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

MARCH 2018
ABOUT IBTS

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.
SOLAR FIELD INSPECTIONS

September 2013– January 2018

159 MW
26,000+
2.78M
27
52

RESIDENTIAL PV INSPECTED
SITE LOCATIONS
SITE PHOTOS
STATES
FIELD INSPECTORS
WHAT TO LOOK FOR WHEN CONDUCTING PHYSICAL INSPECTIONS
DEFICIENCY PERCENTAGES

Top 10 faults for Mass

<table>
<thead>
<tr>
<th>Modality</th>
<th>Deficiency Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.28, NEC Workspace Clearance 1</td>
<td>62.6%</td>
</tr>
<tr>
<td>3.27, Is Inverter Operating?</td>
<td>56.3%</td>
</tr>
<tr>
<td>3.25, Inverter CPDP Property Size?</td>
<td>50.1%</td>
</tr>
<tr>
<td>5.15, Are conduits loose beneath array?</td>
<td>43.8%</td>
</tr>
<tr>
<td>5.31, Are obvious code violations?</td>
<td>37.6%</td>
</tr>
<tr>
<td>6.22, Are conduits clearly marked?</td>
<td>31.3%</td>
</tr>
<tr>
<td>6.9, Flashing and waterproofing done right?</td>
<td>25.1%</td>
</tr>
<tr>
<td>5.16, Are any conductions touching the roof?</td>
<td>18.8%</td>
</tr>
<tr>
<td>5.9, Are strain relief fittings appropriate?</td>
<td>12.5%</td>
</tr>
<tr>
<td>5.5, Splices suitable for their locations?</td>
<td>6.26%</td>
</tr>
<tr>
<td>5.4, Are conduits clearly marked?</td>
<td>0%</td>
</tr>
</tbody>
</table>
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.
SYSTEM EQUIPMENT/GROUNDING

10-15% Deficiency
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.
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.
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))
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))
SYSTEM GROUNDING- INTEGRATED

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

Example, courtesy of UNIRAC SOLAR Mount
Difficult to understand if torque requirements are met

Loose clamp not holding module and not bonded.
SYSTEM GROUNDING

Improperly seated WEEB  

Improperly seated WEEB
SYSTEM GROUNDING

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

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

Improper EGC termination

Lugs not tightened to EGC
SYSTEM GROUNDING

Bonding strip at rails splice

Lug on rail with WEED
SYSTEM GROUNDING

Ground lug on rail

Lug on module with star washer
SYSTEM GROUNDING

Transition to insulated, run in conduit

Myers Ground Hub
SYSTEM GROUNDING

Array Conduit Grounded

Conduit Grounded
SYSTEM GROUNDING

Enclosure is grounded.

Enclosure is not grounded.
GEC irreversibly connected to primary system grounding electrode by mechanical attachment or crimp.
PENETRATION AND FLASHING

10-22% Deficiency Rate
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.
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
PENETRATIONS & FLASHING

Improperly Installed Flashing

Improperly Installed Flashing
PENETRATIONS & FLASHING

Halfway there!

Broken Shingles
PENETRATIONS & FLASHING

No Flashing

Incorrect Flashing Type
PENETRATIONS & FLASHING

Not Secured; Flashed?

Potential Water Entry
PENETRATIONS & FLASHING

Flashed and Secured

Flashed and Secured
Tile roof conduit support

Low Slope Penetration Option
Chem Curb
PENETRATIONS & FLASHING

Metal Roof Conduit Flashing and Supporting Options
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.
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
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 from grounded and EGC
- NEC 690.31(B): AC and DC must be separated, grouped, identified
WIRE MANAGEMENT

Wires Touching Roof Surface

Conductor strung up tightly between modules with UV exposure.
Splice not consistent with conductor rating

Incorrect Splice of Ground
No Conduit Used on Rooftop

Unmanaged conductors beneath a ground mount array. Left readily accessible on “commissioned” system.
WIRE MANAGEMENT

AC and DC Unidentified and Unmanaged

No Strain Relief or Conduit Bushing
WIRE MANAGEMENT

Oxide Inhibitor in Wire Nut - OK

Wet Rated Lugs - Preferred

Line Side Splice

Coloring of Conductors
WIRE MANAGEMENT

Conduit installation as it effects wiring; PVC Expansion
“DIS” HONORABLE MENTION
“DIS” HONORABLE MENTION

Fire caused by wire chaffing on sharp edge of metal

Photos Courtesy of Standard Solar Inc.
SOMETHING TO CONSIDER WHEN ADOPTING NEW CODE
SYSTEM LABELING

20-50% Deficiency Rate
SYSTEM LABELING

- 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.

20-50% deficiency rate
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: ANSI Z535.4-2011: .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
SOME BASIC LABELING ISSUES
SOURCES:

NATIONAL ELECTRIC CODE 2017, NFPA, 2017

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

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