



# Solar PV System Code Compliance

*Best Practices, 2017 NEC Updates, and Opportunities for Improvement*

MassCEC Webinar  
April 2017



Presented by:  
**Matt Piantedosi**  
*Manager of Solar Field Operations*  
The Cadmus Group



# Table of Contents

- **Introduction**
  - About The Cadmus Group
  - PV Inspections and Score Classifications
- **PV Interconnection**
- **Array**
  - Grounding and Bonding
  - Wiring Methods
  - Microinverters
  - Modules
  - Roof Penetrations
- **PV System Labeling**
- **String/Central Inverters**
- **Grounding Electrode System**
- **Inverter Output and AC Circuits**
  - Disconnecting Means
  - Production Meter
- **Outdoor Wiring Methods**
- **Rapid Shutdown**





# About Matt Piantedosi

- **Manager of Solar Field Operations - CADMUS**
- BS Electrical Engineering
  - Western New England College
- Inspected over 600 residential/commercial PV systems
- Licensed Master Electrician in MA and NH
- Licensed Journeyman Electrician in MA, RI, and CT
- Working in the trade for over 17 years
  - B. A. Piantedosi Jr. Master Electrician
  - Logan Electrical Company
- IAEI – Boston Paul Revere Chapter
  - Executive Board Member





# About The Cadmus Group

- Renewable energy technical and economic expertise
- More than a decade of experience aiding clients to develop and support renewable energy in New England.
- Cadmus performs solar PV quality assurance inspections and design reviews for:
  - **Massachusetts Clean Energy Center**
    - Commonwealth Solar Program
    - Solar Loan Program
    - Solarize Massachusetts
    - Mass Solar Connect
  - Rhode Island Renewable Energy Fund, Renewable Energy Growth
  - New York State Energy Research and Development Authority
  - Various PV installers/investors
- Provide Owner's Agent Technical Assistance
  - Department of Energy Resources Green Communities





# Cadmus PV Inspections

- Typically 1-2 hours onsite
  - Determined by quality observed and complexity
- A comprehensive inspection of **all** components.
  - Program compliance:
    - Equipment verification
    - Production/TSRF
    - Technical
  - NEC compliance





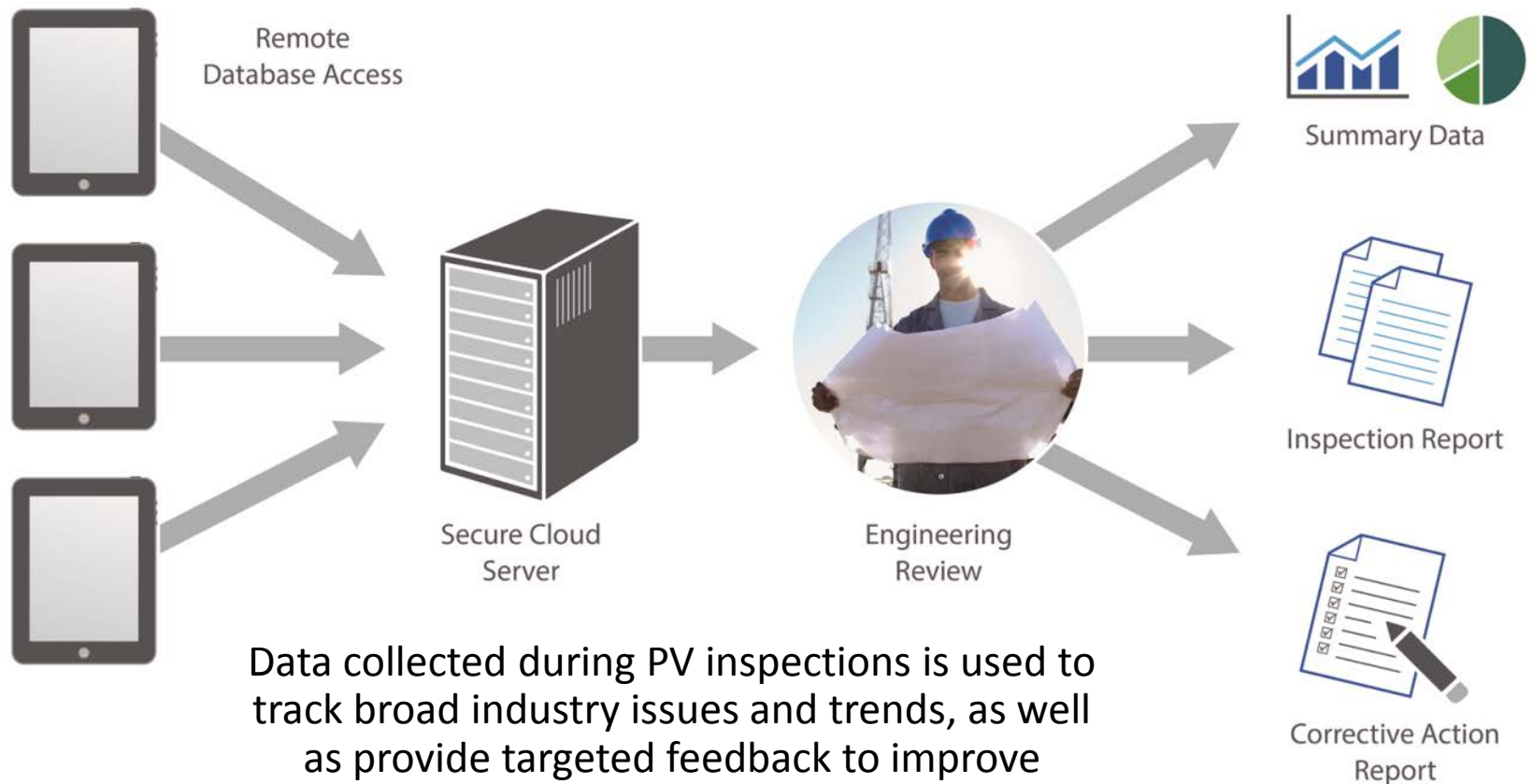
# Cadmus PV Inspections

- Random & Targeted
  - New installers to program
  - Expedited installers
- Post AHJ Inspection
- Work with installers, inspectors to resolve issues by providing guidance and education.
- For more information:
  - <http://files.masscec.com/uploads/attachments/QualityAssuranceProcessMassCECPrograms.pdf>





# Our Data-Driven Approach to PV Inspections





# How We Classify Issues

- Each inspection is scored from 1 (poor) to 5 (excellent) based on how numerous and severe the issues are
- Issues classified as:
  - Incidental
  - Minor
  - Major
  - Critical







# Incidental Non Conformance (4)

Incidental issues are not expected to impact system operation or safety under normal operating conditions but still represent non-compliance with relevant codes/standards. Examples include:

- Missing screws on indoor enclosure covers (but cover is still secure and renders interior of enclosure inaccessible)
- Installation debris (e.g., bits of wire, packing materials) left onsite
- Poor wire management that is not expected to cause a fault condition
- Equipment installed does not match Program records but is considered equivalent
- Missing/incomplete labels
- Incorrect color code on wires



## Minor Non Conformance (3)

Minor issues pose a mid to long term risk of system failure or safety hazard

- Bonding neutral to ground downstream of service disconnect
- Insufficient clearance around boxes
- Undersized circuit protection (nuisance tripping)
- Improperly supported conductors or conduit



## Major Non Conformance (2)

Major issues are deemed likely to impact system performance or safety in the short-term, though they do not pose an immediate hazard

- Missing equipment grounding
- Missing or undersized grounding electrode conductor
- Improperly secured PV modules
- Missing/inadequate thermal expansion joints in long conduit runs



# Critical Non Conformance (1)

Critical issues pose an immediate risk of system failure and/or safety hazard. Often, we shut down systems with this level of defect for safety reasons.

- Exceeding current limits on busbars and/or conductors
- System not operational (ground fault, disconnected conductors, etc.)
- Exceeding inverter voltage limits
- Use of non-DC rated equipment in DC circuits

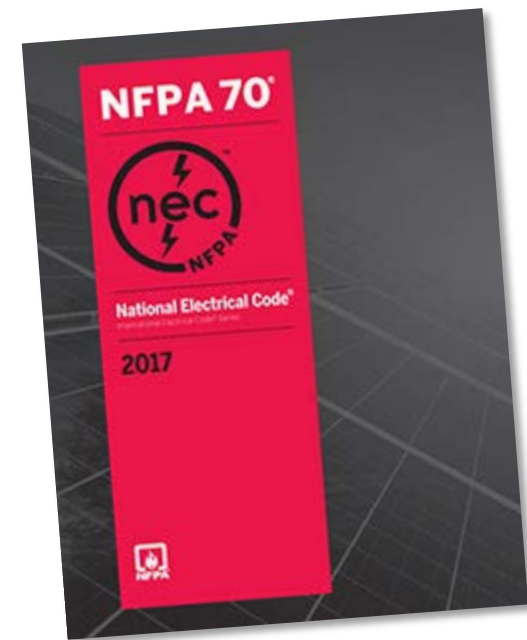




# 2017 National Electrical Code

## *Key Articles to Solar PV*

- **Article 250**
  - Grounding and Bonding
- **Article 300**
  - Wiring Methods
- **Article 690**
  - Solar Photovoltaic (PV) Systems
- **Article 705**
  - Interconnected Electric Power Production Sources





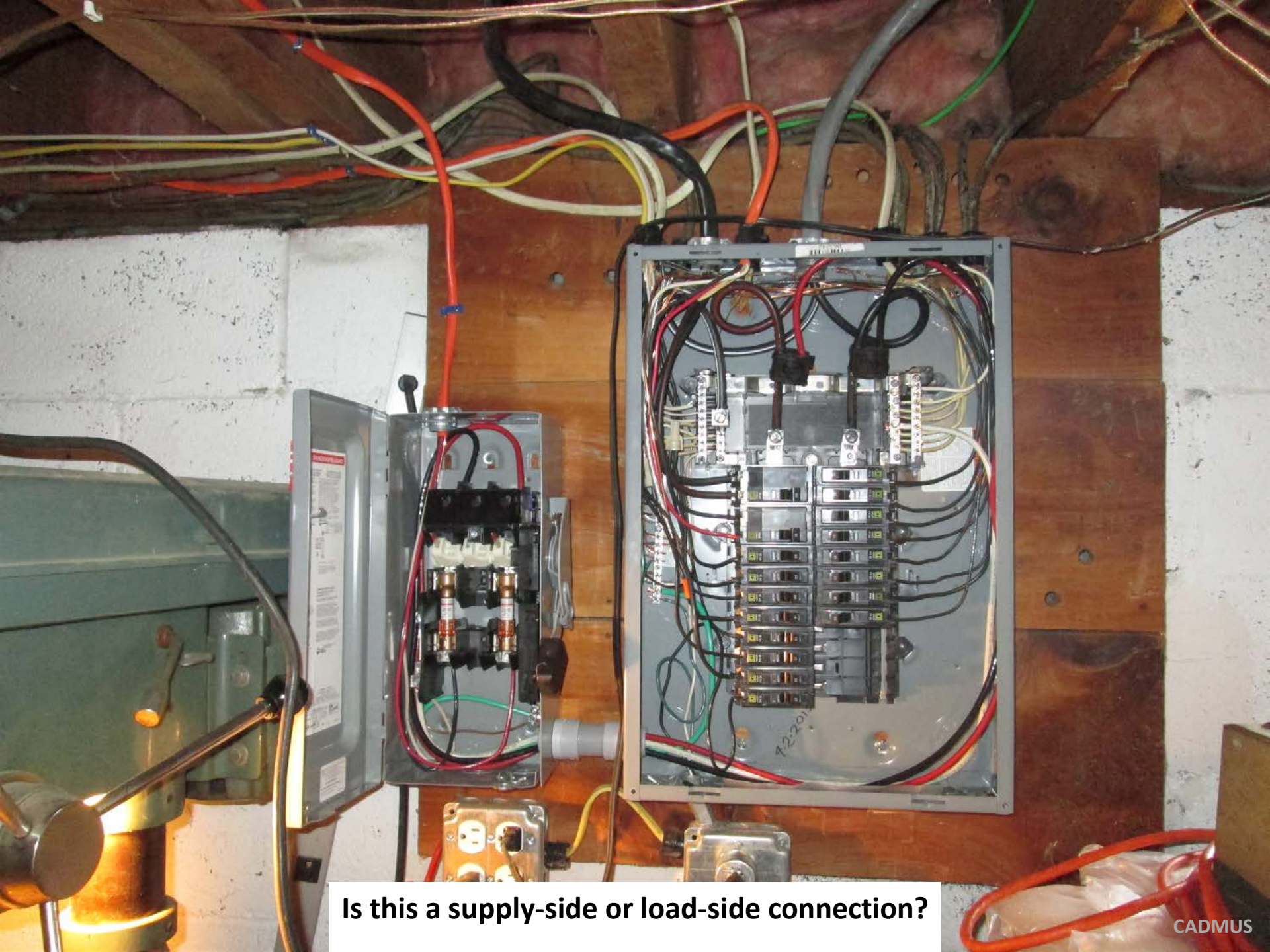
# PV Interconnection





**Is this a supply-side or load-side connection?**





**Is this a supply-side or load-side connection?**





# Article 705.12

- 705.12 Point of Connection
  - (A) Supply Side
  - (B) Load Side
    - Feeder tap
    - Backfed breaker



# Supply Side Connection

NEC Article 705.12(A)

- Interconnection on utility side of main service disconnect, 230.82(6)
- Typically on customer side of utility meter
- “Second set” of service entrance conductors (Article 230)
- PV disconnect must service-rated
  - NEC Article 690.13(C)
- Wiring methods per 230.43

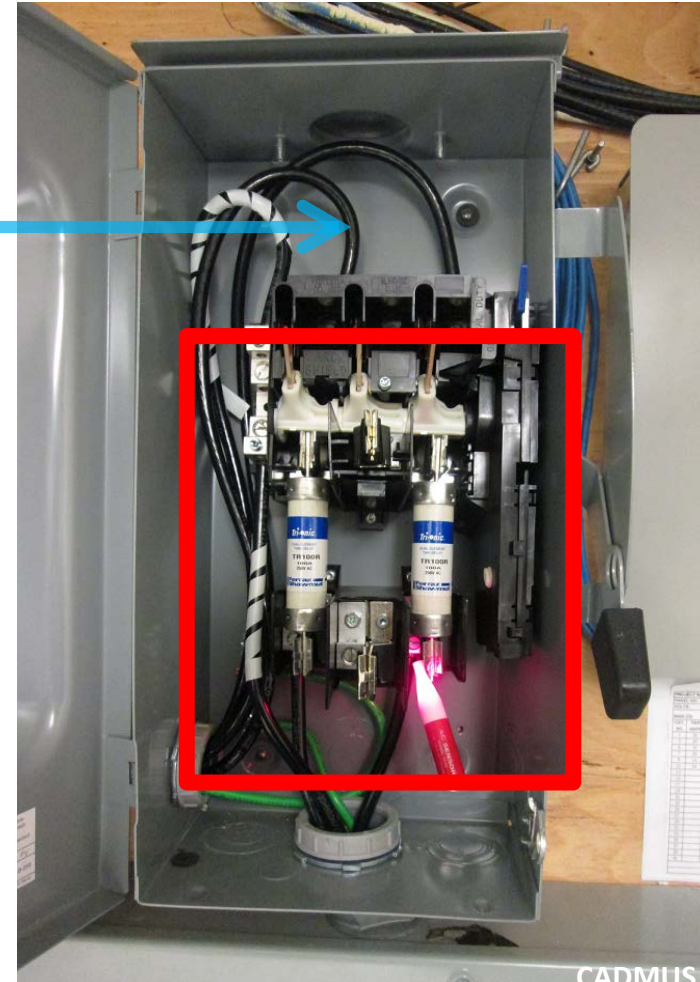




# Supply Side Connection

NEC Article 705.12(A)

- Utility conductors must be on line terminals of disconnect
  - These remain energized when disconnect is opened (turned off)



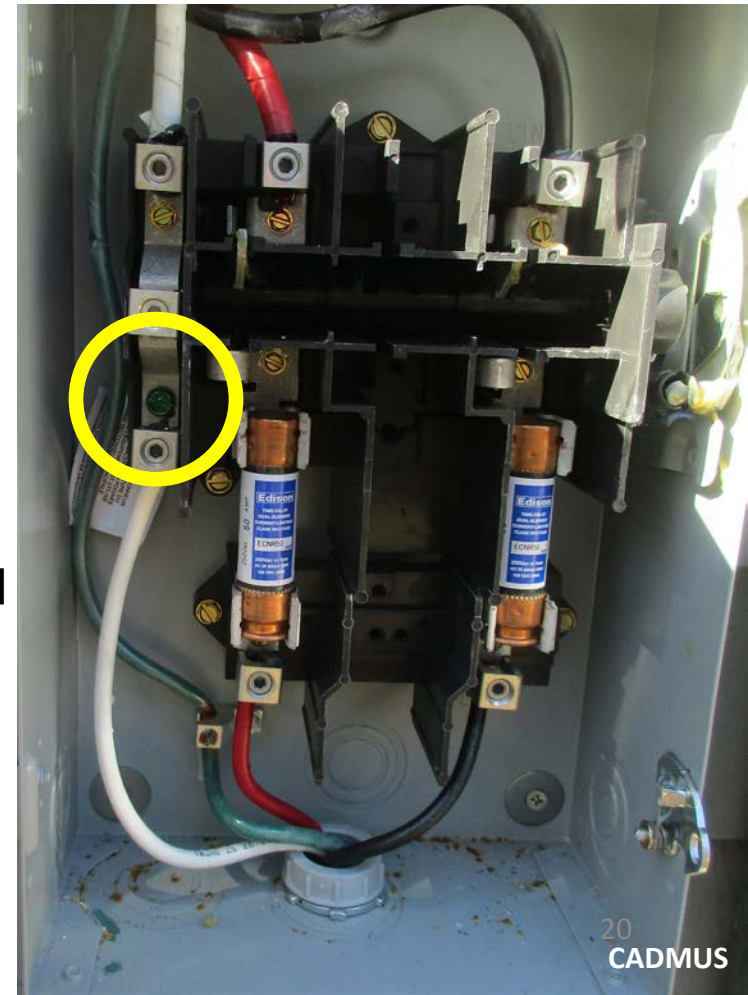
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# Supply Side Connection

## Grounding Service-Supplied Alternating-Current Systems

- NEC Article 250.24(A)(1)
  - The GEC shall be made at any accessible point from the load end of the:
    - Overhead service conductors
    - Service drop
    - Underground service conductors
    - Service lateral
  - To the terminal or bus to which the grounded service conductor is connected at the service disconnecting means
- See also 250.92

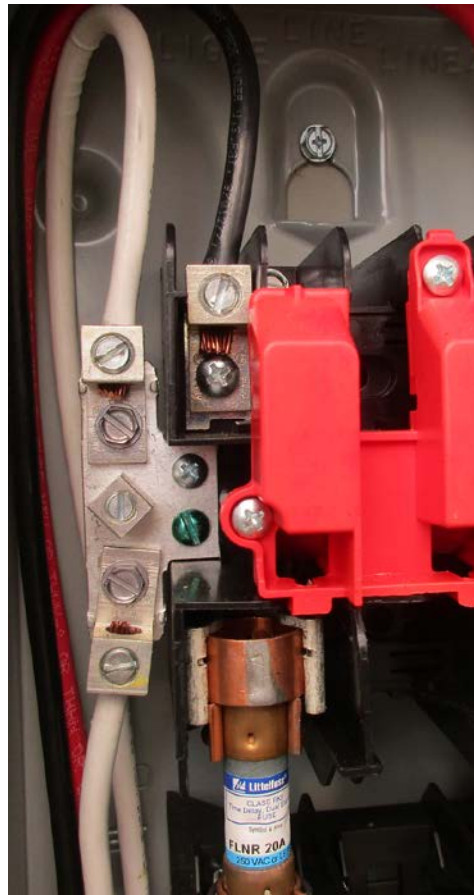
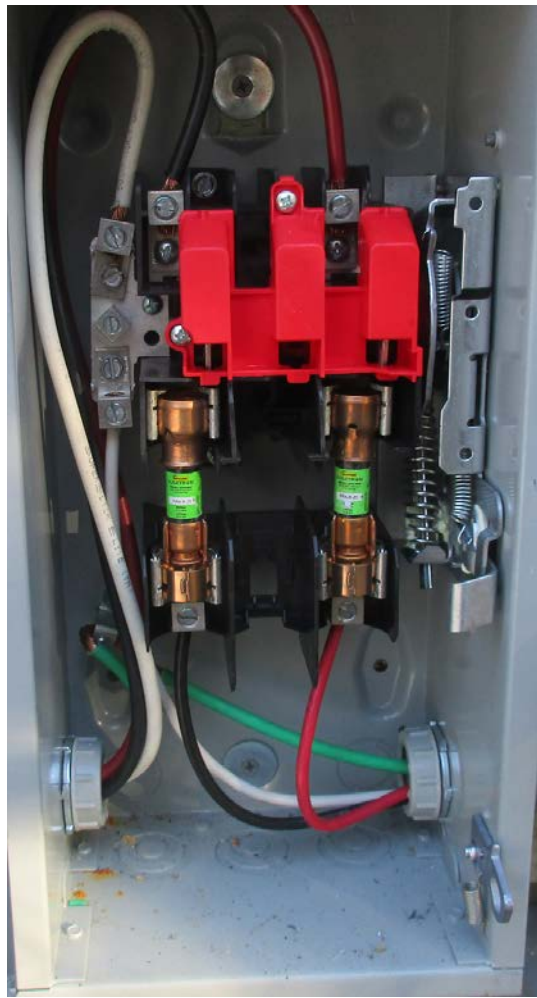






# Supply Side Connection

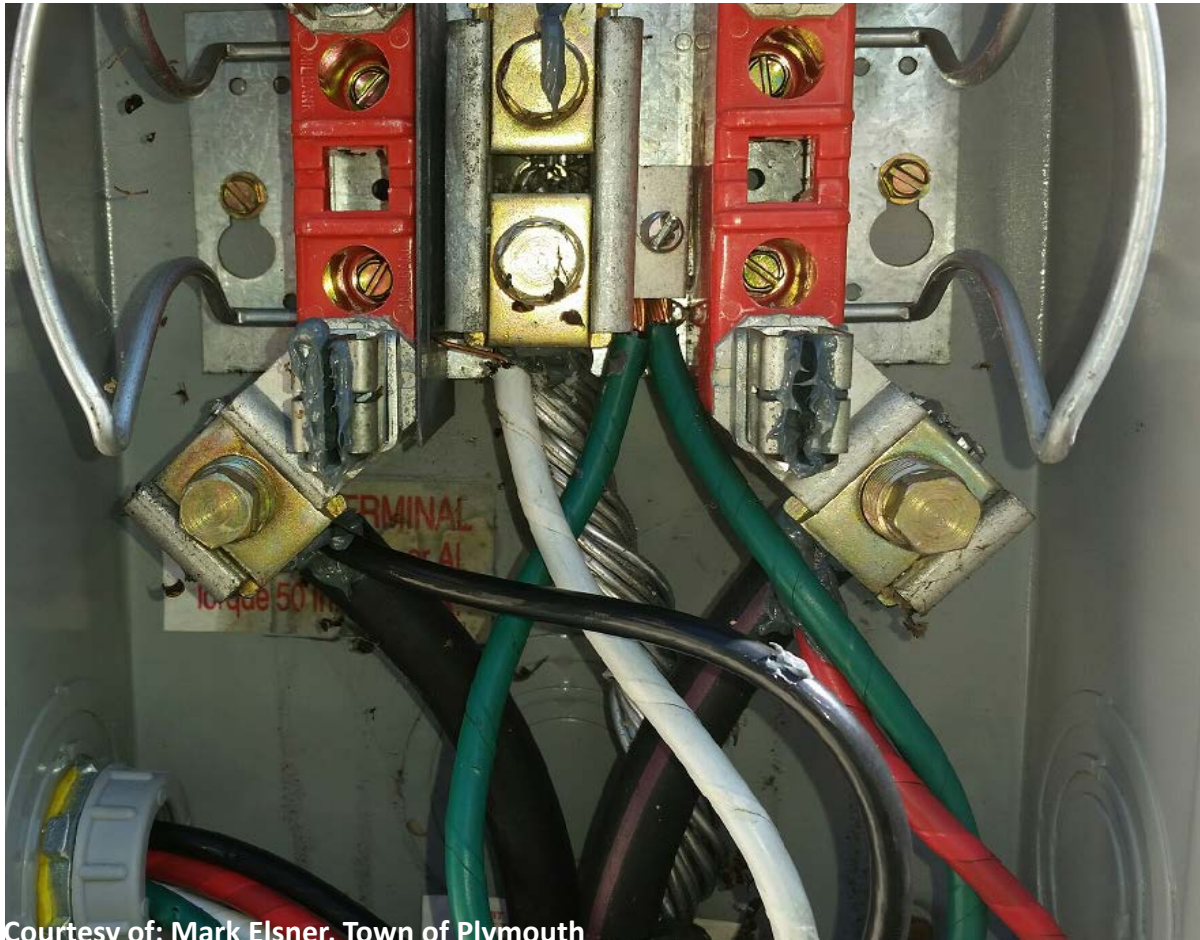
Grounding Service-Supplied Alternating-Current Systems





# Examples of Tapped SE Conductors

*The Wrong Way...*



Courtesy of: Mark Elsner, Town of Plymouth

Conductors are terminated under lugs that are only rated for one wire, and dissimilar metals in contact with each other.





# Examples of Tapped SE Conductors

## *The Wrong Way...*



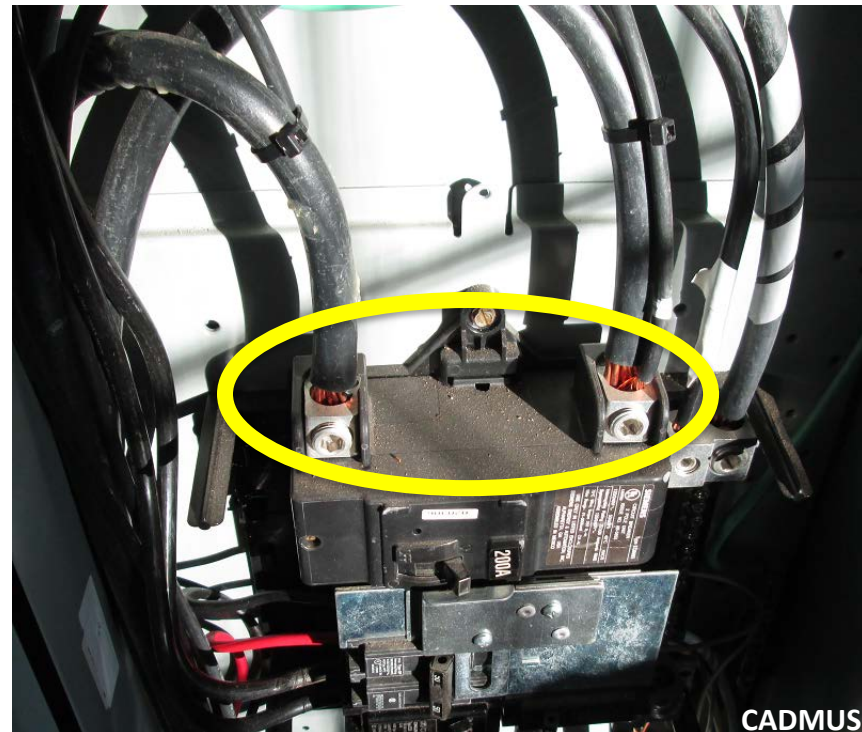
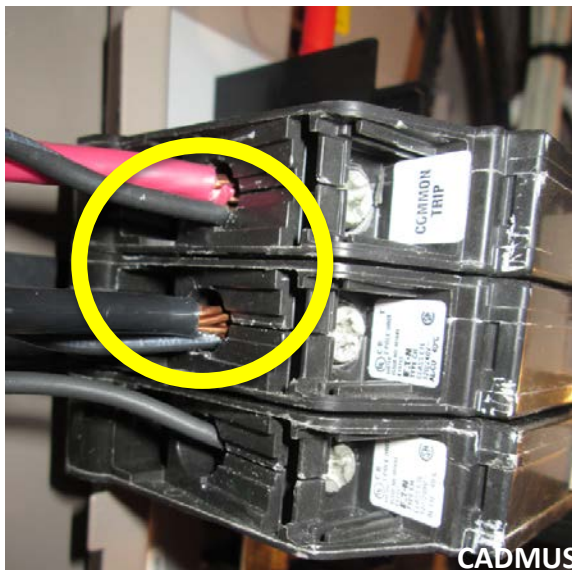
Connection is made inside the utility meter enclosure.



# PV Interconnection

*Considerations...*

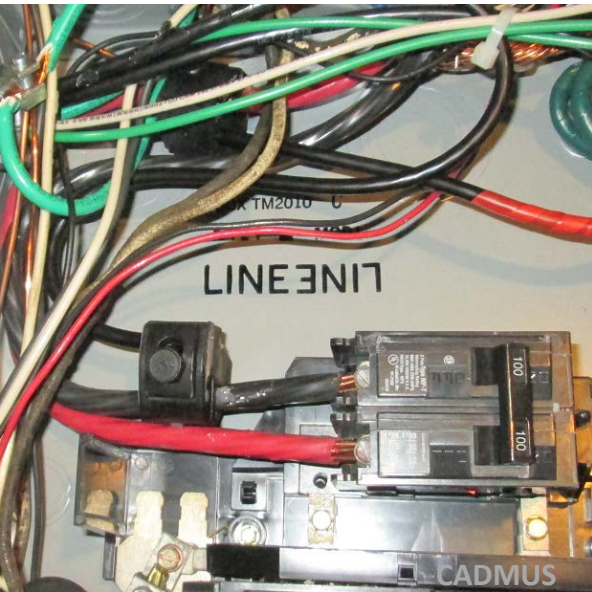
- Terminal ratings should be followed:
  - Conductor size
  - Max conductors



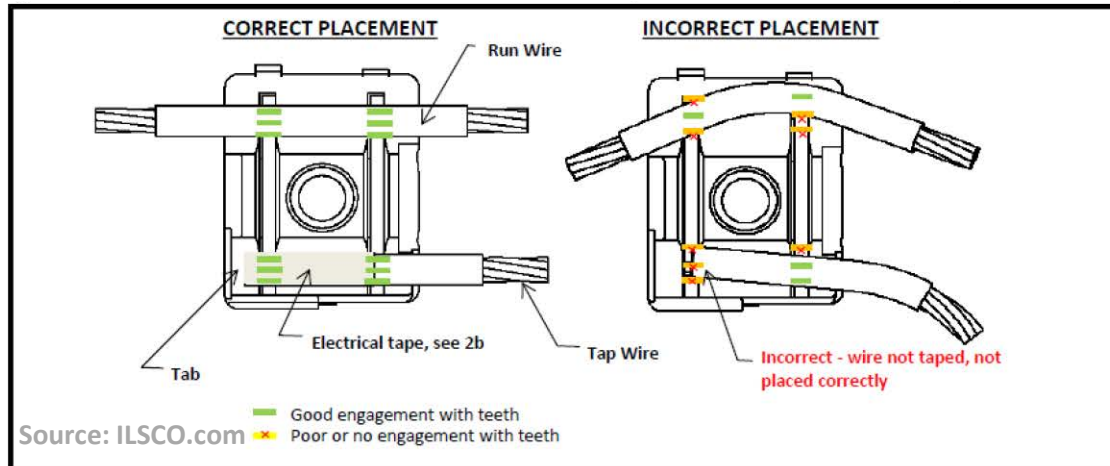
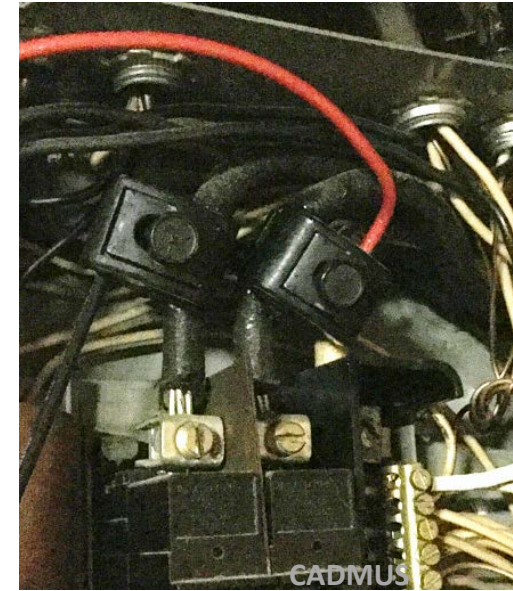




# Insulation-Piercing Connectors/Taps



Source: ILSCO.com







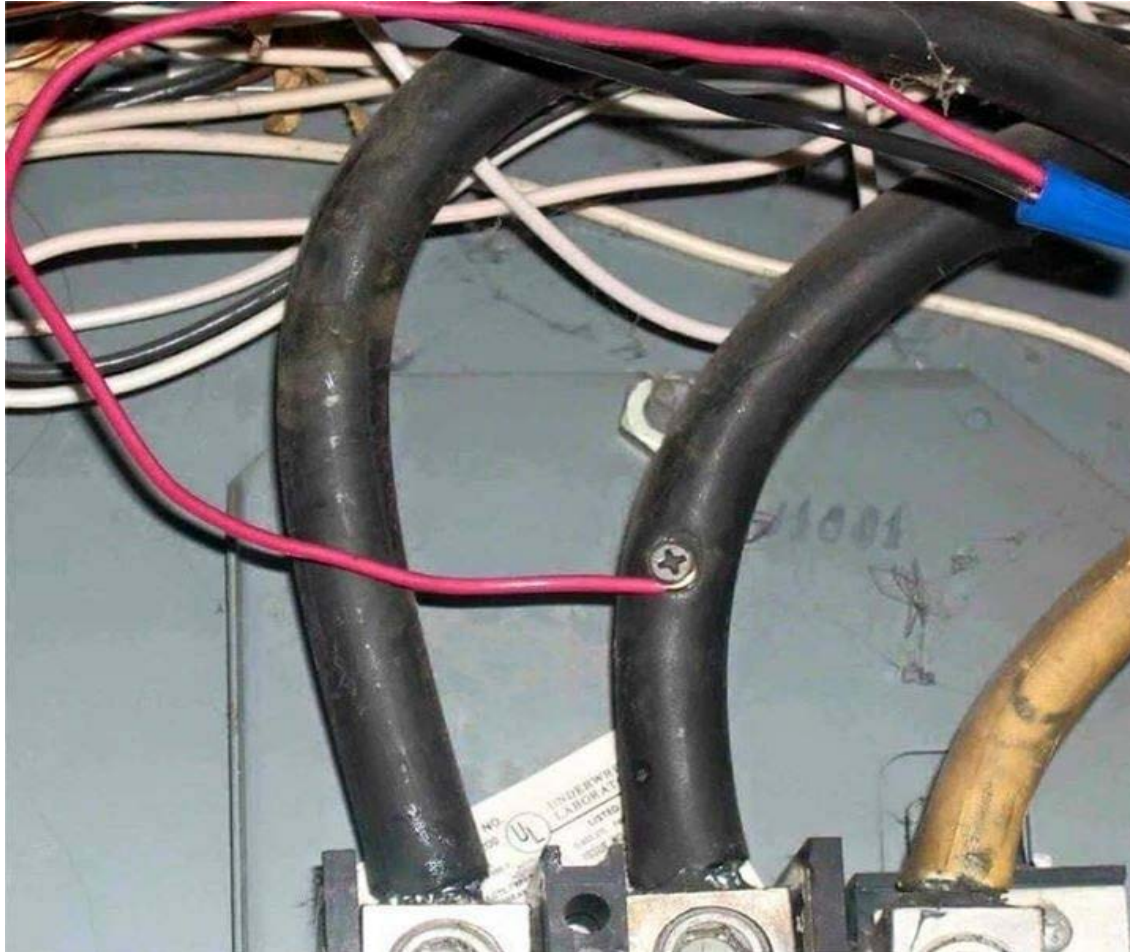
# Insulation-Piercing Connectors/Taps



**Connectors installed outdoors must be rated for the environment.**



## Custom Taps?



Wire is wrapped the wrong way around the screw.

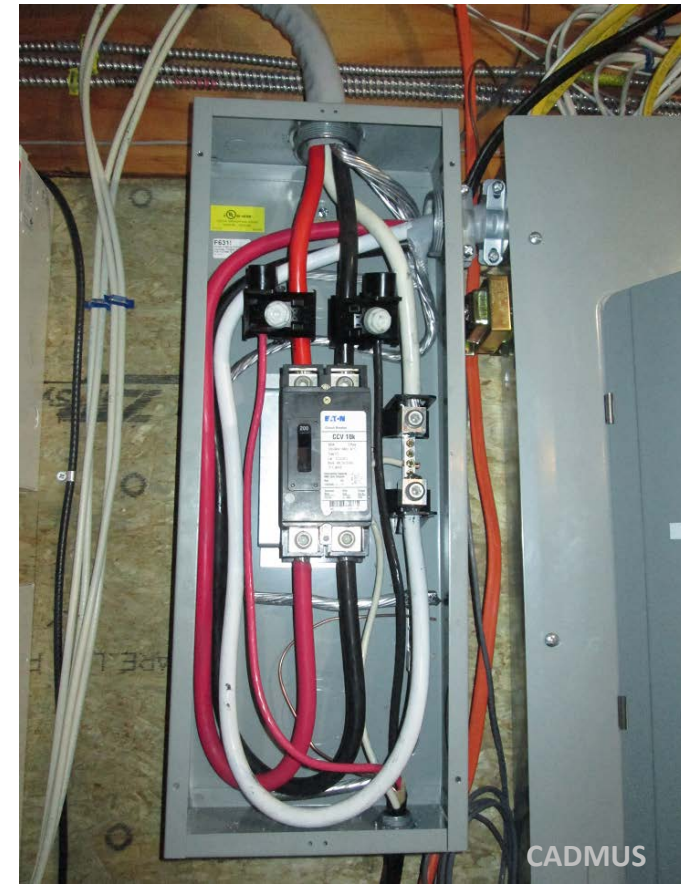




# Load Side Connection

NEC Article 705.12(B)

- Key sections include:
  - (B)(2)(1) Feeders
  - (B)(2)(3) Busbar Interconnection

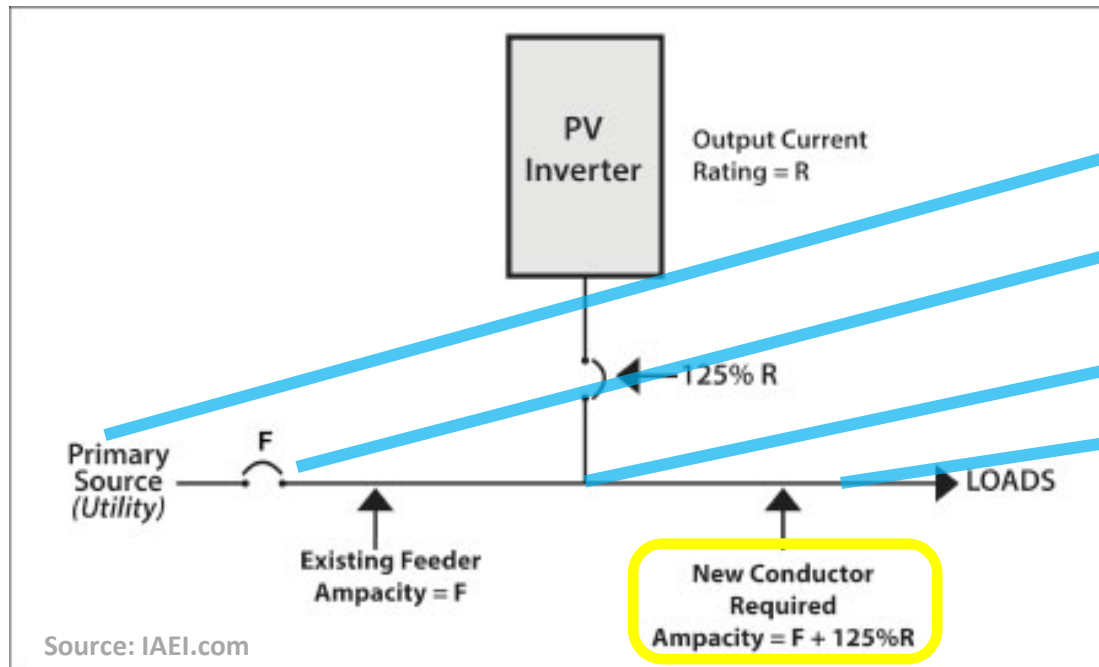




# Bus or Conductor Ampere Rating - Feeders

NEC Article 705.12(B)(2)(1)(a)

- **Option (A)**
- Feeder ampacity not less than sum of:
  - Primary source OCPD
  - 125% of inverter current



Existing conductors must be increased in size (Option A)

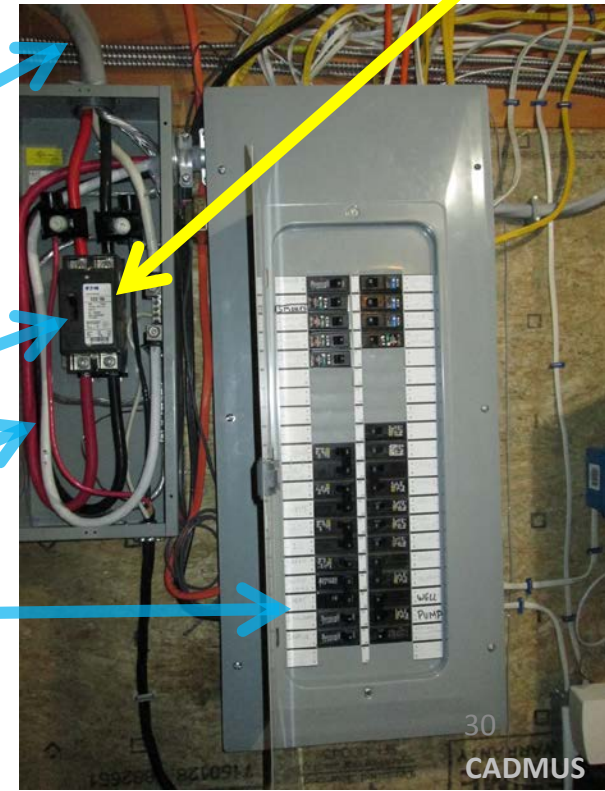
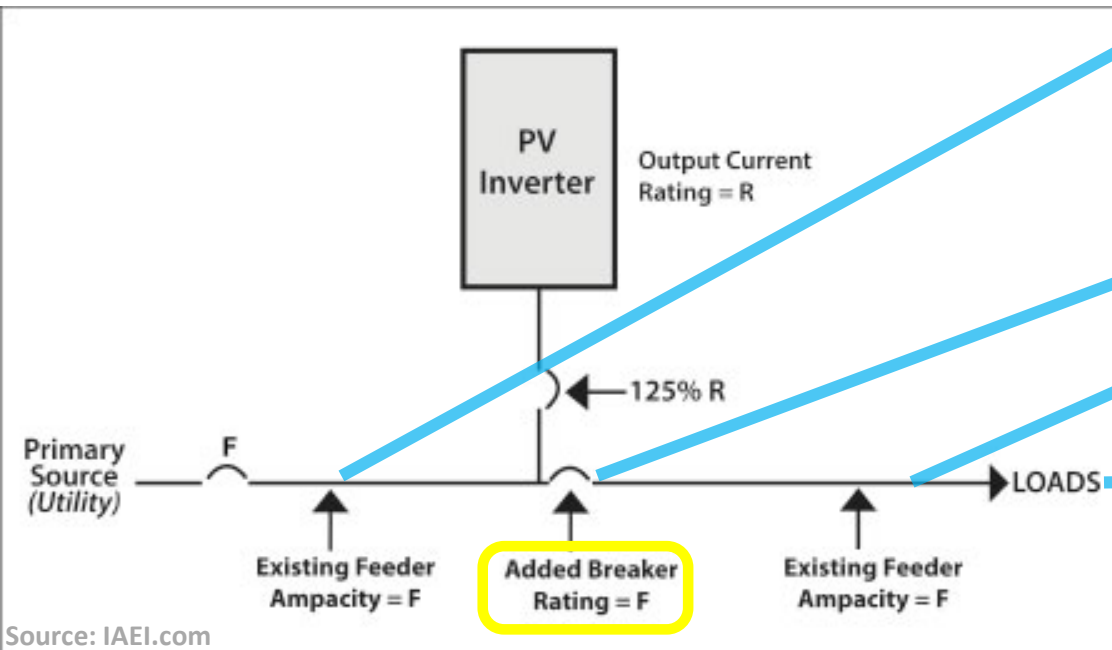


# Bus or Conductor Ampere Rating - Feeder

NEC Article 705.12(B)(2)(1)(b)

- **Option (B)**
- Feeder ampacity not less than primary source OCPD
  - Must add OCPD at interconnection

Existing conductors must be protected (Option B)

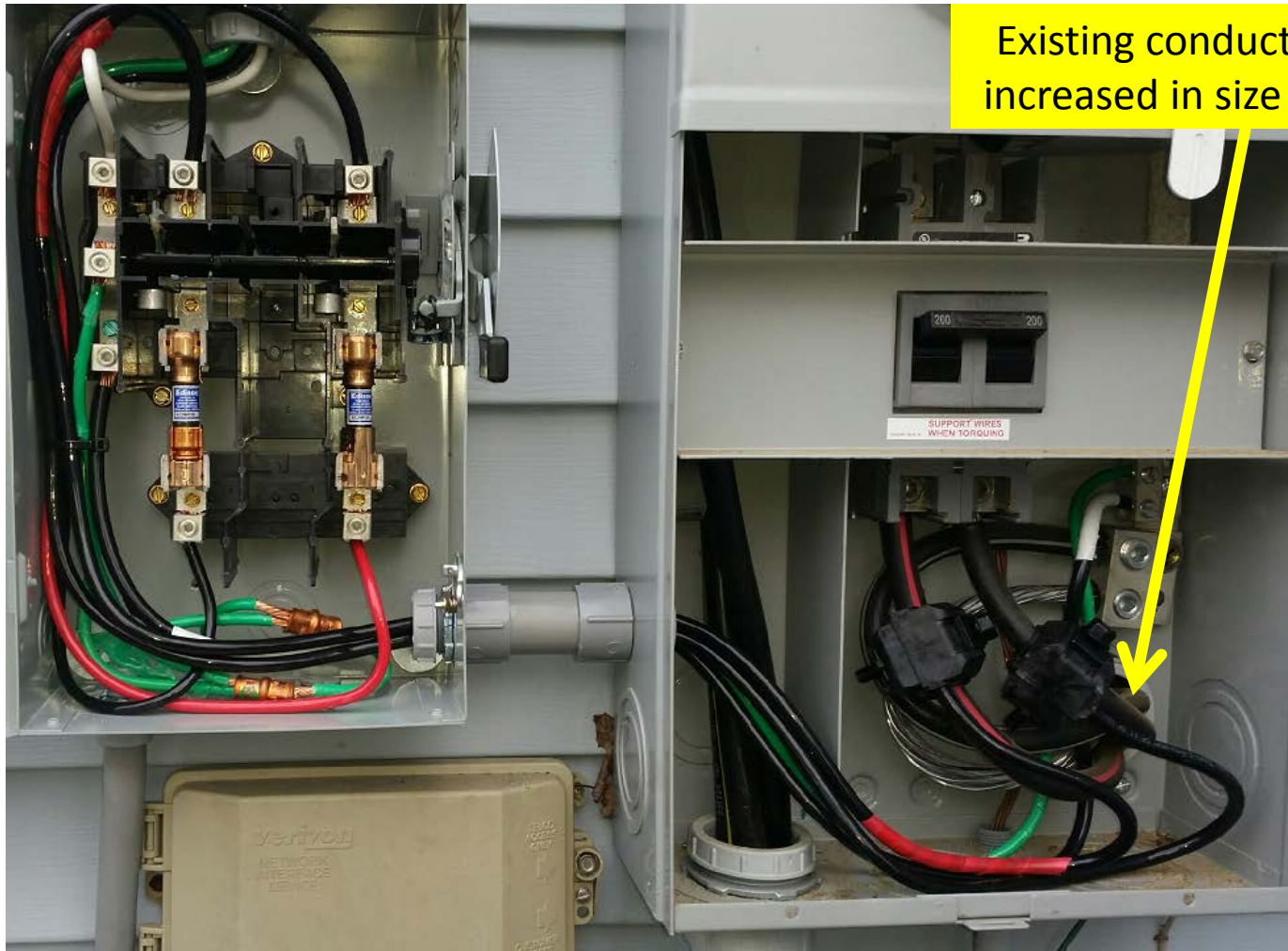






# Bus or Conductor Ampere Rating - **Feeders**

NEC Article 705.12(B)(2)(1)

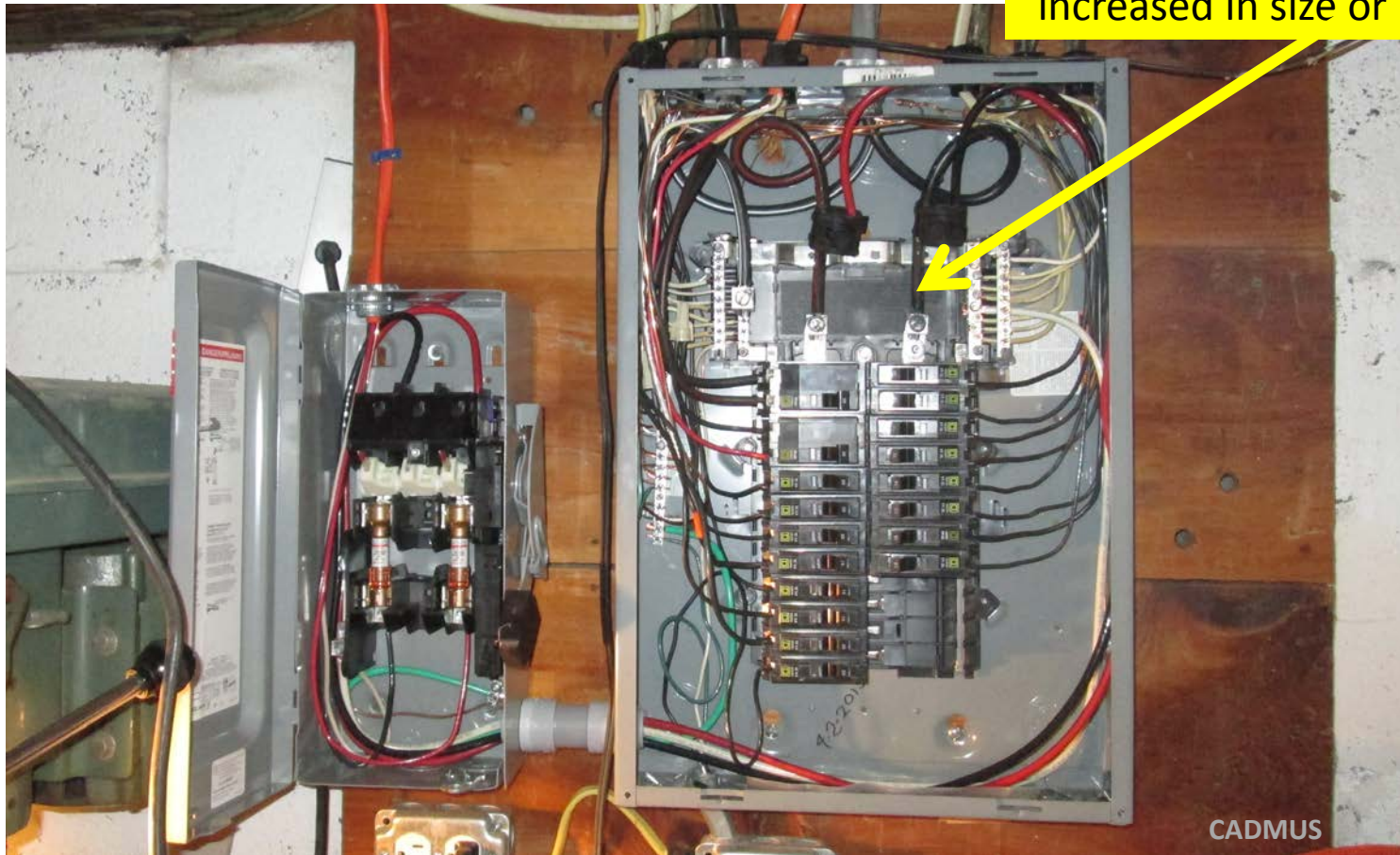




# Bus or Conductor Ampere Rating - **Feeders**

NEC Article 705.12(B)(2)(1)

Existing conductors must be increased in size or protected

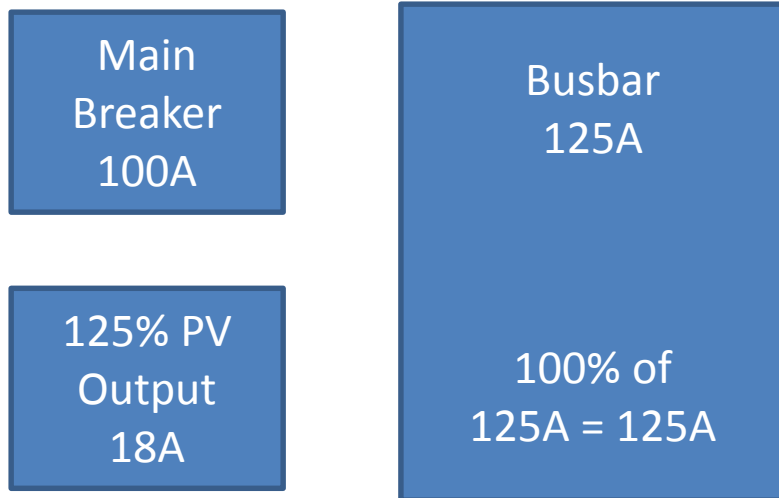




# Bus or Conductor Ampere Rating - Busbars

NEC Article 705.12(B)(2)(3)(a)

- Option (A) *PV & Main less or equal to busbar*
- Busbar ampacity not less than sum of:
  - Main OCPD
  - 125% of power source output current



Example:

Inverter current = 14.4A

$14.4A \times 125\% = 18A$

Main + PV = 118A

100% Busbar = 125A

**118A feeds < 125A bus**

- PV breaker can be located anywhere

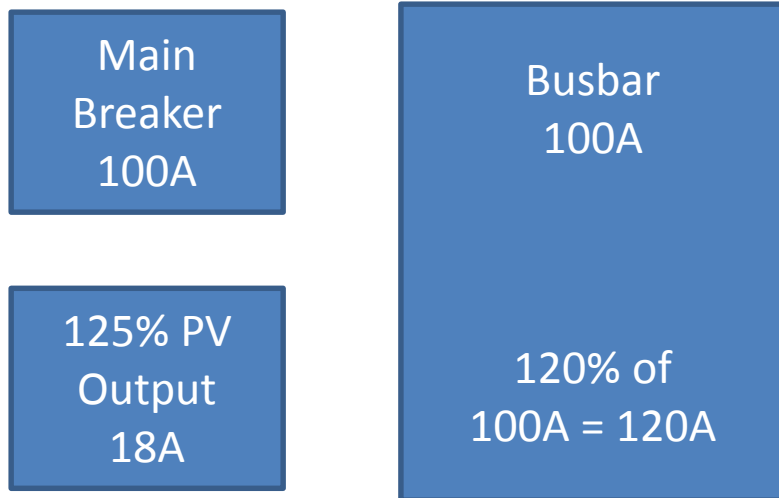




# Bus or Conductor Ampere Rating - Busbars

NEC Article 705.12(B)(2)(3)(b)

- Option (B) ***“120% Rule”***
- 120% of busbar ampacity not less than sum of:
  - Main OCPD
  - 125% of power source output current



Example:

Inverter current = 14.4A

$14.4\text{A} \times 125\% = 18\text{A}$

Main + PV = 118A

120% Busbar = 120A

**118A feeds < 120A bus**

- PV breaker must be at opposite end
  - “Do not relocate” label required

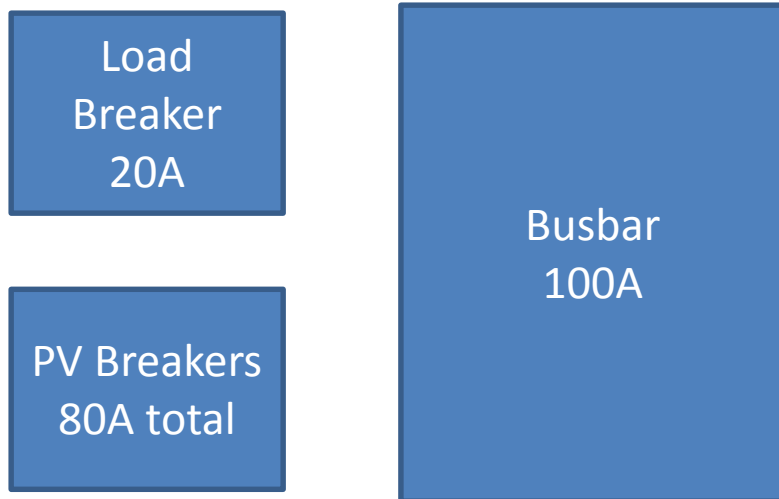




# Bus or Conductor Ampere Rating - Busbars

NEC Article 705.12(B)(2)(3)(c)

- Option (C) ***“AC Combiner Panelboard”***
- Busbar ampacity not less than sum of:
  - All breaker ratings (PV or other loads)
  - Excluding main OCPD



Example:  
4 20A inverter breakers  
 $4 \times 20A = 80A$

Loads + PV = 100A

100% Busbar = 100A

**100A loads & PV = 100A bus**

- Permanent warning label required



# Bus or Conductor Ampere Rating - Busbars

NEC Article 705.12(B)(2)(3)(d)

- Option (D) ***“120% Rule (Center-Fed Panelboard in Dwellings)”***
- 120% of busbar ampacity not less than sum of:
  - Main OCPD
  - 125% of power source output current

125% PV  
Output  
18A

Main  
Breaker  
200A



Example:

Inverter current = 14.4A

$14.4A \times 125\% = 18A$

Main + PV = 218A

120% Busbar = 240A

**218A feeds < 240A bus**

- PV breaker can be at either end, but not both



# Wire Harness and Exposed Cable AFCI Protection

## **Former** NEC Article 705.12(D)(6)

- **Removed in 2017 NEC, no products available**
- Intended for micro inverters
- Wire harness or cable output circuit rated:
  - 240 Volts
  - 30 Amps or less
- Not installed in a raceway, listed AFCI protection
  - Circuit breaker, suitable for backfeed





# Breaker Fastening

NEC Article 705.12(B)(5)

- Listed plug-in type circuit breakers backfed from electric power sources that are listed and identified as interactive shall be **permitted to omit the additional fastener** normally required by 408.36(D) for such applications.







# Array

Grounding/Bonding  
Wiring Methods  
Microinverters  
Modules





# Equipment Grounding and Bonding

NEC Article 690.43 / 250.4

- A moderate amount of inspections contain issues with Array equipment grounding





# Equipment Grounding and Bonding

NEC Article 690.43 / 250.4

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

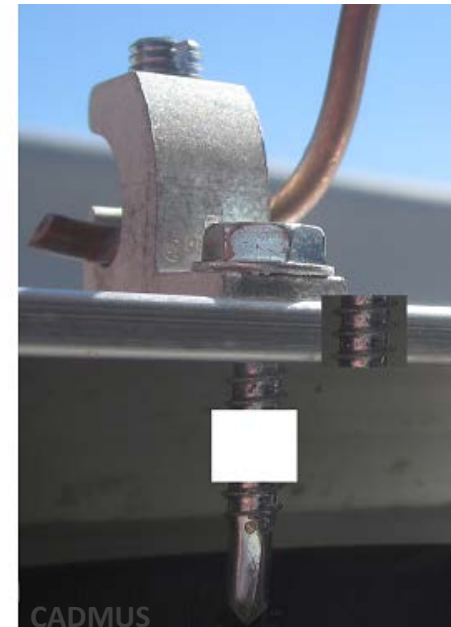
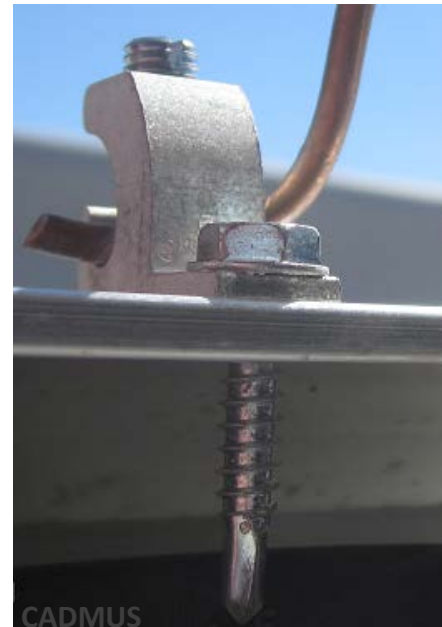




# Connection of Grounding and Bonding Equipment

## 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
  - ***Read the instructions!!!***





# Grounding the Racking

## *Considerations*

- Wire management
- Conductor type/material
- Size
  - 690.46, PV modules, raceway/protection for smaller than #6 AWG
- Splices
  - Where permissible
  - Not in lay-in lugs



# Grounding the Racking

## Wrong Screw (110.3(B) and 250.8)







# Grounding the Racking

## Trip Hazard





# Module Frame Grounding

## 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
  - Integrated bonding
    - Check the model!
  - Plastic frame
    - No ground required





# Module Frame Grounding

*Unless it's plastic!*







# Module Frame Grounding

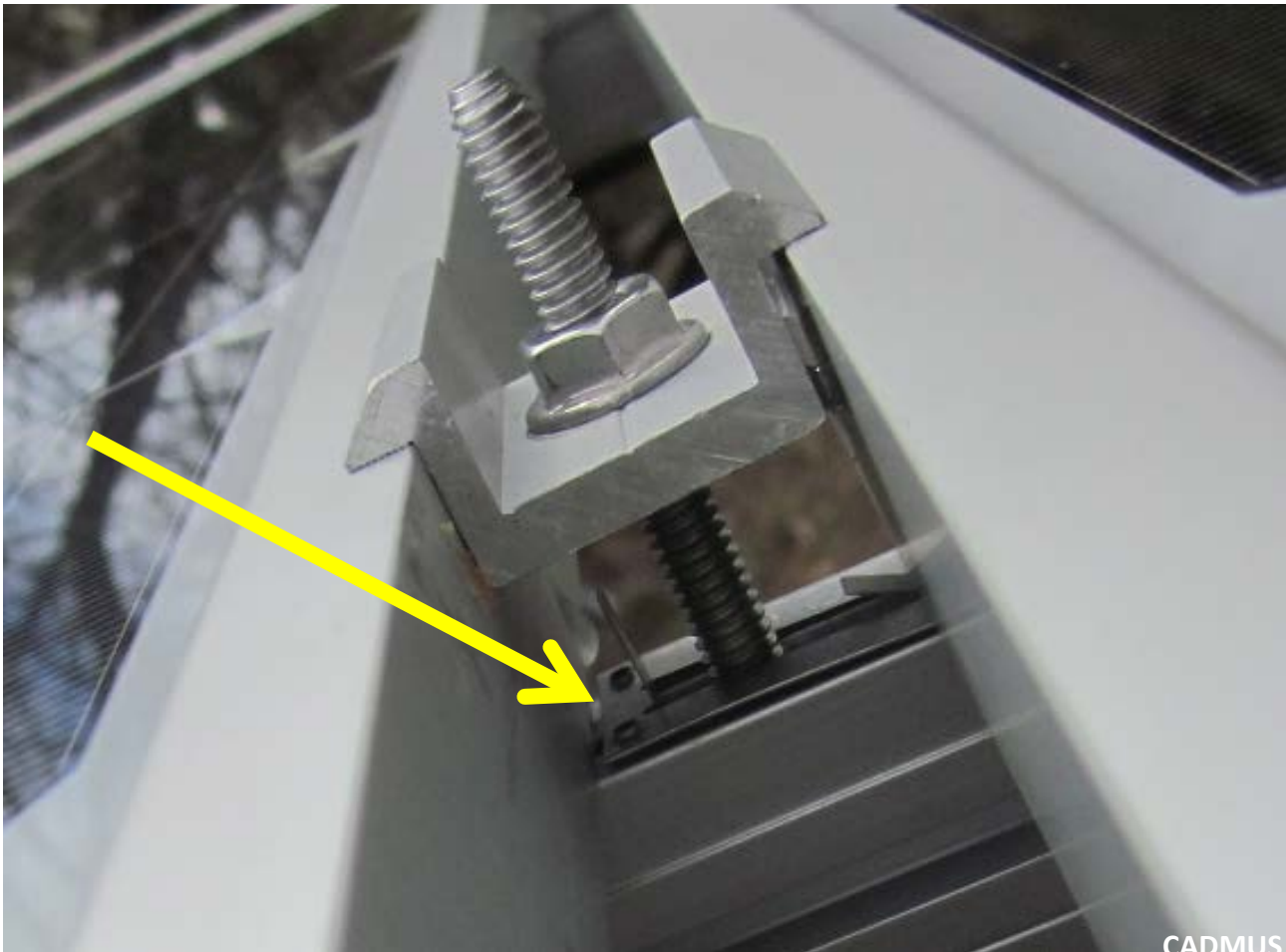
Wrong Lugs – (Copper or Not Listed for Outdoor)





# Module Frame Grounding

Right Fitting, Installed Wrong

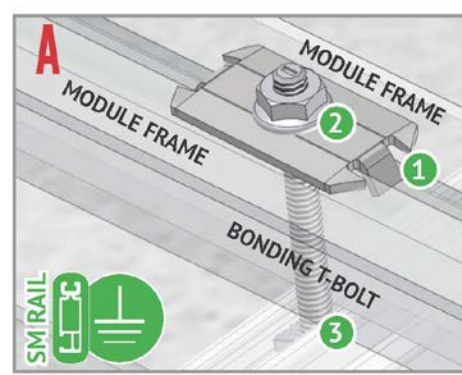




# Module Frame Grounding

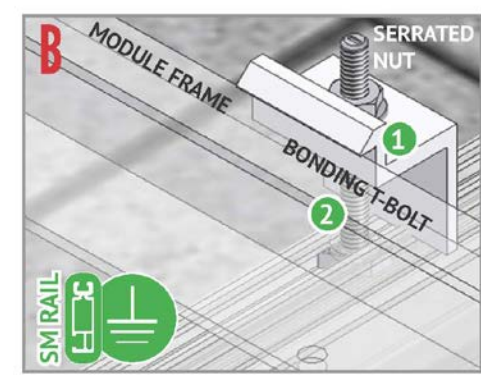
## Integrated Bonding Considerations

- Some manufacturers:
  - Only midclamps listed to bond module frames, not end clamps
- READ THE INSTRUCTIONS



### BONDING MIDCLAMP ASSEMBLY

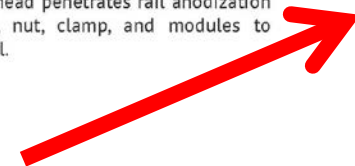
- 1 Stainless steel Midclamp points, 2 per module, pierce module frame anodization to bond module to module through clamp.
- 2 Serrated flange nut bonds stainless steel clamp to stainless steel T-bolt
- 3 Serrated T-bolt head penetrates rail anodization to bond T-bolt, nut, clamp, and modules to grounded SM rail.



### ENDCLAMP ASSEMBLY

- 1 Serrated flange nut bonds aluminum Endclamp to stainless steel T-bolt
- 2 Serrated T-bolt head penetrates rail anodization to bond T-bolt, nut, and Endclamp to grounded SM rail

Note: End clamp does not bond to module frame.







# Module Frame Grounding

## Integrated Bonding Considerations

- Other manufacturers:
  - Midclamps and endclamps are listed to bond module frames

Tech Brief

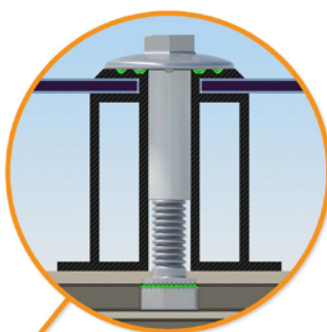


UFO Family of Components

### Simplified Grounding for Every Application

The UFO family of components eliminates the need for separate grounding hardware by bonding solar modules directly to IronRidge XR Rails. All system types that feature the UFO family—Flush Mount, Tilt Mount and Ground Mount—are fully listed to the UL 2703 standard.

UFO hardware forms secure electrical bonds with both the module and the rail, resulting in many parallel grounding paths throughout the system. This leads to safer and more reliable installations.



**Universal Fastening Object (UFO)**  
The UFO securely bonds solar modules to XR Rails. It comes assembled and lubricated, and can fit a wide range of module heights.



**Stopper Sleeve**  
The Stopper Sleeve snaps onto the UFO, converting it into a bonded end clamp.



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# Conductor Protection

Almost half of inspections contain issues with conductor protection...

- Conductors shall be protected against physical damage (including those beneath array)
  - Articles:
    - 300.4
    - 338.10(B)(4)(b)
    - 334.30
    - 338.12(A)(1)





**PV conductors are not supported under the array.**





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**PV conductors are subject to abrasion.**







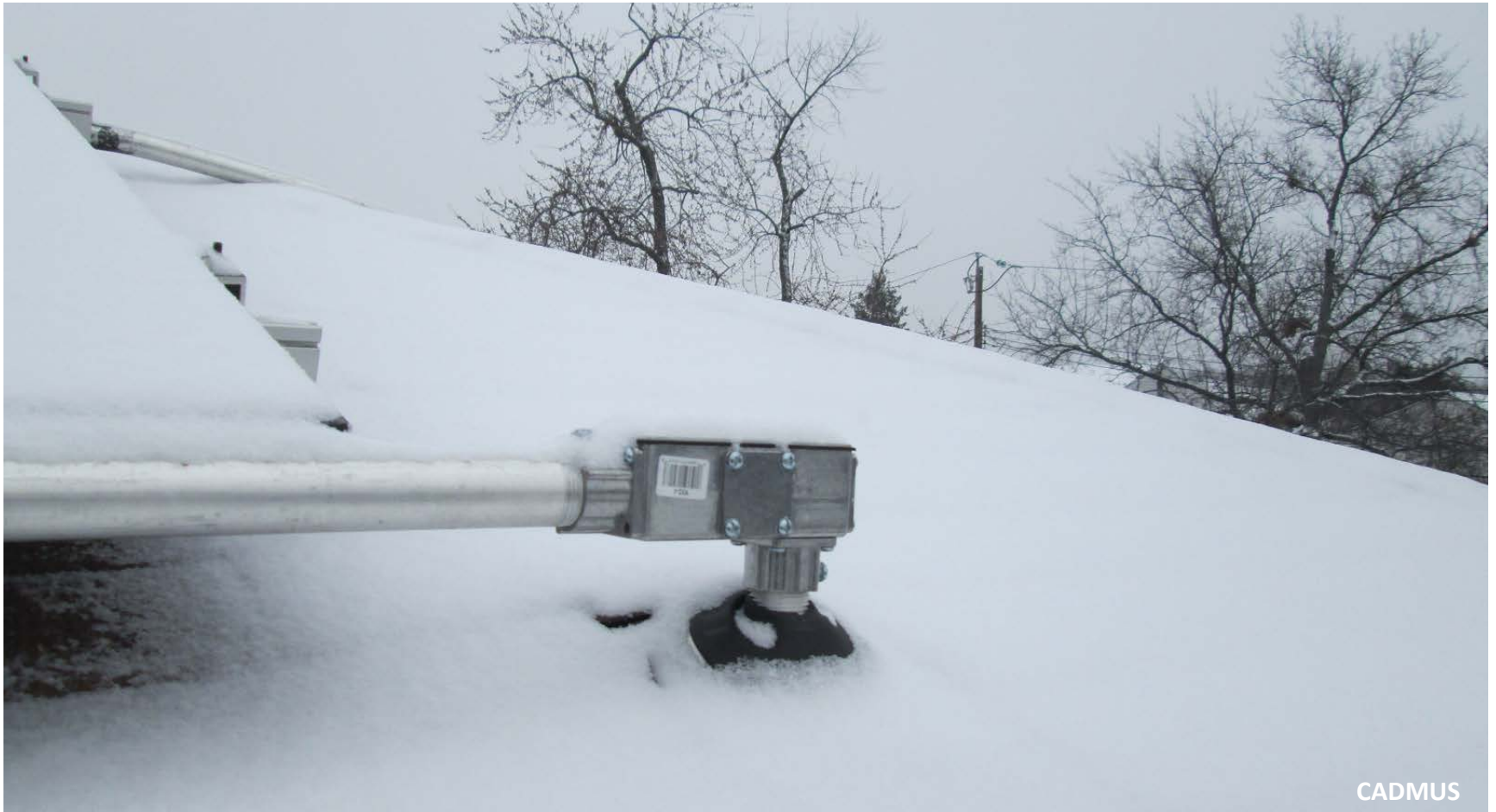
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**Unprotected PV output conductors.**





# The Right Way...



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PV output conductors installed in conduit.



## The Right Way...



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PV output conductors installed in conduit.





## The Right Way...



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PV conductors free from physical damage.





## The Right Way...



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PV conductors supported from roof surface.



PV conductors are properly supported under the array. Upper photo taken from ladder, lower photo taken from ground.



# Microinverter Mounting Hardware

- Be aware of microinverter mounting bolt length relative to module frames!!







# Readily Accessible Locations

NEC Article 690.31(A)

- Ground-mount arrays
  - In readily accessible locations, conductors **shall be guarded** or installed in a raceway





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**PV conductors in readily accessible locations shall be guarded (preferably not with CAUTION tape) or be installed in a raceway.**





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PV conductors in readily accessible locations shall be installed in a raceway.

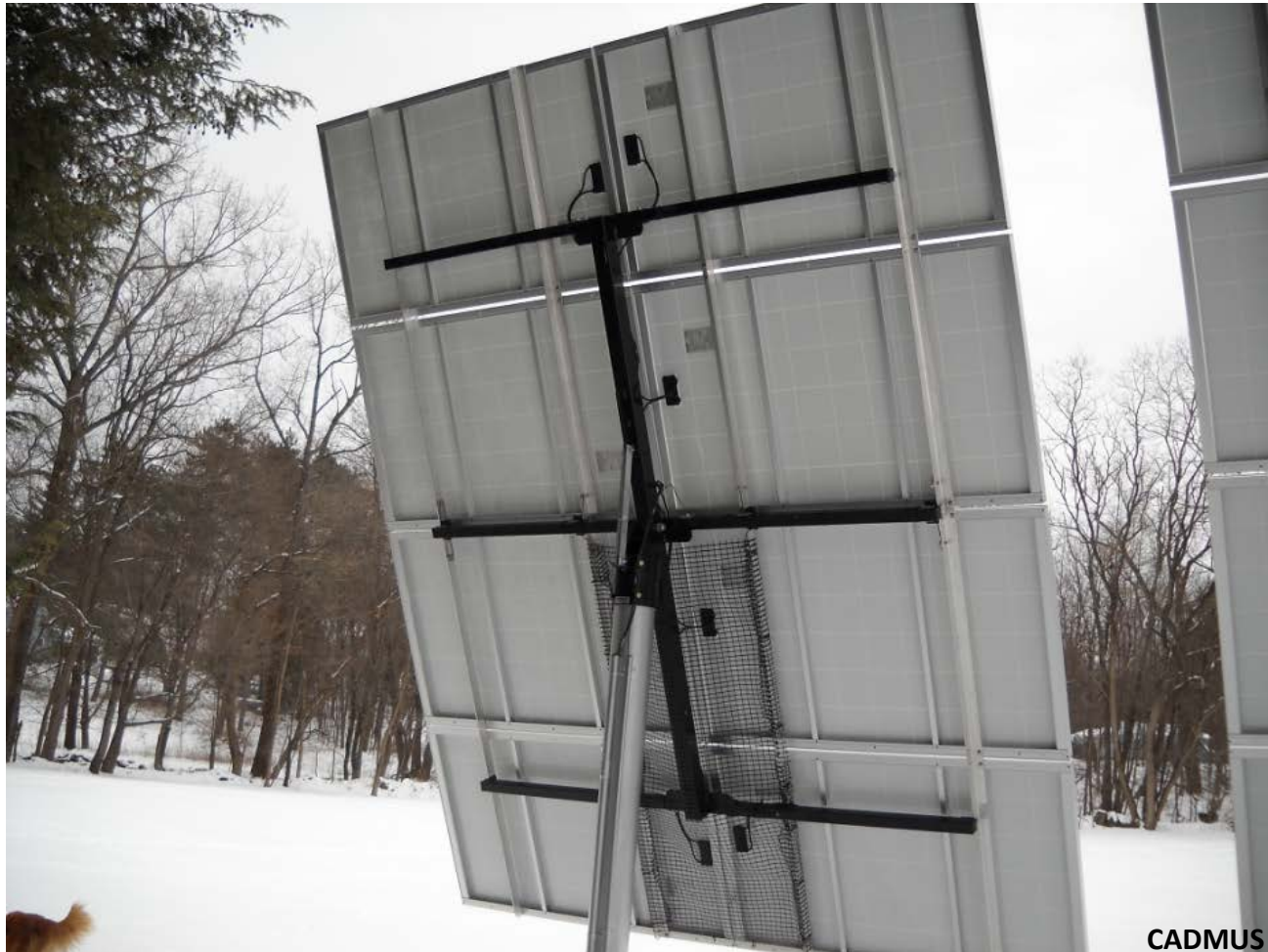




**PV conductors in readily accessible locations shall be guarded or installed in a raceway.**



## The Right Way...



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**Readily accessible PV conductors properly guarded.**





## The Right Way...



**Readily accessible PV conductors properly guarded.**





# Module Mounting/Securing

More than a quarter of all inspections contain issues with module/racking installation...

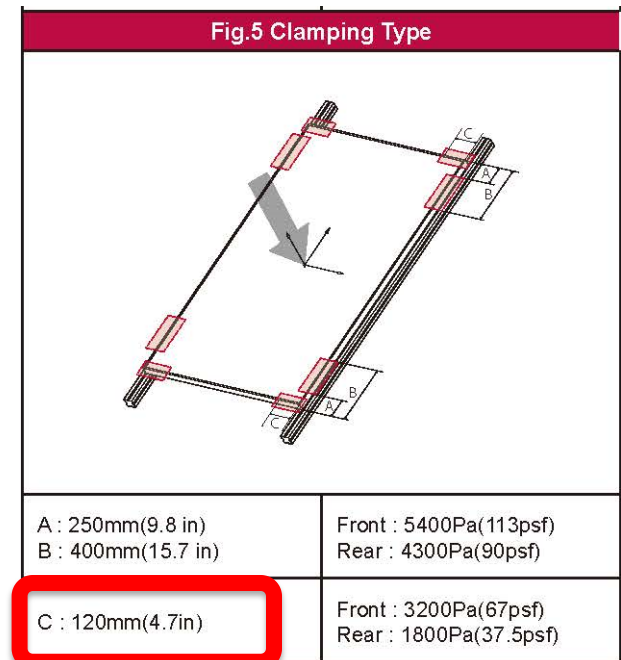
- Modules shall be installed in accordance with their **installation instructions**, as required by NEC Article 110.3(B):
  - Secured at proper locations
  - Utilizing the proper hardware



# Module Mounting/Securing

Proper Locations

- Limitations for supporting modules in landscape



Source: LGSolarUSA.com

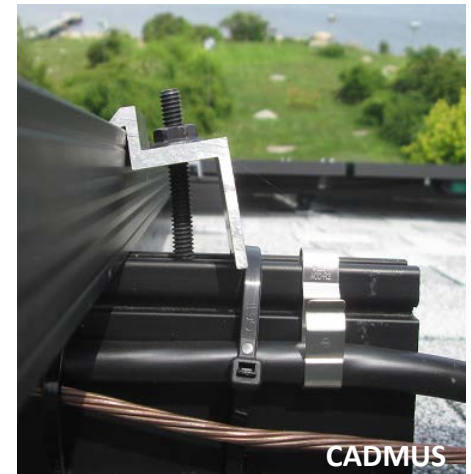




# Module Mounting/Securing

Proper Hardware

- Endclamps are **not** one-size fits-all
- Midclamps typically can't be installed as endclamps



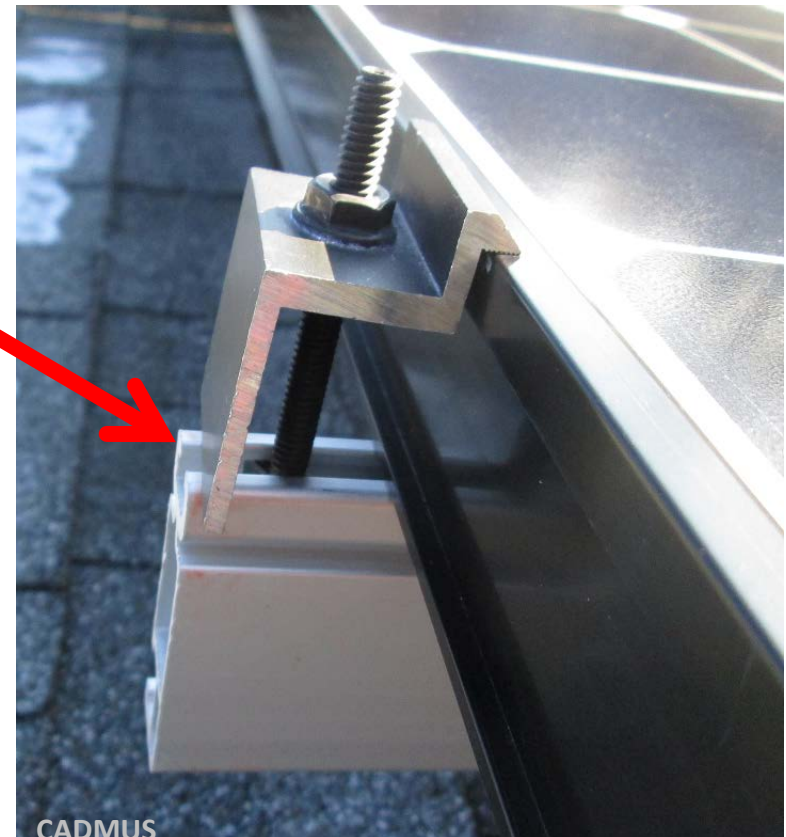




# Module Mounting/Securing

Rail Length

- Most manufacturers specify at least  $\frac{1}{2}$ " of space:
  - Between the end clamp and the end of the rail to
  - Allow for thermal expansion and vibration.

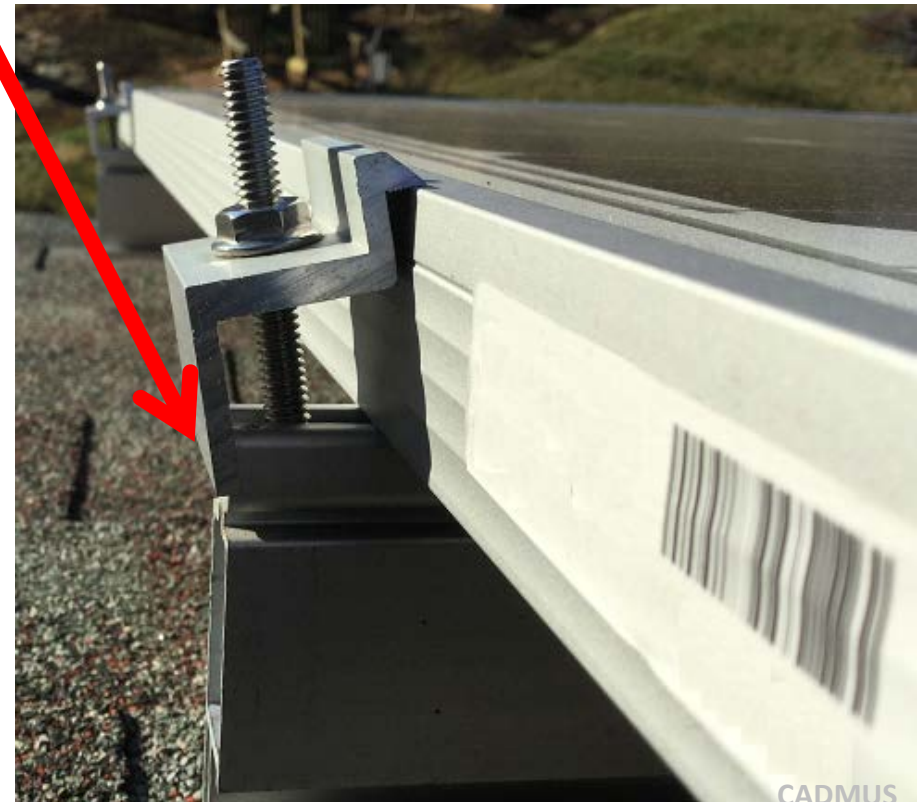
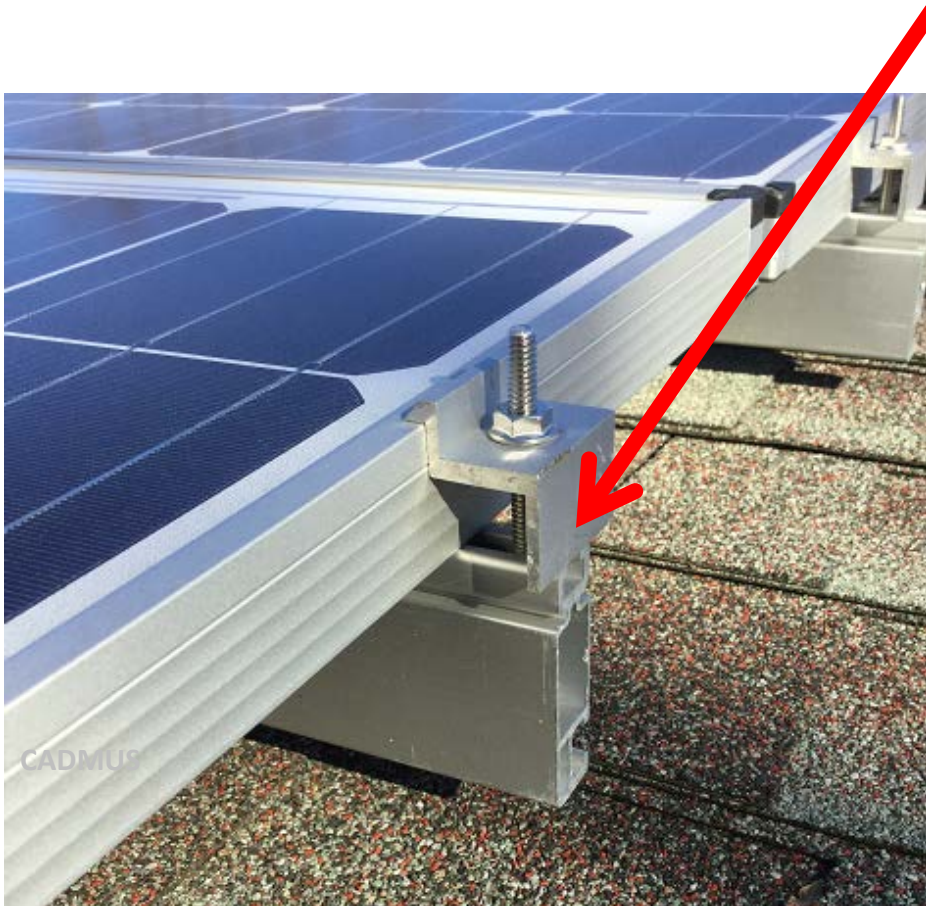


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# Module Mounting/Securing

## Rail Length

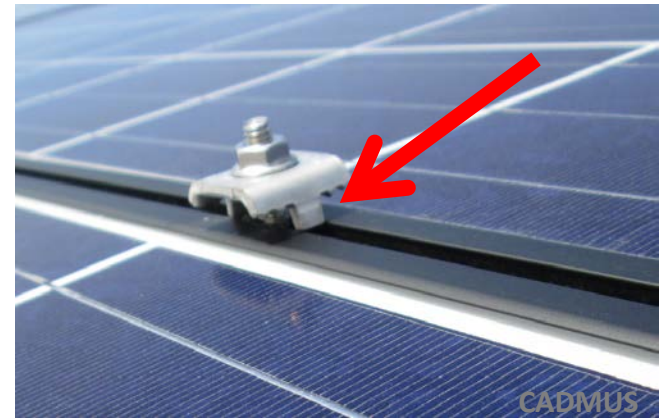
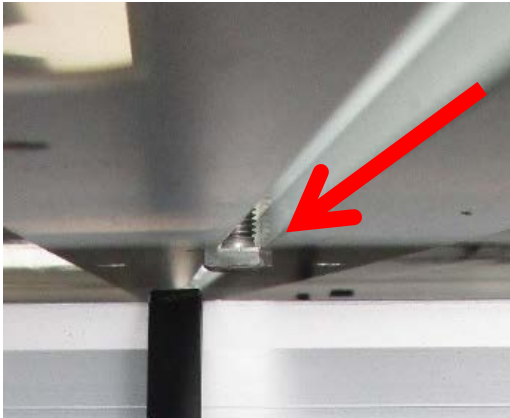






# Module Mounting/Securing

Missing Hardware/Improperly Secured







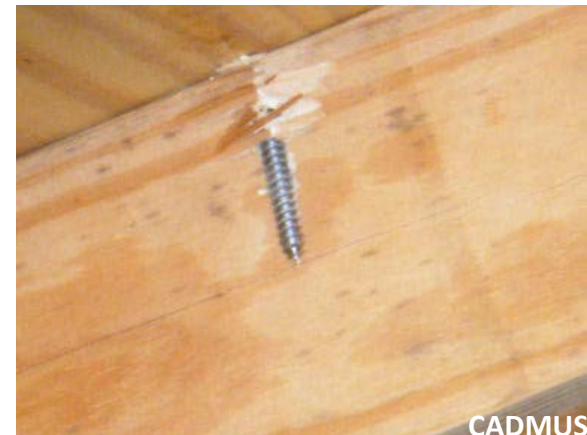
# Roof Penetrations/Flashing

- Improper/missing flashing





# Lag Bolts



Lag bolt missed the rafter.





# Lag Bolts



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Lag bolts missed the rafter.



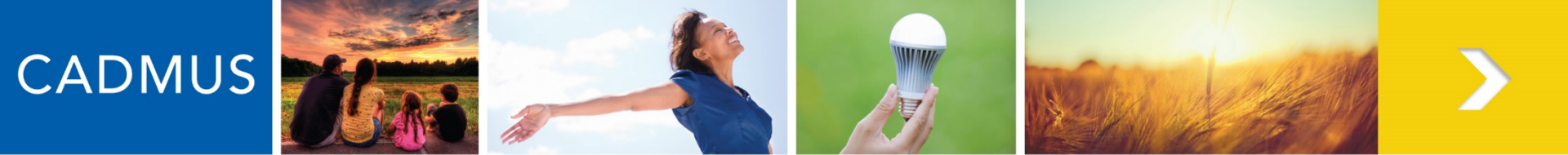






# PV System Labeling





# PV System Labeling

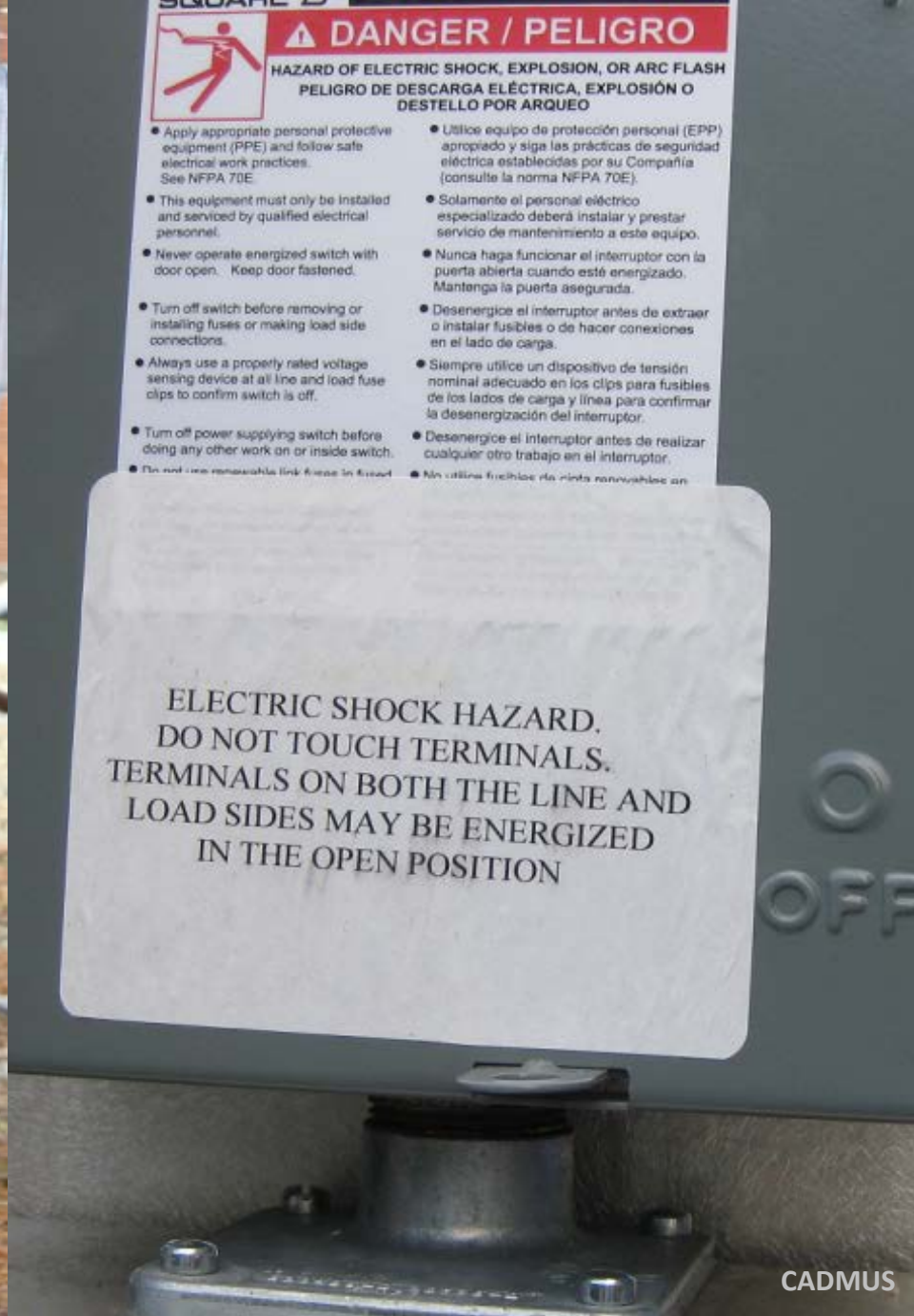
## Key Articles

The majority of inspections contain issues labeling...

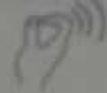
- Many labeling requirements refer to 110.21(B)
- Field-Applied Hazard Markings
  - Words, colors, symbols to meet ANSI Z535.4-2001
  - **NOT HAND WRITTEN**
  - **Sufficient to withstand the environment involved**







Labels are faded and not suitable for the environment.



System 651W  
Today 21.604kWh

Xantrex

Solar Inverter



online



ground fault



PV SYSTEM DISCONNECT

# WARNING

Photovoltaic Power Source

DC VOLTAGE IS ALWAYS PRESENT WHEN MODULES ARE EXPOSED TO  
LIGHT

RATED MAXIMUM POWERPOINT CURRENT(IMP)(15) ADC

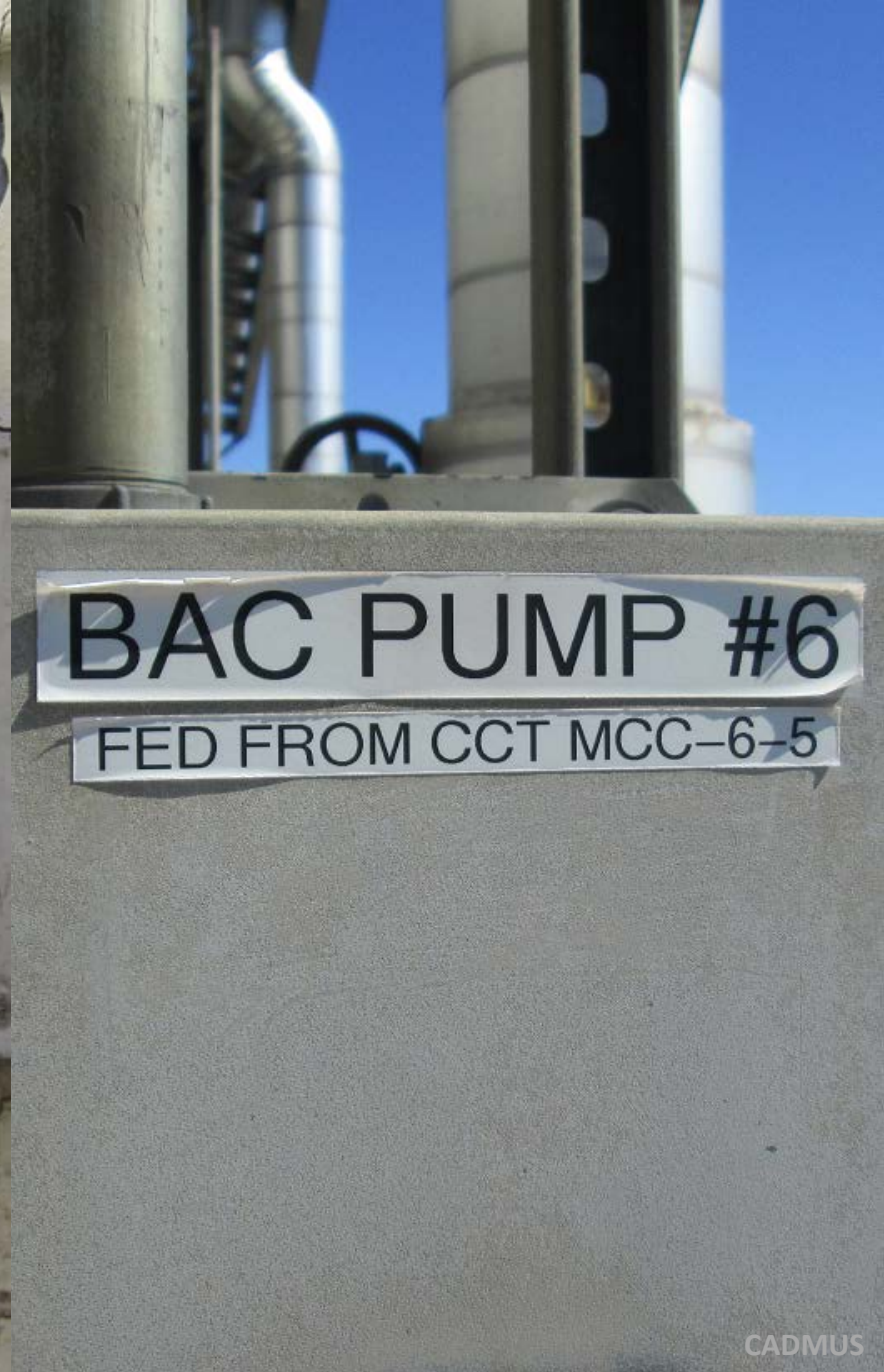
RATED MAXIMUM POWERPOINT CURRENT(VMP)(242) VDC

MAXIMUM SYSTEM VOLTAGE(VOC)(525) VOC

MAXIMUM SYSTEM CURRENT(ISC)( 16.32) ADC

OPERATING DC POWER 5040 WATTS





Labels are peeling and not suitable for the environment.





Labels are faded and not suitable for the environment.



# DC Raceway Label

NEC Article 690.31(G)(3) and (G)(4)

- On or in a building
- Raceways, enclosures, every 10'

**WARNING:  
PHOTOVOLTAIC POWER SOURCE**

– Minimum 3/8" CAPS

– **White** on **Red**

– **Reflective**



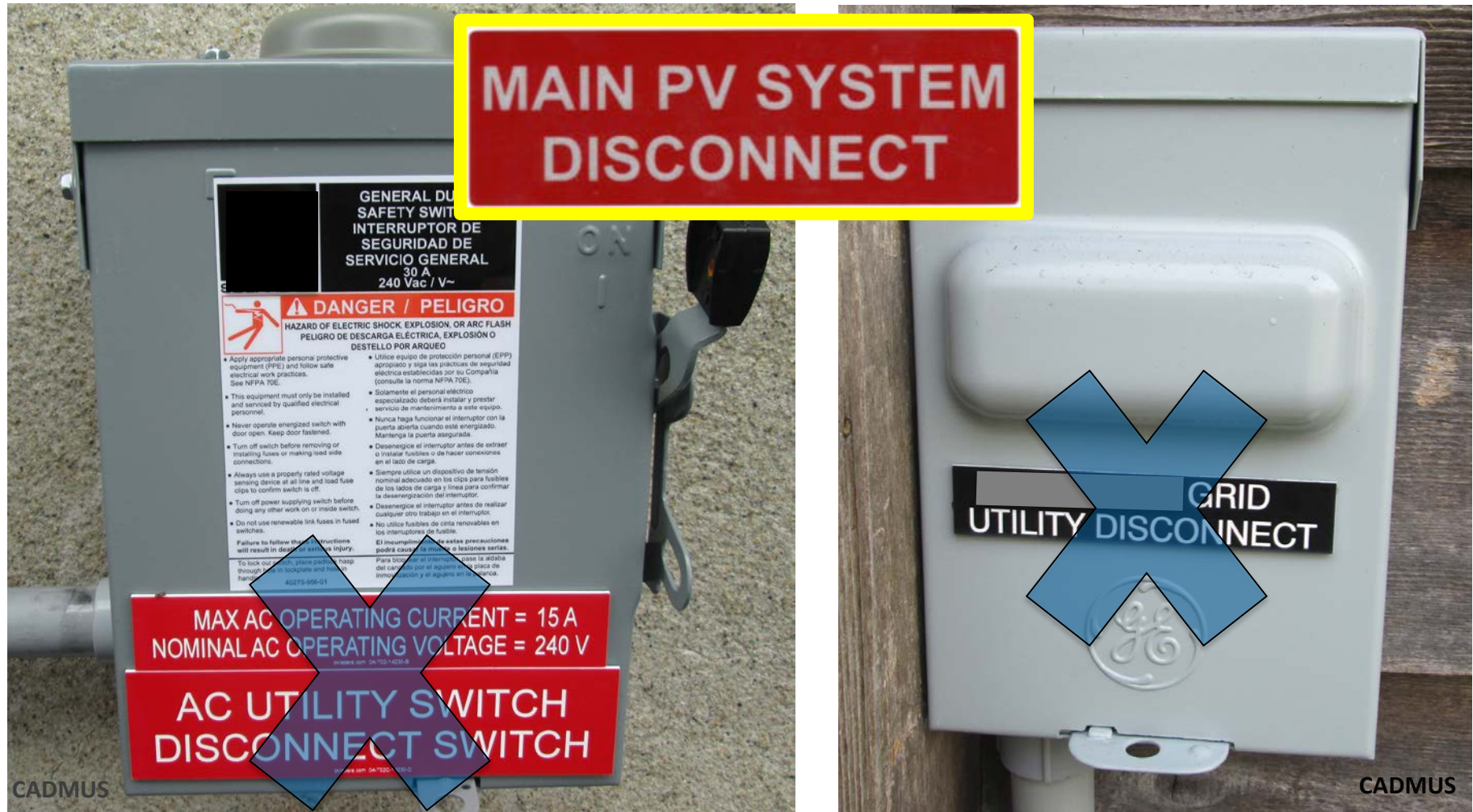
Warning labels for DC raceways shall be reflective.

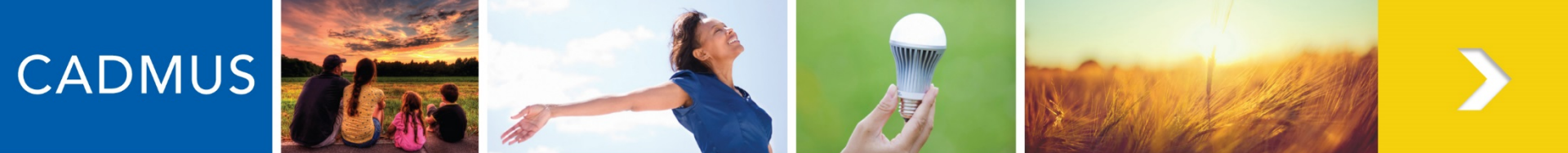




# PV System Disconnect

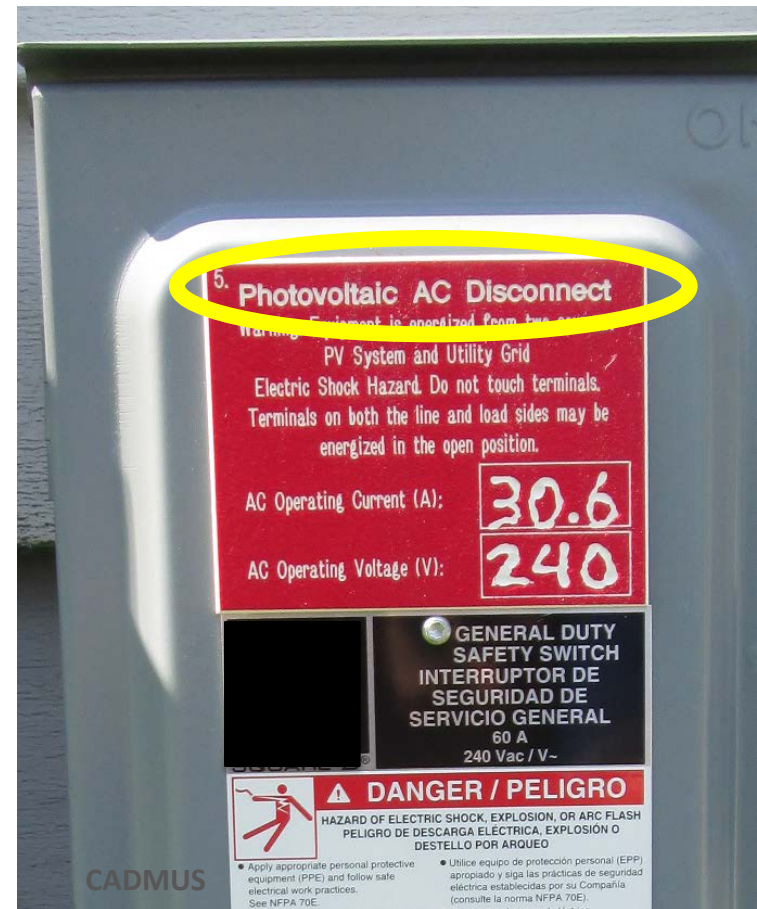
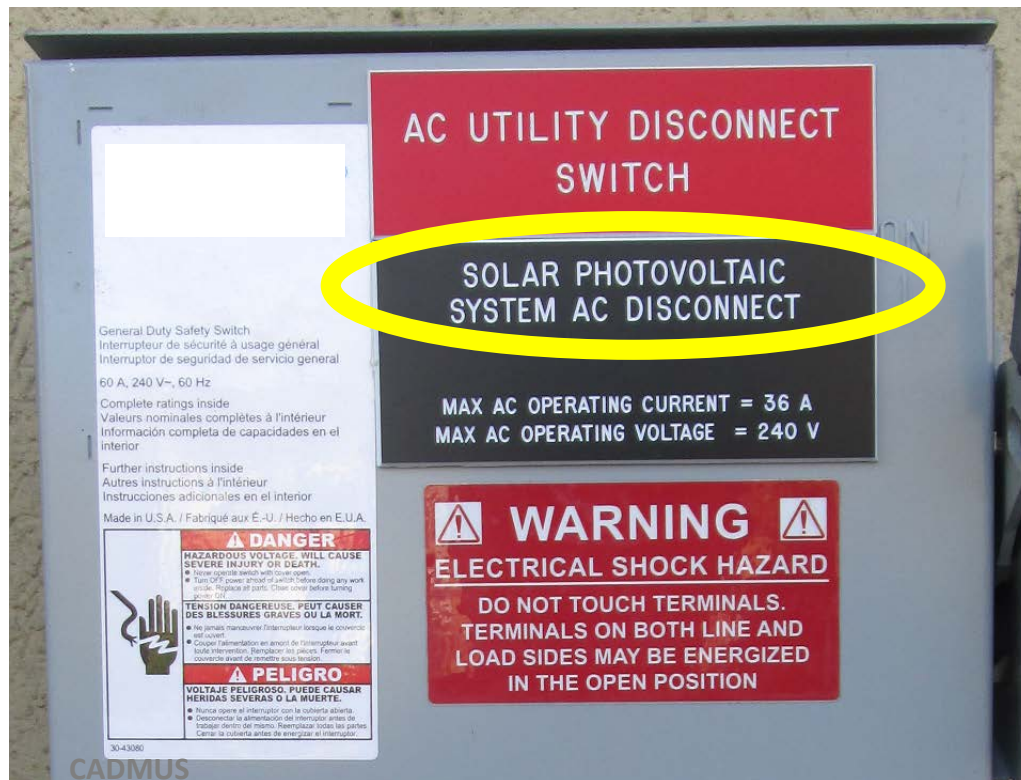
NEC Article 690.13(B)





# PV System Disconnect

*The Right Way...*



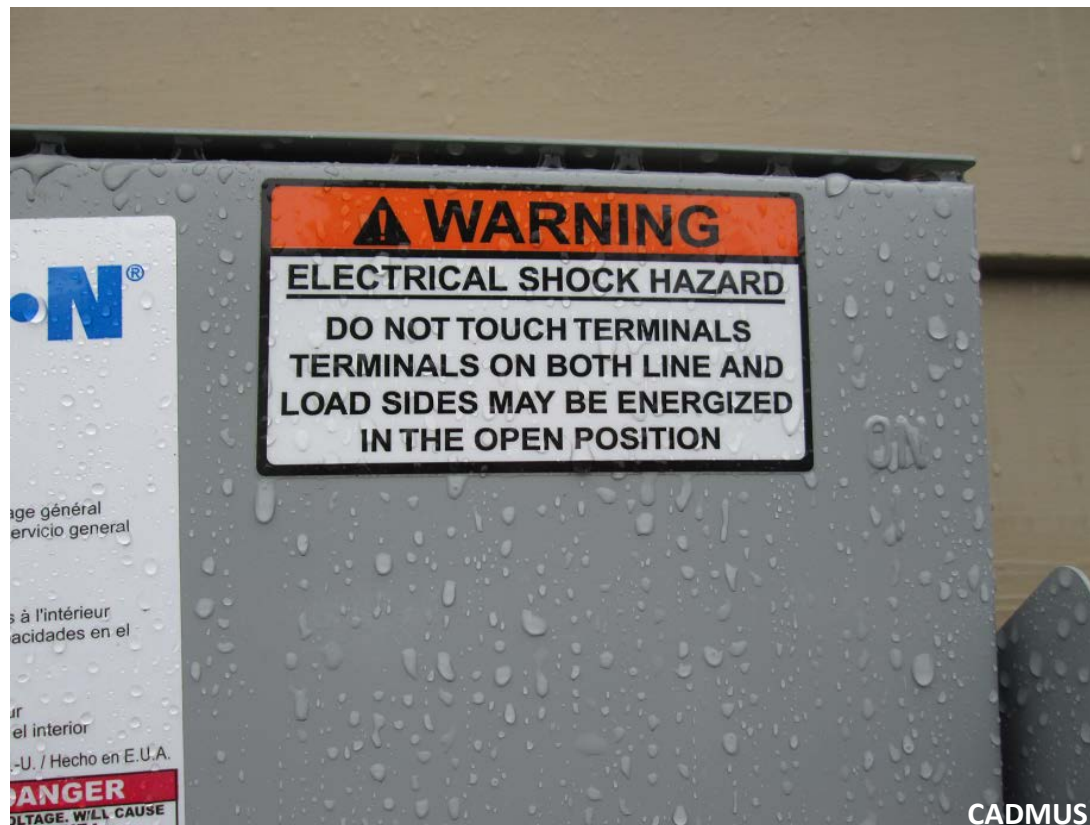




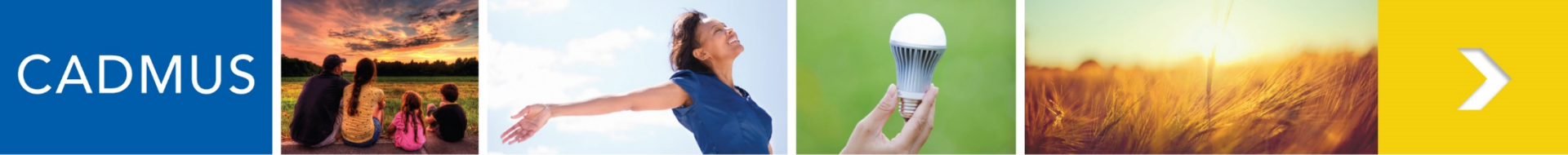
# Disconnect Line/Load Energized

NEC Article 690.13(B)

**Per  
110.21(B)**







# DC Power Source

NEC Article 690.53

**2017 NEC**

**PHOTOVOLTAIC SYSTEM**  
**⚡ DC DISCONNECT ⚡**

OPERATING VOLTAGE		VDC
OPERATING CURRENT		AMPS
MAX SYSTEM VOLTAGE		VDC
MAX SYSTEM CURRENT		AMPS
DC-DC Converter MAX		AMPS

**PHOTOVOLTAIC SYSTEM INVERTER**

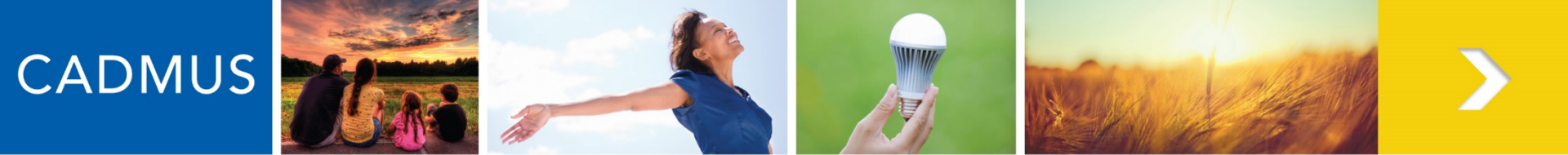
RATED MAX.POWER CURRENT	10.26 ADC
RATED MAX.POWER VOLTAGE	378 VDC
MAXIMUM SYSTEM VOLTAGE	465 VDC
SHORT CIRCUIT CURRENT	11.22 ADC
RATED SYSTEM MAX.POWER	3.87 KW

**WARNING!**  
**DC POWER**  
**ELECTRIC SHOCK HAZARD**  
**ROOFTOP SOLAR SYSTEM**  
**COMBINER BOX**

**DC SOURCE CIRCUIT**  
(STRINGS OF 11 SOLON 280W SOLAR PANELS • STC)  
SHORT CIRCUIT CURRENT (ISC): 8.95 ADC  
RATED MAXIMUM POWER-POINT CURRENT (IMP): 8.15 ADC  
RATED MAXIMUM POWER POINT VOLTAGE(VMP): 378.4 VDC  
MAXIMUM SYSTEM VOLTAGE (VOC): 467.5 VDC

**DANGER**  
**HIGH**  
**VOLTAGE**

COMBINER "A"



# AC Power Source

NEC Article 690.54

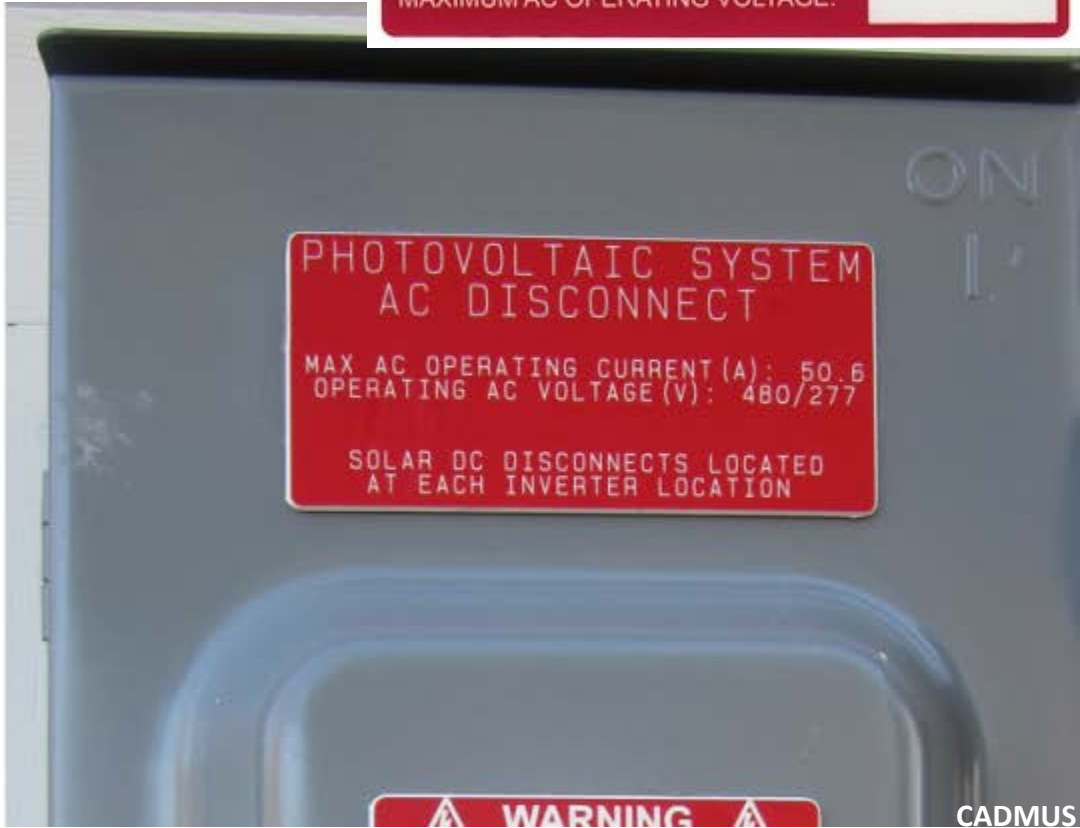
**PHOTOVOLTAIC AC DISCONNECT**

MAXIMUM AC OPERATING CURRENT:

MAXIMUM AC OPERATING VOLTAGE:



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CADMUS



# Dual Power Sources

NEC Article 705.12(B)(3)



CADMUS







# “Do Not Relocate”

NEC Article 705.12(B)(2)(3)(b)

Per  
110.21(B)





# AC Combiner Panel

NEC Article 705.12(B)(2)(3)(c)

Per  
110.21(B)



# WARNING

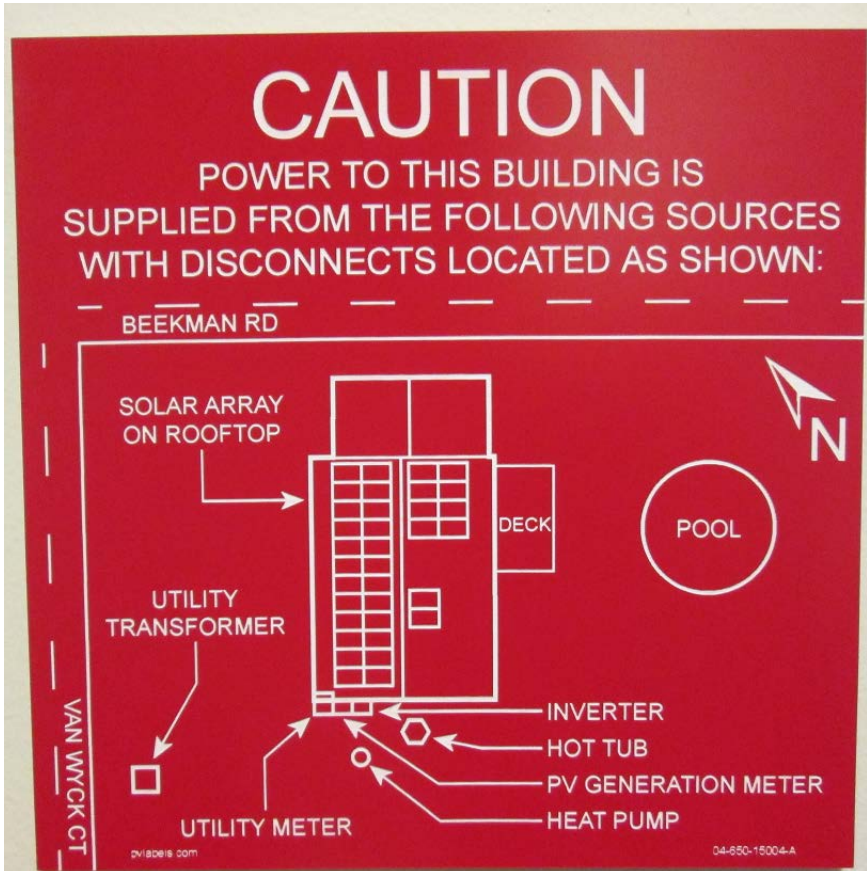
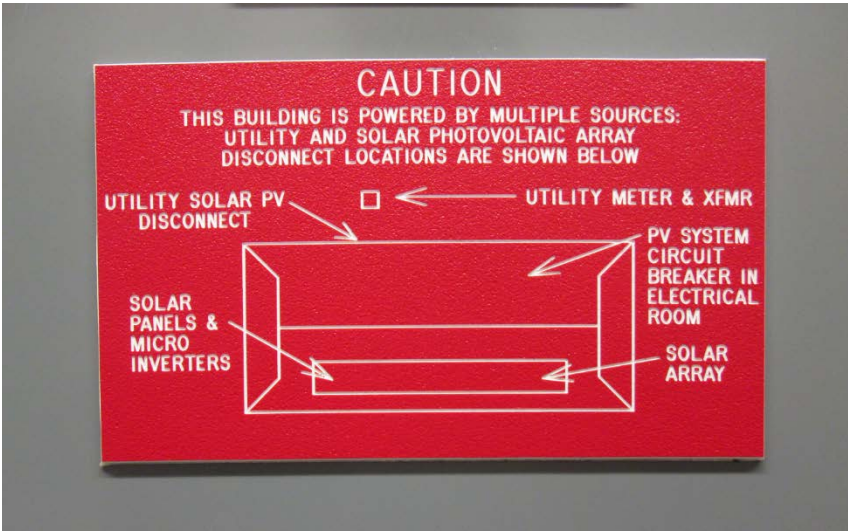
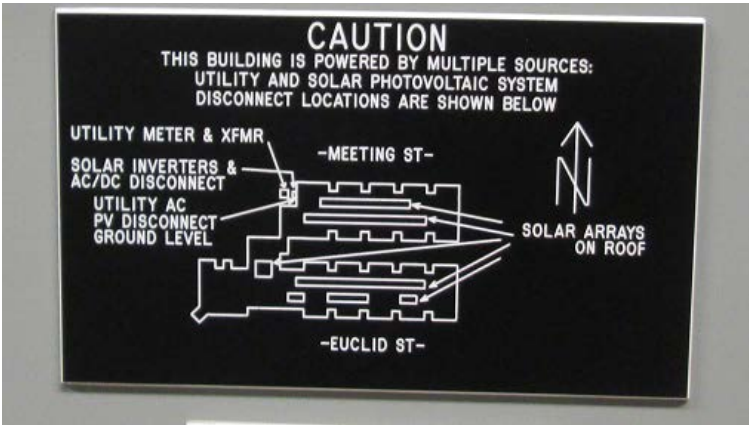
THIS EQUIPMENT FED BY MULTIPLE SOURCES.  
TOTAL RATING OF ALL OVERCURRENT DEVICES,  
EXCLUDING MAIN SUPPLY OVERCURRENT DEVICE,  
SHALL NOT EXCEED AMPACITY OF BUSBAR.



# Service Disconnect Directory

NEC Article 690.56(B)/705.10

Per  
110.21(B)







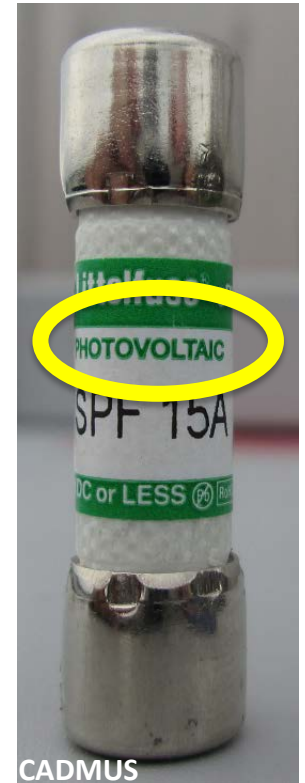
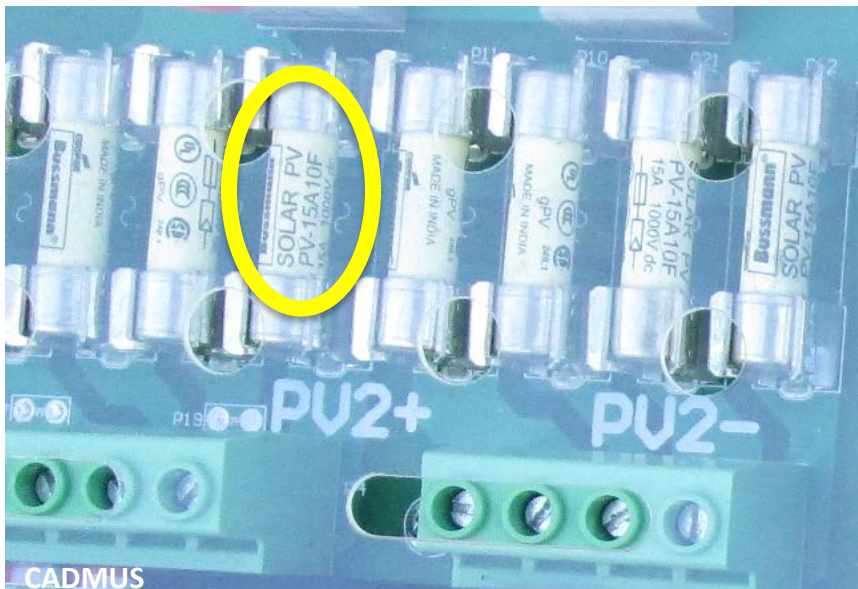
# String/Central Inverter





# Fuses

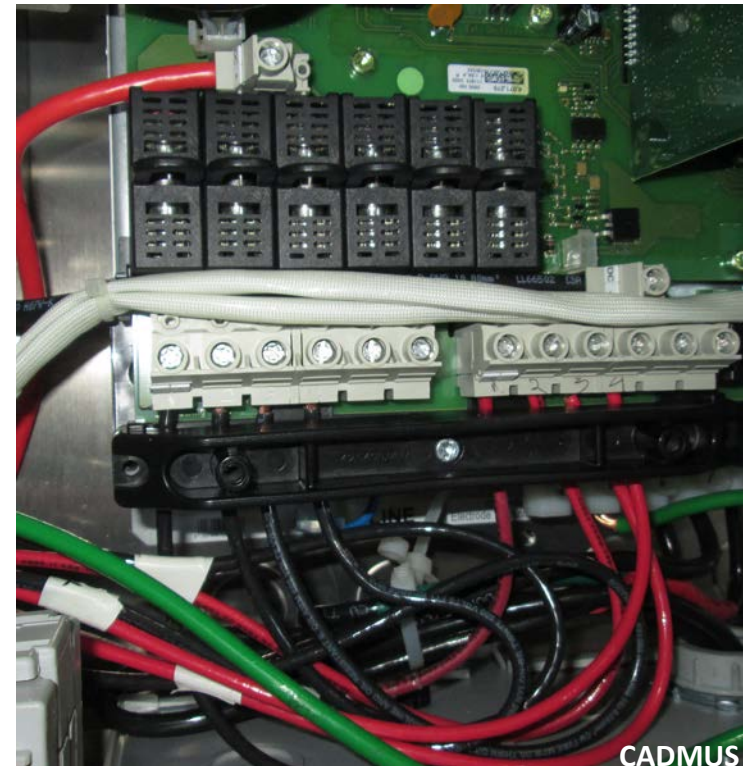
- **690.9(D)** requires listed PV overcurrent devices for DC conductors





# Fuses

- Some inverters ship from factory without fuses.
- Fusing may be required depending on number of combined strings.
  - See 690.9(A) and its exception.

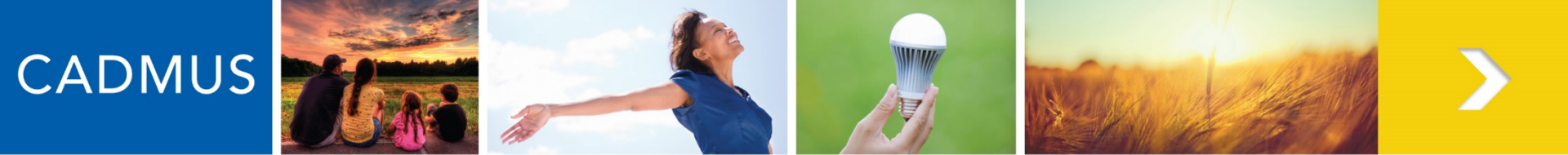






# Grounding Electrode System

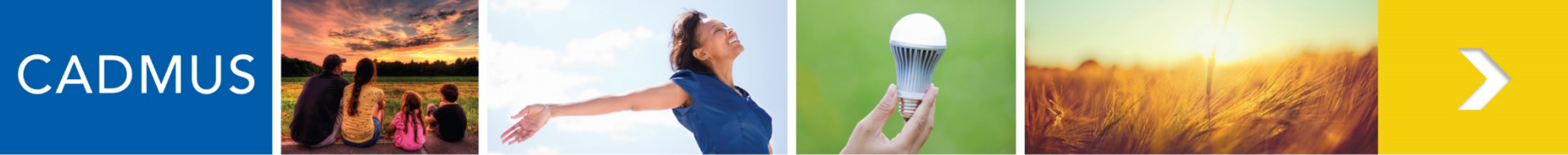




# Grounding Electrode System

NEC Article 690.47

- 690.47(A) Buildings or Structures Supporting a PV Array
  - Building or structure supporting a PV array shall have a grounding electrode system installed in accordance with Part III of Article 250.
  - PV array equipment grounding conductor shall be connected to the grounding electrode system of the building or structure supporting the PV system in accordance with Part VII of Article 250.
  - Sized in accordance with 690.45.



# Optional Array Grounding Electrode Conductor

NEC Article 690.47(B)

- Ground rod intended for “lightning protection”
  - Removed in 2011 NEC
  - Back in 2014 NEC
  - **Now optional for 2017 NEC, 690.47(B)**
  - Close as practical to roof mounted arrays
  - Connection per 250.52 and 250.54
    - Building steel may be considered a grounding electrode
    - Permitted to connect to equipment ground
    - Not required to connect to building grounding electrode system
    - Direct connection to array frame or structure







# Optional Array Grounding Electrode Conductor

## NEC Article 690.47(B)

- Axillary electrode required on ground mounted arrays
  - Connection per 250.52 and 250.54
    - Pole may be considered a grounding electrode
    - Permitted to connect to equipment ground
    - Not required to connect to building grounding electrode system
    - Direct connection to array frame or structure





# Inverter Output and AC Circuit

Disconnecting Means  
Wiring Methods





# Disconnection of PV Equipment

(Isolating Devices) NEC Article 690.15



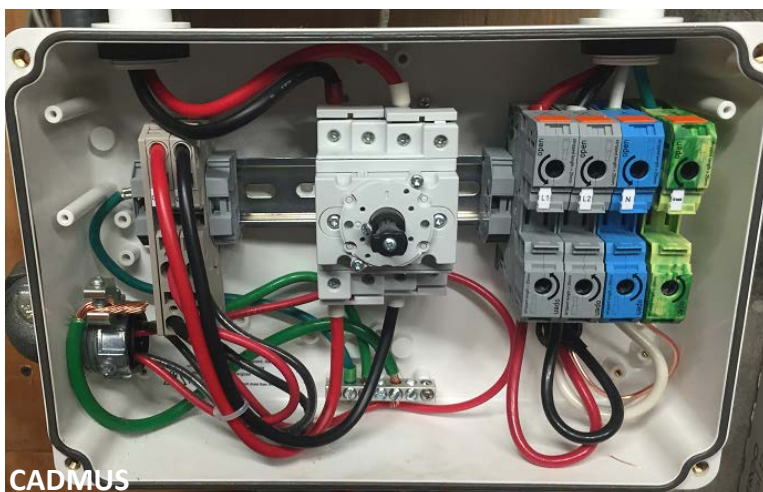
- ***“Isolating devices** shall be provided to isolate PV modules, ac PC modules, fuses, dc-dc converters, inverters, and charge controllers from all conductors that are not solidly grounded...”*





# Disconnection of PV Equipment

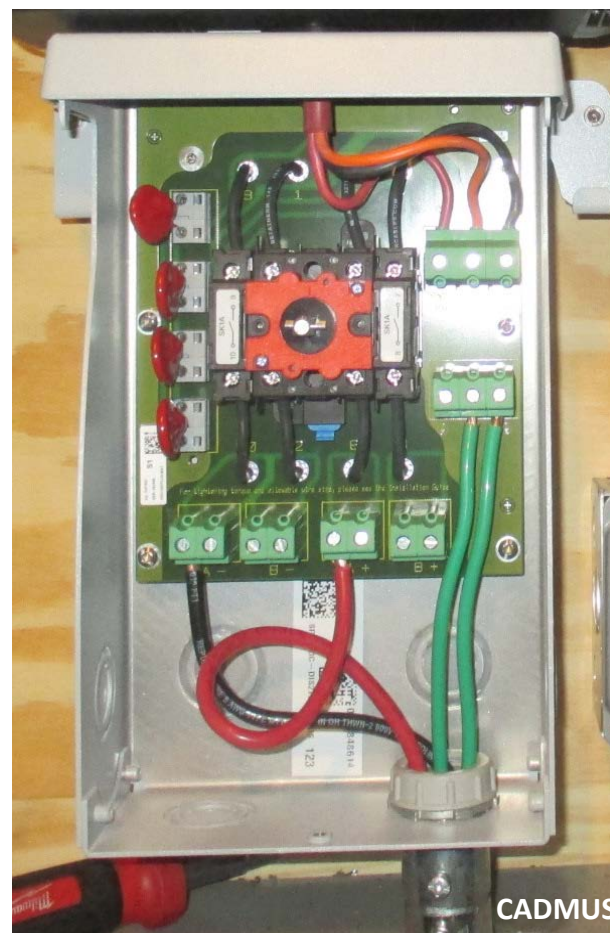
*Inside the "S" brand...*



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CADMUS



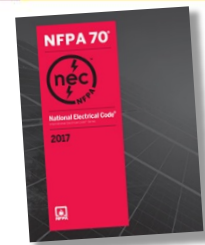
CADMUS

Some inverters only include a DC disconnect.



# Disconnection of PV Equipment

(Isolating Devices) NEC Article 690.15



- Isolate equipment from all (power sources) *“conductors that are not solidly grounded”*
- Located either:
  - Within the equipment
  - Within sight **and** within 10' of equipment



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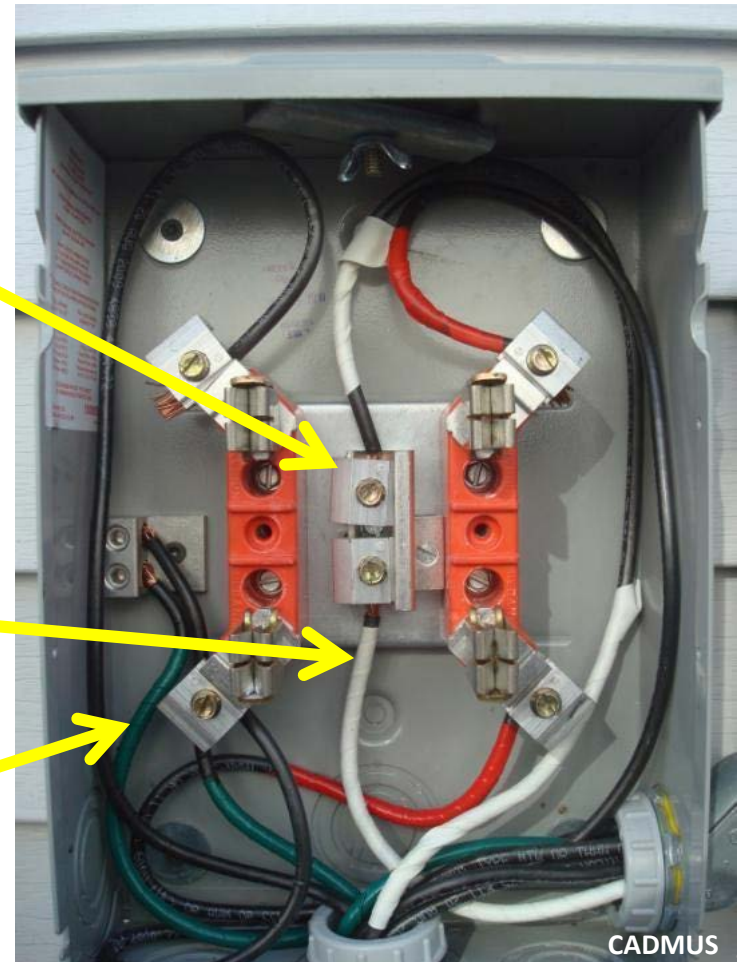
An additional AC disconnect may be required if the inverter does not contain one.





# Production Meter Violations

- Article 250.24(A)(5)
  - Neutral conductor bonded to frame
- *For bonus points:*
  - Article 200.6(A)
    - #6 AWG & smaller reidentified
  - Article 250.119
    - #6 AWG & smaller reidentified

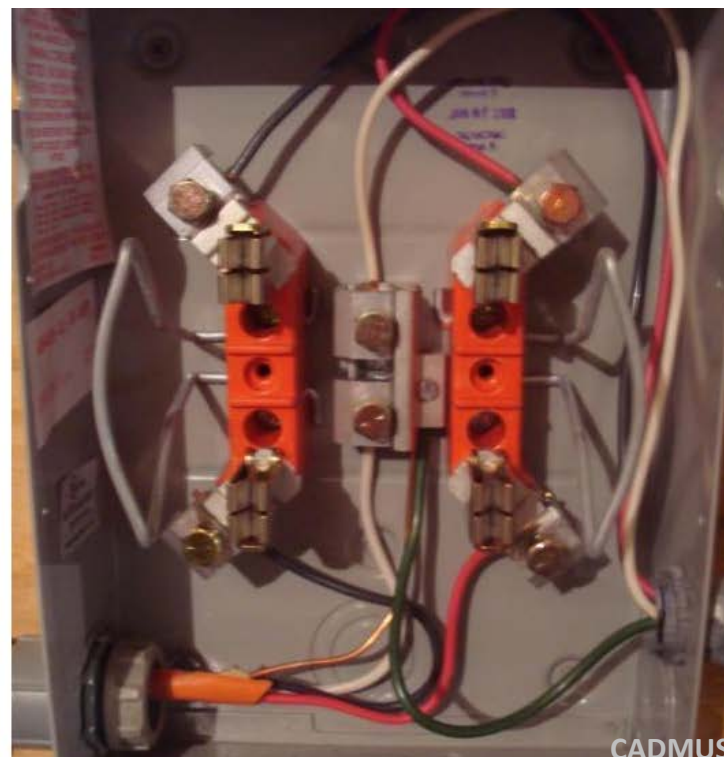
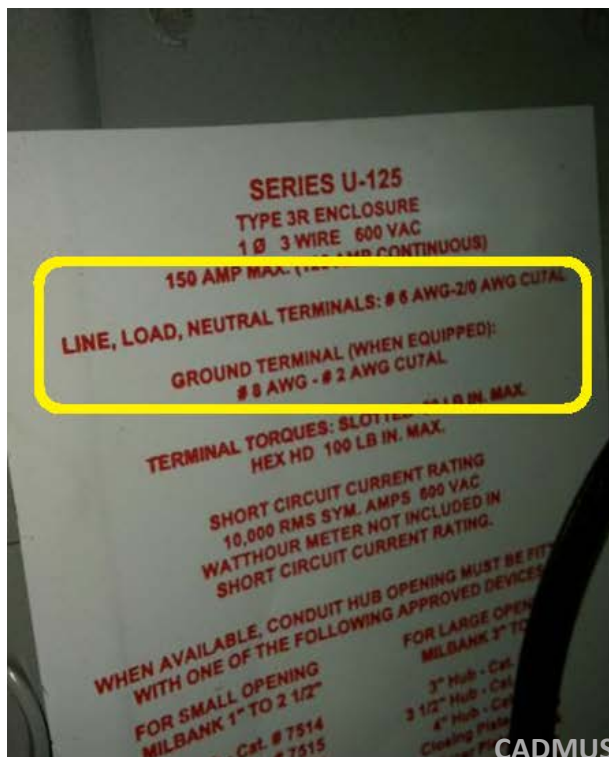






# Production Meter Violations

- Article 110.3(B)
  - Small conductors on lugs





# Outdoor Wiring Methods





# Type NM Cable

NEC Article 334.12

Article 310.120 requires conductors to be marked.

- Prohibited in wet/damp locations
  - Articles 334.12(B)(4), 310.10(C)
- Outdoor raceways are wet locations!
  - Article 300.9
    - *Since 2008 NEC*



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# Outdoor Enclosures

- Common violations:
  - Not installed “so as to prevent moisture from entering or accumulating...” in accordance with 314.15
  - Penetrations not sealed, as required by 300.7(A)
  - Indoor wire connectors, 110.3(B), **110.28**



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Enclosures must be installed “so as to prevent moisture from entering or accumulating...” in accordance with 314.15.



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Enclosures must be installed “so as to prevent moisture from entering or accumulating...” in accordance with 314.15.

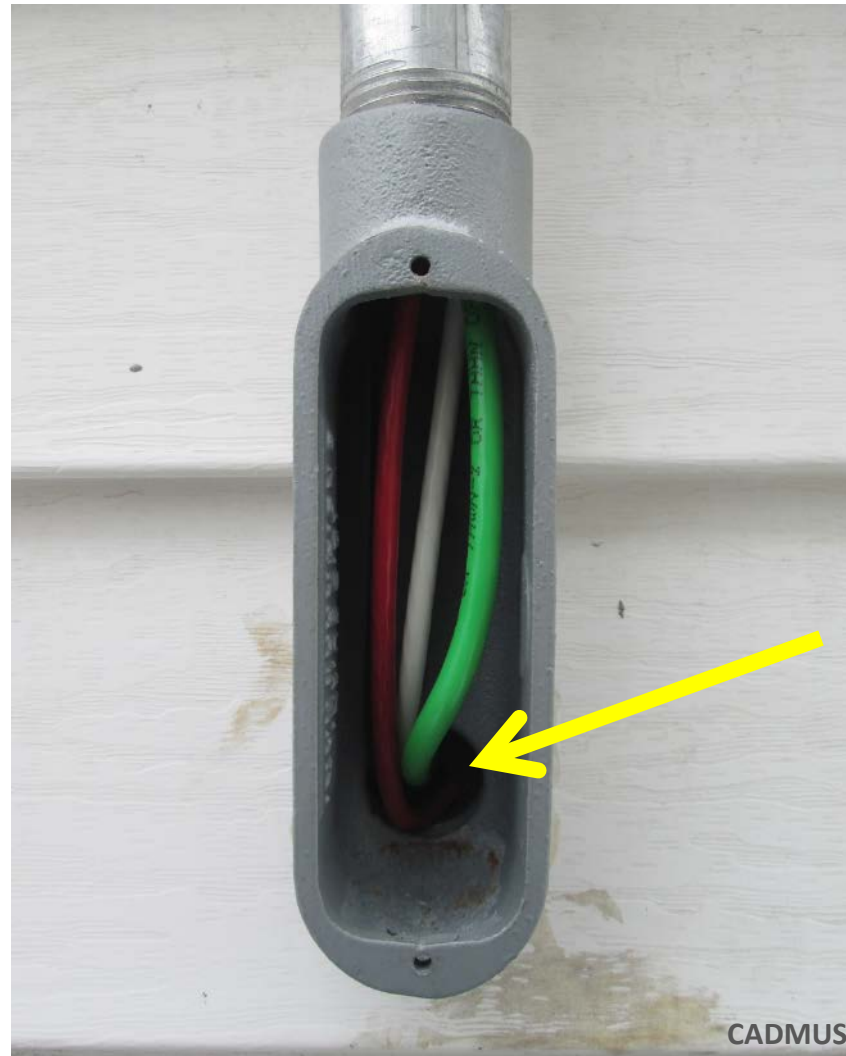






Enclosures must be installed “so as to prevent moisture from entering or accumulating...” in accordance with 314.15.





**Raceway must be sealed when passing between the interior and exterior of a building per 300.7(A).**





## PRODUCT DATA SHEET

**RTV Silicone Sealant - Blue, 6.5 Wt Oz**  
**Part Number: 14057**

### Product Description

For general-purpose sealing, bonding, protecting and waterproofing applications. Blue formulation is designed as a heavy-duty industrial gasket sealant.

### Applications

Sealing, bonding, protection & waterproofing in HVAC, electrical, construction, metal working, for filling gaps between mating parts, gearboxes, pumps, motors & for general gasket sealing.

### Unit Package Description

8 Ounce Pressurized Tube with "Select a Bead"

### Brand

Blue

### Generic Description 1

Blue Silicone Sealant

### Net Fill

6.5 Wt Oz

### UPC Code

078254140575

### Unit Dimensions

11.37H x 2.18W x 2.48D in

### Units Per Case

12

### Case Dimensions

11.75H x 7.37W x 7.37D in

### Cases Per Pallet

90

### Case Weight

7 lbs

### I 2 of 5 Code

30078254140576

### Appearance

Blue Paste

### Flashpoint

>212°F

### CPSC Flammability Class

None

### Specific Gravity

1.007

### Plastic Safe

Yes

### Evaporation Rate

Slow

### Curing Time

24 Hours

### Dielectric Strength

25 kV/mm

### Working Temp

-76 to 400°F

### Propellant

Nitrogen

### Aerosol Flammability Level

I

Last revised: 7/30/2015  
Page 1 of 2



CRC Industries is a worldwide leader in the production of specialty chemicals for maintenance and repair professionals serving industrial, electrical, aviation, automotive and marine markets. CRC is ISO 9001:2008 certified and adheres to the strictest guidelines for quality in all facets of research, development and production.

Customer Care: 800-556-5074  
Technical Assistance: 800-521-3168  
www.crcindustries.com



## PRODUCT DATA SHEET

**Minimal Expansion Foam, 12 Wt Oz**  
**Part Number: 14077**

### Product Description

Fill, seal, bond, retrofit, insulate and deaden sound in and around cracks and cavities. Forms a permanent, waterproof and airtight bond to most surfaces. UL classified as a caulking sealant.

### Applications

Filling, insulating, sealing, bonding, HVAC, electrical, industrial, plumbing, around electrical outlets, utility panels, ducts, pipes, doors, windows, base plates, joints, cracks, crawlspaces, foundations, spot insulation touch-ups

### Unit Package Description

16 Ounce Aerosol

### Brand

Blue

### Generic Description 1

Expansion Aerosol Foam Sealant

### Net Fill

12 Wt Oz

### UPC Code

078254140773

### Unit Dimensions

8.06H x 2.19W x 2.19D in

### Units Per Case

12

### Case Dimensions

9.38H x 8.63W x 11.25D in

### Cases Per Pallet

108

### Case Weight

13 lbs

### I 2 of 5 Code

30078254140774

### Appearance

Tan Foam

### Flashpoint

None

### CPSC Flammability Class

None

### Specific Gravity

1.2

### Plastic Safe

Yes

### Evaporation Rate

Not Determined

### Curing Time

12 to 24 Hours

### Dielectric Strength

Not Determined

### Working Temp

65 to 100°F

### Viscosity @68 F [cP]

Not Determined

Last revised: 7/15/2015  
Page 1 of 2



CRC Industries is a worldwide leader in the production of specialty chemicals for maintenance and repair professionals serving industrial, electrical, aviation, automotive and marine markets. CRC is ISO 9001:2008 certified and adheres to the strictest guidelines for quality in all facets of research, development and production.

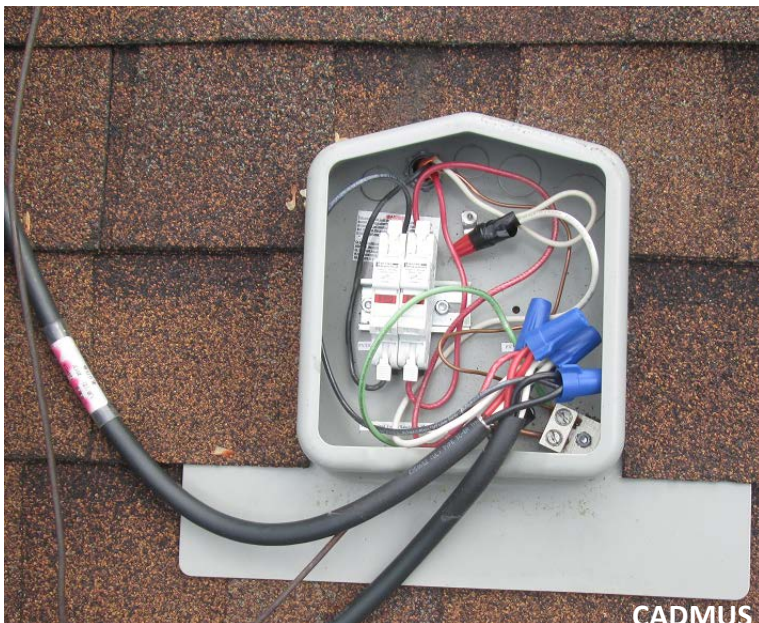
Customer Care: 800-556-5074  
Technical Assistance: 800-521-3168  
www.crcindustries.com



# Conductors Entering Boxes

NEC Article 314.17

- Conductors entering boxes shall be protected
- The raceway or cable shall be secured to such boxes and conduit bodies



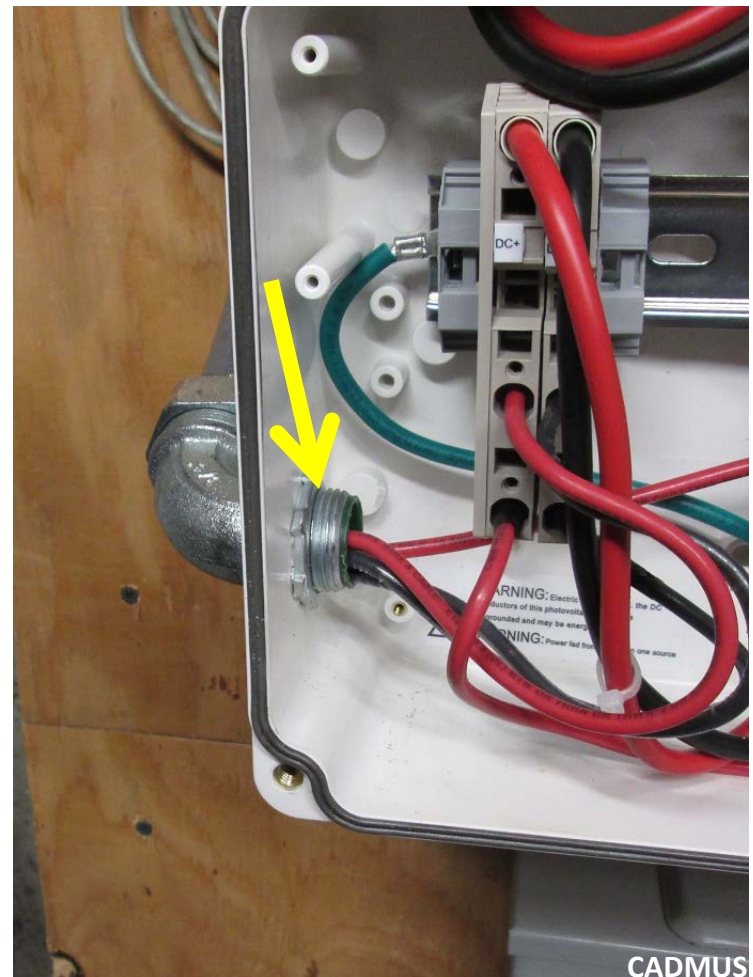




# Bonding the Raceway

NEC Article 250.4

- Conductive materials enclosing conductors **SHALL BE BONDED!**
  - Plastic enclosure outside
  - Metal inside
  - Plastic DC disconnect



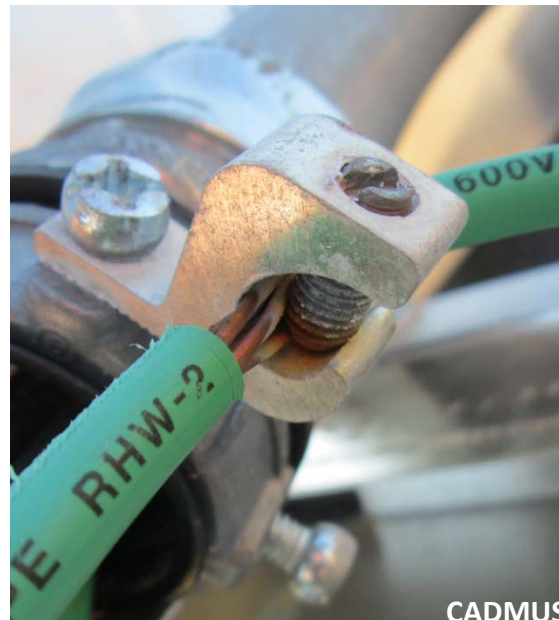
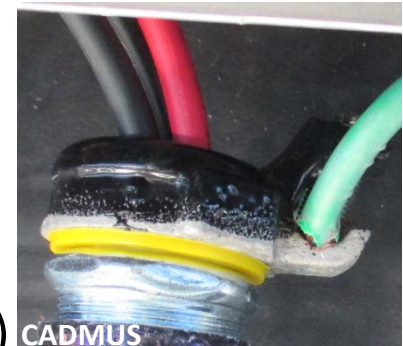




# Bonding Bushings

*Rated for Outdoor Use?*

- Lay-in lug
  - Must be suitable for the environment
    - Outdoor/wet locations (suitable for direct-burial)









# Dissimilar Metals

*Beyond the lugs...*



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Dissimilar metals in contact will result in corrosion.





# Dissimilar Metals

*Beyond the lugs...*



CADMUS

**Bare copper conductor is corroding because of contact with steel raceway.**



# Dissimilar Metals

*Beyond the lugs...*



CADMUS

**Bare copper conductor is corroding because of contact with steel raceway.**



# Rapid Shutdown of PV Systems on Buildings



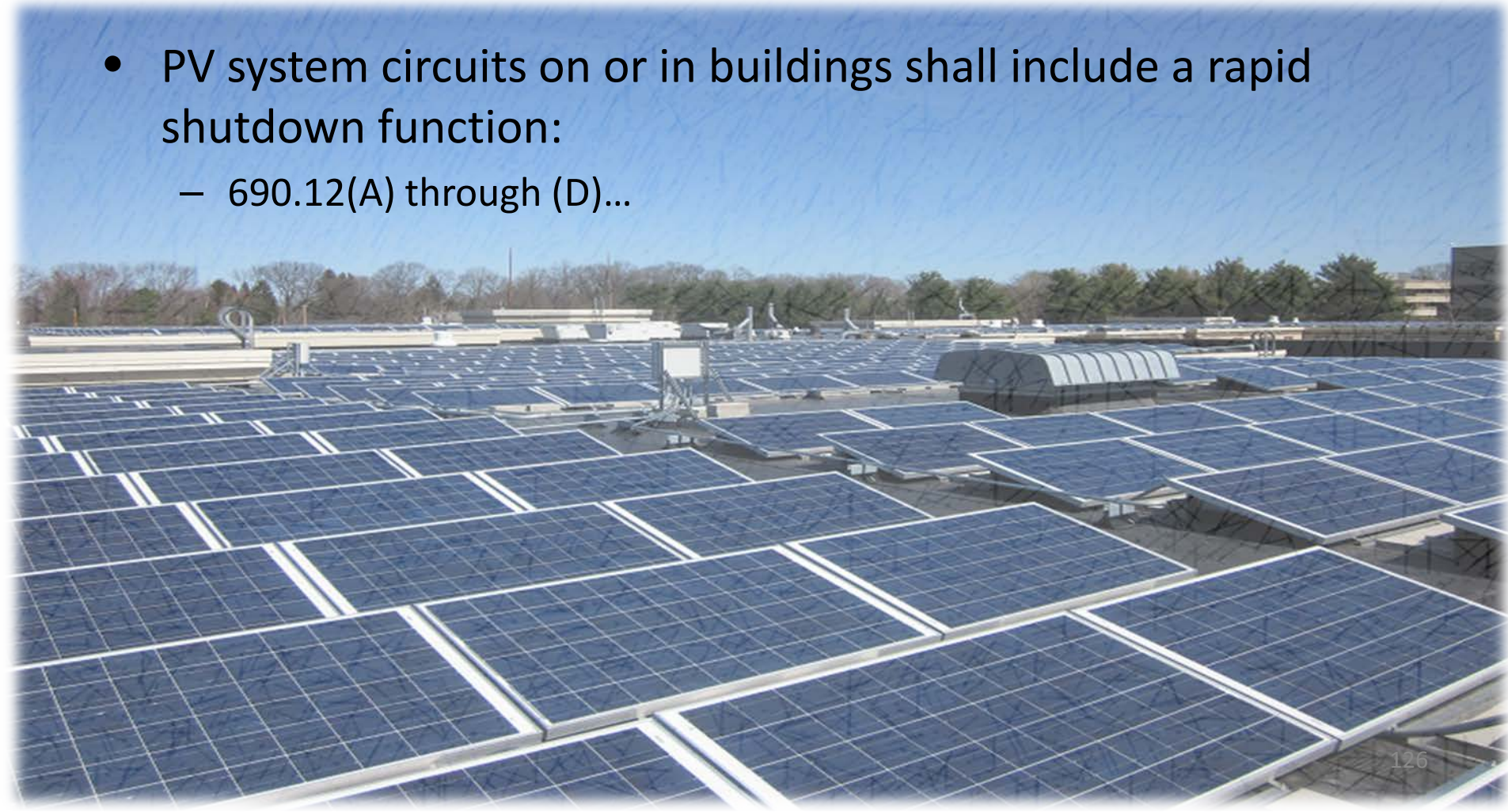




# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- PV system circuits on or in buildings shall include a rapid shutdown function:
  - 690.12(A) through (D)...





## About Article 690.12

- Intended to protect first responders
- Original 2014 proposal:
  - Disconnect power directly under array
    - Module-level shutdown
- 2014 NEC Compromise:
  - Combiner-level shutdown
- 2017 NEC:
  - Back to original, however...



Source: UL.com



# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.12(A) Controlled Conductors
  - *“Requirements for controlled conductors shall apply to PV circuits supplied by the PV system.”*
- 690.12(B) Controlled Limits
  - *Array Boundary*
    - Defined as 1' from array in all directions





# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.12(B)(1)
  - Outside the 1' array boundary
  - More than 3' inside a building





# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.12(B)(1)
  - Under 30 volts within 30 seconds
  - Measured between:
    - Any 2 conductors
    - Any conductor and ground





# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.12(B)(2)
  - **Effective January 1, 2019**
  - Inside the 1' array boundary, one of following:
    1. Array should be listed/field labeled as rapid shutdown
    2. Controlled conductors limited to 80 volts within 30 seconds
    3. Exception for arrays with no exposed wiring (solar shingles)







# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.12(C) Initiation Device
  - Shall be one of following:
    1. Service disconnecting means
    2. PV system disconnecting means
    3. Readily accessible switch that plainly indicates whether it is in the “off” or “on” position
  - Not more than 6 disconnects
  - **For one-family and two-family dwellings:**
    - **Located outside!**



# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.12(D)
  - *“Equipment that performs the rapid shutdown shall be listed for providing rapid shutdown protection.”*





# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.56(C)(3)
  - Switch label that includes the following:

## RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM

- Minimum 3/8" CAPS
  - White on **Red**
  - **Reflective**
- 
- *Required even for microinverters!*



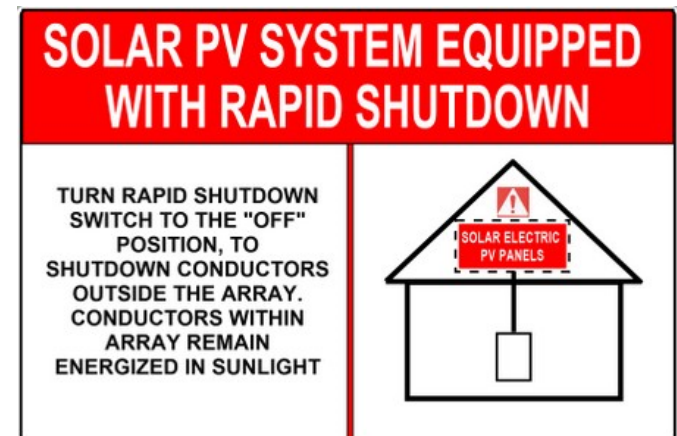
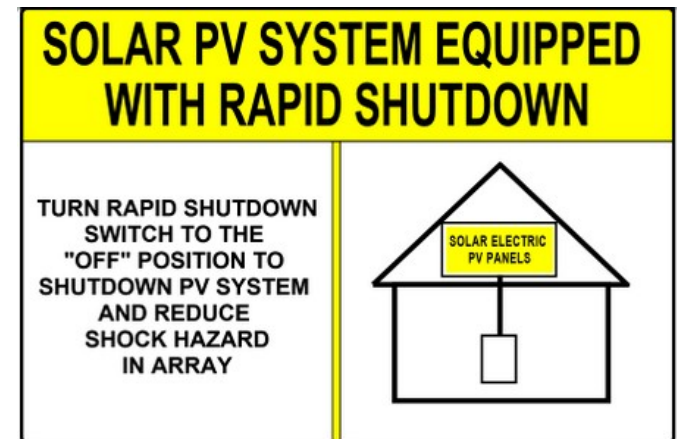




# Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.56(C)(1)(a)
  - Array-level shutdown
  - *2019 requirement*
- 690.56(C)(1)(b)
  - Traditional shutdown outside array boundary
  - *2014 or 2017 requirement*





# Thank You Any Questions?

## Additional Resources:

**For installers:**

<http://files.masscec.com/solar-loan/MassSolarLoanProgramManual.pdf>

<http://files.masscec.com/uploads/attachments/QualityAssuranceProcessMassCECPrograms.pdf>

**For your customer:**

[http://files.masscec.com/uploads/attachments/Cadmus%20Solar%20PV%20Overview\\_MassCEC.pdf](http://files.masscec.com/uploads/attachments/Cadmus%20Solar%20PV%20Overview_MassCEC.pdf)

**And more at:**

[www.masssolarloan.com](http://www.masssolarloan.com)

**Mass Solar Loan Team**  
**Massachusetts Clean Energy Center**

Tel: 617-712-1121 Fax: 617-315-9356

[solarloan@masscec.com](mailto:solarloan@masscec.com)

[www.masssolarloan.com](http://www.masssolarloan.com)

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Tel: 617-673-7102

[www.cadmusgroup.com](http://www.cadmusgroup.com)