Resources

www.irecusa.org/MassCEC
CEUs

CEUs are issued through email

You want them?

Add your name and email to the roster
(legibly and completely, please!)
The Massachusetts Clean Energy Center

ADOPT
Spur deployment of renewable energy technologies.

CONNECT
Connect employers, job seekers, students, communities, and investors to the clean energy industry.

INNOVATE
Promote innovation through infrastructure, funding, and other support.

MassCEC is a quasi-public state agency whose mission to help grow the Commonwealth’s clean energy industry and meet its climate goals.
Goals of Solarize Mass

- Increase education and community outreach
- Model to simplify process
- Reduce installation costs
- Reduce time to contract
- Increase adoption

Drive down the cost stack

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<th>State Average</th>
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WHAT IS SOLARIZE MASS?
SOLARIZE MASS: WHO HAS PARTICIPATED?

18% of Massachusetts communities have participated in Solarize Mass

- 3,200 contracts
- 21 MW contracted capacity
- 20% average savings
MassCEC Project Contacts

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Welcome - Meet the instructors

Jim Rogers

Rudy Saporite
WELCOME

WHO ARE YOU?
WELCOME

- Big picture comprehensive perspective…PROCESS
- Focus on what is…not what if
- Common designs/common errors
- Plan review vs. field inspection
- Interested in learning more? IAEI.org and ICCsafe.org
INTRODUCTION

Mike gets a permit application on his desk for a rooftop mounted PV system. He has a number of other plan reviews to do before he can head out for the day. A residential remodel, HVAC install, etc…

By the time he gets to the solar PV system, he is ready to leave and does not give it his full attention. What could happen if Mike overlooks some things?
WHAT COULD GO WRONG?

If the code official doesn’t find areas of non-compliance/ critical issues
TRAINING OVERVIEW

- Read and interpret a plan
- Evaluate for compliance
- Practice
- Identify field inspection techniques
- Locate resources

GOAL (OBJECTIVE): You will be able to use a concise checklist for reviewing submitted permit plan applications and one for performing field inspections.
COMPLIANCE - BIG PICTURE

STRUCTURAL

FIRE SAFETY

ELECTRICAL
COMPLIANCE - BIG PICTURE

STRUCTURAL
- Verify quantity & spacing of roof attachments
- Verify weather sealing detail

FIRE SAFETY
- Verify access pathways and fire setbacks
- Verify module-rack fire classification

ELECTRICAL
- Verify module-rack grounding/bonding
- Verify AC & DC conductor size & type
- Verify location and rating of the PV system over-current protective device
- Verify all required disconnecting means, types, and locations
- Verify marking & labeling
- Identify what is being used for rapid shutdown

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Check for updates after each code cycle
PV SYSTEM OVERVIEW
PV (Photovoltaic) SYSTEM
ELECTRICITY NOT HEAT

- Produces electricity
- Many modules
- Module size ~ 3’ X 5’
- Conduit leaves module

- Heats water
- 2-6 collectors
- Collector size ~ 4’ x 8’
- Insulating piping leaves collector

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WORKING ASSUMPTIONS

- NEC 2017
- Ground snow load: 40 psf
- Wind Zone 1
- Wind exposure category C
- Design wind speed: 100 mph (3-sec gust) per ASCE 7-05
TEACHING PLAN

PLAN ‘A’
EVALUATING THE PLAN & PRACTICE

1. Verify access pathways and fire setbacks
2. Verify quantity and spacing of structural attachments
3. Verify weather sealing method
4. Verify array fire classification rating
5. Verify module-mounting system (rack) grounding and bonding
6. Verify DC conductor type & size
7. Verify the inverter AC output conductors and overcurrent protection are correctly sized in accordance with NEC 705.60
8. Based on the bus size of the panelboard, verify that the panelboard can handle the PV contribution according to NEC 705.12.
9. Verify required disconnecting means, types, and locations
10. Identify what is used to achieve Rapid Shutdown
11. Verify presence & accuracy of marking & labeling
ROOFTOP ARRAY

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ROOFTOP ARRAY

1. Verify array location is in compliance with access pathways and setbacks
2. Verify the quantity and spacing of structural attachments is compliant
3. Verify weather sealing method is compliant
TASK Confirm the array location meets access pathways & fire setbacks requirements
MURPHY’S LAW

What could possibly go wrong?
WHAT COULD HAPPEN?
RATIONALE FOR CODE

Photo: DOE/ NREL
WHAT DO YOU ALREADY KNOW ABOUT ROOFTOP ACCESS?
YOU ALREADY KNOW

 Required working clearances for HVAC and other rooftop equipment

NEW ABOUT PV

 Energized equipment on the rooftop
 Arrays can cover all or most of a roof, but must still leave room for pathway
COMPLIANCE MEANS

Access Pathways (may be required)
- over areas capable of supporting fire fighters accessing the roof
- two (2) 3’ pathways from eave to the ridge

Setbacks (may be required)
- array not less than 3’ from the ridge
IS OUR SYSTEM COMPLIANT?

EAST-FACING ARRAY

IN THE PLAN- P. A3

©2018 Interstate Renewable Energy Council
IN THE FIELD | IS THIS COMPLIANT?
WHAT IF… HIP ROOF?

EXAMPLE
IS THIS COMPLIANT? - HIP ROOF

Array 1 & 2 Layout

Example
EXCEPTIONS

- Detached, non habitable structures like carports, parking shade structures
- Fire chief determination of no requirements for pathways or setbacks
RESOURCES

11.12

CS 509

605.11
KEY POINTS - RESIDENTIAL
ROOFTOP ARRAY
TASK VERIFY THE QUANTITY AND SPACING OF STRUCTURAL ATTACHMENTS
MURPHY’S LAW

What could possibly go wrong?
“DO NO HARM”
RATIONALE FOR CODE

Photo: DOE/ NREL
WHAT DO YOU ALREADY KNOW ABOUT ROOF ATTACHMENTS?
YOU ALREADY KNOW

- Familiar with rafter span tables and roof live/dead load concepts

NEW ABOUT PV

- Many attachment points (point loads)
- Additional load on the roof (PV array about the weight of extra layer of shingles)
- Mounting system (rails) has span limit between attachment points
COMPLIANCE MEANS

1. Existing structure can support the weight of the array
2. Spacing of array structural attachments are appropriate according to manufacturer's mounting system span table
3. Quantity of array structural attachments distribute the system weight to avoid too heavy point load
4. The rafter spacing corresponds with required span in #1 above
5. Attachment method supports pull-out strength
Stage 1. Prescriptive process for structural approval of small PV systems

Stage 2. Request an engineered drawing
STAGE 1
PRESCRIPTIVE PROCESS
Compliance means that for the cases when the criteria for the home and array are met, the rafter span does not exceed the span in the Maximum Rafter Span Table provided as part of the prescriptive process.

Quantity and spacing of attachment points are installed per manufacturer’s specifications.
1. Introduction to the Prescriptive Process

The goal of this prescriptive structural review process is to provide standard guidelines for the installation of rooftop solar PV systems on one- and two-family residences without the expense and time of utilizing a licensed structural engineer to evaluate load carrying capacity. This process is designed to be applied to all cities and towns in the Commonwealth of Massachusetts.

Residential PV systems, usually sized 10 kW and less, are typically very lightweight, approximately 3.0 to 3.5 pounds per square foot. Adding this amount of weight to a roof compares favorably to adding a second layer of roofing shingles, which does not require the advice of a licensed structural engineer in Massachusetts. The prescriptive method described herein is limited to flush-mounted PV systems, for which the effects of wind and snow accumulation can be better quantified using existing building code metrics.1 PV systems are sometimes installed at a tilt to get the best exposure of the PV modules to the sun, but the tilt can cause an increase in the effect of wind and snow accumulation.

In order to qualify for the prescriptive structural review process, the buildings in question must be a 1-2 family dwelling built after 1975 with a light-frame wood construction and traditional rafters for the roof. Considering lightweight construction and rafter/truss data from 1997 and 2001, one could roughly estimate that approximately 10%-12% of homes in Massachusetts will qualify for the prescriptive process.2 This translates to approximately 188,000 to 225,000 homes out of the 1,902,385 1-2 family dwellings in Massachusetts.3

*1 In flush-mounted PV systems, the modules are installed parallel to the existing roof at a height of no more than 8 to 12 inches above the roofing.
2 In 1997, 30% of homes were newer than 1975 x 74% were of light frame construction x 44.7% of homes were built with rafters = 10%. In 2001, 30% of homes were newer than 1975 x 82.8% were of light frame construction x 47.7% of homes were built with rafters = 12%.
3 Comprised of 1,463,293 1-unit detached, 139,039 1-unit attached and 309,073 2-unit structures.
CRITERIA

Prescriptive Process for Structural Approval of Small PV Systems (< 10 kW)

- House built after 1975
- 1 layer of shingles
- Slope 4:12 or greater
- Roof rafters typical 2x lumber (spruce-pine-fir or hem-fir) of regular spacing
- Compliant fasteners specified
- Skylights/ dormers not within 2’ of array
- No equipment supported from the roof framing within 2’ of array
- No additions/ renovations of existing roof within 6’ of array
- Roof framing shows no signs of distress
- No signs or knowledge of previous damage

PREScriptive Process for Structural Approval of Small PV Systems (< 10 kW)

If all criteria in the checklist were met, use Maximum Rafter Span Table for the evaluation of the roof framing to support the PV system.

IS OUR SYSTEM COMPLIANT?

DRAWING NOTES:
1. PV ARRAY CONTAINS (31) CANADIAN SOLAR 320 WATT PV MODULES WITH (31) SOLAREDGE P325 POWER OPTIMIZERS.
2. PV ARRAY UTILIZES (1) SOLAREDGE SE900A-UD INVERTER.
3. INSTALLERS SHALL VERIFY LOCATION OF RAFTERS PRIOR TO INSTALLATION OF FLEX AND RAILS.

SITE DETAILS:
1. SERVICE VOLTAGE: 120 VAC SINGLE PHASE
2. TAILING & ROOF ATTACHMENT: UNIFAC SOLAR MOUNT RAILS; ECO-FASTEN L-FASTENED WITH ECO-FASTEN GROUND FASTEN FLUSHING.
3. MAX RAIL SPAN = 12' (ORIENTATION), 6' (LANDSCAPE)
4. RAFTERS (EST. 240):
   4.1 24” (MINIMUM) 3” ON CENTER, 12”-4” = MAX RAIL SPAN
   4.2 24” (MINIMUM) 16” ON CENTER, 7”-8” = MAX RAIL SPAN
5. ROOF COMPOSITION: ASPHALT SHINGLES OVER A FINISH DECKING
6. GROUNDING WEIGHTED GROUND LUGS AND VIBED 8.0 GROUND CUPS
7. DISTANCE FROM ARRAY TO INTERCONNECTION POINT = 10'
8. ROOF HEIGHT = 12'
9. GROUND SNOW LOAD = 40 PSF
10. DESIGN WIND SPEED = 100 MPH
11. ARRAY CHARACTERISTICS (EST. SOUTH):
   11.1 ARRAY WEIGHT (EST.): 1,245 lb., 515 lb.
   11.2 ARRAY SURFACE AREA: 432 sq. ft., 120 sq. ft.
   11.3 ARRAY LOAD: 3.33 PSF, 3.33 PSF
   11.4 NUMBER OF ATTACHMENT POINTS = 44, 20
   11.5 WEIGHT PER ATTACHMENT = 4.4 lb., 20.7 lb.
   11.6 MINIMUM DETACH FROM ROOF EDGE = 14", 5’
- PV weight: 3.29 psf
- Ground snow load: 40 psf
- Rafters: 2x6, 16 oc, SPF # 1

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<td>9''</td>
<td>13''</td>
<td>17''</td>
<td>6''</td>
<td>9''</td>
<td>13''</td>
</tr>
</tbody>
</table>

This table provides the maximum rafter spans for non-cathedral ceilings with various loadings. The values are given for different spans and loadings, with the maximum spans listed for each configuration.
If roof rafter span is acceptable, quantity and spacing of attachments should be per racking manufacturer’s installation specifications.
STAGE 2 REQUEST ENGINEERED DRAWING
Examples include:

- Sagging existing roof
- Already an additional load on the roof
- Degraded roof capacity due to weathering or roofing modifications
- High snow loads
- High wind load location
POINT LOADS

RAFTER LOCATION
16 OC

ROOF ATTACHMENT LOCATION
48"

POINT LOADS
20.7 LBS
IN THE FIELD
IN THE FIELD

MISSING ROOF ATTACHMENT

ADEQUATE ROOF ATTACHMENTS

PHOTOS: PETE JACKSON

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Creating a Permit Checklist

Structural Considerations for Solar Installers (WI)

Planning for Solar Energy (APA)
KEY POINTS

- The roof must be capable of supporting the array
- An engineered drawing may not always be required
- There must be enough roof attachment points that point load is not excessive
- Span between attachment points cannot exceed manufacturer’s specification
ROOFTOP ARRAY

Graphic: IBTS

©2018 Interstate Renewable Energy Council
TASK Verify weather sealing method
MURPHY’S LAW

What could possibly go wrong?
WHAT DO YOU ALREADY KNOW ABOUT WEATHER SEALING?
<table>
<thead>
<tr>
<th>YOU ALREADY KNOW</th>
<th>NEW ABOUT PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Roof penetrations (vent pipes, etc.) and flashing</td>
<td>- Attachment goes in to structural member and does NOT penetrate all the way through the roof</td>
</tr>
<tr>
<td>- Changes to roof should not allow leakage</td>
<td>- There are a lot of attachments</td>
</tr>
</tbody>
</table>
COMPLIANCE MEANS

Attachments' weather sealing detail is installed in accordance with the manufacturer’s instructions. Roof penetrations shall be flashed and sealed in accordance with IRC section R909.3.

Photo: IBTS
IS OUR SYSTEM COMPLIANT?

1. Locate the rafters and snap horizontal and vertical lines to mark the installation position for each GreenFasten flashing.
2. Drill a pilot hole (1/4" diameter) for the leg bolt. Backfill with sealant. EcoFasten Solar recommends an EPDM mastic.
3. Insert the flashing so the top part is under the next row of shingles and pushed far enough up slope to prevent water infiltration through vertical joint in shingles. The leading edge of flashing must butt against upper row of nails to prevent curling when torqued. See page 3.2 for vertical adjustment when leading edge of flashing hits nails in upper shingle courses.
4. Line up pilot hole with GreenFasten flashing hole.
   - a: Insert the leg bolt through the EPDM washer, the top compression component bracket (L-102.3, Rock-It SlideComp, SCL-101.3H, Z-101+, Conduit Mount Bracket*) and the gasketed hole in the flashing and into the rafter.
   - b: Insert the leg bolt through the EPDM washer, the Comp Mount Slide compression bracket and the gasketed hole in the flashing and into the rafter.
   - c: Insert the leg bolt through the SS washer, the third-party bracket, the EPDM bonded washer, the CP-SQ Slotted compression bracket and the gasketed hole in the flashing and into the rafter.
5. Torque: The range is between 100-140 torque inch-pounds depending on the type of wood and time of year. The visual indicator for proper torque is when the EPDM on the underside of the bonded washer begins to push out the sides as the washer compresses. Using an impact wrench to install the fasteners be careful not to overtighten.

Consult an engineer or go to www.ecofastensolar.com for engineering data.
IN THE FIELD – IS IT COMPLIANT?
KEY POINTS

- Look for weather sealing detail in plan
- Metal flashing may not be required
- Weather sealing must be done in accordance with the manufacturer’s installation instructions
- What is acceptable for your jurisdiction/local area based on weather conditions and existing constructions?
You are back in your office and someone has submitted this plan. In terms of the three tasks you have just learned, explain if the submitted plan is compliant in each area. If not, why not?

Working in pairs or small groups. Using the PRACTICE plan C, decide if the following items are compliant:

- Access pathways & setbacks
- Quantity and spacing of structural attachments
- Weather sealing method

15 MINUTES
IS OUR PRACTICE PLAN COMPLIANT?

ACCESS PATHWAYS & SETBACKS -- Page C4 & C5
IS OUR PRACTICE PLAN COMPLIANT?

QUANTITY & SPACING OF ROOF ATTACHMENTS - Page C15
IS OUR PRACTICE PLAN COMPLIANT?
ROOFTOP ARRAY

Graphic: IBTS

©2018 Interstate Renewable Energy Council
4. Verify the module/mounting system combination achieves required fire classification
5. Verify the module/mounting system grounding/bonding method
TASK Verify array fire classification rating
MURPHY’S LAW

What could possibly go wrong?
WHAT DO YOU ALREADY KNOW ABOUT FIRE CLASSIFICATION?
### YOU ALREADY KNOW

- **Class A** - effective against severe fire exposure
- **Class B** - effective against moderate fire exposure
- **Class C** - effective against light fire exposure

### NEW ABOUT PV

- Rooftop PV systems (solar module + racking system) must meet the required fire classification
- Modules have a fire classification type
- Racking systems are rated in combination with specified modules
If a fire classification is required for the building roof, the module/mounting system combination included in the plan achieves required fire classification.
ARRAY FIRE CLASSIFICATION

MODULE FIRE TYPE + RACK TESTED IN COMBINATION WITH MODULE FIRE TYPE = FIRE RATED ASSEMBLY
IS OUR PLAN COMPLIANT?

IDENTIFY MODULE FIRE TYPE

Module Fire Performance

**TYPE 1 (UL 1703) or CLASS C (IEC 61730)**

**ELECTRICAL DATA | STC**

<table>
<thead>
<tr>
<th></th>
<th>299MS</th>
<th>295MS</th>
<th>300MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Max. Power (Pmax)</td>
<td>390 W</td>
<td>295 W</td>
<td>300 W</td>
</tr>
<tr>
<td>Opt. Operating Voltage (Vmp)</td>
<td>32.5 V</td>
<td>32.5 V</td>
<td>32.5 V</td>
</tr>
<tr>
<td>Opt. Operating Current (Imp)</td>
<td>9.05 A</td>
<td>9.14 A</td>
<td>9.24 A</td>
</tr>
<tr>
<td>Open Circuit Voltage ( Voc)</td>
<td>39.3 V</td>
<td>39.5 V</td>
<td>39.7 V</td>
</tr>
<tr>
<td>Short Circuit Current ( Isc)</td>
<td>9.67 A</td>
<td>9.75 A</td>
<td>9.82 A</td>
</tr>
<tr>
<td>Module Efficiency</td>
<td>17.72 %</td>
<td>18.02 %</td>
<td>18.33 %</td>
</tr>
<tr>
<td>Operating Temperature</td>
<td>-40°C ~ 65°C</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. System Voltage</td>
<td>1000 V (IEC) or 1000 V (UL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Module Fire Performance</td>
<td>TYPE 1 (UL 1703) or CLASS C (IEC 61730)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max. Series Fuse Rating</td>
<td>15 A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Application Classification</td>
<td>Class A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Power Tolerance</td>
<td>0 ~ +5 W</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**ELECTRICAL DATA | NOCT**

<table>
<thead>
<tr>
<th></th>
<th>299MS</th>
<th>295MS</th>
<th>300MS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal Max. Power (Pmax)</td>
<td>310 W</td>
<td>219 W</td>
<td>216 W</td>
</tr>
<tr>
<td>Opt. Operating Voltage (Vmp)</td>
<td>36.7 V</td>
<td>36.7 V</td>
<td>36.7 V</td>
</tr>
<tr>
<td>Opt. Operating Current (Imp)</td>
<td>7.29 A</td>
<td>7.36 A</td>
<td>7.35 A</td>
</tr>
<tr>
<td>Open Circuit Voltage ( Voc)</td>
<td>36.2 V</td>
<td>36.4 V</td>
<td>36.6 V</td>
</tr>
<tr>
<td>Short Circuit Current ( Isc)</td>
<td>7.76 A</td>
<td>7.83 A</td>
<td>7.92 A</td>
</tr>
</tbody>
</table>

**PERFORMANCE AT LOW IRRADIANCE**

Excellent performance at low irradiance, average relative efficiency of 97.5 % from an irradiance of 1000 W/m² to 200 W/m² (AM 1.5, 25°C).

**TEMPERATURE CHARACTERISTICS**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature Coefficient (Pmax)</td>
<td>-0.39 %/°C</td>
</tr>
<tr>
<td>Temperature Coefficient (Isc)</td>
<td>-0.36 %/°C</td>
</tr>
<tr>
<td>Temperature Coefficient (Isc)</td>
<td>0.053 %/°C</td>
</tr>
<tr>
<td>Nominal Operating Cell Temperature</td>
<td>45.2 °C</td>
</tr>
</tbody>
</table>

**ASSUME CLASS A FIRE RATING IS REQUIRED**

PAGE A12
COMPLIANT?

RACK SPECIFICATION SHEET – CONFIRM FIRE RATING COMBINATION

SYSTEM LEVEL FIRE CLASSIFICATION

The system fire classification requires installation in the manner specified in the SOLARMOUNT Installation Guide. SOLARMOUNT has been classified to the system level fire portion of UL 1703. This UL 1703 classification has been incorporated into our UL 2703 product certification. SOLARMOUNT has achieved system level performance for steep sloped roofs. System level fire performance is inherent in the SOLARMOUNT design, and no additional mitigation measures are required. The fire classification rating is only valid on roof pitches greater than 2:12 (slopes > 2 inches per foot, or 9.5 degrees). There is no required minimum or maximum height limitation above the roof deck to maintain the system fire rating for SOLARMOUNT. Module Types & System Level Fire Ratings are listed below:

<table>
<thead>
<tr>
<th>Rail Type</th>
<th>Module Type</th>
<th>System Level Fire Rating</th>
<th>Rail Direction</th>
<th>Module Orientation</th>
<th>Mitigation Required</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard Rail</td>
<td>Type 1, Type 2, Type 5 &amp; Type 10</td>
<td>Class A, Class B &amp; Class C</td>
<td>East-West</td>
<td>Landscape OR Portrait</td>
<td>None Required</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>North-South</td>
<td>Landscape OR Portrait</td>
<td>None Required</td>
</tr>
<tr>
<td>Light Rail</td>
<td>Type 1 &amp; Type 2</td>
<td>Class A, Class B &amp; Class C</td>
<td>East-West</td>
<td>Landscape OR Portrait</td>
<td>None Required</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>North-South</td>
<td>Landscape OR Portrait</td>
<td>None Required</td>
</tr>
</tbody>
</table>

UL2703 CERTIFICATION MARKING LABEL

Unirac SOLARMOUNT is listed to UL 2703. Marking Labels are shipped with the Midclamps. After the racking system is fully assembled, a single Marking Label should be applied to the SOLARMOUNT rail at the edge of the array. Note: The sticker label should be placed such that it is visible, but not outward facing.
RESOURCES

UL 1703 Fire Code Compliance Database
The companies below have provided CALSIEA with proper documentation confirming they have passed the required testing for UL 1703. Companies that provide full documentation have been added to the list. If a company has not yet passed the testing, they are in the process of undergoing UL 1703 testing. We have made note of that where.

To view the list of companies:

2. Click on the “Resources” tab.
3. Select “UL 1703 Fire Code Compliance Database.”

See Why You Should Choose
A CALSIEA Member
Manufacturer:

CALSIEA

RS403

R902
If the existing roof requires a fire classification:

IN THE PLAN

- Determine module Fire Type from spec sheet, install instructions, or listing cert
- Verify rack-module combination meets required classification

FIELD INSPECTION

- Verify installation is per instructions (racking and modules as shown in the plan)
90.3 Code Arrangement

Chapter 1 - General
Chapter 2 - Wiring and Protection
Chapter 3 - Wiring Methods and Materials
Chapter 4 - Equipment for General Use

Applies generally to all electrical installations

Supplements or modifies Chapters 1 through 7

Chapter 5 - Special Occupancies
Chapter 6 - Special Equipment
Chapter 7 - Special Conditions

Chapter 8 is NOT subject to the requirements of Chapters 1 through 7 except where the requirements are specifically referenced in Chapter 8

Chapter 9 - Tables

Applicable as referenced

Informative Annexes A through J

Information only - not mandatory
ROOFTOP ARRAY

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Graphic: IBTS
TASK Verify module-mounting system (rack) grounding and bonding
MURPHY’S LAW

What could possibly go wrong?
RATIONALE FOR CODE
WHAT DO YOU ALREADY KNOW ABOUT BONDING AND GROUNDING?
## BONDING & GROUNDING

### YOU ALREADY KNOW
- System grounding
- Equipment grounding
- Ground conductor and equipment grounding conductor in the system

### NEW ABOUT PV
- Grounding of DC systems
- Using the rack to bond the module frames
Grounding Electrode Conductor

- Used to connect systems or conductors to earth via a grounding electrode
- Used to keep a current-carrying conductor (neutral) at earth (ground) potential

Equipment Grounding Conductors (EGC)

- Used as a path for fault-current from the load to the source
- A low-impedance path for fault current is required so that overcurrent devices (fuses or circuit breakers) and/or ground-fault detection circuits can operate
Exposed non–current-carrying metal parts of module frames, equipment, and conductor enclosures shall be grounded/bonded (690.43) according to Article 250, using the appropriate size Equipment Grounding Conductor (EGC) (690.45)
HOW CAN THE RACK AND THE MODULES BE BONDED TO THE ECG?
COMPLIANCE MEANS

METHOD 1
Use the rack to ground/bond the modules

METHOD 2
Use an equipment grounding conductor to ground/bond the modules
METHOD 1: USE THE RACK TO GROUND/ BOND THE MODULES

- The module/rack assembly is listed to bonding attribute of UL 2703
- Installed in accordance with the manufacturer's installation instructions

Grounding Mid Clamp
Each Grounding Mid Clamp pierces through the anodized coatings of both the module frame and the mounting rail to form secure electrical bonds, which are repeated throughout the array.
The equipment grounding conductor (EGC) being used is connected to modules and rack in accordance with the manufacturer’s installation instructions.
IS OUR PLAN COMPLIANT?

6. GROUNDING: WEEB 6.7
GROUND LUGS AND WEEB 9.5
GROUND CLIPS
IF THE RACK IS NOT USED TO BOND THE MODULES

Each module frame bonded to Equipment Grounding Conductor (EGC)
Sample of Module grounding equipment
ALL MODULES AND RACKING SHALL BE GROUNDED VIA UL2703-LISTED RACKING SYSTEM’S INTEGRATED GROUNDING (PLEASE SEE DATA SHEET) OR WITH TIN PLATED DIRECT BURITAL RATED LAY IN LUGS USING STAINLESS STEEL HARDWARE, STAR WASHERS, AND THREAD FORMING BOLTS.

E9

EXAMPLE – PLAN NOTES
EXAMPLE - MOUNTING SYSTEM CUT SHEET
### Module Compatibility

The Flush Mount System may be used to ground and/or mount a PV module complying with UL 1703 only when the specific module has been evaluated for grounding and/or mounting in compliance with the included instructions. Unless otherwise noted, "xxx" refers to the module power rating and both black and silver frames are included in the certification.

<table>
<thead>
<tr>
<th>MAKE</th>
<th>MODELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Astronomy Solar</td>
<td>Modules with 35, 40, and 45mm frames and model identifier sa/SMD0xyPzz-xxx; where &quot;sa&quot; can be A or A; &quot;y&quot; can be either 10 or 12; &quot;z&quot; can be blank or (BL); Frameless modules with model identifier CHSM0010P(D)-xxx.</td>
</tr>
<tr>
<td>Axibe</td>
<td>Modules with 35 and 40mm frame and model identifier AC-xx/XXs-XX; where &quot;y&quot; can be M or P; &quot;sa&quot; can be 125 or 150; and &quot;z&quot; can be 546, 606 or 726.</td>
</tr>
<tr>
<td>Canadian Solar</td>
<td>Modules with 40mm frame and model identifier CS4Y-xxx;Z; where &quot;y&quot; can be K, P, Y, or X; and &quot;z&quot; can be M, P, Pk, or P3; Ufm module with model identifier CS4Y-xxx-PF; where &quot;y&quot; is K or X.</td>
</tr>
<tr>
<td>ET Solar</td>
<td>Modules with 35, 40, and 50mm frames and model identifier ET-Y2Z-xxxAA; where &quot;y&quot; can be P, L, M; &quot;z&quot; can be 60 or 72; and &quot;AAA&quot; can be WB, W3, W5, W9, W9S, W50, W9D, W9S9, W9SBO or BB.</td>
</tr>
<tr>
<td>Flex</td>
<td>Modules with 35, 40, and 50mm frame and model identifier FKS-xxXY-ZZ; where &quot;xx&quot; is the module power rating; &quot;y&quot; can be BB or BC; and &quot;z&quot; can be MAA11B, MAA11W, MAA11W, SAA11, SAA11W, SAA11W, SAA11W, SAA11W, SBA11B, SBA11W, SBA11W, SBC11W, or SBC11W.</td>
</tr>
<tr>
<td>Qpolarwa Solar</td>
<td>Modules with 40mm frame and model identifier Qpolarwa-XXY; where &quot;y&quot; can be blank or PB.</td>
</tr>
<tr>
<td>Hamawa Solar</td>
<td>Modules with 40, 45, and 50mm frame and model identifier H Ssdp-3Y-1-xxx2; where &quot;y&quot; can be blank; &quot;z&quot; can be blank or B.</td>
</tr>
<tr>
<td>Hamawa Q CELLS</td>
<td>Modules with 35, 36, 40, and 42mm frames and model identifier Q-YYY-2-zz-xx; where &quot;y&quot; can be plus, Pro, or PEAK; and is on G3, G4, L-02, L-03Y, L-04, BFR-03, BLK-03, BMF-04, BFR-04, O-04A, or O-04/SC.</td>
</tr>
<tr>
<td>Hyundai</td>
<td>Modules with 35 and 50mm frames and model identifier Hsds-XY-XXXZ; where &quot;y&quot; can be M or S; and &quot;z&quot; can be M, M, M, S, RI, R3, T1, or T2.</td>
</tr>
<tr>
<td>Ikei</td>
<td>Modules with 50mm frame and model identifier T-xxx-Y; where &quot;y&quot; can be blank, HE, or SE.</td>
</tr>
<tr>
<td>JA Solar</td>
<td>Modules with 40 and 45mm frames and model identifier JY2zz-xxXY-xxx; where &quot;y&quot; can be M or P; &quot;z&quot; can be blank, (K), (L), (F), (V), (BK), (PA), (T1), (PA)R, (L)R, (L)T1, (PA)R, (PA)R, (L)R, (L)T1, (PA)R, (PA)R, (L)R, (L)T1, or (L)R; and &quot;y&quot; can be blank.</td>
</tr>
<tr>
<td>Hanone</td>
<td>Modules with 35 and 40mm frame and model identifier JMKY-xxxZ-2; where &quot;y&quot; can be blank or blank; and &quot;z&quot; can be M, P, P, P, P, P, P.</td>
</tr>
<tr>
<td>Kyodoana</td>
<td>Modules with 40mm frame and model identifier KY-cy-xxY-ZZ; where &quot;y&quot; can be C or D; and is on P or S; and is on A, B, or S; and is on C or K; and &quot;y&quot; can be A3, B3, G3, or K4.</td>
</tr>
<tr>
<td>LG</td>
<td>Modules with 40mm frame and model identifier PV-YYY-XXXZ; where &quot;y&quot; can be LE or LE; and &quot;z&quot; can be either HO, HDZ, or PF.</td>
</tr>
<tr>
<td>Mitsubishi</td>
<td>Modules with 40mm frame and model identifier PV-YY-XXXZ; where &quot;y&quot; can be blank or blank.</td>
</tr>
<tr>
<td>Nissei</td>
<td>Modules with 40mm frame and model identifier BN-XXXY-1; where &quot;y&quot; can be blank or blank.</td>
</tr>
<tr>
<td>Panasonic</td>
<td>Modules with 30mm frame and model identifier VBN-XXX-24; where &quot;y&quot; can be blank or blank.</td>
</tr>
</tbody>
</table>
WHAT IF THE RAIL IS NON-CONTINUOUS?

Racking must be evaluated in combination with module for bonding.

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GROUNDING FROM MODULES TO INVERTER

DC SIDE – P. A10
IN THE FIELD

Module-rack bonding

Photo: P. Jackson

Photo: IREC ©2018 Interstate Renewable Energy Council
RESOURCES

690.43 & 690.45
KEY POINTS

- A low impedance path for ground fault current from the rack/modules to the inverter is one of the methods of protection against shock and fire hazards.
- The inverter ground fault detection system is less effective without correct grounding/bonding (as tested by NRTL).
- Modules must be properly grounded/bonded.
- Must be a grounding path from array to system ground.
Working in pairs or small groups. Using the PRACTICE plan C, decide if the following items are compliant:

- Module-rack fire classification (assume Class A is required)
- Module-rack grounding/bonding
## Module Compatibility

The roof mount system may be used for ground and/or metal systems complying with UL 1753 only when the specific module has been evaluated for grounding and/or mounting in compliance with the indicated instructions. Unless otherwise noted, “X” indicates to the module power rating and both frame and solar frames are included in the configuration.

### Module Compatibility Table

<table>
<thead>
<tr>
<th>Module</th>
<th>Compatibility Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solar</td>
<td>Modules with 50, 60, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
<tr>
<td>Connectors</td>
<td>Modules with 60, 70, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
<tr>
<td>Inverters</td>
<td>Modules with 60, 70, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
<tr>
<td>Transformers</td>
<td>Modules with 60, 70, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
<tr>
<td>Data Collection</td>
<td>Modules with 60, 70, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
<tr>
<td>Battery Systems</td>
<td>Modules with 60, 70, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
<tr>
<td>Energy Storage</td>
<td>Modules with 60, 70, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
<tr>
<td>Power Monitoring</td>
<td>Modules with 60, 70, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
<tr>
<td>HVAC Systems</td>
<td>Modules with 60, 70, and single frame for module identification and where “X” indicates to the module power rating and both frame and solar frames are included in the configuration.</td>
</tr>
</tbody>
</table>
6. Verify DC conductor size and type
7. Verify the circuit breaker for inverter is correctly sized
8. Verify AC conductor size, type, and wiring method
9. Based on the bus size of the panelboard, verify that the panelboard can handle the PV contribution
CONDUCTORS

DC Conductors

Graphic: IBTS
TASK Verify DC conductor type and size
MURPHY’S LAW

What could possibly go wrong?
WHAT DO YOU ALREADY KNOW ABOUT DC WIRING?
<table>
<thead>
<tr>
<th>YOU ALREADY KNOW</th>
<th>NEW ABOUT PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>DC conductor? What’s that?</td>
<td>DC conductor types are different</td>
</tr>
<tr>
<td>▪ DC conductor types are different</td>
<td>▪ Exposed</td>
</tr>
<tr>
<td>▪ Exposed</td>
<td>▪ Carry high voltage</td>
</tr>
<tr>
<td>▪ Carry high voltage</td>
<td>▪ Portions of the system can never be turned off under light</td>
</tr>
<tr>
<td>▪ Portions of the system can never be turned off under light</td>
<td>▪ Series circuits</td>
</tr>
</tbody>
</table>
COMPLIANCE MEANS

The specified conductor and cable types to be used for module DC source wiring meet requirements of NEC 690.31.

Photo: J. Wages

Photo: P. Jackson
LOCATION OF DC AND AC CONDUCTORS

CONTINUOUS CURRENTS

FROM ARRAY

FROM INVERTER

UP TO 600 VDC

PV ARRAY CURRENT-LIMITED SOURCE

Graphic: IBTS

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IS OUR PLAN COMPLIANT?
Wiring within the array

EXPOSED single conductor wiring is a 90C, wet rated, and sunlight resistant type USE-2 or listed PV wire.

Wiring leaving the array
COMPLIANCE - TRANSITION FROM EXPOSED TO CONDUIT

- Is a junction box indicated?
- Is it appropriate for conditions (outdoor use?)
- Is the appropriate wiring method being used for the conductor leaving junction box?
MODULE

8 AMPS (AVG LARGE MODULE)
STRING

40 v 40 v 40 v 40 v 40 v

200 VDC @ 8 A

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COMPLIANCE MEANS

DC conductors must be sized for the LARGER of either

- 125% of Max current (Isc) WITH adjustments factors for wire fill and ambient temperature
- 156% (125% x 125%) of Max current (Isc) WITHOUT adjustment factors

See resource website for more example calculations

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ADJUSTMENT FACTORS

NEC Tables
310.15(B)(2)(a) – Temperature Correction Factors
310.15(B)(3)(a) – Adjustment Factors for More Than 3 Current-Carrying Conductors

See resource website for more example calculations
MINIMUM DC CONDUCTOR SIZE

TIP

#10 AWG works in almost all cases

WHY?
RESOURCES

NFPA 70®
National Electrical Code®
International Electrical Code® Series
2017

690.31 & 690.8

2015 ISEP™
INTERNATIONAL SOLAR ENERGY PROVISIONS™
Includes all I-Code solar energy provisions, plus SRCC 100, 300 and 600

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KEY POINTS - DC CONDUCTOR TYPE

A. EXPOSED ARRAY CONDUCTORS
- Type PV conductors required for exposed array with non-isolated inverters - NEC 690.35
- Type USE-2 used for isolated inverters (not common) NEC 690.31

B. CONDUCTORS IN RACEWAY LEAVING THE ROOF
- Must account for high operating temperatures in rooftop conduit
- All raceway and cable wiring methods included in the NEC are permitted as appropriate for the conditions per NEC 690.31(A)
- If the DC conductors enter the building/attic, a metal raceway of cable is required if no roof disconnect per NEC 690.31(G)
KEY POINTS - DC CONDUCTOR SIZE

DC conductors must be sized for the LARGER of:

125% x 125% of Max current (Isc) WITHOUT adjustment factors for wire fill and ambient temperature (690.8) OR 125% of Max current (Isc) WITH adjustment factors for wire fill and ambient temperature (690.8)
MAIN SERVICE PANEL

Graphic: IBTS
TASK Verify the inverter AC overcurrent protection is correctly sized in accordance with NEC 705.60
MURPHY’S LAW

What could possibly go wrong?
RATIONALE FOR CODE

Photo: Bill McGovern
WHAT DO YOU ALREADY KNOW ABOUT OVER CURRENT PROTECTION?
YOU ALREADY KNOW

- OCPD rating for a continuous load (like lighting in a commercial building)
- How to size AC conductors

NEW ABOUT PV

- Inverter output is a continuous load
- There is a minimum OCPD rating for inverter output
- Also a maximum for OCPD
The minimum rating of the PV inverter (AC) overcurrent device is 125% of the rated inverter continuous output in accordance with NEC 705.60
### Single Phase Inverters for North America


<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal AC Power Output</td>
<td>3000</td>
<td>3000</td>
<td>5000</td>
<td>6000</td>
<td>7500</td>
<td>9980 @ 208V</td>
<td>11400</td>
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<tr>
<td>Max. AC Power Output</td>
<td>3500</td>
<td>4150</td>
<td>5400 @ 208V</td>
<td>6000</td>
<td>8350</td>
<td>10800 @ 208V</td>
<td>12000</td>
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<td>AC Output Voltage Min.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
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<tr>
<td>Nom., Max.</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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<td>AC Output Voltage Min.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
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<td>-</td>
<td>-</td>
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<tr>
<td>Nom., Max.</td>
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<td>✓</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>183 - 208 - 229 Vac</td>
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<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
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</tr>
<tr>
<td>211 - 240 - 264 Vac</td>
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<td>✓</td>
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<tr>
<td>Max. Continuous Output</td>
<td>12.5</td>
<td>16</td>
<td>24 @ 208V</td>
<td>25</td>
<td>32</td>
<td>48 @ 208V</td>
<td>47.5</td>
</tr>
<tr>
<td>Current</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>72 @ 240V</td>
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</tr>
<tr>
<td>GFDI Threshold</td>
<td>3</td>
<td></td>
<td>22 @ 208V</td>
<td>25</td>
<td>32</td>
<td>48 @ 208V</td>
<td>47.5</td>
</tr>
<tr>
<td>Utility Monitoring,</td>
<td>1</td>
<td>2</td>
<td>24 @ 208V</td>
<td>25</td>
<td>32</td>
<td>48 @ 208V</td>
<td>47.5</td>
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<tr>
<td>Islanding Protection,</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td></td>
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<tr>
<td>Country Configurable</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**INPUT**

| Maximum DC Power (STC) | 4050       | 5100       | 6750       | 8100       | 10250      | 13500       | 15350       |
| Transformer Loss,      | Ungrounded | Yes        | Yes        | Yes        | Yes        | Yes         |             |
| Ground Fault Isolation | Yes        | Yes        | Yes        | Yes        | Yes        | Yes         |             |
| Ground-Fault Isolation | ✓          | ✓          | ✓          | ✓          | ✓          | ✓           |             |
| Detector               | ✓          | ✓          | ✓          | ✓          | ✓          | ✓           |             |
| AC Frequency Min.-Max. | 50 - 60    | 59.3 - 60  | 59.3 - 60  | 59.3 - 60  | 59.3 - 60  | 59.3 - 60   |             |
| Nom. DC Input Voltage  |            |            | 375 @ 208V | 350 @ 240V |            |            |             |
| Max. Input Current(1)  | 9.5        | 13         | 16.5 @ 208V| 16.5 @ 240V| 18         | 23          |             |
| Max. Input Voltage(2)  |            |            | 15.5 @ 240V|            |            |             |             |
| Reverse-Polarity       | Yes        | Yes        | Yes        | Yes        | Yes        | Yes         |             |
| Protection             |            |            |            |            |            |             |             |
| Ground-Fault Isolation |            |            |            |            |            |             |             |
| Detector               | 45         |            |            |            |            |             |             |
| CEC Weighted Efficiency| 97.7       | 98.2       | 97.5       | 98         | 97.5       | 97.5        |             |
| Nighttime Power         | < 2.5      | < 2.5      | < 2.5      | < 2.5      | < 2.5      | < 2.5       |             |
| Consumption            | 4          |            | 98         | 97.5       | 97.5       | 97.5        |             |
| W                      |            |            |            |            |            |             |             |

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TASK Verify the inverter AC output conductors is correctly sized in accordance with NEC 705.60
AC CONDUCTORS
WHAT DO YOU ALREADY KNOW ABOUT AC CONDUCTORS?
YOU ALREADY KNOW

- Requirements for AC circuit from the inverter to the service panel are essentially the same as for any other branch circuit
- PV system is a supply for the panelboard

NEW ABOUT PV

- Size of the inverter output conductors is required to be based on the rated output of the inverter
- Conductor sizing must be verified at PLAN review stage.
Inverter AC output conductors sized to carry not less than 125% of inverter continuous output current (NEC 705.60)
IS THE PLAN COMPLIANT?
AC conductors must be rated for 125% of the Inverter output
CHECK PERMITTED CIRCUIT BREAKER SIZE FOR WIRE GAUGE

For small conductors, there is a limit on circuit breaker. NEC 240.4(D)

<table>
<thead>
<tr>
<th>CONDUCTOR</th>
<th>CIRCUIT BREAKER SIZES</th>
</tr>
</thead>
<tbody>
<tr>
<td>#14 AWG</td>
<td>15 A</td>
</tr>
<tr>
<td>#12 AWG</td>
<td>20 A</td>
</tr>
<tr>
<td>#10 AWG</td>
<td>30 A</td>
</tr>
</tbody>
</table>
AC WIRING METHOD
IN THE FIELD

Photo: P. Jackson
IN THE FIELD - AC CONDUCTORS

Photo: P. Jackson
KEY POINTS – Inverter overcurrent protection

- Minimum (and maximum) OCPD rating is 125% of rated inverter AC current output (NEC 240.4 and 240.6)
- Larger OCPD can be used only if the inverter was tested/listed for a different max rating. See installation instructions.
**KEY POINTS - AC Conductors**

**TYPE**
- All NEC Chapter 3 conductor, cable, wiring method as appropriate for conditions

**SIZE**
- Inverter AC output conductors are sized to carry not less than 125% of inverter continuous current output (NEC 705.60)
- Conductor must be protected at its ampacity [NEC 240.4(D)]
MAIN SERVICE PANEL

Graphic: IBTS
TASK Based on the bus size of the panelboard, verify that the panelboard can handle the PV contribution according to NEC 705.12.
MURPHY’S LAW

What could possibly go wrong?
RATIONALE FOR CODE
WHAT DO YOU ALREADY KNOW ABOUT CONTRIBUTIONS TO THE PANELBOARD/MAIN SERVICE PANEL?
<table>
<thead>
<tr>
<th>YOU ALREADY KNOW</th>
<th>NEW ABOUT PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>▪ Conductors (bus) must be protected at their ampacity</td>
<td>▪ PV system creates a 2nd supply in the panel (2nd main breaker)</td>
</tr>
<tr>
<td>▪ Bus rating determines the main circuit breaker size</td>
<td>▪ Code allows you to supply more current than the panel is rated for</td>
</tr>
</tbody>
</table>
COMPLIANCE MEANS

Bus size (of the panelboard) is sufficient for the sum of the PV and the utility supplies per 705.12

The NEC allows for the sum of the main circuit breaker and 125% of inverter output to not exceed 120% of the bus rating IF THE PV BREAKER IS LOCATED AT THE OPPOSITE END OF THE BUS FROM THE SUPPLY.
Max inverter output = 42 A

42 A x 125% = 52.55 A

60 A + 200 A (MCB) = 260 A

260 A is less than 270 A (225 A x 120%)
COMPLIANT?

NOT COMPLIANT

Max inverter output = 42 A

42 A x 125% = 52.55 A

60 A + 200 A (MCB) = 260 A

260 A is MORE than 240 A (200 A x 120%)

EXAMPLE

EXISTING 200 A MAIN SERVICE PANEL (ITE) WITH 200A MAIN SERVICE DISCONNECT
IN THE FIELD

EXAMPLE

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OTHER WAYS TO BE COMPLIANT

If trying to work with existing panel and bus rating, but PV contribution is too large. The installer could:

- Install a new panelboard with larger bus rating
- Install a smaller main breaker (if load permits)
- Reduce the size of the PV system
- Connect at feeder or supply side of service
No limit for the PV contribution if the sum of the ratings of the PV and all load circuit breakers does not exceed the panel bus rating.

The main circuit breaker rating is not included in the calculation.

A specific warning sign is required for the panel if this method is used. See NEC 705.12(D)(2)(3)(c).
IDENTIFY WHEN SUPPLY SIDE CONNECTIONS ARE USED

CUTLER-HAMMER
Disconnect

SUPPLY SIDE CONNECTION TO BE FIELD LISTED.
RESOURCES

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PV contribution is a supply for the panel

120% rule applies when OCPD is located on opposite end from utility service
You are back in your office and someone has submitted this plan. In terms of the four tasks you have just learned, explain if the submitted plan is compliant in each area. If not, why not?

PRACTICE

Working in pairs or small groups. Using the PRACTICE plan C, decide if the following items are compliant:

- DC conductor size and type
- Circuit breaker for inverter is correctly sized
- AC conductor size, type, and wiring method
- Panelboard can handle the PV contribution

15 MINUTES
IS OUR PRACTICE PLAN COMPLIANT?

THERE SHALL BE ONE SOLAREdge F360 DC OPTIMIZER PER MODULE.

INVERTER

MPPT 1

125A MAIN BREAKER

METER

150A MAIN BREAKER

E (E) LOADS

E (E) LOADS

30A 2P

240V 3P 3-W 1E

1 STRING OF 4 MODULES

OPT. CURRENT = 8.7A

1 STRING OF 10 MODULES

OPT. CURRENT = 13.4A

(4) #10 PV-Wire

(1) #10 ESC FREE AIR

(4) #10 THAN-2

(1) #10 ESC 3/4 EMT

(2) #10 THAN-2

(1) #10 EMT

1/2 EMT

MIN. NEMA UL LISTED JUNCTION BOX WITH 250° TERMINAL RATING LOCATED ON ROOF

MINI-RADIAL-STYLE CABLES

10/3 AWG

12/3 AWG

15 A

15 A

27 MODULES TOTAL

27 x 231.3 (PTC WATTS) x 0.975 = 6889 CEC WATTS

SG600A-US MAX OUTPUT CURRENT = 25A

BREAKER SIZE = 25A x 1.25 = 31.25A ~ 35A

(4) 125A Bryant NCP

INFERNO VIEW

CONDUCT ELEVATION: 1/2 TO 3-1/2" = 22 °C
HIGH AMBIENT TEMPERATURE: 25 °C
EXTREME LOW: 11°C
MAX POWER PER STRING = 650W
MAX DC INPUT POWER = 300W
In = (10 x 260W)/350V = 13.1A

CONDUT FILL (CFTI) = 0.8
CONTINUOUS USE = In x 1.25 = 16.75A

CONDITIONS OF USE = In x 0.9 = 11.75A

CIRCUIT BREAKER SIZE = 10A/0.92 x 0.3 = 22.87A

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### IS OUR PRACTICE PLAN COMPLIANT?

#### Single Phase Inverters for North America


<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal AC Power Output</td>
<td>3000</td>
<td>3200</td>
<td>2500</td>
<td>7000</td>
<td>8500</td>
<td>11400</td>
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<tr>
<td>Max. AC Power Output</td>
<td>3300</td>
<td>4130</td>
<td>2500</td>
<td>8300</td>
<td>10930</td>
<td>12000</td>
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<tr>
<td>AC Output Voltage Min.-Nom.-Max.</td>
<td>118 - 208 - 229 Vac</td>
<td>-</td>
<td>240 @ 208V</td>
<td>240 @ 208V</td>
<td>240 @ 240V</td>
<td>240 @ 240V</td>
</tr>
<tr>
<td>AC Output Voltage Min.-Nom.-Max.</td>
<td>215 - 740 - 764 Vac</td>
<td>-</td>
<td>99.3 - 80 - 602 V</td>
<td>59 - 50 - 40</td>
<td>48 @ 208V</td>
<td>47.5 @ 240V</td>
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<tr>
<td>AC Frequency Min.-Nom.-Max.</td>
<td>47.5 Hz</td>
<td>47.5 Hz</td>
<td>47.5 Hz</td>
<td>47.5 Hz</td>
<td>47.5 Hz</td>
<td>47.5 Hz</td>
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<tr>
<td>Max. Combined Output Current</td>
<td>17.5 A</td>
<td>16 A</td>
<td>21 A</td>
<td>21 A</td>
<td>21 A</td>
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<tr>
<td>EMI threshold</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<td>INPUT</td>
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<td></td>
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<tr>
<td>Maximum DC Power [kW]</td>
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<td>3100</td>
<td>2750</td>
<td>10250</td>
<td>11350</td>
<td>15350</td>
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<td>Max. DC Input Current</td>
<td>1.5 A</td>
<td>13 A</td>
<td>14.5 A</td>
<td>18 A</td>
<td>23 A</td>
<td>38.5 A</td>
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<td>Maximum Inverter Efficiency</td>
<td>97.7 %</td>
<td>95.2 %</td>
<td>91.5 %</td>
<td>90.3 %</td>
<td>96 %</td>
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<td>97.0 %</td>
<td>97.3 %</td>
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<td>&lt; 5 W</td>
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<tr>
<td>Supports Communication interfaces</td>
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</tbody>
</table>

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CHECK PERMITTED CIRCUIT BREAKER SIZE FOR WIRE GAUGE

For small conductors, there is a limit on circuit breaker. NEC 240.4(D)

<table>
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<tr>
<th>CONDUCTOR</th>
<th>CIRCUIT BREAKER SIZES</th>
</tr>
</thead>
<tbody>
<tr>
<td>#14 AWG</td>
<td>15 A</td>
</tr>
<tr>
<td>#12 AWG</td>
<td>20 A</td>
</tr>
<tr>
<td>#10 AWG</td>
<td>30 A</td>
</tr>
</tbody>
</table>
10. Verify disconnecting means, types, & location
11. Identify what is used to achieve Rapid Shutdown
12. Verify presence & accuracy of marking & labeling
DISCONNECTS

Graphic: IBTS
TASK Verify required disconnecting means, types, and locations
MURPHY’S LAW

What could possibly go wrong?
RATIONALE FOR CODE
WHAT DO YOU ALREADY KNOW ABOUT DISCONNECTS?
<table>
<thead>
<tr>
<th>YOU ALREADY KNOW</th>
<th>NEW ABOUT PV</th>
</tr>
</thead>
<tbody>
<tr>
<td>System disconnects - Service main disconnect isolates the premise from utility</td>
<td>There are numerous components within the system that must be able to be isolated from each other for maintenance</td>
</tr>
<tr>
<td>Equipment disconnects for servicing equipment - example HVAC equipment</td>
<td></td>
</tr>
</tbody>
</table>

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Means shall be provided to disconnect all current-carrying DC conductors of a PV system from all other conductors in a building or other structure (required by NEC 690.13 - 690.17 and utility)
COMPLIANT? DISCONNECT LOCATION
COMPLIANT? EQUIPMENT DISCONNECTS

COLOR LEGEND
MOBILES ARE DRAWN IN BLUE
DC-CONDUCTORS ARE DRAWN IN BLACK
GNDING-CONDUCTORS ARE DRAWN IN GREY
LI-CONDUCTORS ARE DRAWN IN BLACK
NN-CONDUCTORS ARE DRAWN IN RED
NEUTRAL CONDUCTORS ARE DRAWN IN GREY

EQUIPMENT OUTSIDE
EQUIPMENT IN BASEMENT

FROM EXISTING
UTILITY SERVICE

PAGE A9
©2018 Interstate Renewable Energy Council
IN THE FIELD

- DC disconnects must be rated for DC use
- Permitted disconnects in NEC 690.17
KEY POINTS - DISCONNECTS

SYSTEM DISCONNECTS (690.13)
- Readily accessible location
- AC Disconnecting means, could be
  - In main service panelboard
  - In feeder panelboard
  - Exterior AC disconnect
- Utility may require a separate AC disconnect

EQUIPMENT DISCONNECTS (690.15)
- Isolate the array (i.e. DC disconnect)
- Isolate the inverter (DC disconnects and breakers in main service panelboard)
- If there is a combiner, must have load-breaking disconnecting means in the combiner (or within 6’ of combiner)
- Fuses require disconnecting means for servicing
- Anything on the DC side must be rated for 600 VDC
TASK Identify what is used to achieve Rapid Shutdown
MURPHY’S LAW

What could possibly go wrong?
WHAT DO YOU ALREADY KNOW ABOUT SHUTTING DOWN A PV SYSTEM?
**YOU ALREADY KNOW**

- PV modules produce DC electricity
- PV arrays are energized under light

**NEW ABOUT PV**

- There are multiple methods available to initiate a system shutdown
COMPLIANCE MEANS

The existence of rapid shutdown system (RSS) means that conductors more than 10’ from the array or more than 5’ upon entry into the building can be de-energized in accordance with NEC 690.12 [See TIA]
IS OUR PLAN COMPLIANT?
IN THE FIELD - MODULE LEVEL ELECTRONICS (DC-DC CONVERTERS) WITH APPROPRIATE INVERTER (SYSTEM)
IN THE FIELD – MICROINVERTERS (OR AC MODULES)
IN THE FIELD – DC and AC CONTACTORS

Photo: P. Jackson
IN THE FIELD - DESIGNED FOR RAPID SHUTDOWN
IN THE FIELD – INVERTERS LOCATED WITHIN 10’ OF ARRAY
RESOURCES

NFPA 70®
National Electrical Code®

2017

NEC 690.12
KEY POINTS – RAPID SHUTDOWN

- Rapid shutdown required for systems installed to NEC 2014 or later
- RS equipment or systems are not required to be listed to specific RS standard per 2014 NEC.
- A variety of ways to achieve RSS
  - Microinverters
  - Module-level electronics (DC-DC converters/power optimizers) with inverter
  - DC or AC contactor
  - Specifically designed RS equipment or system
  - Locate inverter within 10’ of array
TASK Verify presence & accuracy of marking & labeling
COMPLIANT?

Marking & Labeling

- Service main
- PV system disconnect
- PV system over-current device
- Inverter
- All ac/dc disconnects
- All enclosures and raceways
RESOURCES

690.17
690.31
690.53
690.56

11.12
605.11
KEY POINTS – MARKING AND LABELING

- Signs must be durable to withstand environment
- Outdoor signs should be metal or plastic engraved or machine printed letters
- Signs should be attached to the electrical system
- See NEC 110.21(B) for field-applied marking requirements
COMPLIANCE - BIG PICTURE

STRUCTURAL
- Verify quantity & spacing of roof attachments
- Verify weather sealing detail

FIRE SAFETY
- Verify access pathways and fire setbacks
- Verify module-rack fire classification

ELECTRICAL
- Verify module-rack grounding/bonding
- Verify AC & DC conductor size & type
- Verify location and rating of the PV system over-current protective device
- Verify all required disconnecting means, types, and locations
- Verify marking & labeling
- Identify what is being used for rapid shutdown
FIELD INSPECTION
Slides from Rudy
RESOURCES

California Solar Permitting Guidebook
Improving Permit Review and Approval for Small Solar Systems

2015 ISEP INTERNATIONAL SOLAR ENERGY PROVISIONS™
Includes all I-Code solar energy provisions, plus SRCC 100, 300 and 600

PHOTOVOLTAIC POWER SYSTEMS
For Inspectors, Plan Reviewers & Installers

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COURE EVALUATION - online

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THANK YOU

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