



The Solar Quality Assurance Process

An Overview for RI REF Installers



December 1, 2015

Presented by:
Matt Piantedosi
CADMUS




Agenda

- Overview of the RI REF Quality Assurance (QA) system
 - Onsite inspections/reports
 - Self-inspection reports
 - Current inspection results **as of today**
- RI Renewable Energy Growth (RE Growth) Program Requirements:
 - Electrical code and safety considerations
- PV Violations & Inspection Techniques
 - Based on the 2014 National Electrical Code

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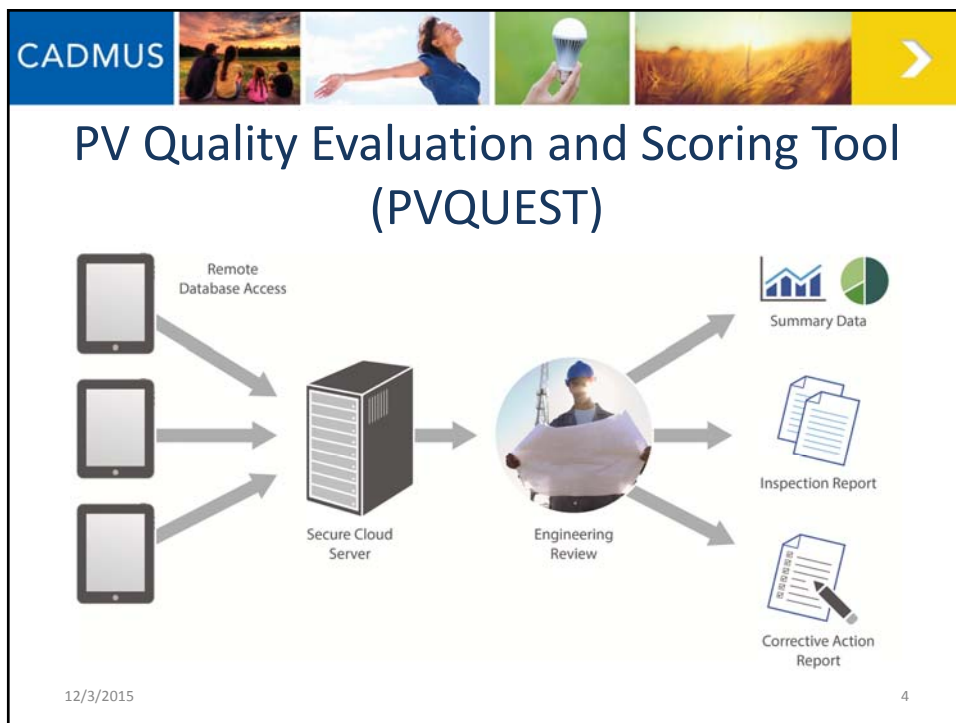
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Outlining the QA Process

- Conduct inspections of all completed projects
 - Installer status
 - Special requests
- Schedule
- Inspect
 - Inspection Report
 - Corrective Action Report
- Summarize
 - MS Excel data
 - Monthly summary reports

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Inspection Summary Tools

- Installer Summary Reports
 - Most frequent installation issues
 - Summary of inspection results by project
- Issue Frequency Report
 - Program-wide most common issues
 - Installers needing support on most common issues

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Inspection Elements

- What part of the system did the issue occur in?

<ul style="list-style-type: none"> -Array -String Inverter/ Microinverter -Transformerless Inverter -DC Disconnect -AC Disconnect -Load Side -Connection/Supply Side Connection 	<ul style="list-style-type: none"> -Battery Backup -Production Meter Subpanel -DC Combiner/AC Combiner -Junction Box -Optimizer
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- Inspectors have a custom checklist for each Inspection Element
- Installers know exactly where we found the issue and can better understand correction action requirements, taking faster action to address the findings

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Example: Grounded Conductor Marking

Balance of System Compliance Issues

Observed **200.6 NEC Color codes not followed**
 #8 AWG Grounded conductor is not properly identified as white or grey, in violation of NEC Article 200.6(A)&(B)

Text in body of report, photo stored in appendix

Program and Code Compliance / *String Inverter_2 : Corrective Action Required*

ID#	Defect Category	Deficiency Description	Inspector Comments
SI_EL11	Incidental	Inverter DC grounded conductors are not correctly identified as white or gray, in violation of NEC 200.6.	

Text and photos stored together in report, organized by inspection element and type of action required by installer

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Inspection Fields

Not Observed **690.47 Grounding electrode conductor not properly sized/installed**

Grounding electrode conductor is sufficiently sized per NEC 690.47(C)

Grounding electrode conductor is properly bonded to the main premise grounding electrode system per NEC 690.47


Not Observed **690.8 Circuit sizing**

PV backfeed breaker rating size is properly sized to protect circuit conductors Per 690.8(B)(1)

PV backfeed breaker is sufficiently sized to prevent nuisance tripping per NEC 690.8(B) and or 310.15

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Scoring

- 5-point scale
- Based on quantity of issues observed in each defect category
 - Failure will require major or critical issues
 - Minor/incidental issues will result in scores of 3-4

Defect Category	Defect Category Observations									
Scenario	1	2	3	4	5	6	7	8	9	10
Incidental	2	3	3	0	0	0	2	0	3	1
Minor	1	1	2	0	0	1	0	2	2	1
Major	2	0	1	0	1	0	0	0	0	0
Critical	0	0	0	1	0	0	0	0	0	0
Overall Report Score	1	4	2	1	2	4	5	4	3	4
Old Scoring Matrix	1	4	2	1	2	4	5	4	4	4

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PVQUEST Inspection Report Violations


Score	Classification	Description	Recommended Rebate Issuance Timeframe
5	No Issues	No issues identified on site.	Immediately Following Inspection
4	Incidental	Issues not expected to impact system operation or safety. Examples: Installation debris left onsite, poor wire management, missing or incomplete labels, and installed equipment not matching program records but considered equivalent.	Immediately Following Inspection
3	Minor	Issues that pose a mid-to long-term risk of system failure or safety hazard. Examples: Bonding neutral to ground in a meter enclosure, insufficient clearance around boxes, undersized circuit protection, and improperly supported conductors.	Following Confirmation of Correction
2	Major	Issues deemed likely to impact system performance or safety in the short-term, though not an immediate hazard. Examples: Missing equipment grounding, module microfractures, missing or undersized grounding electrode conductor, improperly secured PV modules, and missing or inadequate thermal expansion joints in long conduit runs.	Following Confirmation of Correction*
1	Critical	Issues that pose an immediate risk of system failure and/or safety hazard. Systems are often shut down during the inspection due to safety concerns. Examples: Exceeding current limits on busbars or conductors, exceeding inverter voltage limits, and use of non-DC rated equipment in DC circuits.	Following Confirmation of Correction*

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Outputs of the QA Process

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PV SYSTEM INSPECTION REPORT

Application ID: 6558.0001.0100	
Inspection Date: 10/29/2015 11:43:12 AM	System Inspector: Matt Plumbdon
System Complete:	System Quality Assurance Score: 3

Site Information	System Installer Information
Customer Name: John Smith	Installer Name: John Samstone
Company:	Contractor: Sunshine Solar
Site Address: 3 Main St	Phone: (855) 555-5555
City: Providence	Email: johnsmith@gmail.com
State: RI	
ZIP: 02933	
System Status	
Operating Normally	

PV Installation Photograph (Curb View)



The following QR features open a mobile view of the information found during the on-site inspection. The report is also available to download the system's metadata and download the inspection report to the mobile device. The report is also available to download the system's metadata and download the inspection report to the mobile device. The report is also available to download the system's metadata and download the inspection report to the mobile device.

Inspection: The inspection report is provided to the installer and the host customer. The report is also available to download the system's metadata and download the inspection report to the mobile device. The report is also available to download the system's metadata and download the inspection report to the mobile device.


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Inspection Report

- PDF Format
- General Information
 - Site Info
 - Installer Info
 - QA Score
 - Operational status
- Administrative Compliance
 - Equipment Verification
 - TSRF
- Program and Code Compliance
 - NEC
 - REF Minimum Technical Requirements
- Includes all issues found:
 - Corrective Action Required
 - Best Practice Recommendations
 - Issues Corrected Onsite


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Outputs of the QA Process

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PV SYSTEM CORRECTIVE ACTION RESPONSE (CAR)

Application ID: 6558.0001.0182	
Inspection Date: 9/16/2015 11:30 AM	System Inspector: Damian De Camis
Report Date: 9/23/2015 12:32 PM	System Quality Assurance Score: 4

Site Information	System Installer Information
Customer Name: John Smith	Installer Name: John Samstone
Company:	Contractor: Sunshine Solar
Site Address: 3 Main Street	Phone #: (555) 555-5555
City: Providence	Email: johnsmith@gmail.com
State: RI	Inspection Conducted With: Installer, Site Owner
ZIP: 02914	
Phone #:	
Email:	

Corrective Action Response Instructions
Please embed photographs and relevant text describing the actions you have taken to address the deficiencies identified during your recent PV system inspection. The clarity of these photographs and comments will directly impact our ability to complete the inspection process and recommend that Commence Rhode Island approve the incentive payment. We appreciate your prompt response to these corrective action items. If you disagree with any findings presented in this report, please describe your disagreement with as much detail as possible in the space provided. This document may be returned in either MS Word or PDF format. Please provide your response and insert photo evidence using this form and email the inspector or support.team@cadmus.com


Please note that failure to respond or submission of false information is a violation of REF Program rules and will result in disciplinary action including Suspension or Termination from the Program. By submitting this form the installer attests that all information is accurately represents the current state of the installed system.

CAR Items:

Corrective Action Report (CAR)

- MS WORD Format
- Lists ONLY issues requiring action by installer
- For each item, includes:
 - Program Requirement
 - Program Deficiency
 - Inspector Comments
- Provides space/format for installer to respond:
 - Installer Response (text)
 - Photos of Corrections Made (photos)
 - Signature lines for host customer and installer representative

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Sample CAR Item

CAR Items: Violation ID (from report)

A_EL12 Requirement

Requirement: Conductors properly supported Requirement

Deficiency Description: Circuit conductors are sagging and in contact with the roof and/or not supported and secured at least every 4.5' and within 12" of every outlet box, junction box, cabinet, or fitting, in violation of NEC Articles 338.10(B)(4) and 334.30. Deficiency description


Inspector Comments: West side of array, multiple locations. Inspector additional comments (if any)

Installer Response: Installer response line

Photos of Corrections Made: Placeholder for correction photo(s)

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How Does the CAR Work?

- CAR issued for scores of 1 to 4, and will come via email with the inspection report
- Installer must use CAR to submit relevant proof of corrective action taken:
 - Photos
 - Comments/description
 - Dispute
- **CAR corrections should be made as soon as feasible**


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Self-Inspection Reports

- Avenue for qualified installers to expedite inspection process
 - Including electrical subcontractors for a specific installer
- Expedited status can be granted by REF based on a number of consistent, high quality inspections
- An average score of ≥ 4 must be maintained to continue as an expedited installer

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Self-Inspection Memo



Rhode Island Renewable Energy Fund Self-Inspection Review Memorandum

To: Commerce Rhode Island Renewable Energy Fund, John Sunshine
From: Cadmus
RE: Self-Inspection Report Review Results: Jones, Steve (0194)
Date: 11/12/2015

Purpose
 This memo provides the results of Cadmus' review of the submitted self-inspection report. Cadmus' review is based on key system installation characteristics, including photographs, provided in the self-inspection report, which offer a reasonable due diligence review as an alternative for an onsite inspection.

System and Review Information

System Information	Application ID 0194
	System Name Jones, Steve
	Company Sunshine Solar
	Electrical Subcontractor N/A
	(if applicable)
Self-Inspection Report Review Information	Reviewer Mike Koschinsky
	Review Date
	Memo Reviewed By Matt Planteo

Review Summary
 System Quality Assurance Score
5

Deficiency Correction Status
 Cadmus confirms that all deficiencies identified in this memo have been addressed and corrected by the installer.

Additional Comments:

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- Cadmus inspector reviews a report prepared and submitted by system installer
- Reports are scored using same scoring metric as field inspections
- Cadmus will still inspect 10% of sites submitted by an expedited installer

Instructions

The questions in this self-inspection report are intended to collect key system installation characteristics, including photographs, which will allow Commerce Rhode Island staff and contractors to conduct a reasonable due diligence review, as a substitute for an onsite inspection. This report includes a self-inspection checklist and a descriptive photograph sheet. Installers wishing to complete a self-inspection must fill out all applicable fields. In cases where multiple pieces of equipment (e.g., two different types of PV modules) are used, please copy/paste the relevant information table and fill it out for both sets of equipment. Installers are encouraged, but not required, to attach an as-built electrical design drawing to this report.

Once completed, please submit this form in PDF format via email to xxxxx@commerceri.com. For technical questions on completing this self-inspection report, contact Shawn.Shaw@Cadmusgroup.com.

System Information

Grant Number	1234567
System Owner Last Name	Homeowner
Installation Company	Solar Company
Installer Last Name	Mr. Solar
Person Completing This Report	Matt Piantedosi
Phone	617-673-7102
Email	Matt.piantedosi@cadmusgroup.com
Report Date	2/12/2015

Self-Inspection Checklist

Array and PV Modules

Inspection Item	Value
Module Quantity	23
Module Manufacturer	SolarWorld
Module Model Number	SW 275 mono black
Modules per String (or per circuit for microinverters)	12, 13
Number of Strings per Input Circuit	2
Conductor Size/Insulation Type	#10 AWG THHN/THWN-2
Describe grounding method for module frames, rails, metal roofing, and other metallic hardware (NEC 690.43).	Racking listed to bond module frames, #10 solid copper on each rail.
If WEEBs (or equivalent) used, indicate number used per module.	N/A

Conductors supported and protected from damage.	Yes	No	N/A
All enclosures and splicing means rated for outdoor/wet location use (e.g., no indoor wire nuts).	Yes	No	N/A
All roof penetrations are properly flashed and sealed (note that sealant is a supplement, not a replacement, to flashing).	Yes	No	N/A
DC conduit labeled as containing PV circuits (NEC 690.31(G)(3) and 690.31(G)(4)).	Yes	No	N/A

DC Disconnect

Inspection Item	Value		
Max DC Ratings	Voltage 600V	Current 30A	
Location	Inverter Integrated		
DC disconnect located near inverter and readily accessible.	Yes	No	N/A
DC characteristics label present (NEC 690.53).	Yes	No	N/A
Disconnects all ungrounded conductors (note that ungrounded arrays must disconnect both positive and negative conductors).	Yes	No	N/A

String Inverter (includes Transformerless units)

Inspection Item	Value		
Quantity	1		
Manufacturer	SolarEdge		
Model Number	SE6000A-US		
AC Conductor size/insulation type	#6 AWG THHN/THWN-2		
DC Arc Fault Circuit Interrupter (AFCI) device	Inverter Integrated	Other	
If Other, enter manufacturer/model			
Rapid Shutdown device	Inverter Integrated	Other	
If Other, enter manufacturer/model			
Continuous grounding electrode conductor originates at designated inverter terminal.	Yes	No	N/A

Microinverter/DC Optimizer

Inspection Item	Value		
Quantity	23		
Manufacturer	SolarEdge		
Model Number	P300		
Inverter Breaker/Fuse Current Rating (A)			N/A (for Optimizers)

AC Disconnect/AC Combiner

Inspection Item	Value		
Max Enclosure Ratings (AC)	Voltage 240V	Current 30A	
Location(s)	Inverter Integrated		
Disconnect located near inverter and readily accessible.	Yes	No	N/A
AC characteristics label present (NEC 690.54).	Yes	No	N/A
Disconnects all ungrounded conductors.	Yes	No	N/A

Interconnection (Supply Side)

Inspection Item	Value		
PV Service Disconnect Location	Outdoor West wall of house		
Enclosure Rating	Voltage 240V	Current 100A	
	Voltage 250V	Current 35A	
Directories/labeling present on all service disconnects per NEC 230.2(E), 230.70(B), and 690.56(B).	Yes	No	N/A
Grounded conductor bonded to enclosure (NEC 250.24(C)).	Yes	No	N/A
Utility conductors connected to "Line" side of disconnecting means.	Yes	No	N/A

Interconnection (Load Side)

Photos Required

Full Array Image(s)

Include all modules for verifying system capacity.



Notes:

Array Mounting/Flashing Detail

Close shot of mounting bracket, connection to roof, and associated use of flashing/sealant.



Notes:

Under-Array Wire Management



Notes:

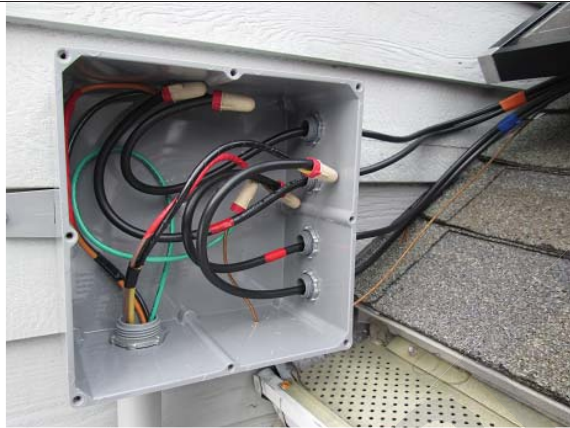
Array Grounding

Show typical grounding hardware installation.



Notes:

Wiring of Junction and/or Combiner Box
Show splice/termination method and conductor fittings.



Notes:

Balance of System (BOS) Overview Photos

Show general location/configuration of DC disconnect, inverter, production meter, panelboards, and other co-located equipment.



Notes:

DC Disconnect Exterior

Show nameplate/labeling details.



Notes: Disconnect integrated in inverter

DC Disconnect Interior

Show wiring details.



Notes:

String Inverter Exterior

Show sufficient detail to verify labeling.



Notes:

String Inverter Interior

Show wiring terminations.

Notes: See DC Disconnect Interior

AC Disconnect Exterior

Show nameplate/labeling details.

Notes: See DC Disconnect Exterior

AC Disconnect Interior

Show wiring details.

Notes: See DC Disconnect Interior

Production Meter Interior

Show wiring of production meter enclosure.



Notes:

Load Side Interconnection-Main Service Panel Exterior (Door Closed)

Show labeling detail, if applicable.

N/A

Notes:

Load Side Interconnection-Main Service Panel (Door Open)

Show labeling detail and backfeed breaker.

N/A

Notes:

Supply Side Interconnection

Show service entrance conductor tap detail.



Notes:

Supply Side Interconnection Disconnect Exterior

Show labeling/nameplate detail.




Notes:

Supply Side Interconnection Disconnect Interior
Show wiring/fuse details.




Notes:

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Self-Inspection Corrective Action

PV System Deficiencies Identified

Checklist Item	Deficiency Description	Reviewer Comments	Installer Correction Photos and Comments
Array and PV Modules	Entire array not observed.	Provide additional photos of array.	
DC Disconnect			
String Inverter (includes transformerless units)			
Microinverter/DC Optimizer			
AC Disconnect/AC Combiner			
Interconnection - Supply Side			
Interconnection - Load Side			
Other Components (if applicable)			


Overall Notes (if applicable)

Installer Corrective Action Response Instructions

For each of the deficiencies identified above, please embed in the table photographs and relevant text describing the actions you have taken to address the deficiencies identified in your PV system self-inspection report. The clarity of these photographs and comments will directly impact

- Observed violations and corrections are listed on the memo, and sent to installer for response, similar to CAR process
- Photos can be added to table in word document

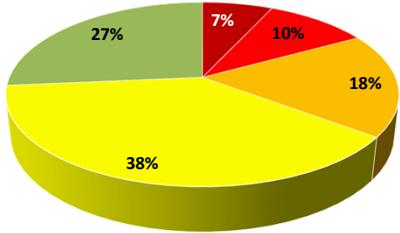
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Current Results from Commerce RI Inspections

PV Inspection Results: Systems by Severity of Issues Found

N=159 Renewable Energy Fund Inspection Violations as of 12/1/15



■	Critical	■	Major	■	Minor	■	Incidental	■	No Issues
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Cadmus interpretation to:

New Interconnection Requirements

RI Renewable Energy Growth (RE Growth) Program - Residential

- Section 4 of the RE Growth Program Tariff document (RIPUC No. 2151) outlines a metering configuration
- Solar PV installation shall be on a new utility meter
- Absolutely no connection to load side of existing utility meter
- Intended for the installer to replace existing utility meter enclosure with multi-gang enclosure (i.e. replace existing 1-gang with new 2-gang)
 - Existing meter is utilized for existing service/loads
 - New PV system/meter is a new “tenant” in the building
- Consideration should be taken for new disconnect/fuse location and marking...



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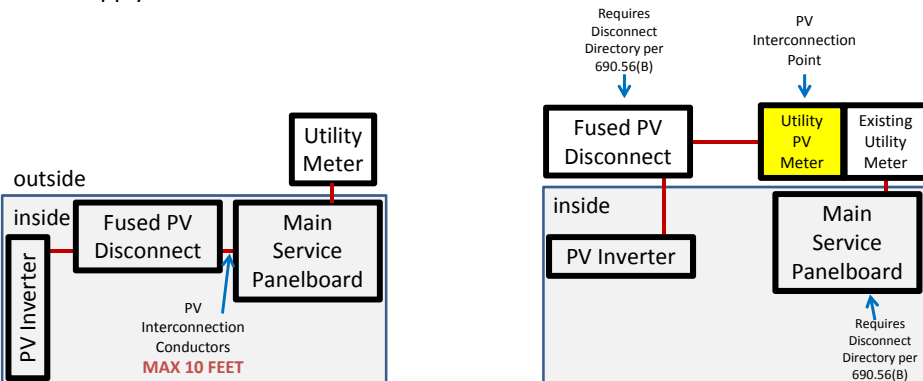
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Cadmus interpretation to:

New Interconnection Requirements

RI Renewable Energy Growth (RE Growth) Program - Residential

- **Traditional Method Example**
 - Supply-side interconnection
- **New Method Example**



outside

inside

Utility Meter

Fused PV Disconnect

Main Service Panelboard

PV Inverter

PV Interconnection Conductors
MAX 10 FEET

Requires Disconnect Directory per 690.56(B)

PV Interconnection Point

Utility PV Meter

Existing Utility Meter

inside

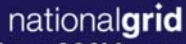
PV Inverter

Main Service Panelboard

Requires Disconnect Directory per 690.56(B)

Technical Issues:

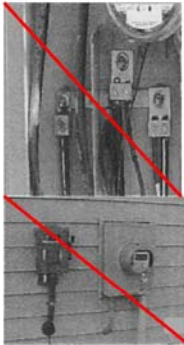
Small Net Metered DG Installations less than 600V




HERE WITH YOU. HERE FOR YOU.

➤ **Taps Ahead of Service Equipment for DG Interconnection – Concerns**


- *The Company's position is consistent with the rules and regulations for electric service contained in the Company's ESB 750-2010 "blue book" regarding taps and splices ahead of service equipment and in meter sockets.*
 - *In addition, our rules are consistent with other utility practices.*
- *Taps and splices in meter sockets having National Grid meters are prohibited according to the electric service requirements of ESB 750.*
 - *Doing so causes undue pressure on the meter socket blocks, increasing the chance of the blocks breaking, and causing a flash when the meter is removed.*




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Technical Issues: (cont'd) Small Net


Metered DG Installations less than 600V





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➤ **Taps Ahead of Service Equipment for DG Interconnection – Concerns**










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Technical Issues: (cont'd) Small Net Metered DG Installations less than 600V




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- ✓ **Where taps and splices are to be considered ahead of service equipment and on the load side of the Company's revenue meter, please refer to the following guidance according to ESB 750 and the NEC.**
- 1. The proposed tap or splice shall be made in an approved enclosure external from the revenue meter enclosure.
- 2. The junction (line tap) box and conduit for service conductors shall meet NEC requirements for the specific installation and its location.
- 3. Rigid galvanized steel conduit should be used between the revenue meter socket enclosure, junction (line tap) box, existing main service equipment, and distributed generator service equipment.
- 4. Wire bending radius shall meet NEC requirements and not cause undue pressure on terminations to devices.
- 5. Service conductor splice shall be in accordance with the NEC and listed materials.
- 6. The distributed generator system's disconnect shall be listed and labeled service equipment and installed immediately adjacent to the existing service equipment. (See definition of "service equipment" in Section 2.0 of ESB 750.)
- 7. Each service equipment shall be labeled according to the NEC (see Article 230).
- 8. Service grounding system shall be installed in accordance with the NEC for the two adjacent service equipment means (see Article 250).
- 9. The distributed generator system connection shall comply with the applicable Company tariff, ESB 756 Appendix B, or C, or D as applicable, and the NEC.
- 10. Where modifications to existing service equipment are proposed, the installer shall obtain the manufacturer requirements in writing (see 110.3(B) in the NEC). (This will be required for the local AHJ Code Enforcement requirements to be met.)
- 11. An approved electrical inspection certificate of the premises wiring changes is required according to Section 1.9 in ESB 750.

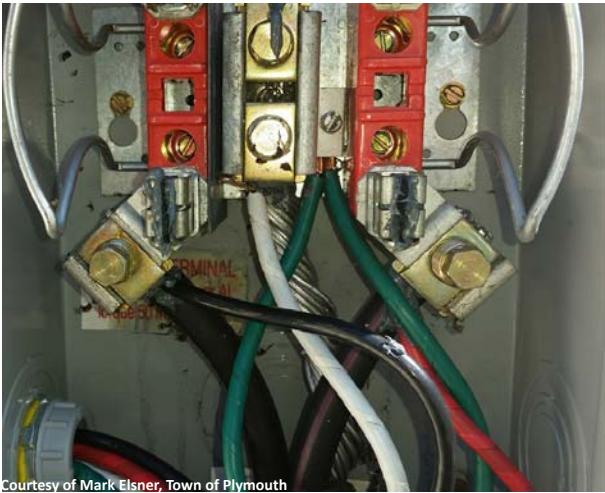


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Examples of Tapped SE Conductors

The Wrong Way...



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Courtesy of Mark Elsner, Town of Plymouth
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Examples of Tapped SE Conductors

The Wrong Way...




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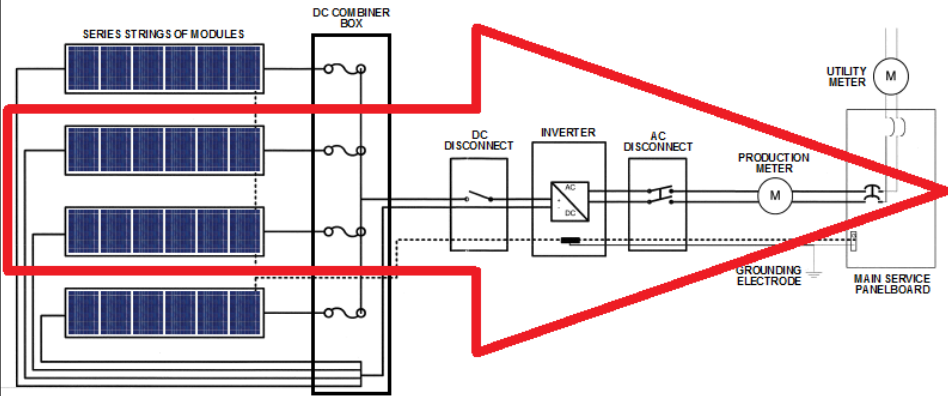
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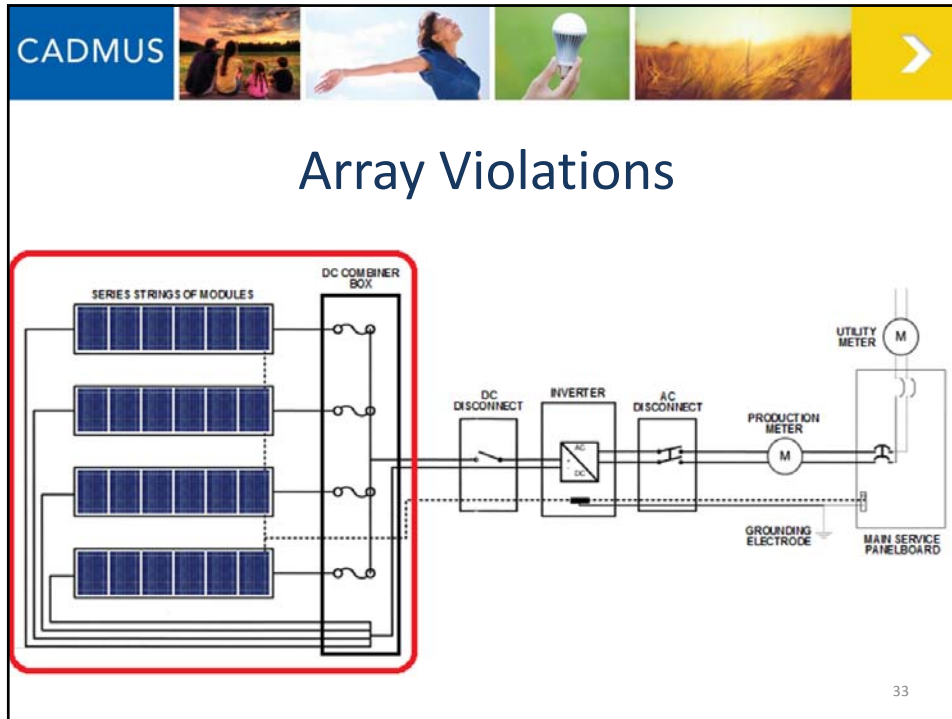


Top PV Violations & Inspection Techniques

from the Sun to the Grid...



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Equipment Grounding System


2014 NEC Article 690.43 / 250.4

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

A close-up photograph shows a green grounding cable being connected to a metal component of a solar array equipment. The cable is looped and secured with a yellow strap. The background shows the dark surface of the solar panel.

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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


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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”



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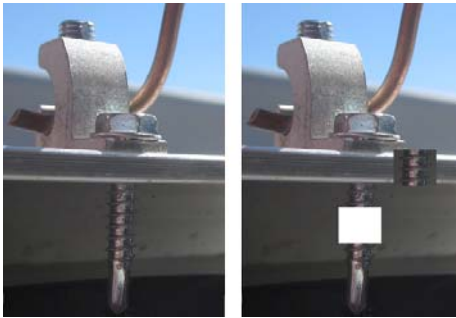
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Connection of Grounding and Bonding Equipment


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!!!***



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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




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Module Frame Grounding

Wrong Lugs – (Copper or Not Listed for Outdoor)



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Module Frame Grounding

Right Fitting, Installed Wrong



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Grounding the Racking

Wrong Screw (110.3(B) and 250.8)


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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



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Grounding the Racking

Considerations

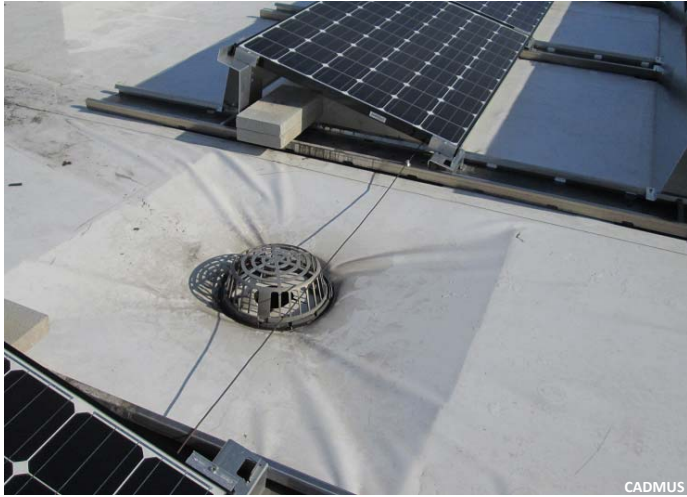
- Wire management
- Conductor type/material
- Size
- Splices
 - Where permissible
 - Not in lay-in lugs

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Grounding the Racking

Trip Hazard



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Common Array Violations

Approximately **25%** of all inspections contain issues with conductor protection...

- DC conductors at array not properly supported and protected
 - Conductors shall be protected against physical damage (including those beneath array)
 - Articles:
 - 300.4
 - 338.10(B)(4)(b)
 - 334.30
 - 338.12(A)(1)

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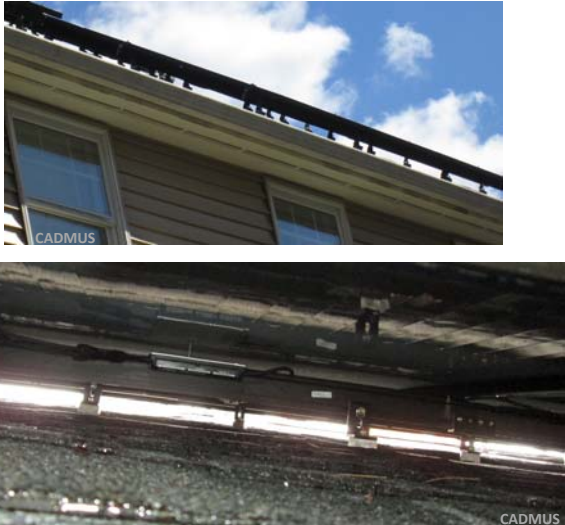




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The Right Way...

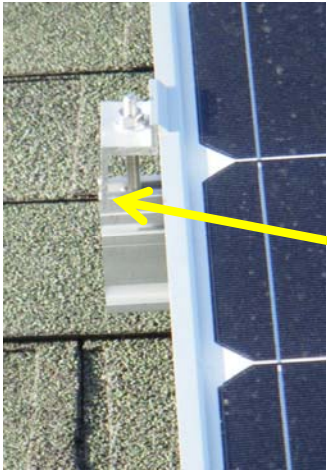


51

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End Clamp Too Close to Rail End



Most manufacturers specify at least ½" of space between the end clamp and the end of the rail to allow for thermal expansion and vibration.

52

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Measure Twice, Cut Once



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PV Rainwater Collection System



- 1) No Flashing
- 2) Lag Bolt not secure
- 3) Probably missed the rafter



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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

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Readily Accessible Locations

NEC Article 690.31(A)

- Ground-mount arrays
 - In readily accessible locations, conductors **shall be guarded** or installed in a raceway
 - Language clarification to adopt standard practice



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PV conductors in readily accessible locations shall be installed in a raceway.

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PV conductors in readily accessible locations shall be guarded or installed in a raceway.

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The Right Way...




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Readily accessible PV conductors properly guarded.

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The Right Way...



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Readily accessible PV conductors properly guarded.

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Dissimilar Metals

Beyond the lugs...




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Dissimilar Metals

Beyond the lugs...



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Dissimilar Metals
Beyond the lugs...



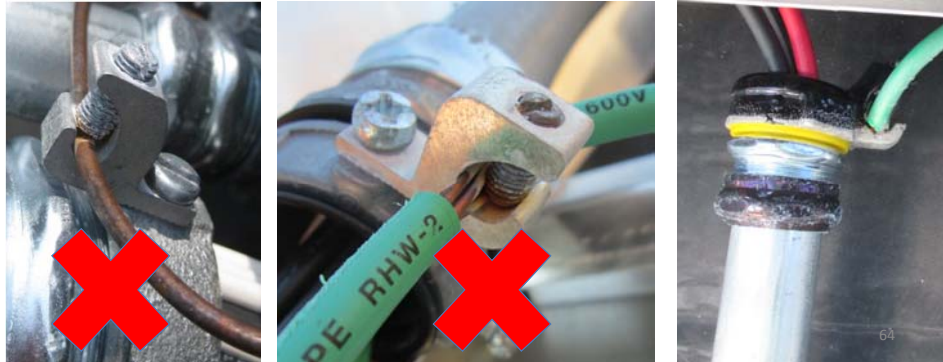
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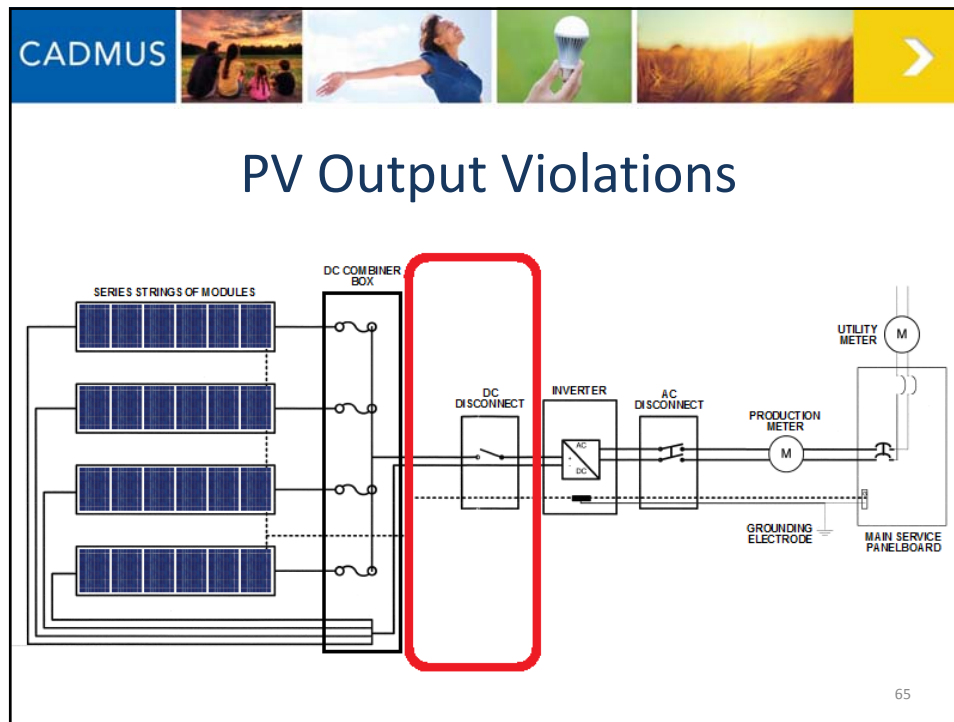


Bonding Bushings
Rated for Outdoor Use?

- Lay-in lug
 - Must be suitable for the environment in which it is installed
 - Outdoor/wet locations (suitable for direct-burial)



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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)

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Unprotected PV output conductors.

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The Right Way...



PV output conductors installed in conduit.

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Common PV Output Violations

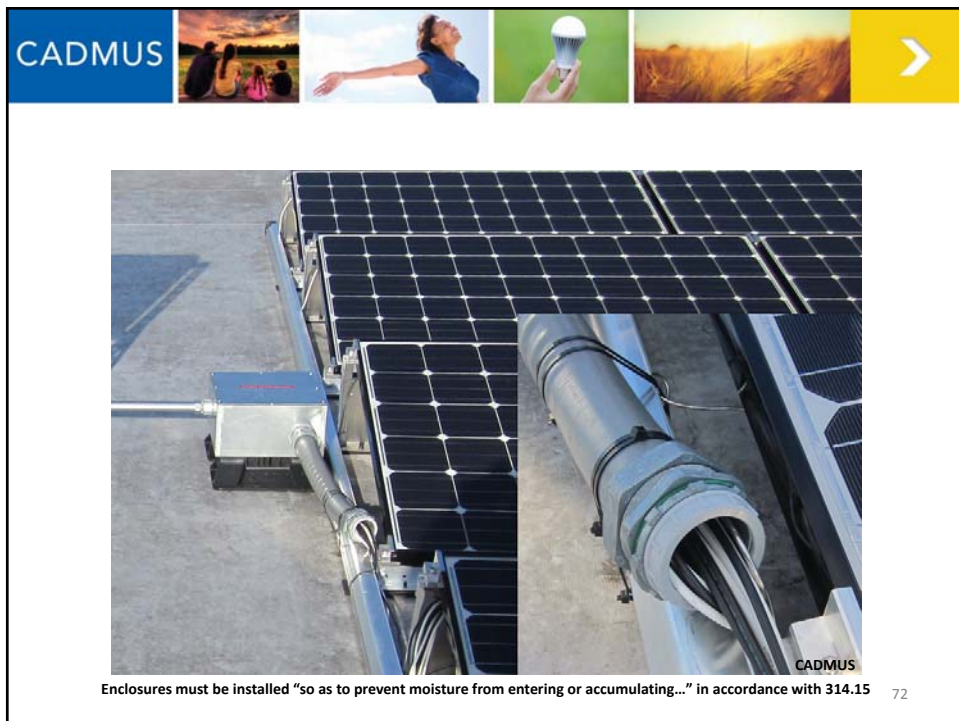
- Outdoor enclosures
 - Not grounded in accordance with 250.8(A)
 - Not installed “so as to prevent moisture from entering or accumulating...” in accordance with 314.15
 - Penetrations not sealed, as required by 300.7(A)
 - Indoor wire connectors, 110.3(B), **110.28**

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Raceway must be sealed when passing between the interior and exterior of a building per 300.7(A)

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Products in contact with conductor insulation should be rated for electrical applications. This is ONE example, there are many other products available.

PRODUCT DATA SHEET

RTV Silicone Sealant - Blue, 6.5 Wt Oz
Part Number: 14057

Product Description
For general-purpose sealing, bonding, protecting and waterproofing applications. Blue formulation is designed as a heavy-duty industrial gasket sealant.

Applications
Sealing, bonding, protection & waterproofing in HVAC, electrical, construction, metal working, for filling gaps between mating parts, gearboxes, pumps, motors & for general gasket sealing.

Unit Package Description
8 Ounce Pressurized Tube with "Select a Bead"

Brand
CRC

Generic Description 1
Blue Silicone Sealant

Net Fill
6.5 Wt Oz

UPC Code
078254140575

Unit Dimensions
11.37H x 2.19W x 2.48D in

Units Per Case
12

Case Dimensions
11.25H x 7.37W x 7.37D in

Cases Per Pallet
90

Case Weight
7 lbs

I 2 of 9 Code
30078254140576

Appearance
Blue Paste

Flashpoint
+212°F

CPSIC Flammability Class
None

Specific Gravity
1.007

Plastic Safe
Yes

Evaporation Rate
Slow

Curing Time
24 Hours

Dielectric Strength
25 kV/mm

Working Temp
-76 to 400°F

Pipefitment
800open

Aerosol Flammability Level
I

PRODUCT DATA SHEET

Minimal Expansion Foam, 12 Wt Oz
Part Number: 14077

Product Description
Fill, seal, bond, retrofit, insulate and deaden sound in and around cracks and cavities. Forms a permanent, waterproof and airtight bond to most surfaces. UL classified as a sealing sealant.

Applications
Filing, insulating, sealing, bonding, HVAC, electrical, industrial, plumbing, around electrical outlets, utility panels, ducts, pipes, doors, windows, base plates, joints, cracks, crownjoints, foundations, spot insulating, touch-up

Unit Package Description
16 Ounce Aerosol

Brand
CRC

Generic Description 1
Expansion Aerosol Foam Sealant

Net Fill
12 Wt Oz

UPC Code
078254140773

Unit Dimensions
8.66H x 2.19W x 2.15D in

Units Per Case
12

Case Dimensions
9.28H x 8.63W x 11.25D in

Cases Per Pallet
108

Case Weight
13 lbs

I 2 of 9 Code
30078254140774

Appearance
Tan Foam

Flashpoint
None

CPSIC Flammability Class
None

Specific Gravity
1.2

Plastic Safe
Yes

Evaporation Rate
Not Determined

Curing Time
12 to 24 Hours

Dielectric Strength
Not Determined

Working Temp
65 to 150°F


Viscosity @68 F [cP]
Not Determined

Last revised: 7/30/2015
Page 1 of 2

Customer Care: 800-558-5074
Technical Assistance: 800-567-5788
www.crcindustrial.com

Last revised: 7/15/2015
Page 1 of 2

Customer Care: 800-558-5074
Technical Assistance: 800-567-5788
www.crcindustrial.com

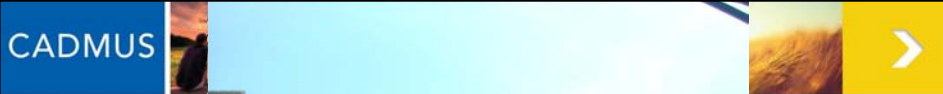


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Common PV Output Violations

- PVC Expansion Fittings
 - Missing – Article 352.44
 - Expansion fittings shall be provided where the length change is expected to be ¼ in. or greater in a straight run between securely mounted items:
 - Boxes
 - Cabinets
 - Elbows
 - Other conduit terminations
 - Installed wrong

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The Right Way...



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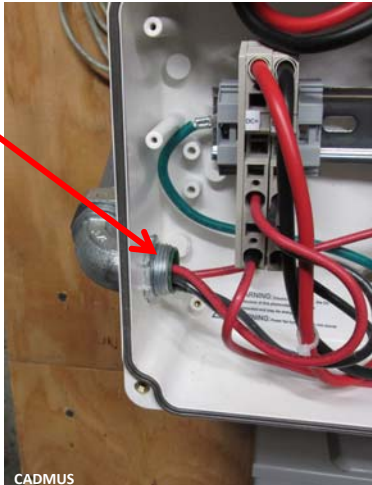
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Bonding the Raceway

NEC Article 250.4

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



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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

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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

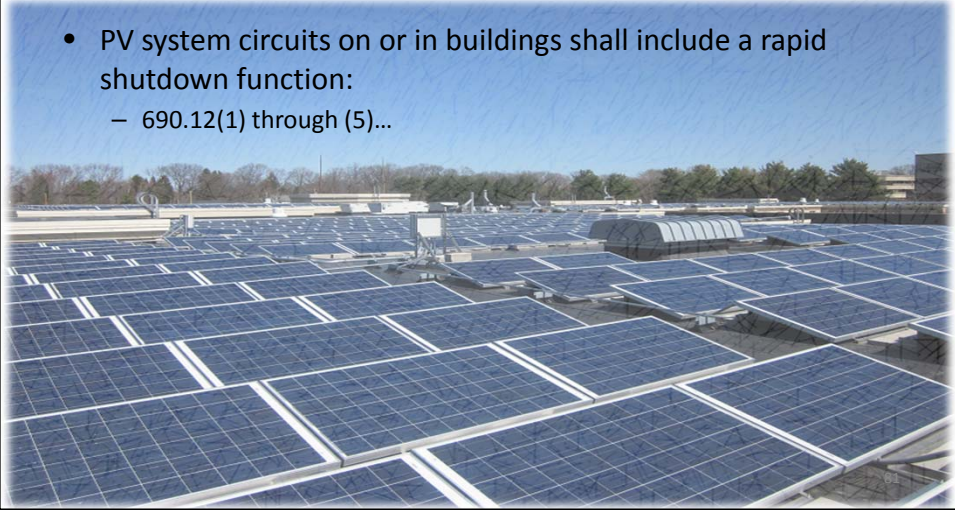
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Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- PV system circuits on or in buildings shall include a rapid shutdown function:
 - 690.12(1) through (5)...





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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




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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

Source: UL.com




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Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.12(4)
 - Labeled per ~~690.56(B)~~
 - Permanent plaque
 - Location of all disconnecting means



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Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.56(C)

PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN

- Minimum 3/8" CAPS
- White on Red
- Reflective
- *Required even for microinverters!*




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Rapid Shutdown of PV Systems on Buildings

NEC Article 690.12

- 690.12(5)
 - *“Equipment that performs the rapid shutdown shall be listed and identified.”*




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About Article 690.12

- Intended to protect first responders
- Original proposal:
 - Disconnect power directly under array
 - Module-level shutdown
- Compromise:
 - Combiner-level shutdown




Source: UL.com

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About Article 690.12

- Open-ended **gray areas**:
 - Location of “rapid shutdown initiation method”
 - Maximum number of switches
 - Type of building
 - Dwelling
 - Commercial



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About Article 690.12

- Considerations:
 - Disconnect power within 10 seconds
 - Inverters can store a charge for up to 5 minutes (UL 1741)

The diagram illustrates the electrical path from solar modules to the utility grid. It starts with 'SERIES STRINGS OF MODULES' connected to a 'DC COMBINER BOX'. A red box highlights the 'DC DISCONNECT' switch. The circuit then passes through an 'INVERTER', an 'AC DISCONNECT' switch, a 'PRODUCTION METER', and finally to a 'MAIN SERVICE PANELBOARD' which includes a 'UTILITY METER' and a 'GROUNDING ELECTRODE'.

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About Article 690.12

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

The top image shows a white microinverter mounted on a light-colored wall. The bottom image shows a solar panel array at night, with the panel's structure and wiring visible.

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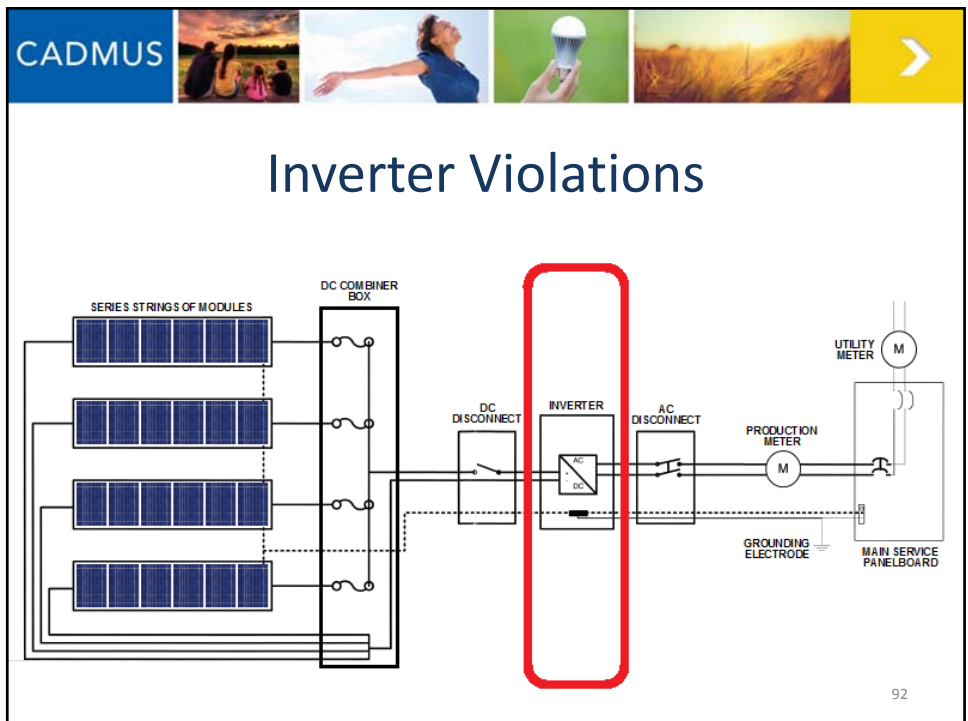
About Article 690.12

- What complies:
 - 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
- Many considerations & variations for full system compliance
 - Plans should be discussed with AHJ prior to installation

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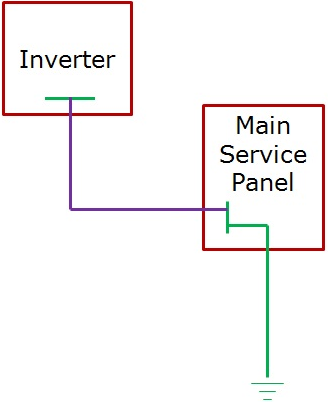


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Grounding Electrode System

NEC Article 690.47

- 690.47(C)(3)
 - Combined DC GEC and AC Equipment Grounding Conductor
 - Sized larger of 250.122 and 250.166 requirements (not smaller than 8 AWG copper, *unless ungrounded system*)



The diagram illustrates a grounding system. A red box labeled 'Inverter' is connected via a purple line to a red box labeled 'Main Service Panel'. From the Main Service Panel, a green line goes down to a ground symbol, representing the grounding electrode system.


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Grounding Electrode Conductor Installation

NEC Article 250.64


- GEC must be continuous
 - 250.64(C)
 - No splices from equipment to grounding electrode
 - Irreversible crimp or weld only



The photograph shows two green insulated conductors joined by a copper crimp splice. The splice is made of copper wire wrapped around the conductors, demonstrating an irreversible connection method.

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Disconnection of PV Equipment

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.”*

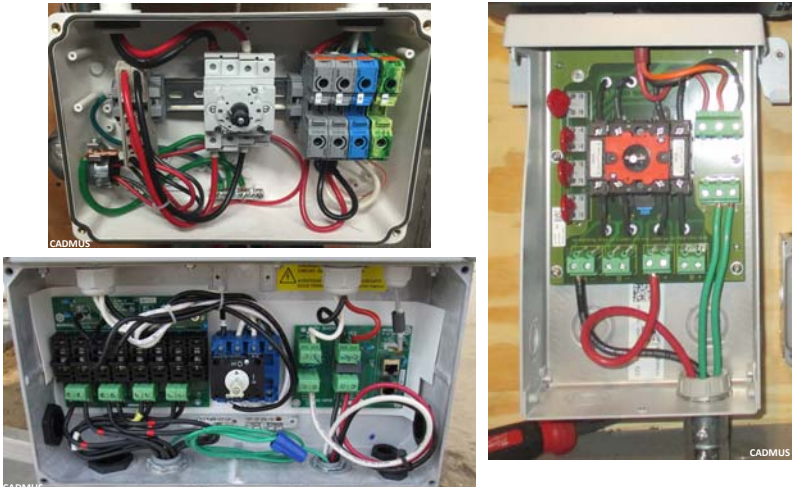
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Disconnection of PV Equipment

Inside the “S” brand...



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Disconnection of PV Equipment

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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Microinverter Mounting

Bolt too long...



Long bolts/hardware can cut into modules and short out. Extreme care should be taken to ensure module will not contact bolt under normal or weighted conditions.

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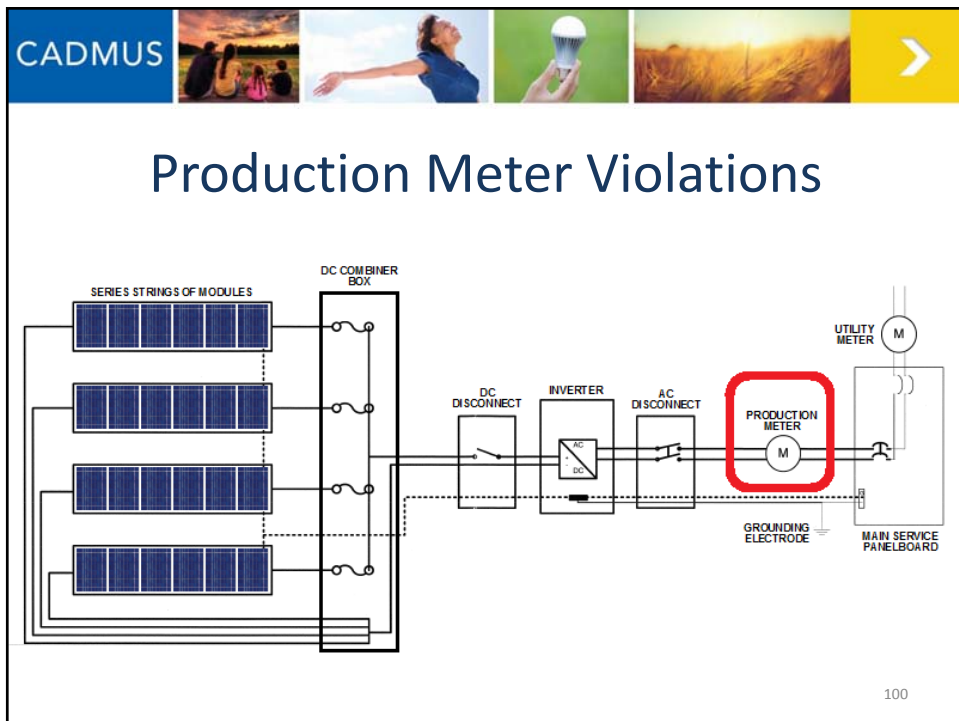
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Type NM Cable

NEC Article 334.12

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

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Production Meter Violations

- Article 250.24(A)(5)
 - Neutral conductor bonded to frame

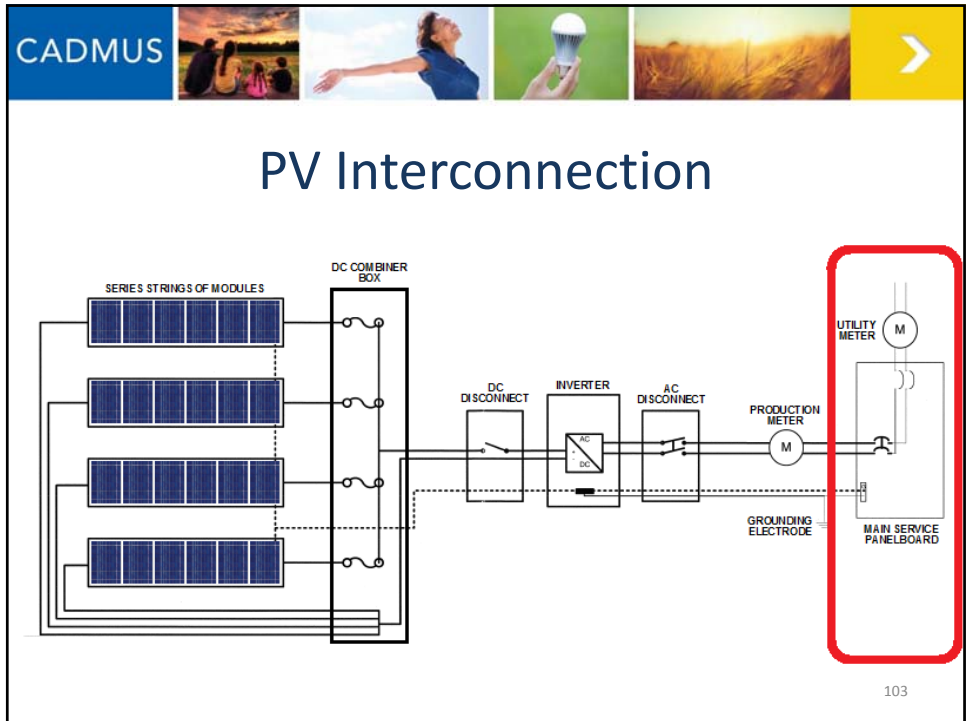
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Production Meter Violations

- Article 110.3(B)
 - Small conductors on lugs

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Article 705.12

- 705.12 Point of Connection
 - (A) Supply Side
 - (D) Load Side

PHOTOVOLTAIC SYSTEM
 OPERATING VOLTAGE - 240 VOLTS
 OPERATING CURRENT - 34.8 AMPS

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Supply Side Interconnection

NEC Article 705.12(A)

- Interconnection on utility side of main service disconnect
- Typically on customer side of utility meter
 - RE Growth program connection will be on new utility meter
- “Second set” of service entrance conductors (Article 230)
- Utility conductors must be on line terminals of disconnect
 - These remain energized when disconnect is opened (turned off)




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Supply Side Interconnection

Grounding Service-Supplied Alternating-Current Systems

- NEC Article 250.24(A)(1)
 - The GEC shall be made at any accessible point from the load end of the:
 - Overhead service conductors
 - Service drop
 - Underground service conductors
 - Service lateral
 - To the terminal or bus to which the grounded service conductor is connected at the service disconnecting means



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Supply Side Interconnection

Disconnect Labeling and Grouping Example

- 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

Requires Disconnect Directory per 690.56(B)

outside

inside

Fused PV Disconnect

Utility Meter

PV Inverter

Main Service Panelboard

PV

Interconnection Conductors **MAX 10 FEET**

Requires Disconnect Directory per 690.56(B)

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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

WARNING - Electric Shock Hazard

WARNING - Electric Shock Hazard - Always de-energize conductors before working on them

SOLAR

PV

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PV Interconnection

Considerations...

- Terminal ratings should be followed:
 - Conductor size
 - Max conductors

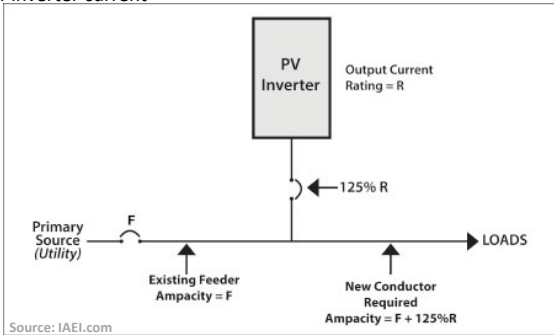
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Bus or Conductor Ampere Rating - Feeders

NEC Article 705.12(D)(2)(1)(a)

- Option (A)
- Feeder ampacity not less than sum of:
 - Primary source OCPD
 - 125% of inverter current



Source: IAEI.com

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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

Source: IAEL.com

111

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Bus or Conductor Ampere Rating - Feeders

NEC Article 705.12(D)(2)(1)(b)

Existing conductors must be increased in size or protected

Courtesy of Mark Elsner, Town of Plymouth

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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


Main Breaker 100A	Busbar 125A
125% PV Output 18A	100% of 125A = 125A

Example:
Inverter current = 14.4A
 $14.4A \times 125\% = 18A$

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

Main Breaker 100A	Busbar 100A
125% PV Output 18A	120% of 100A = 120A

Example:
Inverter current = 14.4A
 $14.4A \times 125\% = 18A$

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

- PV breaker must be at opposite end

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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

Load Breaker
20A

PV Breakers
80A total

Busbar
100A

Example:
4 20A inverter breakers
 $4 \times 20A = 80A$

Loads + PV = 100A
100% Busbar = 100A
100A loads & PV = 100A bus

- Permanent warning label required



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Wire Harness and Exposed Cable AFCI Protection

NEC Article 705.12(D)(6)

- Intended for micro inverters
- 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**

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Wire Harness and Exposed Cable AFCI Protection

NEC Article 705.12(D)(6)

Recommendation from the SEIA Codes and Standards Working Group and SolarABCs (<http://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 how 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

Although double-pole AFCI breakers are available, they are not suitable to be backfed, and would violate their listing in this application.



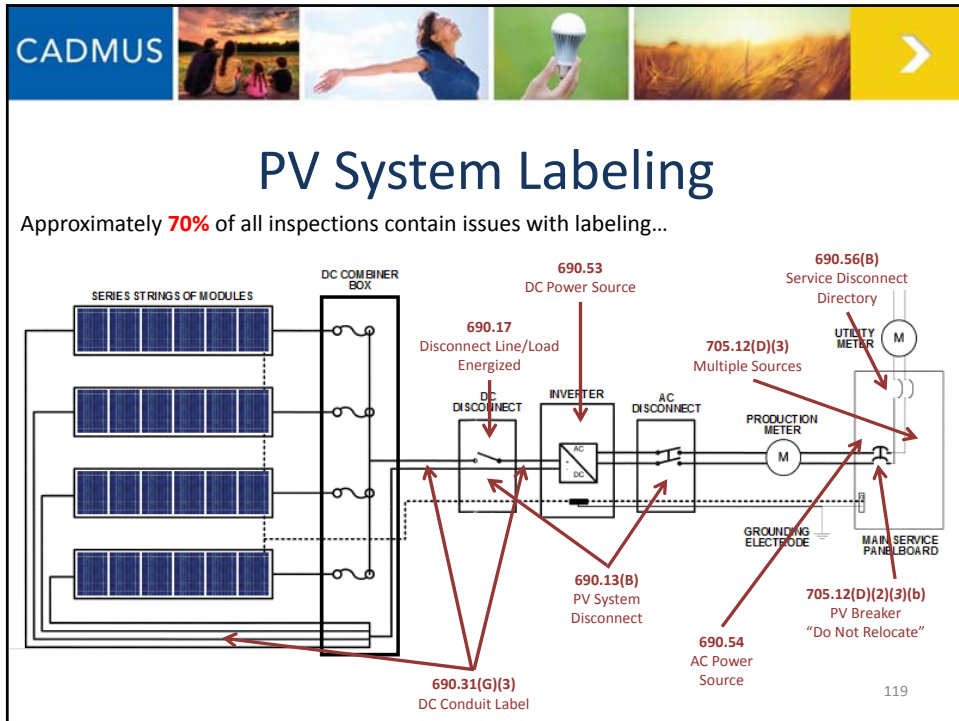
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PV System Labeling

- 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**.

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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**

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PV System Disconnect

Moved to **690.13(B)**

**PV
AC
DISCONNECT**

WARNING!
ELECTRIC SHOCK HAZARD.
DO NOT TOUCH TERMINALS
TERMINALS ON BOTH THE LINE
AND LOAD SIDES MAY BE ENERGIZED
IN THE OPEN POSITION


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Disconnect Line/Load Energized

690.17(E) Per
110.21(B)



WARNING

ELECTRIC SHOCK HAZARD
DO NOT TOUCH TERMINALS.
TERMINALS ON BOTH THE LINE
AND LOAD SIDES MAY BE ENERGIZED IN THE
OPEN POSITION.

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DC Power Source

690.53

PHOTOVOLTAIC SYSTEM INVERTER

RATED MAX. POWER CURRENT	10.26 ADC
RATED MAX. POWER VOLTAGE	378 VDC
MAXIMUM SYSTEM VOLTAGE	465 VDC
SHORT CIRCUIT CURRENT	11.22 ADC
RATED SYSTEM MAX. POWER	3.87 KW

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WARNING!
DC POWER
ELECTRIC SHOCK HAZARD
ROOFTOP SOLAR SYSTEM
COMBINER BOX

DC SOURCE CIRCUIT
(STRINGS OF 11 SOLON 280W SOLAR PANELS • STC)
SHORT CIRCUIT CURRENT (ISC): 8.95 ADC
RATED MAXIMUM POWER-POINT CURRENT (IMP): 8.15 ADC
RATED MAXIMUM POWER POINT VOLTAGE(VMP): 378.4 VDC
MAXIMUM SYSTEM VOLTAGE (VOC): 467.5 VDC



COMBINER "A"

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DC Power Source

SolarEdge Application Notes

http://www.solaredge.com/files/pdfs/pv_power_source_labeling.pdf

4/1/14

PV Power Source Labeling in a SolarEdge system

Introduction

String design and installation is significantly different in a SolarEdge system when compared to a traditional string inverter. PV modules do not get connected in series directly. Every PV module in the array is first connected to the input of a SolarEdge power optimizer, the power optimizer output cables are connected to other power optimizer output cables connecting the power optimizers in series.

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DC Power Source

SolarEdge Application Notes

1. Rated maximum **power point current**
 - **Lower** of following 2 values:
 - Total STC DC power rating for all modules divided by nominal string voltage listed in item (2)
 - Maximum input current rating of inverter
 - For example:
 - SE6000A-US inverter w/ 7.28 kW array
 - $7280W/350Vdc = 20.8A$
 - SE6000A-US inverter **max rating of 18A**

http://www.solaredge.com/files/pdfs/pv_power_source_labeling.pdf

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DC Power Source


SolarEdge Application Notes

2. Rated maximum **power point voltage**

- SolarEdge inverters operate on fixed voltage, determined by AC grid voltage:
 - **Single Phase Inverters**
 - 208 Vac → 325 Vdc nominal string voltage
 - **240 Vac → 350 Vdc nominal string voltage**
 - 277 Vac → 400 Vdc nominal string voltage

http://www.solaredge.com/files/pdfs/pv_power_source_labeling.pdf

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DC Power Source


SolarEdge Application Notes

3. Maximum **system voltage**

- Modules not directly connected to DC output circuit
 - When AC power is off, optimizer output is 1 Vdc per optimizer
- During startup, voltage will be slightly higher than values in (2)
- SolarEdge labeling requirement:
 - **All Single Phase Inverters**
 - **500 Vdc**

http://www.solaredge.com/files/pdfs/pv_power_source_labeling.pdf

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DC Power Source


SolarEdge Application Notes

4. Maximum system current

- String current regulated by inverter
- Will never exceed max input current rating
- Optimizer output circuits limited to 15 Adc
- Inverters can be fully loaded with 1 or 2 strings:
 - If 1 string → 15 Adc
 - If 2 strings → 30 Adc



http://www.solaredge.com/files/pdfs/pv_power_source_labeling.pdf

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AC Power Source

690.54

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Dual Power Sources

705.12(D)(3)



131


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“Do Not Relocate”


705.12(D)(2)(3)(b)

Per 110.21(B)



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

Per 110.21(B)

! WARNING

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

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Service Disconnect Directory
690.56(B)

Per 110.21(B)

CAUTION

THIS BUILDING IS POWERED BY MULTIPLE SOURCES:
UTILITY AND SOLAR PHOTOVOLTAIC ARRAY
DISCONNECT LOCATIONS ARE SHOWN BELOW



UTILITY SOLAR PV DISCONNECT

UTILITY METER & XFMR

SOLAR PANELS & MICRO INVERTERS

PV SYSTEM CIRCUIT BREAKER IN ELECTRICAL ROOM

SOLAR ARRAY

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Inverter Directory
690.15(A)(4)/705.10



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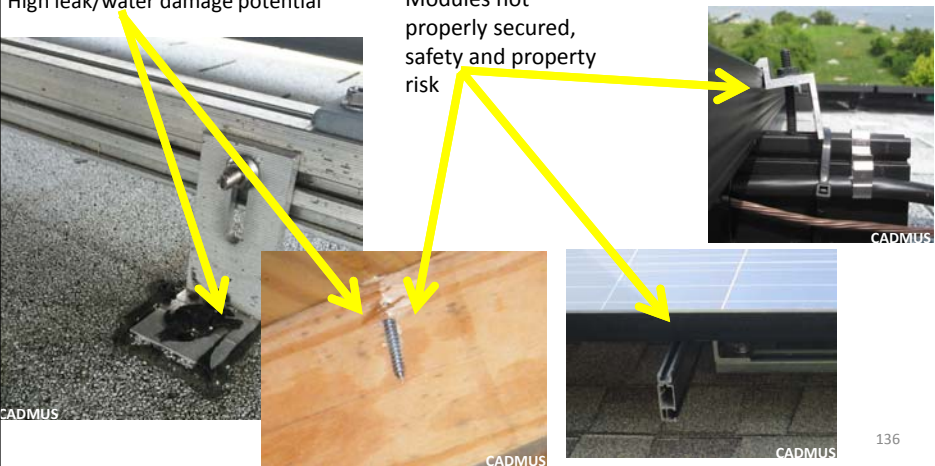
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What Else to Look For
Structural Issues

High leak/water damage potential

Modules not properly secured, safety and property risk



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Questions?

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