breaking of grounded conductor

Correct
Correct Fuses

Correct Fuses ??

Properly Rated Disconnects and Inverters
Inspection Checklist for Array:
e) Array Fastened and Sealed
According To Attachment Detail

- Roof penetrations must be properly
  sealed to preclude leakage.
- Do a hand pull test on a sample of lag
  screw attachments to make sure they
  are secured to rafters.
- Look in attic to see if lags are visible.

Proper and Improper Flashing

Common Installation Mistakes with Mounting Systems:

1. Not using supplied or specified hardware with the mounting
   systems.
2. Substituting Unistrut for special manufactured aluminum
   extrusions.
3. Not installing flashings properly.
4. Not using the correct roof adhesives for the specific type of roof.
5. Not attaching proper lag screws to roofing members.
6. Not drilling proper pilot holes for lag screws and missing or
   splitting roofing members.

Inspection Checklist for Array:
f) Conductor Ratings and Sizes

- Exposed Array Conductors—The only single-conductor cables allowed in 690.31(B) are USE-2
  and PV Wire (Cable).
- Conductors in raceways on rooftops—Table
  310.15(B)(2)(a) adds an additional 14°C-30°C to the ambient temperature. These high
  temperatures nearly always limit ampacity below the terminal temperature ampacity.
Conduit Exposed to Sunlight Above Rooftops – Table 310.15(B)(2)(a)

Common Installation Mistakes with Conductors:

1. Not accounting for high operating temperatures in rooftop conduit.
2. Specifying THHN conductors rather than wet rated conductors in drawings where raceways are clearly located outdoors.
3. Specifying or installing THWN conductors in raceways that may exceed 60°C without properly correcting the THWN conductors for this temperature.

Improperly Rated Conductors

Section 2. Specifics For Ground-Mounted Arrays

- a) Foundation and mounting structure review
- b) Electrical bonding of structural elements
- c) Additional array electrode [690.47(D)]
- d) Attachment method according to plans
- e) Wiring not readily accessible
Support Structure and Attachment

Readily accessible or not?

Common Installation Mistakes with Ground Mounting Systems:

1. Not using supplied or specified hardware with the mounting systems.
2. Substituting Unistrut for special manufactured aluminum extrusions.
3. No bonding of support structure or discontinuous grounding of support structure.
4. Dissimilar metals in contact with one another (e.g. aluminum and galvanized steel).
5. No bonding of aluminum structural elements to steel structural elements.
6. Array wiring readily accessible to other than authorized personnel.

Section 3. Appropriate signs installed

- Sign construction
- Photovoltaic Power Source
- AC point of connection
- Alternative power system
Sign Construction

- The NEC is not extremely specific about what signs should be made of.
- NEC 110.21 states, “The marking shall be of sufficient durability to withstand the environment involved.”
- Electrical industry standards for outdoor signs is that signs should be metal or plastic with engraved or machine printed letters, or electro-photo plating, in a contrasting color to the sign background.

Indoor signs may allow more variety of construction

Photovoltaic Power Source Sign

Signs and Labels
AC Point of Interconnection

Signs and Labels

it is possible to have too many.

Section 4. Check that equipment ratings are consistent with application and signs

Inverter Labels
What are the applicable codes and standards for PV systems?
- Electrical codes - NEC Article 690 - Solar Photovoltaic Systems – NFPA 70
- Building Codes – IBC, IRC, ASCE 7, IFC
- UL Standard 1703, Flat-plate Photovoltaic Modules and Panels
- IEEE 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems
- UL Standard 1741, Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

690.3 Other Articles
- The requirements of Chapters 1 thru 4 apply to PV installations, except as modified by Article 690.
NEC Sections Commonly Applicable to PV Systems

- Article 110: Requirements for Electrical Installations
- Chapter 2: Wiring and Protection
  - Most of the chapter—especially
  - Article 250: Grounding
- Chapter 3: Wiring Methods and Materials
  - Most of the chapter—especially
  - Article 300: Wiring Methods
  - Article 310: Conductors for General Wiring
- Article 480: Storage Batteries
- Article 690: Solar Photovoltaic Systems

NEC Article 690 overview

Key Code References and Summary of 2011 Updates

- Numerous updates to the 2011 NEC for Article 690. Most are editorial in nature.
- Routing and identification requirements for conductors.
- Series Arc Fault detectors required above 80 volts.
- 690.64 moved to 705.12(D)

Part II. Circuit Requirements
690.7 Maximum System Voltage

- Note: A statistically valid source for lowest-expected ambient temperature is the Extreme Annual Mean Minimum Design Dry Bulb Temperature found in the ASHRAE Handbook — Fundamentals [2011].—available at www.solarabcs.org/permitting

- \( V_{\text{max}} = \text{Module Voc} \times \text{Table 690.7 C.F.} \times \# \text{ Modules per String} \)
- \( PV \ V_{\text{max}} = 37 \ \text{Voc} \times 1.14 \times 14 \)
- \( PV \ V_{\text{max}} = 591 \ \text{Voc} \)

<table>
<thead>
<tr>
<th>Ambient Temperature (°C)</th>
<th>Factor</th>
<th>Ambient Temperature (°F)</th>
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<td>24 to 20</td>
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<td>9 to 5</td>
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<td>1.23</td>
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</tr>
<tr>
<td>-36 to -40</td>
<td>1.25</td>
<td>54 to 95</td>
</tr>
</tbody>
</table>

- \( V_{\text{max}} = \text{Rated Voc} \times \{1+[(\text{Min. Temp. °C} - 25°C)\times \text{Coeff%/ °C}]\} \times \# \text{ Modules} \)
- \( V_{\text{max}} = 37V \{1+[-(-7°C-25°C)\times -0.32%/°C] 14 \)
- \( V_{\text{max}} = 37V \{1+[-(-32°C)\times -0.32%/°C] 14 \)
- \( V_{\text{max}} = 37V \times \{1 + 10.24\%\} \times 14 \)
- \( V_{\text{max}} = 37V \times \{1.1024\} \times 14 \)
- \( V_{\text{max}} = 40.79V \times 14 \)
- \( V_{\text{max}} = 571 \ \text{Voc} \)
690.8 Circuit Sizing and Protection
- (B)(2)(a) Circuit conductors must be sized to carry 125% of the maximum current as calculated in 690.8(A) without conductor adjustment and correction factors of 310.15.

690.8(B) Overcurrent Protection
- PV circuit overcurrent, when required, must be sized to carry not less than 125 percent of 690.8(A) calculated current.

690.8 Circuit Sizing and Protection
- (B)(2)(b) Circuit conductors must be sized to carry 100% the maximum current as calculated in 690.8(A) after the application of conductor adjustment and correction of 310.15.
690.11 Arc-Fault Circuit Protection

- Photovoltaic dc circuit conductors operating at 80V or greater on buildings must be protected by a series dc arc-fault circuit interrupter.

III. Disconnecting Means [2005 NEC]

Article 690.14 (Additional Provisions)

- Clarification on location of PV Disconnecting Means and Location of Inverters in Not-Readily-Accessible Locations
- New Section (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.
  - (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).
  - (4) A plaque shall be installed in accordance with 705.10.

690.15 Disconnection of Photovoltaic Equipment

- A disconnecting means is required for inverters, batteries, and charge controllers from all ungrounded conductors of all sources.
**690.16(B) Fuse Servicing**

- The disconnect must be within sight of or integral with the fuse holder, be externally operable, and plainly indicating whether in the open or closed position.

**690.17 Switch or Circuit Breaker**

- Must have warning sign when line and load can be energized in open position.
- Exception allows connectors to be used as disconnecting means provided they meet the requirements of 690.33. (this completes micro-inverter as a viable option)

**Part IV. Wiring Methods**

**690.31(E)(1) Beneath Roofs**

- PV system conductors are not permitted to be located within 10 in. of roof decking, except below PV equipment.
690.31(E)(1) Beneath Roofs
• Note: The 10 in. from the roof decking is to prevent contact to energized conductors from saws used by firefighters for roof ventilation.

690.31(E)(2) Flexible Wiring
• FMC smaller than ¾ or Type MC cable smaller than 1 in. run across ceilings or floor joists must be protected by guard strips as high as the wiring method.

690.31(E)(2) Flexible Wiring
• Where run exposed, other than within 6 ft of their connection to equipment, wiring methods must closely follow the building surface or be protected from physical damage by an approved means.

690.31(E)(4) Marking/Labeling
• The markings must be visible after installation and on every section of the wiring system separated by enclosures, walls, partitions, ceilings, or floors.
690.31(E)(4) Marking/Labeling

- Spacing between labels or markings, or between a label and a marking, must not be more than 10 ft and labels must be suitable for the environment where they are installed.

690.33 Connectors

- New language in 690.33(E)
- "(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.”

Article 690.35 Ungrounded Photovoltaic Power Systems

- Ungrounded systems have not been prohibited, but the 2005 NEC was the first code cycle where the requirements are specifically called out.
- Included is an exception in 690.41 for consistency.
Article 690.35 Ungrounded Photovoltaic Power Systems [2005, 2008]

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

Part V. Grounding

690.41 System Grounding

- All systems above 50 Volts must be grounded or follow 690.35.
- Bi-polar systems must have a center-tap ground.
690.42 Point of System Grounding Connection
• System grounding point at the ground-fault detection device.

690.43 Equipment Grounding [2008 NEC]
• “Devices listed and identified for grounding the metallic frames of PV modules shall be permitted to bond the exposed metallic frames of PV modules to grounded mounting structures. Devices identified and listed for bonding the metallic frames of PV modules shall be permitted to bond the exposed metallic frames of PV modules to the metallic frames of adjacent PV modules.”

Early Improvements for Grounding

690.43(C) Structure as Equipment Grounding Conductor
• Metallic mounting racks must be identified as an equipment grounding conductor or have bonding jumpers/devices connected between the separate metallic racks and be connected to an equipment grounding conductor.
690.45 Size of Equipment Grounding Conductors [2008 NEC]

• "(A) General. Equipment grounding conductors in photovoltaic source and photovoltaic output circuits shall be sized in accordance with Table 250.122."

690.47(C) Grounding Electrode System (2011)

(1) Separate dc Grounding Electrode System Bonded to the ac Grounding Electrode System.

• A separate dc grounding electrode shall be bonded directly to the ac grounding electrode system. Bonding jumper(s) between the ac and dc systems shall be based on the larger grounding electrode conductor.

<table>
<thead>
<tr>
<th>Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Conduit, etc., Not Exceeding (Amperes)</th>
<th>Size (AWG or kcmil)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copper</td>
<td>Aluminum or Copper-Clad Aluminum*</td>
</tr>
<tr>
<td>15</td>
<td>14</td>
</tr>
<tr>
<td>20</td>
<td>12</td>
</tr>
<tr>
<td>60</td>
<td>10</td>
</tr>
<tr>
<td>100</td>
<td>8</td>
</tr>
<tr>
<td>200</td>
<td>6</td>
</tr>
<tr>
<td>300</td>
<td>4</td>
</tr>
<tr>
<td>400</td>
<td>3</td>
</tr>
<tr>
<td>500</td>
<td>2</td>
</tr>
<tr>
<td>600</td>
<td>1</td>
</tr>
</tbody>
</table>

690.47(C) Grounding Electrode System (2011)

(2) Common dc and ac Grounding Electrode.

• A dc grounding electrode conductor of the size specified by 250.166 shall be run from the marked dc grounding 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.
690.47(C) Grounding Electrode System (2011)

(3) Combined DC Grounding Electrode Conductor and AC Equipment Grounding Conductor.

- An unspliced, or irreversibly spliced, combined grounding conductor shall be run from the marked dc grounding point to the grounding busbar in the associated ac equipment. This combined conductor shall be the larger of the sizes specified by 250.122 or 250.166

690.53 Marking: DC PV Power Source [2008 NEC]

- (1) Rated maximum power-point current
  - Imp x number of series strings
- (2) Rated maximum power-point voltage
  - Vmp x number of modules in series
- (3) Maximum system voltage
  - FPN to (3): See 690.7(A) for maximum photovoltaic system voltage.
- (4) Short-circuit current
  - FPN to (4): See 690.8(A) for calculation of maximum circuit current.
- (5) Maximum rated output current of the charge controller (if installed)
Article 705—Interconnected Electric Power Production Sources

705.12 Point of Connection

705.12(D) Point of Connection Load Side
• Where this distribution equipment is capable of supplying multiple branch circuits or feeders or both, the interconnecting provisions for the utility-interactive inverter(s) must comply with (D)(1) through (D)(7).

705.12(D) Point of Connection Load Side
“(1) Dedicated Overcurrent and Disconnect. Each source interconnection shall be made at a dedicated circuit breaker or fusible disconnecting means.”
705.12(D) Point of Connection
Load Side
“(2) Bus or Conductor Rating. The sum of
the ampere ratings of overcurrent
devices in circuits supplying power to a
busbar or conductor shall not exceed 120
percent of the rating of the busbar or
conductor.”

705.12(D) Point of Connection
Load Side
“(3) Ground-Fault Protection. The
interconnection point shall be on the line
side of all ground-fault protection
equipment.” Exception-listed for backfeed

(4) Marking. Equipment containing circuits
supplying power to a busbar or conductor
shall be marked to indicate the presence of
all sources.

705.12(D) Point of Connection
Load Side
“(5) Suitable for Backfeed. Circuit breakers,
if backfed, shall be suitable for such
operation.” Note about breakers
• (6) Fastening. Listed plug-in-type circuit
breakers backfed from utility-interactive
inverters shall be permitted to omit the
additional fastener normally required by
408.36(D) for such applications.

705.12(D)(7) Inverter Output
Connection
• When the sum of the OCPDs supplying
power to a panelboard exceeds the bus
bar rating as permitted in 705.12(D)(2),
a dedicated ac inverter circuit breaker
must be located at the opposite end
from the input feeder supply conductors.
705.12(D) Got overhauled—Load-Side Connections Continue to Confuse Contractors and AHJs

- Busbars and Conductors are lumped together when they needed to be separated. New 705.12(D) creates three categories: 1. Feeders, 2. Taps, and 3. Busbars. Each have different rules since they have different characteristics.

Load Side Connections: Scenario 1

Scenario 1:
- Largest allowable PV system on load side at the opposite end of the primary supply OCPD
- 200-amp feeder
- 9’, 100-amp tap to 100-amp subpanel
- Large PV at opposite end of feeder—requires 200-amp connection—size governed by inverter output
- OKAY—Overcurrent protection covers all cases of overcurrent (tap prohibition not required)
Load Side Connections: Scenario 2

Scenario 2:
- Largest allowable PV system on load side at the opposite end of the primary supply OCPD
- 200-amp feeder
- 24’, 100-amp tap to 100-amp subpanel must be sized for 133A to meet tap rule.
- Large PV at opposite end of feeder—requires 200-amp connection—size governed by inverter output
- OKAY—Overcurrent protection covers all cases of overcurrent (tap prohibition not required)

Load Side Connections: Scenario 3

Scenario 3:
- Largest allowable PV system on load side.
- 200-amp feeder
- Large PV requires 200-amp connection—size governed by inverter output
- NOT OKAY since 200-amp feeder and panelboard bus could be overloaded
Load Side Connections: Scenario 4

Scenario 4:
- Largest allowable PV system on load side.
- 200-amp feeder
- Large PV requires 200-amp connection—size governed by inverter output
- OKAY—Load-side section of feeder protected with OCPD

Load Side Connections: Scenario 5

Scenario 5:
- Largest allowable PV system on load side.
- 200-amp feeder on supply side of U-I inverter, and 400-amp feeder and panelboard on load side
- Large PV requires 200-amp connection—size governed by inverter output
- OKAY—Load-side section of feeder sufficient for both currents