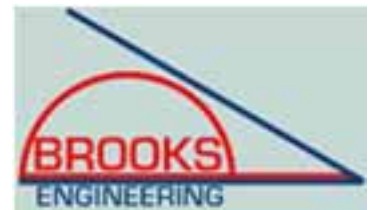


PV System Permitting and Inspection

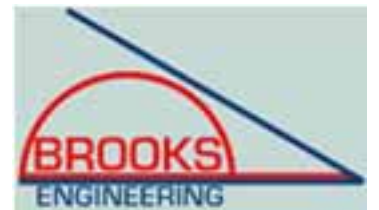
Presented by

Bill Brooks, PE

Brooks Engineering



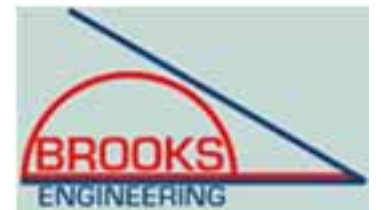
PV Codes and Standards 101



What are the applicable codes and standards for PV systems?

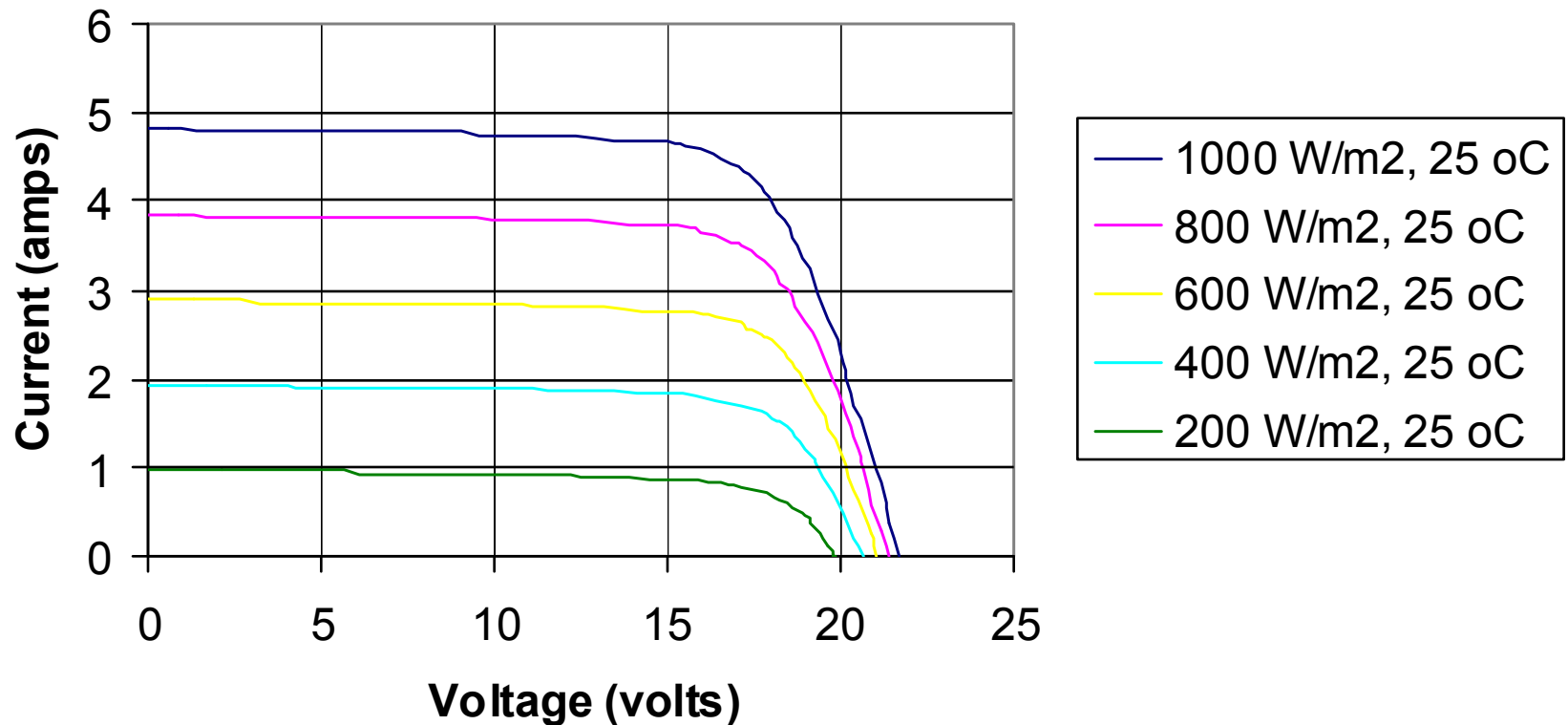
- Electrical codes - NEC Article 690 - Solar Photovoltaic Systems – NFPA 70
- Building Codes – ICC, ASCE 7
- 2009 Uniform Solar Energy Code—IAPMO
- UL Standard 1703, Flat-plate Photovoltaic Modules and Panels
- IEEE 1547, Standard for Interconnecting Distributed Resources with Electric Power Systems
- UL Standard 1741, Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

Photovoltaic System *Basics*



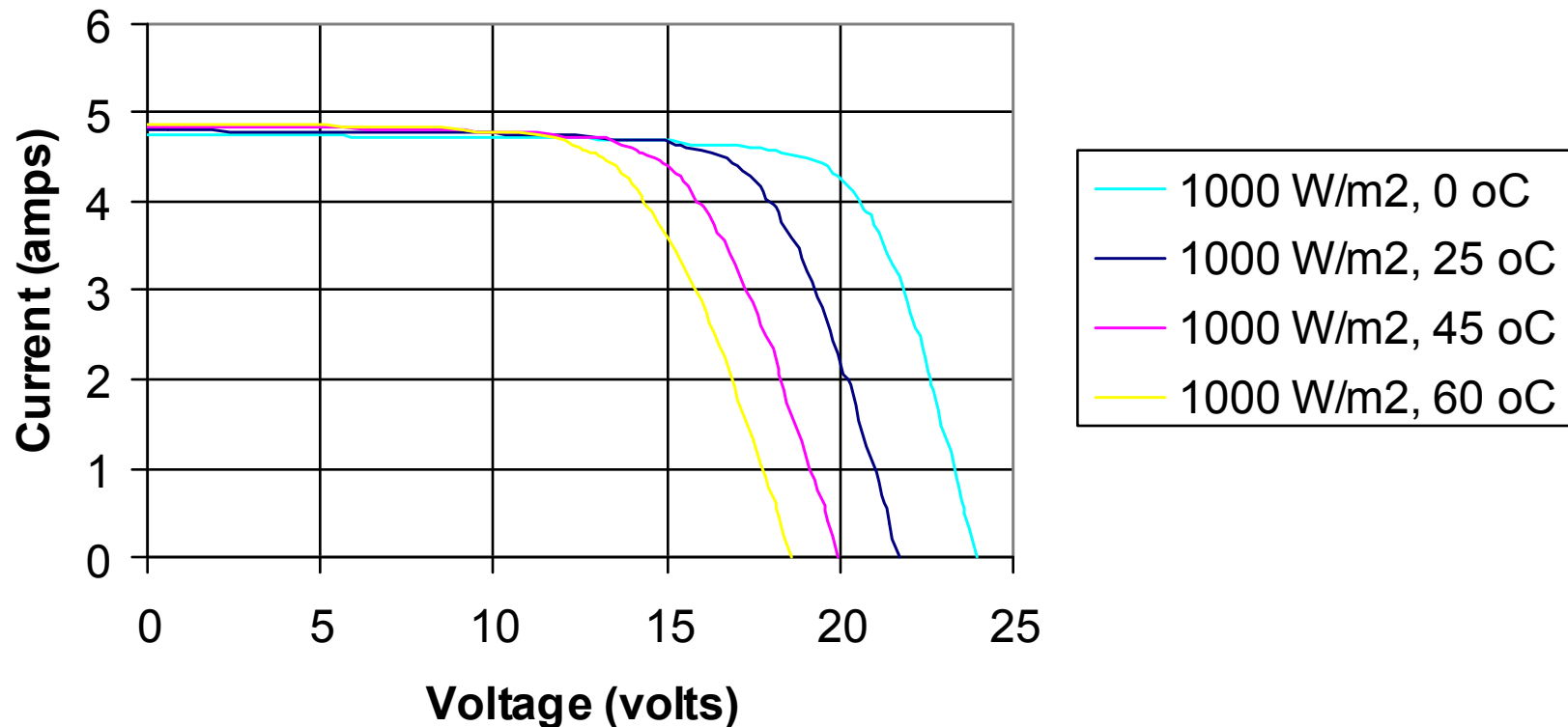
Current varies with irradiance

Siemens Solar Module SP75 Performance at Different Irradiances



Voltage varies with temperature

Siemens Solar Module SP75 Performance at Different Cell Temperatures



Differences Between PV and Conventional Electrical Systems

- PV systems have *dc circuits* that require special design and equipment.
- PV systems can have *multiple energy sources*, and special disconnects are required to isolate components.
- Energy flows in PV systems may be *bi-directional*.
- Utility-Interactive PV systems require an interface with the ac utility-grid and special considerations must be adopted. (utility must be involved-hence utility training)

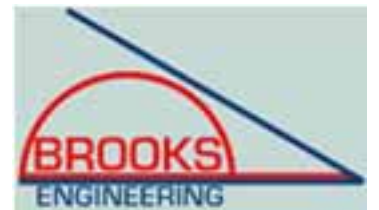
Ain't that purdy....



...and this is so much better...



NEC Article 690 overview



PV Systems and the NEC

- **Article 690** addresses safety standards for the installation of PV systems.
- Many other articles of the NEC may also apply to most PV installations.

NEC Sections Applicable to PV Systems

- Article 110: Requirements for Electrical Installations
- Chapter 2: Wiring and Protection
 - Most of the chapter--especially
 - Article 250: Grounding
- Chapter 3: Wiring Methods and Materials
 - Most of the chapter—especially
 - Article 300: Wiring Methods
 - Article 310: Conductors for General Wiring
- Article 480: Storage Batteries
- Article 690: Solar Photovoltaic Systems

NEC Article 690:

Solar Photovoltaic Systems

- I. General (definitions, installation)
- II. Circuit Requirements (sizing, protection)
- III. Disconnect Means (switches, breakers)
- IV. Wiring methods (connectors)
- V. Grounding (array, equipment)
- VI. Markings (ratings, polarity, identification)
- VII. Connection to Other Sources
- VIII. Storage batteries
- IX. Systems over 600 Volts

NEC Article 690:

Solar Photovoltaic Systems

- I. General (definitions, installation)
 - 690.1 Scope—PV Systems (only)
 - 690.2 Definitions—PV Output Circuit, Inverter Input Circuit—1 ½ pages of PV-specific jargon
 - 690.3—“Wherever the requirements of other articles of this Code and Article 690 differ, the requirements of Article 690 shall apply”
 - 690.4—Installation “Equipment: ...shall be identified and listed for the application”
 - 690.5—Ground-Fault Protection—to reduce fire hazards
 - 690.6—AC Module—dc wiring is considered internal

Electrical Equipment Listing

- AHJs generally require listing for components and electrical hardware.
- Some components available for PV systems may not have applicable or any listing.
- Recognized testing laboratories include:
 - UL
 - ETL Semko (Intertek)
 - CSA
 - TÜV

NEC Article 690:

Solar Photovoltaic Systems

- II. Circuit Requirements (sizing, protection)
 - 690.7 Maximum Voltage—Table 690.7 and manufacturers data. Max. 600Vdc for residential.
 - 690.8 Circuit Sizing and Current
 - 690.8(A) Max current = rated I_{sc} x 1.25 = I_{max}
 - 690.8(B) Min ampacity and overcurrent = I_{max} x 1.25
 - 690.9 Overcurrent Protection
 - 690.9(A) Generally required on all source circuits—exception: a.) no backfeed; and, b.) total I_{max} less than conductor ampacity.
 - 690.10 Stand-Alone Systems
 - Inverter output need only meet demand.
 - No multi-wire circuits on 120V inverters.

NEC Article 690:

Solar Photovoltaic Systems

- III. Disconnect Means (switches, breakers)
 - 690.13—Need to disconnect all conductors connected to building. No disconnect in grounded conductor
 - 690.14—Location—details and options (more to come)
 - 690.17—Switch or Circuit Breaker—Warning sign when line and load energized in open position.

NEC Article 690: Solar Photovoltaic Systems

- IV. Wiring methods
 - 690.31(A) FPN—PV modules get HOT
 - 690.31—single conductors outside conduit allowed in array.
 - Table 690.31—temp. correction must be applied to conductors.
 - 690.33—requirements for connectors.
 - 690.35—Ungrounded PV Power Systems

NEC Article 690:

Solar Photovoltaic Systems

- V. Grounding (system, equipment)
 - 690.41 System Grounding
 - Over 50Vdc must be grounded or comply with 690.35
 - 690.42 Point of System Grounding Connection—one point, at GFP device if provided.
 - 690.43 Equipment Grounding—metal likely to become energized must be grounded—listed equipment can be used to bond modules to support structure..
 - 690.45 Size of EGC—Table 250.122 with GFP
 - 690.47 Size of GEC—ac use Table 250.66; dc use Table 250.166

Electrical System Grounding

- The NEC defines grounding as a connection to the *earth* with sufficiently low impedance and having sufficient current-carrying capacity to prevent the buildup of voltages.
- Grounding of electrical systems offers personnel safety and minimizes the effects of lightning and surges on equipment.

Electrical Grounding Types

(Huge Confusion Over These Terms)

- System Ground (grounding): Connecting the circuit to ground (i.e. the negative of a dc array, the neutral of a split single-phase system, or the neutral of a bi-polar dc system)
- Equipment Ground (bonding): Connecting all non-current carrying metal parts to ground (metal enclosure, module frame, etc...)

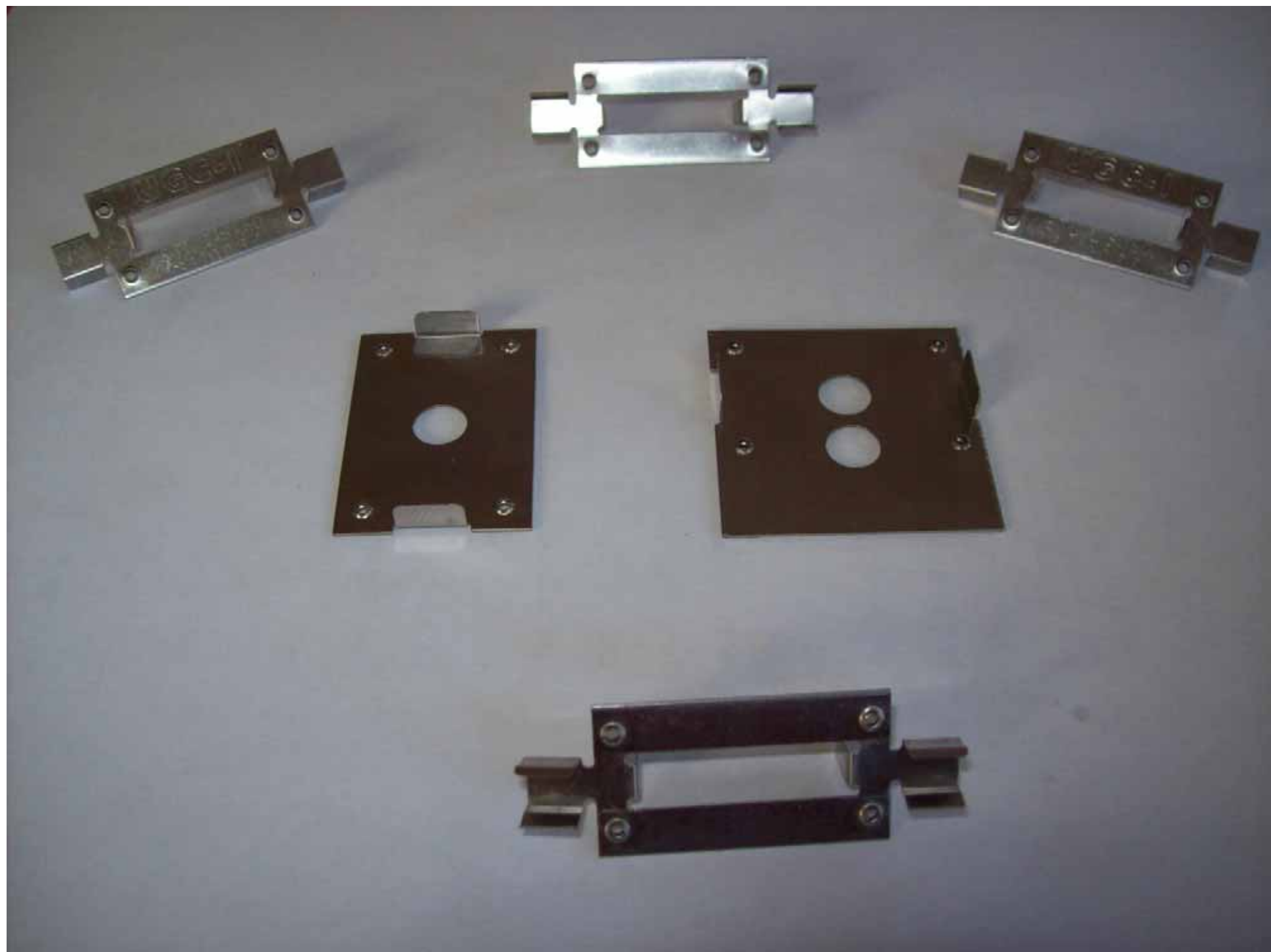
Nice Lugs! (poor fasteners)



690.43 Equipment Grounding

[2008 NEC]

- “Devices listed and identified for grounding the metallic frames of PV modules shall be permitted to bond the exposed metallic frames of PV modules to grounded mounting structures. Devices identified and listed for bonding the metallic frames of PV modules shall be permitted to bond the exposed metallic frames of PV modules to the metallic frames of adjacent PV modules.”





NEC Article 690:

Solar Photovoltaic Systems

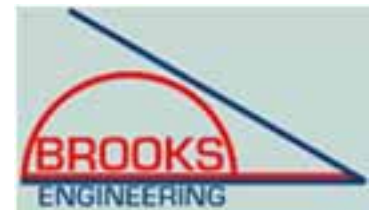
- VI. Markings (ratings, polarity, identification)
 - 690.53—DC PV Power Source—4 items; rated current, rated voltage, max voltage, max current
 - 690.54—Interactive System Point of Interconnection—rated ac current and voltage
 - 690.56—Sign at service entrance when PV disconnect not located at the service disconnect.

NEC Article 690:

Solar Photovoltaic Systems

- VII. Connection to Other Sources
 - 690.60 Listed inverters for grid-connected systems
 - 690.61 inverter deenergize when utility is out (part of listing process)
 - 690.64 Point of Connection
 - 690.64(A) Supply Side—230.82
 - 690.64(B) Load Side—dedicated breaker; 120% of busbar or conductor; 2008 NEC requires sign and breaker location to obtain 120% allowance for all PV systems.
- VIII. Storage Batteries
- IX. Systems over 600 Volts

Summary of Key PV-Related Changes for the 2005 and 2008 National Electrical Code



II. Circuit Requirements [2008 NEC]

690.7 Maximum Voltage.

- New table and calculation option.
- Table 690.7 is now graduated in 4°C increments.
- “When open-circuit voltage temperature coefficients are supplied in the instructions for listed PV modules, they shall be used to calculate the maximum photovoltaic system voltage as required by 110.3(B) instead of using Table 690.7.”

II. Circuit Requirements [2008 NEC]

690.7 Maximum Voltage.

- Example Calculation
- Shell SQ-175PC has a Voc Temperature Coefficient in their literature of:
 - $\alpha V_{oc} = -129 \text{ mV}/^{\circ}\text{C}$; $V_{oc} = 44.6\text{V}$
 - Coldest expected Temp= -25°C ; Rating @ 25°C (STC)
- $V_{max} \text{ (per module)} = 44.6\text{V} + [-129 \text{ mV}/^{\circ}\text{C} \times (1\text{V}/1000\text{mV}) \times (-25^{\circ}\text{C}-25^{\circ}\text{C})] = 51.05 \text{ Volts.}$
- Table 690.7 [2008]: $V_{max} = 44.6\text{V} \times 1.20 = 53.52\text{V}$
- Table 690.7 [2005]: $V_{max} = 44.6\text{V} \times 1.25 = 55.75\text{V}$

III. Disconnecting Means [2005 NEC]

Article 690.14 (Additional Provisions)

- Clarification on location of PV Disconnecting Means and Location of Inverters in Not-Readily-Accessible Locations
- New Section (D) Utility-Interactive Inverters Mounted in Not-Readily Accessible Locations. Utility-interactive inverters shall be permitted to be mounted on roofs or other exterior areas that are not readily accessible. These installations shall comply with (1) through (4):
 - (1) A direct-current photovoltaic disconnecting means shall be mounted within sight of or in the inverter.
 - (2) An alternating-current disconnecting means shall be mounted within sight of or in the inverter.
 - (3) The alternating-current output conductors from the inverter and an additional alternating-current disconnecting means for the inverter shall comply with 690.14(C)(1).
 - (4) A plaque shall be installed in accordance with 705.10.

Article 690.31 [2005 NEC]

Wiring Methods Permitted

- New 690.31(E) related to PV Output Circuits in metallic raceways.
- **“(E) Direct-Current Photovoltaic Source and Output Circuits Inside a Building.** Where direct current photovoltaic source or output circuits of a utility-interactive inverter from a building-integrated or other photovoltaic system are run inside a building or structure, they shall be contained in metallic raceways or **metal** enclosures from the point of penetration of the surface of the building or structure to the first readily accessible disconnecting means. The disconnecting means shall comply with 690.14(A) through 690.14(D).”

Article 690.31 [2008 NEC]

Wiring Methods Permitted

- New language in 690.31(B)
- “**(B) Single-Conductor Cable.** Single-conductor cable type USE-2, and single-conductor cable listed and labeled as photovoltaic (PV) wire shall be permitted in exposed outdoor locations in photovoltaic source circuits for photovoltaic module interconnections within the photovoltaic array. *Exception: Raceways shall be used when required by 690.31(A).*”

Side Note on Temperature

310.15(B)(2)[2008 NEC]

- Table 310.15(B)(2)(c) Ambient Temperature Adjustment for Conduits Exposed to Sunlight On or Above Rooftops Temperature Adder

Distance Above Roof to Bottom of Conduit	°C °F
0 - 13 mm (1/2 in.)	33 60
Above 13 mm (1/2 in.) - 90 mm (3 1/2 in.)	22 40
Above 90 mm (3 1/2 in.) - 300 mm (12 in.)	17 30
Above 300 mm (12 in.) - 900 mm (36 in.)	14 25

Article 690.33 [2008 NEC]

Connectors

- New language in 690.33(F)
- **“(E) Interruption of Circuit.** Connectors shall be either (1) or (2):
- (1) Be rated for interrupting current without hazard to the operator.
- (2) Be a type that requires the use of a tool to open and marked “Do Not Disconnect Under Load” or “Not for Current Interrupting.” ”

Article 690.35 Ungrounded Photovoltaic Power Systems

- Ungrounded systems have not been prohibited, but the 2005 NEC was the first code cycle where the requirements are specifically called out.
- Included is an exception in 690.41 for consistency.

Article 690.35 Ungrounded Photovoltaic Power Systems [2005, 2008]

- “Photovoltaic power systems shall be permitted to operate with ungrounded photovoltaic source and output circuits where the system complies with 690.35(A) through 690.35(G).
 - **(A) Disconnects.** All photovoltaic source and output circuit conductors shall have disconnects complying with 690, Part III.
 - **(B) Overcurrent Protection.** All photovoltaic source and output circuit conductors shall have overcurrent protection complying with 690.9.
 - **(C) Ground-Fault Protection.** All photovoltaic source and output circuits shall be provided with a ground-fault protection device or system that complies with (1) through (3):
 - (1) Detects a ground fault.
 - (2) Indicates that a ground fault has occurred
 - (3) Automatically disconnects **all conductors or causes** the inverter or charge controller **connected to the faulted circuit to automatically cease supplying power to output circuits.**

Article 690.35 Ungrounded Photovoltaic Power Systems (cont.)

- (D) The photovoltaic source and output conductors shall consist of the following:
 - (1) Nonmetallic jacketed multiconductor cables
 - (2) Conductors installed in raceways, or
 - (3) Conductors listed and identified as Photovoltaic (PV) Wire installed as exposed, single conductors.
- (E) The photovoltaic power system direct-current circuits shall be permitted to be used with ungrounded battery systems complying with 690.71(G).
- (F) The photovoltaic power source shall be labeled with the following warning at each junction box, combiner box, disconnect, and device where the ungrounded circuits may be exposed during service:

WARNING
ELECTRIC SHOCK HAZARD
THE DC CIRCUIT CONDUCTORS OF THIS
PHOTOVOLTAIC POWER SYSTEM ARE
UNGROUND AND MAY BE ENERGIZED
WITH RESPECT TO GROUND DUE TO
LEAKAGE PATHS AND/OR GROUND FAULTS.

- (G) The inverters or charge controllers used in systems with ungrounded photovoltaic source and output circuits shall be listed for the purpose.

690.45 Size of Equipment Grounding Conductors [2008 NEC]

- “(A) General. Equipment grounding conductors in photovoltaic source and photovoltaic output circuits shall be sized in accordance with Table 250.122. Where no overcurrent protective device is used in the circuit, an assumed overcurrent device rated at the photovoltaic rated shortcircuit current shall be used in Table 250.122. Increases in equipment grounding conductor size to address voltage drop considerations shall not be required. The equipment grounding conductors shall be no smaller than 14 AWG.”

690.47(C) Systems with Alternating-Current and Direct-Current Grounding Requirements [2005 NEC]

- “Photovoltaic power systems with both alternating-current and direct-current (dc) grounding requirements shall be permitted to be grounded as described in (1) or (2):
 - (1) A grounding-electrode conductor shall be connected between the identified dc grounding point to a separate dc grounding electrode. The dc grounding-electrode conductor shall be sized according to 250.166. The dc grounding electrode shall be bonded to the ac grounding electrode to make a grounding electrode system according to 250.52 and 250.53. The bonding conductor shall be no smaller than the largest grounding electrode conductor, either ac or dc.
 - (2) The dc grounding electrode conductor and ac grounding electrode conductor shall be connected to a single grounding electrode. The separate grounding electrode conductors shall be sized as required by 250.66 (ac) and 250.166 (dc).”

690.47(C) Systems with Alternating-Current and Direct-Current Grounding Requirements [2008 NEC]

- 2008 NEC has 8 qualifying provisions to “assist” in specifying the grounding requirements.
- Attempt is to combine the ac equipment grounding conductor on the output of the inverter with the grounding electrode conductor for utility-interactive inverters with GFP.
- The requirements are difficult to follow and do not encourage straightforward enforcement of provisions.
- The 2011 NEC provides and understanding of the intent of 2008 NEC.

690.47(D) Additional Electrodes for Array Grounding [2008 NEC]

- “Grounding electrodes shall be installed in accordance with 250.52 at the location of all ground- and pole-mounted photovoltaic arrays and as close as practicable to the location of roof-mounted photovoltaic arrays. The electrodes shall be connected directly to the array frame(s) or structure.”
 - GEC from array frames to electrode sized to 250.166
 - No substitute for equipment grounding conductor
 - Ground-mount structure meeting 250.52 complies
 - Roof-mounted may use building steel meeting 250.52(A)(2)
- Exception 1—Arrays with integral loads (area lights)
- Exception 2—If closer than 6’ from existing electrode

690.53 Marking: DC PV Power Source[2008 NEC]

- (1) Rated maximum power-point current
 - $I_{mp} \times$ number of series strings
- (2) Rated maximum power-point voltage
 - $V_{mp} \times$ number of modules in series
- (3) Maximum system voltage
 - FPN to (3): See 690.7(A) for maximum photovoltaic system voltage.
- (4) Short-circuit current
 - FPN to (4): See 690.8(A) for calculation of maximum circuit current.
- (5) Maximum rated output current of the charge controller (if installed)

2008 NEC Complete Rewrites

Article 690.64 Point of Connection (B) Load Side

- “Where distribution equipment, including switchboards and panelboards, is fed simultaneously by a primary source(s) of electricity and one or more utility-interactive inverters, and where this distribution equipment is capable of supplying multiple branch circuits or feeders, or both, the interconnecting provisions for the utility-interactive inverter(s) shall comply with (B)(1) through (B)(7).”

Article 690.64(B) (cont.)

- **“(1) Dedicated Overcurrent and Disconnect.** Each source interconnection shall be made at a dedicated circuit breaker or fusible disconnecting means.
- **(2) Bus or Conductor Rating.** The sum of the ampere ratings of overcurrent devices in circuits supplying power to a busbar or conductor shall not exceed 120 percent of the rating of the busbar or conductor. In systems with panelboards connected in series, the rating of the first overcurrent device directly connected to the output of a utility-interactive inverter(s) shall be used in the calculations for all busbars and conductors.”

Article 690.64(B) (cont.)

- **“(3) Ground-Fault Protection.** The interconnection point shall be on the line side of all ground-fault protection equipment.
Exception: Connection shall be permitted to be made to the load side of ground-fault protection, provided that there is ground-fault protection for equipment from all ground-fault current sources. Ground-fault protection devices used with supplies connected to the load-side terminals shall be identified and listed as suitable for backfeeding.
- **(4) Marking.** Equipment containing overcurrent devices in circuits supplying power to a busbar or conductor supplied from multiple sources shall be marked to indicate the presence of all sources.”

Article 690.64(B) (cont.)

- **(5) Suitable for Backfeed.** Circuit breakers, if backfed, shall be suitable for such operation.

FPN: Circuit breakers that are marked “Line” and “Load” have been evaluated only in the direction marked. Circuit breakers without “Line” and “Load” have been evaluated in both directions.

- **(6) Fastening.** Listed plug-in-type circuit breakers backfed from utility-interactive inverters complying with 690.60 shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications.”

Article 690.64(B) (cont.)

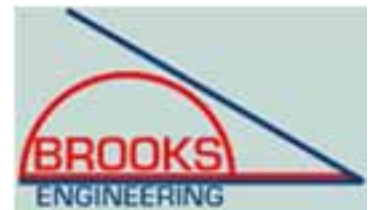
- **“(7) Inverter Output Connection.** Unless the panelboard is rated not less than the sum of the ampere ratings of all overcurrent devices supplying it, a connection in a panelboard shall be positioned at the opposite (load) end from the input feeder location or main circuit location. The bus or conductor rating shall be sized for the loads connected in accordance with Article 220. A permanent warning label shall be applied to the distribution equipment with the following or equivalent marking:

WARNING

**INVERTER OUTPUT CONNECTION, DO NOT
RELOCATE, THIS OVERCURRENT DEVICE”**

Expedited Permit Process for PV Systems

available at
[www. Solarabcs.org/permitting](http://www.Solarabcs.org/permitting)



Why do we need Permit Guidelines?

- Variations in compliance requirements—some are insufficient to protect the public, others may not be consistent with established standards.
- Need a predictable process with uniform enforcement of code requirements for jurisdictional authorities and installing contractors.

Required Information for Permit

- Site plan showing location of major components on the property. This drawing need not be exactly to scale, but it should represent relative location of components at site (see supplied example site plan). PV arrays on dwellings with a 3' perimeter space at ridge and sides do not need fire service approval.
- Electrical diagram showing PV array configuration, wiring system, overcurrent protection, inverter, disconnects, required signs, and ac connection to building (see supplied standard electrical diagram).
- Specification sheets and installation manuals (if available) for all manufactured components including, but not limited to, PV modules, inverter(s), combiner box, disconnects, and mounting system.

Step 1: Structural Review of PV Array Mounting System

- Is the array to be mounted on a defined, permitted roof structure? Yes/No
(structure meets modern codes)
- *If No due to non-compliant roof or ground mount, submit completed worksheet for roof structure WKS1.*

Roof Information:

- Is the roofing type lightweight (Yes = composition, lightweight masonry, metal, etc...)_____
- *If No, submit completed worksheet for roof structure WKS1 (No = heavy masonry, slate, etc...).*
- Does the roof have a single roof covering? Yes/No
- *If No, submit completed worksheet for roof structure WKS1.*
- Provide method and type of weatherproofing roof penetrations (e.g. flashing, caulk)._____

Mounting System Information:

- The mounting structure is an engineered product designed to mount PV modules?
Yes/No
 - *If No, provide details of structural attachment certified by a design professional.*
- For manufactured mounting systems, fill out information on the mounting system below:

Mounting System Information:

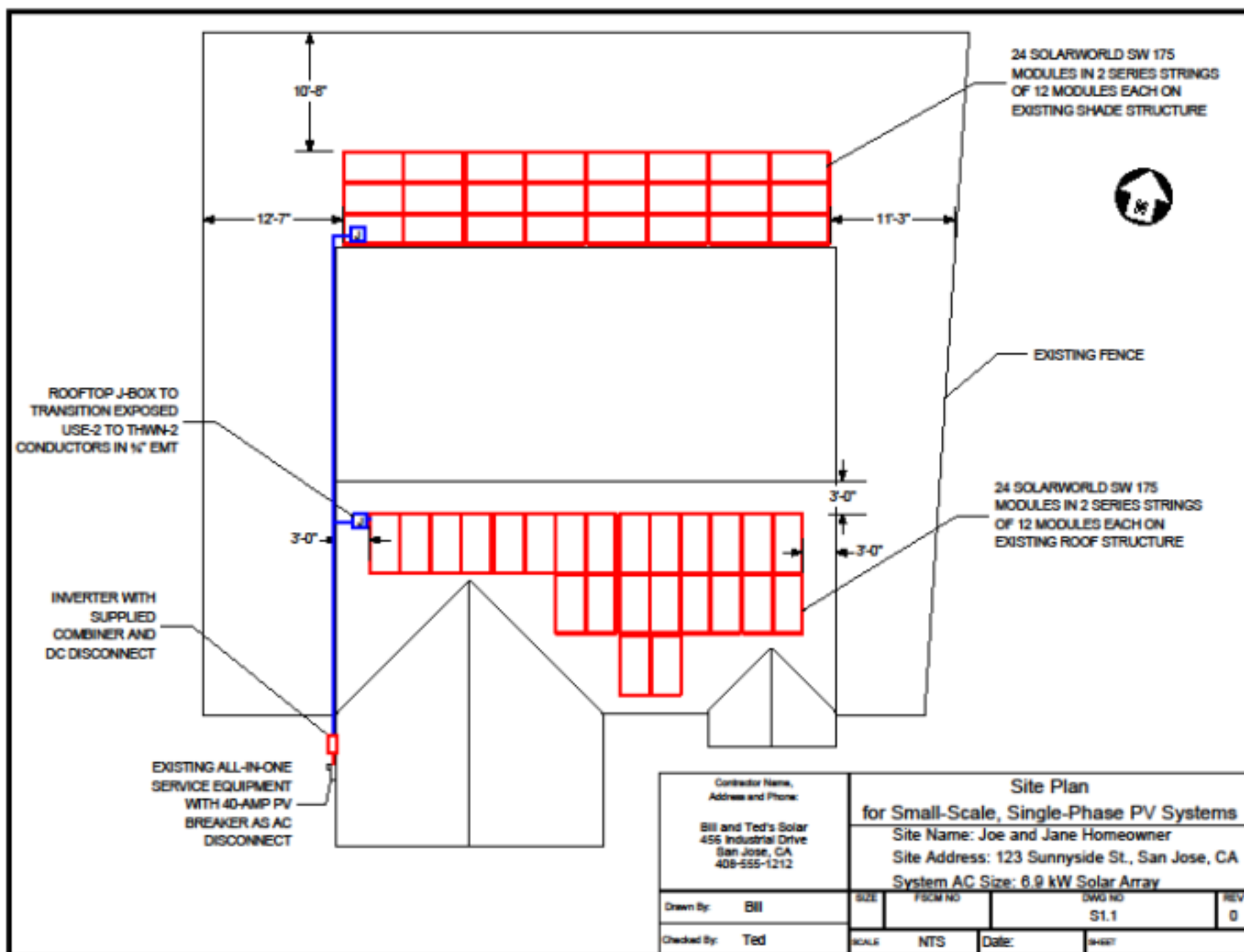
- a) Mounting System Manufacturer _____ Product Name and Model# _____
- b) Total Weight of PV Modules and Rails _____ lbs
- c) Total Number of Attachment Points _____
- d) Weight per Attachment Point ($b \div c$) _____ lbs (if greater than 45 lbs, see WKS1)
- e) Maximum Spacing Between Attachment Points on a Rail _____ inches (see product manual for maximum spacing allowed based on maximum design wind speed)
- f) Total Surface Area of PV Modules (square feet) _____ ft²
- g) Distributed Weight of PV Module on Roof ($b \div f$) _____ lbs/ft²
 - *If distributed weight of the PV system is greater than 5 lbs/ft², see WKS1.*

Step 2: Electrical Review of PV System (Calculations for Electrical Diagram)

- In order for a PV system to be considered for an expedited permit process, the following must apply:
 1. PV modules, utility-interactive inverters, and combiner boxes are identified for use in PV systems.
 2. The PV array is composed of 4 series strings or less
 3. The Inverter has a continuous power output 13,440 Watts or less
 4. The ac interconnection point is on the load side of service disconnecting means (690.64(B)).
 5. The electrical diagram (E1.1) can be used to accurately represent the PV system.

Site Diagram

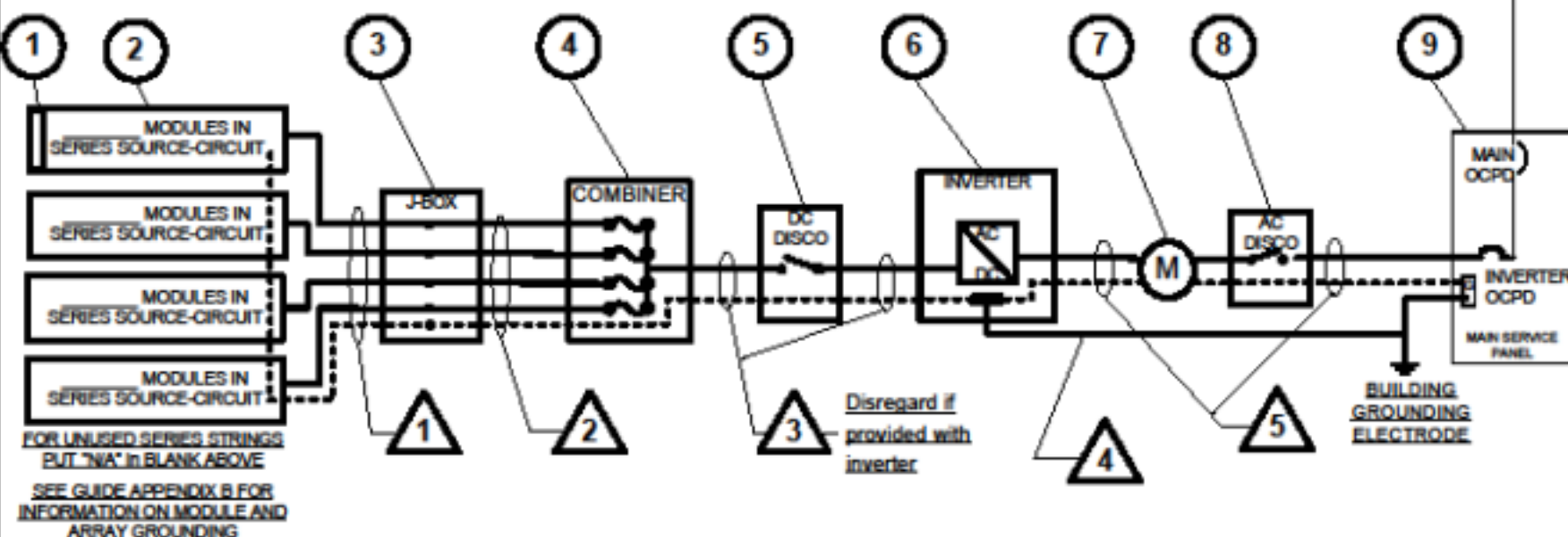
- Drawing does not need to be to scale, but it should basically show where the major components are located.
- If array is ground mounted, it should show that it conforms with allowable setbacks.



One-line Diagram

- Should have sufficient detail to call out the electrical components, the wire types and sizes, number of conductors, and conduit type and size where needed.
- Should include information about PV modules and inverter(s).
- Should include information about utility disconnecting means (required by many utilities).

EQUIPMENT SCHEDULE			
TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE		
2	PV ARRAY		
3	J-BOX (IF USED)		
4	COMBINER (IF USED)		
5	DC DISCONNECT		
6	DC/AC INVERTER		
7	GEN METER (IF USED)		
8	AC DISCONNECT (IF USED)		
9	SERVICE PANEL		VAC, A MAIN, A BUS, A INVERTER OCPD
(SEE NOTE 5 FOR INVERTER OCPDs, ALSO SEE GUIDE SECTION 9)			



CONDUIT AND CONDUCTOR SCHEDULE					
TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 <input type="checkbox"/> or PV WIRE <input type="checkbox"/>			N/A	N/A
	BARE COPPER EQ. GRD. COND. (EGC)			N/A	N/A
2	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>				
3	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>				
	INSULATED EGC				
4	DC GROUNDING ELECTRODE COND.				
5	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>				
	INSULATED EGC				

Contractor Name, Address and Phone: _____ _____ _____		One-Line Standard Electrical Diagram for Small-Scale, Single-Phase PV Systems			
		Site Name: _____ Site Address: _____ System AC Size: _____			
Drawn By: _____	SIZE	FSM NO	DWG NO	REV	
Checked By: _____	SCALE	NTS	Date: _____	E1.1	
				B-4827	

PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	
MODULE MODEL	
MAX POWER-POINT CURRENT (I_{mp})	A
MAX POWER-POINT VOLTAGE (V_{mp})	V
OPEN-CIRCUIT VOLTAGE (V_{oc})	V
SHORT-CIRCUIT CURRENT (I_{sc})	A
MAX SERIES FUSE (OCPD)	A
MAXIMUM POWER (P_{max})	W
MAX VOLTAGE (TYP 600V _{DC})	V
VOC TEMP COEFF (mV/°C <input type="checkbox"/> or %/°C <input type="checkbox"/>)	
IF COEFF SUPPLIED, CIRCLE UNITS	

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE
NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS (NEC XXX.XX)

INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	
INVERTER MODEL	
MAX DC VOLT RATING	V
MAX POWER @ 40°C	W
NOMINAL AC VOLTAGE	V
MAX AC CURRENT	A
MAX OCPD RATING	A

SIGNS—SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

PHOTOVOLTAIC POWER SOURCE	
RATED MPP CURRENT	A
RATED MPP VOLTAGE	V
MAX SYSTEM VOLTAGE	V
MAX CIRCUIT CURRENT	A
WARNING: ELECTRICAL SHOCK HAZARD—LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION	

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM AC POINT OF CONNECTION	
AC OUTPUT CURRENT	A
NOMINAL AC VOLTAGE	V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix D):

- 1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP _____ °C
- 2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE _____ °C
- 2.) 2005 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES).
 - a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I_{sc} OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
 - b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I_{sc} OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☐
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF _____ INVERTER OCPD(S). ONE FOR EACH INVERTER. DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES ☐ NO ☐

Contractor Name, Address and Phone: _____ _____ _____		Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems			
		Site Name: _____ Site Address: _____ System AC Size: _____			
Drawn By: _____	SIZE	FROM NO	TO NO	REV	
			E1.2		
Checked By: _____	SCALE	NTS	Date: _____	SHEET	

Major Component and Array Electrical Information

- Inverter information
- Module information
- Combiner Box
- Disconnects

Inverter information

- Model number and manufacturer's "cut sheets" for the specific model.
- Listing—is the inverter listed to UL1741 and labeled "Utility-Interactive"? For a current list of compliant inverters, visit the California Solar Program website. www.gosolarcalifornia.com
- Maximum continuous output power at 40°C



Module information

- Manufacturer's "cut sheets" for the specific model.
- Listing. The module should be listed to UL 1703. For a current list of modules that are listed to UL 1703, visit the California website.

www.gosolarcalifornia.com

- Listing label information

Typical PV Module Label

PHOTOVOLTAIC MODULE			
MODEL	KC120-1		
SER NO.	01632A1055		
DATE	2001.6		
IRRADIANCE AND CELL TEMPERATURE	1000Wm ⁻² AM 1.5 25 °C	800Wm ⁻² AM 1.5 47 °C	MAX. SYS VOLT. 600 V
	P _{max}	120 W 87 W	SERIES FUSE 11 A
	V _{pmax}	16.9 V 15.2 V	
	I _{pmax}	7.10 A 5.74 A	MASS 11.9 kg
	V _{oc}	21.5 V - - -	
I _{sc}	7.45 A - - -		
 C UL US LISTED BP82	FIELD WIRING		FIRE RATING
	STRANDED COPPER ONLY 10 ~14 AWG INSULATED FOR 90°C		CLASS C

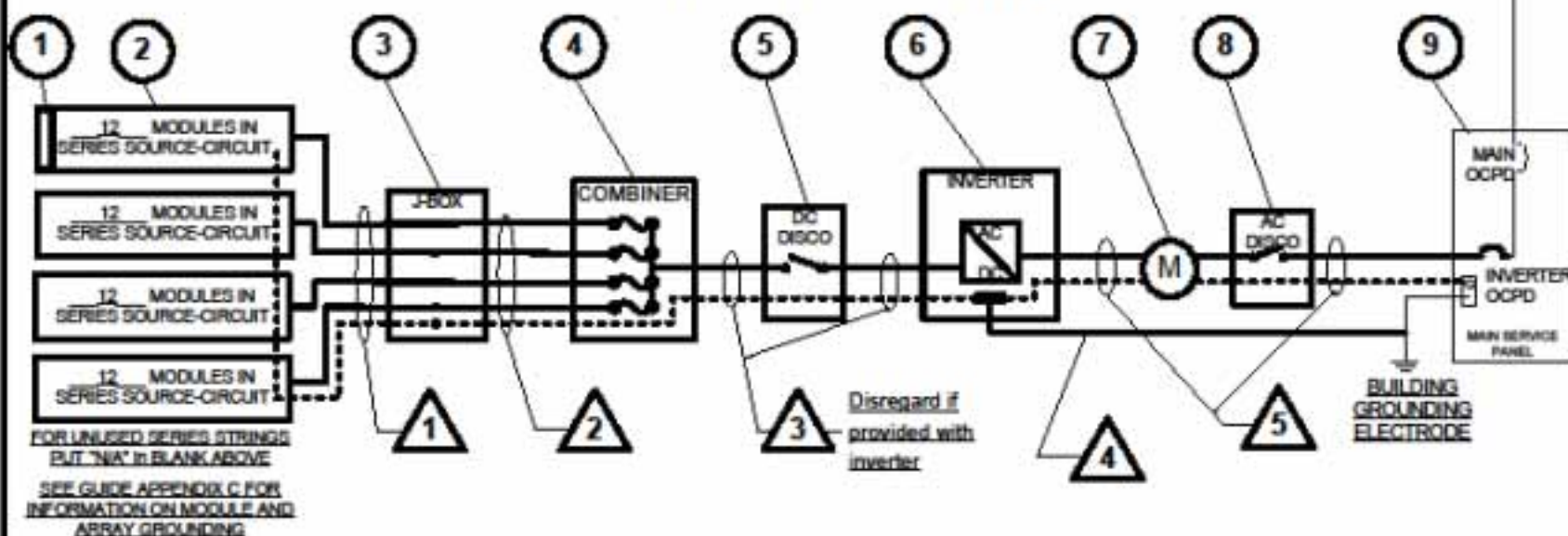
Array electrical information

- Number of modules in series
- Array operating voltage
- Array operating current
- Maximum system voltage
- Array short circuit current



EQUIPMENT SCHEDULE

TAG	DESCRIPTION	PART NUMBER	NOTES
1	SOLAR PV MODULE	AS 175	AMERICAN SOLAR, QUANTITY - 48 (SEE NOTES SHEET FOR DETAILS)
2	PV ARRAY	N/A	ARRAY IS 4 STRINGS WITH 12 MODULES PER SERIES STRING
3	J-BOX (IF USED)		6"x6"x4" NEMA 4, PVC JUNCTION BOX
4	COMBINER (IF USED)	MFR-supplied	15-A MAX FUSE W/15-A FUSES, 600VDC, 4-STRING MAX
5	DC DISCONNECT	MFR-supplied	LISTED WITH INVERTER, 600VDC, 60-AMP (SEE GUIDE APPENDIX C)
6	DC/AC INVERTER	AI-7000	7000 WATT, SINGLE PHASE (SEE NOTES SHEET FOR DETAILS)
7	GEN METER (IF USED)	FORM 29	4-JAW, 240V CYCLOMETER REGISTER KWH METER IN 100-A BASE
8	AC DISCONNECT (IF USED)	D222NRB	240VAC, 60-AMP FUSED W/ 40-A FUSES (SEE GUIDE APPENDIX C)
9	SERVICE PANEL	SD200SL	240VAC, 200-A MAIN, 200-A BUS, 40-A INVERTER OCPD (SEE NOTE 5 FOR INVERTER OCPDs, ALSO SEE GUIDE SECTION 9)



CONDUIT AND CONDUCTOR SCHEDULE

TAG	DESCRIPTION OR CONDUCTOR TYPE	COND. GAUGE	NUMBER OF CONDUCTORS	CONDUIT TYPE	CONDUIT SIZE
1	USE-2 <input type="checkbox"/> or PV WIRE <input type="checkbox"/>	10 AWG	8 BLACK	N/A	N/A
	BARE COPPER EQ. GRD. COND. (EGC)	10 AWG	1 BARE CU	N/A	N/A
2	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	10 AWG	4-R, 4-W, 1-G	EMT	1/2"
3	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	N/A	N/A	N/A	N/A
	INSULATED EGC	N/A	N/A		
4	DC GROUNDING ELECTRODE COND.	6 AWG	1 BARE CU	N/A	N/A
5	THWN-2 <input type="checkbox"/> or XHHW-2 <input type="checkbox"/> or RHW-2 <input type="checkbox"/>	8 AWG	1-R, 1-B, 1-W	EMT	1/2"
	INSULATED EGC	10 AWG	1 GREEN		

Contractor Name,
Address and Phone

Bill and Ted's Solar
456 Industrial Drive
San Jose, CA
408-555-1212

Drawn By: Bill

Checked By: Ted

One-Line Standard Electrical Diagram
for Small-Scale, Single-Phase PV Systems
Site Name: Joe and Jane Homeowner
Site Address: 123 Sunnyside St., San Jose, CA
System AC Size: 6.9 kW Solar Array

SIZE	FORM NO.	DWG NO.	REV
		E1.1	0
SCALE	NTS	Date	1/1/2017

PV MODULE RATINGS @ STC (Guide Section 5)

MODULE MAKE	AMERICAN SOLAR
MODULE MODEL	AS 175
MAX POWER-POINT CURRENT (I_{mp})	4.89 A
MAX POWER-POINT VOLTAGE (V_{mp})	35.8 V
OPEN-CIRCUIT VOLTAGE (V_{oc})	44.4 V
SHORT-CIRCUIT CURRENT (I_{sc})	5.3 A
MAX SERIES FUSE (OCPD)	15 A
MAXIMUM POWER (P_{max})	175 W
MAX VOLTAGE (TYP 600V _{DC})	600 V
VOC TEMP COEFF (mV/°C □ or %/°C □)	-0.33
IF COEFF SUPPLIED, CIRCLE UNITS	

NOTES FOR ALL DRAWINGS:

OCPD = OVERCURRENT PROTECTION DEVICE
NATIONAL ELECTRICAL CODE® REFERENCES SHOWN AS (NEC XXX.XX)

INVERTER RATINGS (Guide Section 4)

INVERTER MAKE	AMERICAN INVERTER
INVERTER MODEL	AI-7000
MAX DC VOLT RATING	600 V
MAX POWER @ 40°C	7000 W
NOMINAL AC VOLTAGE	240 V
MAX AC CURRENT	29 A
MAX OCPD RATING	50 A

SIGNS-SEE GUIDE SECTION 7

SIGN FOR DC DISCONNECT

PHOTOVOLTAIC POWER SOURCE	
RATED MPP CURRENT	19.6 A
RATED MPP VOLTAGE	430 V
MAX SYSTEM VOLTAGE	577 V
MAX CIRCUIT CURRENT	26.5 A
WARNING: ELECTRICAL SHOCK HAZARD-LINE AND LOAD MAY BE ENERGIZED IN OPEN POSITION	

SIGN FOR INVERTER OCPD AND AC DISCONNECT (IF USED)

SOLAR PV SYSTEM AC POINT OF CONNECTION	
AC OUTPUT CURRENT	29 A
NOMINAL AC VOLTAGE	240 V
THIS PANEL FED BY MULTIPLE SOURCES (UTILITY AND SOLAR)	

NOTES FOR ARRAY CIRCUIT WIRING (Guide Section 6 and 8 and Appendix E):

- 1.) LOWEST EXPECT AMBIENT TEMPERATURE BASED ON ASHRAE MINIMUM MEAN EXTREME DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. LOWEST EXPECTED AMBIENT TEMP 0 °C
- 2.) HIGHEST CONTINUOUS AMBIENT TEMPERATURE BASED ON ASHRAE HIGHEST MONTH 2% DRY BULB TEMPERATURE FOR ASHRAE LOCATION MOST SIMILAR TO INSTALLATION LOCATION. HIGHEST CONTINUOUS TEMPERATURE 34 °C
- 2.) 2005 ASHRAE FUNDAMENTALS 2% DESIGN TEMPERATURES DO NOT EXCEED 47°C IN THE UNITED STATES (PALM SPRINGS, CA IS 44.1°C). FOR LESS THAN 9 CURRENT-CARRYING CONDUCTORS IN ROOF-MOUNTED SUNLIT CONDUIT AT LEAST 0.5" ABOVE ROOF AND USING THE OUTDOOR DESIGN TEMPERATURE OF 47°C OR LESS (ALL OF UNITED STATES).
 - a) 12 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I_{sc} OF 7.68 AMPS OR LESS WHEN PROTECTED BY A 12-AMP OR SMALLER FUSE.
 - b) 10 AWG, 90°C CONDUCTORS ARE GENERALLY ACCEPTABLE FOR MODULES WITH I_{sc} OF 9.6 AMPS OR LESS WHEN PROTECTED BY A 15-AMP OR SMALLER FUSE.

NOTES FOR INVERTER CIRCUITS (Guide Section 8 and 9):

- 1) IF UTILITY REQUIRES A VISIBLE-BREAK SWITCH, DOES THIS SWITCH MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☒
- 2) IF GENERATION METER REQUIRED, DOES THIS METER SOCKET MEET THE REQUIREMENT? YES ☐ NO ☐ N/A ☒
- 3) SIZE PHOTOVOLTAIC POWER SOURCE (DC) CONDUCTORS BASED ON MAX CURRENT ON NEC 690.53 SIGN OR OCPD RATING AT DISCONNECT
- 4) SIZE INVERTER OUTPUT CIRCUIT (AC) CONDUCTORS ACCORDING TO INVERTER OCPD AMPERE RATING. (See Guide Section 9)
- 5) TOTAL OF 1 INVERTER OCPD(S), ONE FOR EACH INVERTER, DOES TOTAL SUPPLY BREAKERS COMPLY WITH 120% BUSBAR EXCEPTION IN 690.64(B)(2)(a)? YES ☒ NO ☐

Contractor Name, Address and Phone:		Notes for One-Line Standard Electrical Diagram for Single-Phase PV Systems			
Bill and Ted's Solar 456 Industrial Drive San Jose, CA 408-555-1212		Site Name: Joe and Jane Homeowner Site Address: 123 Sunnyside St., San Jose, CA System AC Size: 6.9 kW Solar Array			
Drawn By: Bill	SIZE	FIGURE NO	DWG NO	REV	
Checked By: Ted	SCALE	NTS	Date:	0	

Field Inspection



Section 1. Field Inspection Checklist for Array:

- a) Array matches plans
- b) Wire Management
- c) Module and Array Grounding
- d) Electrical enclosures on Roof Accessible and Connections Suitable for the Environment
- e) Array Fastened and Sealed According To Attachment Detail
- f) Conductor Ratings and Sizes

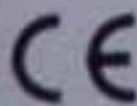


Inspection Checklist for Array:

a) Array Matches Plans

- PV module model number matches plans and spec sheets
- Get a digital photo of module label, if possible



Typical PV Module Label

PHOTOVOLTAIC MODULE			 
MODEL	KC120-1		
SER NO.	01632A1055		
DATE	2001.6		
IRRADIANCE AND CELL TEMPERATURE	1000Wm ⁻² AM 1.5 25 °C	800Wm ⁻² AM 1.5 47 °C	MAX. SYS VOLT. 600 V
	P _{max}	120 W 87 W	SERIES FUSE 11 A
	V _{pmax}	16.9 V 15.2 V	
	I _{pmax}	7.10 A 5.74 A	MASS 11.9 kg
	V _{oc}	21.5 V - - -	
I _{sc}	7.45 A - - -		
 LISTED BP82	FIELD WIRING		FIRE RATING
	STRANDED COPPER ONLY 10 ~14 AWG INSULATED FOR 90°C		CLASS C

Common Installation Mistakes with Array Modules and Configurations

- 1. Changing the array wiring layout without changing the submitted electrical diagram.
- 2. Changing the module type or manufacturer as a result of supply issues.
- 3. Exceeding the inverter or module voltage due to improper array design.
- 4. Putting too few modules in series for proper operation of the inverter during high summer array temperatures.

Inspection Checklist for Array:

b) Wire Management

- The most important safety issue is proper support and protection of conductors.



Wire Management



Proper Installation of Exterior Cables

- NEC 338.10(B)(4)(b) states how USE-2 is to be installed in exterior locations.
- PV Wire/Cable should follow the same installation methods as USE-2.
- Section 338.10 refers the installer on to Article 334.30 (NM Cable) for support methods

Proper Installation of Exterior Cables—Article 334.30

- 1. Secured by staples, cable ties, straps, hangers, or similar fittings at intervals that do not exceed 4.5 feet
- 2. Secured within 12 inches of each box, cabinet, conduit body, or other termination
- 3. Sections protected from physical damage by raceway shall not be required to be secured within the raceway
- 4. Cable shall closely follow the surface of the building finish or of running boards ((NEC 334.15)—the analogous installation for USE-2 in PV arrays is for the conductors to follow support rails or module extrusions)
- 5. Protected from physical damage by raceway when necessary

Wire Management—Proper



Wire Management—Room for Improvement



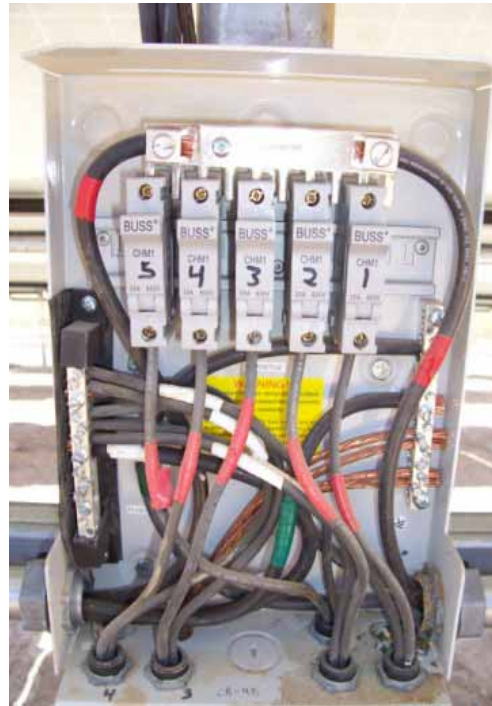
Wire Management—Support?



Common Installation Mistakes with Wire Management

- 1. Not enough supports to properly control cable.
- 2. Conductors touching roof or other abrasive surfaces exposing them to physical damage.
- 3. Conductors not supported within 12 inches of boxes or fittings.
- 4. Not supporting raceways at proper intervals.
- 5. Multiple cables entering a single conductor cable gland (aka cord grip)
- 6. Not following support members with conductors.

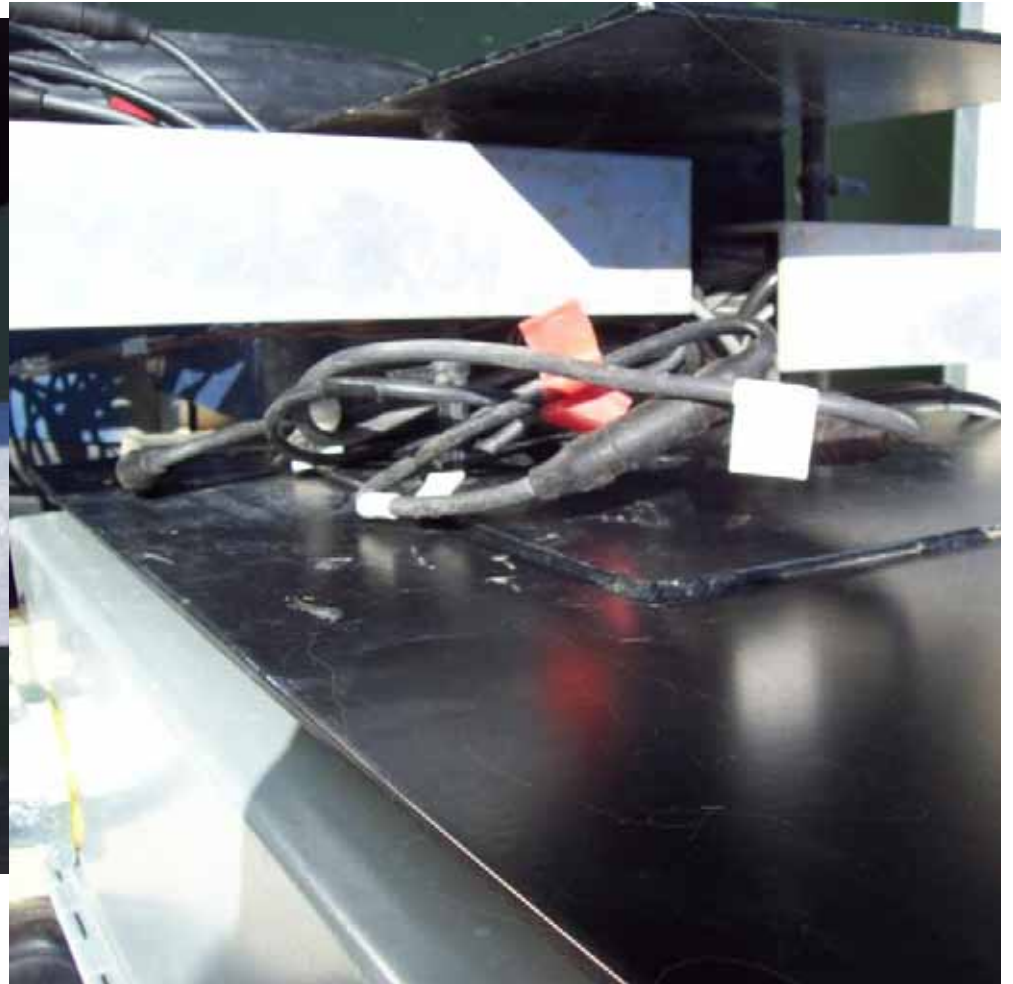
Proper cable glands into Combiner Box



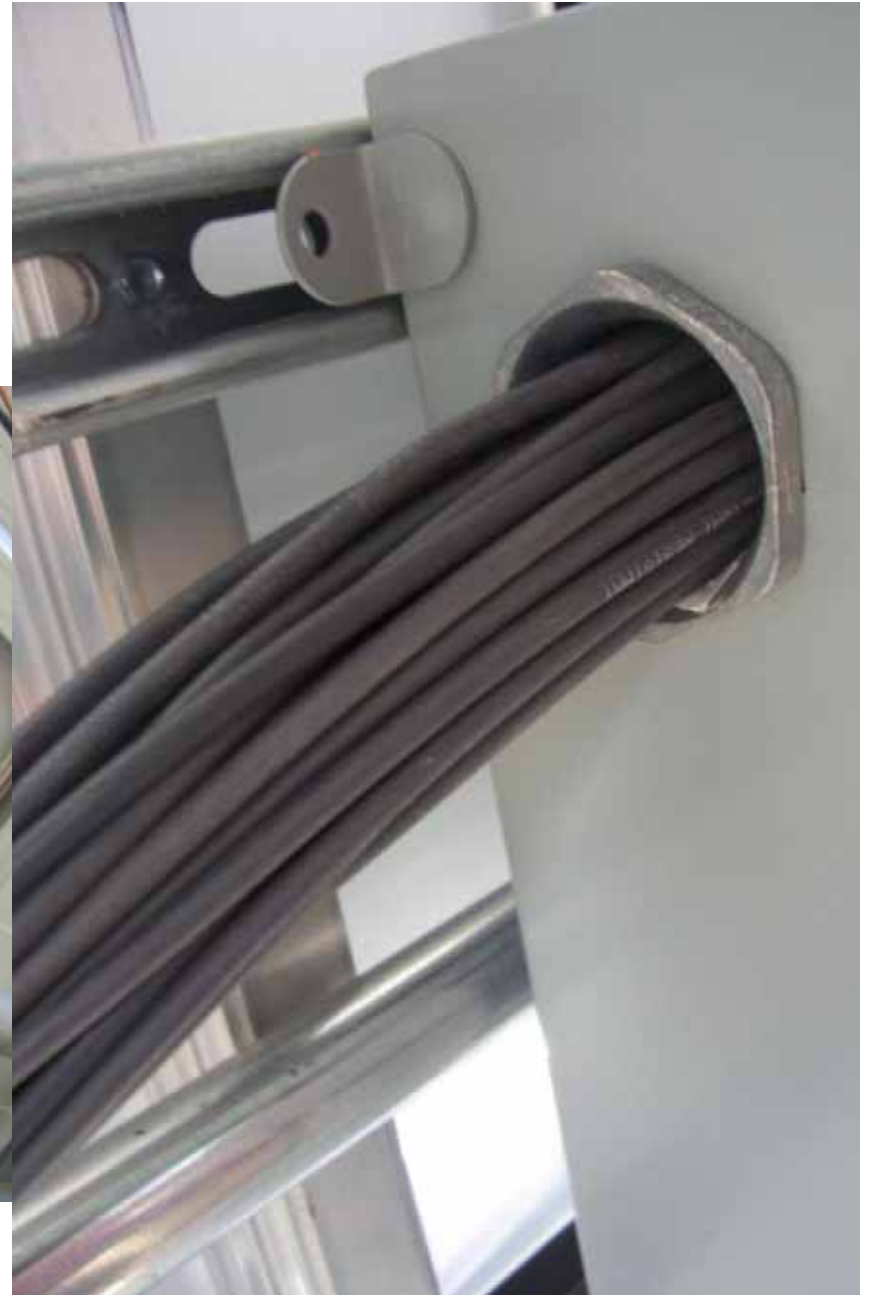
Common Installation Mistakes with Wire Management—cont.

- 7. Pulling cable ties too tight or leaving them too loose.
- 8. Not fully engaging plug connectors.
- 9. Bending conductors too close to connectors.
- 10. Bending USE-2 cable tighter than allowable bending radius.
- 11. Plug connectors on non-locking connectors not fully engaged

Wire Management—Physical Damage

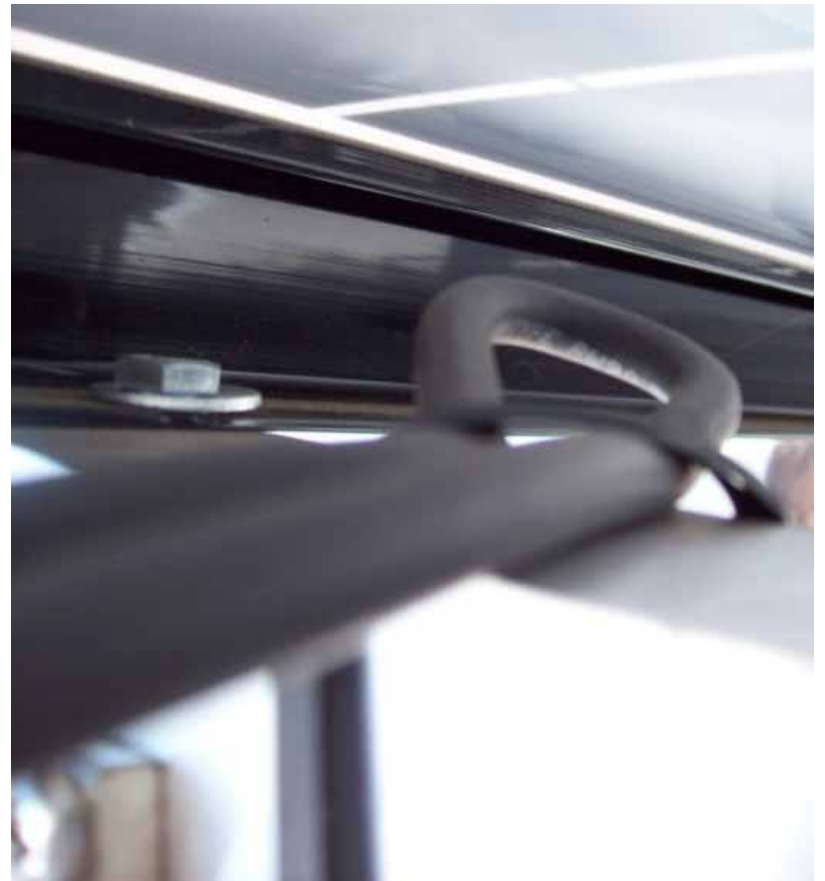


Wire Management count the bad ideas



Wire Management

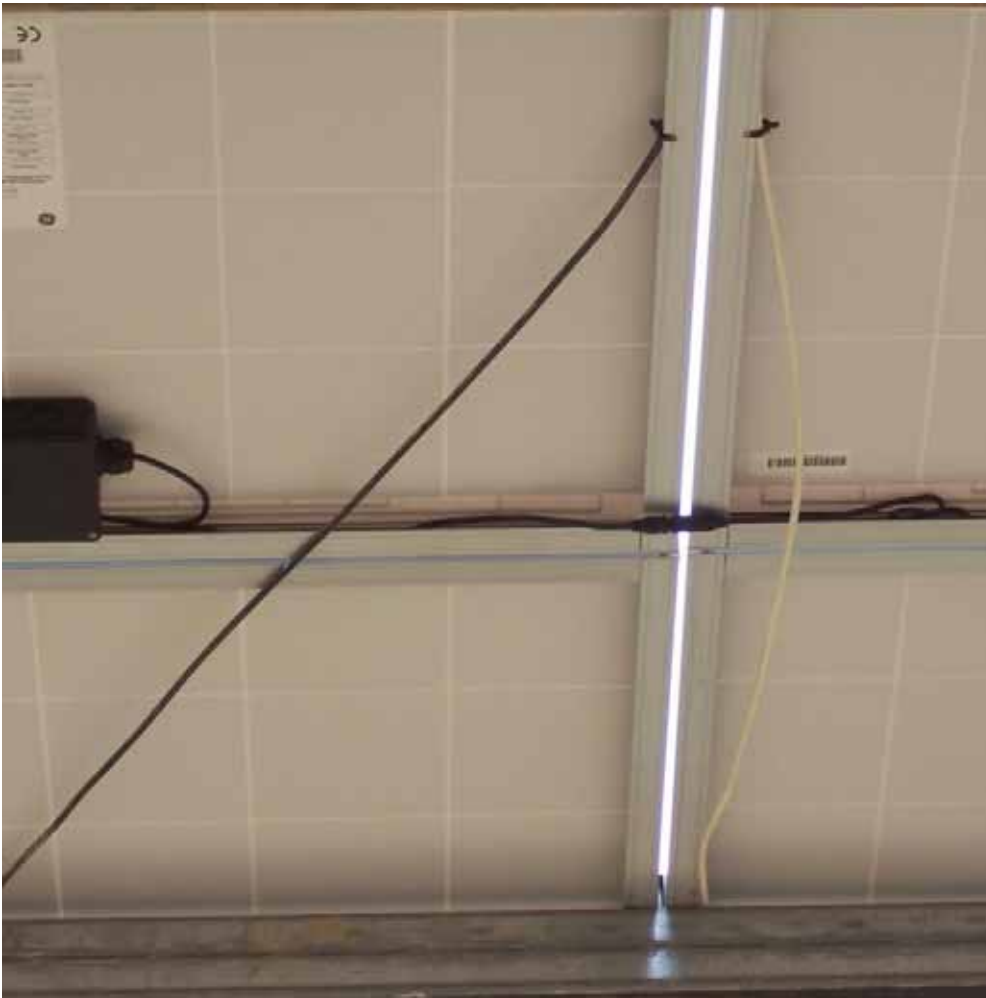
—wire bending radius



Wire Management—plug engagement



Wire Management—Follow structural members & What the...?



What you can't see won't hurt you??

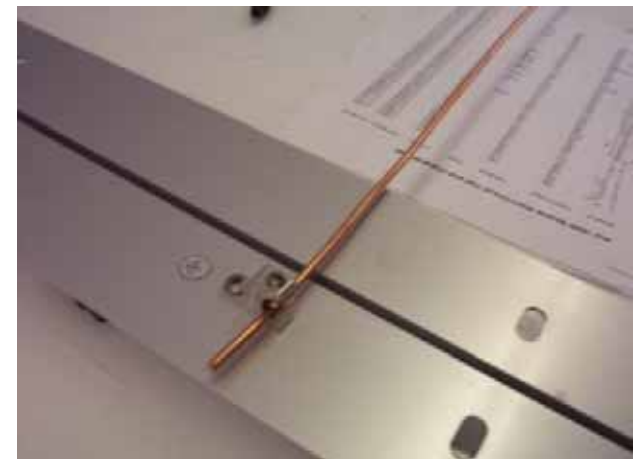
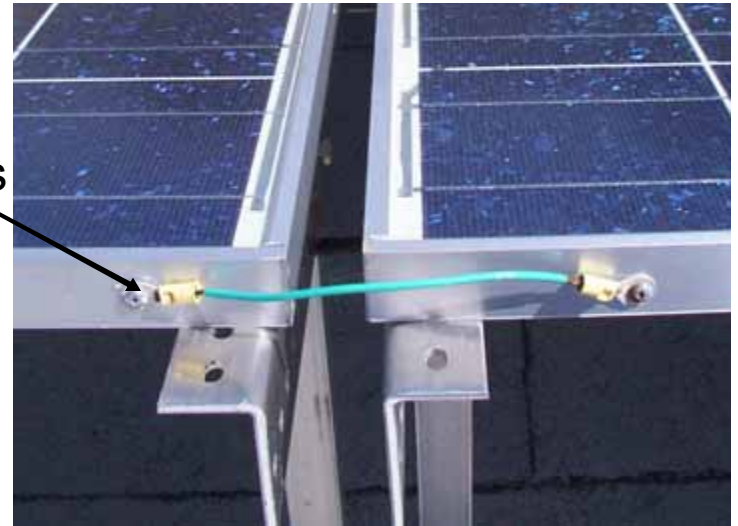


Inspection Checklist for Array:

c) Module and Array Grounding

- Most common concern of field inspectors.
- Ungrounded module frames are a potential safety hazard.
- All array metal “likely to become energized” must be properly bonded together and grounded with lugs on each module and mounting rails or some equivalent equipment grounding method.

Wrong
connectors



Module bonding and grounding methods

- 1. Some modules are designed to be grounded using a stainless-steel thread-forming screw threaded into the module frame holding the EGC at a grounding symbol. An isolating washer, such as a stainless cup washer is often used to isolate the copper conductor from the aluminum frame to prevent galvanic corrosion.
- 2. Some modules can be grounded to their mounting structures with stainless steel star washers placed between the module and the support structure. This creates an electrical bond while isolating the aluminum frame from dissimilar materials such as galvanized steel. The EGC is attached to an electrically continuous support member with a properly installed grounding lug.

Module bonding and grounding methods—cont.

- 3. Some modules can be grounded by properly installing a properly rated lay-in lug to the either the grounding point on the module, or any unused mounting hole. The EGC is run through this lay-in lug to bond the modules together.
- 4. For specific module mounting products (e.g. UniRac, ProSolar, DPW, etc...), there exists listed grounding clips to bond typical aluminum framed modules to the mounting structure. Only the proper clip can be used with each mounting structure. This allows the EGC to be connected to the electrically continuous rail. This method is consistent the NEC 690.43 and NEC 250.136.
- 5. Some modules can be grounded together using serrated clips that hold the module to the support structure and electrically bond with the module. One lug on any module can ground a whole row.

Early module and structure grounding improvements

UGC-1

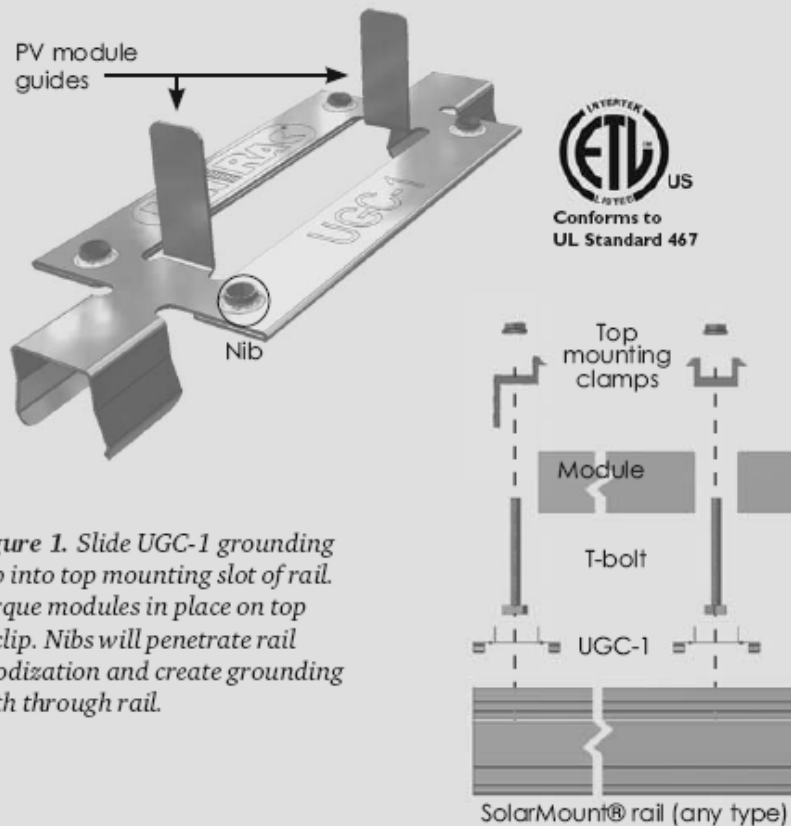


Figure 1. Slide UGC-1 grounding clip into top mounting slot of rail. Torque modules in place on top of clip. Nibs will penetrate rail anodization and create grounding path through rail.

WEEBLug

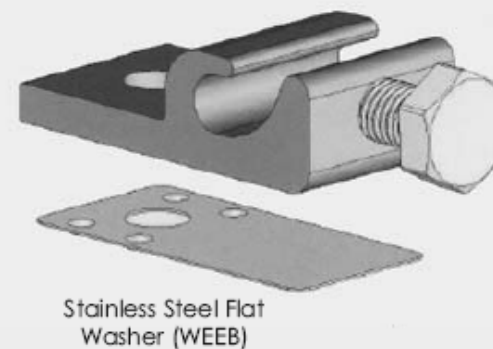
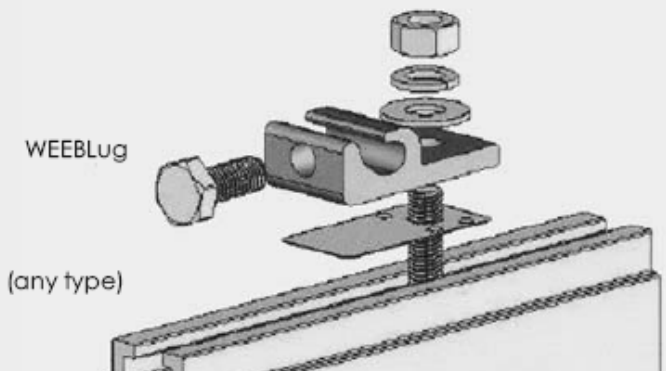


Figure 2. Insert a bolt in the aluminum rail or through the clearance hole in the stainless steel flat washer. Place the stainless steel flat washer on the bolt, oriented so the dimples will contact the aluminum rail. Place the lug portion on the bolt and stainless steel flat washer. Install stainless steel flat washer, lock washer and nut. Tighten the nut until the dimples are completely embedded into the rail and lug. The embedded dimples make a gas-tight mechanical connection and ensure good electrical connection between the aluminum rail and the lug through the WEEB.





Identifying Grounding Clips



Notice slight gap caused by properly installed clip.

Common Installation Mistakes with Module and Array Grounding

- 1. Not installing a grounding conductor on the array at all.
- 2. Using cad-plated Tek screws to fasten ground wires or lugs to modules.
- 3. Using indoor-rated grounding lugs on PV modules and support structures.
- 4. Not protecting EGCs smaller than 6 AWG from physical damage.
- 5. Allowing copper EGC to come in contact with the aluminum rails and module frames.
- 6. Assuming that simply bolting aluminum frames to support structures provides effective grounding.

Nice Lugs! (poor fasteners)

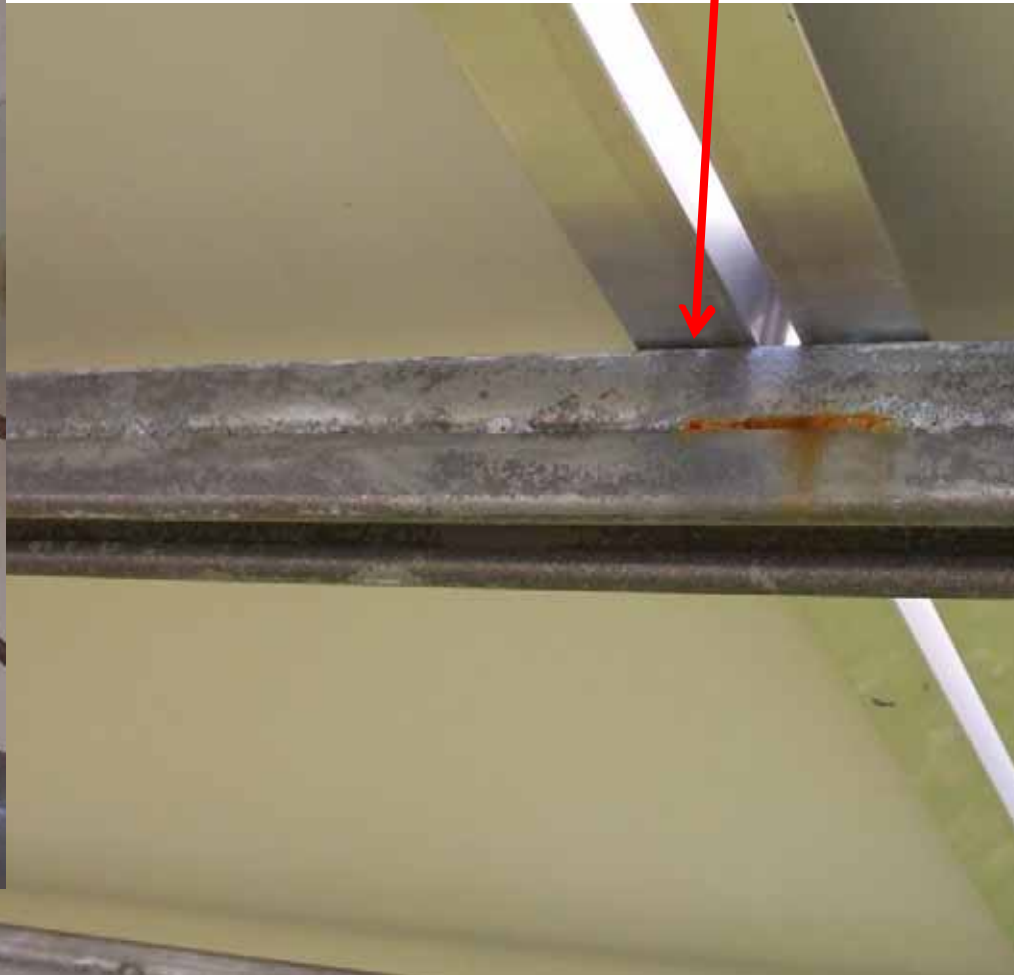


Improper Cad
Tek screw
used to hold
lug

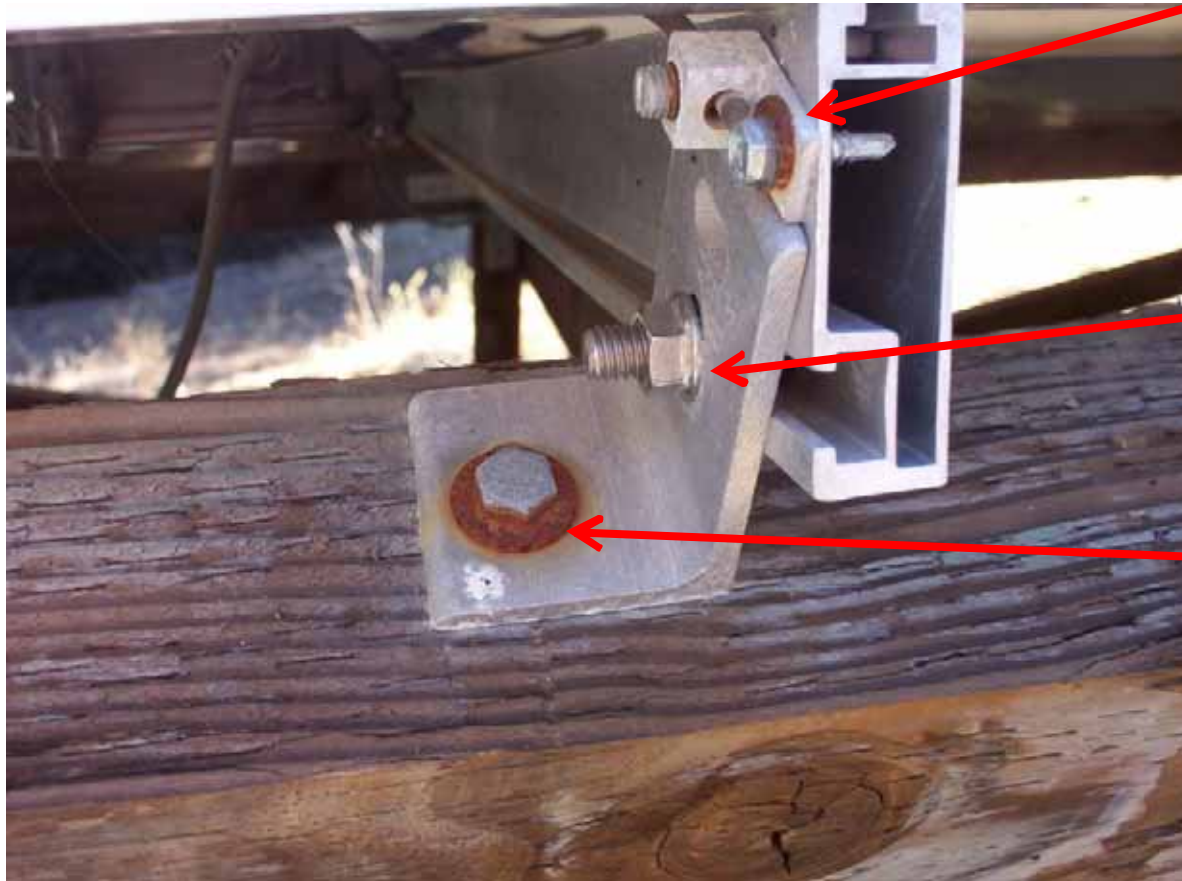
Indoor lugs and Tek screws



Aluminum bolted to steel without isolation washers and no effective bond



Grounding Hardware and Components



Indoor lug and
Tek screw

Stainless
hardware looks
like new

Galvanized washer
showing galvanic
corrosion with
aluminum contact

Inspection Checklist for Array:

d) Electrical enclosures on Roof Accessible and Connections Suitable for the Environment

- **NEC 690.34 Access to Boxes.** Junction, pull, and outlet boxes located behind modules or panels shall be so installed that the wiring contained in them can be rendered accessible directly or by displacement of a module(s) or panel(s) secured by removable fasteners and connected by a flexible wiring system.

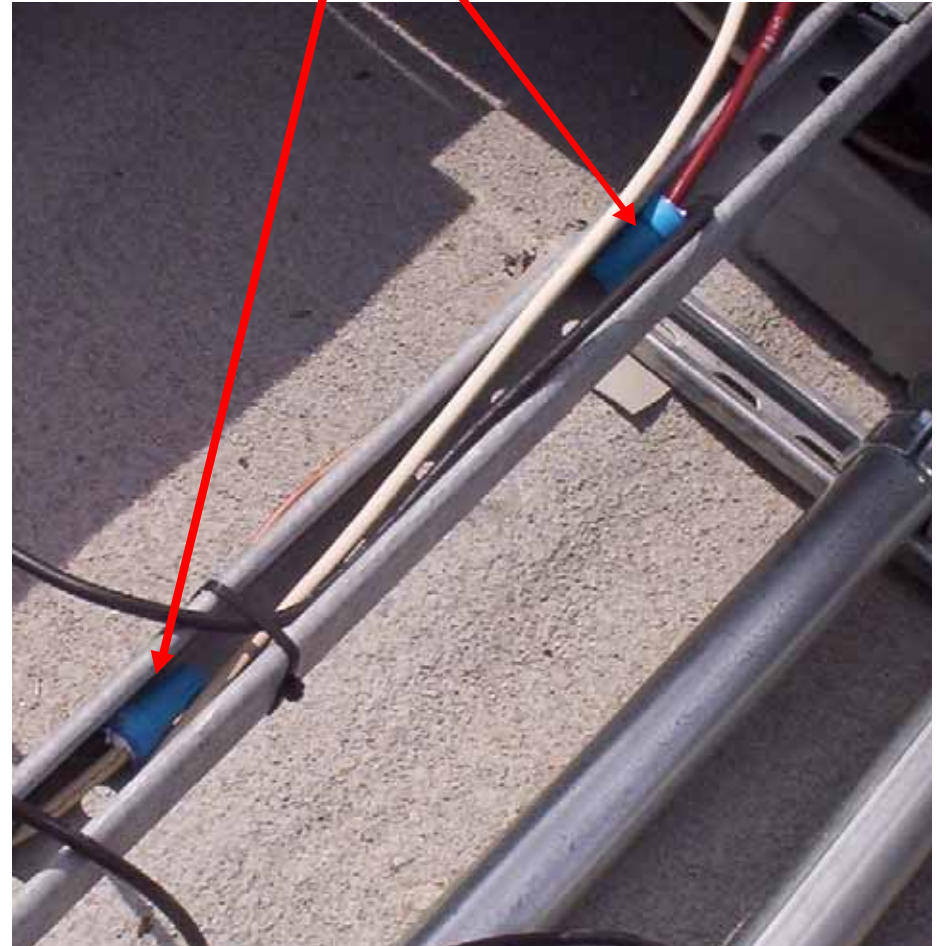
Rooftop j-boxes in compliance with 690.34



Junction Boxes

- Connection between conductors in an outdoor location generally must be done within a rainproof junction box, NEMA 3R, or 4 (unless with approved connector)
- Junction boxes are commonly used to transition conductors from exterior to conduit conductors and for combining array source circuits.

Waterproof
wirenuts must be
in j-boxes



Improper Connections

Wire twisted together, wrapped in tape, and in the sun



Dry wirenut and not in a j-box

Ratings and locations of Disconnects



NEMA 3R
disconnect on
sloped roof
designed for
vertical mounting
only

Black cover to
shield improperly
installed switch
only served to
make switch
invisible

Ratings and locations of Combiner Boxes



NEMA 4
Combiner Box
with disconnect
built-in. Designed
for horizontal or
vertical mounting

Common Installation Mistakes with Electrical Boxes, Conduit Bodies, and Disconnecting Means

- 1. Installing disconnects rated for vertical installation in a non-vertical application.
- 2. Installing improperly rated fuses in source combiners and fused disconnects.
- 3. Covering boxes or conduit bodies making them nearly inaccessible for service.
- 4. Not following manufacturer's directions for wiring disconnect for 600 Vdc ratings.
- 5. Installing dry wire nuts in wet locations and inside boxes that get wet routinely.
- 6. Using improper fittings to bring conductors into exterior boxes.

Many disconnects like these require the ungrounded conductor to be broken twice in series to get the 600Vdc rating

Incorrect
Breaking of
grounded
conductor



Correct



Correct Fuses



Correct Fuses



Correct Fuses ??



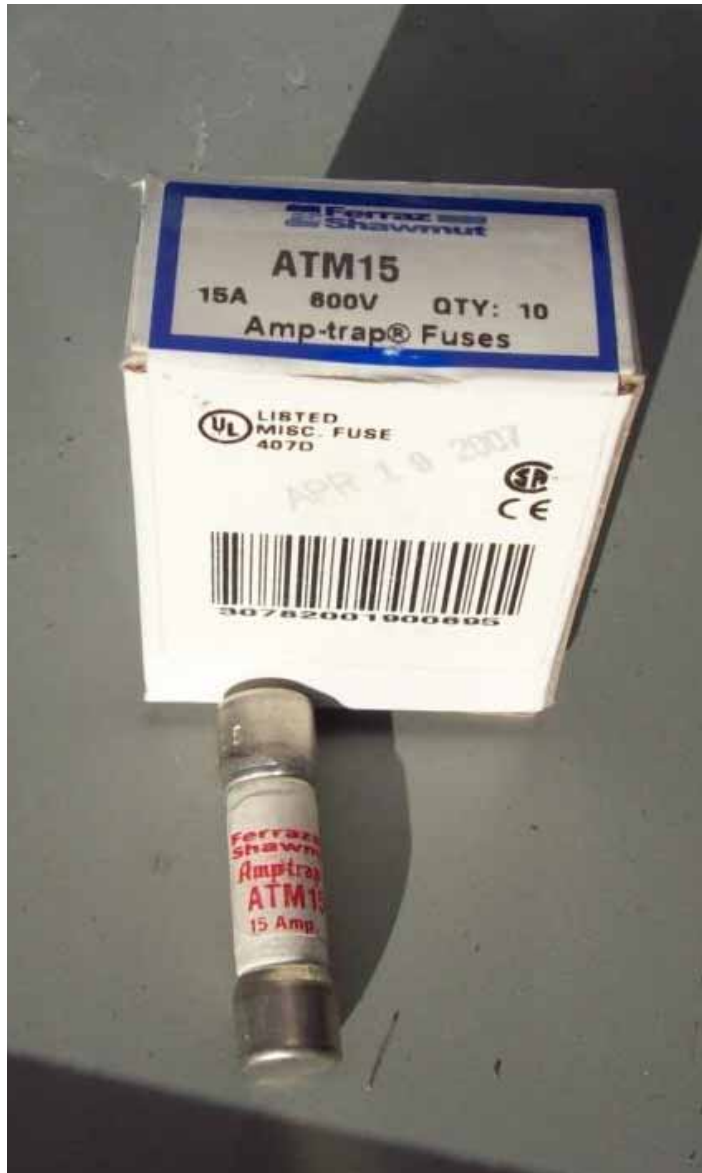
Correct Fuses ??



Correct Fuses and Terminals ?



Proper Current Rating?



Proper Current Rating?



Properly Rated Disconnects and Inverters



Inspection Checklist for Array:

e) Array Fastened and Sealed According To Attachment Detail

- Roof penetrations must be properly sealed to preclude leakage.
- Do a hand pull test on a sample of lag screw attachments to make sure they are secured to rafters.
- Look in attic to see if lags are visible.

Proper and Improper Flashing



Common Installation Mistakes with Mounting Systems:

- 1. Not using supplied or specified hardware with the mounting systems.
- 2. Substituting Unistrut for special manufactured aluminum extrusions.
- 3. Not installing flashings properly.
- 4. Not using the correct roof adhesives for the specific type of roof.
- 5. Not attaching proper lag screws to roofing members.
- 6. Not drilling proper pilot holes for lag screws and missing or splitting roofing members.

Inspection Checklist for Array:

f) Conductor Ratings and Sizes

- Exposed Array Conductors—The only single-conductor cables allowed in 690.31(B) are USE-2 and PV Wire (Cable).
- Conductors in raceways on rooftops—Table 310.15(B)(2)(a) adds an additional 14°C - 30°C to the ambient temperature. These high temperatures nearly always limit ampacity below the terminal temperature ampacity.

Conduit Exposed to Sunlight Above Rooftops –Table 310.15(B)(2)(a)



Common Installation Mistakes with Conductors:

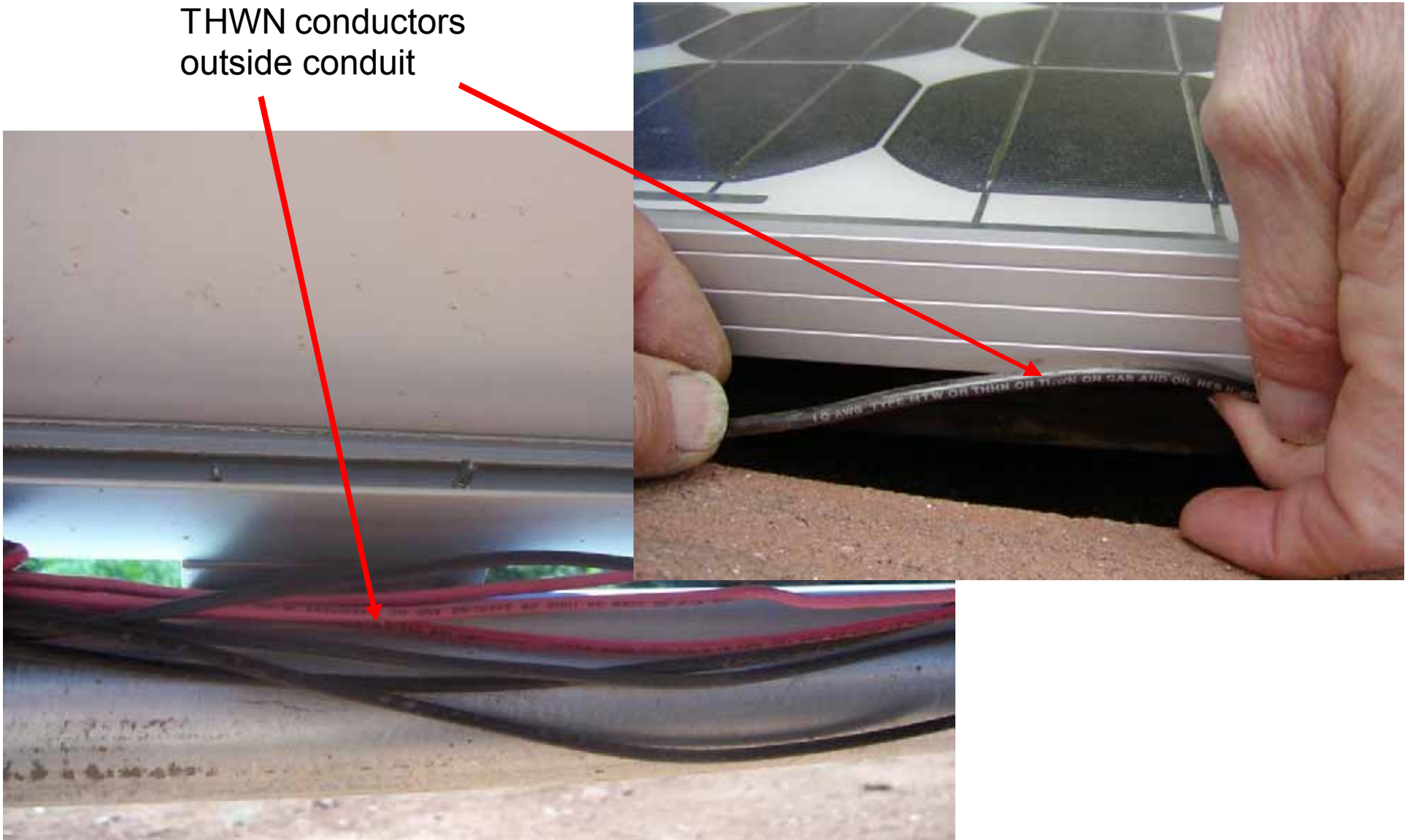
- 1. Not accounting for high operating temperatures in rooftop conduit.
- 2. Specifying THHN conductors rather than wet rated conductors in drawings where raceways are clearly located outdoors.
- 3. Specifying or installing THWN conductors in raceways that may exceed 60° C without properly correcting the THWN conductors for this temperature.

Incorrect conductors and roof plumbing into combiner box



Improperly Rated Conductors

THWN conductors
outside conduit



Section 2. Specifics For Ground-Mounted Arrays

- a) Foundation and mounting structure review
- b) Electrical bonding of structural elements
- c) Additional array electrode [690.47(D)]
- d) Attachment method according to plans
- e) Wiring not readily accessible

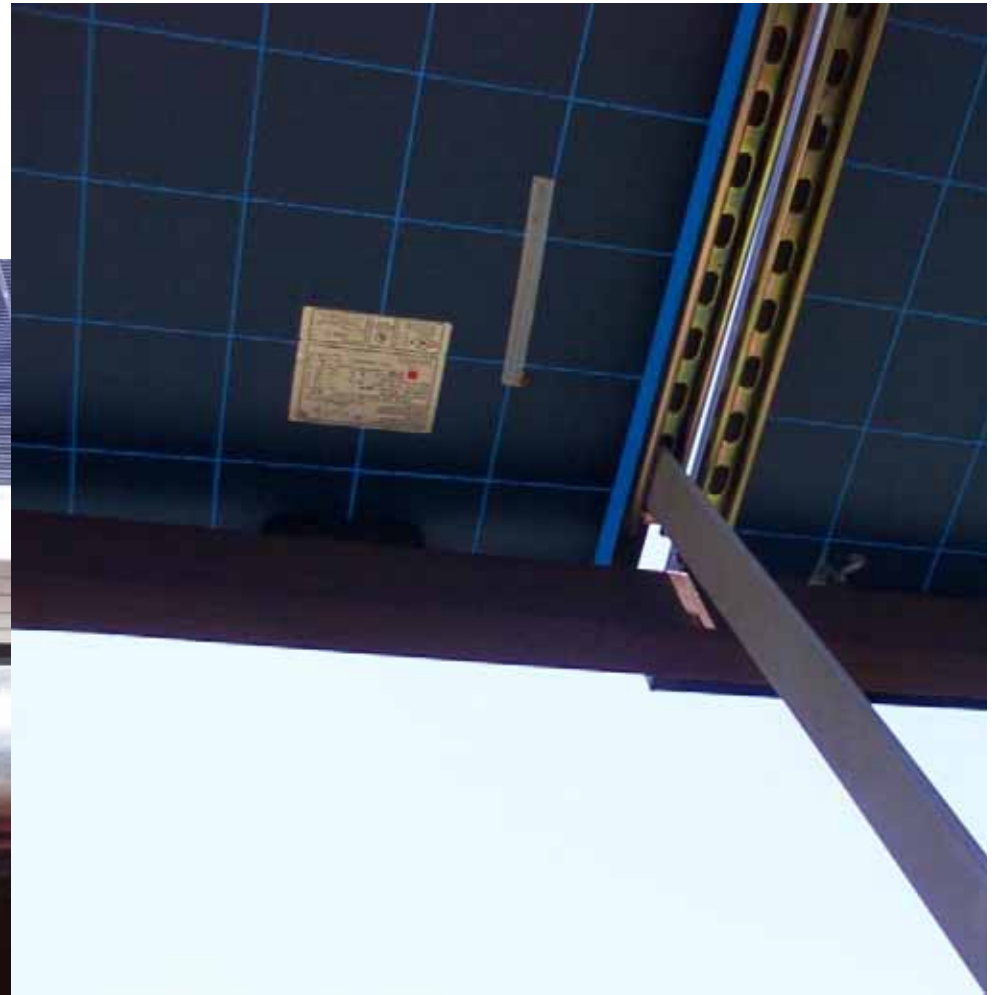
Support Structure and Attachment



Support Structure and Attachment



Support Structure and Attachment



Wiring not readily accessible?



Readily accessible or not?



Common Installation Mistakes with Ground Mounting Systems:

- 1. Not using supplied or specified hardware with the mounting systems.
- 2. Substituting Unistrut for special manufactured aluminum extrusions.
- 3. No bonding of support structure or discontinuous grounding of support structure.
- 4. Dissimilar metals in contact with one another (e.g. aluminum and galvanized steel).
- 5. No bonding of aluminum structural elements to steel structural elements.
- 6. Array wiring readily accessible to other than authorized personnel.

Section 3. Appropriate signs installed

- Sign construction
- Photovoltaic Power Source
- AC point of connection
- alternative power system

PV POWER SOURCE DC RATINGS		
WAREHOUSE		
STANDARD TEST CONDITIONS CELL TEMPERATURE = 25°C IRRADIANCE = 1000 W/m ²		
OPERATING DC CURRENT	53.6	Amps
OPERATING DC VOLTAGE	415	Volts
OPERATING DC POWER	23,760	Watts
MAXIMUM SYSTEM DC VOLTAGE	600	Volts
SHORT-CIRCUIT DC CURRENT	65.2	Amps
SCHOTT		



Sign Construction

- The NEC is not extremely specific about what signs should be made of.
- NEC 110.21 states, “The marking shall be of sufficient durability to withstand the environment involved.”
- Electrical industry standards for outdoor signs is that signs should be metal or plastic with engraved or machine printed letters, or electro-photo plating, in a contrasting color to the sign background.

Indoor signs may allow more variety of construction

WAREHOUSE

**PV POWER SOURCE
DC RATINGS**

STANDARD TEST CONDITIONS
CELL TEMPERATURE = 25°C
IRRADIANCE = 1000 W/m²


OPERATING DC CURRENT	53.6	Amps
OPERATING DC VOLTAGE	415	Volts
OPERATING DC POWER	23,760	Watts
MAXIMUM SYSTEM DC VOLTAGE	600	Volts
SHORT-CIRCUIT DC CURRENT	65.2	Amps

SCHOTT

PHOTOVOLTAIC DC DISCONNECT

WARNING! ELECTRIC SHOCK HAZARD!

Voc	542 V
Vmp	392 V
Isc	504 A
Isc	471 A

 **SolarCity** (888) SOL-CITY
WWW.SOLARCITY.COM

Photovoltaic Power Source Sign



Signs and Labels



AC Point of Interconnection



Signs and Labels
it is possible to
have too many.



Section 4. Check that equipment ratings are consistent with application and signs

Inverter Labels

Sunny Boy
Utility Interactive 1-Phase Inverter

FCC Tested To Comply
With FCC Standards

FOR HOME OR OFFICE USE

SB6000U

SMA

SMA Technologie AG
Hannoversche Straße 1-5
D-34266 Niestetal
Germany

Serial Number: 2000105773 Date of manufacture 05/2005

<p>AC Max. continuous output Power* 6000 W</p> <p>AC Operating voltage range (Vac) *</p> <table style="width: 100%;"> <tr> <th>MIN</th> <th>NOMINAL</th> <th>MAX</th> </tr> <tr> <td>183</td> <td>208</td> <td>229</td> </tr> <tr> <td>211</td> <td>240</td> <td>264</td> </tr> <tr> <td>244</td> <td>277</td> <td>305</td> </tr> </table> <p>AC Operating frequency range (Hz)</p> <table style="width: 100%;"> <tr> <th>MIN</th> <th>NOMINAL</th> <th>MAX</th> </tr> <tr> <td>59.3</td> <td>60.0</td> <td>60.5</td> </tr> </table> <p>AC Max. continuous output current 25 A RMS (22 A @ 277V AC)</p> <p>AC Max. output fault current 25 A</p> <p>AC Max. branch circuit overcurrent protection 40 A</p>	MIN	NOMINAL	MAX	183	208	229	211	240	264	244	277	305	MIN	NOMINAL	MAX	59.3	60.0	60.5	<p>AC Max. utility backfeed current 40 A</p> <p>DC Max. system voltage under all conditions 600 V</p> <p>DC Range of operating DC voltage 250 - 480 Vdc (at Vacnom)</p> <p>DC Max. operating current 25 A</p> <p>DC Max. array short circuit current 37.5 A</p> <p>Operating temperature range -13°F to +113°F (-25°C to +45°C)</p> <p>This unit contains DC Ground Fault Detector and Interrupter</p> <p>This unit contains active anti-islanding protection (IEEE 929)</p>	
MIN	NOMINAL	MAX																		
183	208	229																		
211	240	264																		
244	277	305																		
MIN	NOMINAL	MAX																		
59.3	60.0	60.5																		

SMA America Inc.
phone: 530.273.4895
www.sma-america.com

* For more details see the
Operator's Manual

ENCLOSURE
Type 3R (IP54)

UL US LISTED

Utility interactive inverter
LISTED UL 1741 36AN

FREQUENCY FACTORY SET IN COMPLIANCE WITH LOCAL UTILITY REQUIREMENTS
ONLY BE CHANGED BY TRAINED SERVICE TECHNICIANS
WITH APPROVAL BY BOTH THE LOCAL UTILITY AND
EQUIPMENT OWNER.

REFER TO THE OPERATOR'S
MANUAL FOR FURTHER DETAIL.

TYPE 3R

xantrex
Smart Choice for Power

61CM

161-G South Vasco Rd., Livermore, CA USA

LISTED UTILITY INTERACTIVE 3 PHASE INVERTER

<p>DC Max. system DC Voltage 600V</p> <p>DC Max. operating current 95.7A</p> <p>DC Range of oper. volts 330-480V</p> <p>DC Max. array short circuit current 138A</p> <p>AC Nominal output voltage 208V</p> <p>AC Maximum utility feedback current 94A</p> <p>AC Maximum continuous output current 94A</p>	<p>AC Max. Input current 300ma</p> <p>AC Oper. Volt. range 187-220 L-L</p> <p>AC Oper. freq. range 59.3 - 60.5</p> <p>AC Normal output freq. 60 Hz</p> <p>AC Max. output overcurrent protection 125A</p> <p>AC Maximum output fault current 94A</p> <p>AC Max. continuous output power 30 KVA</p>
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Maximum operating ambient

MODEL NUMBER PV-30208

SERIAL NUMBER 1100

50° C

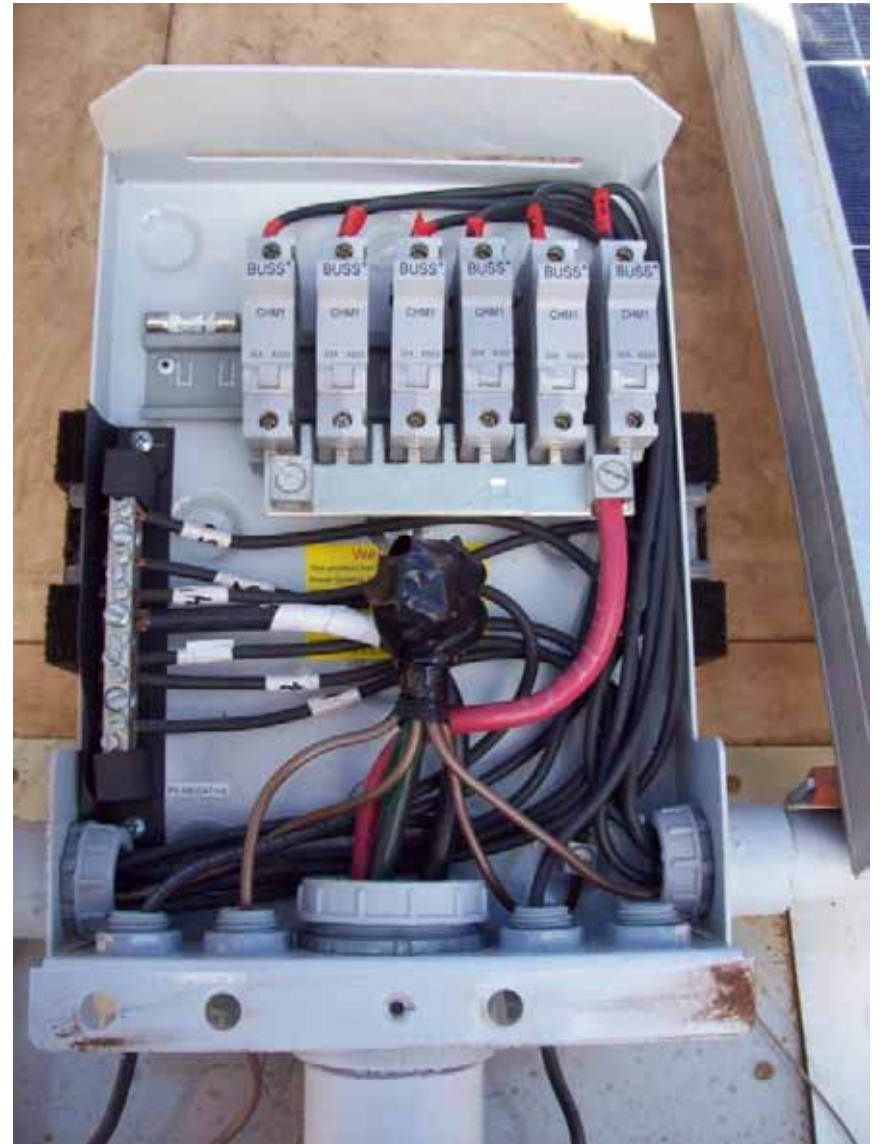
MANUFACTURED

☒ JAN ☒ MAY ☒ SEP ☒ 02
☒ FEB ☒ JUN ☒ OCT ☒ 03
☒ MAR ☒ JUL ☒ NOV ☒ 04
☒ APR ☒ AUG ☒ DEC ☒ 05

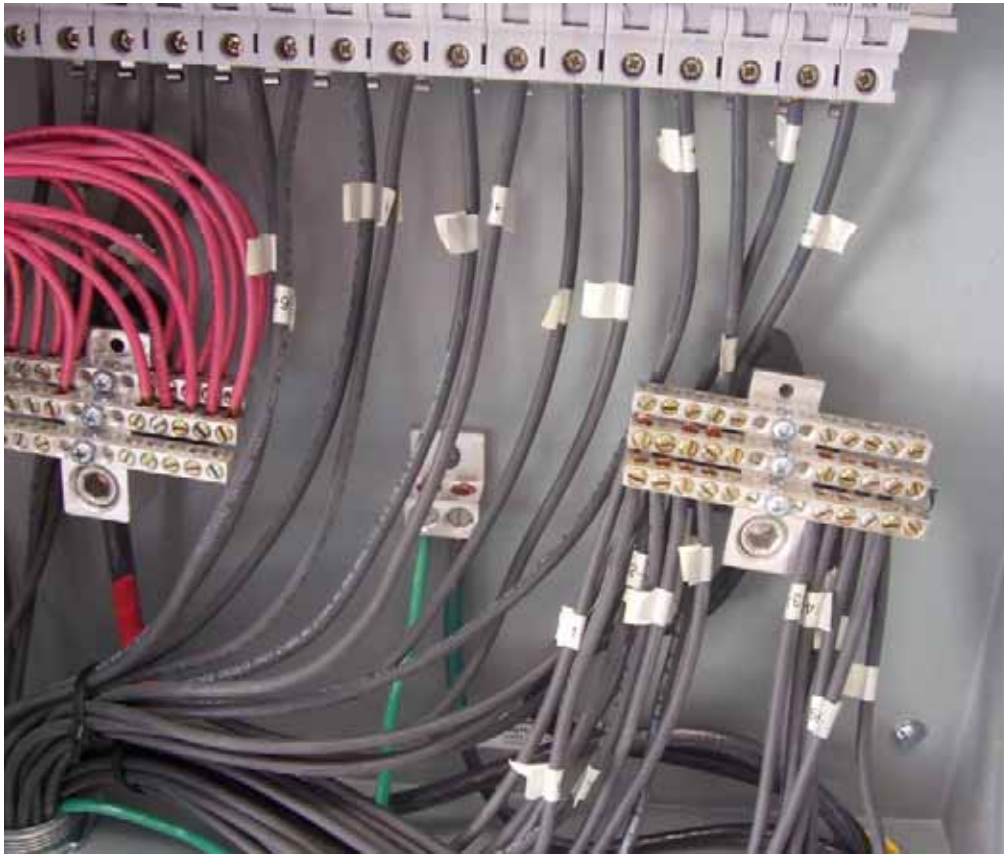
Disconnects consistent with requirements



Guts—show and tell



Guts—show and tell



Guts—show and tell



Guts—show and tell



Good Installation Practices



Good Installation Practices



Good Installation Practices



Good Installation Practices



Nice Work



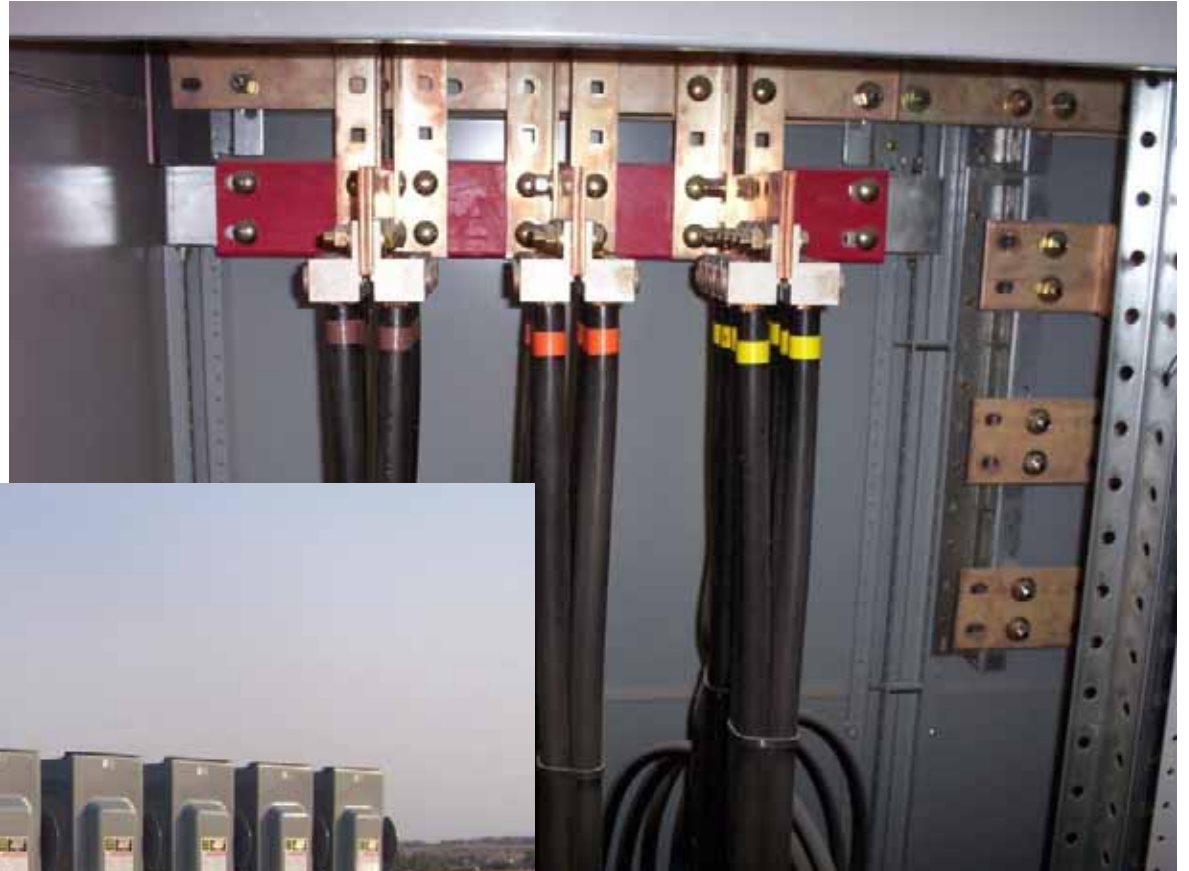
Nice Work



Nice Work



Nice Work



Nice Work



Nice Work



Nice Work

