



2014 National Electrical Code Updates for PV Systems

February 24, 2015

Duluth Energy Design Conference

Continuing Education

In accordance with the Department of Labor and Industry's statute 326.0981, Subd. 11,

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Course Overview

1. New NEC Definitions
2. Code wide changes:
 - Field Applied Labeling
 - DC Color Coding
3. Changes to Article 690

Definitions: Article 100

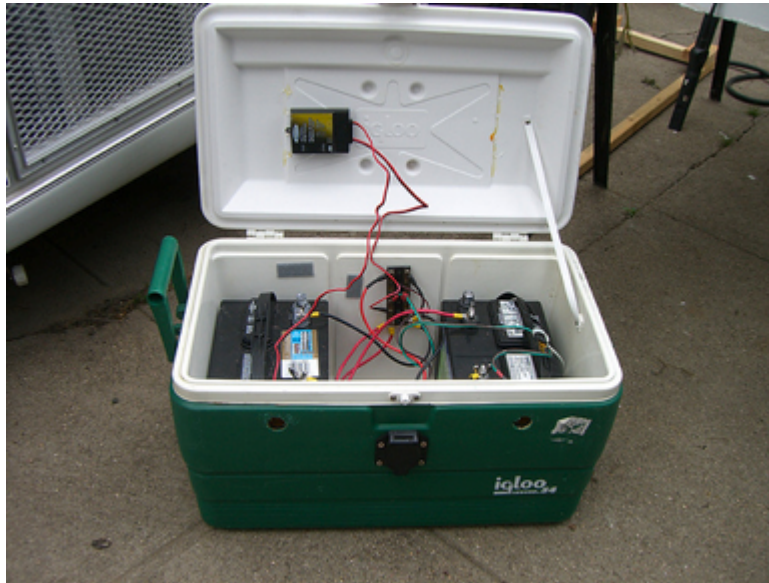
Accessible, Readily (Readily Accessible).

Capable of being reached quickly for operation, renewal, or inspections without requiring those to whom ready access is requisite *to actions such as to use tools*, to climb over or remove obstacles, or to resort to portable ladders, and so forth.

Definitions: Article 100

Battery System.

Interconnected battery subsystems consisting of one or more storage batteries and battery chargers, and can include inverters, converters, and associated electrical equipment.



Source: : National Fire Protection Association. *NFPA-70 National Electrical Code 2014 Edition*. Quincy, MA. <https://www.flickr.com/photos/danlin/2333525862/in/photostream/>.

Definitions: Article 100

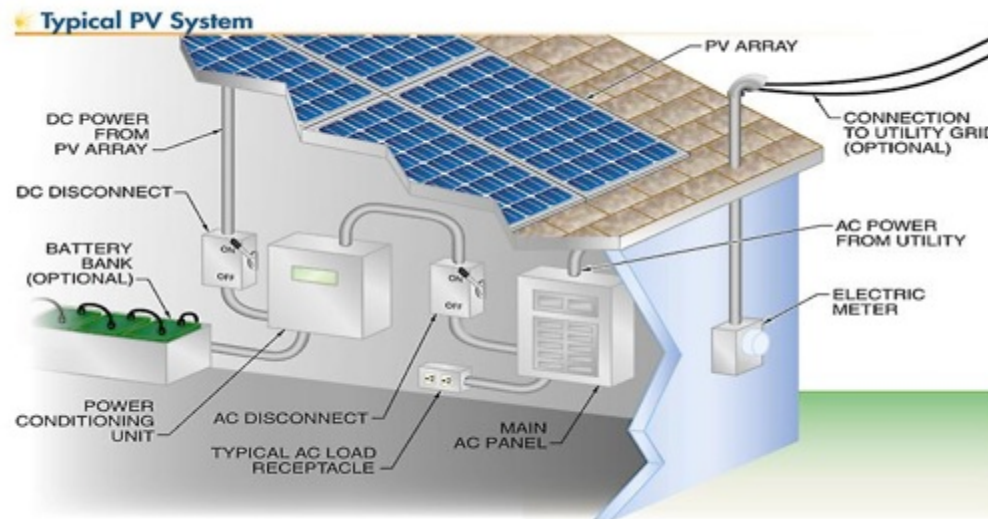
Charge Controller.

Equipment that controls dc voltage or dc current, or both, and that is used to charge a battery or other energy storage device.

Definitions: Article 100

Photovoltaic (PV) System.

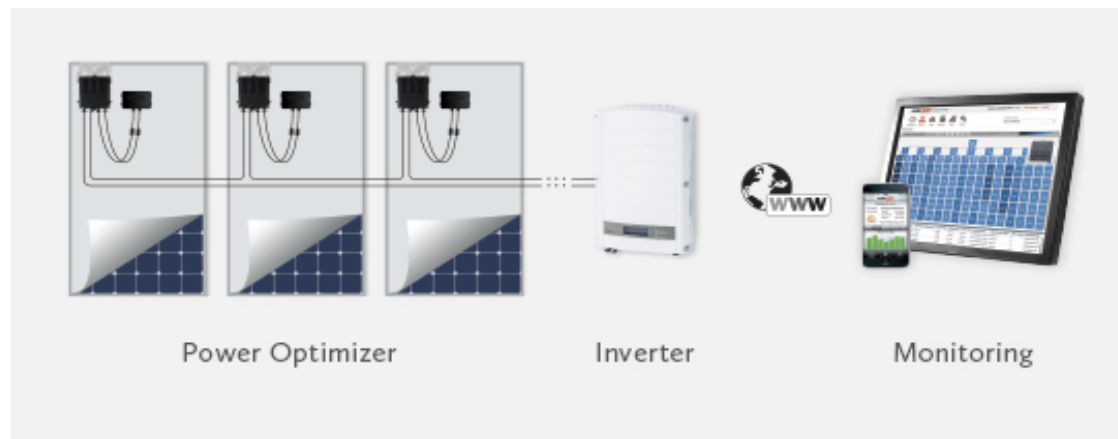
The total components and subsystem that, in combination, convert solar energy into electric energy suitable for connection to a utilization load.



Definitions: Article 690

DC-to-DC Converter.

A device installed in the PV source circuit or PV output circuit that can provide an output dc voltage and current at a higher or lower value than the input dc voltage and current.



Definitions: Article 690

Direct-Current (dc) Combiner.

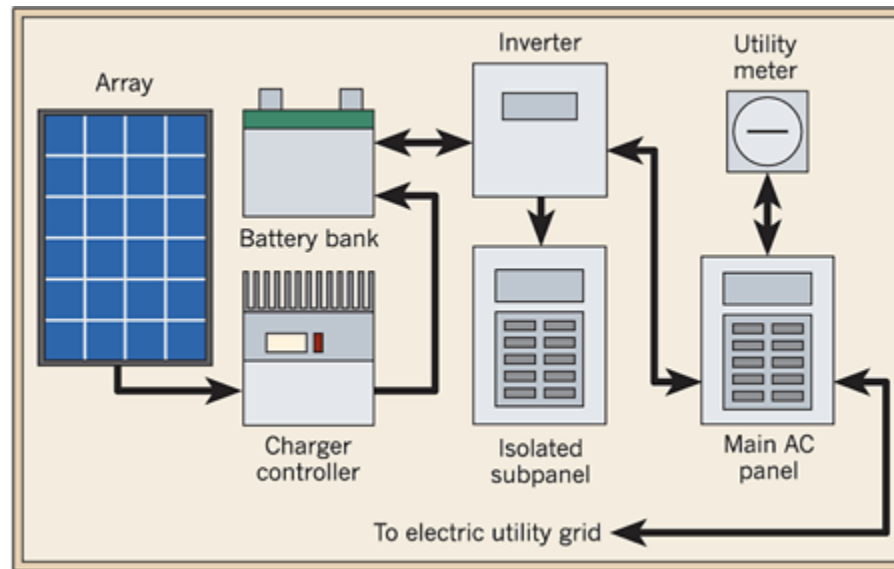
A device used in the PV source and PV output circuits to combine two or more dc circuit inputs and provide one dc circuit output.



Definitions: Article 690

Multimode Inverter.

Equipment having the capabilities of both the utility-interactive inverter and the stand-alone inverter.



Source: National Fire Protection Association. *NFPA-70 National Electrical Code 2014 Edition*. Quincy, MA. Mayfield, Ryan, Renewable Energy Associates. "The Fundamentals of Photovoltaic Systems". Electrical Construction & Maintenance (EC&M). <http://ecmweb.com/contractor/fundamentals-photovoltaic-systems>.

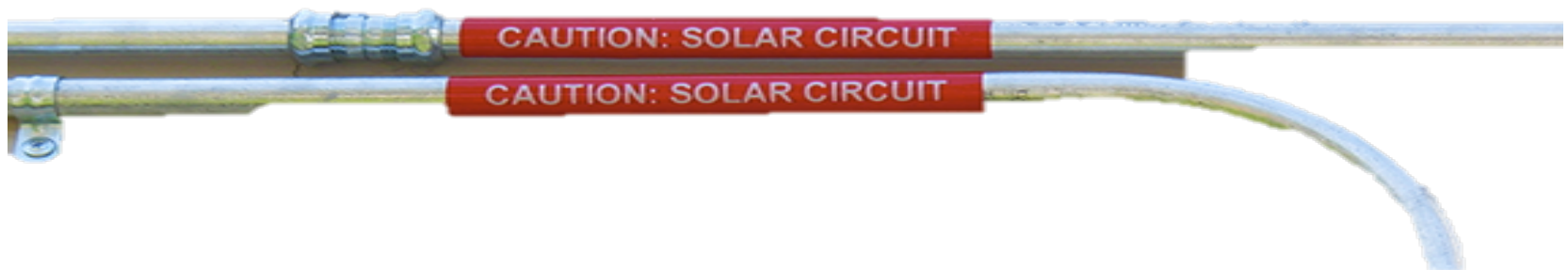
Field Applied Labels

110.21 (B)

110.21 (B)

(B) Field-Applied Hazard Markings.

Where caution, warning, or danger signs or labels are required by this Code, the labels shall meet the following requirements: (three)



Field Applied Labels

110.21 (B)(1) The marking shall adequately warn of the hazard using effective words and/or colors and/or symbols.

Informational Note: ANSI Z535.4-2011, *Product Safety Signs and Labels*, provides guidelines for suitable font sizes, words, colors, symbols, and location requirements for labels.



ANSI Z535.4-2011

Danger label:

- Immediate danger; will cause death or serious injury if not avoided
- Black text, white and red background



Warning label:

- May cause death or injury if warning is not heeded
- Black text with yellow and orange background



Caution label:

- Potential hazards may cause minor or moderate injury; caution against unsafe practices
- Black text with yellow and white background



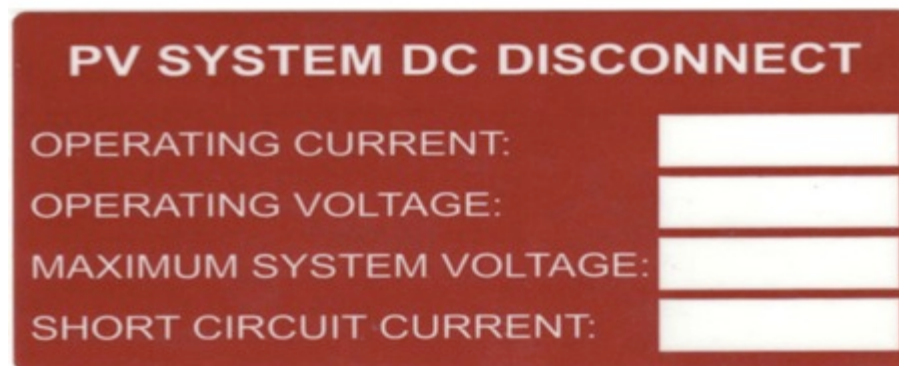
Source: National Electrical Manufacturers Association. *American National Standard for Product Safety Signs and Labels*. September, 2011.

<https://www.nema.org/Standards/ComplimentaryDocuments/Z535-4-Contents-and-Scope.pdf>

Field Applied Labels

110.21 (B)(2) The label shall be permanently affixed to the equipment or wiring method and shall not be hand written.

- Exception to (2): Portions of labels or markings that are variable, or that could be subject to changes, shall be permitted to be hand written and shall be legible.



PV SYSTEM DC DISCONNECT

OPERATING CURRENT:

OPERATING VOLTAGE:

MAXIMUM SYSTEM VOLTAGE:

SHORT CIRCUIT CURRENT:

Field Applied Labels

110.21 (B)(3) The label shall be of sufficient durability to withstand the environment involved.

Informational Note: ANSI Z535.4-2011, *Product Safety Signs and Labels*, provides guidelines for the design and durability of safety signs and labels for application to electrical equipment.

Spaces about Electrical Equipment

110.26 (E) (2)

(2) Outdoor. Outdoor installations shall comply with 110.26(E)(2)(a) and (b).

(b) Dedicated Equipment Space. The space equal to the width and depth of the equipment, and extending from grade to a height of 1.8 m (6 ft) above the equipment, shall be dedicated to the electrical installation. No piping or other equipment foreign to the electrical installation shall be located in this zone.

DC Color Coding

210.5 (C)

210.5 Identification for Branch Circuits.

(C) Identification of Ungrounded Conductors.

(2) Branch Circuits Supplied From Direct-Current Systems.

- These are dc utilization circuits operating at over 50 volts.
- 4 AWG and larger: identified by polarity at terminations, connections and splices by tape, tagging or approved method
- 6 AWG and smaller:
 - Positive identified with red jacket, red stripe, or imprinted "+", "POSITIVE" or "POS" at 24" intervals; and at at terminations, connections and splices
 - Negative identified with black jacket, black stripe or imprinted "—", "NEGATIVE" or "NEG" at 24" intervals; and at at terminations, connections and splices

Conduits on a Rooftop

310.15 (B) (3) (c)

exception:

(c) Raceways and Cables Exposed to Sunlight on Rooftops.

Where raceways or cables are exposed to direct sunlight on or above rooftops, the adjustments shown in Table 310.15(B)(3)(c) shall be added to the outdoor temperature to determine the applicable ambient temperature for application of the correction factors in Table 310.15(B)(2)(a) or Table 310.15(B)(2)(b).

Exception: Type XHHW-2 insulated conductors shall not be subject to this ampacity adjustment.

Conduits on a Rooftop

Table 310.15 (B) (3) (c)

Table 310.15(B)(3)(c) Ambient Temperature Adjustment for Raceways or Cables Exposed to Sunlight on or Above Rooftops

Distance Above Roof to Bottom of Raceway or Cable	Temperature Adder	
	°C	°F
On roof 0 – 13 mm (0 — ½ in.)	33	60
Above roof 13 mm (½ in.)	22	40
Above 90 mm – 300 mm (3½ in. – 12 in.)	17	30
Above 300 mm – 900 mm (12 in. – 36 in.)	14	25

Changes in Article 690

690.4 (reorganization)

- 690.4 (2011 NEC) shortened-
 - (A) **PV permitted**
 - (B) Identification/grouping (690.31 B)
 - (C) Module connection arrangement (690.31 J)
 - (D) **Equipment identified and listed**
 - (E) **Wiring and connections**
 - (F) Circuit routing (690.31 G)
 - (G) Bipolar (690.31 I)
 - (H) **Multiple inverters**

Changes in Article 690

690.9 Overcurrent Protection

690.9 Overcurrent Protection.

(A) Circuits and Equipment. PV source circuit, PV output circuit, inverter output circuit, and storage battery circuit conductors and equipment shall be protected in accordance with the requirements of Article 240.

2011 NEC 690.9 (C) called for fuses in one amp increments between 1 amp and 15 amps. No More.

Changes in Article 690

690.9 Overcurrent Protection

240.6 Standard Ampere Ratings.

(A) Fuses and Fixed-Trip Circuit Breakers. The standard ampere ratings for fuses and inverse time circuit breakers shall be considered 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, 4000, 5000, and 6000 amperes. Additional standard ampere ratings for fuses shall be 1, 3, 6, 10, and 601. The use of fuses and inverse time circuit breakers with nonstandard ampere ratings shall be permitted.

Changes in Article 690

690.9 Overcurrent Protection

... Protection devices for PV source circuits and PV output circuits shall be in accordance with the requirements of 690.9(B) through (E). Circuits, either ac or dc, connected to current-limited supplies (e.g., PV modules, ac output of utility-interactive inverters), and also connected to sources having significantly higher current availability (e.g., parallel strings of modules, utility power), shall be protected at the source from overcurrent.

(exception is the same)

Changes in Article 690

690.9 Overcurrent Protection

690.9 (D) Photovoltaic Source and Output Circuits.

Listed PV overcurrent devices shall be required to provide overcurrent protection in PV source and output circuits. The overcurrent devices shall be accessible but shall not be required to be readily accessible.

Changes in Article 690

690.9 Overcurrent Protection

(E) Series Overcurrent Protection. In grounded PV source circuits, a single overcurrent protection device, where required, shall be permitted to protect the PV modules and the interconnecting conductors. In ungrounded PV source circuits complying with 690.35, an overcurrent protection device, where required, shall be installed in each ungrounded circuit conductor and shall be permitted to protect the PV modules and the interconnecting cables.

Changes in Article 690

690.10 (E) Back-Fed Circuit Breakers

690.10 (E) Back-Fed
Circuit Breakers. Plug-
in type back-fed
circuit breakers
connected to a stand-
alone or multimode
inverter output in
stand-alone systems
shall be secured in
accordance with
408.36(D).



Changes in Article 690

690.10 (E) Back-Fed Circuit Breakers

Fastener exception...

705.12 (D) (5) Fastening. Listed plug-in-type circuit breakers backfed from utility-interactive inverters that are listed and identified as interactive shall be permitted to omit the additional fastener normally required by 408.36(D) for such applications.

Clarified...

Changes in Article 690

690.11 Arc-Fault Circuit Protection

690.11 Arc-Fault Circuit Protection (Direct Current).

Photovoltaic systems with dc source circuits, dc output circuits, or both, operating at a PV system maximum system voltage of 80 volts or greater, shall be protected by a listed (dc) arc-fault circuit interrupter, PV type, or other system components listed to provide equivalent protection.

(no longer says “on or penetrating a building”)

Changes in Article 705

705.12 (D) (6)

(6) Wire Harness and Exposed Cable Arc-Fault Protection.

A utility-interactive inverter(s) that has a wire harness or cable output circuit rated 240 V, 30 amperes, or less, that is not installed within an enclosed raceway, shall be provided with listed ac AFCI protection.



Emergency Disconnect?



Source: Fink, Dan. "PV Systems and Firefighter Safety: A Proactive Approach". SolarPro. Issue 4.1, Dec/Jan, 2011. <http://solarprofessional.com/articles/design-installation/pv-systems-and-firefighter-safety>.

Changes in Article 690

690.12 Rapid Shutdown of PV Systems on Buildings

690.12 Rapid Shutdown of PV Systems on Buildings.

PV system circuits installed on or in buildings shall include a rapid shutdown function that controls specific conductors in accordance with 690.12(1) through (5) as follows.

Changes in Article 690

690.12 Rapid Shutdown of PV Systems on Buildings

690.12 Rapid Shutdown of PV Systems on Buildings.

- (1) Requirements for controlled conductors shall apply only to PV system conductors of more than 1.5 m (5 ft) in length inside a building, or more than 3 m (10 ft) from a PV array.

Changes in Article 690

690.12 Rapid Shutdown of PV Systems on Buildings

690.12 Rapid Shutdown of PV Systems on Buildings.

(2) Controlled conductors shall be limited to not more than 30 volts and 240 volt-amperes within 10 seconds of rapid shutdown initiation.

(3) Voltage and power shall be measured between any two conductors and between any conductor and ground.

Changes in Article 690

690.12 Rapid Shutdown of PV Systems on Buildings

690.12 Rapid Shutdown of PV Systems on Buildings.

(4) The rapid shutdown initiation methods shall be labeled in accordance with 690.56(B).

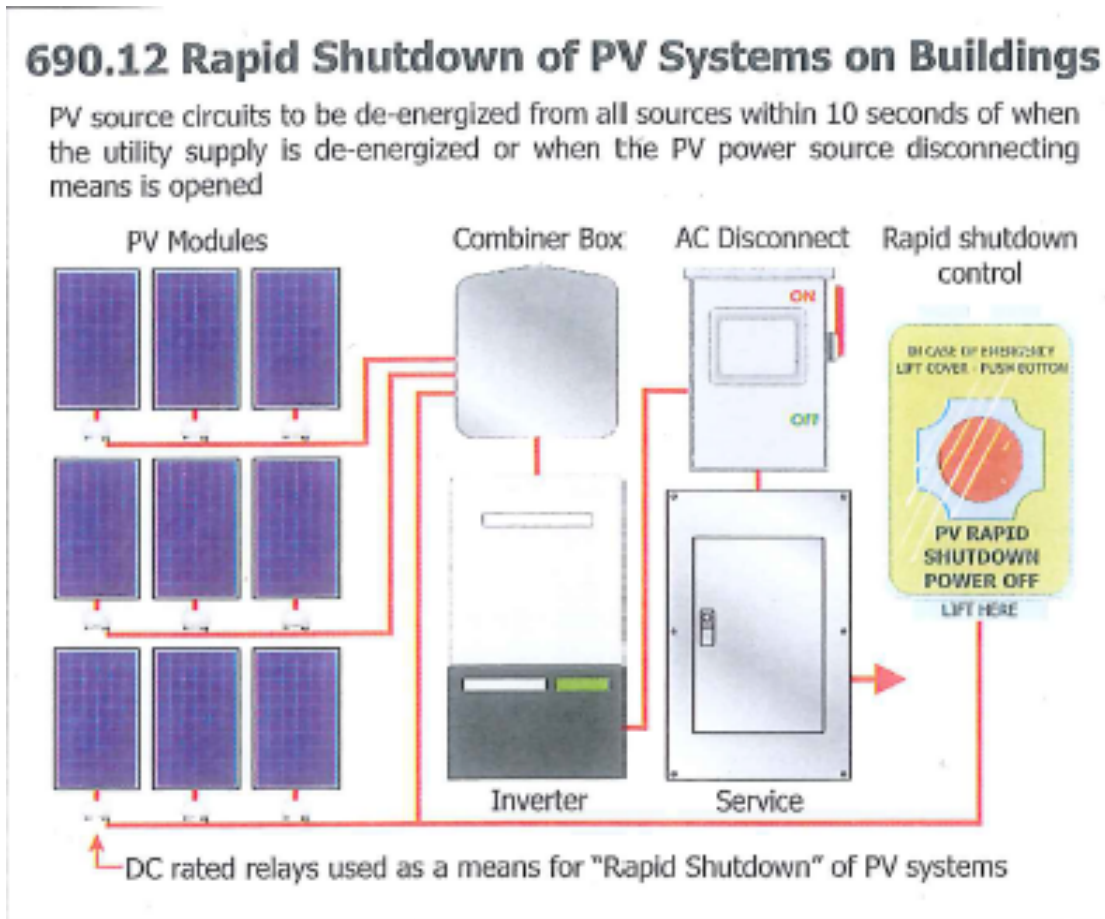


**PHOTOVOLTAIC SYSTEM
EQUIPPED WITH
RAPID SHUTDOWN**

(5) Equipment that performs the rapid shutdown shall be listed and identified.

Changes in Article 690

690.12 Rapid Shutdown of PV Systems on Buildings



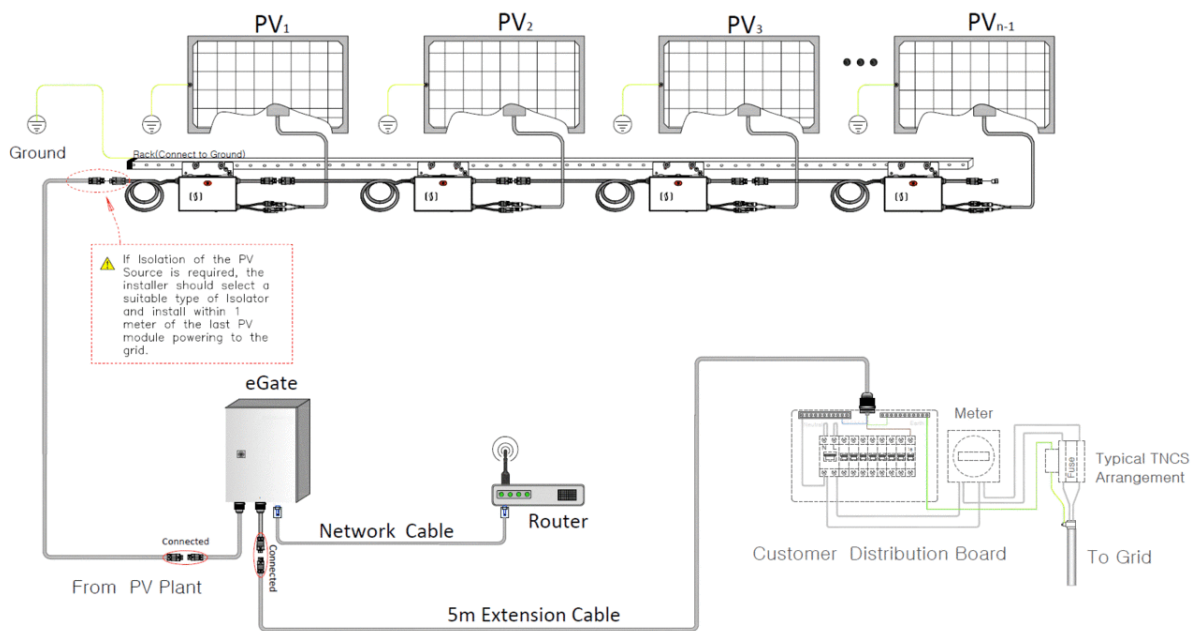
How to Comply with Rapid Shutdown Requirements?

- *Bentek*
- *Midnite Birdhouse*



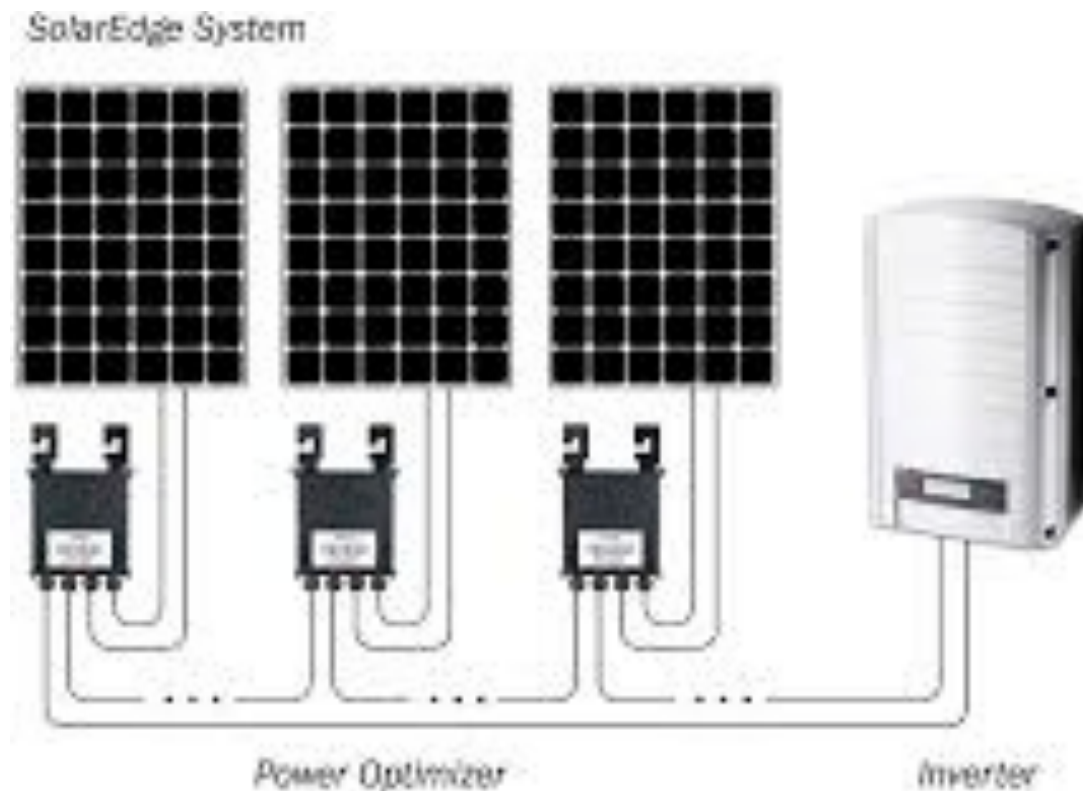
How to Comply with Rapid Shutdown Requirements?

Microinverters



How to Comply with Rapid Shutdown Requirements?

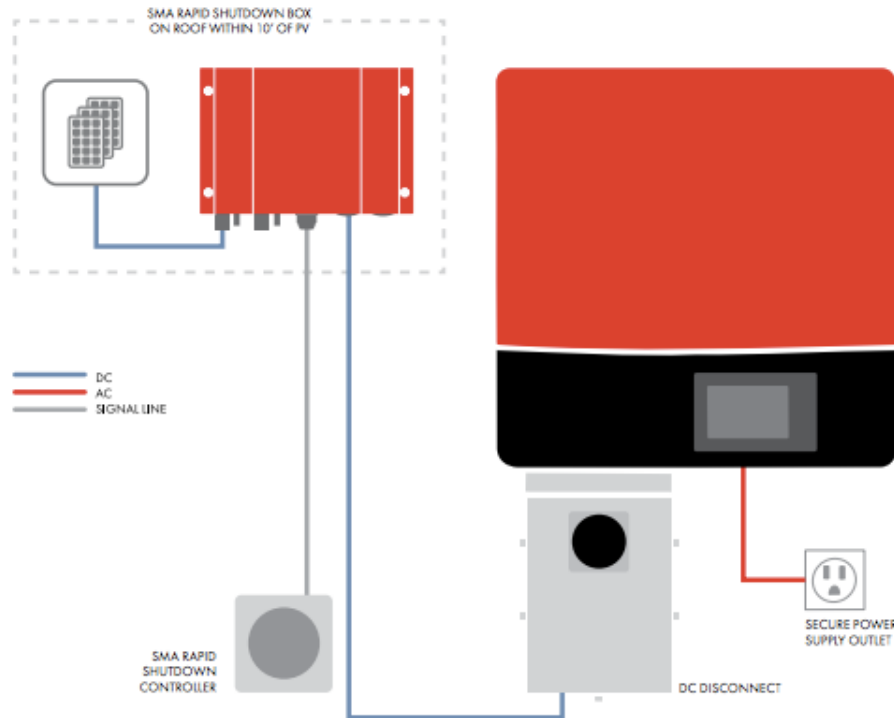
DC Optimizers



How to Comply with Rapid Shutdown Requirements?



SMA RAPID SHUTDOWN SYSTEM FREQUENTLY ASKED QUESTIONS



Changes in Article 690

690.31

(B) Identification and Grouping. PV source circuits and PV output circuits shall not be contained in the same raceway, cable tray, cable, outlet box, junction box, or similar fitting as conductors, feeders, branch circuits of other non-PV systems, or inverter output circuits, unless the conductors of the different systems are separated by a partition.

Changes in Article 690

690.31

(D) Multiconductor Cable.

Multiconductor cable Type TC-ER or Type USE-2 shall be permitted in outdoor locations in PV inverter output circuits where used with utility interactive inverters mounted in locations that are not readily accessible. The cable shall be secured at intervals not exceeding 1.8 m (6 ft). Equipment grounding for the utilization equipment shall be provided by an equipment grounding conductor within the cable.

Changes in Article 690

690.31

(G) Direct-Current Photovoltaic Source and Direct-Current Output Circuits on or Inside a Building.

(4) Marking and Labeling Methods and Locations. The labels or markings shall be visible after installation. The labels shall be reflective, and all letters shall be capitalized and shall be a minimum height of 9.5 mm (3/8 in.) in white on a red background.

Changes in Article 690

690.35

690.35 Ungrounded Photovoltaic Power Systems

(D) Conductors.

The PV source conductors shall consist of the following:

- (1) Metallic or nonmetallic jacketed multiconductor cables
- (2) Conductors installed in raceways
- (3) Conductors listed and identified as PV wire installed as exposed, single conductors, or
- (4) Conductors that are direct-buried and identified for direct-burial use

Changes in Article 690

Part 4: Grounding

690.41 System Grounding. Photovoltaic systems shall comply with one of the following: (removes “over 50 Volts”)

- (1) Ungrounded systems shall comply with 690.35.
- (2) Grounded two-wire systems shall have one conductor grounded or be impedance grounded, and the system shall comply with 690.5.
- (3) Grounded bipolar systems shall have the reference (center tap) conductor grounded or be impedance grounded, and the system shall comply with 690.5.
- (4) Other methods that accomplish equivalent system protection in accordance with 250.4(A) with equipment listed and identified for the use shall be permitted to be used.

Changes in Article 690

690.47

690.47 Grounding Electrode System.

(D) Additional Auxiliary Electrodes for Array Grounding.

A grounding electrode shall be installed in accordance with 250.52 and 250.54 at the location of all ground- and pole-mounted PV arrays and as close as practicable to the location of roof-mounted PV arrays. The electrodes shall be connected directly to the array frame(s) or structure. The dc grounding electrode conductor shall be sized according to 250.166. Additional electrodes are not permitted to be used as a substitute for equipment bonding or equipment grounding conductor requirements. The structure of a ground- or pole-mounted PV array shall be permitted to be considered a grounding electrode if it meets the requirements of 250.52. Roof-mounted PV arrays shall be permitted to use the metal frame of a building or structure if the requirements of 250.52(A)(2) are met.

Changes in Article 690

690.47

690.47 Grounding Electrode System.

(D) Additional Auxiliary Electrodes for Array Grounding.

Exception No. 1: An array grounding electrode(s) shall not be required where the load served by the array is integral with the array.

Exception No. 2: An additional array grounding electrode(s) shall not be required if located within 1.8 m (6 ft) of the premises wiring electrode.

Changes in Article 690

690.47

Mike Holt objects:

<https://www.youtube.com/watch?v=YuDqXFvRv94>

Changes in Article 690

690.47

DANGEROUS GROUND

Direct lightning strikes on a person are rare. A lot more injuries are caused by the side-effects of a nearby strike.

If you are standing, say, at a bus stop, chances are that lightning will strike a taller object nearby like a tree or light pole.

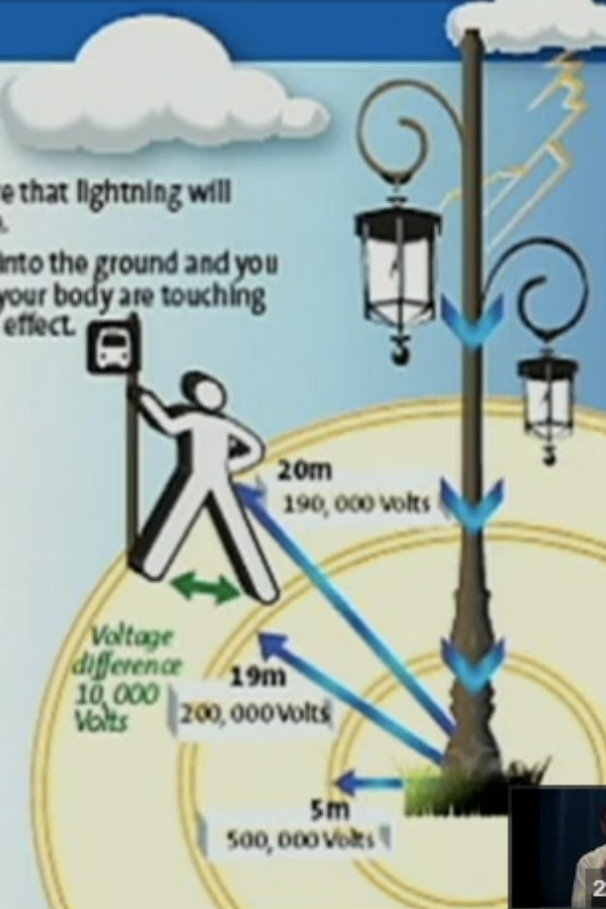
Immense power will be channelled downwards into the ground and you will be injured (or even killed) if different parts of your body are touching the ground. This is due to the "voltage difference" effect.

How does that happen?

The voltage of electrical power from lightning decreases the further away you are from the strike point.

For instance, when a bolt hits a light pole, the voltage 5m away can be a sizzling 500,000 volts. At 19m and 20m from the pole, the voltage can still be as intense as 200,000 and 190,000 volts respectively, explains Prof Liew Ah Choy of the National University of Singapore.

So if a person is at that bus stop, with his left leg at 19m and right leg at 20m distance, he will be injured because the voltage difference is a massive 10,000 Volts. Electricity will flow up the left leg and down the right, causing shock and burns, especially to the lower part of the body

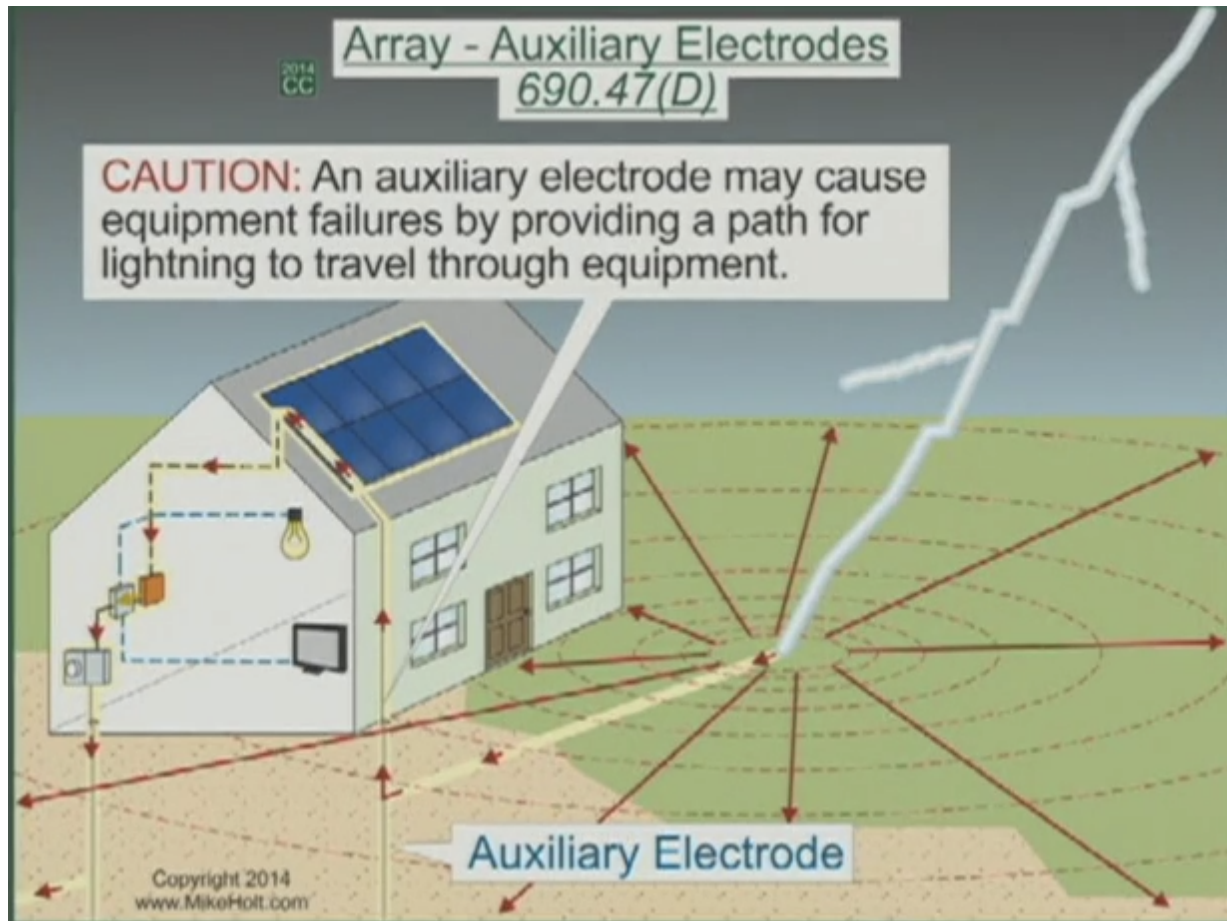


22:

Source: Holt, Mike. "NEC 2014 Solar – Additional Auxiliary Electrodes for Array Grounding". YouTube Video. MikeHoltNEC. <https://www.youtube.com/watch?v=YuDqXFvRv94>

Changes in Article 690

690.47



Source: Holt, Mike. "NEC 2014 Solar – Additional Auxiliary Electrodes for Array Grounding". YouTube Video. MikeHoltNEC. <https://www.youtube.com/watch?v=YuDqXFvRv94>

Changes in Article 690

690.71 Battery Disconnects

(H) Disconnects and Overcurrent Protection.

Where energy storage device input and output terminals are more than 1.5 m (5 ft) from connected equipment, or where the circuits from these terminals pass through a wall or partition, the installation shall comply with the following:

Changes in Article 690

690.71 Battery Disconnects

(H) Disconnects and Overcurrent Protection. (five conditions)

- 1) A disconnecting means and overcurrent protection shall be provided at the energy storage device end of the circuit. Fused disconnecting means or circuit breakers shall be permitted to be used.



Changes in Article 690

690.71 Battery Disconnects

- (H) Disconnects and Overcurrent Protection. (five conditions)
- (2) Where fused disconnecting means are used, the line terminals of the disconnecting means shall be connected toward the energy storage device terminals.

Changes in Article 690

690.71 Battery Disconnects

(H) Disconnects and Overcurrent Protection.
(five conditions)

(3) Overcurrent devices or disconnecting means shall not be installed in energy storage device enclosures where explosive atmospheres can exist.



Changes in Article 690

690.71 Battery Disconnects

(H) Disconnects and Overcurrent Protection. (five conditions)

(4) A second disconnecting means located at the connected equipment shall be installed where the disconnecting means required by 690.71(H)(1) is not within sight of the connected equipment.

Changes in Article 690

690.71 Battery Disconnects

(H) Disconnects and Overcurrent Protection. (five conditions)

(5) Where the energy storage device disconnecting means is not within sight of the PV system ac and dc disconnecting means, placards or directories shall be installed at the locations of all disconnecting means indicating the location of all disconnecting means

Changes in Article 690

Part 10: EV Charging

690.90 General.

Photovoltaic systems used directly to charge electric vehicles shall comply with Article 625 in addition to the requirements of this article.

690.91 Charging Equipment.

Electric vehicle couplers shall comply with 625.10.

Personnel protection systems in accordance with 625.22 and automatic de-energization of cables in accordance with 625.19 are not required for PV systems with maximum system voltages of less than 80 volts dc.

Changes in Article 705

705.12 (D)(2)

(2) Bus or Conductor Ampere Rating. One hundred twenty-five percent of the inverter output circuit current shall be used in ampacity calculations for the following:

- (1) Feeders.
- (2) Taps
- (3) Busbars



Changes in Article 705.12 (D)(2)(3)(a)

(3) Busbars.

One of the methods that follows shall be used to determine the ratings of busbars in panel boards.

(a) The sum of 125 percent of the inverter(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed the ampacity of the busbar.

Informational Note: This general rule assumes no limitation in the number of the loads or sources applied to busbars or their locations.

Changes in Article 705

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

(3) Busbars.

(b) Where two sources, one a utility and the other an inverter, are located at opposite ends of a busbar that contains loads, the sum of 125 percent of the inverter(s) output circuit current and the rating of the overcurrent device protecting the busbar shall not exceed 120 percent of the ampacity of the busbar. The busbar shall be sized for the loads connected in accordance with Article 220.

Changes in Article 705

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

Continued...

A permanent warning label shall be applied to the distribution equipment adjacent to the back-fed breaker from the inverter that displays the following or equivalent wording:

WARNING:

INVERTER OUTPUT CONNECTION;

DO NOT RELOCATE THIS OVERCURRENT DEVICE.

The warning sign(s) or label (s) shall comply with 110.21(B)

Changes in Article 705

705.12 (D) (2) (3) (c)

(c) The sum of the ampere ratings of all overcurrent devices on panelboards, both load and supply devices, excluding the rating of the overcurrent device protecting the busbar, shall not exceed the ampacity of the busbar. The rating of the overcurrent device protecting the busbar shall not exceed the rating of the busbar.

Changes in Article 705

705.12 (D) (6)

(6) Wire Harness and Exposed Cable Arc-Fault Protection.

A utility-interactive inverter(s) that has a wire harness or cable output circuit rated 240 V, 30 amperes, or less, that is not installed within an enclosed raceway, shall be provided with listed ac AFCI protection.



Changes in Article 705

705.31

705.31 Location of Overcurrent Protection.

Overcurrent protection for electric power production source conductors, connected to the supply side of the service disconnecting means in accordance with 705.12(A), shall be located within 3m (10 ft) of the point where the electric power production source conductors are connected to the service.

Informational Note: This overcurrent protection protects against short-circuit current supplied from the primary source(s) of electricity.

Changes in Article 705

705.31

Exception: Where the overcurrent protection for the power production source is located more than 3 m (10 ft) from the point of connection for the electric power production source to the service, cable limiters or current-limited circuit breakers for each ungrounded conductor shall be installed at the point where the electric power production conductors are connected to the service.

Changes in Article 705

705.100

705.100 Unbalanced Interconnections.

(A) Single Phase. Single-phase inverters for hybrid systems and ac modules in interactive hybrid systems shall be connected to three-phase power systems in order to limit unbalanced voltages to not more than 3 percent.

Informational Note: For utility-interactive single-phase inverters, unbalanced voltages can be minimized by the same methods that are used for single-phase loads on a three-phase power system. See ANSI/C84.1-2011, Electric Power Systems and Equipment — Voltage Ratings (60 Hertz).

Thank you!