NEC Code Calculations for Solar Installations

for Inspectors and Building Officials

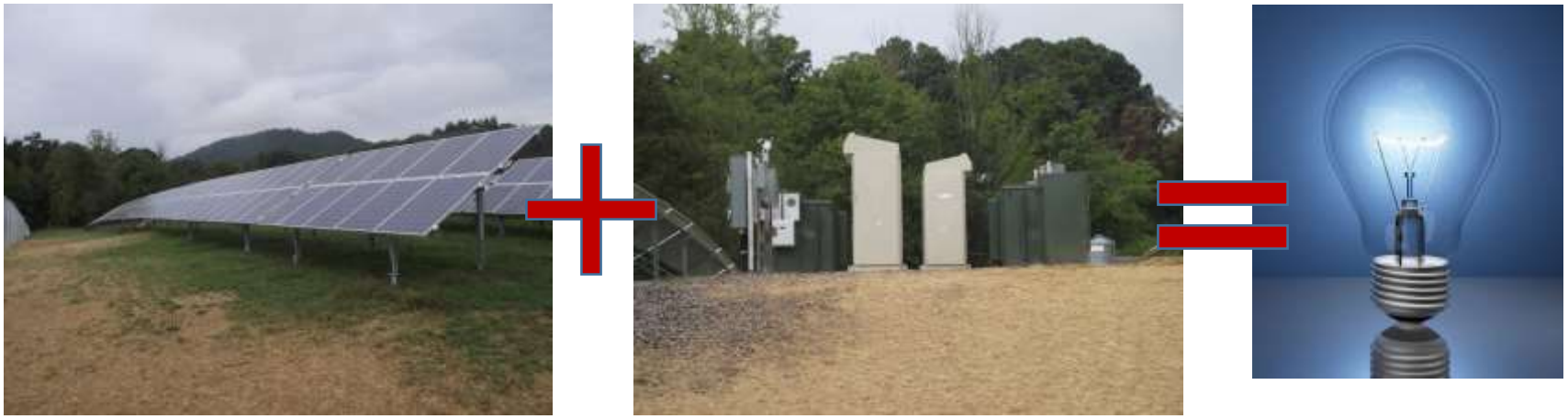
ecovision ELECTRIC

- Cari Williamette works with EcoVision Electric in Minneapolis, MN performing 3rd party testing and installation of solar PV systems. She is a licensed master electrician, and an ICC certified electrical inspector and building official. When not in the field, she teaches classes in code calculations, code update, and Article 690 (solar PV).

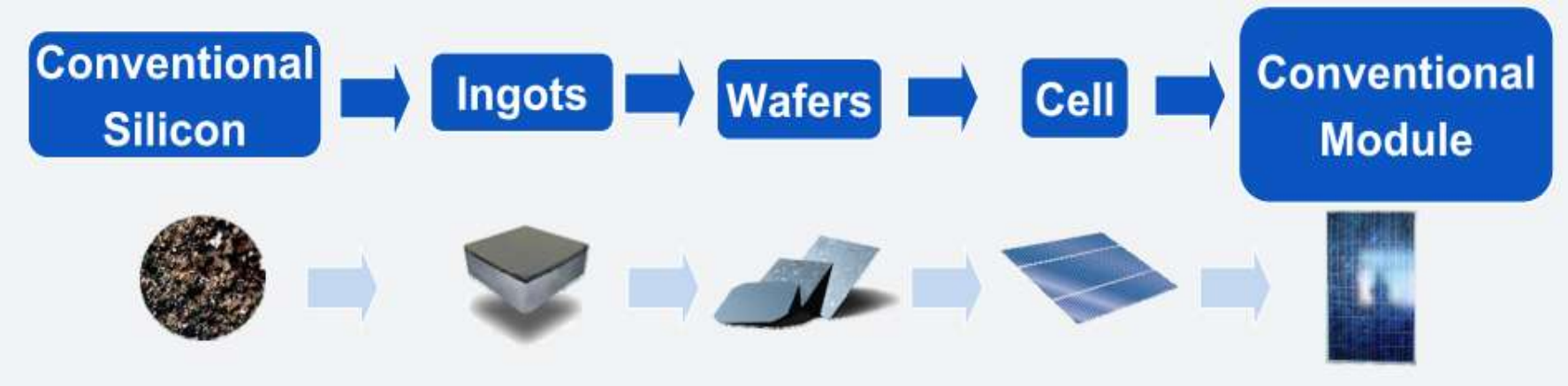
ecovision ELECTRIC

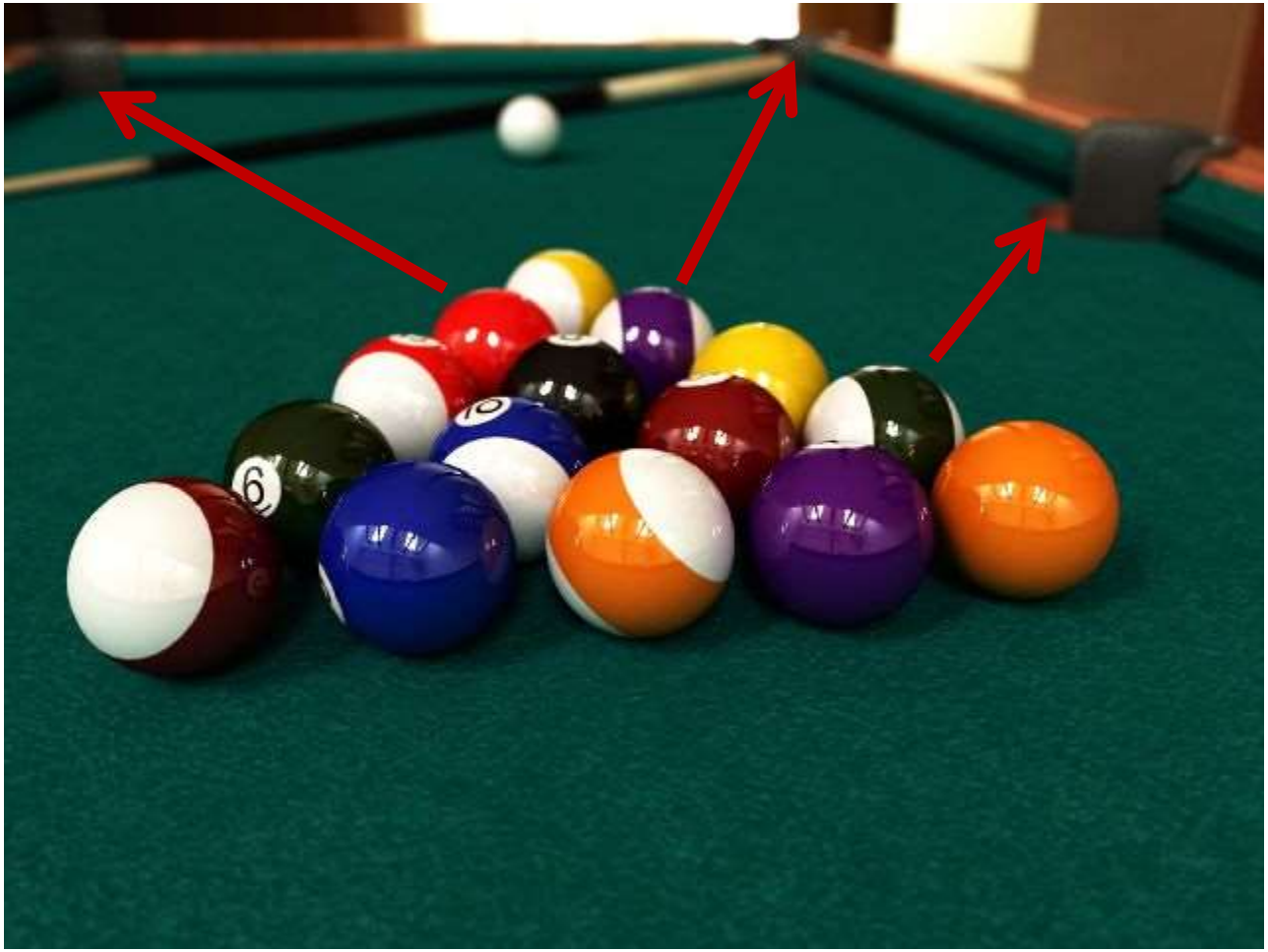
- What is it?
- How does it work?
- Basic terms

- The total components and subsystems that, in combination, convert solar energy into electric energy suitable for connection to a utilization load. (NEC 690.2)

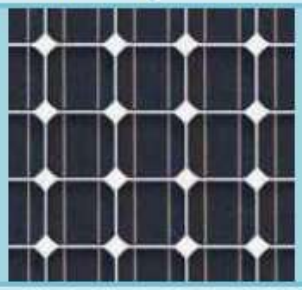
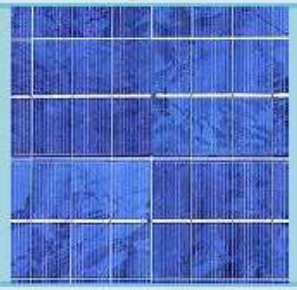


- The basic photovoltaic device that generates electricity when exposed to light. (NEC 690.2)





There are four main different types of solar PV cells. The table below gives an indication of how they compare to each other.

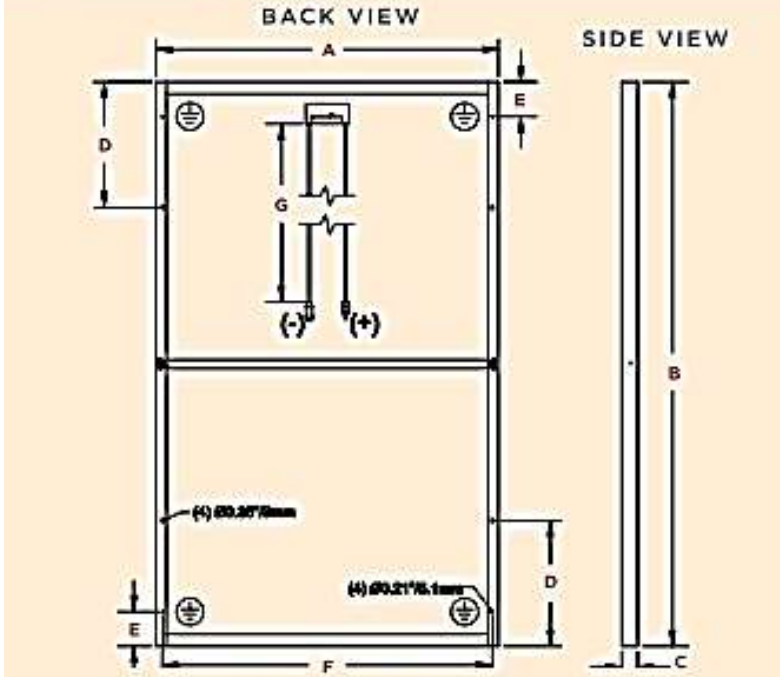
	Thin Film	Monocrystalline	Polycrystalline	Hybrid*
Appearance				
Efficiency @ STC**	7-8%	11-13%	14-16%	17-19%
Area/kW	180 ft^2	107 ft^2	90 ft^2	73 ft^2

*Hybrid PV combines monocrystalline and thin-film silicon to produce cells with the best features of both technologies

**Standard Test Conditions (STC) are: 25 °C, light intensity of 1000W/m^2, air mass = 1.5

- A complete, environmentally protected unit consisting of solar cells, optics, and other components, exclusive of tracker, designed to generate dc power when exposed to sunlight. (NEC 690.2)

DIMENSIONS



A	B	C	D	E
39.1"/994 mm	64.6"/1640 mm	1.8"/46 mm	14.4"/365 mm	3.9"/100 mm

F	G
37.7"/958 mm	43.3"/1100 mm

- 240 Watt

MECHANICAL CHARACTERISTICS

Dimensions (A x B x C below)	39.1" x 64.6" x 1.8"/994 x 1640 x 46 mm
Cable Length (G)	43.3"/1100 mm
Output Interconnect Cable**	12 AWG with MC4 Locking Connector
Weight	41.9 lbs / 19.0 kg
Max Load	50 psf (2400 Pascals)
Operating Temperature (cell)	-40 to 194°F / -40 to 90°C

**A safety lock clip (Multi Contact part number PV-5SH4) may be required in readily accessible locations per NEC 2008 690.33 (C)
**PV Wire per UL Subject 4703

- A complete, environmentally protected unit consisting of solar cells, optics, inverter, and other components, exclusive of tracker, designed to generate ac power when exposed to sunlight. (NEC 690.2)

- Addition of a micro-inverter on site DOES NOT qualify as an AC module.

- A mechanically integrated assembly of modules or panels with a support structure and foundation, tracker, and other components, as required, to form a direct-current power-producing unit. (NEC 690.2)

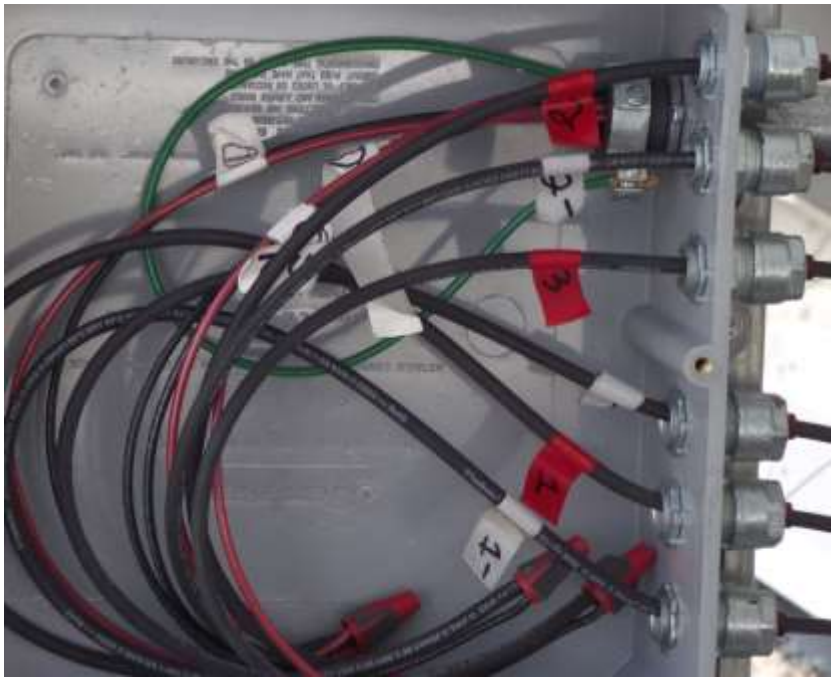
- Photovoltaic cells, devices, modules, or modular materials that are integrated into the outer surface or structure of a building and serve as the outer protective surface of that building. (NEC 690.2)

- A roof covering composed of flat-plate photovoltaic modules fabricated in sheets that resemble three-tab composite shingles. (2012 IBC, 202)

- All of the system components except the PV modules. (Sandia Labs)

- A device used in the PV Source and PV Output circuits to combine two or more dc circuit inputs and provide one dc circuit output. (NEC 690.2, proposed 2014)

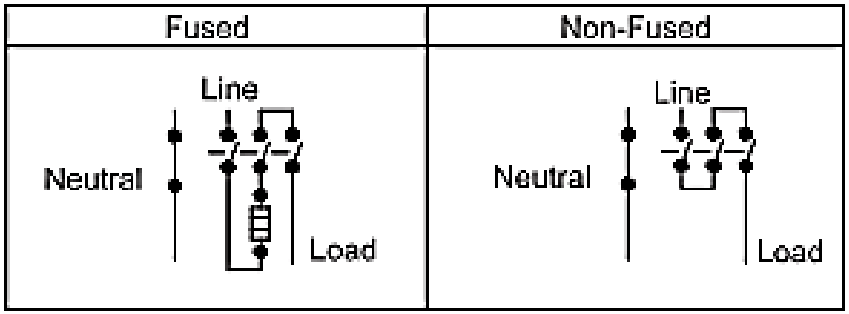
- Also called RHH or RHW wire, AWC cross-link insulation, type XLPE, can be used in aerial, raceway or direct burial allocations. Conductor is copper.

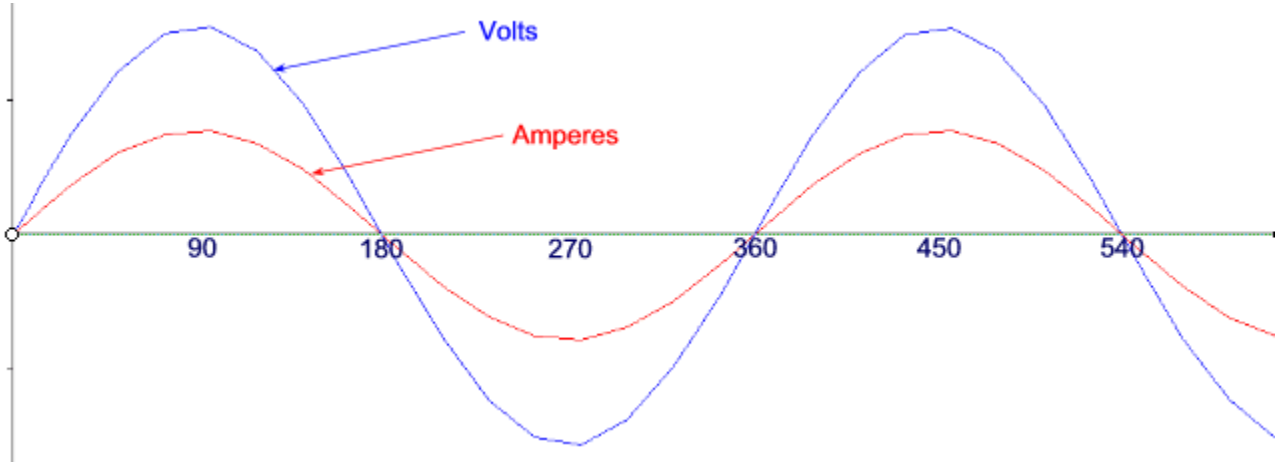



E316464 (O) (UL) PV WIRE 10 AWG (5.26mm²) 90°C DRY
VW-1 OR RHW-2 2000V
RoHS

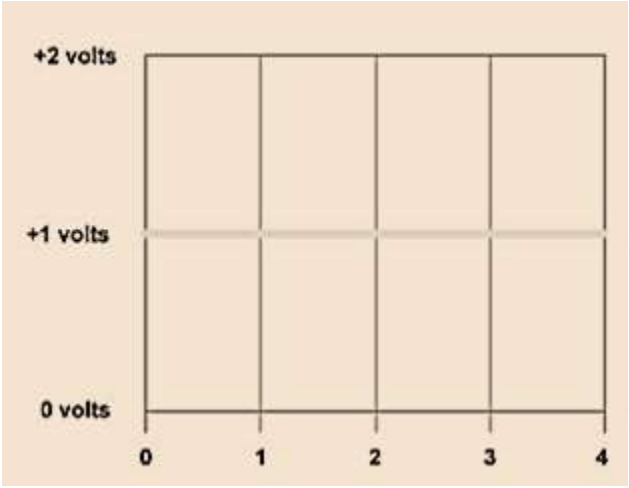
- Note wiring requirements for increased arcing capability of DC circuits

Typical Wiring Diagram




Volts
Amperes
90
180
270
360
450
540

AC


+2 volts
+1 volts
0 volts
0
1
2
3
4

DC

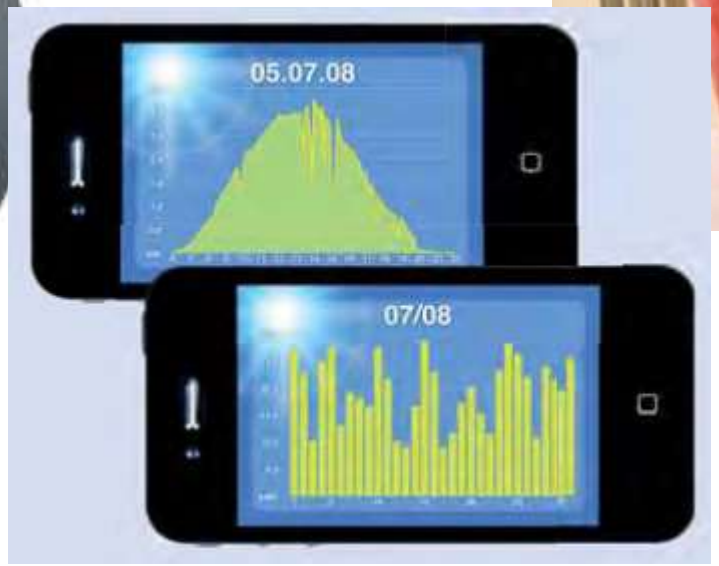
- Equipment that is used to change voltage level or waveform, or both, of electrical energy. (NEC 690.2)


ON
OFF
ON
OFF
ON
OFF

- Production Meter
- Bi-directional Utility Meter

- Wind and temperature
- Pyranometer or Irradiance Sensor


Solar-Log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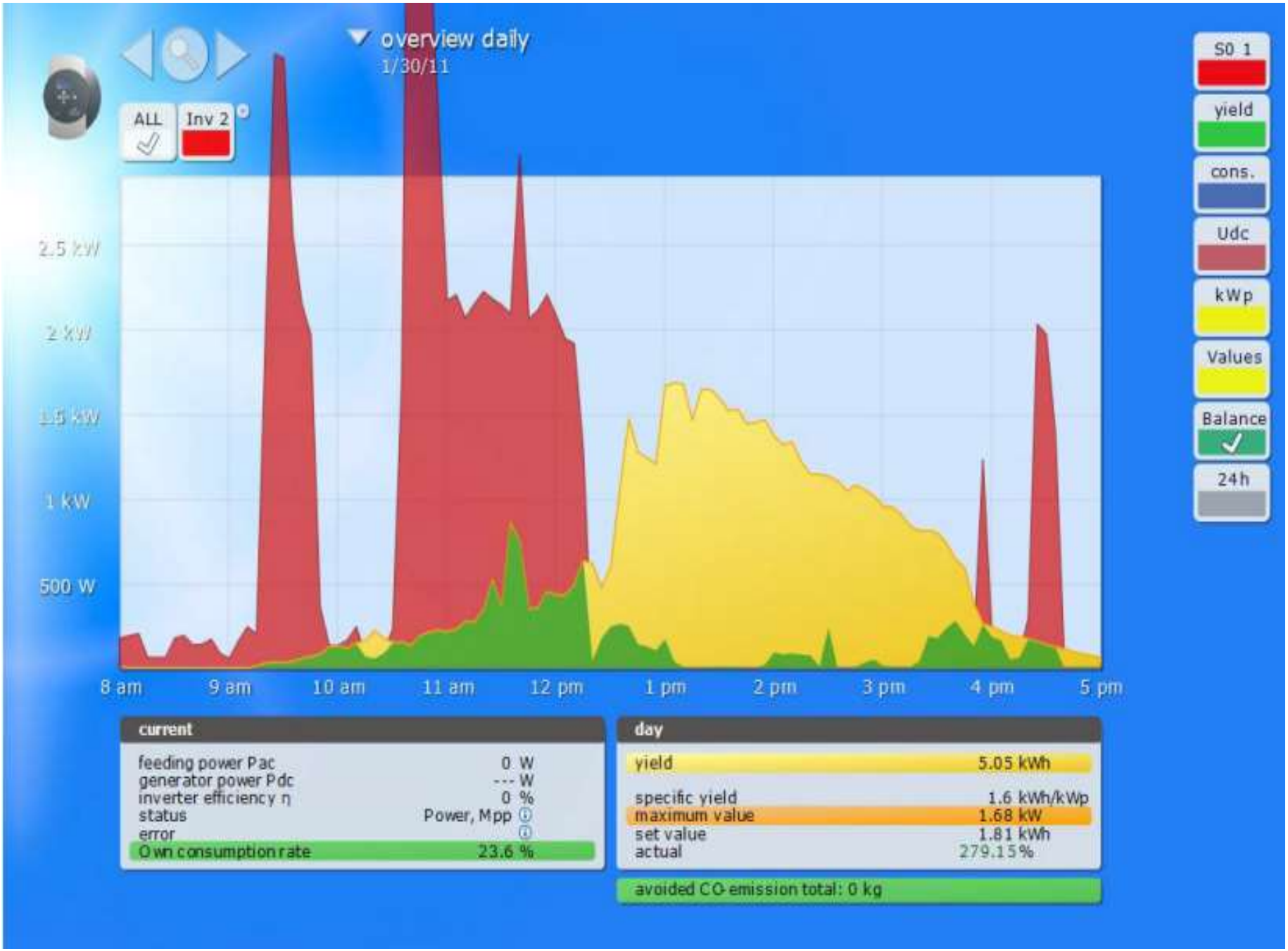
AcquiSuite


overview daily
1/30/11
ALL
Inv 2
S0 1
yield
cons.
Udc
kWp
Values
Balance
24h
2.5 kW
2 kW
1.5 kW
1 kW
500 W
8 am
9 am
10 am
11 am
12 pm
1 pm
2 pm
3 pm
4 pm
5 pm
current
feeding power Pac 0 W
generator power Pdc --- W
inverter efficiency η 0 %
status Power, Mpp
error
Own consumption rate 23.6 %
day
yield 5.05 kWh
specific yield 1.6 kWh/kWp
maximum value 1.68 kW
set value 1.81 kWh
actual 279.15%
avoided CO-emission total: 0 kg

Metro SELF STORAGE for more information, call: (952) 400-6600

SolarVu ENERGY PORTAL

SITE | LIVE | ANALYZER | SETUP | CONTACT | HOME

Metro RV and Mini Storage - Bloomington, MN

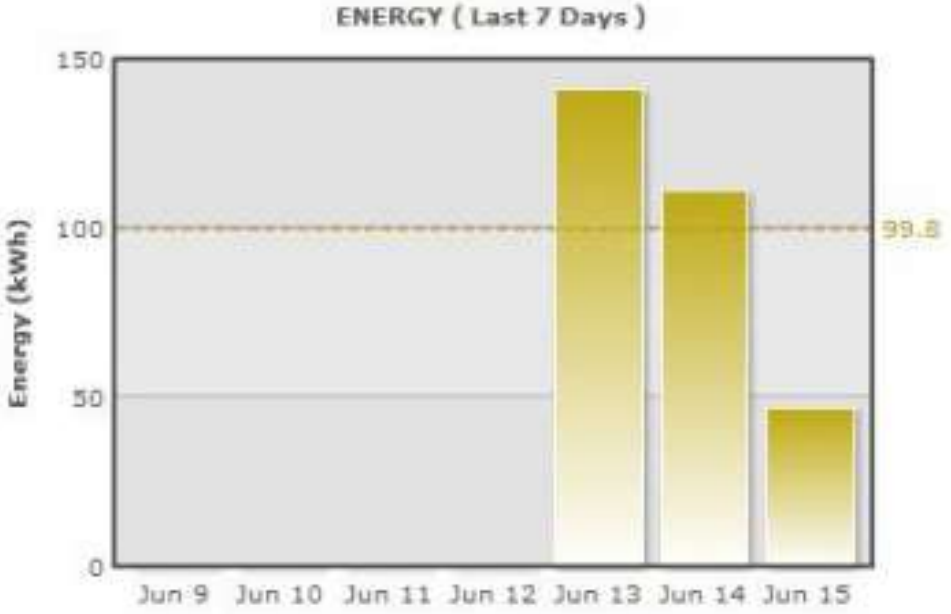
HELP

39 kW

POWER NOW	4,404	Watts
REVENUE TODAY	$1.17	USD
LIFETIME ENERGY	321	kWh
TOTAL REVENUE	$17.03	USD

SYSTEM OK Listen

Last Updated: Jun 16, 2011, Thu 10:22 AM (GMT -6:00)



>1Y 12M YTD 30D 7D 3D 24H Revenue

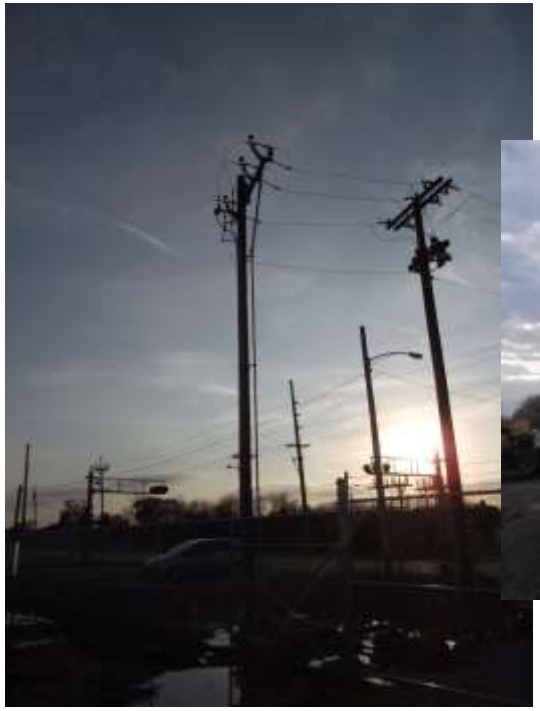
REVENUE	USD $15.86	In Last 7 Days
ENERGY	299 kWh	
SAVED	8.2 US Gals Of Gasoline	

- A system comprised of multiple power sources. (NEC 690.2)

- A solar PV system that supplies power independently of an electrical production and distribution network. (NEC 690.2)

- A solar PV system that operates in parallel with, and may deliver power to, an electrical production and distribution network. (NEC 690.2)

- Equipment having capabilities of both the utility-interactive inverter and the stand-alone inverter (NEC 690.2 proposed 2014)



- A PV subarray that has two conductors in the output circuit, one positive (+) and one negative (-). (NEC 690.2)

- A PV array that has two outputs, each having opposite polarity to a common reference point. (NEC 690.2)

- Single Axis
- Dual Axis

- NEC
- NESC
- IBC
- IRC
- IFC

- 2011 Edition unless otherwise noted

- Covers installation of one or more electric power production sources operating in parallel with a primary source of electricity.

- A PV system shall be permitted to supply a building in addition to any other electricity supply systems.

- PV circuits shall not be contained in the same raceway as conductors of non-PV systems unless separated by a partition.
- PV conductors shall be identified and grouped as required in (B)(1) – (4)

- (1) PV source circuits
- (2) PV output & inverter circuits
- (3) Multiple systems
- (4) Grouping

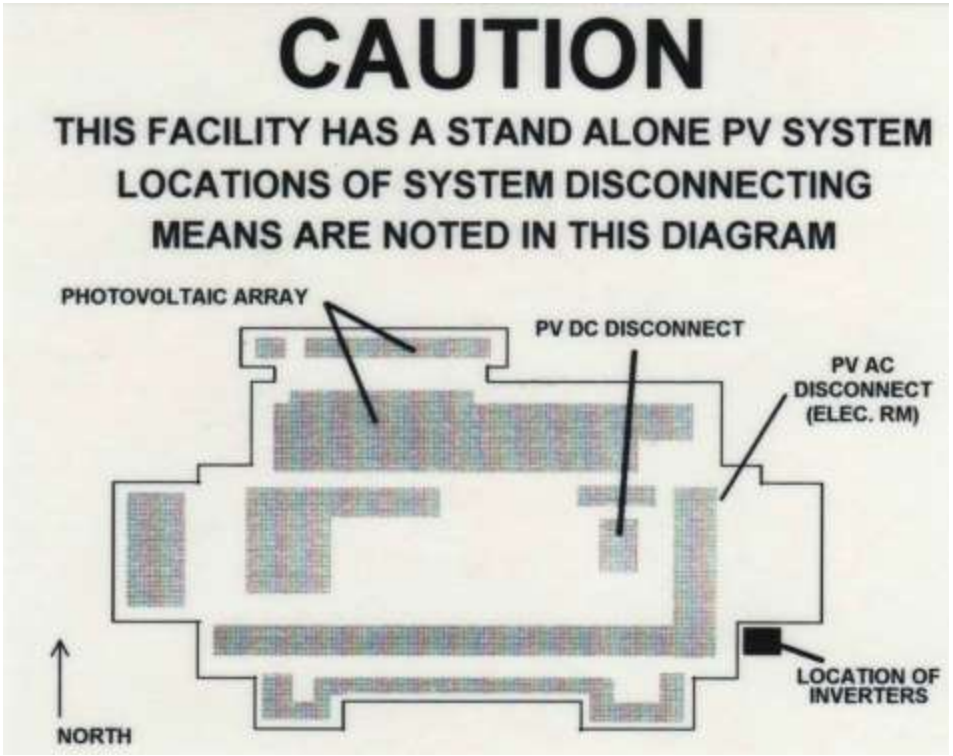
- Removal of a module shall not interrupt a grounded conductor

- Identified and listed for the application

- Shall be installed only by qualified persons
- See Art. 100 for definition
- NABCEP certification? (North American Board of Certified Energy Practitioners)

- PV source & output conductors
- In or out of conduit
- Inside of a building
- Routed along structural members
- Where imbedded in roofing (or concealed by roofing material), location shall be clearly marked

- Disconnecting means and OCPD for each monopole shall be in separate enclosures, unless listed for bipolar.



- Directory required (705.10) showing location of all AC and DC disconnecting means, unless grouped together

- USE-2
- PV wire
- In raceway only when > 30 volts and readily accessible, 690.31(A)

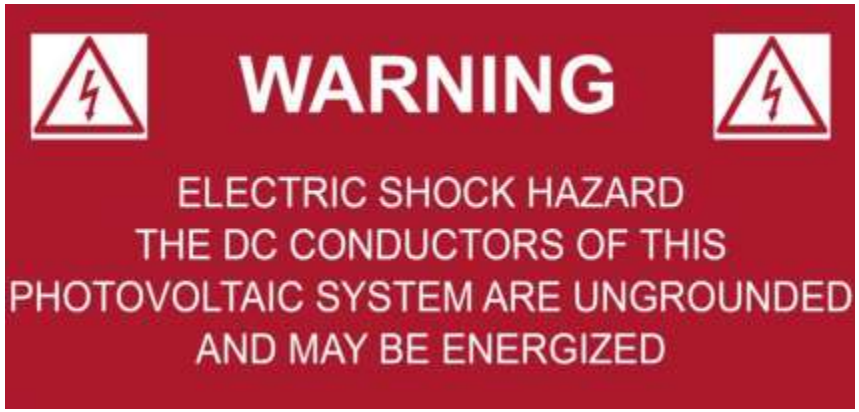
- DC PV source or output circuits where run inside a building, shall be contained in metal raceways or MC cable.

- Beneath roofs requires min. 10 inch clearance
- FMC < 1” requires guard strips, follow building surface, or be protected from damage
- Raceways, enclosures, conduit bodies shall be marked. (ANSI Z 535.4)


CAUTION: SOLAR CIRCUIT

- Connectors shall be rated for interrupting current OR
- Require the use of a tool to open and be marked.

- Ground fault detection system required
- Warning label
- Listed for purpose



- Sum of Voc (Open Circuit Voltage) of modules in series
- Multiply by correction factor in Table 690.7
- Or use manufacturer’s correction factors
- St. Paul average mean low temperature is approximately 4 deg. F = 1.18 (-16 deg. C)

ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)*	230 W
Tolerance of Pmax	+10%/-5%
Type of Cell	Polycrystalline silicon
Cell Configuration	60 in series
Open Circuit Voltage (Voc)	36.9 V
Maximum Power Voltage (Vpm)	29.3 V
Short Circuit Current (Isc)	8.45 A
Maximum Power Current (Ipm)	7.85 A
Module Efficiency (%)	14.1%
Maximum System (DC) Voltage	600 V
Series Fuse Rating	15 A
NOCT	47.5°C
Temperature Coefficient (Pmax)	-0.485%/°C
Temperature Coefficient (Voc)	-0.36%/°C
Temperature Coefficient (Isc)	0.053%/°C

*Illumination of 1 kW/m² (1 sun) at spectral distribution of AM 1.5 (ASTM E892 global spectral irradiance) at a cell temperature of 25°C.

Note Max. System Voltage

Using 13 modules per string (in series)

Using Table 690.7

36.9 volts X 1.18 = 43.54 volts

43.54 X 13 = 566.02 volts

Using Manufacturer's Info

25 – (-16) = 41 deg. C

41 X .36% = 14.76 %

(increase by 14.76%)

36.9 volts X 1.1476 = 42.35 volts

42.35 X 13 = 550.55 volts

NEC prefers to use manufacturer's info when possible

See 690.7(A), second paragraph

- Watch DC voltage range on inverter
- Inverter only puts out at voltage on nameplate – matching utility

- In one and two family dwellings, PV source and output circuits (DC) are permitted to have a max. voltage up to 600 volts (1000 Vdc for 2014)
- Over 600 volts shall comply with Part IX and Art. 490

- Edge-of-Cloud Effect

ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)*	230 W
Tolerance of Pmax	+10%/-5%
Type of Cell	Polycrystalline silicon
Cell Configuration	60 in series
Open Circuit Voltage (Voc)	36.9 V
Maximum Power Voltage (Vpm)	29.3 V
Short Circuit Current (Isc)	8.45 A
Maximum Power Current (Ipm)	7.85 A
Module Efficiency (%)	14.1%
Maximum System (DC) Voltage	600 V
Series Fuse Rating	15 A
NOCT	47.5°C
Temperature Coefficient (Pmax)	-0.485%/°C
Temperature Coefficient (Voc)	-0.36%/°C
Temperature Coefficient (Isc)	0.053%/°C

*Illumination of 1 kW/m² (1 sun) at spectral distribution of AM 1.5 (ASTM E892 global spectral irradiance) at a cell temperature of 25°C.

(1) PV Source Circuit Currents

(2) PV Output Circuit Currents

sc (derated) X 125% for edge-of-cloud effect

Using Manufacturer's Info

33° C (avg. high MN) - 25 = 8° C

8 X .053% = 0.424 %

(increase by 0.424 %)

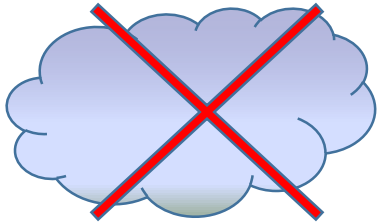
8.45 X 1.00424 = 8.49 A

8.49 X 1.25 = 10.61 Amps

- (3) Inverter Output Currents = Inverter Rating (AC)

SPECIFICATIONS		PVI 3000	PVI 4000	PVI 5000	PVI 5300	PVI 6500	PVI 7500
DC Input							
Absolute Maximum Input Voltage		600 VDC					
MPPT Input Voltage Range		200-550 VDC				230-500 VDC	
Maximum Operating Input Current		16 A	20 A	25 A	25 A	35 A	35 A
AC Output							
Nominal Output Voltage		208 or 240 VAC				208, 240 or 277 VAC	
AC Voltage Range (Standard)		-12%/+10%					
Continuous Output Power	208 VAC	2700W	3400W	4300W	4600W	6500 W	7500 W
	240 VAC	2900W	3900W	4900W	5300W	6500 W	7500 W
	277 VAC	--				6500 W	7500 W
Continuous Output Current	208 VAC	13 A	16.3 A	20.7 A	22.1 A	31.3 A	36.1 A
	240 VAC	13 A	16.3 A	20.7 A	22.1 A	27.1 A	31.3 A
	277 VAC	--				23.5 A	27.1 A
Maximum Backfeed Current		0 A					
Nominal Output Frequency		60 Hz					
Output Frequency Range		59.3-60.5 Hz					
Power Factor		Unity, >0.99					
Total Harmonic Distortion (THD)		<3%					
Efficiency							
Peak Efficiency	208 VAC	96.4%	96.5%	96.4%	96.2%	96.0%	96.2%
	240 VAC	96.7%	96.7%	96.7%	96.4%	96.3%	96.5%
	277 VAC	--				96.7%	96.7%
CEC Efficiency	208 VAC	95.5%	95.5%	96.0%	95.5%	95.5%	
	240 VAC	96.0%	96.0%	96.0%	96.0%	96.0%	
	277 VAC	--				96.0%	
Tare Loss		0.5 W					

No Edge-of-Cloud effect



13 Amps

- PV system currents considered continuous
- Max. current from (A) X 125%
- Permitted to “round up” from 240.4(B), (C), (D)

DC circuits

From 690.8(A)(1)

8.45 X 1.25 = 10.61 Amps

From 690.8(B)(1)

10.61 X 1.25 = 13.26 Amps

15 Amp fuse

AC circuits

From 690.8(A)(3)

13 Amps

From 690.8(B)(1)

13 X 1.25 = 16.25 Amps

20 Amp fuse

- Sized to carry the ***larger*** of (a) ***or*** (b) ***and*** (c)
- (a) Max current from (A) X 125% for continuous
- (b) Max current from (A) after conditions of use have been applied
- (c) Conductor selected must be protected by OCPD after conditions of use have been applied

DC conductor sizing

690.8(B)(2)(a)

From 690.8(A)(1) 8.45 X 1.25 = 10.56 Amps

From 690.8(B)(1) 10.61 X 1.25 = 13.26 Amps

OR

690.8(B)(2)(b)

Table 310.15(B)(3) Conduit 3” off roof, add 40° F

Table 310.15(B)(2)(a) 90 + 40 = 130° F = .76 correction

Table 310.15(B)(3)(a) 8 conductors in conduit = 70%

10.56/(.76 X .7) = 19.84 Amps

690.8(B)(2) Use larger number 19.84 Amps

#12 Cu [verify fuse sizing 690.8(B)(2)(c)]

AC conductor sizing

690.8(B)(2)(a)

From 690.8(A)(3) 13 Amps

From 690.8(B)(1) 13 X 1.25 = 16.25 Amps

OR

690.8(B)(2)(b)

Table 310.15(B)(3) Conduit 3” off roof, add 40° F

Table 310.15(B)(2)(a) 90 + 40 = 130° F = .76 correction

Table 310.15(B)(3)(a) 8 conductors in conduit = 70%

13/(.76 X .7) = 24.44 Amps

690.8(B)(2) Use larger number 24.44 Amps

#12 Cu [verify fuse sizing 690.(B)(2)(c)]

- (A) Circuits and Equipment Art. 240
  - PV source circuit
  - PV output circuit
  - Inverter output circuit
  - Storage battery conductors
  - Equipment

- Exceptions:
  - No external sources

    OR
  - Short-circuit currents from all sources do not exceed the ampacity of the conductors

- Available fault currents in DC system limited to Isc, limited supply system
- For ballpark sizing, industry rule of thumb is 2 X Isc.
- Possibility of 6 X I(max) on AC side of inverter, depending on characteristics, for 3 sine waves or fewer
- Currently being researched

INVERTER #	t_{SC} Minimum (ms)	t_{SC} Maximum (ms)	I_{SC} Minimum (%)	I_{SC} Maximum (%)
SCE_1	13	17	436%	525%
SCE_2	6	17	290%	423%
SCE_3	9	25	163%	423%
SCE_4	1	6	174%	525%
SCE_5	2	34	123%	406%
SCE_6	2	3	373%	423%
SCE_7	3	14	200%	310%
SCE_8	2	130	161%	555%
SCE_10	32	41	290%	600%
SCE_11	20	63	156%	688%
SCE_12	2	18	217%	529%
SCE_13	1	14	80%	324%
SCE_14	1	14	159%	355%
SCE_16	1	228	110%	326%

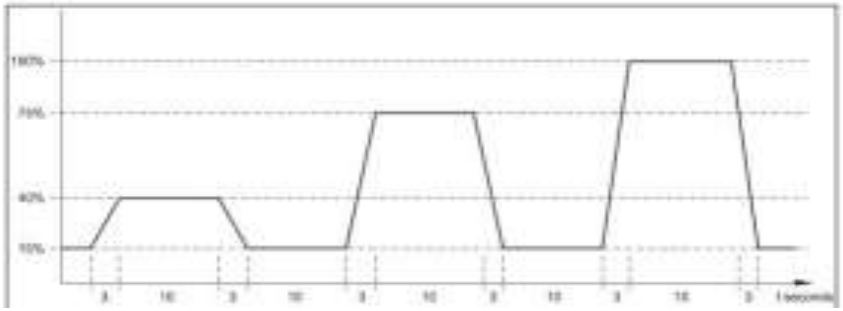
- Accessible, not Readily Accessible

- OCPD shall be listed for use in dc circuits and have the appropriate voltage, current, and interrupt ratings
- 600 Vdc, 1000 Vdc, 1200Vdc, 1500 Vdc


AMP-TRAP
A6D110R
AMP-TRAP
A6D110R
AMP-TRAP
A6D150R

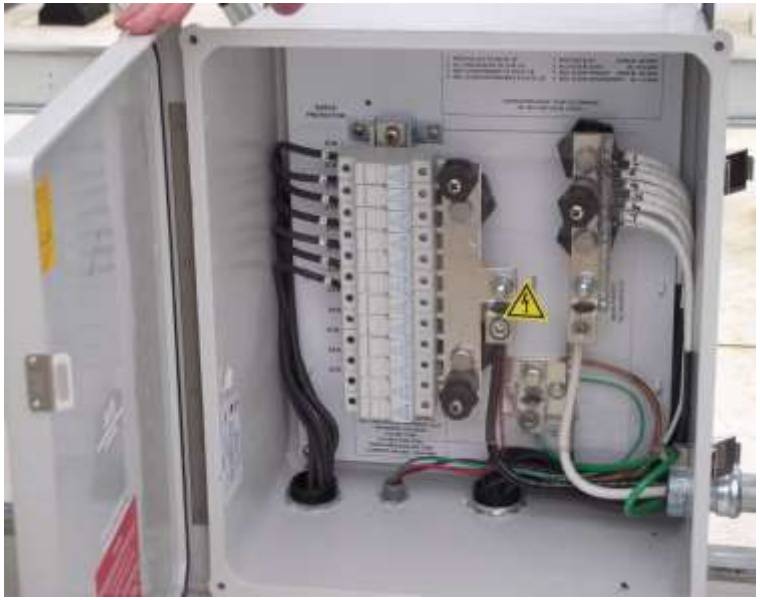
PV Fuse Design Highlights

- Fuse must be marked "PV", "gPV" or "Photovoltaic Fuse"
- Verification: "Freedom from Unacceptable Levels of Thermally Induced Drift"
  - 50 cycles of heating and cooling (-40degC to 90degC), 15 minutes each
  - Subject to same tests as above
- Current Cycling [Simulating Environmental Conditions]
  - Measure initial resistance
    - Set 1: Cycle in temperature chamber; 3000 Cycles as shown below
    - Set 2: Cycle in temperature chamber as noted above;
      Put in Humidity Chamber for 5 days above 90% relative humidity
      3000 Cycles as shown below
  - Measure final resistance of each → no more than 10% change
  - No cracking or grazing of body

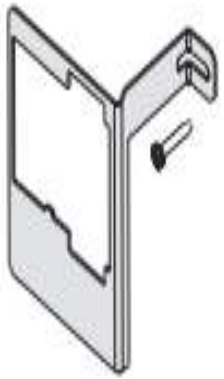


- Ability to mitigate low magnitude faults
- Performance in extreme temps
- Proven in solar environments

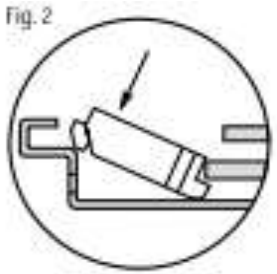
- In PV source circuits, a single overcurrent protection device shall be permitted to protect the PV modules and the interconnecting conductors.



- Plug-in type back-fed breakers connected to a stand-alone inverter output shall be secured, 408.36(D)



PK5RK
Hold-down Bracket /
Soporte de sujeción /
Support de maintien
en place




15
20
200

- Means shall be provided to disconnect all current-carrying dc conductors of a PV system from all other conductors in a building
- A switch shall not disconnect the grounded conductor (exceptions)

- Part of ground-fault detection system - or
- Part of an arc-fault detection system - or

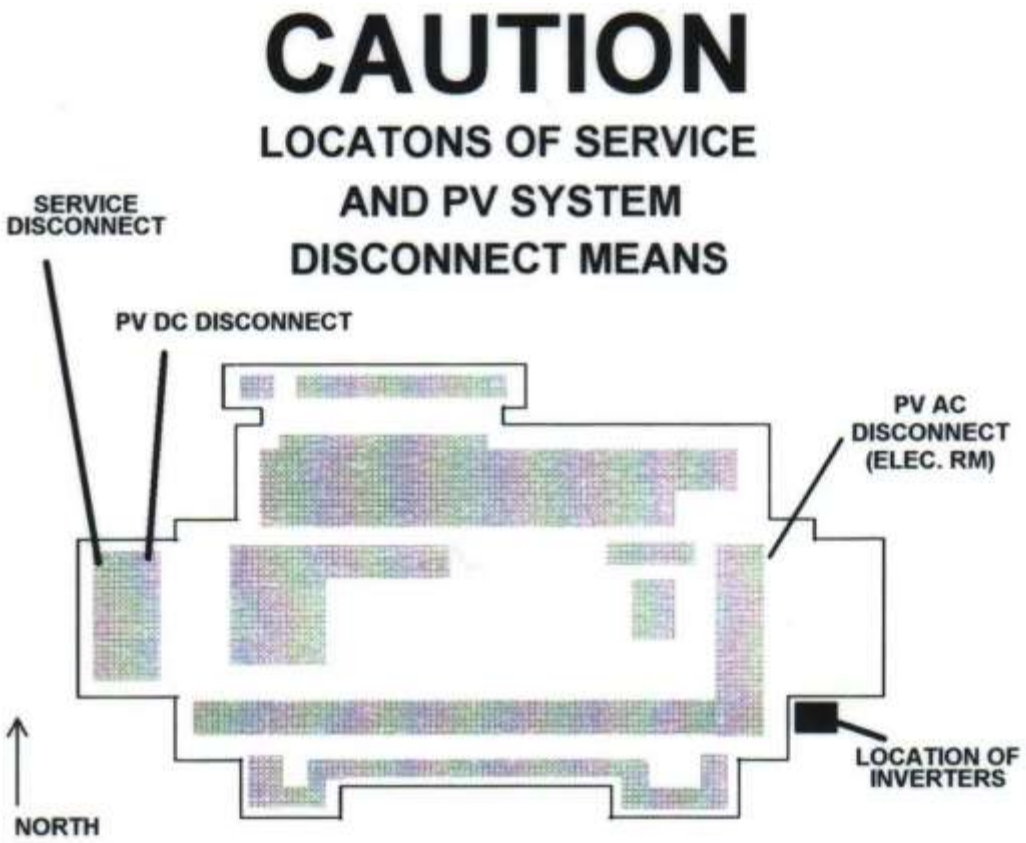
- Only for PV array maintenance - and
- Accessible only by qualified persons - and
- Rated for max. dc voltage and current

- (A) not required to be SUSE rated
- (C)(1) readily accessible
  - (2) Permanently marked
  - (3) Suitable for use – location
  - (4) Maximum of 6
  - (5) Grouped (not required at array)
- Art. 690 does not specify line-load orientation

- (D) Utility-Interactive Inverters in Not-Readily-Accessible locations
  - Permitted to be mounted in areas that are not readily accessible
  - (1) DC disconnect within site of inverter
  - (2) AC disconnect within site of inverter
  - (3) Additional AC disconnecting means in readily accessible location, 690.14(C)(1)
  - (4) Plaque shall be installed, 705.10


SOLECTRIA
RENEWABLES
SOLECTRIA
RENEWABLES
AC disconnect
DC disconnect

Art. 705.10


CAUTION
LOCATONS OF SERVICE
AND PV SYSTEM
DISCONNECT MEANS
SERVICE DISCONNECT
PV DC DISCONNECT
PV AC DISCONNECT (ELEC. RM)
LOCATION OF INVERTERS
NORTH

- Means shall be provided to disconnect equipment
  - Inverters
  - Batteries
  - Charge controllers
  - Etc.
- If energized from more than 1 source, all disconnects shall be grouped and identified

- (A) Disconnecting means shall be provided to disconnect a fuse from all sources of supply if the fuse is energized from both directions
- (B) Fuse Servicing
  - Disconnecting means shall be installed on PV output circuits where fuses must be serviced that cannot be isolated from energized circuits
  - Shall be within sight of, and accessible to, the location of the fuse
  - If more than 6 ft away, directory is required
  - Non-load-break-rated shall be marked

Compact Combiner Boxes (BCBCT Series)

Compact combiners provide a low-cost and space-saving solution to combine up to 6 photovoltaic panel input circuits into a single output going to the inverter. This series is geared towards residential and small commercial solar applications. The BCBCT passthrough variant combines the positive inputs and lets the negative inputs pass through without being combined. This product series uses time-tested Cooper Bussmann 600Vdc DCM and KLM fuse lines to provide the most reliable over-current protection on the market, and finger-safe fuse holders for increased safety. Available in a NEMA 4X polycarbonate enclosure with external mounting feet.

Standard Combiner Box (BCBS 600Vdc and 1000Vdc Series)

Standard combiners offer the means to combine up to 24 solar circuits into a single output, which is ideal for medium to large commercial applications. This series comes in 600Vdc configurations (with Cooper Bussmann DCM/KLM fuses) and 1000Vdc configurations (with Cooper Bussmann PV Solar fuses) for project flexibility. Both series configurations boast finger-safe fuse holders for increased safety, provide variations for both positive and negative grounded arrays, and use 90°C rated output terminals. Available in NEMA 3R, 4, or 4X fiberglass enclosure configurations.

Integrated Disconnect Combiner Box (BCBD Series)

The integrated disconnect combiner box provides an all-in-one package for circuit combination with a disconnecting means in order to save time and money during both the design and implementation phases of a project. With the same features as the 600Vdc standard combiner configurations, the disconnect combiner series adds the ability to break the current going to the inverter for safety and ease of maintenance, and provides lockout/tagout capability for regulatory compliance. The breaking ampacity options are 150 and 245A. Available in NEMA 3R, 4, or 4X fiberglass enclosure configurations.

Recombiner (Array Combiner) Box (BCBR Series)

The recombiner box combines the outputs of multiple string combiners (typically standard or disconnect combiners) into one or more outputs going to the inverter. This series is applicable to large solar array projects where many combiner boxes are specified and the inverter doesn't have enough input circuits. With a 100A or 200A case size category, the recombiner showcases the fast-acting 600Vdc Class RK5 PVS-R fuse specifically designed to protect solar power systems in extreme ambient temperature, high cycling and low level fault current conditions. Available in NEMA 3R, 4, or 4X fiberglass enclosure configurations.

- Disconnecting means shall consist of a manually operable switch(es) or circuit breaker(s)
  - Readily accessible
  - Externally operable
  - Plainly indicating
  - Interrupting rating sufficient for nominal voltage and current
  - Where all terminals may be energized in the open position, a warning sign shall be required


SIEMENS
WARNING:
TURN OFF PHOTOVOLTAIC AC DISCONNECT PRIOR TO WORKING INSIDE PANEL
PHOTOVOLTAIC
AC DISCONNECT
ON
Heavy Duty Safety Switch
OFF
WARNING
MAIN PV SYSTEM
AC DISCONN

- (A) Supply Side
  - Power production source is permitted to be connected to the supply side of the service disconnecting means
  - Sum of the ratings of all overcurrent devices connected to power production sources shall not exceed the rating of the service (new)

- (D) Utility-Interactive Inverters
  - Permitted to be connected to the load side of the service disconnecting means
  - (1) Dedicated OCPD and disconnect
  - (2) The sum of the amp ratings of OCPD in circuits supplying power to a busbar shall not exceed 120% of busbar/conductor rating
  - (3) Shall be on the line side of all ground-fault protection
  - (4) Equipment shall be marked
  - (5) Suitable for backfeed (no line-load marking)
  - (6) Utility-interactive backfeed can omit tie-down


RF-40
3HP
AHU-41
3HP
AHU-40
20HP
RF-38
20HP
WARNING
DO NOT RELOCATE
THIS OVERCURRENT DEVICE
EF-311
5HP
RF-37
15HP
RF-41
3HP


ELEV 15
12
14
WARNING – Dual Power Sources
Second source is photovoltaic system
PV INVERTER/UTILITY INTERFACE
16

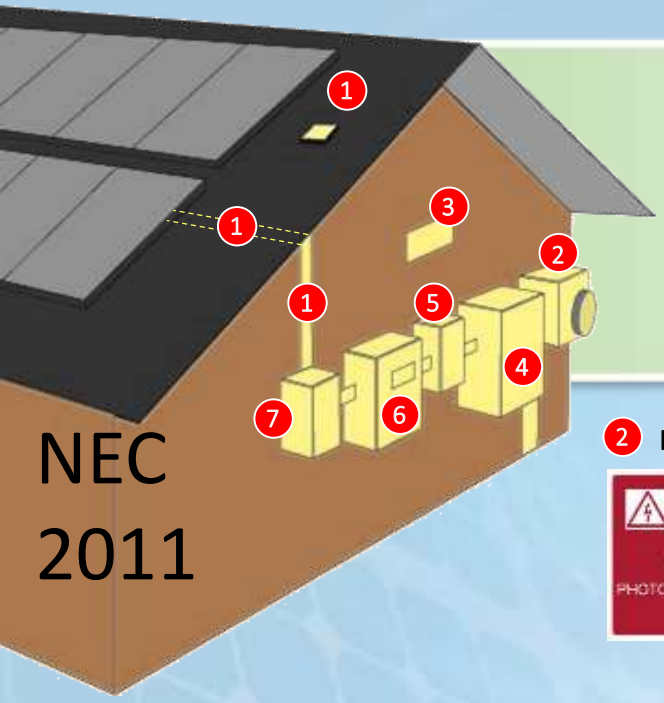

ON
INVER
DO
THIS
WARNING – Dual Power Sources
Second source is photovoltaic system

- (D)(2) The sum of the amp ratings of OCPD in circuits supplying power to a busbar shall not exceed 120% of busbar/conductor rating

- 8 X 30 Amp OCPD’s = 240 Amps
- 225 Amp main + 240 = 465 Amps
- 400 Amp bussbar X 120% = 480 Amps
- Panel is acceptable

- 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.
- A permanent warning label shall be applied


SIEMENS
ON
WARNING
INVERTER OUTPUT CONNECTION
DO NOT RELOCATE
THIS OVERCURRENT DEVICE
WARNING – Dual Power Sources
Second source is photovoltaic system



NEC 2011

Materials used for marking shall be reflective, weather resistant and suitable for the environment. IFC 605.11.1.1.

The markings shall be of sufficient durability to withstand the environment involved. NEC 110.21

1 MAIN SERVICE DISCONNECT

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

Per NEC 690.17 (4)

WARNING:
TURN OFF PHOTOVOLTAIC AC DISCONNECT PRIOR TO WORKING INSIDE PANEL

Per NEC 110.27(C)

WARNING
ELECTRIC SHOCK HAZARD
THE DC CONDUCTORS OF THIS PHOTOVOLTAIC SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED

Per NEC 690.35(F)

NEC690.4(F) Where circuits are embedded under roofing and not covered by PV modules, they shall be clearly marked.

PHOTOVOLTAIC POWER SOURCE

DC conduit, raceways, enclosures, cable assemblies and junction boxes. Use every 10', at every turn, above and below penetrations, and all DC combiner junction boxes per IFC 605.11.1.4 & NEC 690.31 (E)(3)

2 Net Meter

WARNING
ELECTRIC SHOCK HAZARD
THE DC CONDUCTORS OF THIS PHOTOVOLTAIC SYSTEM ARE UNGROUNDED AND MAY BE ENERGIZED

Per NEC 690.5(C)

3 Building/Structure

CAUTION
POWER TO THIS SERVICE IS ALSO SUPPLIED FROM THE FOLLOWING SOURCES WITH DISCONNECTS LOCATED AS SHOWN

Per NEC 690.56(B)

At the location of the ground-fault protection, normally at the inverter, warning of a shock hazard (*NEC* 690.5[C]).

4 Main Service Disconnect

MAIN PV SYSTEM DISCONNECT

Per NEC690.14(2)

CAUTION:
SOLAR ELECTRIC SYSTEM CONNECTED

SOLAR DISCONNECT

4 Breaker Panel/ Pull Boxes

WARNING DUAL POWER SOURCE
SECOND SOURCE IS PV SYSTEM

CAUTION
PHOTOVOLTAIC SYSTEM CIRCUIT IS BACKFED

Per NEC 705.12(D)(4) & NEC 690.64

DO NOT DISCONNECT UNDER LOAD

Per NEC690.33(E)(2)

Conductors at switch or circuit breakers (pull boxes) per NEC 690.4 Main circuit breaker panel and meter per NEC 690.17, Dual power source NEC 705.12(D)(4) and Back-Fed Breakers per NEC705.22.4 and NEC690.64

5 AC Disconnect / Breaker / Points of Connection

PHOTOVOLTAIC
AC DISCONNECT

Per NEC 690.14(C)(2) & 690.15

6 Inverter

PHOTOVOLTAIC AC DISCONNECT
MAXIMUM AC OPERATING CURRENT
NOMINAL OPERATING AC VOLTAGE

Per NEC 690.54

7 DC Disconnect/Breaker

RATED MAX POWER-POINT CURRENT
RATED MAX POWER-POINT VOLTAGE
MAXIMUM SYSTEM VOLTAGE
SHORT CIRCUIT CURRENT
MAX RATED OUTPUT CURRENT OF THE CHARGE CONTROLLER IF INSTALLED

Per NEC 690.52

PV SYSTEM DC DISCONNECT
OPERATING CURRENT
OPERATING VOLTAGE
MAXIMUM SYSTEM VOLTAGE
SHORT CIRCUIT CURRENT

Per NEC 690.53

PHOTOVOLTAIC
DC DISCONNECT

WARNING
ELECTRICAL SHOCK HAZARD
DO NOT TOUCH TERMINALS. TERMINALS ON BOTH LINE AND LOAD SIDES MAY BE ENERGIZED IN THE OPEN POSITION
DC VOLTAGE IS ALWAYS PRESENT WHEN SOLAR MODULES ARE EXPOSED TO SUNLIGHT

Per NEC 690.17(4)

- Grounded dc arrays shall be provided with dc ground-fault protection
- (C) Warning label shall be applied on inverter or near the ground-fault indicator at a visible location
- When the system has batteries, the same warning shall also be applied at the batteries


WARNING
ELECTRICAL SHOCK HAZARD
IF A GROUND FAULT IS INDICATED,
NORMALLY GROUNDED CONDUCTORS
MAY BE UNGROUNDED AND ENERGIZED
PV Ground Fault
ADVANCED ENERGY
solAron 500

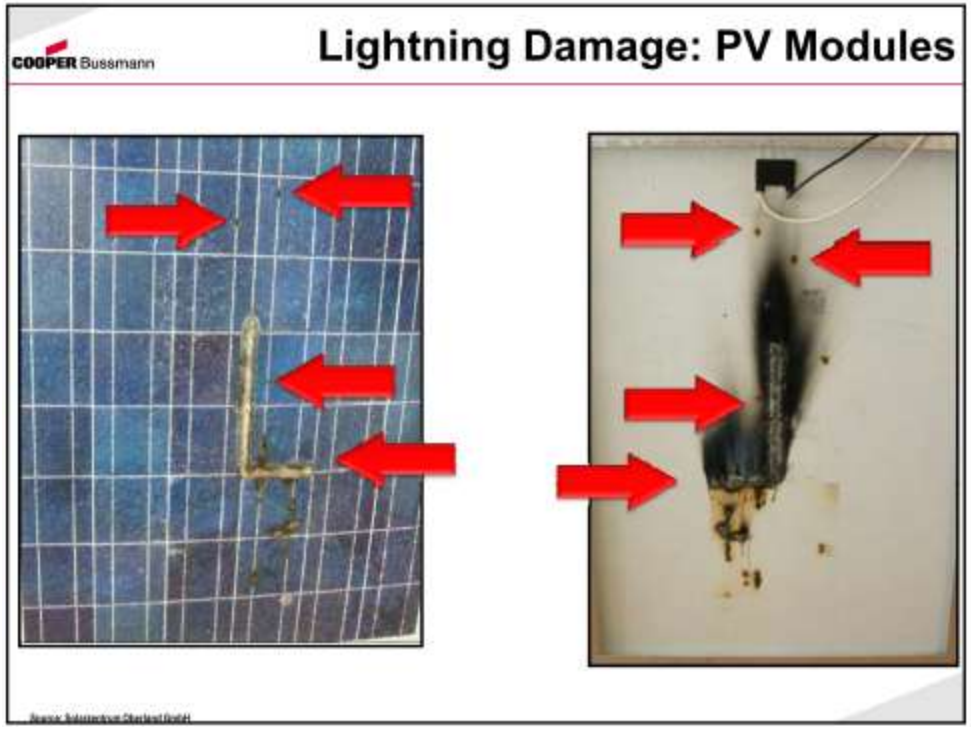
- PV systems with dc circuits
- On or penetrating a building
- Operating at 80 volts or greater
- Shall be protected by a listed dc arc-fault circuit interrupter or other system components listed to provide equivalent protection

- (1) Shall detect and interrupt arcing faults in dc system
- (2) Shall disable inverters or charge controllers or system components
- (3) Shall require equipment be manually restarted
- (4) Shall have an annunciator that provides a visual indication. Indication shall not reset automatically

- **QIDC.E210376 Photovoltaic DC Arc-fault Circuit Protection**
- See General Information for Photovoltaic DC Arc-fault Circuit Protection
- **SMA SOLAR TECHNOLOGY AG**
- E210376
- BLDG 1, 4/4A
- SONNENALLEE 1
- 34266 NIESTETAL, GERMANY

- **Inverter with integral Type 1 Photovoltaic DC Arc-Fault Circuit Protection (transformer)**, Model(s) SB5000-US-12, SB6000-US-12, SB7000-US-12, SB8000-US-12
- **Inverter with integral Type 1 Photovoltaic DC Arc-Fault Circuit Protection (transformer-less)**, Model(s) SB10000TLUS-12, SB8000TLUS-12, SB9000TLUS-12
- Last Updated on 2012-02-21
- QIDC.E210376 E210376 QIDC 133377001 Listing Active 20120221 20120221

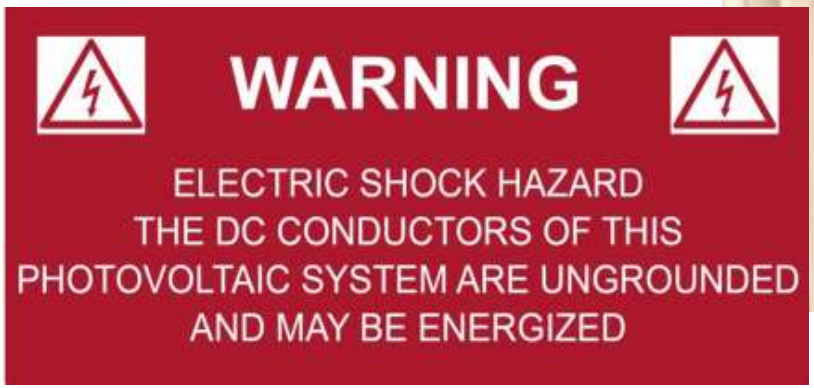
- Not specifically mentioned in Art. 690
- But a good idea

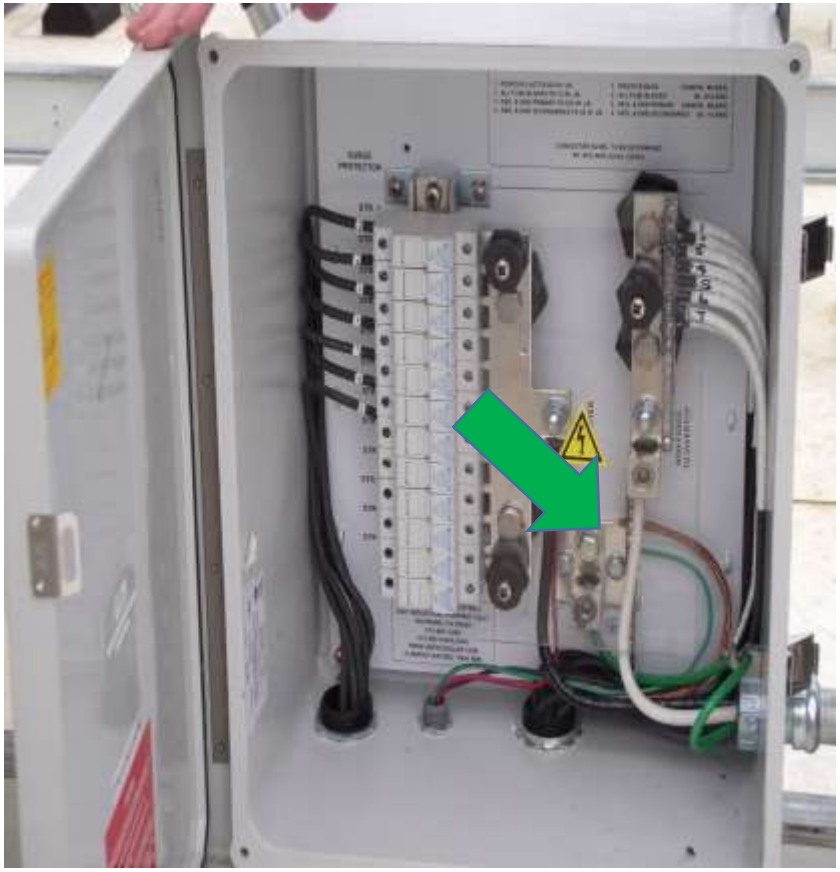


- UL 1449

TVSS
UL OWHX
NOT UL 1449
See Art. 285

- PV systems with a voltage over 50 volts shall be solidly grounded
- Exception, 690.35

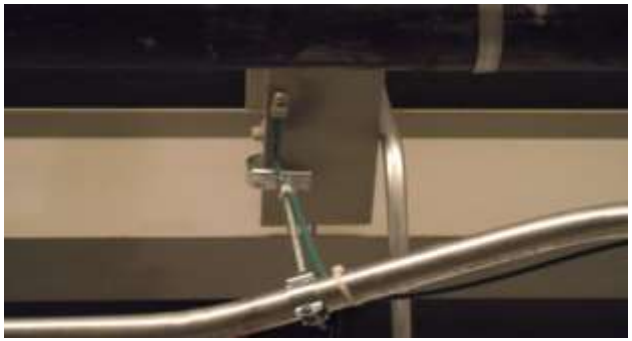




- Grounding connection shall be
  at any single point on the PV output circuit
- Note: Location as close as practicable
  to the PV source
  better protects from lightning

- (A) Exposed non-current-carrying metal parts shall be grounded, 250.134
  - Module frames
  - Electrical equipment
  - Conductor enclosures
- (B) Equipment Grounding Conductor between PV array and other equipment shall be required, 250.110

- (C) Structure as Equipment Grounding Conductor
  - Devices listed and identified for grounding
  - Other equipment
  - Metallic mounting structures shall be identified as equipment grounding conductors
    - Or have identified bonding jumpers or devices connected between the metallic sections
  - Shall be bonded to grounding system



- (D) PV mounting systems that are used to provide grounding shall be identified for the purpose
- (E) Devices identified and listed for bonding the frames shall be permitted to bond the frames to adjacent frames
- (F) EGC's must be run with the PV circuit conductors


WEEB

- (A) Table 250.122
  - Overcurrent protection device if present
  - Assumed OCPD size based on Isc
  - Voltage drop increases not required
  - No smaller than 14 AWG

- (B) Ground fault protection not provided
  - Minimum of 2 X temp. and conduit fill corrected circuit conductor ampacity

Back to 690.8(B)(2) for DC
19.84 Amps X 2 = 39.68 Amps
#8 CU

- Smaller than #6 shall comply with 250.120(C)

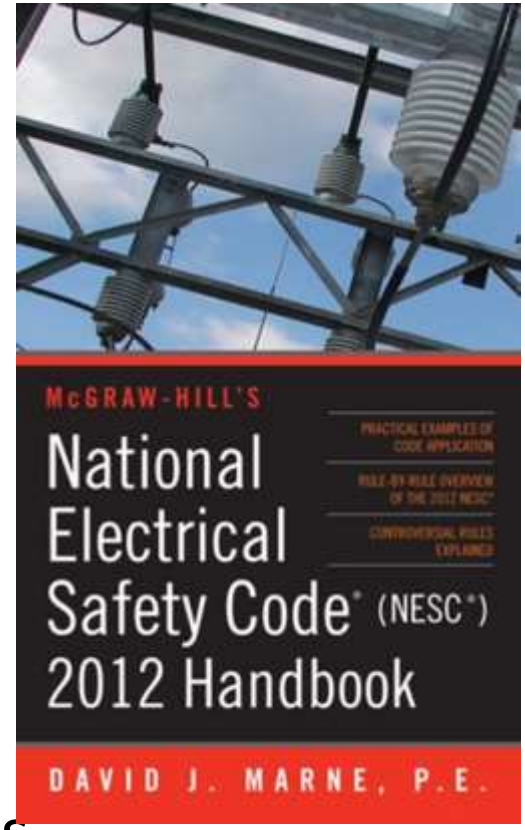
- (A) AC systems: see 250.50 – 250.60
- (B) DC systems: see 250.166 & 250.169
  - Common GEC permitted to serve multiple inverters
  - Sizing according to 250.166
  - Common GEC without splice or joint

- (C) AC & DC systems:
  - (1) Separate dc grounding electrode system bonded to ac grounding electrode system
  - (2) Common dc and ac grounding electrode
  - (3) Combined dc grounding electrode conductor and ac equipment grounding conductor

DC

AC

- 2012 Edition
- No specific reference to solar
- Basis for utility requirements
  - Blue Book
  - Green Book
  - General Orders 95
- Metering requirements
- Anti-Islanding requirements
- For “behind-the-fence” installations



Xcel Energy®

Xcel Energy Solar*Rewards
Final Electrical Inspection Form

Directions

1. Fill out top part of this form with customer name, address and Solar*Rewards Application ID.
2. Provide this form to the Inspector for their signature.
3. Send signed form back to the MN Solar*Rewards team.

Failure to follow these directions will result in application processing delays.

Customer: _____

Address: _____

Solar*Rewards Application ID: _____

The Photovoltaic Array installed at the address above has passed its Final Electrical Inspection by:

City/County: _____

Inspector name: _____

Inspector signature: _____

Phone number: _____

Date: _____

Please return signed form to:

E-mail: SolarProgramMN@xcelenergy.com

Fax: 612-318-4785

Mail: Xcel Energy
Attn: MN Solar*Rewards
414 Nicollet Mall, 6th floor
Minneapolis, MN 55401

Anti-Islanding Test

- Required to energize the system and install bidirectional meter
- Witnessed by utility (Xcel Energy)
- Performed by electrician/installer
- Includes “final” sign-off by electrical inspector

UL 1741

- 2012 Edition

- Rooftop installed PV systems that are adhered or attached to the roof covering or PV modules/shingles installed as roof coverings shall be labeled to identify their fire classification.

- The installation of photovoltaic modules/shingles shall comply with the provisions of this section
  - .1 Material Standards (UL 17030)
  - .2 Attachment (manufacturer's instructions)
  - .3 Wind resistance (ASTM D 3161)

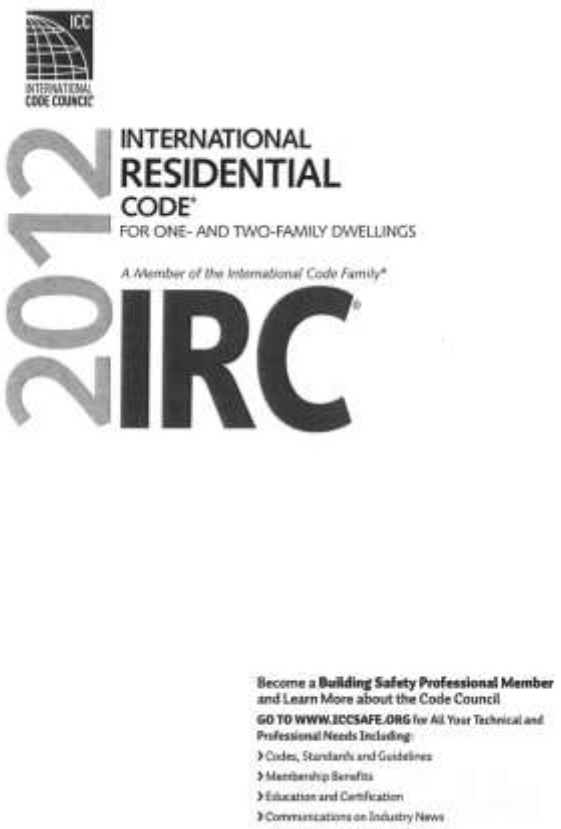
- Shall comply with IFC
- Structural frame and roof construction supporting the load imposed shall comply with Table 601

TABLE 601
FIRE-RESISTANCE RATING REQUIREMENTS FOR BUILDING ELEMENTS (HOURS)

BUILDING ELEMENT	TYPE I		TYPE II		TYPE III		TYPE IV	TYPE V	
	A	B	A[d]	B	A[d]	B	HT	A[d]	B
Primary structural frame[g] (see Section 202)	3[a]	2[a]	1	0	1	0	HT	1	0
Bearing walls Exterior[e,g] Interior	3 3[a]	2 2[a]	1 1	0 0	2 1	2 0	2 1/HT	1 1	0 0
Nonbearing walls and partitions Exterior	See Table 602								
Nonbearing walls and partitions Interior[e]	0	0	0	0	0	0	See Section 602.4.6	0	0
Floor construction and associated secondary members (see Section 202)	2	2	1	0	1	0	HT	1	0
Roof construction and associated secondary members (see Section 202)	1½[b]	1[b,c]	1[b,c]	0[c]	1[b,c]	0	HT	1[b,c]	0

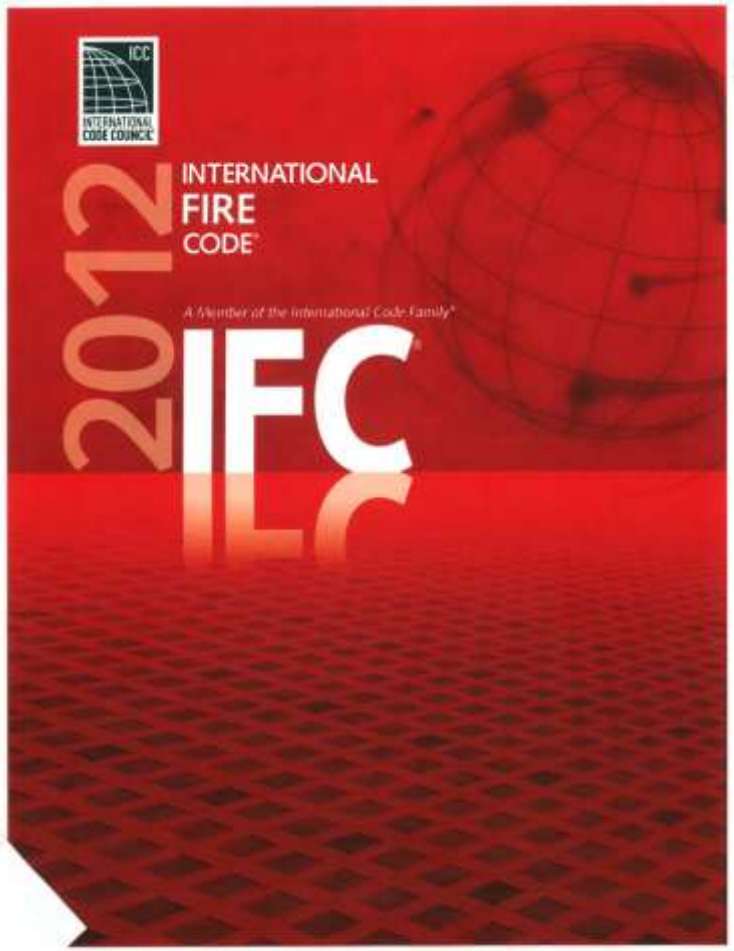
- Solar photovoltaic panels/modules shall comply with the requirements of this code and the International Fire Code

- 2012 Edition



- This section provides for the design, construction, installation, and repair of PV equipment and systems.
  - Shall comply with the manufacturer's instructions and NEC
  - Roof-mounted panels:
    - The roof shall be constructed to support the loads imposed.
    - Panels that serve as roof covering shall conform to Chap. 9.
    - Where mounted on or above the roof, shall be constructed of noncombustible materials or fire-retardant-treated wood.

- 2012 Edition



- A construction permit is required to install or modify solar photovoltaic power systems.

GENERAL BUILDING PERMIT APPLICATION

PROJECT ADDRESS

Contractor

State Building Contr. Lic. #

Contractor's Email:

Property Owner

Select the Type of Work ► ☐ New Structure ☐ Addition ☐ Remodel/Alter ☐ Repair

Select Applicable Installation Below.

☐ Windows: # of windows ►

☐ Roofing: # of squares ►

☐ Siding: # of squares ►

► Note: 1 Square = 100 Square Feet

Select Type of Use ►

Mixed Commercial/ Residential buildings enter information for both the Residential and Commercial Use.

☐ Residential: # of Existing Dwelling Units ► / Final # of Dwelling Units ► / # of Dwelling Units Worked On ►

☐ Commercial: Value of Contr. Work ► $

Est. Start Date ►

Est. Finish Date ►

Total Value ► $

Description of Project:

Applicant certifies that all information is correct and that all pertinent state regulations and city ordinances will be complied with in performing the work for which this permit is issued.

Applicant's Signature

PLEASE COMPLETE THIS SECTION ONLY FOR NEW STRUCTURE OR ADDITION

Structure Dimensions (In Feet)

Width	Length	Height	Total Square Feet (include basement)	Basement	# of Stories
				Yes No	

Is a Fire Suppression System Available? (i.e. – Sprinklers) Yes ☐ No ☐

Lot Dimensions (In Feet)		Set Backs from Property Lines			
Lot Width	Lot Depth	Front	Back	Side 1	Side 2

For Office Use Only

Change/Expansion of Use? Yes / No

Existing Primary Use | Occupancy Group

Proposed Primary Use | Construction Type

Zoning District | Plan Number

PLAN REVIEW REMARKS

SUMMARY OF FEES	
Building Permit Fee	$
Plan Check Fee	$
State Surcharge	$
SAC	$
SAC Processing Fee	$
Design Review Fee	$
Park Dedication Fee	$
Total Permit Fee	$

S.A.C. #: Charge Credit | Reviewed By: | Date: | Warning Folder # | Vacant Bldg. Folder #

State Valuation : $

PERMIT # ►

Signature of Cardholder (required for all charges):

☐ American Express ☐ Discover ☐ MasterCard ☐ Visa

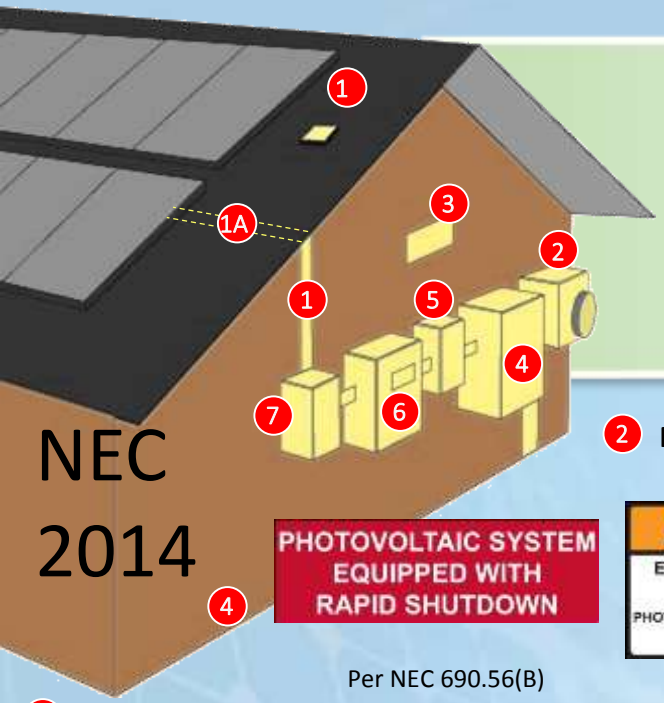
Expiration Month/Year ►

Enter Account Number ►►

- Solar photovoltaic power systems shall be installed in accordance with Sections 605-11-1 through 605.11.4, the IBC, and NFPA 70 (NEC).
- **Exception**: Detached, nonhabitable Group U structures including, but not limited to, parking shade structures, carports, solar trellises and similar structures shall not be subject to the requirements of this section.

- Marking is required on interior and exterior DC conduit, enclosures, raceways, cable assemblies, junction boxes, combiner boxes and disconnects.
  - Reflective, weather resistant and suitable for the environment. All letters capitalized, min height of 3/8”, white on red background.
  - “WARNING: PHOTOVOLTAIC POWER SOURCE”
  - At main service disconnect
  - On raceways, enclosures, cable assemblies every 10 ft., within 1 ft. of turns, within 1 ft. of penetrations.

NEC 2014



Materials used for marking shall be reflective, weather resistant and suitable for the environment.
IFC 605.11.1.1.

The label shall be suitable for the environment where it is installed.
NEC 110.21

5 AC Disconnect / Breaker / Points of Connection

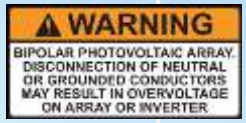
Per NEC 690.54

Per NEC 690.13(B) & 690.15

6 Inverter

Per NEC 690.54

Per NEC 690.5(C)

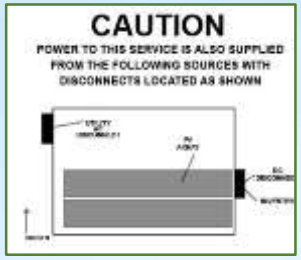


Per NEC 690.4(G)

2 Net Meter

Per NEC 690.5(C)

3 Building/Structure

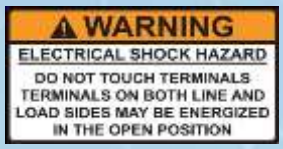


Per NEC 690.56(A)

4 PHOTOVOLTAIC SYSTEM EQUIPPED WITH RAPID SHUTDOWN

Per NEC 690.56(B)

4 Main Disconnect



Per NEC 690.17(E)

Per NEC 110.27(C)

Per NEC 690.35(F)

Conduit

1A

NEC690.4(F) Where circuits are embedded under roofing and not covered by PV modules, they shall be clearly marked.

1

WARNING: PHOTOVOLTAIC POWER SOURCE

DC conduit, raceways, enclosures, cable assemblies and junction boxes. Use every 10', at every turn, above and below penetrations, and all DC combiner junction boxes per IFC 605.11.1.4 & NEC 690.31 (E)(3)

5 AC Disconnect

MAIN PHOTOVOLTAIC SYSTEM DISCONNECT

Per NEC690.13(B)

CAUTION: SOLAR ELECTRIC SYSTEM CONNECTED

SOLAR DISCONNECT

Per NEC 690.52

4 Panel Breakers/ Pull Boxes

WARNING DUAL POWER SOURCE
SECOND SOURCE IS PHOTOVOLTAIC SYSTEM

Per NEC705.12(D)(4)

CAUTION
PHOTOVOLTAIC SYSTEM CIRCUIT IS BACKFED

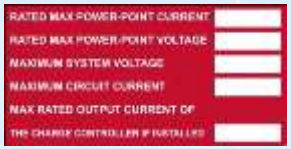
Per NEC 705.12(D)(4) & NEC 690.64

DO NOT DISCONNECT UNDER LOAD

Per NEC690.33(E)(2)

At the location of the ground-fault protection, normally at the inverter, warning of a shock hazard (*NEC* 690.5[C]).

7 DC Disconnect/Breaker



Per NEC 690.53

Per NEC 690.15

Per NEC 690.17(E)

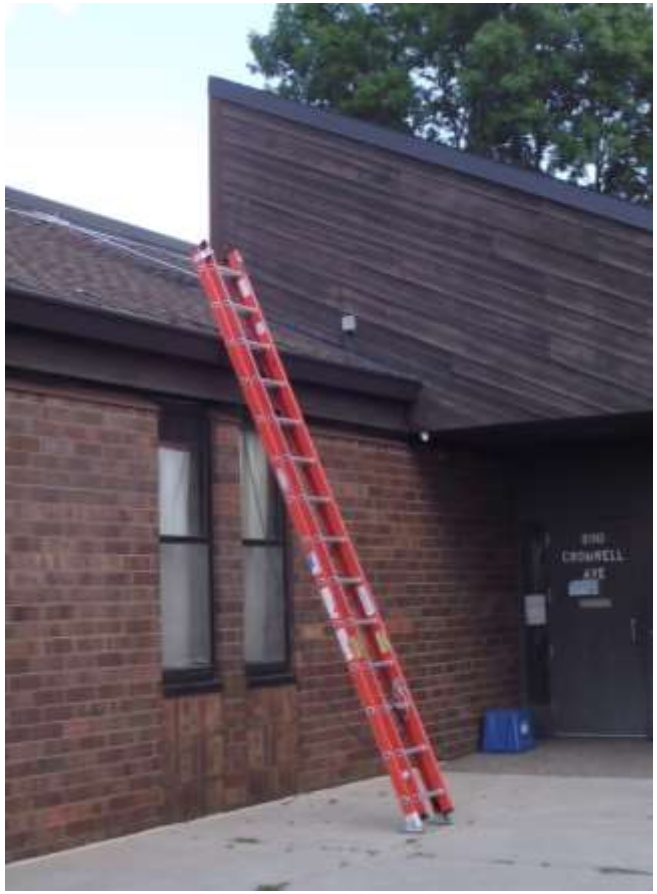
ecoVISION ELECTRIC

HellermannTyton

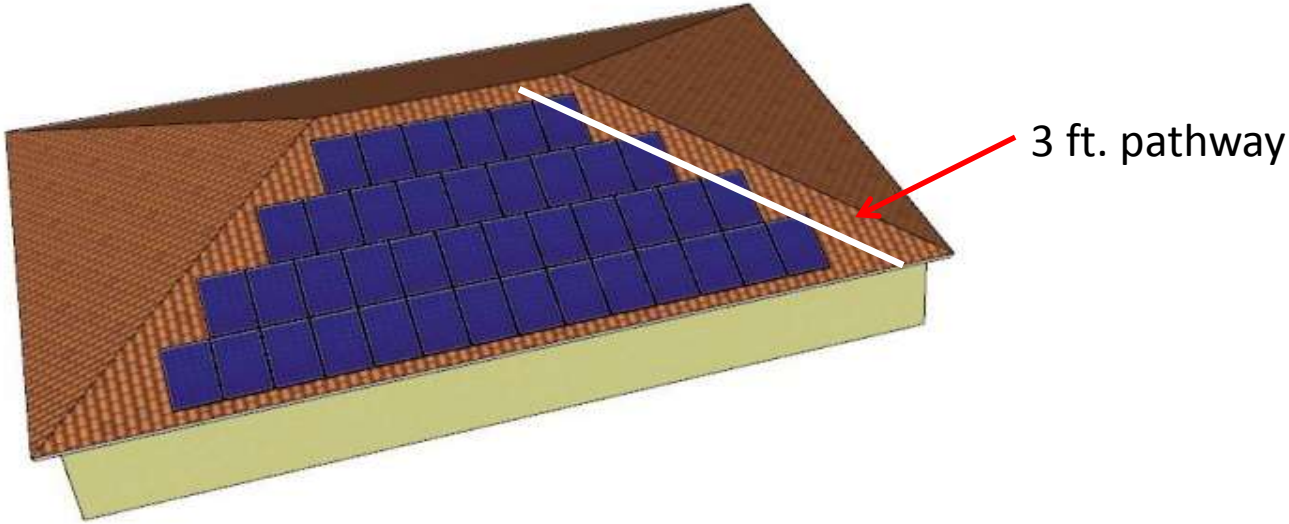
- Locations of DC conductors
  - As close as possible to the ridge or hip or valley, then as directly as possible to an outside wall
    - Reduce trip hazards
    - Maximize ventilation opportunities
    - Minimize total amount of conduit on roof
    - Installed in metallic conduit/raceway when inside building
    - Conduit run along the bottom of load bearing members

- Roof access, pathways, and spacing requirements shall be provided in accordance with 3.1 – 3.3
- Exception:
  - Residential structures shall be designed so that each PV array is no greater than 150 ft. by 150 ft. in either axis
  - Panels shall be permitted to be located up to the roof ridge where an alternative ventilation method approved by the fire chief has been provided

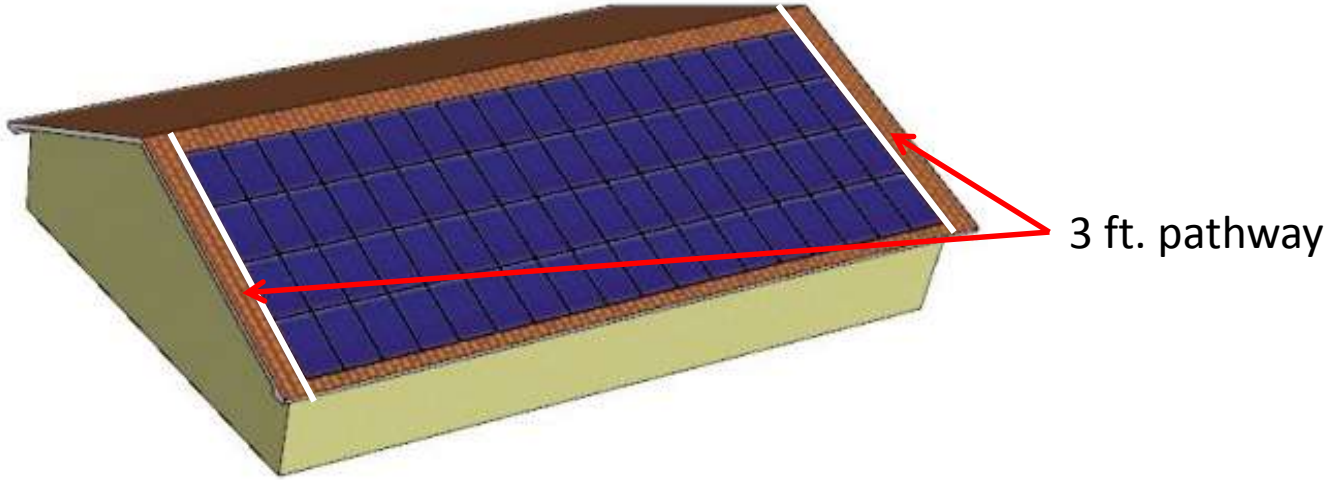
- Access and pathways
  - Roof access points shall be located in areas that do not require the placement of ladders over openings such as windows or door, and located at strong points of building construction in locations where the access point does not conflict with overhead obstructions such as tree limbs, wires, or signs.



- Residential systems for 1 and 2 family dwellings
  - With hip roof: panels shall be located in a manner that provides a 3 ft. wide clear access pathway from the eave to the ridge on each roof slope where panels are located
    - Exception: Does not apply to roofs with slopes of 2:12 or less.



- Residential systems for 1 and 2 family dwellings
  - With single ridge: panels shall be located in a manner that provides two, 3 ft. wide clear access pathways from the eave to the ridge on each roof slope where panels are located
    - Exception: Does not apply to roofs with slopes of 2:12 or less.



- Residential systems for 1 and 2 family dwellings
  - With roof hips and valleys: panels shall be located no closer than 18” to a hip or valley where panels are to be places on both sides of a hip or valley. Where panels are located on only one side of a hip or valley that is of equal length, the panels shall be permitted to be placed directly adjacent to the hip or valley.
    - Exception: Does not apply to roofs with slopes of 2:12 or less.

- Residential building smoke ventilation
  - Panels installed on residential buildings shall be located no higher than 3 feet below the ridge in order to allow for smoke ventilation operations.

- Other than residential buildings. Access shall be provided in accordance with 3.1 – 3.3
  - Exception: Where it is determined by the fire code official that the roof configuration is similar to that of a one- or two-family dwelling, the residential access requirements in 605.11.3.2.1 – 605.11.3.2.4 shall be permitted.

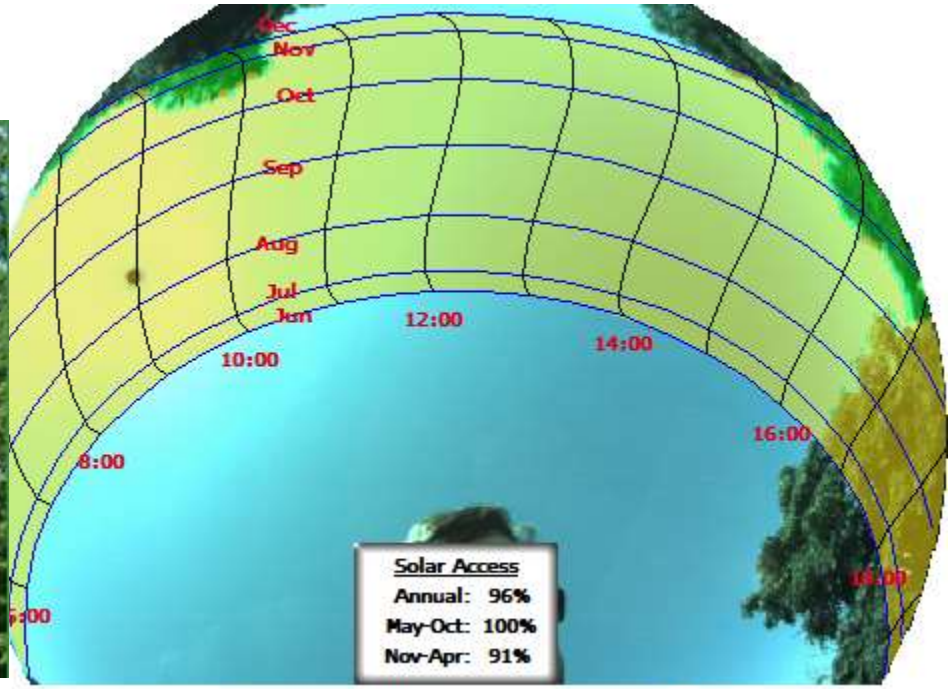
- Access: There shall be a minimum 6 ft. wide clear perimeter around the edges of the roof.
  - Exception: Where either axis of the building is 250 ft. or less, there shall be a minimum 4 ft. wide clear perimeter around the edges of the roof.

- Pathways: The solar installation shall be designed to provide designated pathways.
  - Shall be over areas capable of supporting the live load of fire fighters
  - Centerline axis pathways shall be provided in both axes of the roof.
  - Shall be a straight line not less than 4 ft. clear to skylights or ventilation hatches
  - Shall be a straight line not less than 4 ft. clear to roof standpipes
  - Shall provide not less than 4 ft. clear around roof access hatch with at least one clear pathway to parapet or roof edge

- Smoke ventilation
  - Arrays shall be no greater than 150 ft. by 150 ft. in either axis to create opportunities for smoke ventilation operations.
  - Smoke ventilation options between array sections shall be one of the following:
    - A pathway 8 ft. or greater in width
    - A 4 ft. or greater pathway and bordering roof skylights or smoke/heat vents
    - A 4 ft. or greater pathway and bordering 4 ft. X 8 ft. “venting cutouts” every 20 ft. on alternating sides of the pathway.

- Ground-mounted photovoltaic arrays
  - Shall comply with 605.11 through 605.11.2 and this section.
  - Setback requirements shall not apply to free-standing PV arrays.
  - A clear, brush-free area of 10 ft. shall be required.

- Design for full sun from 10 AM to 2 PM (solar time) at winter solstice
- Account for growth of vegetation
- Dirt accumulation



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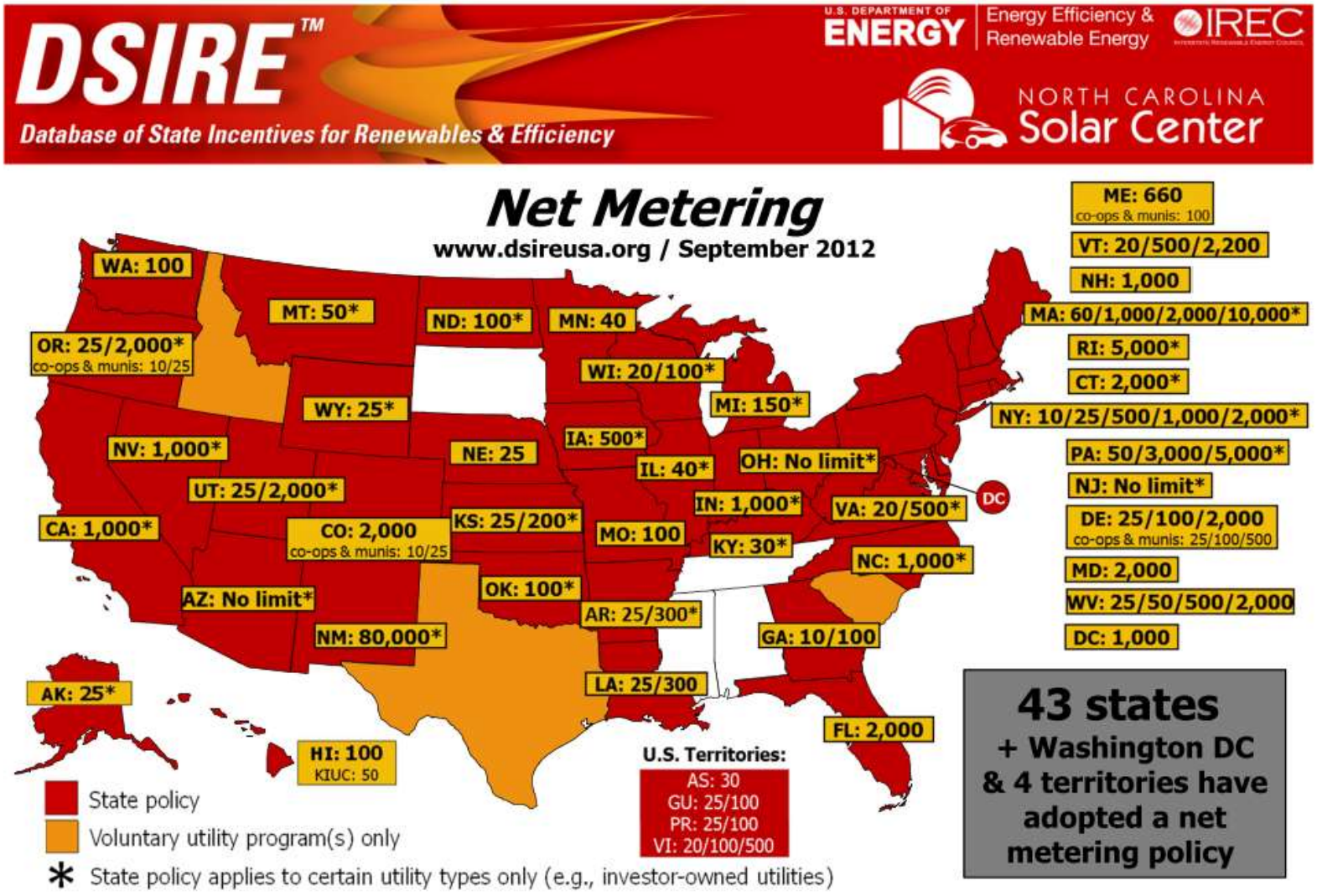
- TIF’s
- REC’s
- Net Metering
- FIT’s
- Etc.

- Tax Increment Financing for solar PV projects
- Residential solar projects frequently exempt from property tax
- Some states allow price of solar system install to offset taxes

- Renewable Energy Certificates
- 1 REC = 1 Megawatt-hour of renewable energy production
- Electrons are difficult to track
- Provides tracking source for who gets credit for the power produced.


DSIRE™
Database of State Incentives for Renewables & Efficiency
U.S. DEPARTMENT OF ENERGY
Energy Efficiency & Renewable Energy
IREC
NORTH CAROLINA Solar Center
Net Metering
www.dsireusa.org / September 2012
WA: 100
OR: 25/2,000*
co-ops & munis: 10/25
CA: 1,000*
NV: 1,000*
MT: 50*
WY: 25*
UT: 25/2,000*
AZ: No limit*
CO: 2,000
co-ops & munis: 10/25
NM: 80,000*
ND: 100*
NE: 25
KS: 25/200*
OK: 100*
TX
MN: 40
IA: 500*
MO: 100
AR: 25/300*
LA: 25/300
WI: 20/100*
IL: 40*
MI: 150*
IN: 1,000*
OH: No limit*
KY: 30*
TN
MS
AL
GA: 10/100
FL: 2,000
SC
NC: 1,000*
VA: 20/500*
DC
WV: 25/50/500/2,000
PA: 50/3,000/5,000*
NY: 10/25/500/1,000/2,000*
NJ: No limit*
DE: 25/100/2,000
co-ops & munis: 25/100/500
MD: 2,000
CT: 2,000*
RI: 5,000*
MA: 60/1,000/2,000/10,000*
VT: 20/500/2,200
NH: 1,000
ME: 660
co-ops & munis: 100
DC: 1,000
AK: 25*
HI: 100
KIUC: 50
U.S. Territories:
AS: 30
GU: 25/100
PR: 25/100
VI: 20/100/500
State policy
Voluntary utility program(s) only
* State policy applies to certain utility types only (e.g., investor-owned utilities)
43 states
+ Washington DC
& 4 territories have
adopted a net
metering policy

- Feed In Tariffs (Performance Based Incentives)
- A payment above the market rate paid to a small-scale producer of renewable energy by a large energy provide
- Based on state requirements and individual utility policy

From solar
$$

From utility
$

- www.dsireusa.org
- www.energy.mn.gov

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