COLUMBUS
INTERNATIONAL CODE COUNCIL 2017

What to Look for When Conducting Plan Reviews and Inspections of Solar PV

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Tuesday, September 12, 2017

9:45 AM - 11:15 AM

ICC INTERNATIONAL CODE COUNCIL®

WHAT TO LOOK FOR WHEN CONDUCTING PLAN REVIEWS AND INSPECTIONS OF SOLAR PV SYSTEMS

SEPTEMBER 2017

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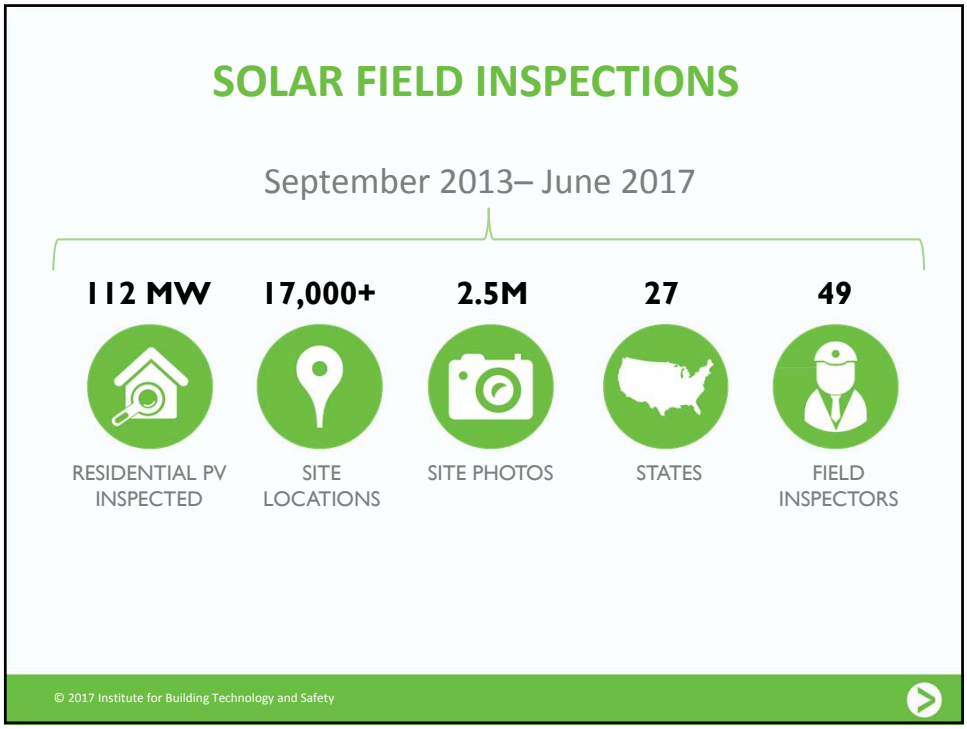
The Institute for Building Technology and Safety is a 501(c)(3) nonprofit organization established to provide unbiased professional services, while enhancing the communities in which we work.

IBTS provides solar PV Quality Management services to some of the largest solar stakeholders in the nation. All have chosen IBTS for our industry expertise and for our proven capacity to deliver.

public sector
accountability

private sector
flexibility


SOLAR FIELD INSPECTIONS
September 2013– June 2017
112 MW
RESIDENTIAL PV INSPECTED
17,000+
SITE LOCATIONS
2.5M
SITE PHOTOS
27
STATES
49
FIELD INSPECTORS
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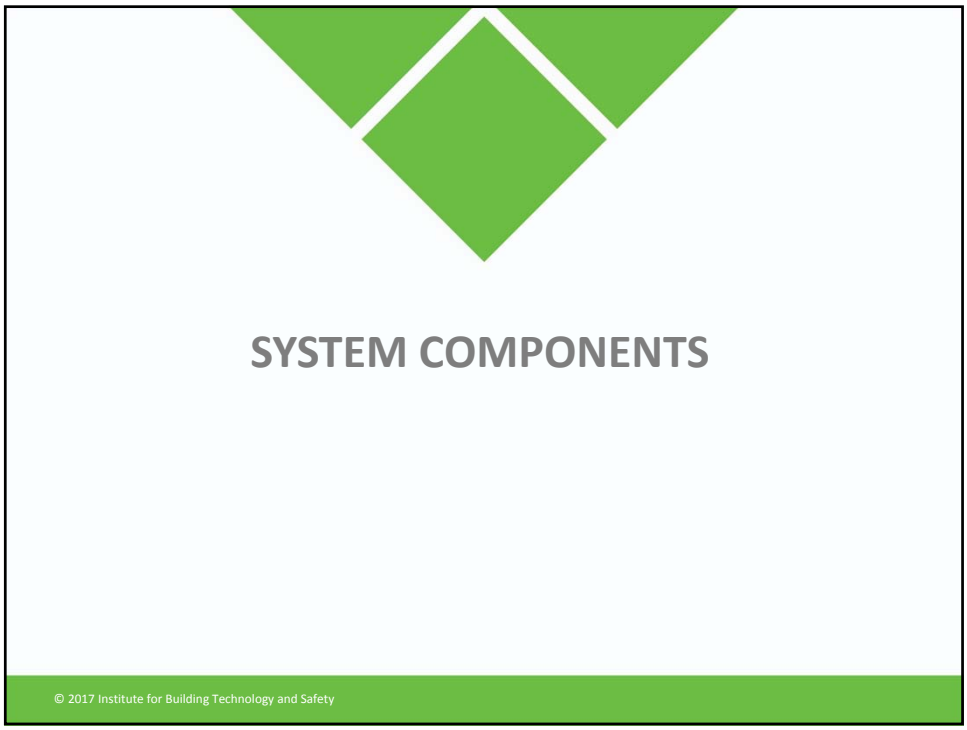
SYSTEM COMPONENTS
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MAIN COMPONENTS

Modules

Often called **"Panels, Modules, or Collectors"** the commonly known "Flat plate collector" type of Solar PV module is typically made up of individual Silicon cells arranged in rows laminated between a tempered glass and EVA or membrane type backsheet, mounted within an aluminum or metal frame.

Inverter(s)

Micro Inverter, String Inverter, String Inverter w/ DC Power Optimizers – Whether Module Level Power Electronics (MLPE) are utilized, or in a separate location via a string type inverter… DC power is converted to AC by an **"Inverter".**

Racking

Two main types of racking are used and can generally be categorized into **traditional** and those including **integrated ground** attachments for attaching modules. Most have manufacturers recommendations for installation in order to meet the listing of the equipment that must be followed to ensure proper operation.

Balance of System (BOS) Components

Balance of System components are things such as combiner boxes, rapid shutdown equipment, breakers/fuses/disconnects, solar tracking equipment, flashing, or any other equipment that is installed to allow the PV system to integrate and operate as designed.

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MODULES

Module Specifics:

Materials: Aluminum frame, tempered glass, EVA or similar backsheet, poly or monocrystalline cells, aluminum or copper conductors, ABS or similar connectors.

Mono/Poly Crystalline – Individual "Cell" construction. Mono is a single cell made from a single silicon wafer. Poly means the "cells" are made up of many smaller silicon pieces pressed together. (Polycrystalline cells have an "OSB" look to them)

Typical Configuration:

- 60 Cells (ranging from sub 200W to just over 300W)
- 72 Cells (generally 300W+)
- Cells arranged flat and encapsulated in top and backsheet.
- "Panel" on back of module with (+) and (-) leads having male and female "plug" type connectors.
- DC Output (Note: AC Modules)

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INVERTERS

Inverter Specifics:

- Convert **DC** power input to **AC** power output by matching the frequency/wattage/voltage of utility. **(UL 1741 Compliance Required)**
- **Micro Inverter**
  - Often 1 per module but newer models allow for multiple.
  - Branch Circuit – circuit or chain of micro-inverters.
  - Attached to or mounted beneath PV modules.
  - Module Level Power Electronics (MLPE)
  - NEC 690.12 Rapid shutdown compliant
- **String (Central) Inverter**
  - Single inverter with inputs for multiple "strings" of PV modules.
  - Usually mounted ground level or indoors.
  - Integrated DC disconnect for all system source circuits with one single output.
  - Often times coupled with DC power optimizers (MLPE for string inverters)
- **Transformerless** (ungrounded) vs **Transformer** (grounded).

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RACKING

Racking Specifics:

Integrated grounding – Utilizes specifically designed attachments to create bonds and when installed to manufacturer specifications, acts as sufficient ground path bonding the modules to the EGC.

Traditional – Uses WEEBS or other module level attachments to achieve grounding.

Things to know:

- Structurally attached to roof or footing in the case of ground mount.
- Main support for system components.
- Has specific manufacturer requirements for installation to ensure bonding.
- Must show compliance with **UL 2703**
  - **Specific height and spacing requirements based on fire classification.**
  - **Specific component classes**

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BALANCE OF SYSTEM (BOS)

BOS Specifics:

Types

- **Combiners:** used to combine multiple strings before transition to inverter.
- **Panelboards:** branch circuit panel, subpanel, point of interconnection, etc.
- **Disconnects:** visible blade, fused, remote or rooftop
- **Monitoring:** production meter, proprietary hardware
- **Protection**: nuisance protection or netting, fencing.

Things to know:

- Components have specific installation instructions to match listing and ensure protection.
- Many components exist and some mitigate deficiencies better than others… good to research.
- Components can be newly created to address an existing issue.

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COMMON FINDINGS DURING PLAN REVIEW AND PHYSICAL INSPECTIONS

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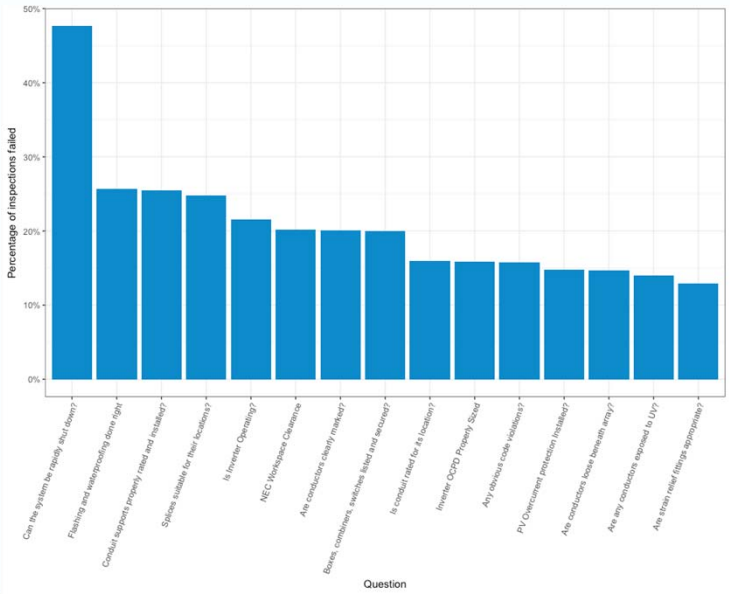
DEFICIENCY PERCENTAGES



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COMMON DEFICIENCIES

System Labeling
20-50% Deficiency Rate. System labeling includes NEC and IFC requirements to label system components. Incorrect labels, label material not withstanding elements, incorrect system information on labels, etc.

Wire Management
10-41% Deficiency Rate. Wires touching roof surfaces, exposure to UV, extended bending radius, non-wet location nuts used, conductors not fully engaged.

Penetration Sealant and Flashing
10-22% Deficiency Rate. Overall building envelope protection with roof penetrations, safety anchors, racking and conduit penetrations. Improperly flashing for various roof types

System/Equipment Grounding
10-15% Deficiency. Wire markings, disconnect wired improperly, and module/racking grounding.

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SYSTEM EQUIPMENT/GROUNDING

10-15% Deficiency

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COMMON GROUNDING METHODS

- LUGS
- WEEBS- Stainless steel spacers with teeth for bonding aluminum components.
- INTEGRATED- Components designed to be grounded by mechanical fastening during installation process.

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SYSTEM GROUNDING

10-15% deficiency rate

- WEEB not properly seated.
- Improper rail splice detail.
- Bare copper EGC run in contact with aluminum rack components (dissimilar metals, NEC110.14).
- EGC is not continuous to all metal system components.
- No Grounding Electrode or GEC.
  - EGC is unnecessarily subject to damage or failure.
- Improper installation of splice or termination.

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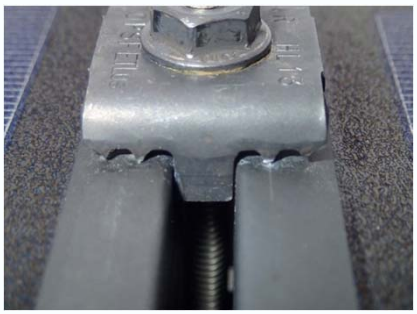
SYSTEM GROUNDING



Difficult to understand if torque requirements are met

Loose clamp not holding module and not bonded.

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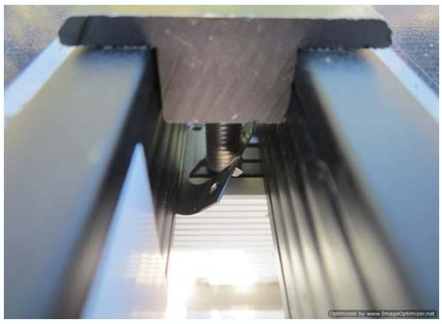
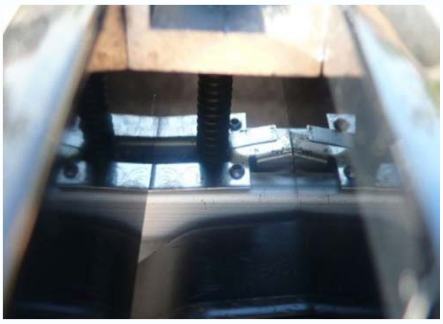
SYSTEM GROUNDING



Improperly seated WEEB



Improperly seated WEEB

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SYSTEM GROUNDING

Dissimilar Metals – Aluminum lug used instaed of zinc plated aluminum.

Dissimilar lug used without jumper. Will result in EGC failure.

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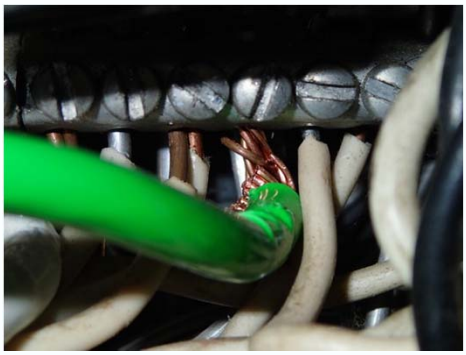
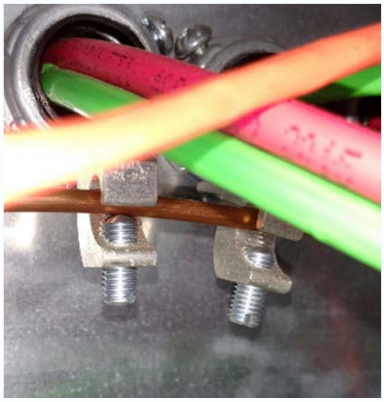
SYSTEM GROUNDING



Improper EGC termination



Lugs not tightened to EGC

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SYSTEM GROUNDING

- NEC 690.43: Exposed non-current carrying parts of PV systems must be grounded in accordance with NEC 250.66 (AC GEC), 250.122 (EGC size) and 260.166 (DC GEC).
- NEC 110.3(B): shall be installed in accordance with any instructions included in the listing or labeling
  - Torque requirements
  - Inclusion of all bonding components
- Run in the same raceway with other conductors when leaving array (690.43(F))

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GROUNDING - A FEW NEC SPECIFICS

- Equipment Grounding Conductor Installation: NEC 250.120
  - Minimum #6AWG if subject to physical damage
- Size of EGC: 250.122, Table 250.122
  - Based on the size of the overcurrent protection device in the circuit
- NEC Article 690, Section V
  - All metal parts must be grounded (690.43(A))
  - And more...
- Ungrounded systems may use AC EGC as GEC (NEC 690.47(C)(3))
- AC system GEC- must be continuous (NEC 250.64(C))

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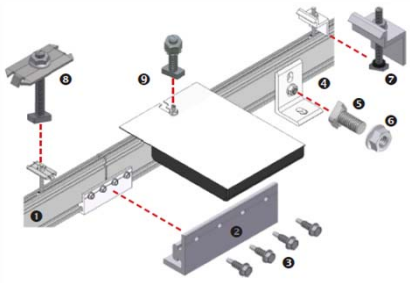
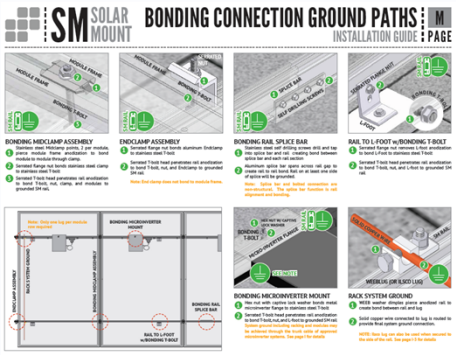
SYSTEM GROUNDING- INTEGRATED

Manufacturers provide specific installation requirements and instructions- following these ensure compliance with UL2703 and engineered stability of racking.



SM SOLAR MOUNT



Example, courtesy of UNIRAC SOLARMOUNT

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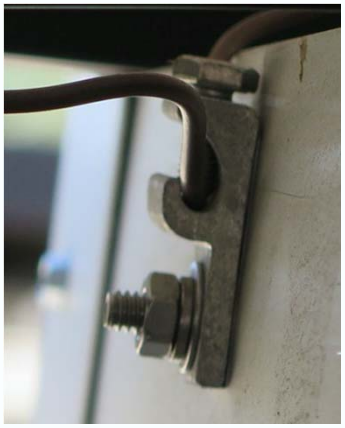
SYSTEM GROUNDING

Bonding strip at rails splice



Lug on rail with WEEB

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SYSTEM GROUNDING

Ground lug on rail

Lug on module with star washer

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SYSTEM GROUNDING

Transition to insulated, run in conduit

Myers Ground Hub

Array Conduit Grounded

Conduit Grounded

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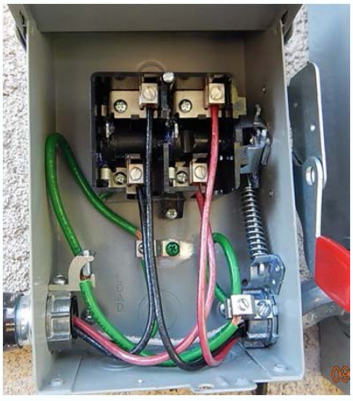
SYSTEM GROUNDING



Enclosure is grounded.

Enclosure is not grounded.

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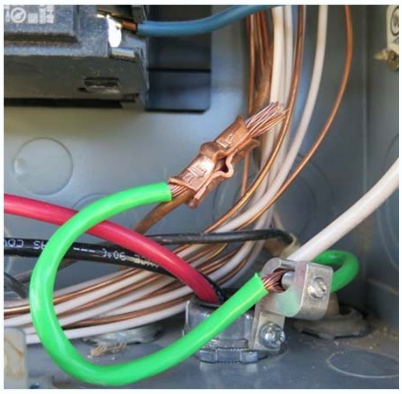
SYSTEM GROUNDING



EGC/GEC irreversibly connected to primary system GEC by mechanical attachment or crimp.

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PENETRATION AND FLASHING

10-22% Deficiency Rate

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PENETRATIONS & FLASHING

10-22% deficiency rate

- Flashing not designed for roof type.
- Flashing installed improperly.
  - Improper install depth.
  - Nailed through face.
  - Broken roof material around flashing.
  - Fastener too tight causing deflection.
- No sealant or flashing used at all.
- Sealant not approved for use in location.
- Wall and under eave penetrations not sealed.

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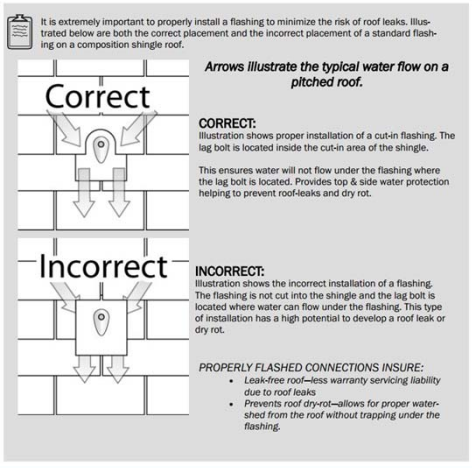
PENETRATIONS & FLASHING

- Flashing should allow for critical overlap as identified by IRC.
- Installed as defined by manufacturer.
  - Under 3rd course of shingles
  - Not overhanging shingle below



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PENETRATIONS & FLASHING

Improperly Installed Flashing

Improperly Installed Flashing

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PENETRATIONS & FLASHING

No Flashing

Incorrect Flashing Type

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PENETRATIONS & FLASHING

Not Secured; Flashed?

Potential Water Entry

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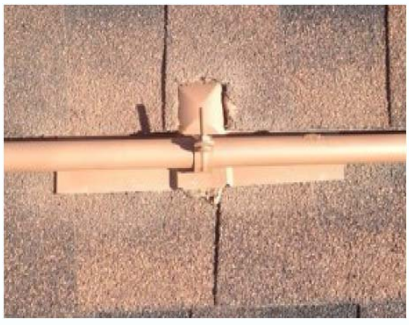
PENETRATIONS & FLASHING

Flashed and Secured



Flashed and Secured

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PENETRATIONS & FLASHING

Tile roof conduit support

Low Slope Penetration Option
Chem Curb

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PENETRATIONS & FLASHING

Metal Roof Conduit Flashing and Supporting Options

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WIRE MANAGEMENT

10-41% Deficiency Rate

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WIRE MANAGEMENT

10-41% deficiency rate

- Conductors in direct contact with roof surface.
- Improper identification of conductor (wrong wire colors, fused strings not identified).
- AC/DC conductors sharing a trough without separation or identification.
- No bushings used at conduit entry.
- Conductors not protected from prolonged exposure.
- Splice not consistent with insulation rating.
- Conductors with improper bend radius and strained.

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WIRE MANAGEMENT

- Conductor management
  - NEC 334.15: Protected from physical damage
  - NEC 334.24: Radius of inner curve of bend shall not be less than 5 times diameter
  - NEC 334.30: Secured every 4.5ft and within 12” of enclosures, conduit entry points
  - NEC 690.31(B): Clearly grouped and identified (points of termination, connection and splice points)
  - NEC 110.14(B): Spliced adequately

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WIRE MANAGEMENT

- Conductor Identification
  - NEC 200.6: grounded conductors must be white, gray or 3 striped (#6AWG ≥)
  - NEC 250.119: EGC must be green bare, or green with yellow stripes (#6AWG ≥)
  - NEC 310.110: Ungrounded- must be distinguishable form grounded and EGC
  - NEC 690.31(B): AC and DC must be separated, grouped, identified

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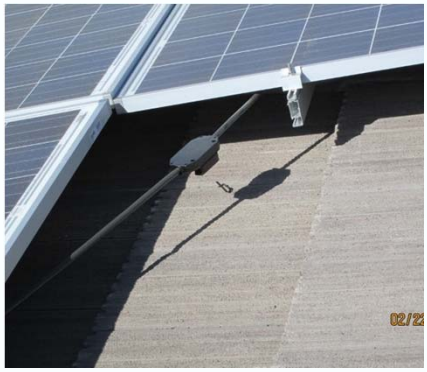
WIRE MANAGEMENT

Wires Touching Roof Surface



Conductor strung up tightly between modules with UV exposure.

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WIRE MANAGEMENT

Splice not consistent with conductor rating

Incorrect Splice of Ground

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WIRE MANAGEMENT

No Conduit Used on Rooftop

Unmanaged conductors beneath a ground mount array. Left readily accessible on "commissioned" system.

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WIRE MANAGEMENT

AC and DC Unidentified and Unmanaged

No Strain Relief or Conduit Bushing

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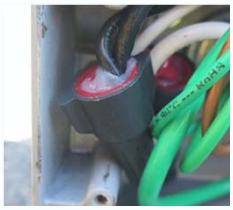
WIRE MANAGEMENT



Oxide Inhibitor in Wire Nut- OK

Wet Rated Lugs- Preferred

Line Side Splice

Coloring of Conductors

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WIRE MANAGEMENT

- Conduit installation as it effects wiring; PVC Expansion

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"DIS" HONORABLE MENTION






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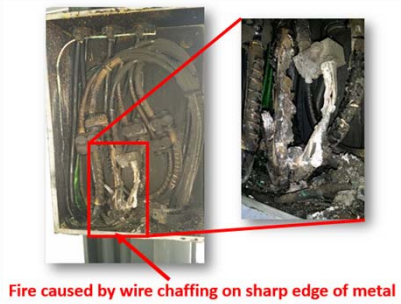
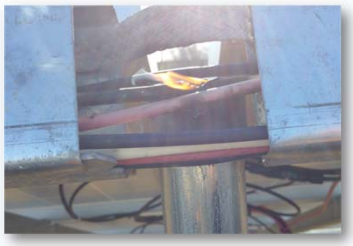
"DIS" HONORABLE MENTION



Fire caused by wire chaffing on sharp edge of metal


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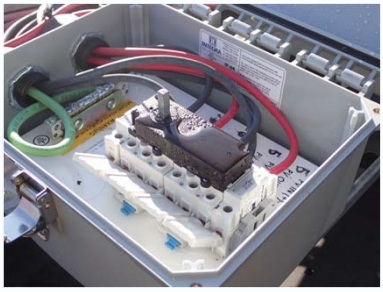
SOMETHING TO CONSIDER WHEN ADOPTING NEW CODE



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SYSTEM LABELING

20-50% Deficiency Rate

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SYSTEM LABELING

20-50% deficiency rate

- Handwritten or illegible.
- Labeling is present but values are not present or are incorrect.
- Improper identification of hazard (AC vs. DC, Grounded vs. Ungrounded).
- Labels not suited for location or falling off, faded.
- Labels are missing.

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WARNINGS AND LABELING

- Shall meet the requirements of 110.21(B)
- Field Applied Hazard Marking
  - (1) Must effectively warn personnel (words, colors, symbols)
    - Info. Note: ANSIZ535.4-2011: .12" tall and visible from a safe viewing distance form the hazard
  - (2) Permanently affixed and not handwritten
    - Exception: if likely to change, can be handwritten (NA)
  - (3) Must be durable enough to handle environment where in stalled

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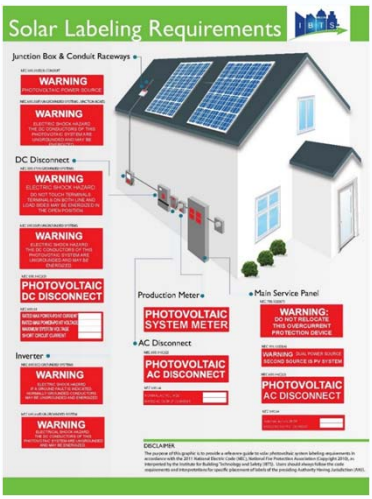
SYSTEM LABELING



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SOURCES:

NATIONAL ELECTRIC CODE 2014, NFPA, 2014

"MIKE HOLT'S ILLUSTRATED GUIDE TO DIRECTORY, IDENTIFICATION, LABEL, MARKING, PLAQUE AND SIGN REQUIREMENTS FOR SOLAR PV SYSTEMS", MIKE HOLT, FREE ONLINE DOWNLOAD 2016

NEW LABELS BRING CLARITY TO PV INFRASTRUCTURE, TODD FRIES, SOLAR INDUSTRY MAGAZINE, ZACKIN PUBLICATIONS- 2013, ACCESSED 2016

UNDERSTANDING THE NEC AND ITS IMPACT ON PV SYSTEMS, SOLARPRO, REBEKAH HREN AND BRIAN MEHALIC, ISSUE 7.3 APRIL/MAY 2014

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