

Solar PV Inspections in New York State

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NYSERDA

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Central Hudson Solar Summit

Agenda

- **What are Field Inspectors Looking For?**
- **Common Errors**
- **Q&A**

Field Inspection Checklist

> Key System Components Subject to Inspection

- Array
- DC Optimizers
- Structural (not applicable to ground mounts)
- Junction Boxes
- Inverters
- Microinverter
- AC Combiner Panels
- Interconnections
 - Load Side Connection
 - Supply Side Connection
- General Observations
 - Work done neatly
 - Working clearances maintained

> Helpful Resource

- NEC References
- Informational Notes

The Array

Can be Roof, Ground, or Pole mounted

**Have proper
safety equipment
for roof top
inspections!**



The Array

Equipment Verification

- Specs Matter: Design is based on equipment specifications
- Does the module count, manufacturer, and model match the plan set?

ELECTRICAL THREE-LINE				
EQUIPMENT SCHEDULE				
KEY	QTY	MAKE	MODEL	LOCAT
I	20	SUNPOWER	SPR-E20-435-COM	FLUSH

SUNPOWER™

MODEL: SPR-E19-320

Rated Power (P _{max}) ¹ (+5/-0%)	320	W
Voltage (V _{mp})	54.7	V
Current (I _{mp})	5.86	A
Open-Circuit Voltage (V _{oc})	64.8	V
Short-Circuit Current (I _{sc})	6.24	A
Maximum Series Fuse	15	A

UL US LISTED
PHOTOVOLTAIC MODULE
19KC
Module Fire Performance: Type 2
600V max. system voltage

TUV Rheinland
CERTIFIED
IEC 61215
IEC 61730
www.tuv.com
ID: 0000022009

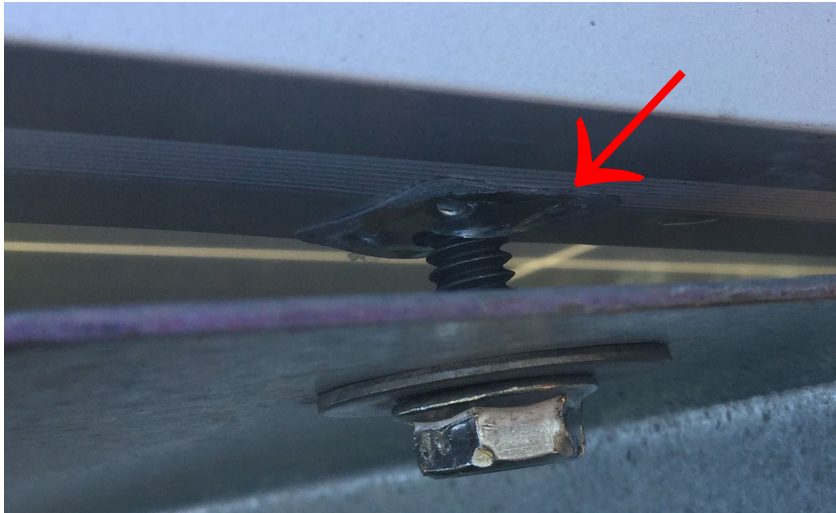
Safety Class II



The Array

What to look for:

Modules effectively grounded with lugs, weeps, or integrated method?

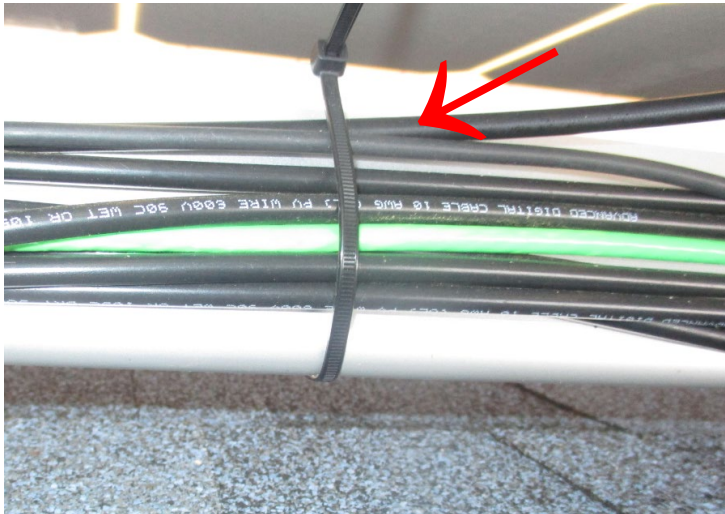


The Array

What to look for:

Outdoor components are UL-listed for the environment NEC 110.3(B)

UV rated zip ties
(Usually black)



Look for
rusted
equipment

Optimizers and Micro-Inverters

What to look for:

4.2 DC Optimizer

1. DC Optimizer chassis is properly grounded per manufacturer's instructions [NEC 110.3(B), 250.4(A)(5), 250.64(E), 250.97]	N	Y	N/A
2. Rapid Shutdown label is present and meets the requirements of NEC 690.56(C)(1)(a)	N	Y	N/A

Note 1: Many violations from the "Array" section also apply to the "DC Optimizer" section.

Note 2: DC optimizer can have an integrated ground, or not. Bring the specifications sheet to the inspection for quick reference.

4.6 Microinverter

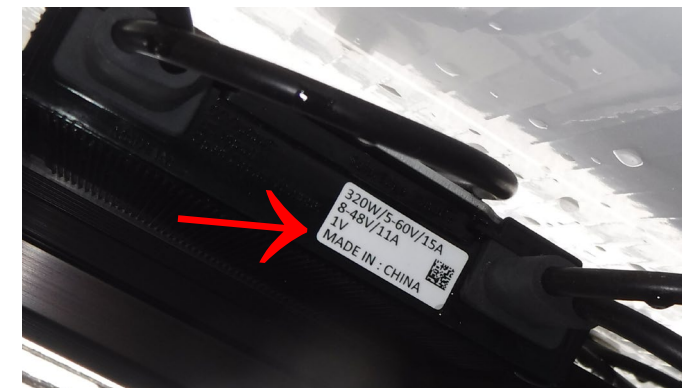
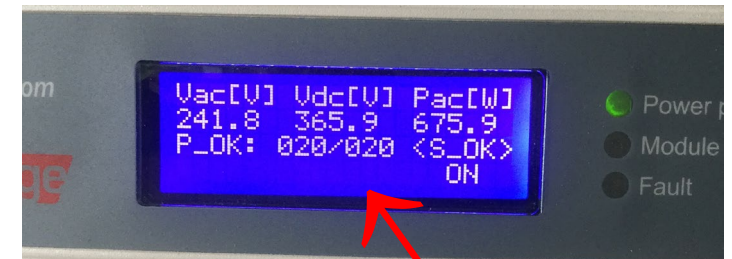
1. Microinverter chassis is properly grounded per manufacturer's instructions [NEC 690.43(A), 250.4, 110.3(B)]	N	Y	N/A
2. EGC is protected if smaller than #6 AWG [NEC 690.46, 250.120(C)]	N	Y	N/A
3. Rapid Shutdown label is present and meets the requirements of NEC 690.56(C)(1)(a)	N	Y	N/A

Note 1: Many items from the "Array" section also apply to the "Microinverter" section.

Note 2: Microinverters can have an integrated ground, or not. This information is found on the specification sheet.

Note 3: As long as the microinverters are listed, they are inherently equipped with rapid shutdown, which is required by NEC 690.12. This does not negate the label requirement in NEC 690.56(C)(1)(a).

- Equipment Verification
- Manufacturer Model and Count



Optimizers and Micro-Inverters

What to look for:

- Chassis Grounded?
- Refer to install guides

4.2 DC Optimizer

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3. Rapid Shutdown label is present and meets the requirements of NEC 690.56(C)(1)(a)	N	Y	

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Optimizers and Micro-Inverters

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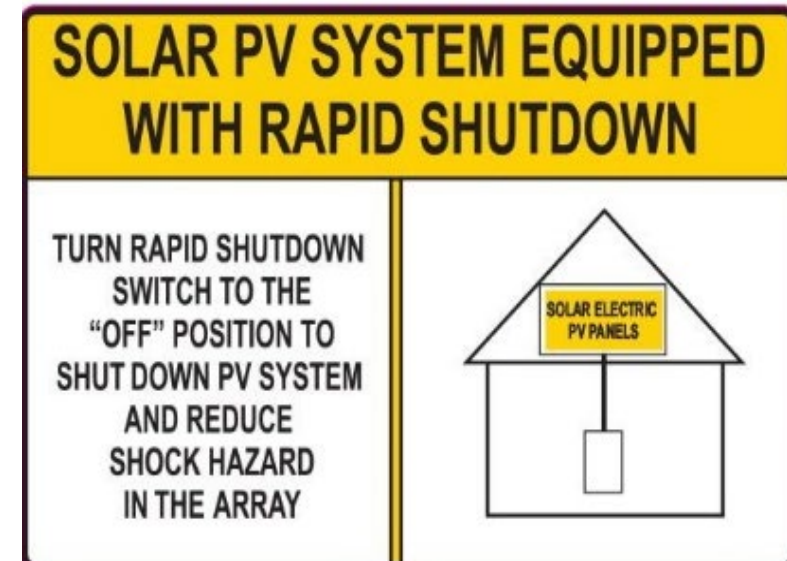
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**Rapid Shutdown
Required by
NEC 690.56(C)(1)(a).**

Structural Roof Top Considerations

What to look for:

4.3 Structural (Roof-Mounted Only)

1. All roof penetrations are properly flashed and sealed per 2020 NYS Uniform Code and NEC 110.3(b)	N	Y	N/A
2. Lag bolts are properly installed, not over torqued deforming the flashing	N	Y	N/A
3. Rafter spacing/material matches construction documents	N	Y	N/A
4. Roof appears to be in good condition, with no signs of leaking or damage; Roof is free of debris	N	Y	N/A
5. All racking splices are properly supported per manufacturer requirements (generally splices must be supported on both sides of the joint by a structural attachment)	N	Y	N/A
6. Modules cannot be moved by pushing or pulling with one hand	N	Y	N/A

- **Proper Flashing for Penetrations**



Required by 2020 NYS Residential Code.



Junction Box

What to look for:

4.4 Junction Box

1. Wire nuts and splices are suitable for the environment [NEC 110.3(B)]	N	Y	N/A
2. Junction box is UL listed for the environment [NEC 110.3(B)]	N	Y	N/A
3. Junction box is properly grounded [NEC 110.3(B), 250.4, 250.8, 250.12, 690.43]	N	Y	N/A
4. Grounding equipment is properly installed [NEC 110.3(B), 250.4, 250.8, 250.12, 690.43]	N	Y	N/A

Rated for the environment
NEC 110.3(B)



Grounding:
Required by NEC 690.43,



String Inverter

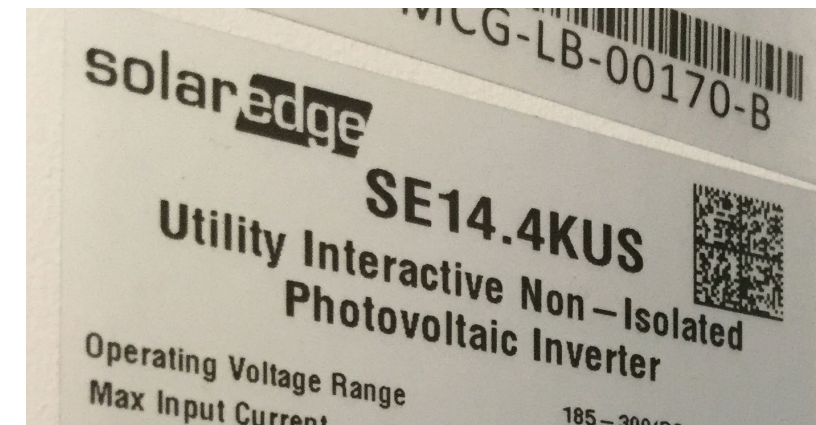
What to look for:

4.5 Inverter

1. The number of strings match the plan set	N	Y	N/A
2. The conductors have sufficient ampacity for each string	N	Y	N/A
3. DC conductors in metal when on or inside a building [NEC 690.31(G)]	N	Y	N/A
4. Conduit penetrations are properly sealed between conditioned and unconditioned space [NEC 300.7(A)]	N	Y	N/A
5. Conduit is properly supported e.g., [LFMC NEC 350.30, EMT NEC 358.30, PVC NEC 352.30]	N	Y	N/A
6. Conduit is not being used as conductor support [NEC 725.143]	N	Y	N/A
7. The enclosure is properly grounded [NEC 690.43, 250.8, 250.12]	N	Y	N/A
8. Grounding equipment is properly installed [NEC 690.43, 250.8, 250.12]	N	Y	N/A
9. Point of interconnection enclosure is labeled as a PV disconnect [NEC 110.21(B) and/or 690.13(B)]	N	Y	N/A
10. DC characteristics label is present [NEC 690.53]	N	Y	N/A
11. The ungrounded DC conductors are properly identified (shall not be white, gray, or white striped) [NEC 200.6(A)(B)]	N	Y	N/A
12. Max string voltage below inverter max [NEC 110.3(B), 690.7]	N	Y	N/A
13. Inverter string fuses are rated for use in application [NEC 110.3(B), 690.9]	N	Y	N/A
14. DC and AC disconnecting means are located within sight of or in each inverter [NEC 690.15]	N	Y	N/A
15. AFCI protection is present and enabled [NEC 690.11]	N	Y	N/A
16. System is equipped with Rapid Shutdown [NEC 690.12]	N	Y	N/A
17. Rapid Shutdown label is present and meets the requirements of NEC 690.56(C)(1)(a)	N	Y	N/A
18. System is marked with a permanent label with the following wording: "PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN" [NEC 690.56(C)]	N	Y	N/A



- Conductors in metal cable or conduit when inside the building NEC 690.31(G)
- Equipment Verification Quantity and Model

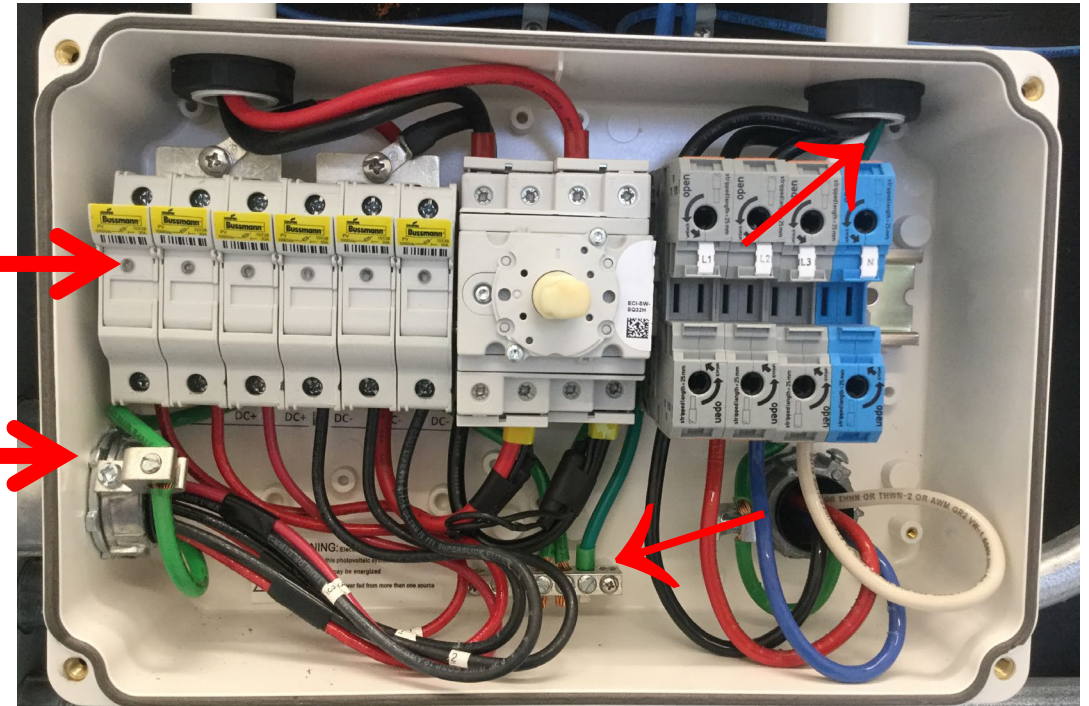


String Inverter

What to look for:



- Inverter string fuses are rated for use in application NEC 690.9
- Conduit and Enclosure Grounded NEC 690.43, NEC 250.8, NEC 250.12



String Inverter

What to look for:

PV disconnect Label
NEC 690.13(B)



Required by
NEC
690.56(C)(1)(b).

AC Combiner

What to look for:

4.7 AC Combiner

1. The number of branch circuits match the plan set.	N	Y	N/A
2. The conductors have sufficient ampacity for each branch circuit.	N	Y	N/A
3. The Overcurrent Protective Device (OCPD) for the conductors have a rating sufficient to protect them [NEC 240.4]	N	Y	N/A
4. Conduit penetrations are properly sealed between conditioned and unconditioned space [NEC 300.7(A)]	N	Y	N/A
5. Conduit is properly supported e.g., [LFMC NEC 350.30, EMT NEC 358.30, PVC NEC 352.30]	N	Y	N/A
6. Conduit is not being used as conductor support [NEC 300.11(B), 725.143]	N	Y	N/A
7. The enclosure is properly grounded [NEC 690.43, 250.8, 250.12]	N	Y	N/A
8. Grounding equipment is properly installed [NEC 690.43, 250.8, 250.12]	N	Y	N/A
9. Enclosure is labeled as a disconnect [NEC 690.13]	N	Y	N/A
10. AC characteristics label is present (voltage and amperage), [NEC 690.54]	N	Y	N/A
11. The main breaker is fastened in place [NEC 408.36(D)]	N	Y	N/A
12. Grounded conductors are isolated from enclosure [NEC 250.24(A)(5)]	N	Y	N/A

**Grounded
Conductor
(Neutral) isolated
from enclosure
per NEC
250.24(A)(5)**

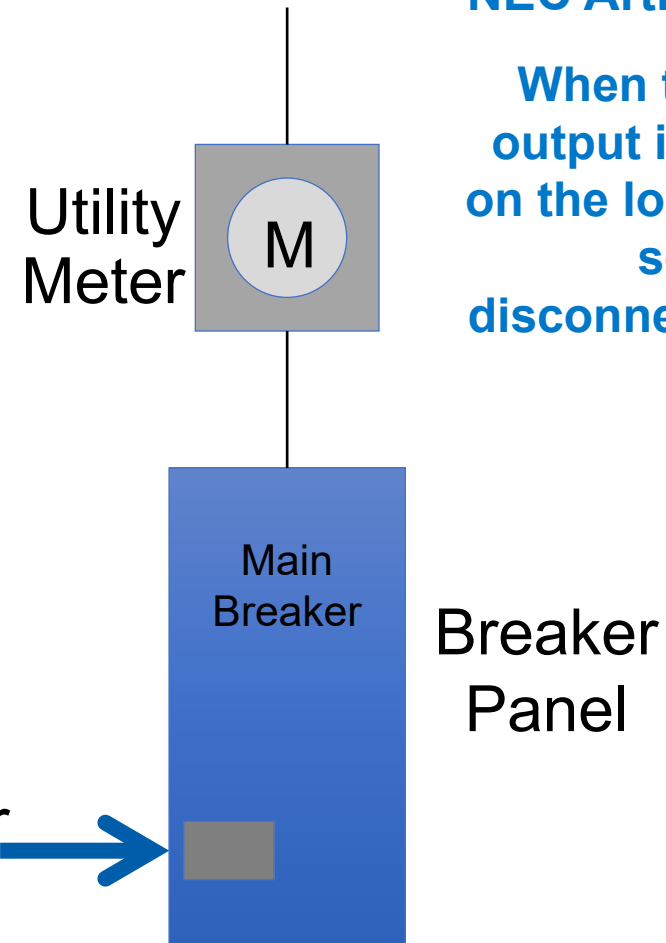


Load Side Connection

What to look for:

4.8 Load-Side Connection

1. Circuit conductors have sufficient ampacity [NEC 690.8, 310.15]	N	Y	N/A
2. The AC OCPD is properly sized for the expected output current of the PV system. [NEC 690.9]	N	Y	N/A
3. Grounded conductors properly identified [NEC 200.6(A), (B)]	N	Y	N/A
4. The Grounding Electrode Conductor (GEC) is present and sufficiently sized [NEC 690.47(C), 250.66, 250.122, 250.166]	N	Y	N/A
5. The GEC is continuous (or irreversibly spliced) [NEC 250.64(C), 690.47(C)]	N	Y	N/A
6. Ferrous conduit and the enclosure are appropriately bonded to the GEC [NEC 250.4, 250.8, 250.12, 690.43]	N	Y	N/A
7. PV breakers are properly identified [NEC 110.21(B), 705.10]	N	Y	N/A
8. AC characteristics label is present and suitable for the environment (voltage and amperage) [NEC 690.54, 110.21(B)]	N	Y	N/A
9. Dissimilar metals are separated and will not cause a galvanic reaction [(NEC 110.14, RMC NEC 344.14, EMT NEC 358.12(6))]	N	Y	N/A
10. Inverter directory present [NEC 705.10]	N	Y	N/A
11. Backfed breaker or fuse is sized to protect circuits [NEC 690.8(B)(1) and/or NEC 310.15]	N	Y	N/A
12. Source breakers follow 120% rule [NEC 705.12(D)(2)(3)(b)]	N	Y	N/A
13. Backfed breaker properly located in panel [NEC 705.12(B)(3)(b)]	N	Y	N/A
14. Clearances maintained/live parts secured [NEC 110.27(A), 110.26]	N	Y	N/A



NEC Article 705.12(B)

When the inverter output is connected on the load side of the service disconnecting means.

Load Side Connection

What to look for:

AC RATING	
Nominal Output Voltage	277 V~ / 240 V~ / 208 V~ 1Ø
Operating Voltage Range	244-304 V~ / 211-264 V~ / 183-228 V~
Nominal Output Frequency	60 Hz (factory preset)
Operating Frequency Range	59.3 (°) - 60.5 (°) Hz
Output Power Factor	>0.995
● Max. Output Current ● for each phase >	● 16 A / 16 A / 17.2 A (rms)
Max. Continuous Output Power	3600 W @ 55°C amb.
Max. Output Overcurrent Protection	20 A / 20 A / 25 A

- Circuit conductors have sufficient ampacity per NEC 690.8, 310.15

(Inverter output ampacity x 1.25)
 $16 \times 1.25 = 20A$
Conductor sized Min #12 AWG

Load Side Connection

What to look for:



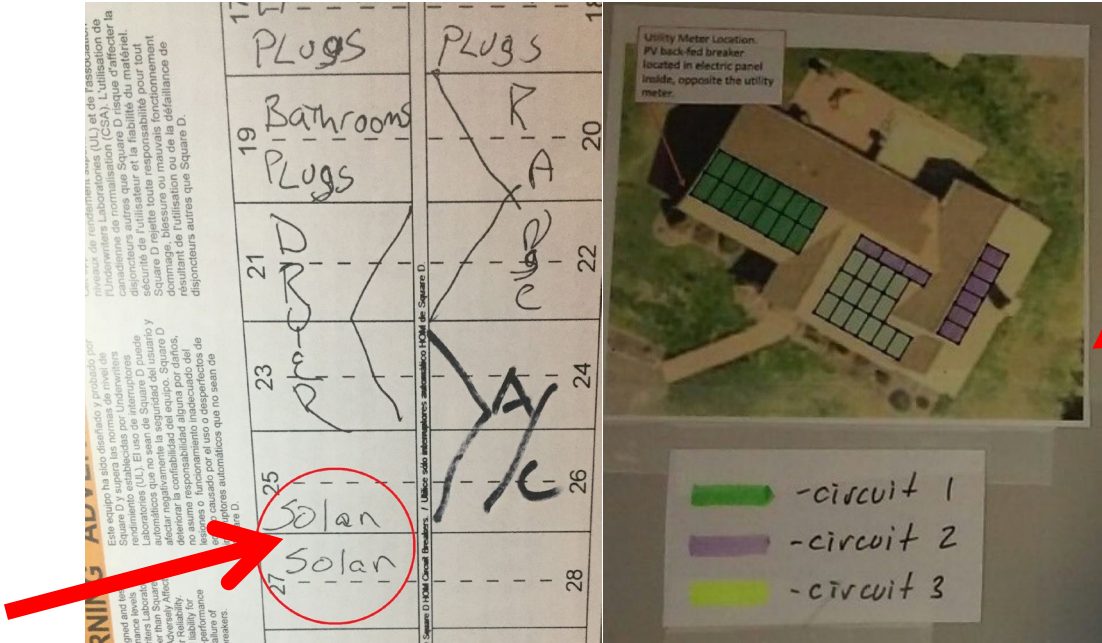
- The OCPD is sufficient to protect the circuit conductors Per NEC 240.4

(Inverter output ampacity x 1.25)
 $16 \times 1.25 = 20A$
Overcurrent Protection Max 20A

Load Side Connection

What to look for:

Circuit Directory
per NEC 408.4(A)



Inverter directory present Per
NEC 705.10

Load Side Connection

What to look for:

Main
Breaker
100A

120% of
100A = 120A

125% PV
Output
18A

Example:

Inverter current = 14.4A

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

Main + PV = 118A

120% Busbar = 120A

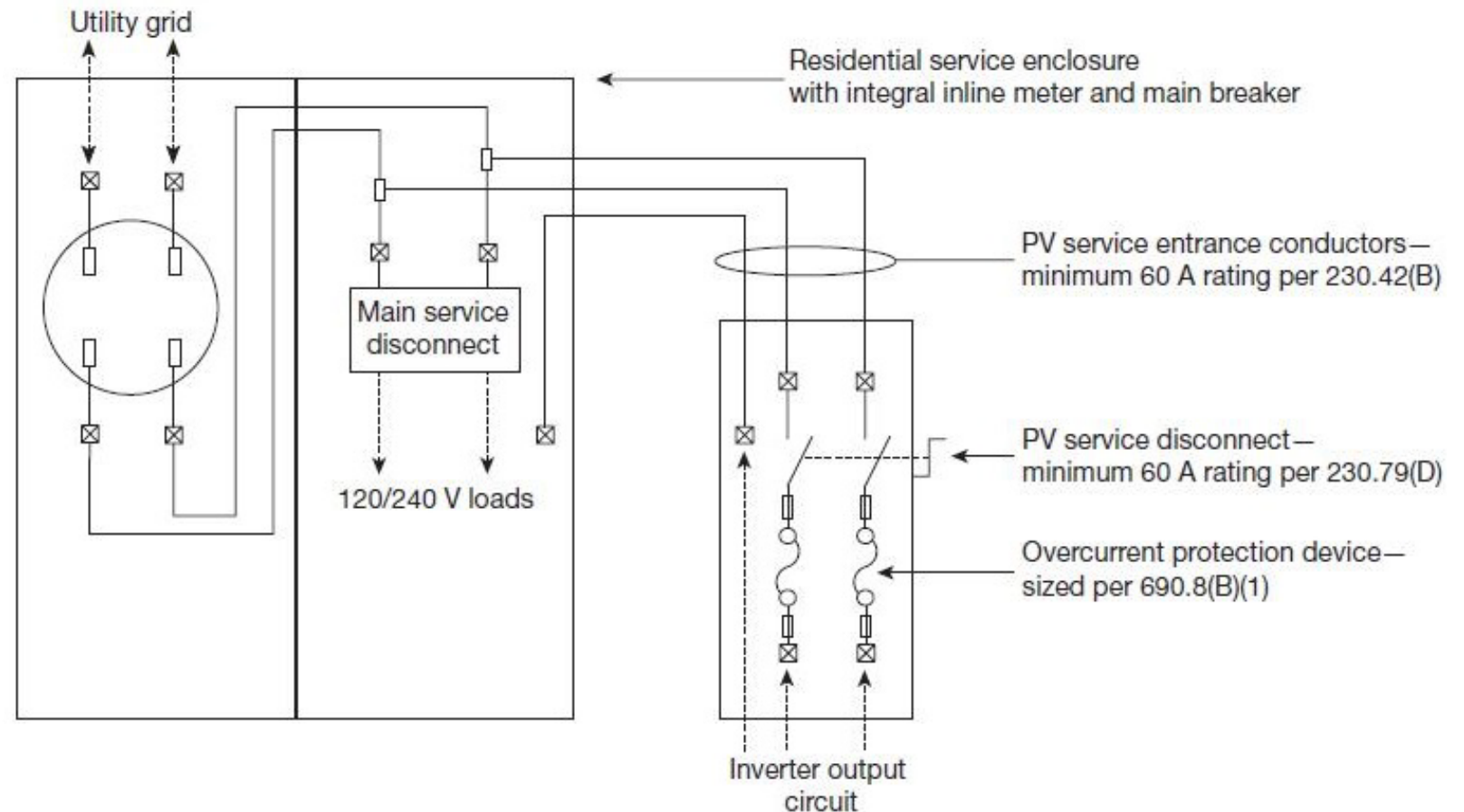
118A feeds < 120A bus Okay

- Source breakers follow 120% rule Per NEC 705.12(D)(2)(3)(b)

120% of busbar ampacity not less than sum of: Main OCPD
125% of inverter current

Supply Side Connection

When the inverter output is connected on the supply (Line) side of the service disconnecting means.



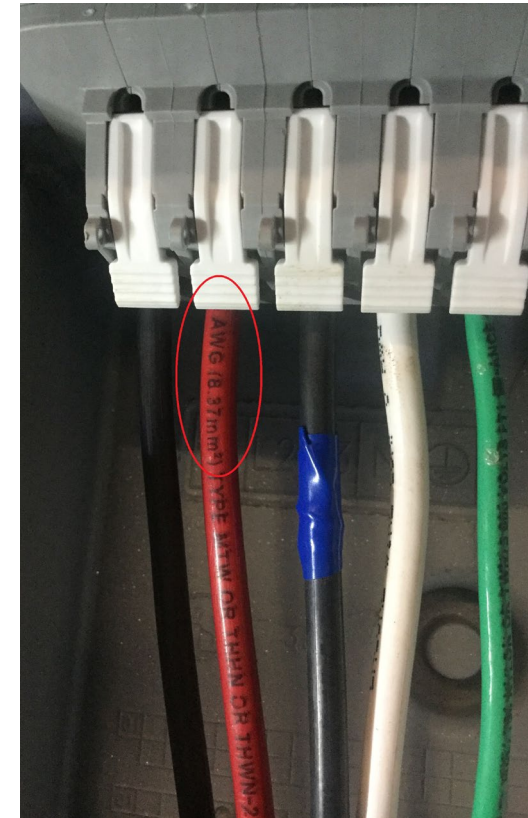
Supply Side Connection

What to look for:

solar edge	
SE5000A – US	
Utility Interactive Non – Isolated Photovoltaic Inverter	
Operating Voltage Range	270 – 500Vdc
Max Input Current	16.5A _{dc}
Max Continuous Output Power	5400W _{ac} @ 208V 5450W _{ac} @ 240V
Voltage Min-Nom-Max	183 – 208 – 229Vac 211 – 240 – 264Vac
Max Continuous Output Current	24A _{ac} @ 208V 21A _{ac} @ 240V
Max Output Fault Current	26A _{ac}
Max Utility Backfeed Current	0A _{ac}
Frequency Min-Nom-Max	59.3 – 60.0 – 60.5 Hz
Output Power Factor	> 0.99
Max Ambient Temperature	60 C
Enclosure	IP65 / Type 3R
With integrated ground fault protection per NEC 690.35 (C) Type 1 Photovoltaic Arc – Fault Circuit – Protection	

- **Circuit conductors have sufficient ampacity**
Per NEC 690.8, NEC 310.15

(Inverter output ampacity x 1.25)
21 x 1.25=26.25A
Conductor sized Min #10 AWG



Supply Side Connection

What to look for:

The length of the conductors Between Points A and B must be less than 10 feet



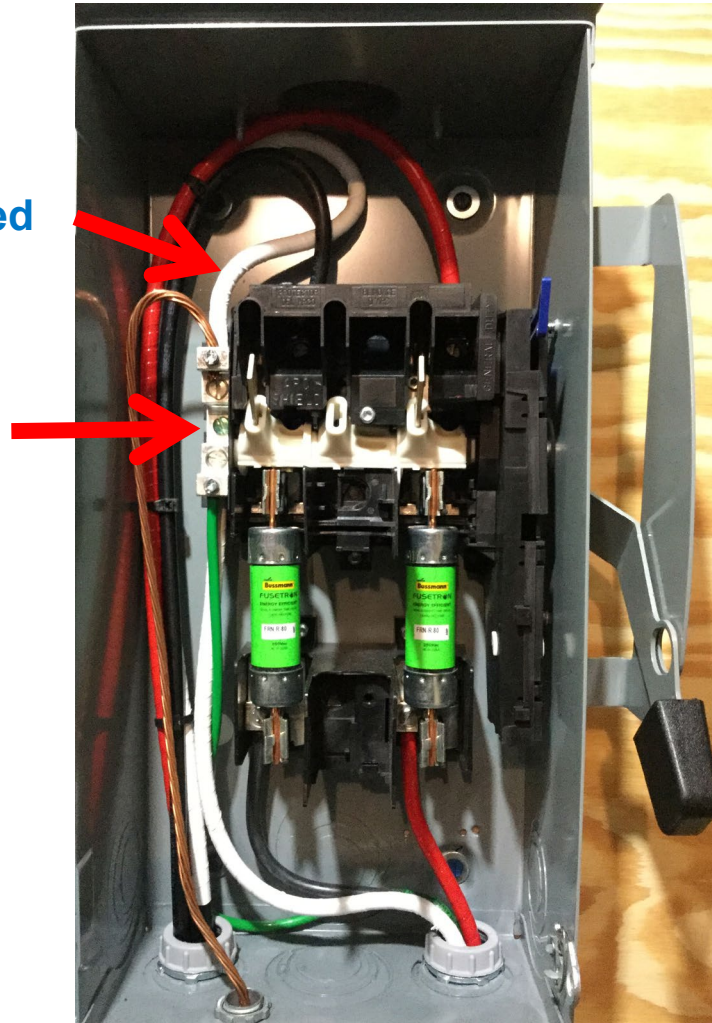
New service entrance conductors are less than 10 feet NEC 705.31

Supply Side Connection

What to look for:

Grounded Conductor is unfused

Green bonding screw is installed

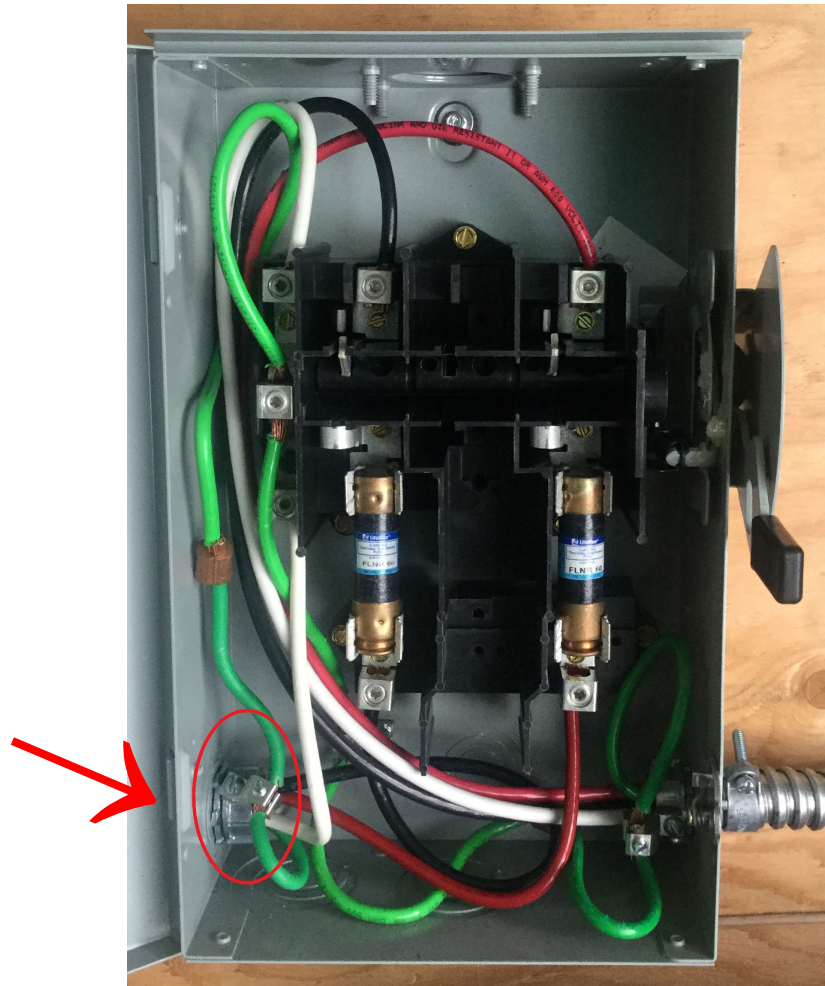


- There is no OCPD in the grounded conductor NEC 230.90(B)
- Neutral bonded to enclosure NEC 250.24(C)

Supply Side Connection

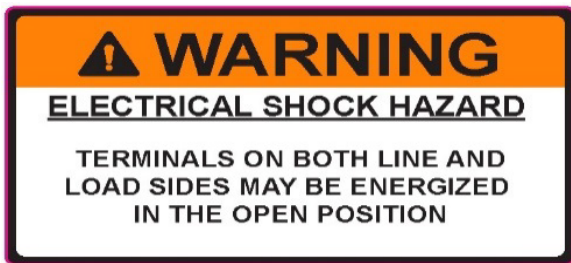
What to look for:

Ferrous conduit and the enclosure are appropriately bonded to the GEC Per NEC 250.64(E), NEC 250.4(A)(5)



Supply Side Connection

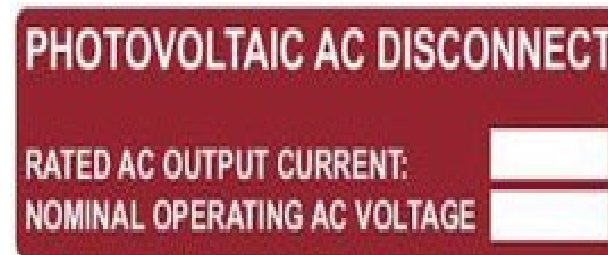
Per NEC Article 110.27(C) and OSHA 1910.145(f)(7)



Labeling

← Power source directory is present, denoting all locations of power sources and disconnects on premises, at each service equipment location
Per NEC 110.21(B), NEC 705.10

← AC characteristics label is present and suitable for the environment (voltage and amperage)
Per NEC 690.54, NEC 110.21(B)



Solar PV System Labeling Guidelines

> **Materials and Construction**

- Labeling used outdoors must be of durable construction and intended to withstand conditions including high temperatures, UV exposure, and moisture as required by NEC 110.21(B)(3). Heavy duty UV resistant vinyl, metal, or plastic may all be suitable materials, depending on the specific product ratings. Installers should also consider the label attachment method (e.g. adhesive) when considering longevity and are encouraged to review ANSI Z535.4-2011 for guidance on selecting the appropriate labeling and adhesive materials.

> **Placement**

- It is a violation of an enclosure's UL listing (and NEC 110.3(B)) to cover any existing manufacturer applied labels with installation specific labels, so this should be avoided. Additionally, it is highly recommended that the installer attaches a label or magnet with the company name and contact information at the inverter or interconnection point for easy reference.

> **Colors**

- Label colors are chosen per OSHA 29 CFR 1910.145 direction that the requirements of ANSI Z535.4-2011 be used. NFPA 70 (NEC) is driven by NFPA 1 (Fire Code) which provides specific colors and characteristics for certain labels as required by the NEC, so these requirements over rule the referenced ANSI standards in these cases.

> **Marking**

- Marking on labels for system specific values, such as short circuit current, shall not be hand-written and must be legible, as required by NEC 110.21(B)(2). Marking may be achieved by means of engraving or use of a long-lasting ink or paint as part of the printing process.

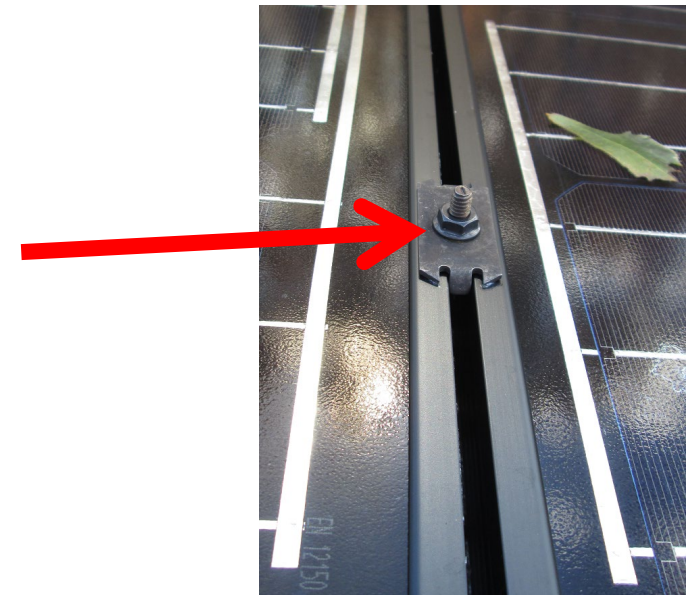
Most Common Installation Errors

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

NEC Article 100: Suitable for a specified purpose

Wrong
Lugs (Copper
or Not Listed for
Outdoor)



Grounding the Racking

NEC Articles 110.3(B) and 250.8

Wrong Screw



DC conductors at array not properly supported and protected

- Conductors shall be protected against physical damage (including those beneath array)

- Articles:

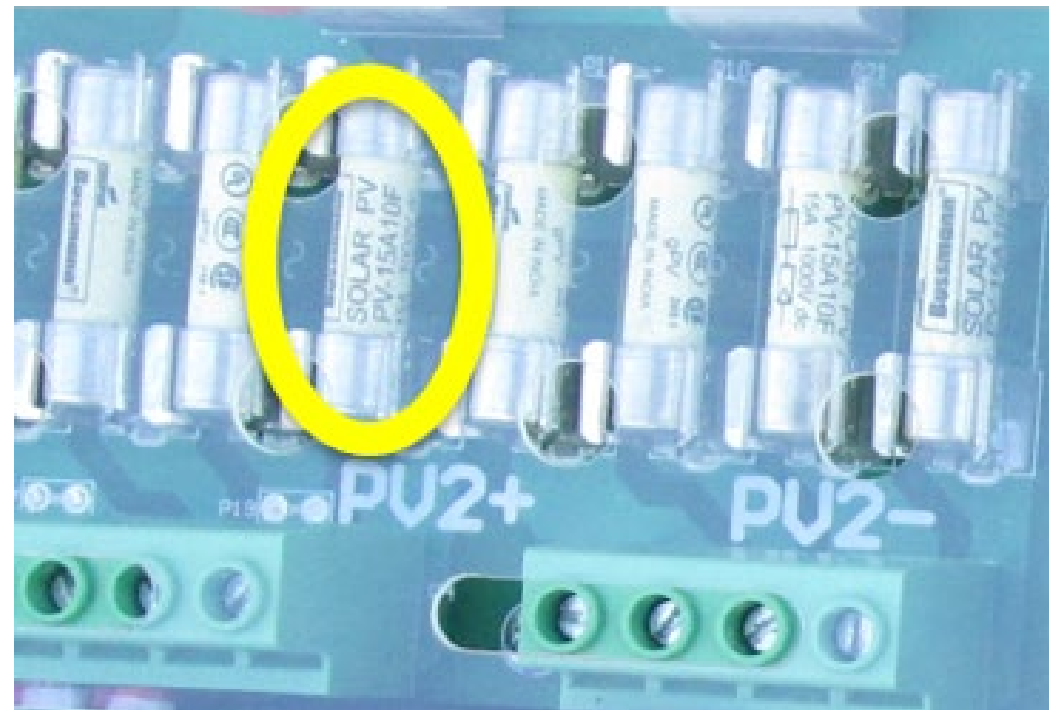
- 300.4
- 338.10(B)(4)(b)
- 334.30
- 338.12(A)(1)



Overcurrent Devices for DC Conductors

NEC Article 690.9(B)

Requires listed PV overcurrent devices for DC conductors

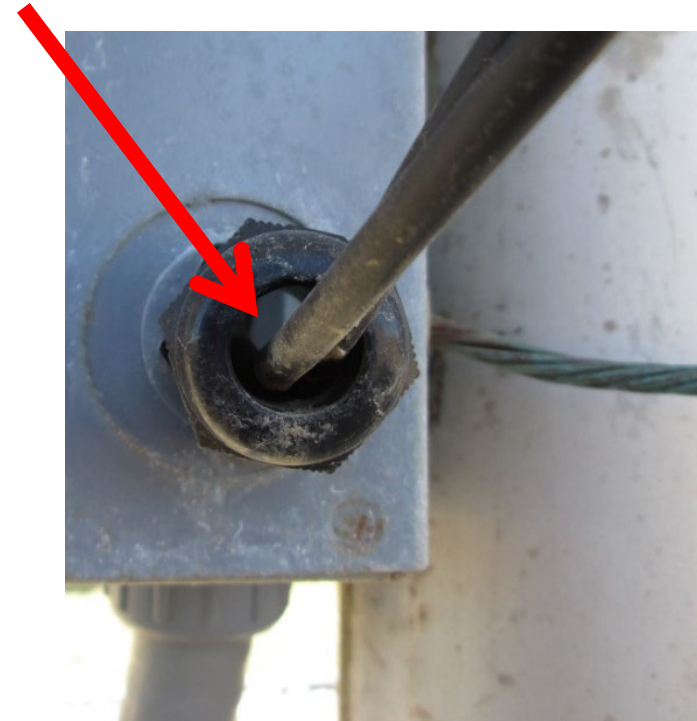


Conductors Entering Boxes

NEC Article 314.17

Conductors entering boxes shall be protected

The raceway or cable shall be secured to such boxes and conduit bodies



Dissimilar Metals

NEC Article 342.14

Galvanic
Corrosion



Dissimilar Metals & Conductor Support

NEC Article NEC 342.14 and 300.11(B)



Unsecured and Unprotected Conductors

NEC Article 300.4



Common PV Output Violations

Outdoor enclosures

- Not installed “so as to prevent moisture from entering or accumulating...” in accordance with 314.15
 - 2017 NEC allows the use of openings not less than 1/8” “approved drainage openings”.
- Penetrations not sealed, as required by 300.7(A)



**Weep hole doing its job.
Notice where water line ends.**

Enclosures

NEC Article 314.15



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

Enclosures

NEC Article 314.15



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

Preventing Moisture Entry

NEC Article 300.7(A)

Issues with raceway sealing...



Raceway must be sealed when passing between the interior and exterior of a building per 300.7(A). Ensure product is **rated for application** (contact with electrical insulation, wet location, etc.).

Bonding the Raceway

NEC Article 250.4

Conductive materials enclosing conductors **SHALL BE BONDED!**

- Plastic enclosure outside
- Metal inside
- Plastic DC disconnect



Supply Side Connection

NEC Article 705.12(A)

- Interconnection on utility side of main service disconnect
- Typically on customer side of utility meter
- “Second set” of service entrance conductors (Article 230)
- NEC 240.40 Requires the fuses to be de-energized when the switch is open
- Utility conductors must be on line terminals of disconnect
 - These remain energized when disconnect is opened (turned off)



Supply Side Connection

NEC Articles 250.24(A)(1) and 250.92

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 Bonding of Equipment for Services

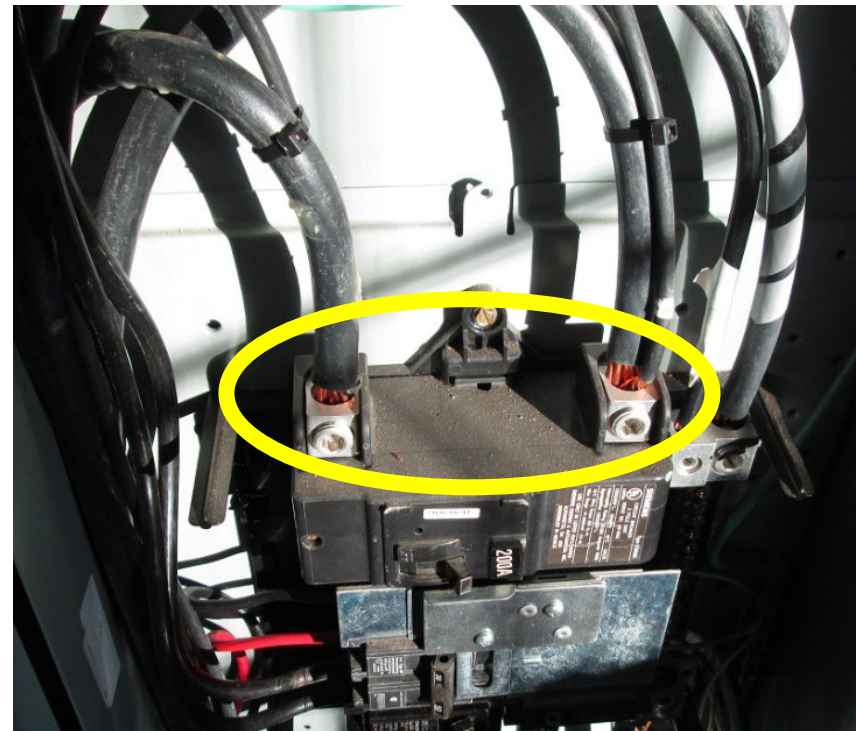
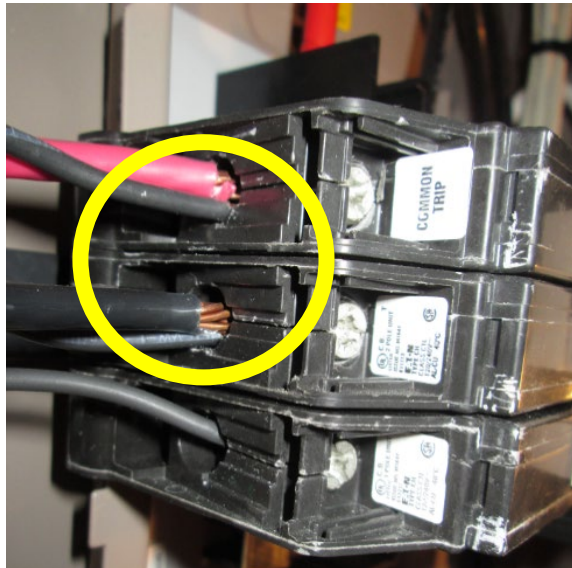


PV Interconnection

Considerations... NEC 110.14

Terminal ratings should be followed:

- Conductor size
- Max conductors

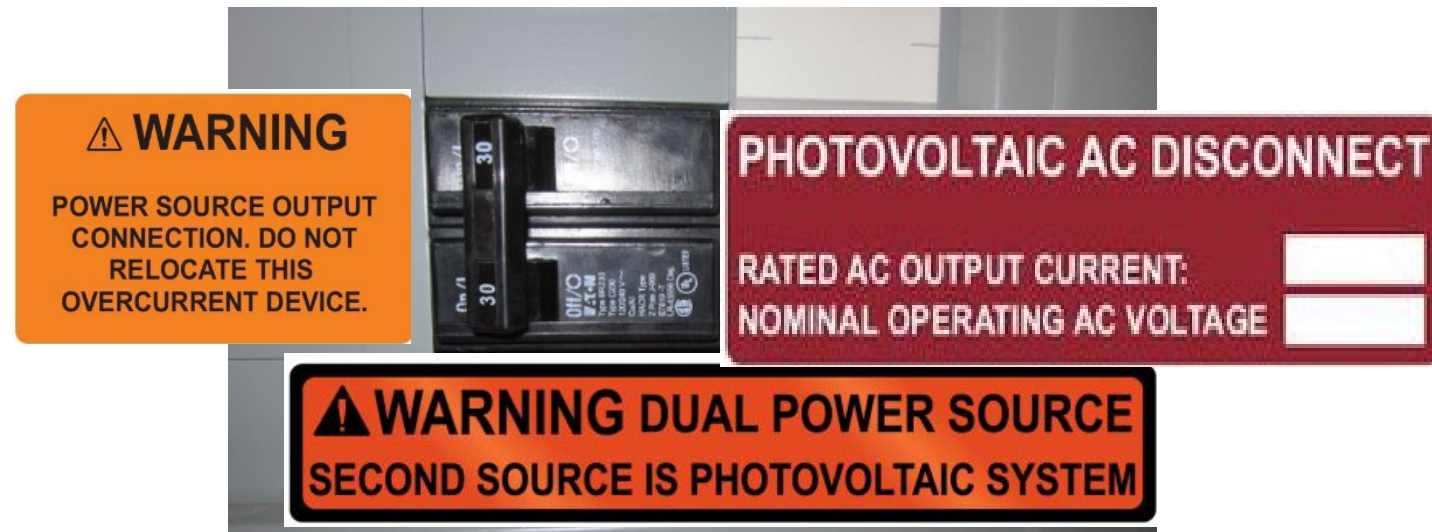


Load Side Connection

NEC Article 705.12(B)

Key sections include:

1. Interconnection shall be made at dedicated OCPD
2. Feeders, Taps, Busbar Interconnection
3. Equipment shall be marked to indicate presence of all sources



No Flashing

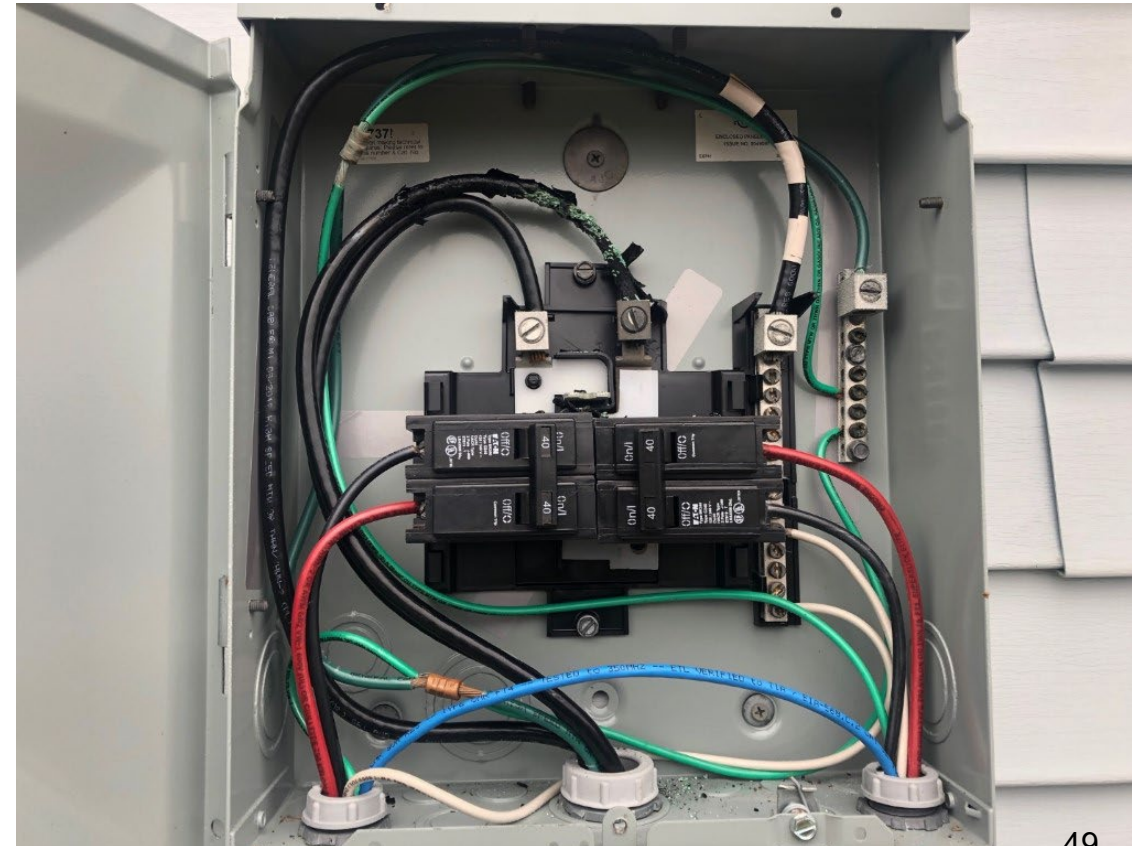
Improper Conduit Penetration vs. Listed for the purpose



Improper Torque, Loose Connection

NEC Article 110.12 and 110.14(D)

Mechanical Execution of Work “ Shall be installed in a neat and workman like manner”



Additional Resources

New York State Solar Guidebook

<https://www.nyserda.ny.gov/SolarGuidebook>

Quality Assurance reference Guides

<https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Contractors/Resources-for-Contractors>

Energy Storage Guidebook

<https://www.nyserda.ny.gov/All-Programs/Programs/Clean-Energy-Siting/Battery-Energy-Storage-Guidebook>

Questions?



Photo Courtesy of Wheeler Drone
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