Model Permitting and Safety for Solar PV in Massachusetts

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Training Overview

• Sun to the Grid: Solar PV Inspections
  ➢ Useful information to the permitting process
    ▪ Best practices
    ▪ Regulatory requirements
  ➢ Ensure solar PV systems are:
    ▪ Safe
    ▪ Comply with Massachusetts Requirements
  ➢ DOER Rooftop Solar Challenge:
Training Overview

- Parties building and supporting solar PV development in Massachusetts:
  - Electrical and building inspectors
  - Solar developers
  - Electricians
- Electrical permitting overview & information
- Building permitting overview & information
- Key PV safety concerns and considerations
- Best practices for installing and inspecting solar PV

Training Outline

- Solar PV Basics
- Permitting
  - Building
  - Electrical
- PV System Review
  - Covering all components of PV system
- Frequent Violations and Inspection Best Practices
About The Cadmus Group

- Renewable energy technical and economic expertise, with 12+ years of experience aiding 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:
  - Massachusetts Clean Energy Center
  - Rhode Island Renewable Energy Fund
  - New York State Energy Research and Development Authority

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
About the Trainer: Matt Piantedosi

- BS Electrical Engineering
  - Western New England College
- Senior Associate Engineer, 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 Trainer: Glenn Burt

- NABCEP Certified PV Installation Professional™ since 2009
- Member IEEE
- Renewable Energy Engineer with Cadmus
- Former Instructor, DOE Solar Instructor Training Network – Train the Trainer program
- Former Adjunct Instructor, Hudson Valley Community College; Entry Level and Advanced PV
- Former Technical Specialist for RPS Power, Alteris Renewables and Real Goods Solar
About the Trainer: Shawn Shaw

- Principal of Cadmus Renewable Energy Team
- Lead on solar QA projects inspecting more than 3,200 PV installations in MA, NY, and RI
- Completed hundreds of design reviews, inspections, and technical analyses on solar PV systems
- Registered electrical engineer (NY license 095231)
- Member of NREL’s PV Quality Assurance Task Force and contributing author on numerous solar QA guides and documents

Cadmus Inspection Process

- Evaluate system compliance with NEC and program technical requirements
  - Comprehensive inspection of all components
  - Random and targeted (i.e., new installers)
  - Post-AHJ Inspection
  - Prior to receipt or qualification of incentives
  - Work with installers, inspectors, AHJs to resolve issues by providing guidance and education
Solar PV Basics

Simplified Solar Diagram

- Photovoltaic (PV) Modules
- DC Disconnect
- Inverter
- Production Meter
- House Breaker Panel
- Utility Meter
- DC
- AC
PV Modules: Creating Electricity

- Solar modules are made up of rows of PV cells
  - Convert sunlight into DC electricity
  - Solar cells made of silicon
  - When sunlight (photons) interact with silicon atoms, electrons move and create electricity

PV Modules: Creating Electricity

- Typically 250 – 325W per module
- Aluminum-frame, glass-covered
- Factors affecting production:
  - Panel orientation
  - Panel tilt
  - Shading (by trees, buildings, etc.)
Racking: Securing Modules

- Modules are mounted to aluminum rails
- Aluminum rails are mounted to structure, such as:
  - Rafters
  - Pipes
  - Poles

Inverters: Converting DC to AC

- Inverters convert DC electricity from solar modules into AC electricity
  - Central inverters – DC to AC conversion occurs at a central point; serves multiple modules or whole array
  - Microinverters – DC to AC conversion occurs at the module-level; typically serves one module
Meters: Measuring Production

• New meter is typically installed to measure production from the PV system
  ➢ In support of production-based incentives
    ▪ Net metering
    ▪ Solar Renewable Energy Certificates

PV System Basics

• Inverter monitors grid voltage/power quality
  ➢ UL 1741 requires inverter to shut off within fraction of a second if power goes out of range, or completely off
  ➢ Inverter will remain off until it detects 5 minutes of continuous power
PV System Basics

• During production times, power goes to grid if not completely used behind the meter
  ➢ Typically there is no onsite energy storage (today)

PV System Basics

• At night, electricity is supplied by grid
Why Do We Need to Inspect Solar

Why Should We Care About Quality?

- Less downtime
- Fewer service calls
- Safer
- Better perception
Goals of the Inspection Process

- Ensure that public funds are supporting PV systems that are:
  - Safe
  - Productive
  - Long-lived
- Provide independent feedback to help installers improve installations and minimize customer call-backs

And Because We Know it Works
Is it a Quality Installation?

- Installed by a firm with relevant industry certifications (e.g., NABCEP, UL, PV-1)
- Approved by the local Authority Having Jurisdiction (AHJ)
- System design reviewed and approved by a third party
- System will reliably and safely produce kWh for its expected life

Is this sufficient to ensure high quality installations?

Who Gets Inspected?

- **High Risk Installations = More Scrutiny**
  - New installer-partners
  - Installers with past QA issues
  - Rollout of new technologies
  - Major technology or policy changes
  - Sampling rates may range from 25%-100%

- **Low Risk Installations = Less Scrutiny**
  - Established installer-partners
  - High performing installers
  - “Tried and true” designs/technologies
  - But…it makes sense to spot check 5%-10% of installations
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Quality is Not Guaranteed

PV Inspection Results: Systems by Severity of Issues Found

Sample Data:
2,209 projects
635 installers

All systems were installed by qualified lead installers, received a third party design review, and were inspected by local wiring inspectors.

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

• DOER Rooftop Solar Challenge:
  [Link to the website for the Rooftop Solar Challenge]

MGL Ch. 143 §3 L 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
MA Licensing Requirements
Guidance Memo 13-01

- Massachusetts Electricians Licensing requirements relating to the installation of PV systems:
  - Board of State Examiners of Electricians
  - Solar PV systems often require work from many trades
- Board Guidance Memo 13-01
  - Solar PV system is defined by 527 CMR 12.00, Article 690.2
  - Electrical work consists of installing elements which carry electricity, or are part of an equipment grounding system
  - Non-electrical work could include roof penetrations, installing mounting brackets, or components not intended as part of equipment grounding system
  - Many variations of system components, check with AHJ with questions concerning licensing

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.

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
Optional Application Requirements

• Site Plan Drawing

Optional Application Requirements

• Manufacturers specification sheets
  ➢ Solar PV Modules
  ➢ Racking
  ➢ Inverter
Prior: Send Letter from the Inspector

- 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

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
Structural Approval of Small Solar PV

Prescriptive Process

• Developed as part of the Rooftop Solar Challenge:
• Prescriptive process provides:
  ➢ Guidelines for installing and approval of rooftop residential solar
  ➢ May preclude need for a licensed structural engineer to evaluate rooftop load carrying capacity
  ➢ Applies to all cities and towns in Massachusetts
  ➢ Approximately 10-12% of homes (188,000 – 225,000)
• Developed in conjunction with the Dept. of Public Safety and Board of Building Regulation Standards
Prescriptive Process

• Applies to only Small Residential Solar PV System:
  ➢ Capacity of ≤ 10 kW
  ➢ Flush-mounted solar PV systems
  ➢ Range from 3.0-3.5 lbs./sq. ft., comparable to a second layer of roofing singles
  ➢ One- and Two-Family Residences built after 1976
    ▪ Compliant with Massachusetts State Building Code (MSBC), enacted 1975
    ▪ Light-frame wood construction with traditional roof rafters
  ➢ Arrays installed parallel to roof, ≤ 8” to 12” offset

• Prescriptive Process Flowchart:
  ➢ 11 Questions
  ➢ Requires familiarity with structure under consideration
  ➢ Requires expertise in construction/ engineering

Prescriptive Process

• Expertise required to use the prescriptive process:
  ➢ A knowledgeable person in construction/engineering must become familiar with the structure under consideration.
  ➢ Knowledgeable person must be able to differentiate between:
    ▪ Material dimensions, species, or grades sufficiently to be able to properly evaluate the conditions discussed in the prescriptive process
    ▪ Areas of expertise could include Building Construction, Framing, Carpentry, or Codes
Prescriptive Process

• Prior to evaluating a structure, familiarize yourself with the **Prescriptive Process Flowchart for Residential PV <10 kW**
  - 7 Steps
  - 11 Questions

• Evaluate the structure
  - Observe the structural components specified in the Flowchart
  - Determine if they are in accordance with the stated questions
Prescriptive Process

• If structural components specified in the Flowchart are not observable, or are not in accordance with the stated questions:
  ➢ Use a Registered Design Professional (RDP) to determine whether there is adequate support for the proposed solar PV system

• If the structural components specified in the Flowchart are:
  ➢ Observable and in accordance with the Flowchart, and do not require further evaluation:
    ▪ Proceed to the Maximum Rafter Span Table

Prescriptive Process Flowchart

1. Is the house older than 1976?
   ➢ Yes: Employ a RDP to evaluate rooftop
   ➢ No: Proceed to Question 2

2. Is there only one layer of roofing shingles?
   ➢ Yes: Proceed to Question 3
   ➢ No: Employ a RDP to evaluate rooftop

3. Is the slope of the roof 4:12 or greater?
   ➢ Yes: Proceed to Question 4
   ➢ No: Employ a RDP to evaluate rooftop
Prescriptive Process Flowchart

4. Are the roof rafters typical 2x lumber of a regular spacing?
   - **Yes**: Proceed to **Question 5**
   - **No**: Employ a RDP to evaluate rooftop

5. Are the roof rafters Spruce-Pine-Fir (SPF) or Hem-Fir?
   - **Yes**: Proceed to **Question 6**
   - **No**: Employ a RDP to evaluate rooftop

Prescriptive Process Flowchart

6. Have fasteners been observed and determined to be compliant with the requirements of the Fastener Table?
   - **Yes**: Proceed to **Question 7**
   - **No**: Employ a RDP to evaluate rooftop

**Fastener Table for Structural Members**
- Ceiling Joists to plate, toe nail (3-8d)
- Ceiling Joist, laps over partitions, face nail (3-10d)
- Ceiling joist to parallel rafters, face nail (3-10d)
- Rafters to plate, toe nail (2-16d)
- Roof rafters to ridge, valley or hip, to nail (4-16d)
- Roof rafter to ridge, valley or hip, face nail (3-16d)
- Collar tie to rafter, face nail (3-8d)
Prescriptive Process Flowchart

7. Are the skylights, dormers, or other similar components in the roof within 2 feet of the proposed PV system?
   - Yes: Employ a RDP to evaluate rooftop
   - No: Proceed to Question 8

8. Is there any equipment supported form the roof framing (above or below) within 2 feet of the proposed PV system?
   - Yes: Employ a RDP to evaluate rooftop
   - No: Proceed to Question 9

9. Are there any additions or renovations to the existing roof or directly abutting the roof within 6 feet of the proposed PV system?
   - Yes: Employ a RDP to evaluate rooftop
   - No: Proceed to Question 10

10. Are there any indications of distress of the roof framing (i.e., ridge sagging, walls out of plumb, significant ceiling cracks?)
    - Yes: Employ a RDP to evaluate rooftop
    - No: Proceed to Question 11
Prescriptive Process Flowchart

11. Are there signs of knowledge of previous damage (i.e., water incursion, fire damage, impacts from an object, etc.) or repairs to the roof?

- Yes: Employ a RDP to evaluate rooftop
- No: If no answers result in the need for an RDP to evaluate the structure, you may proceed to utilize the **Maximum Rafter Span** table for the evaluation of the roof framing to support the proposed solar PV system

Prescriptive Process

- Before using the Maximum Rafter Span Table:
  - Determine the ground snow load requirements (30, 40, or 50 psf) for the structure based on the Snow Load Zones identified in the MSBC
  - Identify the structure's rafter species, grade, size, and spacing
Prescriptive Process

• Use the Maximum Rafter Span Table to:
  - Identify the maximum span for the structure framing that can support the proposed solar PV system
  - If the structure’s existing span is less than the maximum span listed in the table, the solar PV system may be installed on the roof without further structural analysis

Maximum Rafter Spans

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Notes and Assumptions for Use of Above Table

1. Prior to use of this Table, comply with the Prescriptive Process Flowchart for Residential PV/CEM.
2. This Table to be utilized by occupants knowledgeable engineering or construction individuals.
3. Use of this table assumes construction is CodeCompliant, i.e., collar ties exist in appropriate spacing, rafters are correctly located on opposite sides of ridge beam.
4. Actual spans exceeding the Table values may be reduced by installing rafter bracing at appropriate bearing wall locations, employ a Registered Design Professional (RPD) for proper details.
5. Ground snow loads (W) based on 7000 S.F. S / 100.
6. Allowable stress design based on 0.20 kpsi, maximum total load deflection limited to 1%/8.
7. PV panels installed parallel to the roof plane and the distance between the roof covering and bottom of the PV panel is 12".
Prescriptive Process

• If the structure’s existing span exceeds the maximum span identified in the Maximum Rafter Span Table:
  ➢ Use an RDP to identify other qualifying structural conditions, or recommend bracing or other improvements to the structure, which could enable the proposed solar PV system to be installed

Prescriptive Process

• Additional weight from a PV system requires an increase to roof framing support:
  ➢ Increased from building code specified snow load at time of construction to the sum of:
    ▪ Proposed solar PV system weight
    ▪ Increased effects of the snow load due to the inclusion of the coefficient of temperature
    ▪ Possible increases in the snow load requirements in the current MSBC
  ➢ These factors can increase the roof framing support requirements by 20%
  ➢ The prescriptive process is designed to incorporate this increase
Questions?

Solar Permitting and Structural Review:

Technical Contacts
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Structural Concerns
Consideration for Ground-mounts

- Footings
- Metal structures
- Wooden structures
- Bracing
- Engineered drawings
- Top of pole systems
  - Depth of footing
  - Pipe strength and diameter
  - Mass of footing
  - Height of sail (array)

Considerations for Commercial Rooftops

- Attached or ballasted?
- Roofing membrane types and array compatibility
- Module racking and tilt
- Wind effects
  - Perimeter ballast
  - Wind deflectors
- BOS on rooftops
- Sealing/flashing penetrations

Warranty Impact?
Residential Rooftops

- Areas of concern
  - Additional weight of array
  - Point loading of structural members
  - Wind loading
  - Structural attachment
  - Weatherproofing

Prescriptive Process

- Prescriptive Process for Structural Approval of Small PV Systems document
- 1 to 2 family wood framed Dwellings
- Truss/rafter strength
  - If house built within the last few years, probably truss and OK
  - Structural engineer should be involved if any doubt
  - Often rafters are sistered, and collar ties added to increase roof strength
Weight of Array

- Additional weight loading roughly equivalent to another layer of comp shingles (3-3.5lb/ft²)
- If single layer of comp shingles exist, probably OK to add PV, other lightweight materials, but not slate or clay tile

Point Loading

- All L feet on too few rafters – spread the load
- Blocking or spanners may be employed
- Reinforcement of rafters/trusses may be necessary
- Array weight is concentrated on attachments to structure
  - Module weight, racking weight, snow loading
  - Typical attachment is by an L foot of structural aluminum
Wind Loading

- Flush mounted array – parallel to roofing surface
- Wind lifts against modules, opposed by attachment methods
- Tilt-up racking – creates additional concerns
  - More surface area exposed to winds
  - Aesthetics
  - Snow loading more concentrated
  - Drifting of snow changes loading

Hoist the Sail

Wind accelerates up roof slope into back side of array
Creative Mounting Options

Custom Structures
How Modules Attach to Roofs

- Rails vs. rail-less attachment systems

End Clamp Too Close to Rail End

Most manufacturers specify at least ¼” of space between the end clamp and the end of the rail to allow for thermal expansion and vibration.
Measure Twice, Cut Once

PV Rainwater Collection System

1) No Flashing
2) Lag Bolt not secure
3) Probably missed the rafter
Bad – Lag Split Rafter

Bad – Lag(s) Split Truss
Trusses Strengthened

Some Attachments Are Acceptable for Sheathing Attachment
Mount for Sheathing Only

Weatherproofing

- Flashing required per most roofing manufacturers as well as 780 CMR 5903.2
  - Attachment points
  - Conduit penetrations
How Flashing Should Look

Insufficient Flashing/Poor Materials
Good Product Choice, Bad Installation

Not Weather Protected
Metal Roof

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Penetration-less Attachment Example

Ballasted Arrays
Not All Concrete Created Equal

Things to Look For

- Flashing
- Check attic for shiners
- Ballast loading and materials
- Impact on roof warrantees
- Engineering on anything questionable
Load Side Interconnection

NEC Article 705.12(D)

- Most often at a back fed breaker in the main service panel
- Used at most residential PV systems
- Also used at commercial installations but can be problematic for larger PV systems
- Involves adding a second power source (PV) to main panelboard
Load Side Interconnection
NEC Article 705.12(D)

• 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

PV Interconnection
Considerations...

• Terminal ratings should be followed:
  ➢ Conductor size
  ➢ Max conductors
Backfeed Breaker Ratings

- Ensure BFB is Listed for use in panelboard
  - Manufacturers match
  - Some breakers are cross-Listed (classified) for use in other manufacturers’ panelboards
- BFB current rating per NEC 705.60(B)
  - 125% of Inverter Continuous Output

12.5A x 125% = 15.6A
Per 240.4(B), BFB=20A Rating

Bus or Conductor Ampere Rating - Feeders
NEC Article 705.12(D)(2)(1)(a)

- Option (A)
- Feeder ampacity not less than sum of:
  - Primary source OCPD
  - 125% of inverter current
Bus or Conductor Ampere Rating - Feeders
NEC Article 705.12(D)(2)(1)(b)

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

Bus or Conductor Ampere Rating - Feeders
NEC Article 705.12(D)(2)(1)

Existing conductors must be increased in size or protected
Bus or Conductor Ampere Rating - Busbars

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

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

Example:
Inverter current = 14.4A
14.4A x 125% = 18A

Main + PV = 118A
100% Busbar = 125A
**118A feeds < 125A bus**

- PV breaker can be located anywhere

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Bus or Conductor Ampere Rating - Busbars

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

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

Example:
Inverter current = 14.4A
14.4A x 125% = 18A

Main + PV = 118A
120% Busbar = 120A
**118A feeds < 120A bus**

- PV breaker must be at opposite end
**Bus or Conductor Ampere Rating - Busbars**

NEC Article 705.12(D)(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
  - “Do Not Add Loads”

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**Wire Harness and Exposed Cable AFCI Protection**

NEC Article 705.12(D)(6)

- Intended for microinverters
- 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**
Wire Harness and Exposed Cable AFCI Protection
NEC Article 705.12(D)(6)

Recommendation from the SEIA Codes and Standards Working Group and SolarABCs (www.solarabcs.org) PV Industry Forum to remove 705.12(D)(6) from the 2017 Code. Why?

• No suitable devices are widely available on the market
  ➢ Suitable for backfeed
  ➢ 3-pole, 3-phase devices
• Requirements are not aligned with Arc-Fault protection as implemented for ac premises wiring 210.12
  ➢ Single phase 120 V circuits
  ➢ Convenience outlets and zip cords
  ➢ Outdoor circuits are exempted
  ➢ Fire classified roof surface with PV modules evaluated for ignition and flame spread
• Safety standards do not adequately cover PV applications (UL 1699)
  ➢ Backfeed
  ➢ 3-phase circuits
  ➢ Nuisance tripping

Load Side Interconnection Labeling

Always Look For:
• NEC 705.12(D)(3): Presence of All Sources
• NEC 408.4: Marked on Circuit Directory
• (If multiple inverters) NEC 705.10(D): Inverter Directory

Look for One Of These:
• NEC 705.12(D)(2)(3)(b)-“120% Rule”
  ➢ Inverter Output Location, Do Not Relocate
• NEC 705.12(D)(2)(3)(c)-AC combiner
  ➢ Sum of OCPD Shall Not Exceed Busbar
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Supply Side Connection

Defined

- Service Head
- Terminal box, meter, or other enclosure
- Service-entrance conductors
- Service equipment—general
- Grounding and bonding
- Disconnecting means
- Over current protection
- Branch Circuits
- Transformers

Related Sections:
- Part III
- Part IV
- Part V
- Article 2.50
- Part VI
- Part VII
- Articles 210, 215
- Articles 231, 235
The Need for 705.12(A)

- Although not a service, it is connected as if it were, and unprotected service conductors are involved, so 230 applies
- Not tapping a feeder, so tap rules do not apply
- Allowed under 230.82(6)
- PV systems exceeding 3800W where a 100A panel (20A limit) is in use per 705.12(D)2
- PV systems exceeding 7600W where a 200A panel (40A limit) is in use
- Many commercial scale PV systems

Minimum Size

- Minimum of 60A service disconnecting means per 230.79(D)
- OCPD sized based on connections per 690.8
- Sum of all ratings shall not exceed rating of service
- Panelboard or fused disconnect
- Observe AIR/AIC requirements in 110.9 & 110.10
- Equipment must be marked as suitable for use as service equipment per 230.66
Residential Supply Side Connection

Wiring

- New service conductors to LINE side of PV disconnect to prevent exposure to personnel to live voltages 404.6(C)
- Interconnection on utility side of main service disconnect
- Typically on customer side of utility meter
- “Second set” of service entrance conductors (Article 230)
- Bond N to G
Wiring

- Supply conductors best practice is size of original service conductors as there is no protection back to utility fusing of service 230.42(B) sets minimum of 60A conductors
- SE conductors in FMC or LFMC are limited to 6’ in length and need a supply side bonding jumper
- Conduit sealing 300.7(A)

Wiring

- SE conductors must be protected from physical damage per 230.50
- Bonding of GE to conduit and equipment – 250.64(E), 250.4(A)5
- No KOs – 250.97
- Bonding over 250V – 250.97
- Wired so blades de-energized – 404.6(C)
- Accessibility and grouping – 404.8
- Splicing and tap conductor sizes
- Wiring methods per 230.43
**Wiring**

- Article 240 tap rules do not apply to inverter connections since the tap rules were developed for circuits with only one source. “10-foot tap rule” does not apply
- 230.7 only service conductors in single raceway
- Splicing allowed 230.46
- 705.31 limits distance to OCPD to 10’ from connections

**Examples of Tapped SE Conductors**
Examples of Tapped SE Conductors

The Wrong Way...

Examples of Tapped SE Conductors

Crossing the Line

Courtesy of Mark Elster, Town of Plymouth
Grouping of Disconnects

- Interconnection inside main panelboard
  - Supply side of main breaker
- Fused PV disconnect located outside
  - Metal raceway between main panelboard and outdoor disconnect MAX 10 FEET per 705.31
- Panelboard and PV disconnect labeled per 705.10 and 705.12
- Article 690.56(B)
  - Requires plaque in this situation

Supply-Side Disconnect

Understanding Grouping Requirements

- Grouping with main service disconnect is best-practice
- NOT REQUIRED by NEC
- Why?
Supply-Side Disconnect
*Understanding Grouping Requirements*

- Start at Article 705.12(A)
  - An electric power production source shall be permitted to be connected to the supply side of the service disconnecting means as permitted in 230.82(6).
- Article 230.82(6)
  - Only the following shall be permitted to be connected to the supply side of the service disconnecting means: *solar PV systems*
- Article 230.2(A)(5)
  - Special conditions: Additional services shall be permitted to supply parallel power *production* systems

**Exception No. 5**
- *One set of service-entrance conductors connected to the supply side of the normal service disconnecting means shall be permitted to supply each or several systems covered by 230.82(5) or 230.82(6).*
Supply-Side Disconnect
Understanding Grouping Requirements

• Article 230.71(A)
  ➢ The service disconnecting means for each set of service-entrance conductors permitted by 230.40, Exception No. 1, 3, 4, or 5, shall consist of not more than six switches or sets of circuit breakers, or a combination of six switches and sets of circuit breakers, mounted in a single enclosure, in a group of separate enclosures, or in or on a switchboard or in switchgear. There shall not be more than six sets of disconnects per service grouped in any one location.

• Article 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.

• Article 690.56(B)
  ➢ Buildings or structures with both utility service and a PV system shall have a permanent plaque or directory providing the location of the service disconnecting means and the PV system disconnecting means if not located at the same location.
Supply-Side Disconnect
Understanding Grouping Requirements

Bonding - Grounding

- Installing a Supply Side Connection is essentially paralleling the existing main load center and its rules for wiring a new service
- Article 230 Services & 250 Grounding & Bonding
- N-G bond performed in the new Service Equipment per 250.24(A)1
- Originate a new GEC
- GEC bonded to all ferrous conduit per 250.64(E), in accordance with 250.92(B)
Neutral connected to manufacturer provided terminal block
New GEC originated – continuing on to GE. Also where EGC for downstream equipment originates

Bonding screw installed correctly creating code required N-G bond in new service equipment
New neutral connected to manufacturer provided terminal block, providing grounded conductor for downstream equipment

Compression connection creates an irreversible splice
Ampere Interrupt Capability (AIC) of New Service Disconnect

- Also referred to as AI Rating (AIR) of device
- Short circuit current values can be obtained from the utility providing electrical service to the location, or at a minimum, you can match the rating of the existing main breaker to meet 110.9 & 110.10
- Branch circuit breakers are typically only rated to 10 kAIC. Most main breakers you will see in main load centers are rated to 20 kAIC or more.
Specific Labeling

- Defined in 230.2(E), 705.10 and 705.12
- 690.56(B) requires permanent plaque or directory providing locations of all service disconnecting means and the PV system disconnecting means if not located at the same location
Commercial PV Systems
Supply Side Connections

• Verify AIC required for disco
• Be sure to accurately identify where the utility meters the service. If current transformer (CT) metering is used, be sure the PV system will be connected on the appropriate side of the CT’s.
• Some main breakers and disconnects have provisions for additional conductors. Be sure which side of the breaker you are connecting to and apply the 120% rules when on the LOAD side.
PV and Generators

- It is important not to design a system that can backfeed a generator during operation, and damage the generator. Systems whole house generators will need to have the PV point of interconnection before the Automatic or Manual Transfer Switch, or be provided with relaying to prevent PV system operation during generator operation.
- Correct labeling of additional sources of power are also required for safety and code compliance per 690.54.
Look for Generator Transfer Switches

Transfer switches typically indicate the presence of a generator.

If a generator is upstream from your intended point of interconnection, you will have to interconnect ahead of it to avoid the possibility of damage during its operation.
Creating A Cleaner Energy Future For the Commonwealth

Inverters and Grounding Electrode Conductor Requirements

Types of Inverters

- **Grounded** “Isolated” (typically older systems)
  - Central Inverter
  - String Inverter
  - Microinverter

- **Ungrounded** “Transformerless” (most common)
  - String Inverter
  - Microinverter
Grounded “Isolated” Inverters

- Central Inverter

- String Inverter
Grounded “Isolated” Inverters

- **Microinverter**

Grounding Electrode Conductor Terminal

1. **NOT** common today
2. Inverters usually grounded the DC negative conductor
   - Think of this as a “neutral”
     - It is grounded
     - It needs to be white
Grounded “Isolated” Inverters

- Grounded conductor shall not be broken inside disconnect switches
  - Article 690.17(D)

- Grounded conductor shall not be fused
  - Article 240.22
Ungrounded “Transformerless” Inverters

• String Inverter

Utility-Interactive String Inverter System
With DC Optimizers
Utility-Interactive String Inverter System
With DC Optimizers

Ungrounded “Transformerless” Inverters

• Microinverters
Utility-Interactive AC (Microinverter) System

Ungrounded “Transformerless” Inverters

- Most-common type today
- Both DC conductors are “floating”
  - No connection to ground
- Typically black and red
Ungrounded “Transformerless” Inverters

- Disconnect breaks both ungrounded conductors
  - Article 690.17(B)

- Overcurrent protection on ALL ungrounded conductors per 690.9(E)
  - Only where 3 or more combined strings
  - Not necessary for 1 or 2 strings
Ungrounded “Transformerless” Inverters

- MidNite Solar disconnect/combiner for ungrounded PV systems

Ungrounded “Transformerless” Inverters

- Equipment grounding conductor still required per 250.4(A)(5)
  - All metal parts likely to become energized
1000V PV Systems

• 120 proposals submitted for 2014 NEC
  ➢ Raise 600V PV limit to 1000V
• High Voltage Task Group (HVTG)
  ➢ Appointed by NEC Correlating Committee
  ➢ Review all requirements for over 600V

1000V PV Systems

• All products must be rated for 1000V or 1kV:
  ➢ Modules
  ➢ Wire
  ➢ Disconnect switches
  ➢ Fuses
  ➢ Connectors
  ➢ PV inverters

• Article 690.7(C)
  ➢ One- and two-family dwellings still 600V MAX

• See 690.80 for over 1000V
1000V PV Systems

• UL white book shows many products already listed for 1000V and above
• Codes/standards must keep up with new products
• AHJ must recognize new systems

These inverters are ungrounded
- Follow requirements of 690.35
- “String Inverters” designed to replace combiner boxes
  - Short runs of 1000V then AC inside
  - Can easily meet rapid shutdown requirements
    If located within 10 feet of array

• Advantages
  - More modules per string
  - Fewer strings per array size
  - Fewer combiner boxes
  - Smaller feeder conductors
1000V PV Systems

Grounding Electrode System
NEC Article 690.47

Creating A Cleaner Energy Future For the Commonwealth
Grounding Electrode System
NEC Article 690.47

- Most inverters prior to 2014:
  - AC and DC requirements
  - 690.47(C)
  - Conductor sized to Table 250.66
    - Minimum #8 AWG copper
    - Based on largest ungrounded conductor
  - 3 options to connect to grounding electrode

- 690.47(C)(1)
  - Separate DC Grounding Electrode System Bonded to the AC Grounding Electrode System
  - Bonding jumper shall be sized to largest GEC per 250.166(B)
  - Not smaller than #8 AWG copper
Grounding Electrode System
NEC Article 690.47

- 690.47(C)(2)
  - Common DC and AC Grounding Electrode System
  - DC GEC shall be connected to either:
    - Directly to AC grounding electrode
    - AC GEC in accordance with 250.64(C)(1) (irreversible splice, crimp, etc.) when AC grounding electrode not accessible

- 690.47(C)(3)
  - Combined DC GEC and AC Equipment Grounding Conductor
  - Unspliced or irreversibly spliced
  - Sized to 250.122
  - Not required to be larger than largest ungrounded
    - Under #8 AWG may be ok for small systems

*Current method for today’s transformerless inverters*
Bonding the Raceway
NEC Article 250.4

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

General Inverter Disconnect Requirement
NEC Article 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.*"
Inverter Disconnect Requirements

*In a Nutshell*

- **690.15**
  - Isolate inverter from all power sources
- **690.17**
  - DC disconnect requirements
    - Externally operable
    - Simultaneously disconnect all ungrounded conductors
    - Suitable for voltage and current (may or may not be “PV” type)

*Some utilities require outdoor externally operable AC disconnect switches, but not the NEC.*

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**Inverter Disconnect Requirements**

*Inside the “S” brand...*
String Inverter Disconnect Requirements

- 690.13(A)
  - DC disconnect required in readily accessible location
    - Outside
    - At nearest point of entry
  - Or shall comply with 690.31(G)
    - Metal raceway/MC cable to first readily accessible disconnect

No NEC disconnect requirements for array location

Microinverter Disconnect Requirements

- AC wiring harness/connector listed for use as AC disconnect
  
- DC module connectors listed for use as DC disconnect
  
- No other disconnect required at array
AC Disconnect Requirements

- Wiring between load-side (breaker) interconnection and inverter(s)
  - No different than branch circuit wiring methods
AC Disconnect Requirements

• What about an outdoor AC disconnect?
• Some utilities may require it
• **Not required by the NEC**
• May be nice option for Rapid Shutdown disconnect
DC AFCI Protection
NEC Article 690.11

- All PV systems with DC operating at 80 Volts or greater
  - Protected by listed “PV type” AFCI
    - Or equivalent

Comply with the following requirements:

1. Detect and interrupt faults
   - PV source circuits
   - PV output circuits
2. Manually restarted
3. Annunciator with visual indication
DC AFCI Protection
NEC Article 690.11

• All major brands **NOW AVAILABLE**
  ➢ Inverters
  ➢ Combiner boxes
  ➢ Micro inverters (not required)
    ▪ Typically operate **under 80 Volts DC**

• **CHECK THE MODEL!!!**
• Ensure AFCI mode is enabled

**Creating A Cleaner Energy Future For the Commonwealth**

**Meters**
Production Meter Violations

- Article 250.24(A)(5)
  - Neutral conductor bonded to frame
  - *Do not ground the “neutral” on the load side of the service disconnecting means”*
  - Applies to subpanels and devices downstream of service disconnect
Production Meter Violations

• Article 110.3(B)
  ➢ Small conductors on lugs
  ➢ Watch terminal ratings

Production Meter Best Practices

• CT ratings- can they carry the maximum current?
Production Meter Best Practices

• Three-Phase
  ➢ Typically 7 jaw (connections) or 5 jaw as shown
  ➢ Notice the PVC breaking continuity and ground not attached
Production Meter Best Practices

• Three Phase
  ➢ 7 jaw meters typically have a neutral terminal bonded to ground
  ➢ Neutral is kept isolated on this installation to prevent violation of NEC Article 250.24(A)(5).

Rapid Shutdown
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(1) through (5)...

Rapid Shutdown of PV Systems on Buildings
NEC Article 690.12

• 690.12(1)
  ➢ More than 10’ from an array
  ➢ More than 5’ inside a building
Rapid Shutdown of PV Systems on Buildings
NEC Article 690.12

- 690.12(2)
  - Within 10 seconds
    - Under 30 Volts
    - 240 Volt-Amps (Watts)
  - A typical module:
    - ~250 Watts
    - ~30 Volts

- 690.12(3)
  - Measured between:
    - Any 2 conductors
    - Any conductor and ground

- 690.12(4)
  - Labeled per 690.56(C):
    - Minimum 3/8” CAPS
    - White on Red
    - Reflective
Rapid Shutdown of PV Systems on Buildings
NEC Article 690.12

• 690.12(5) [MA Amendment: Effective Jan. 1, 2017]
  ➢ “Equipment that performs the rapid shutdown shall be listed and identified.”

About Article 690.12

• Intended to protect first responders
• Original proposal:
  ➢ Disconnect power directly under array
    ▪ Module-level shutdown
• Compromise:
  ➢ Combiner-level shutdown
About Article 690.12

• Open-ended gray areas:
  ➢ Location of “rapid shutdown initiation method”
  ➢ Maximum number of switches

About Article 690.12

• Considerations:
  ➢ Disconnect power within 10 seconds
  ➢ Inverters can store a charge for up to 5 minutes (UL 1741)
About Article 690.12

• What complies:
  ➢ Microinverters
  ➢ AC modules
  ➢ DC-to-DC Optimizers/Converters
    • May or may not depending on the model

• Exterior string inverters if either:
  ➢ Located within 10 feet of array
  ➢ Inside building within 5 feet

➢ “Contactor” or “Shunt Trip” Combiner Boxes/Disconnects
  ➢ Must be listed for “Rapid Shutdown” as a system
    • See MA Amendment to 690.12(5)
  ➢ Many considerations & variations for full system compliance
    • Plans should be discussed with AHJ prior to installation
PV Disconnect Switch Recap

• Inverter Disconnects 690.15 “isolation switches”
  ➢ Microinverter
    ▪ All AC & DC connectors listed to satisfy disconnect requirement
    ▪ No other disconnect switches required at location
  ➢ String/Central Inverter
    ▪ New inverters typically contain DC only
    ▪ Require AC disconnect grouped
Disconnect Switch Recap

- AC Disconnect
  - Load-Side Connection
    - Similar to branch circuit wiring
    - Not required to be outdoors
  - Supply-Side Connection
    - Best-practice is to group with main breaker
    - NEC permits located elsewhere, but requires permanent plaques per 690.56(B)

PV Array Grounding
Equipment Grounding System
2014 NEC Article 690.43 / 250.4

- Approximately **15%** of all inspections contain issues with Array equipment grounding

Array Equipment Grounding System
2014 NEC Article 690.43 / 250.4(A)(5)

- All metal parts *likely to become energized*
  - Module frames
  - Racking
  - Metal roof
  - Metal conduit/enclosures

- Low impedance ground-fault current path back to the source or ground detector
  - Inverter or AC panelboard
Equipment Grounding System
2014 NEC Article 690.43 / 250.4

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

Connection of Grounding and Bonding Equipment
2014 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!!!
Module Frame Grounding
2014 NEC Article 690.43

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

Module Frame Grounding
Wrong Lugs – (Copper or Not Listed for Outdoor)
Module Frame Grounding
Right Fitting, Installed Wrong

Grounding the Racking
Wrong Screw (110.3(B) and 250.8)
Grounding the Racking
2014 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
  - New racking-integrated bonding
    - Check the model!
  - Plastic (non-metallic) racking
    - No ground required

Grounding the Racking
Unless it’s plastic!
Grounding the Racking

Considerations

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

Grounding the Racking

Trip Hazard
Grounding the Racking
Splice in Lay-In Lug

Grounding the Racking
Wrong application for bonding jumper
Array Equipment Grounding

• Grounding lugs
  - Must be listed for **outdoor use**
    • “DB” (tin plated copper)
  - Watch bonding bushings!
  - Number of conductors
    • Hint: probably **ONE**

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Bonding Bushings

*Rated for Outdoor Use?*

• Lay-in lug
  - Must be suitable for the environment in which it is installed
    • Outdoor/wet locations (suitable for direct-burial)
Array Equipment Grounding System
NEC Article 110.3(B) / 250.12

- All ground lugs must be suitable and rated for the environment they are used
- How do you know it’s indoor rated when you don’t see rust?
- Hints:
  - Rust is caused by a non-stainless steel set screw
  - All major manufacturers of lay in lugs share a common standard of stainless steel screws
  - For outdoor rated lay in lugs

Use a Magnet!

- Can’t verify label on lug? Indoor rated lay in lug(s) shown with non stainless set screw that sticks to magnet used in wet location in violation of listing and NEC Article 110.3(B) with cross reference to rating of Ilsco: GBL-4, CMC PENN-UNION:LI-505, T&B Blackburn: LL414, HOMAC: CLA-70-219 FCI Burndy: BGBL-4, NSI: GLA-4, Brumall: GLA-4.
- Painting of set screw maybe considered as recognized substitute for outdoor lugs.
- Watch out for bushings these are typically indoor lugs.
Metal Roofs

- An array using standing seam roof clamps allows continuity among module frames
- **What’s missing?**
Metal Roofs

- An array’s roof clamps are insulated with sealant and/or roof paint
- Panel sections of the metal roof may not be bonded for continuity

Clamps Attached to Clean Surface

Removing protective coatings from such a large area of roofing is unwise. Especially if not subsequently protected from further deterioration, and definitely will void the roofing warranty. Further, there are no standing seam roof clamps that are listed to perform this bond.
Additional Things to Look Out For

Grounding array to gas line!

Array Grounding Electrode Conductor
NEC Article 690.47(D)

- Ground rod intended for lightning protection
  - Removed in 2011 NEC
  - Back in 2014 NEC
  - May be optional for 2017 NEC
    - CMP-4 currently reviewing
  - 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
Array Grounding Electrode Conductor
NEC Article 690.47(D)

- Axillary electrode still required on ground mounted arrays in accordance with 250.32
  - 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

Array Protection, Wire Management, and Physical Damage
Common Array Violations

• 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)
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The Right Way...
Readily Accessible Location
NEC Article 690.31(A)

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

PV conductors in readily accessible locations shall be guarded or installed in a raceway.
PV conductors in readily accessible locations shall be guarded or installed in a raceway.
The Right Way...
Shingles and Flashings

- Installation of flashings must follow the manufacturer’s instructions per NEC Article 110.3(B).

Incorrect: The flashings are not under two layers of shingles.
The Right Way...
Physical Damage

Holes drilled into the modules voids the warranty

Flat Roof Trip Hazards

Make sure plan set specifies route and type of conduit.
Trip hazards are especially dangerous when hidden beneath snow.
Common Array Violations
Listed for PV?

- **690.35(D)** requires type **PV WIRE** to be used in exposed applications, or conductors shall be in a cable or raceway
- **690.9(D)** 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

Beyond the lugs...
Dissimilar Metals

Beyond the lugs...

Common PV Output Violations

• Not properly sized for conditions
  ➢ 690.8 calculations
  ➢ 310.15 ampacity/temperature/conduit fill

• Not properly secured/supported
  ➢ Article 338.10(B)(4)(b) → 334.30

• Not properly protected
  ➢ Article 338.12(A)(1)
Undersized PV output conductors.

Unprotected PV output conductors.
The Right Way...

PV output conductors installed in conduit.
The Right Way...

PV output conductors installed in conduit.

Common PV Output Violations

• Outdoor enclosures
  ➢ Not grounded in accordance with 250.8(A)
  ➢ 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
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)
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
Labeling

Correct Labeling and Marking

• NEC Article 110.21(B)
  ➢ Field Applied Hazard Marking shall meet the following requirements:
    1. The marking shall adequately warn of the hazard using effective words and/or colors and/or symbols.
    2. The label shall be permanently affixed to the equipment or wiring method and shall not be hand written.
       ▪ Exception: Portions of the labels or markings that are variable, or that could be subject to change, shall be permitted to be hand written and shall be legible.
    3. The label shall be of sufficient durability to withstand the environment involved.
PV System Labeling

Approximately 70% of all inspections contain issues with labeling...

DC Raceway Label
NEC Article 690.31(G)(3)

- On or inside a building
- New wording:

WARNING: PHOTOVOLTAIC POWER SOURCE

- Minimum 3/8” CAPS
- White on Red
- Reflective
PV System Disconnect
Moved to NEC Article 690.13(B)

Solar Disconnect
Disconnect Line/Load Energized
NEC Article 690.17(E)

DC Power Source
NEC Article 690.53
AC Power Source
NEC Article 690.54

Dual Power Sources
NEC Article 705.12(D)(3)
“Do Not Relocate”
NEC Article 705.12(D)(2)(3)(b)

![WARNING]

INVERTER OUTPUT CONNECTION;
DO NOT RELOCATE
THIS OVERCURRENT DEVICE

Per 110.21(B)

AC Combiner Panel
NEC Article 705.12(D)(2)(3)(c)

![WARNING]

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

Per 110.21(B)
Service Disconnect Directory
NEC Article 690.56(B)

Per 110.21(B)

Inverter Directory
NEC Article 690.15(A)(4)/705.10

Creating A Cleaner Energy Future For the Commonwealth

Massachusetts Department of Energy Resources
Common PV Violations and Inspection Best Practices

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?
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
- 16% at the inverter
  - Improper string fusing
  - Ungrounded enclosure
  - GEC missing
- 16% at the supply side connection
  - Improper/missing OCPD
  - Insufficient kAIC rating
  - GEC missing
  - Taps not properly made
- 11% at load side connections
  - Excess backfeed current for busbar
Frequent PV Code Violations

- NEC 705.10/690.56: Missing power source directories
  - 33% of systems
- NEC 690.54: Missing AC characteristics labels
  - 20% of systems
- NEC 338.10(B)(4)/334.30/300.4: Array conductors not supported
  - 17% of systems
- Other violations of note:
  - 780 CMR 5903.2: Roof penetrations not flashed
    - 5% of systems

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
  - MassCEC’s Minimum Technical Requirements

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

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