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DOER
Massachusetts Department of Energy Resources

Solar PV Inspection Techniques for Municipal Inspectors

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Matt Piantedosi, The Cadmus Group

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Training Outline

- Importance of Quality
- MA Model Electrical Permitting Requirements for PV Installations
- Inspection Best Practices
- Common Violations

About the Trainer: Matt Piantedosi

- BS Electrical Engineering
  - Western New England College
- Cadmus Senior Associate Engineer and Solar PV Inspector
- Inspected over 500 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 15 years
  - B. A. Piantedosi Jr. Master Electrician
  - Logan Electrical Company
- IAEI – Boston Paul Revere Chapter
  - Executive Board Member

About The Cadmus Group

- Energy consulting firm with renewable energy technical and economic expertise
  - 13+ years of experience
  - Assisting clients to develop and support renewable energy in the Northeast
- Cadmus has conducted quality assurance inspections for more than 20 MW of solar PV installations

About The Cadmus Group

Supporting clean energy programs since 2002

Technical Due Diligence

- Inspections
- Design Reviews
- Feasibility Studies

Policy and Financial Analysis

- Power purchase agreements
- Net Metering
- Program Design & Evaluation

Training

- Code Officials
- Installers
- First Responders

EnergyTrust of Oregon

NY-Sun Solar Powering New York ny-sun.ny.gov

Massachusetts Clean Energy Center

Clean Energy Finance and Investment Authority

REF Commerce RI Renewable Energy Fund

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Why Should We Care About Quality?

- Safer
- Less downtime
- Fewer service calls
- Better perception

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Is it a Quality Installation?

- Goal is to ensure that PV systems are:
  - Safe
  - Productive
  - Long-lived

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Model Electrical Installation and Permitting Requirements for PV Systems

Model Electrical Requirements

- Guide for installers & wiring officials
  - **Supplement** to the Uniform Application for Permit to Perform Electrical Work
  - Information on by-law requirements
  - Best practices
- Goal: Ensure that solar PV systems:
  - Are installed safely
  - Comply with Massachusetts' code requirements

Model Electrical Requirements

- MGL Ch. 143 § 3L requires individuals installing electrical wiring to:
  - Give notice on start and completion of electrical work
    - Notice of commencement must be received within 5 days of starting work
  - AHJ is required to approve/disapprove work within 5 days of notice of completion
    - If disapproval is given, applicable sections of Massachusetts Electrical Code (527 CMR 12) must be provided
- Installation of PV components must be by ***Massachusetts-licensed*** electricians per the ratio requirements specified in MGL Ch. 141 §1
  - One-to-One Ratio
    - Licensed Electrician per Apprentice
  - Master license required for companies employing electricians
  - Guidance Memo 13-01
    - http://www.mass.gov/ocabr/licensee/dpl-boards/el/regulations/board-policies/guidance-memo-pv-installation.html

Model Electrical Requirements

- Key Guidance for ***Installers***:
  - Electrical work ***must not be covered, concealed, modified, or energized*** until approved by the AHJ
    - If covered before AHJ approval, the inspector may require you to remove modules or other elements to provide access during an inspection
  - Applicant listed on the Uniform Permit Application ***must notify the AHJ when work is complete***
  - Responsible party (applicant, designee) ***must be onsite during the inspection***
  - Multiple inspections may be required in various phases, at the discretion of the AHJ

Example of an installation that may require a rough inspection before the installation of PV modules.

Example of an installation that may require a rough inspection before the installation of PV modules.

For flat-roof applications, rough inspection can include wire management/protection plan as well as proposed conduit layout, in an effort to reduce trip hazards.

Model Electrical Requirements

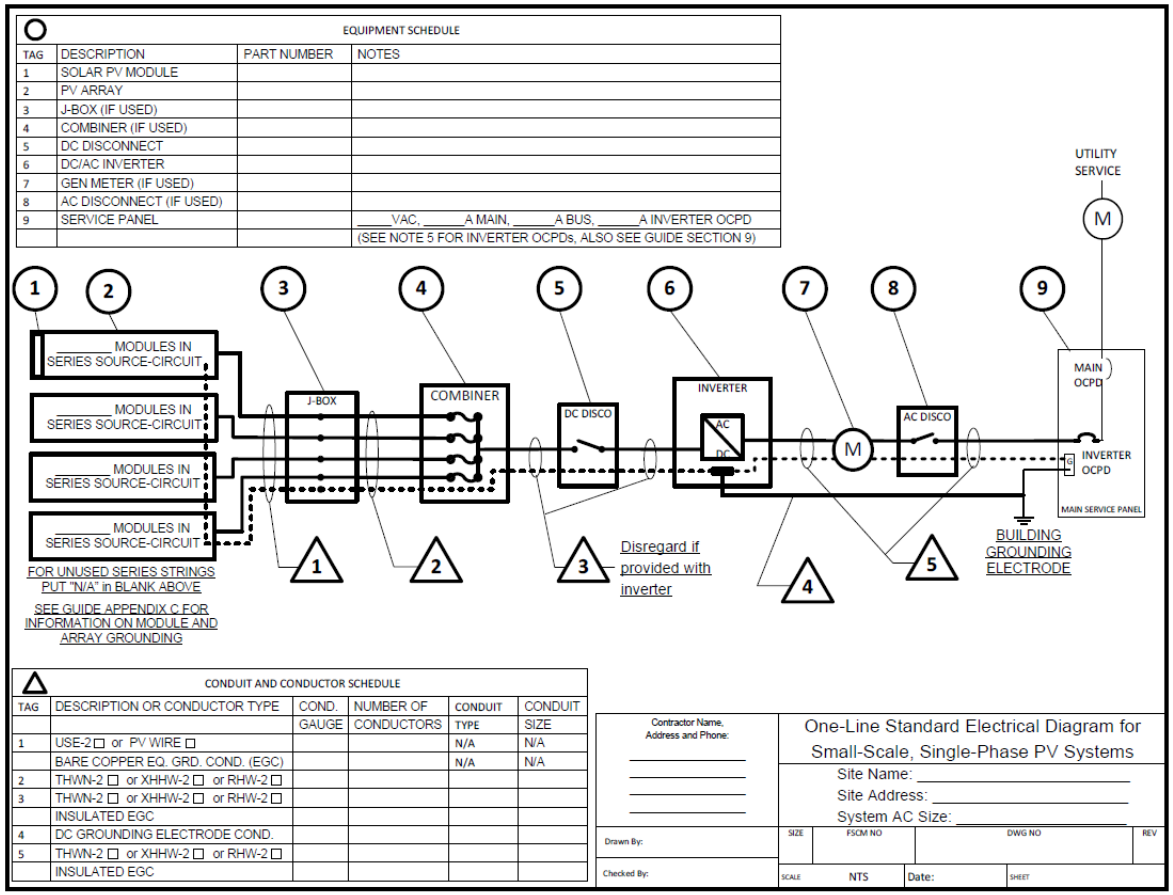
- Key Recommendations for ***Installers***:
  - Establish open communications with the AHJ
  - ***Contact the AHJ prior to commencing work:***
    - Plan reviews may be necessary and should be completed before beginning work
    - Equipment is changing rapidly, have all installation instructions available for review
  - Contact the ***local fire department*** to confirm a solar PV system is being installed in their jurisdiction

Model Electrical Requirements

- Key Guidance for ***Inspectors***:
  - In addition to the Uniform Permit Application, AHJs may require (not limited to):
    - One-Line Electrical Drawing
    - Site Plan
    - Specifications Sheets

Optional Application Requirements

- One-Line Electrical Drawing



EQUIPMENT SCHEDULE

TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE		
2	PV ARRAY		
3	J-BOX (IF USED)		
4	COMBINER (IF USED)		
5	DC DISCONNECT		
6	DC/AC INVERTER		
7	GEN METER (IF USED)		
8	AC DISCONNECT (IF USED)		
9	SERVICE PANEL		____VAC, _____A MAIN, _____A BUS, _____A INVERTER OCPD
			(SEE NOTE 5 FOR INVERTER OCPDs, ALSO SEE GUIDE SECTION 9)

CONDUIT AND CONDUCTOR SCHEDULE

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2☐ or PV WIRE ☐			N/A	N/A
	BARE COPPER EQ. GRD. COND. (EGC)			N/A	N/A
2	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
3	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
	INSULATED EGC				
4	DC GROUNDING ELECTRODE COND.				
5	THWN-2 ☐ or XHHW-2 ☐ or RHW-2 ☐				
	INSULATED EGC				

Contractor Name, Address and Phone:

One-Line Standard Electrical Diagram for Small-Scale, Single-Phase PV Systems

Site Name: _____

Site Address: _____

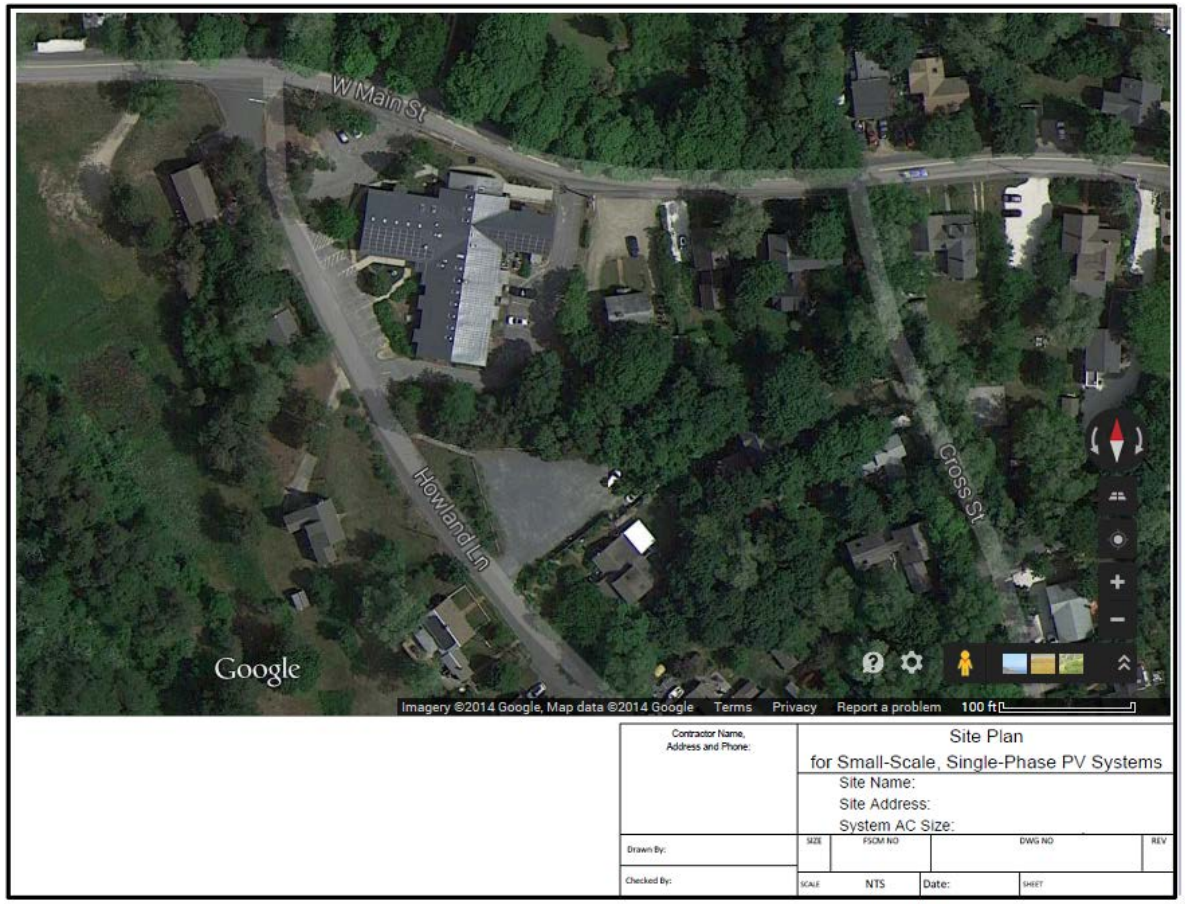
System AC Size: _____

Drawn By: | SIZE | FSCM NO | DWG NO | REV

Checked By: | SCALE NTS | Date: | SHEET

Optional Application Requirements

- Site Plan Drawing



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Optional Application Requirements

- Manufacturers specification sheets and/or instruction manuals
  - Solar PV Modules
  - Racking
  - Inverter

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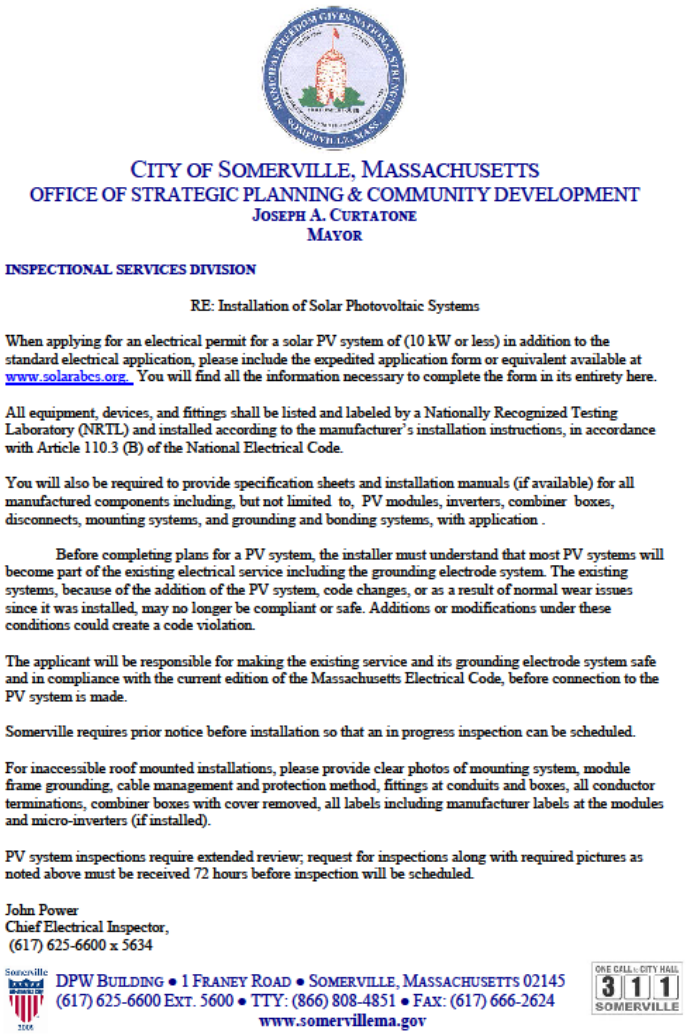
Prior: Send Letter from the Inspector



CITY OF SOMERVILLE, MASSACHUSETTS
OFFICE OF STRATEGIC PLANNING & COMMUNITY DEVELOPMENT
JOSEPH A. CURTATONE
MAYOR

INSPECTIONAL SERVICES DIVISION

RE: Installation of Solar Photovoltaic Systems

When applying for an electrical permit for a solar PV system of (10 kW or less) in addition to the standard electrical application, please include the expedited application form or equivalent available at www.solarabcs.org. You will find all the information necessary to complete the form in its entirety here.

All equipment, devices, and fittings shall be listed and labeled by a Nationally Recognized Testing Laboratory (NRTL) and installed according to the manufacturer's installation instructions, in accordance with Article 110.3 (B) of the National Electrical Code.

You will also be required to provide specification sheets and installation manuals (if available) for all manufactured components including, but not limited to, PV modules, inverters, combiner boxes, disconnects, mounting systems, and grounding and bonding systems, with application .

Before completing plans for a PV system, the installer must understand that most PV systems will become part of the existing electrical service including the grounding electrode system. The existing systems, because of the addition of the PV system, code changes, or as a result of normal wear issues since it was installed, may no longer be compliant or safe. Additions or modifications under these conditions could create a code violation.

The applicant will be responsible for making the existing service and its grounding electrode system safe and in compliance with the current edition of the Massachusetts Electrical Code, before connection to the PV system is made.

Somerville requires prior notice before installation so that an in progress inspection can be scheduled.

For inaccessible roof mounted installations, please provide clear photos of mounting system, module frame grounding, cable management and protection method, fittings at conduits and boxes, all conductor terminations, combiner boxes with cover removed, all labels including manufacturer labels at the modules and micro-inverters (if installed).

PV system inspections require extended review; request for inspections along with required pictures as noted above must be received 72 hours before inspection will be scheduled.

John Power
Chief Electrical Inspector,
(617) 625-6600 x 5634

DPW BUILDING • 1 FRANEY ROAD • SOMERVILLE, MASSACHUSETTS 02145
(617) 625-6600 EXT. 5600 • TTY: (866) 808-4851 • FAX: (617) 666-2624
www.somervillema.gov

ONE CALL - CITY HALL 3 1 1 SOMERVILLE

Example letter from Somerville, MA:
http://www.somervillema.gov/sites/default/files/SolarLtrLtrHead.pdf

- Instructions to supplement the Uniform Application for Permit to Perform Electrical Work
  - Intended for systems ≤ 10 kW
  - Requires listed components
  - Requires data sheets for all components

Prior: Send Letter from the Inspector

- Solar PV system will be interconnected with the existing electrical service and rely on the grounding electrode system:
  - Existing grounding electrode system may not meet the current code requirements
  - Installation shall not increase the magnitude of an existing violation
    - MEC (527 CMR 12.00) Rule 3
    - MEC 690.47(C)
- Solar PV installation requires “rough” and “final” inspections

Prior: Review Installation Documentation

- To ***supplement*** an onsite inspection, detailed photos should be available for all:
  - Module mounting system
  - Module frame grounding
  - Rooftop grounding/bonding methods
  - Cable management and protection method
  - Conduit/enclosure fittings
  - All conductor terminations
  - Interior of all enclosures
- Evidence associating photos with site
- Review documentation to:
  - Identify areas of concern to review onsite
  - Estimate duration of onsite inspection

Priorities for Your Next Inspection

- Questions to ask yourself:
  - Do I have safe access to all system components?
  - Where should I look for common violations?
  - What are the most common violations to look for?
  - How long **can** I spend at this inspection?
  - How long **should** I spend at this inspection?

During the Inspection

- Review the PV system from the sun to the grid
- Keep an eye out for common violations
  - Top issues at the array, inverter, and interconnection to the grid
- Use review of installation documentation to pinpoint areas for additional scrutiny
- Pace of the inspection should be determined by the quality of the workmanship
  - Poor workmanship may require longer time on-site
- Document any violations with photos

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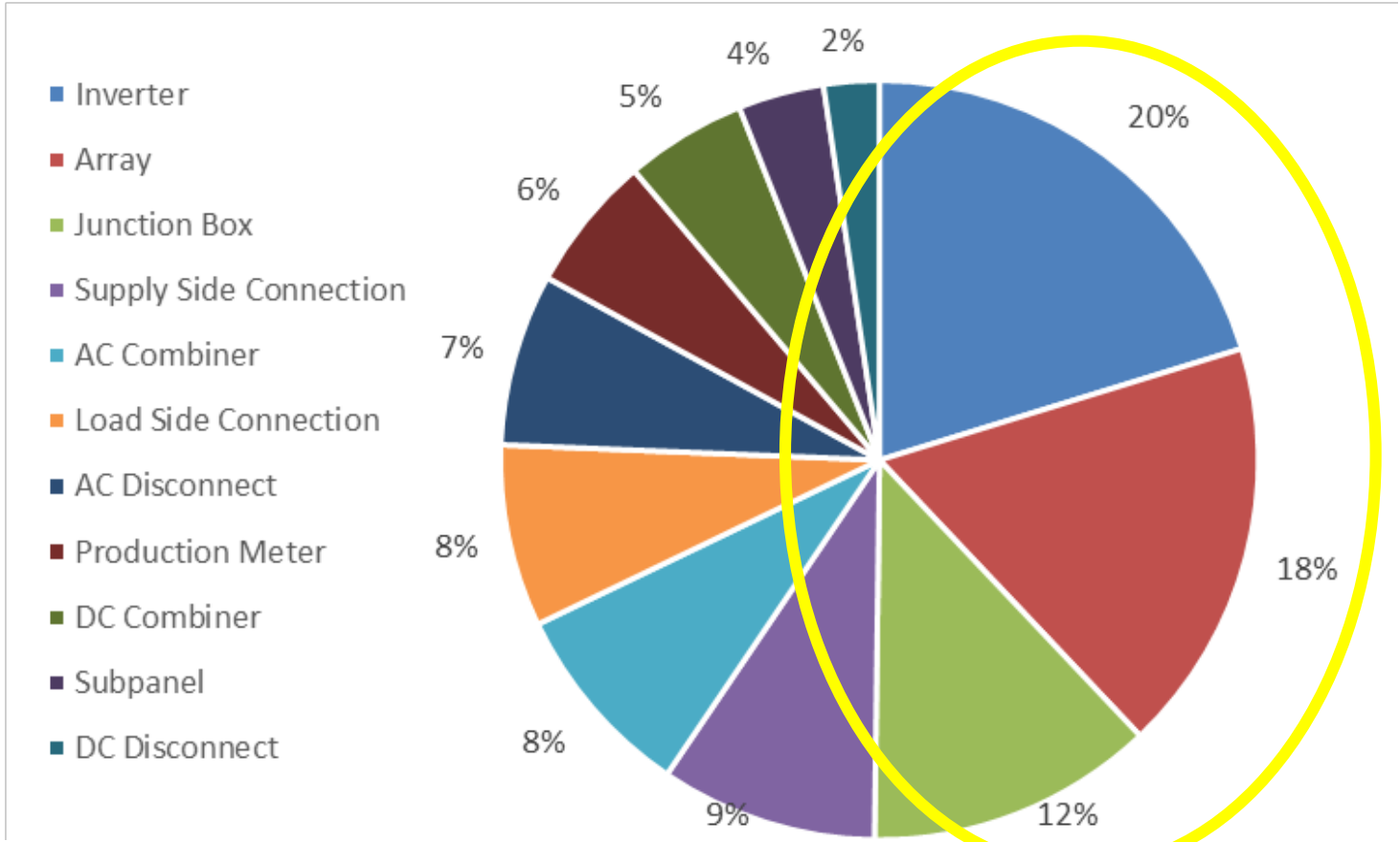
Common PV Violations

Where Do Most PV System Violations Occur?

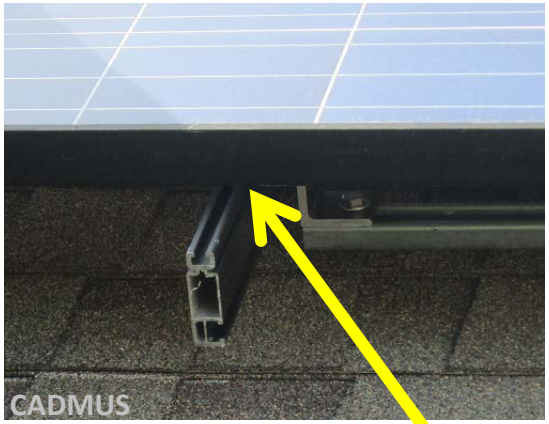


50% of issues can be found in 3 places:

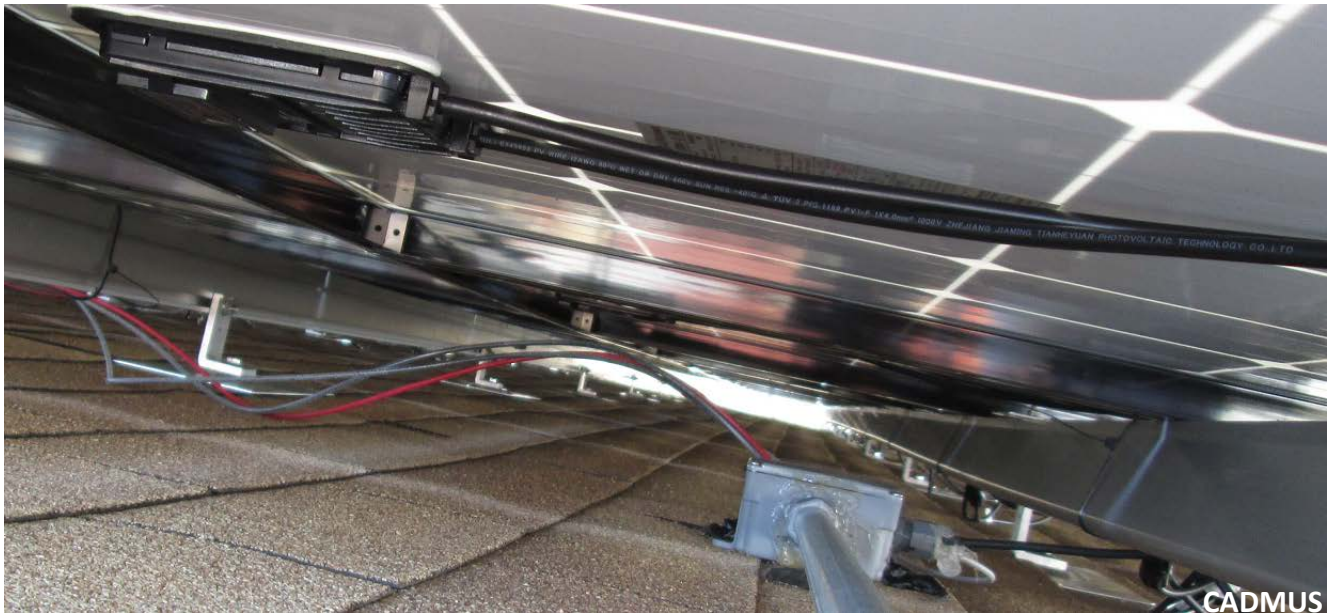
- **Inverter**
- **Array**
- **Junction Boxes/enclosures**

Where Do Critical and Major Issues Occur?

- 18% at the array
  - Ungrounded equipment
  - Poor mechanical connections



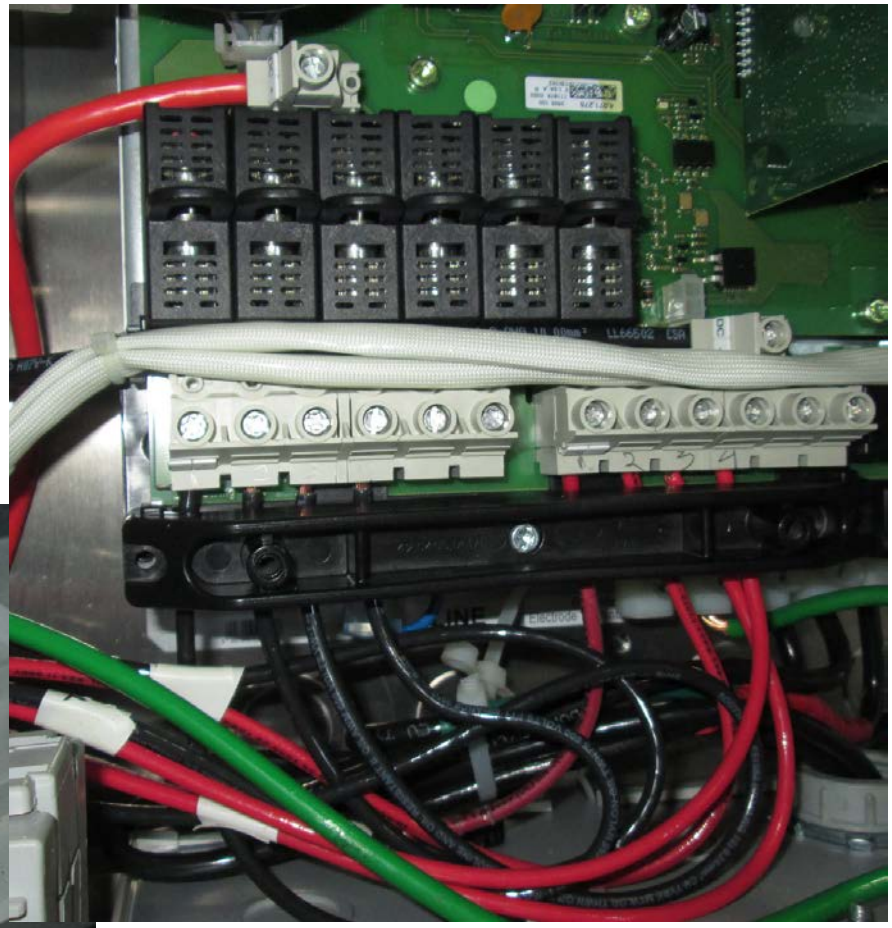
Module missing support hardware



Array containing unprotected conductors and no equipment grounding.

Where Do Critical and Major Issues Occur?

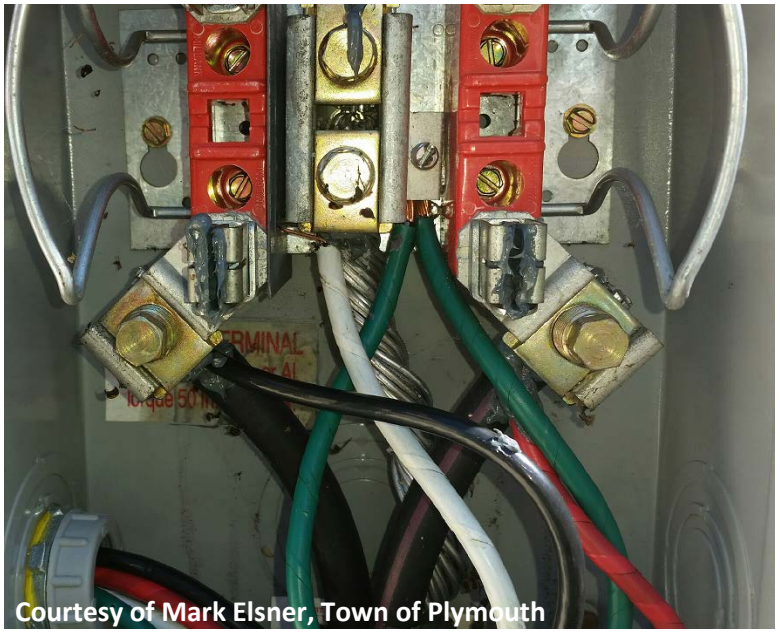
- 16% at the inverter
  - Improper string fusing
  - Ungrounded enclosure
  - GEC missing



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

Where Do Critical and Major Issues Occur?

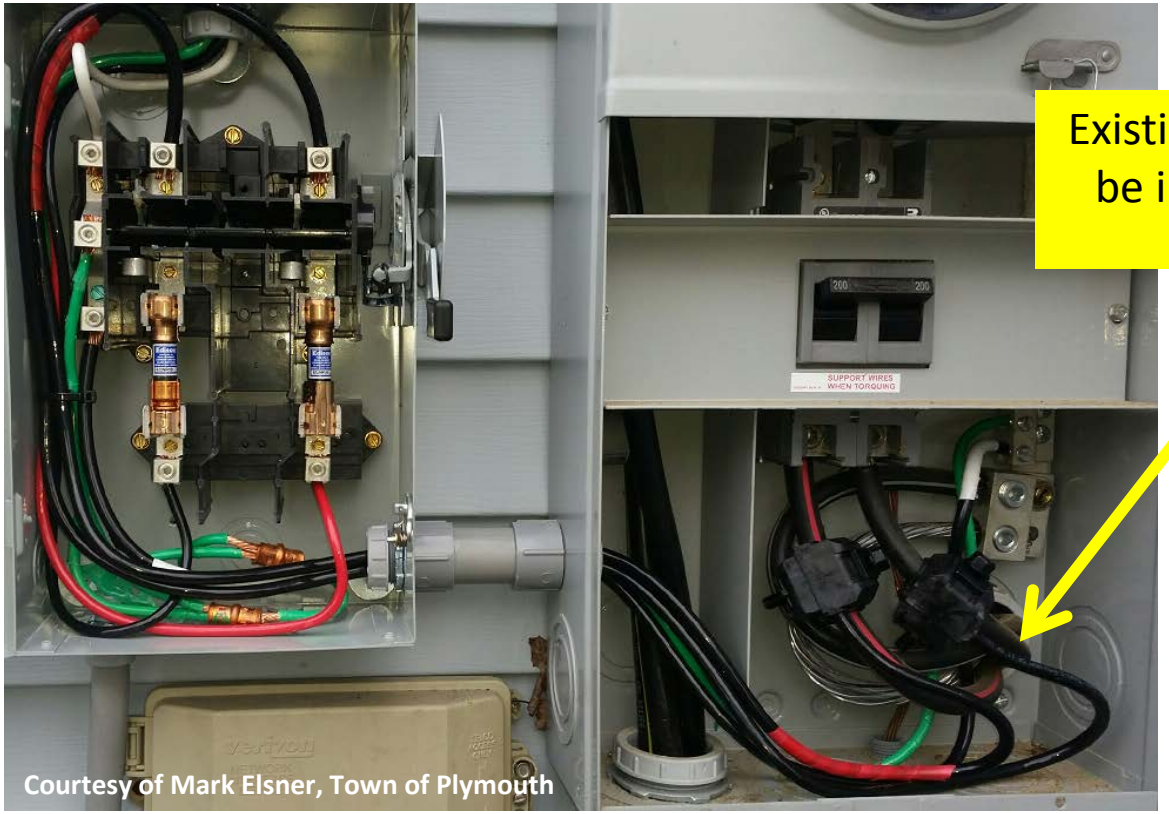
- 16% at the supply side connection
  - Improper/missing OCPD
  - Insufficient kAIC rating
  - GEC missing
  - Taps not properly made



Courtesy of Mark Elsner, Town of Plymouth

Where Do Critical and Major Issues Occur?

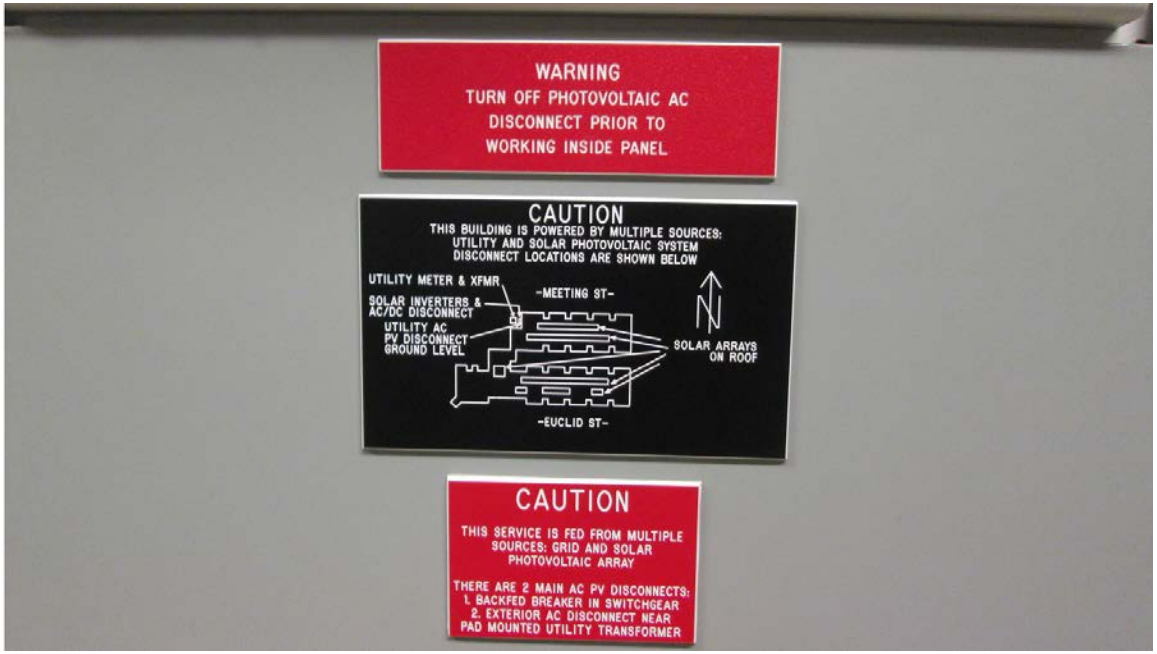
- 11% at load side connections
  - Excess backfeed current for busbar or conductor



Beyond oversized load-side connection breakers, connections in a meter-main will increase the available current on a conductor and/or busbar.

Frequent PV Code Violations

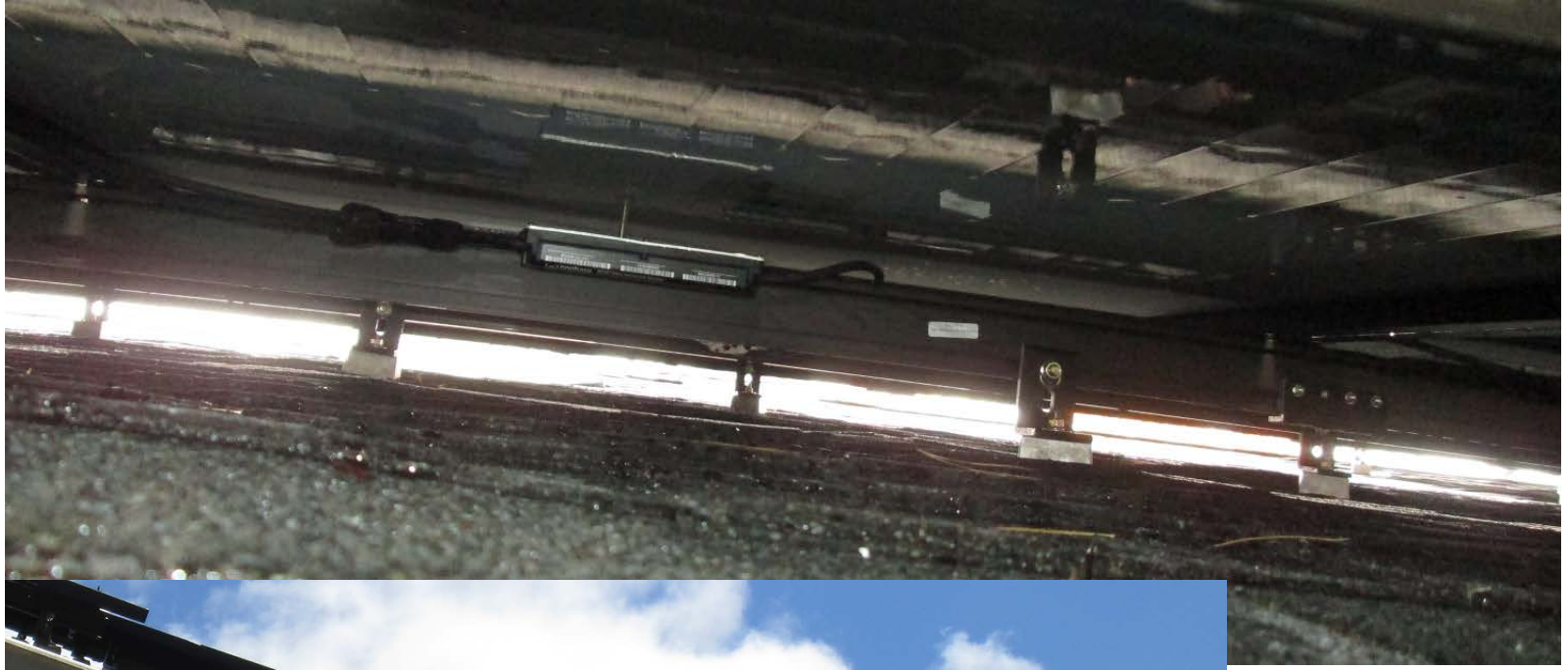
- NEC 705.10/690.56: Missing power source directories
  - 33% of systems

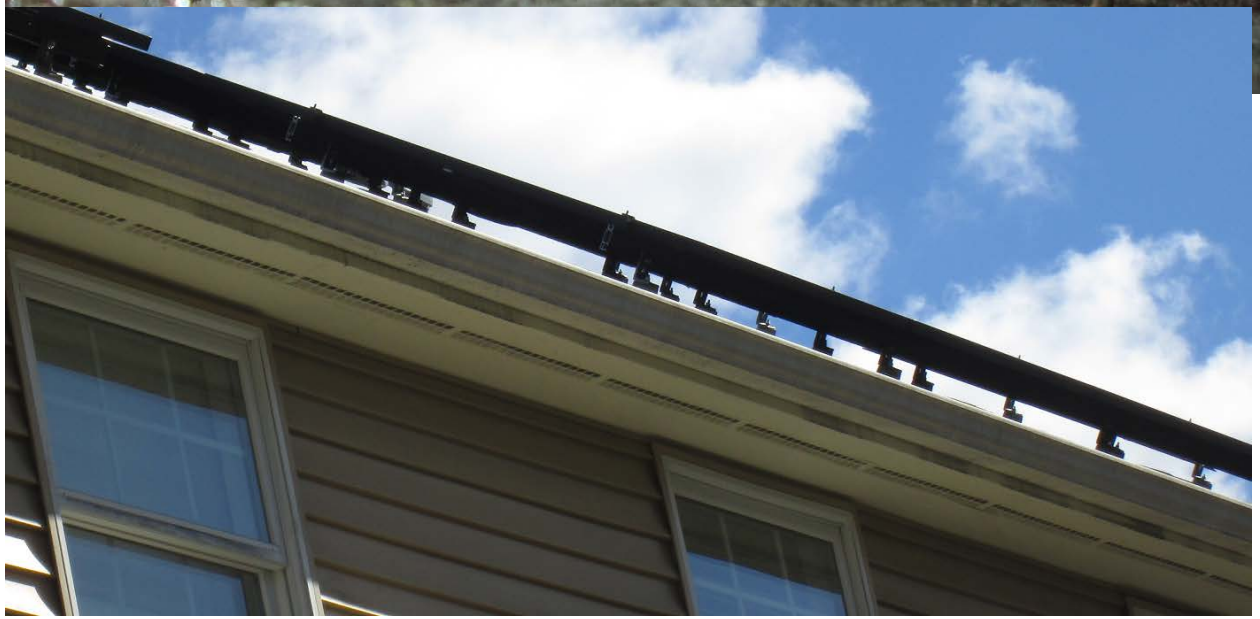


705.10: A permanent plaque or directory, denoting all electric power sources on or in the premises, shall be installed at each service equipment location and at locations of all electric power production sources capable of being interconnected.

Frequent PV Code Violations

- NEC 338.10(B)(4)/334.30/300.4: Array conductors not supported or protected
  - 17% of systems





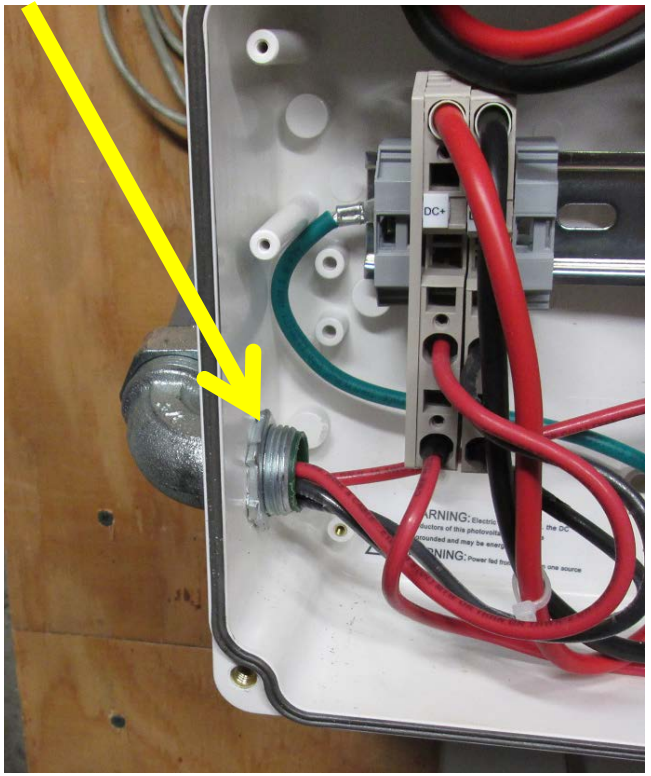
Proper wire management is often easy to verify from a ladder (upper photo) or the ground (lower photo).

Frequent PV Code Violations

- 780 CMR 5903.2: Roof penetrations not properly-flashed
  - 5% of systems

Frequent PV Code Violations

- NEC 250.4: Conductive materials enclosing conductors **SHALL BE BONDED!**
  - Plastic enclosure outside
  - Metal inside
  - Plastic DC disconnect



Frequent PV Code Violations

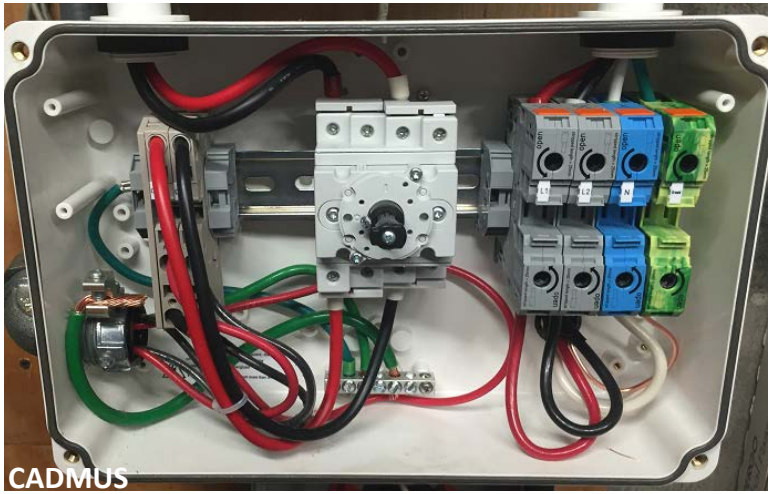
- NEC 690.15:

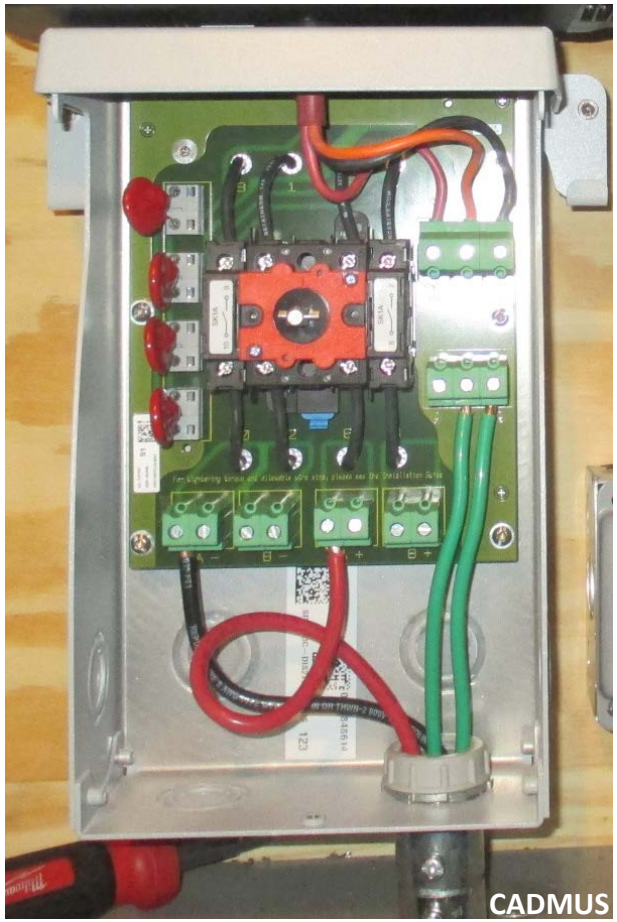
  "Means shall be provided to disconnect equipment, such as inverters, batteries, and charge controllers, from all ungrounded conductors of all sources. If the equipment is energized from more than one source, the disconnecting means shall be grouped and identified."

An external AC disconnect may be required if the inverter does not contain an internal AC disconnect

Inverter Disconnect Requirements

Inside the "S" brand…





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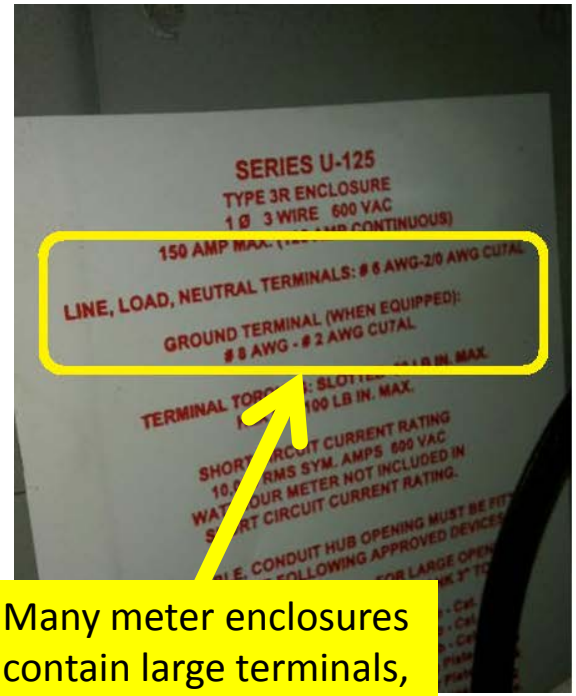
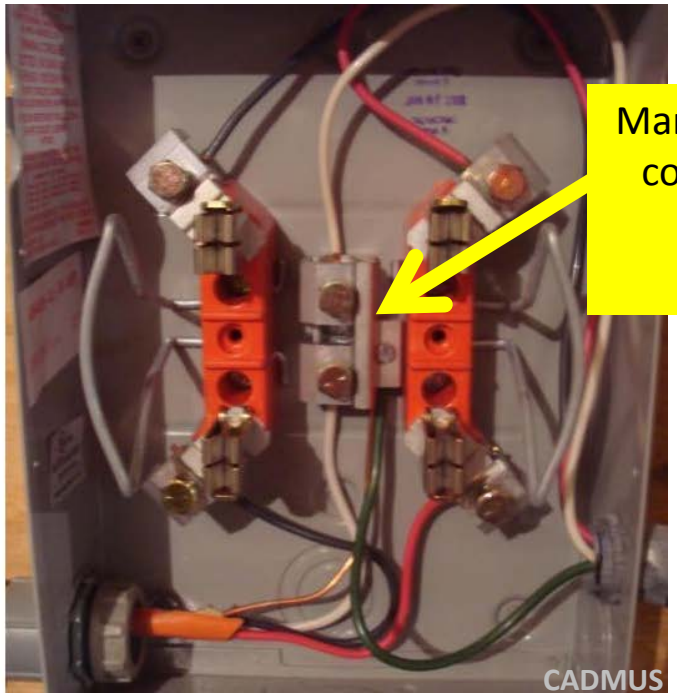
Frequent PV Code Violations

- NEC 250.24(A)(5) and 110.3(B):
  - Grounded (neutral) conductor bonded to PV meter enclosure downstream of main breaker
  - Small conductors under large terminals



Many meter enclosures contain large terminals, accommodating down to a #6 AWG conductor



Many meter enclosures contain a neutral lug bonded to the enclosure

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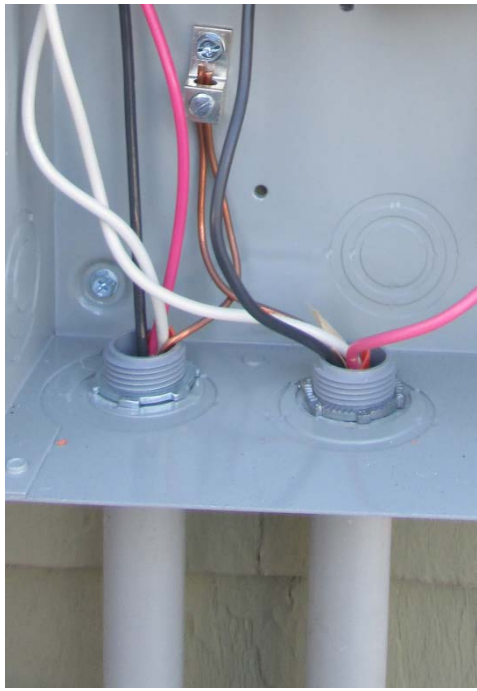
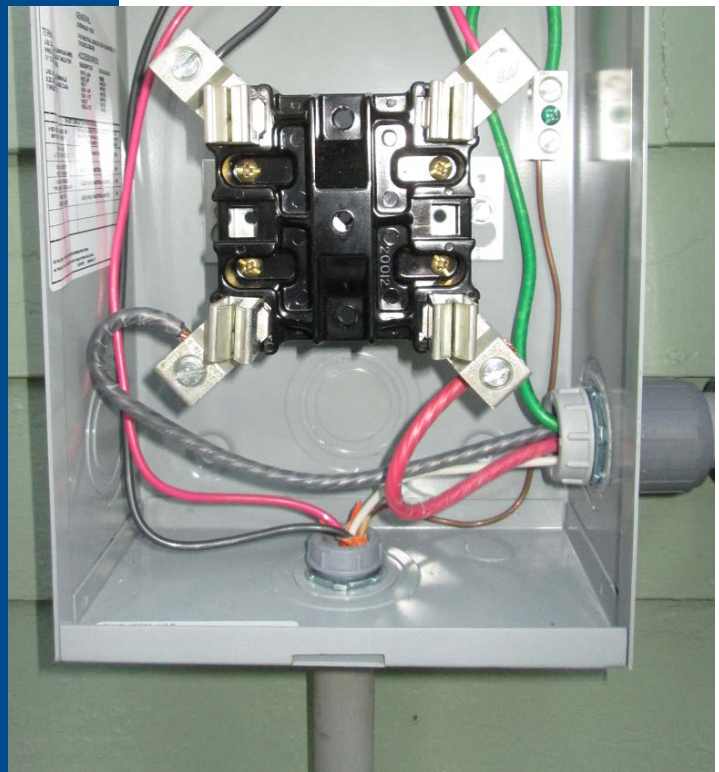
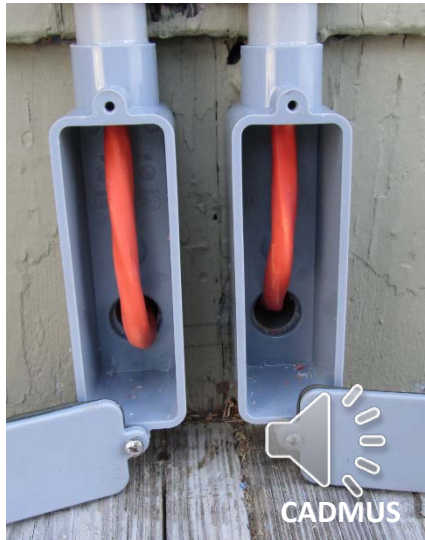
Type NM Cable

NEC Article 334.12

- Prohibited in wet/damp locations
  - Article 334.12(B)(4)
- Outdoor raceways are wet locations!
  - Article 300.9







Practical Field Advice

- Prior to commencement of work:
  - Send a ***Letter from the Inspector***
  - Require and review Installation Documentation
- During the inspection:
  - Focus on top issues at
    - Array
    - Inverter
    - Interconnection to the grid
- Understand solar PV-specific requirements:
  - Common confusion
  - PV Violations and safety concerns

The inspection process and procedures are evolving alongside the industry–to ensure safe installation practices are used.

Questions?

Matt Piantedosi

The Cadmus Group, Inc.

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http://www.mass.gov/eea/energy-utilities-clean-tech/renewable-energy/solar/solar-permitting-and-structural-review-rsc2.html

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