



CADMUS



Grounding and Labeling

An Independent Contractor to:
nyserda
Energy. Innovation. Solutions.

Solar Photovoltaic Installation Best Practices

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Matt Piantedosi

Associate Engineer
Master Electrician
MA License #A21036
The Cadmus Group





About Cadmus

- Energy and environmental consulting firm
- Completed hundreds of solar inspections and design reviews
- Owner's Agent on ~50 municipal solar projects
- Staff includes
 - PE's
 - Licensed electricians
 - NABCEP certified installers





Outline

- **PV System Grounding**
 - Introduction
 - Grounding Electrode Conductor/System
 - Equipment Grounding Conductor/System
- **Q&A**
- **PV System Labeling**
 - Where?
 - What?
 - Why?
- **Q&A**



Before we get too far...

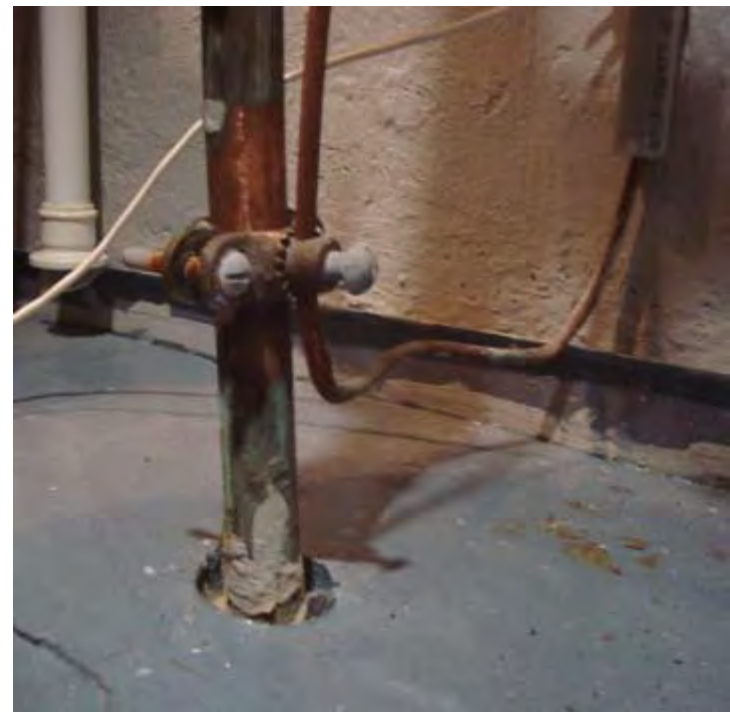
Equipment Grounding Conductor (EGC)





Before we get too far...

Grounding Electrode Conductor (GEC)





Before we get too far...

Grounded Conductor





Grounding Electrode System

2011 NEC Article 690.47

- Approximately **33%** of all inspections contain issues with the grounding electrode system

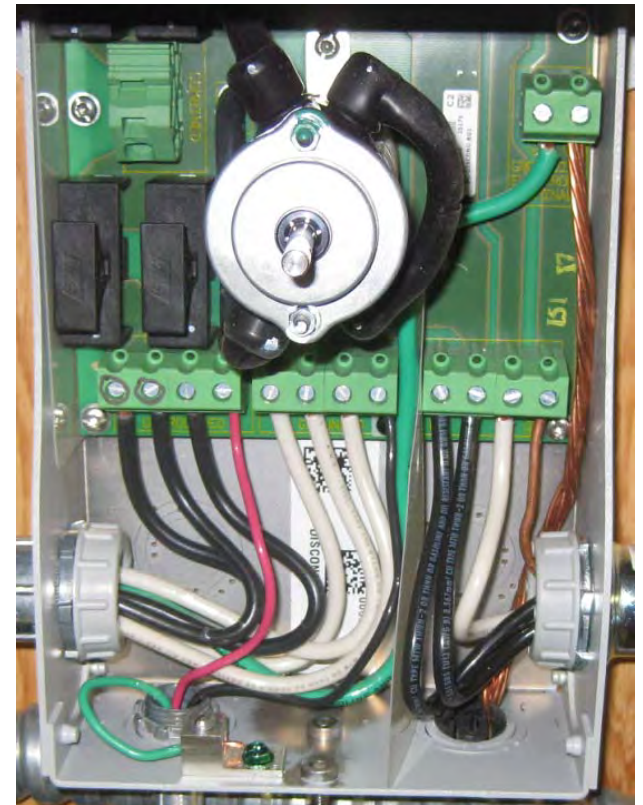




Grounding Electrode System

2011 NEC Article 690.47

- Most inverters today:
 - AC and DC requirements
 - 690.47(C)
 - Conductor sized to Table 250.66
 - Minimum #8 AWG copper
 - Based on largest ungrounded conductor
 - 3 options to connect to grounding electrode...

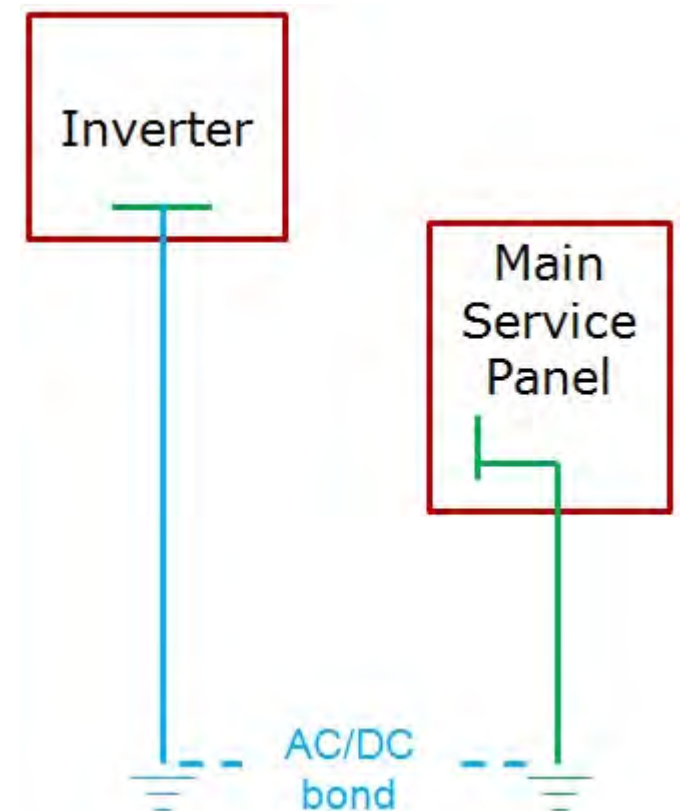




Grounding Electrode Conductor

2011 NEC Article 690.47

- 690.47(C)(1)
 - Separate DC Grounding Electrode System Bonded to the AC Grounding Electrode System
 - Bonding jumper shall be sized to largest GEC



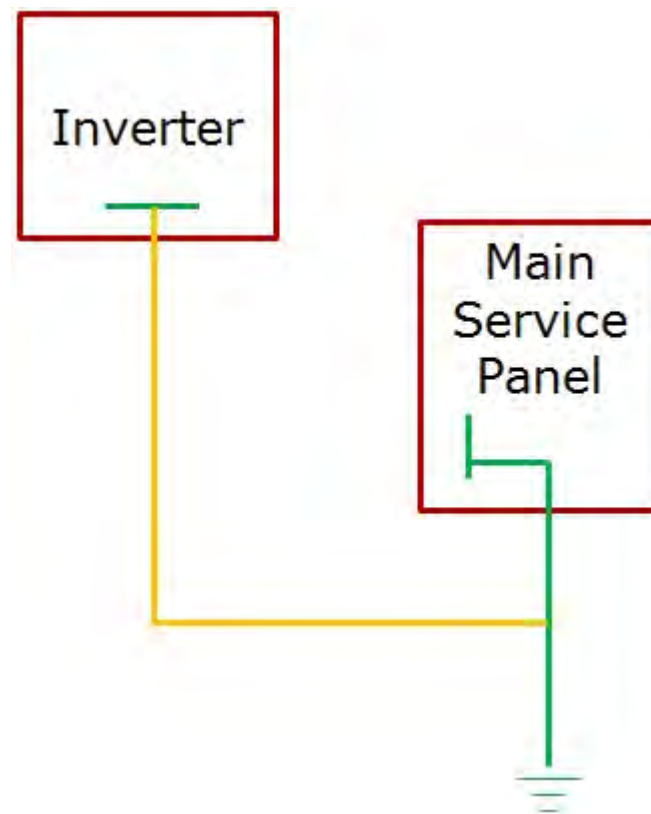
Note: Equipment Grounding Conductor not shown



Grounding Electrode Conductor

2011 NEC Article 690.47

- 690.47(C)(2)
 - Common DC and AC Grounding Electrode System
 - DC GEC shall be connected to either:
 - directly to AC grounding electrode
 - AC GEC in accordance with 250.64(C)(1) (irreversible splice, crimp, etc.)



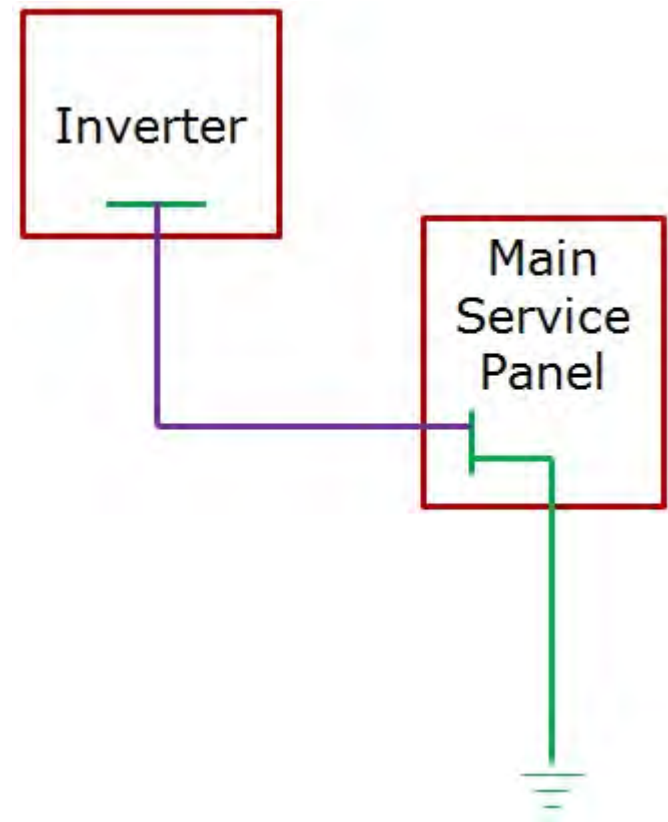
*Note: Equipment Grounding Conductor
not shown*



Grounding Electrode Conductor

2011 NEC Article 690.47

- 690.47(C)(3)
 - Combined DC GEC and AC Equipment Grounding Conductor
 - Sized larger of 250.122 and 250.166 requirements (not smaller than 8 AWG copper)





Grounding Electro Conductor Installation

2011 NEC Article 250.64

- Securing and Protecting
 - 250.64(B)
 - Shall be protected where exposed to physical damage

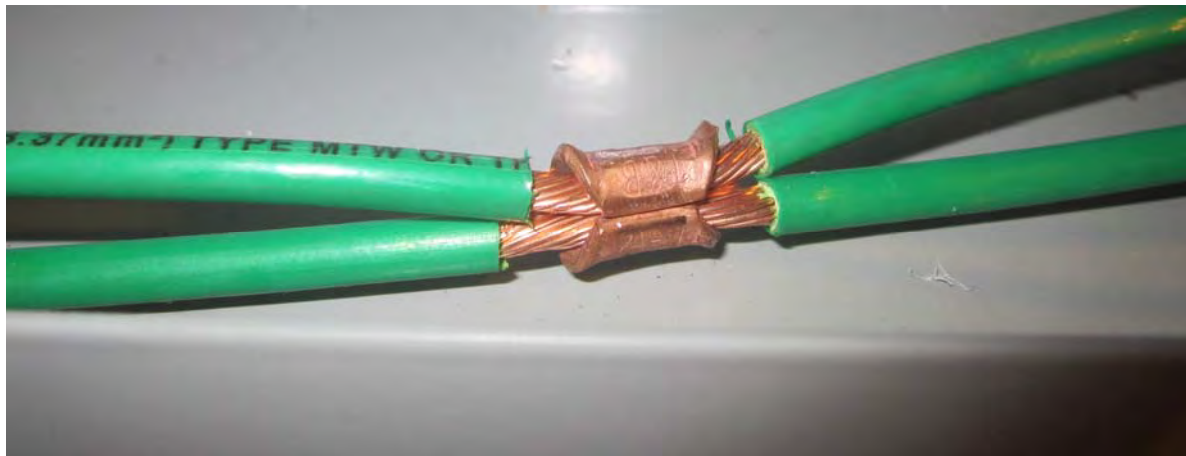


Grounding Electro Conductor Installation

2011 NEC Article 250.64

- **Continuous!!!**

- 250.64(C)
- No splices between equipment and grounding electrode
- Irreversible crimp or weld only





Grounding Electro Conductor Installation

2011 NEC Article 250.64(C)

- What about “sections of busbars” per (C)(2)?



That's a
“terminal bar”

Google it.



Grounding Electro Conductor Installation

2011 NEC Article 250.64(C)

- What about “sections of busbars” per (C)(2)?

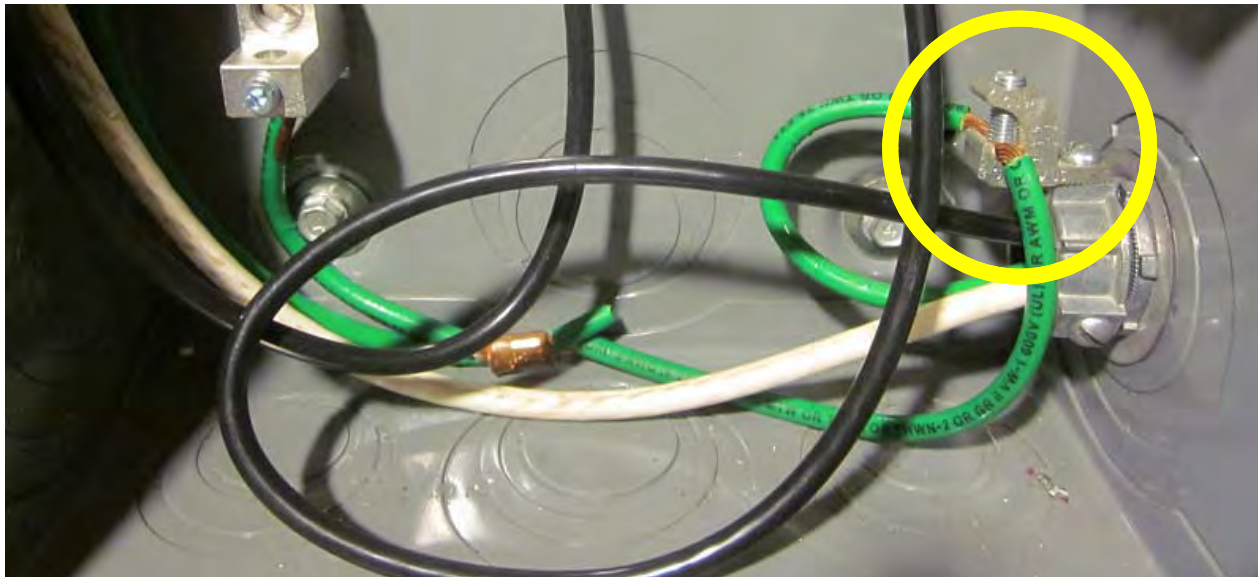




Grounding Electrode Conductor Installation

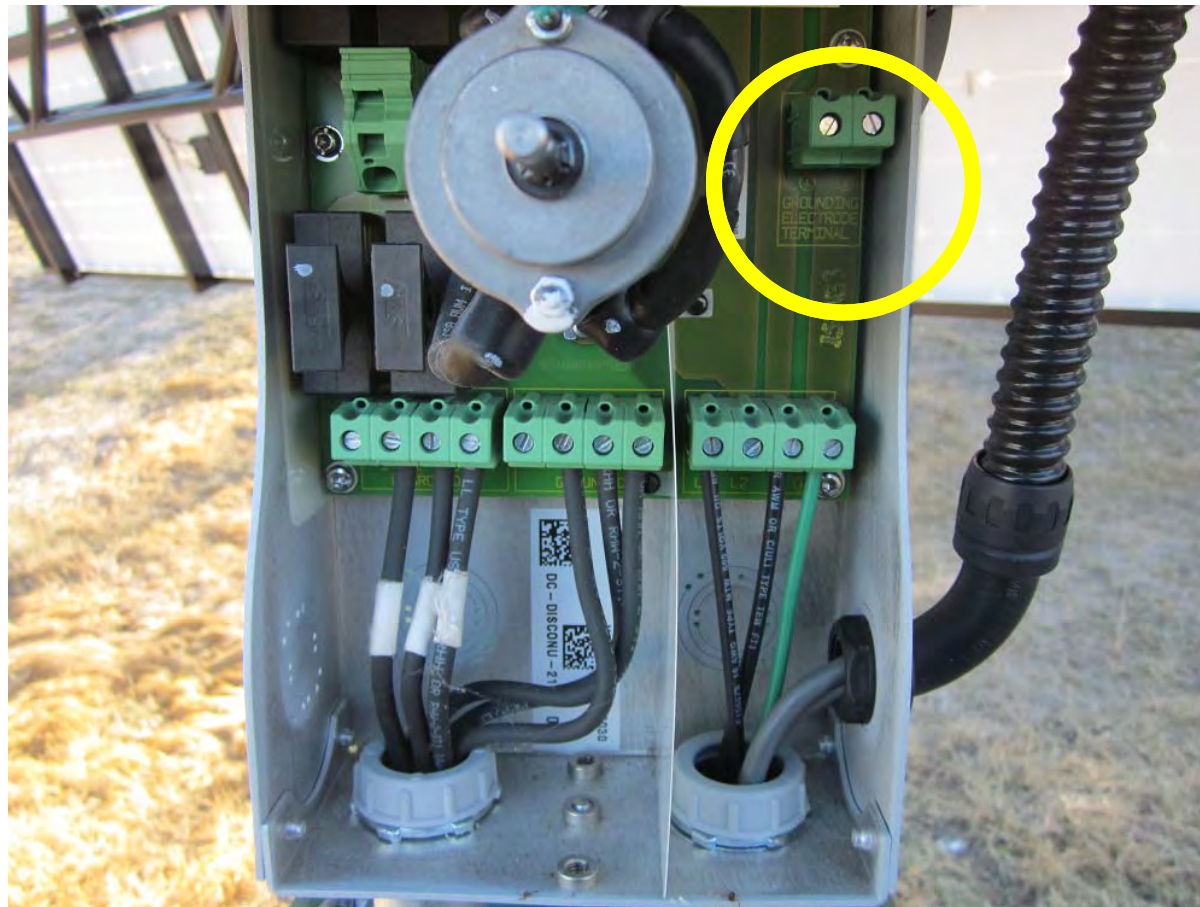
2011 NEC Article 250.64(E)

- Ferrous metal enclosures containing GEC
- Not physically continuous
- Bond both ends



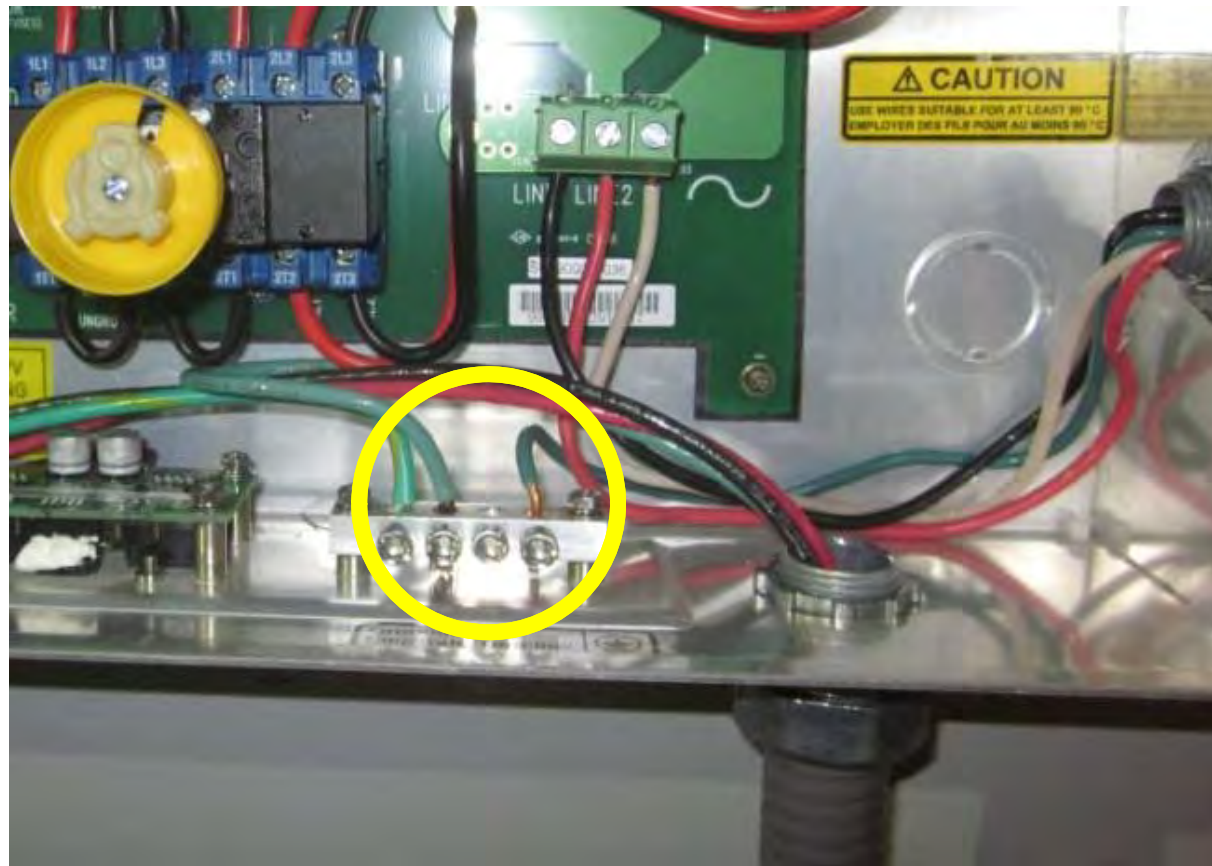


Grounding Electro Conductor Missing





Grounding Electro Conductor Undersized





Grounding Electro Conductor Spliced





Microinverter Grounding

- Each Enphase microinverter requires a GEC
 - Two possible methods
 - #8 AWG copper on each microinverter
 - Continuous to grounding electrode





Microinverter Grounding

- Each Enphase microinverter requires a GEC
 - Two possible methods
 - WEEB lugs to listed racking
 - Continuous #8 AWG copper from racking → grounding electrode
 - Enphase maintains a list of compatible racking
 - » **Please check!**



2011 NEC Article 690.43 / 250.4

-



Equipment Grounding System

2011 NEC Article 690.43 / 250.4(A)(5)

- All metal parts “likely to become energized”
 - Module frames
 - Racking
 - Metal roof
 - Metal conduit/enclosures
- Low impedance ground-fault current path back to the source or ground detector
 - Inverter or AC panelboard



Equipment Grounding System

Metal Roof Bonding Example





Equipment Grounding System

2011 NEC Article 690.43 / 250.4

- Article 250.4(A)(5) / 250.4(B)(4)
 - The earth shall not be considered as an effective ground-fault current path
 - You can't *"just drive a ground rod"*

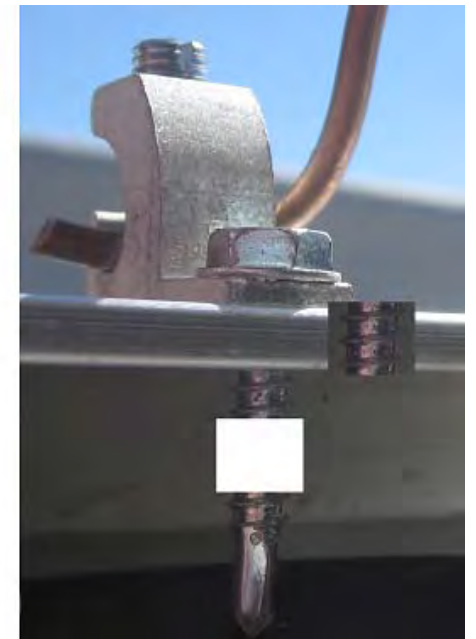
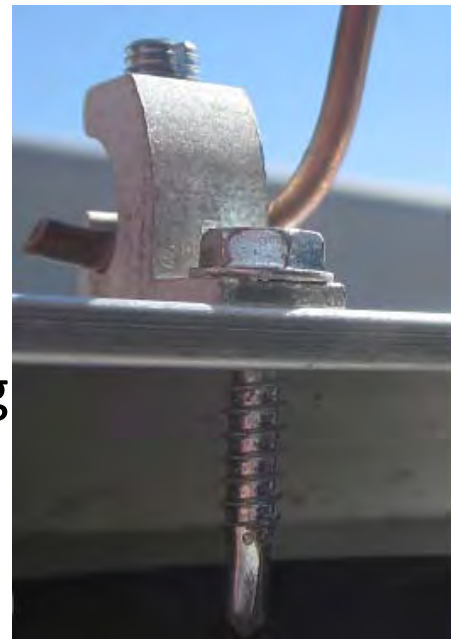




Connection of Grounding and Bonding Equipment

2011 NEC Article 250.8

- Listed pressure connectors
- Terminal bars
- Exothermic welding
- Machine screws
 - Standard or thread-forming
 - Engage 2 or more threads
 - Secured with a nut
- Listed assembly/means





Module Frame Grounding

2011 NEC Article 690.43

- Many methods per manufacturer's instructions
 - Lay-in lug
 - Must be suitable for the environment in which it is installed
 - Contact with aluminum (usually tin-plated copper)
 - Outdoor/wet locations (suitable for direct-burial)
 - Listed fitting
 - WEEB
 - Racking
 - Plastic frame
 - No ground required





Module Frame Grounding

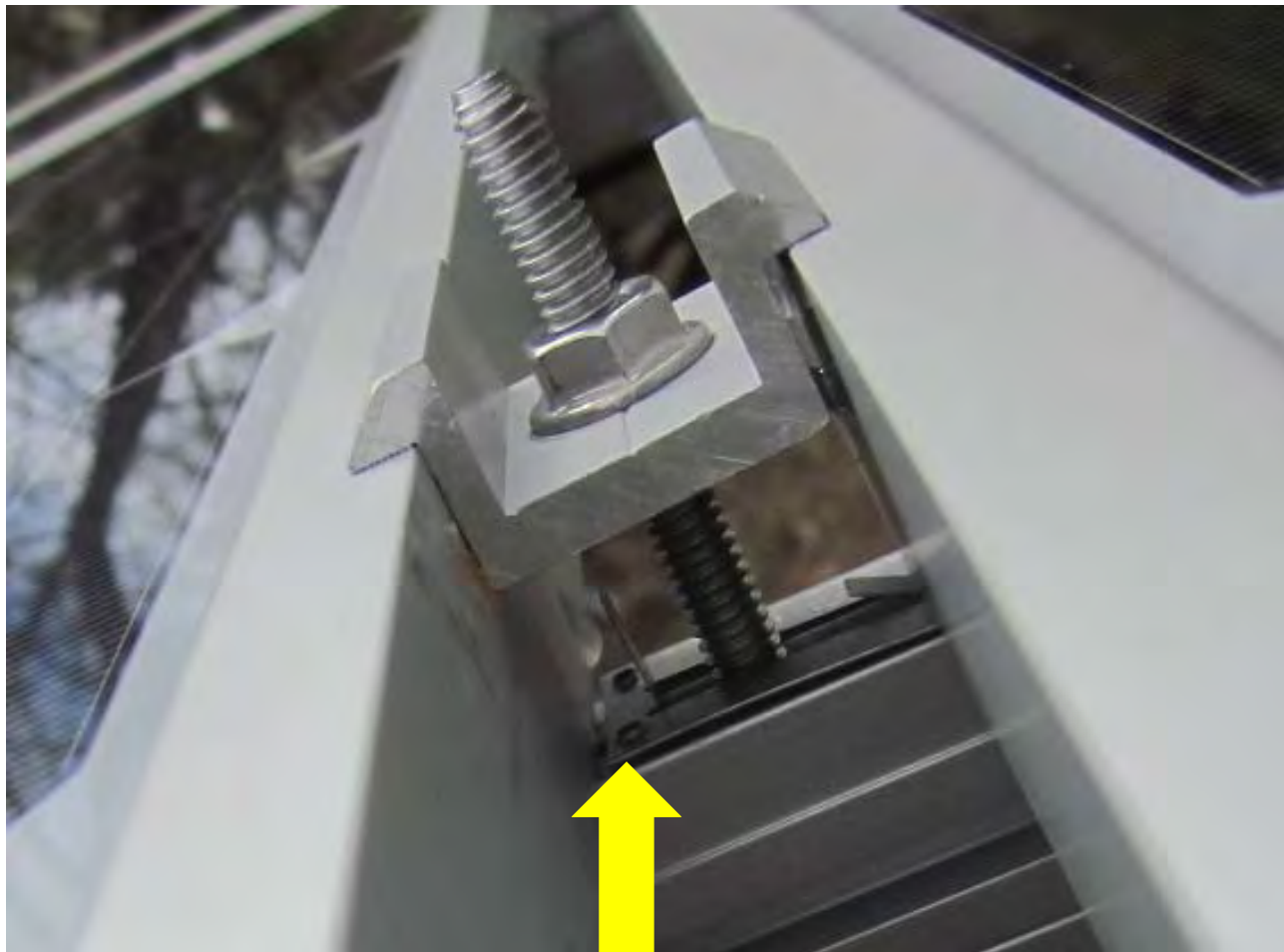
Wrong Lugs – (Copper or Not Listed for Outdoor)





Module Frame Grounding

Right Fitting, Installed Wrong

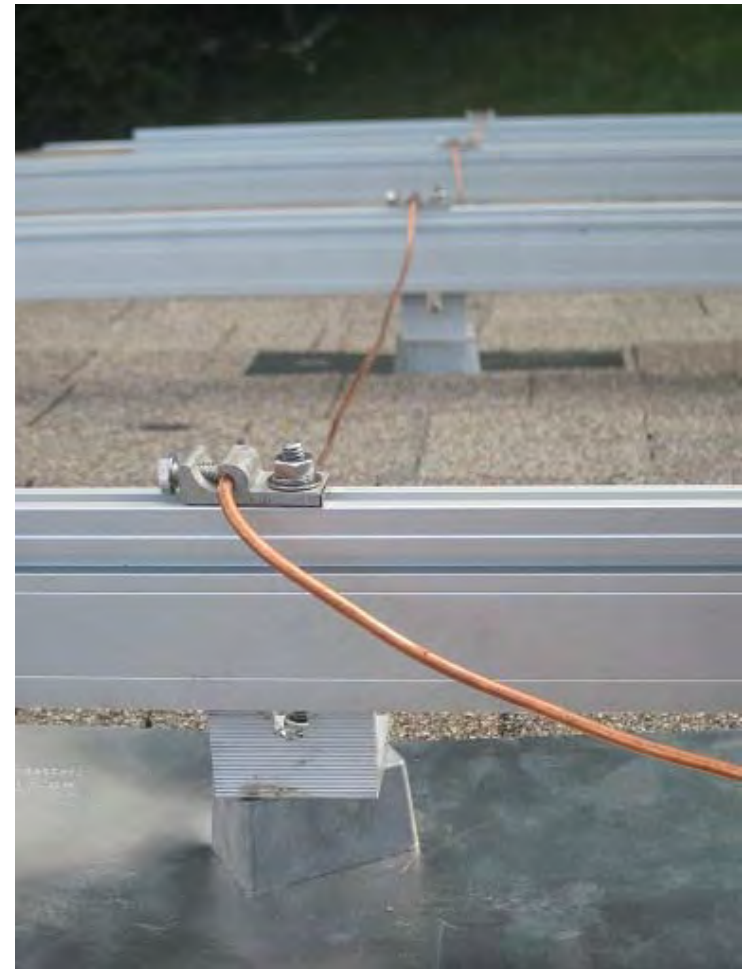




Grounding the Racking

2011 NEC Article 690.43

- Many methods per manufacturer's instructions
 - Lay-in lug
 - Must be suitable for the environment in which it is installed
 - Contact with aluminum (usually tin-plated copper)
 - Outdoor/wet locations (suitable for direct-burial)
 - Listed fitting
 - WEEB
 - Plastic racking
 - No ground required





Grounding the Racking

Unless it's plastic!





Grounding the Racking

Considerations

- Wire management
- Conductor type/material
- Size
- Splices
 - Where permissible
 - Not in lay-in lugs



Grounding the Racking

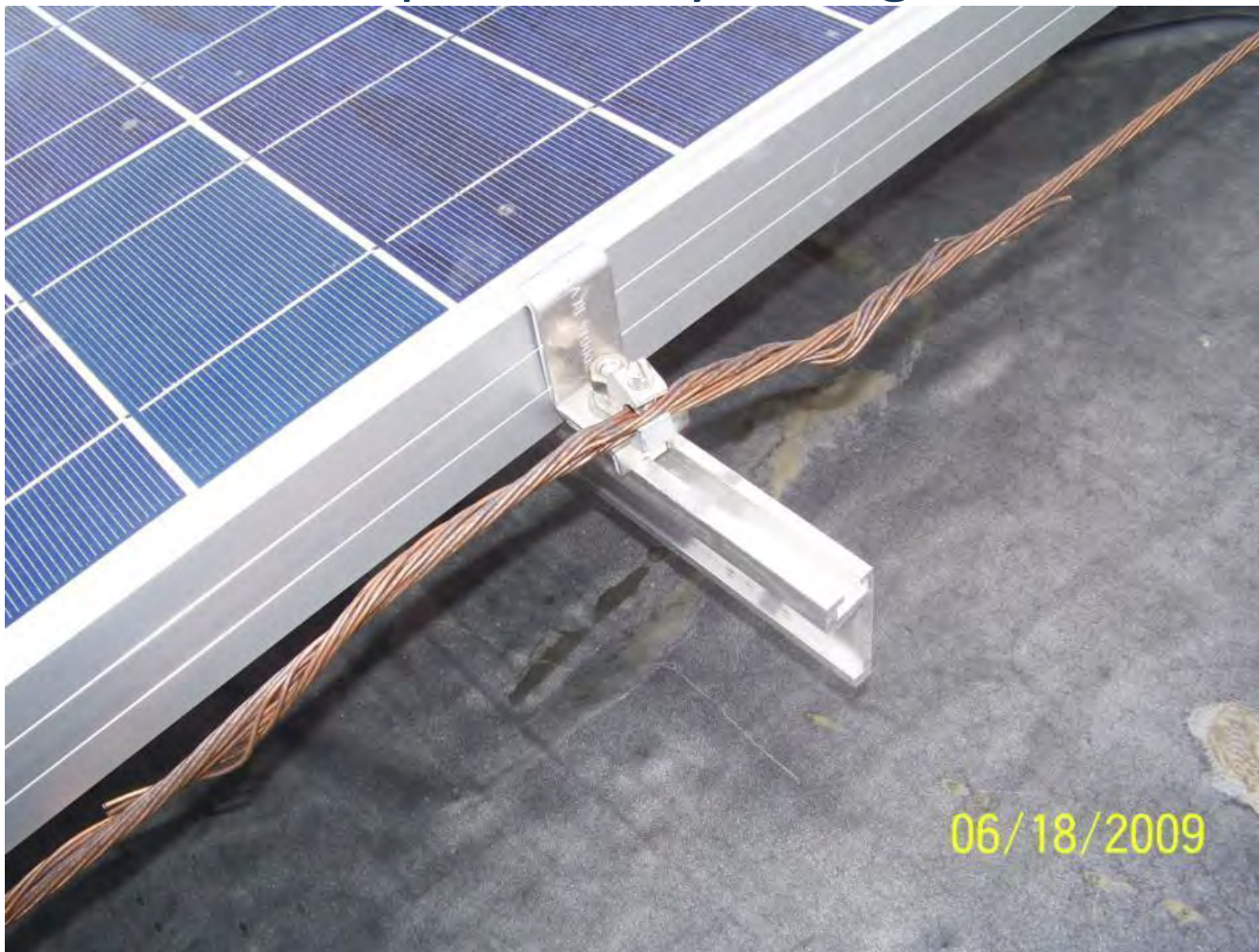
Trip Hazard





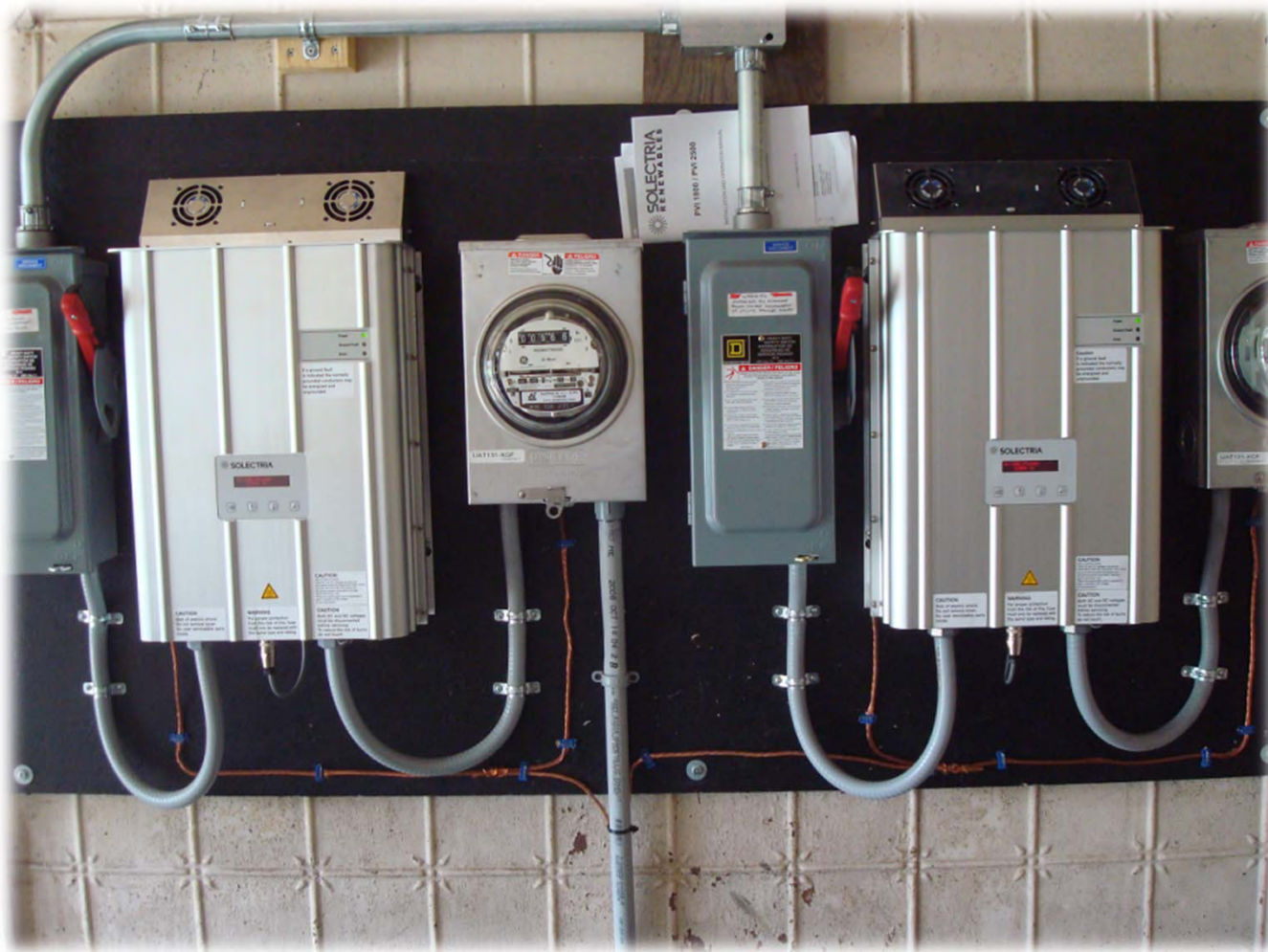
Grounding the Racking

Splice in Lay-In Lug





Grounding Q&A





PV System Labeling

- Labeling issues:
 - About **50%** of all inspections
 - Represent more than **33%** of balance of system issues we identify





PV System Labeling

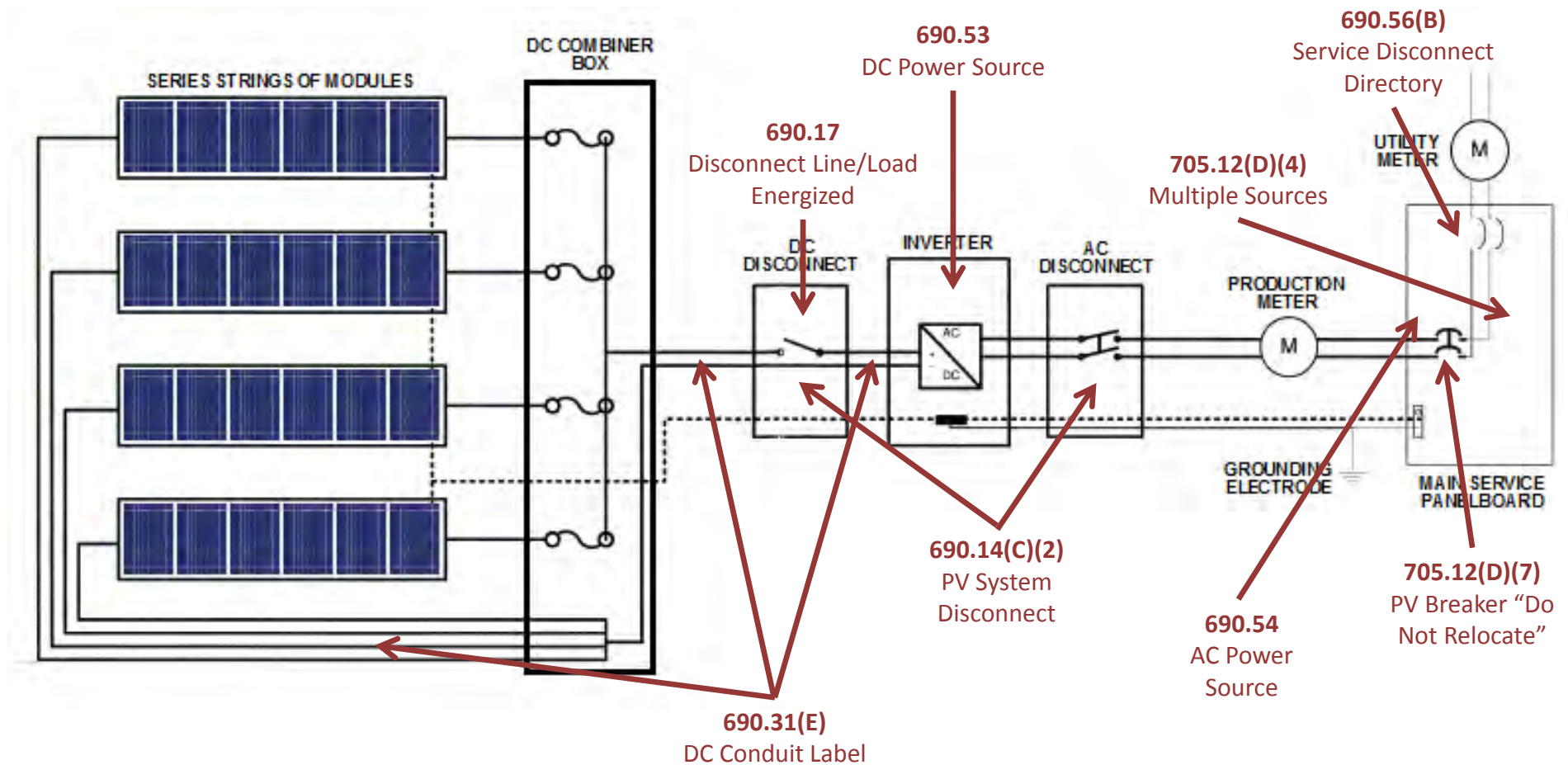
- Slides show 2011 NEC but mostly apply to 2008 also:
 - New requirement to label indoor DC conduit
 - Backfeed breaker references moved from 690.64 to 705.12





PV System Labeling

In a Nutshell

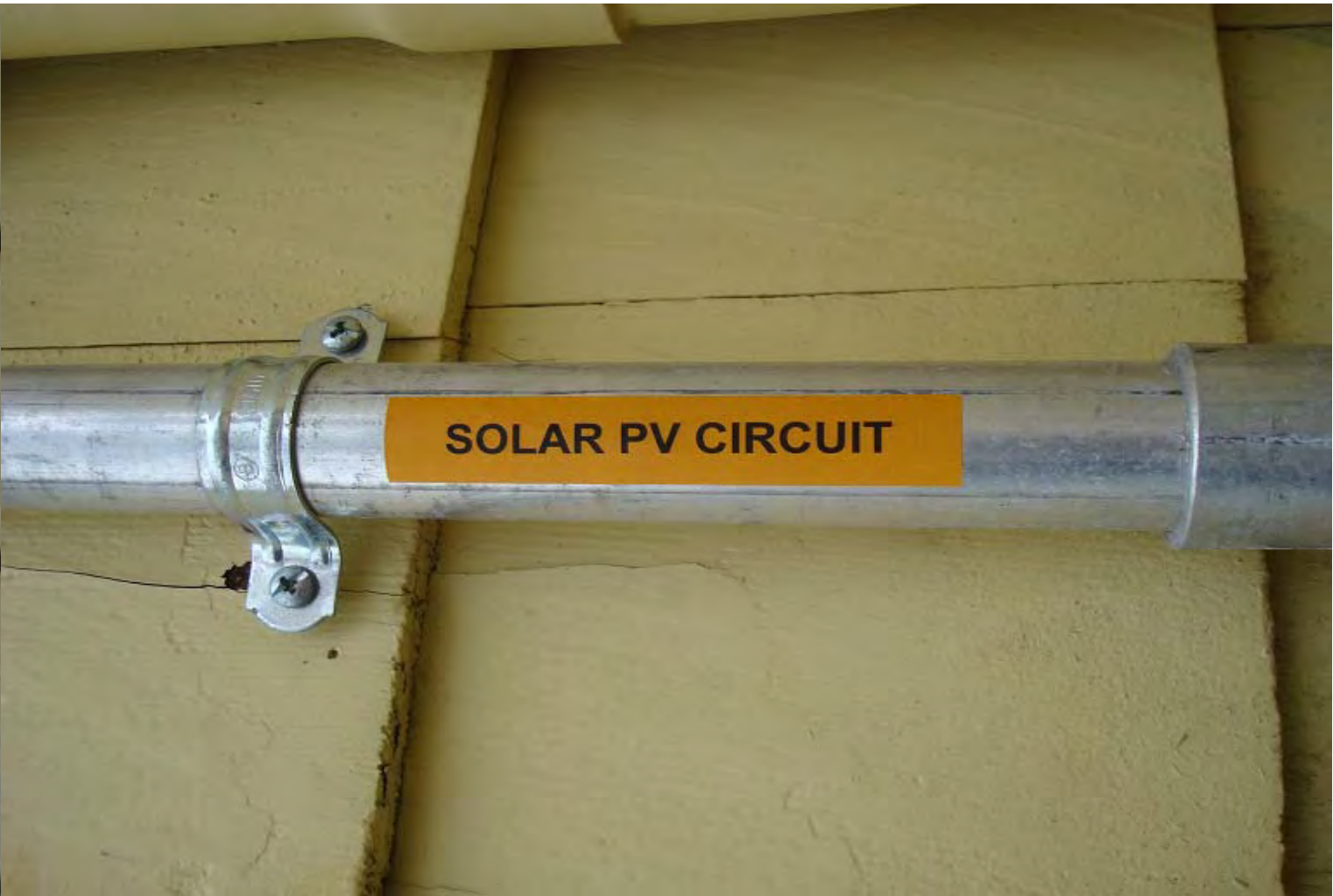




DC Conduit Label

690.31(E)(3)







PV System Disconnect 690.14(C)(2)





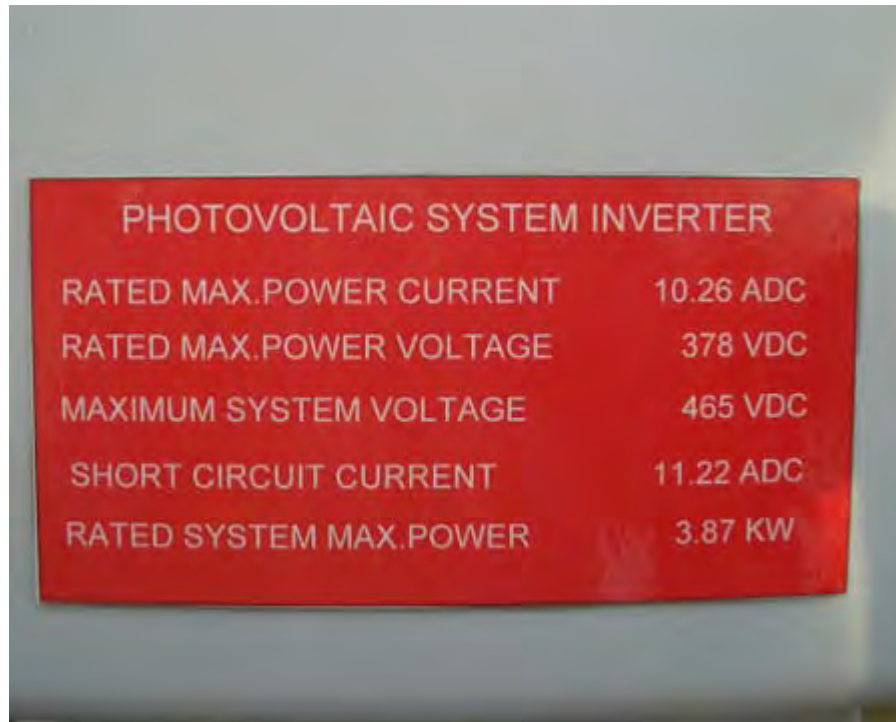
Disconnect Line/Load Energized 690.17





DC Power Source

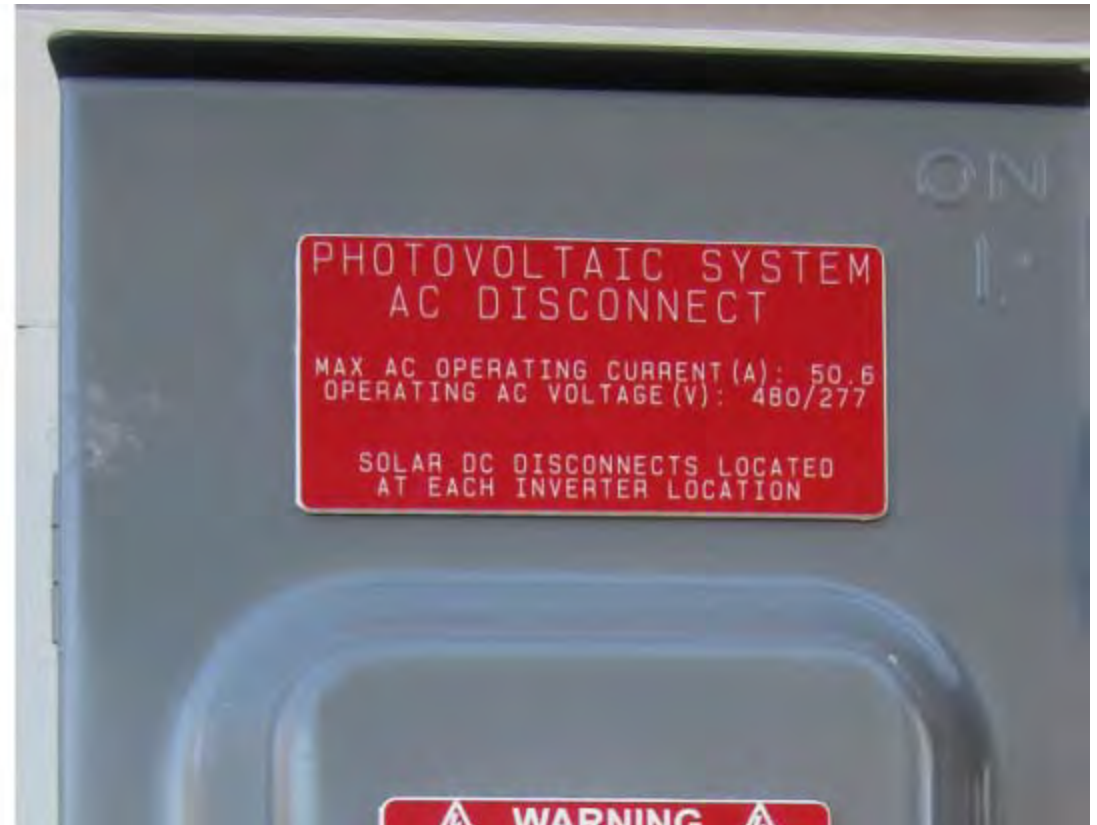
690.53





AC Power Source

690.54





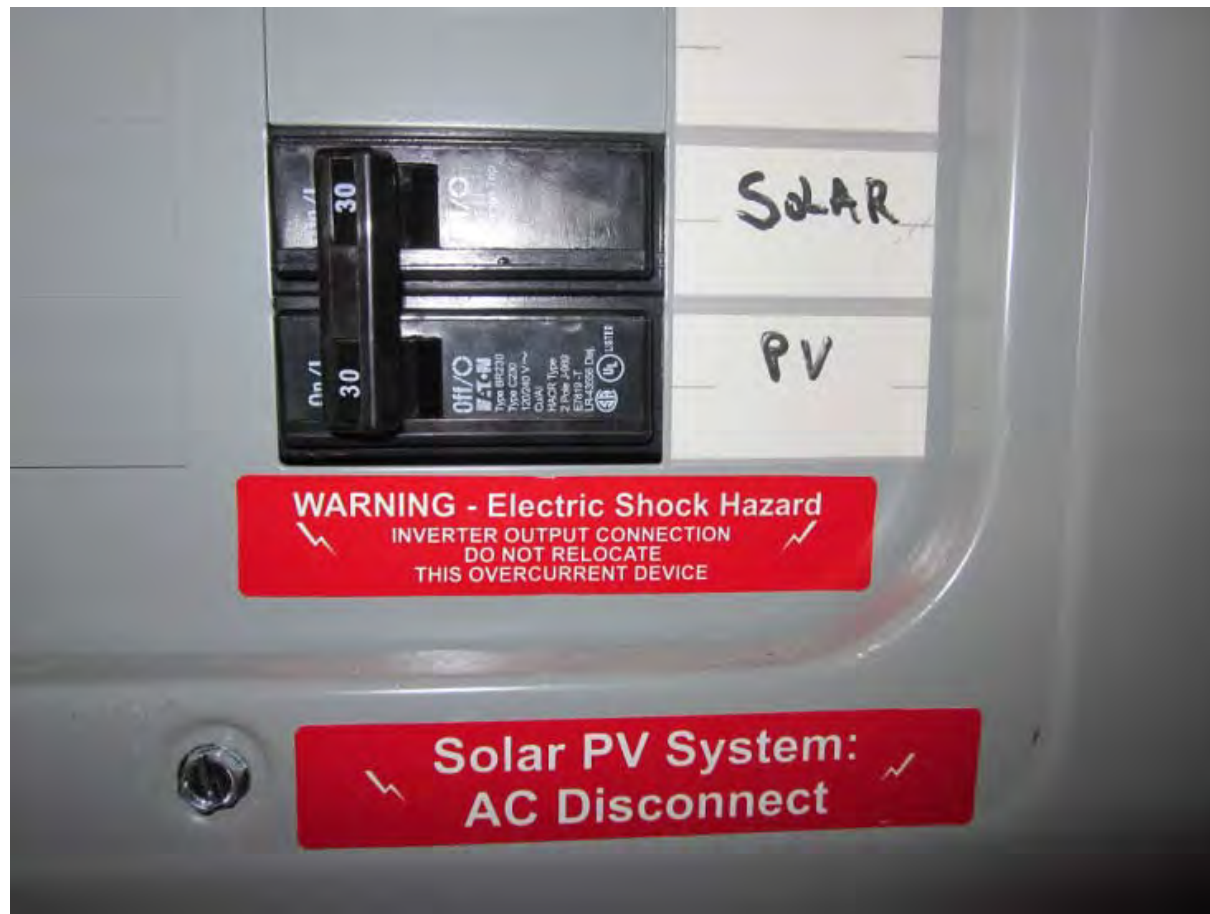
Multiple Power Sources

705.12(D)(4)





PV Breaker “Do Not Relocate” 705.12(D)(7)





26

Monitoring

28

Solar

30

Solar

**DO NOT
RELOCATE THIS
OVERCURRENT
DEVICE**

5419506



Service Disconnect Directory

690.56(B)





PV System Labeling

Why?

- System Maintenance/Troubleshooting
- Future Electrical Work
- **First Responders**





Final Q&A



NYSERDA Webinar Q&A

These questions and answers were discussed during the webinar. In some cases, answers given during the webinar have been expanded upon or clarified.

With three inverters combined into a subpanel, say with 3 breakers, how do you run the inverter ground to the main panel? Do you need 3 dedicated conductors or one conductor?

Article 250.64(D) allows for the installation of an irreversibly spliced/welded tap but the single GEC must be sized appropriately for the combined output of the three inverters, which may mean it is larger than the conductors used for each individual inverter. See also Note 1 below Table 250.66.

Were the screws in Slide 26 zinc-plated self tapping screws?

Article 250.8 allows the use of thread-forming screws as a grounding connection method (when 2 or more threads are engaged). When these are used in an outdoor application, they should be “suitable for the environment in which they are installed.” The screws in the slide should be plated or stainless steel.

Is my understanding correct that bonding screws are required to be 10/32 thread count, therefore nut and bolt rather than self-tapping screw?

Article 250.8 allows the use of thread-forming screws if they engage 2 or more threads. The 10/32 screws contain 32 threads per inch and are often used with metal electrical enclosures that are 1/16 of an inch. A screw with fewer threads per inch can be used to bond a thicker metal.

Do you need to install an additional ground rod for steel pole mounted PV systems?

Per 2011 this additional ground rod is not required, but is required so long as 2008 NEC is still in force, unless the pole mount/foundation meets the requirements of a concrete encased electrode.

On a metal roof using S-5! Connectors direct to the roof seam, the S-5!s are listed for bonding the panel frames, but do they also bond the roof?

According to the manufacturer, the screws used are not listed to bond the standing seam metal roof. At this point the clamp is only listed to bond the module frames.

Can a copper lug be used on an aluminum frame if used with a 10-32 Stainless steel machine screw and anti-oxidant compound?

The question is whether the anti-oxidant compound will last in this environment for a period that exceeds the life of the modules (usually over 25 years). We do not recommend this practice and suggest that installers consider the properties of dissimilar metals when specifying and installing components.

Is there a separation distance of the DC GE and the AC GE when bonding is not required?

Article 690.47(C)(1) will still require bonding of electrodes. Article 250.53(B) requires a distance of 6 feet or more to be used between two electrodes.

In a system installed on/in a structure remote from the main system, say on a barn fed by a sub panel, that is located a large distance from the main panel, do we have to bring the grounding electrode conductor back to the main panel, or can we use the sub panel for our grounding electrode requirements?

Per the 2011 NEC, a grounding electrode conductor on a PV system shall meet one of the three requirements outlined in 690.47(C). In a nutshell, there should be a minimum 8 AWG copper conductor between the inverter and main grounding electrode. Article 250.64 lists methods to install a grounding electrode conductor. If the sub-panel wiring meets the methods outlined in 250.64, and the installation complies with 690.47(C)(3), an additional grounding electrode conductor may not be required.

Metal Roof Grounding - Since there are no listed devices for grounding a metal roof, at least I don't know of any, what are your suggestions for best practice?

One often "effective" method is similar to that shown in slide 24. Every metal roof panel will contain a direct-burial rated lay-in lug with a stainless steel nut and bolt. The lug will be located on the overhang, to prevent a penetration into dry space. This method may not always work. If the structure is metal, the roof may already be effectively grounded through the building steel. Due to the increased need to ground a metal roof, we may see more equipment for this in the future.

An array is mounted on a garage roof 100 ft from the house where the inverter is. Should I run an equipment ground from the array to a separate grounding electrode at the garage?

By 2008 NEC, a separate ground rod is required for lightning protection but this is not required under the 2011 NEC. Running an equipment grounding conductor back to the inverter and the rest of the balance of system grounding system will be sufficient.

Interesting discussion on the S-5! grounding issue with the screws attaching to the raised seam roof. S-5! has a PV Kit version that has weeb type grounding features on the large washer disks under the module frames. Comments?

The PV kit is only listed to help satisfy the module grounding requirements as outlined in Article 690.43. This kit has not been listed to bond the metal roof (as of September 2012).

On a metal roof with existing lightning rods, do we still have to bond the metal roof to the PV array? Is this a bad idea?

Per Article 250.4(A)(5), you cannot rely on the roof and lightning rod system as an effective ground path: *"The earth shall not be considered as an effective ground-fault current path."* It is also not a good idea to combine lightning protection with equipment grounding.

Does every roof panel need a lay in lug?

The roof panel frames must be electrically continuous per Article 690.43. Roof panels that are not connected by some sort of threaded fittings or listed racking/washer will most likely require a lug on each roof panel. It is important that the lug is listed for the application, therefore not copper against aluminum and rated for outdoors, "direct burial."

Is there a problem with the bare EGC (#10) coming in contact with the galvanized PV support structure? What if the copper is touching say Unistrut?

According to the NEC, dissimilar metals must always be isolated to eliminate the possibility of galvanic reaction. For a bare copper conductor, it is recommended that it is isolated from other dissimilar metals. A great example is in the upper left portion of the photo in slide 28. There are many types of Unistrut and it may depend on the coating to determine if dissimilar metal isolation is required.

Is there any other method to irreversibly splice GEC besides the copper crimp?

There are several options for this described in 250.64(C), including exothermic welds or crimp fittings listed for the purpose.

Confused about 690.47(D) in 2008. In an earlier conversation with NYSDERDA reps I understood that for roof mounted PV the "additional" DC grounding electrode was considered optional and we could bond into the house grounding electrode conductor. Under 2008 code, is the separate DC grounding electrode actually required?

No, you can use the grounding electrode already installed for the residence.

Labeling

My understanding is the 690.56(B) directory should be at the utility meter. Should it be at the main panelboard AND utility meter?

Article 690.56(B) reads: *"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."*

It is best practice that this label is installed at every service disconnecting means, whether PV or utility, where they are located remotely from each other.

On the AC label for Volts and Amps as required by Article 690.54, how are you figuring the Amps of the PV? We use the sizing tool values vs the total system watts divided by the 240V. It is saying that is wrong in the reports we get back?

Article 690.54 requires that a label containing the "rated AC output current" be installed at the system point of interconnection. According to Article 690.8(A)(3), the inverter output circuit current is the inverter continuous output current rating (defined by the inverter specifications).

On 690.56 with a line-tie system that is outdoors located right next to the utility kWh it would seem that a plaque/directory would not be required. Is this the case?

No, it is not required if all of the equipment is within sight of each other

Back to labels - do we need to have a directory of disconnect locations as a map (like in your picture) or can we write out locations?

705.10 permits description of these locations by using lists but the point is to be as clear as possible so the directory is useful to personnel not familiar with the site.

If there are multiple DC disconnects in a system, do they all need DC power source labeling per 690.53?

Article 690.53 requires a label “at the photovoltaic disconnecting means.” If a PV system has multiple DC disconnects, it is best practice to label all disconnects as this is helpful to people performing maintenance on the system.