# 2017 Solar PV Key Code Updates and Common Violations for MassCEC Solar Programs

**Based on the 2017 Massachusetts Electrical Code**

This document summarizes key changes to the Massachusetts Electrical Code (MEC), augmented with common solar electric or solar photovoltaic (solar PV) violations based on inspection results under MassCEC programs.[1] The MEC is based on the National Electrical Code (NEC) with amendments.[2] Local codes and standards may supersede any of the references below.

## *Solar PV Array and Outdoor Wiring*

The solar PV array is one of the most common locations where MEC violations occur. With any outdoor wiring method, equipment must be suitable for the environment in which it is installed, conductors must be protected, and metal parts likely to become energized must be grounded.

### Array Grounding (Article 690.43)

Grounding must be in accordance with 690.43, and 250.134 or 250.136(A). Article 690.43 was revised for clarity and subsections have been reorganized to better identify integrated bonding equipment and hardware:

- **690.43(A) Photovoltaic Module Mounting System and Devices**
  - Mounting equipment shall be listed, labeled, and identified if used for bonding metal frames
- **690.43(B) Equipment Secured to Grounded Metal Supports**
  - Devices listed, labeled, and identified for bonding and grounding are permitted to bond equipment to metal frames and support structures. The equipment must be bonded to the equipment grounding conductor
- **690.43(C) With Circuit Conductors**
  - Equipment grounding conductors for the PV array must be contained in the same raceway, cable, or otherwise run with the circuit conductors when leaving the array

*Figure 1. Conductors below array not properly supported and exposed to physical damage*

Because many newer systems may rely on fewer points of field wiring connections for array equipment grounding, these terminations are critical for proper continuity for the life of the system. Common violations include hardware that is not listed for the application or the environment in which it is installed.

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1 MassCEC programs primarily consist of residential installations.

2 Commonwealth of Massachusetts. *527 CMR 1.00, 2012 edition. The Massachusetts Comprehensive Fire Safety Code and Base Code*. 2012. Available online: http://www.mass.gov/eopss/agencies/dfs/osfm/fire-prev/527-cmr-index.html

### Conductor Support and Protection (Chapter 3)

Article 690.31 was modified to recognize the use of metal-clad (MC) cable as a suitable wiring method for PV source and output circuits in readily accessible locations, without further guarding. In addition, Article 690.31(C)(1) permits the use of single-conductor Type USE-2 in exposed outdoor locations in PV source circuits within the PV array. Lastly, the same article now provides a clear reference for Type PV wire wiring methods. Like Type USE-2, PV wire shall be installed in accordance with Articles 338.10(B)(4)(b) and 334.30.

## *Inverter*

### DC Arc-Fault Circuit Protection (Article 690.11)

Systems with DC operating at 80 volts or greater must be protected by listed "PV type" arc-fault circuit interrupter (AFCI). Most major inverters have AFCI models, and the AFCI must be enabled. There is a new exception for systems not installed on buildings that follow certain wiring methods.

*Figure 2. DC conductors greater than 3 feet from building penetration must be controlled*

### Rapid Shutdown of PV Systems on Buildings (Article 690.12)

The entire section of Article 690.12 has been revised. The array boundary has been reduced to one foot and from five feet to three feet inside building. The time limit increased from 10 seconds in the 2014 MEC to 30 seconds for controlled conductors. Other changes include these:

- Equipment shall be listed for providing rapid shutdown protection
- Effective Jan 1, 2019, conductors within array limited to 80 volts after 30 seconds.
- Labeled per 690.56(C), including microinverter systems
- Initiation device must now be located outside for one-family and two-family dwellings:
  - Service disconnect or
  - Readily accessible PV system disconnect

*Figure 3. AC disconnect required within sight and within 10 feet where inverter contains only DC disconnect*

### Disconnect Grouping (Article 690.15)

Article 690.15 has been combined with the former 690.17. Further clarity has been added to inverters requiring an AC disconnect, within sight and within 10 feet. Many inverters only contain DC disconnect.

### Grounding Electrode System (Article 690.47)

Like the 2014 MEC, buildings or structures supporting a PV array shall have a grounding electrode system in accordance with Part III of Article 250:

- Supplemental electrodes may be required if they are not existing

- The PV array equipment grounding conductor is required to be connected to grounding electrode system of building or structure
- The additional electrode for array grounding (690.47(B)) is now optional

## Inverter Output and AC Wiring

### Terminal Ratings (Articles 110.3(B), 110.14)

A change in Article 110.14(D) requires tightening torque values to be followed, when provided by the equipment manufacturer. In addition:

- All electrical terminals are marked to indicate the size and quantity conductors that they are listed for.
- Many electrical meter enclosures contain terminals listed for larger conductors than often used in a residential PV system.
- Many circuit breakers and disconnect switches contain terminals that are only listed for a single conductor.

*Figure 4. PV meter enclosure containing a neutral-ground connection and oversized terminals for conductors*

## Interconnection (Article 705)

### Load-Side Connection (Article 705.12(B))

This section, formerly Article 705.12(D), has been moved to 705.12(B) and refers to an interconnection on the load side of the service disconnecting means. The two most-common types of load-side connections are feeder taps and back-fed breakers in panelboards. This article now provides an allowance for center-fed panelboard interconnection, where it can be at either end, but not both ends, in accordance with 705.12(B)(2)(3)(d).

## PV System Labeling

Labeling for PV system installations is the most significant area of common violations and misinterpretation. In general, markings must be suitable for the environment and be easily understood, not only by the inspector, but also a first-responder or a future electrician not affiliated with the installation. The following examples are the most common used in residential installations. There may be additional labels required by the local utility or inspector.


*Figure 5. Labels on outdoor equipment not suitable for the environment*

### Field-Applied Hazard Markings (Article 110.21(B))

- Many requirements in Article 690 reference Article 110.21(B)
- Labels must be sufficient to withstand the environment involved

- Labels shall be permanently affixed and shall not be handwritten
- Informational note to follow ANSI Z535.4-2001, words, colors, symbols

*Figure 6. Example of ANSI Z535.4-2001 markings*

## Common Labels throughout a PV System

- **690.31(G)(3) and (G)(4), DC Raceway Label**
  - No changes from 2014; however, very specific wording is required
  - Required on **DC** raceways, cables, enclosures on or in a building, every 10 feet
  - White lettering, red background, reflective
  - Minimum 3/8-inch capitalized letters

  WARNING: PHOTOVOLTAIC POWER SOURCE
- **690.13(B), PV System Disconnect**
  - Article has been rewritten to consolidate requirements of former Article 690.17.
  - Each PV system disconnecting means must be permanently marked "**PV SYSTEM DISCONNECT**" or equivalent.
- **690.13(B), Line/Load Energized**
  - Formerly 690.17(E), relocated to 690.13(B)
  - Where the line and load terminals may be energized in the open position, the disconnect shall be marked with the following words, or equivalent:

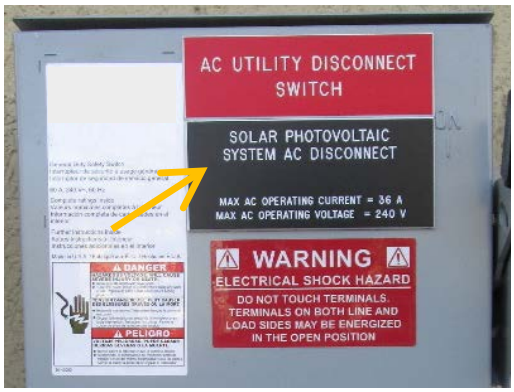

*Figure 7. (Left) Disconnect with no indication it is for PV system, may be misinterpreted for service disconnect*
*(Right) Proper PV identification marking, per Article 690.13(B)*

**WARNING:**
**ELECTRIC SHOCK HAZARD**
**TERMINALS ON THE LINE AND LOAD SIDES MAY BE**
**ENERGIZED IN THE OPEN POSITION**

- **690.56(C)(3), Rapid Shutdown Switch**
  - This entire article has been rewritten to incorporate new requirements in 690.12.
  - A rapid shutdown switch shall have a label on or within 3 feet that includes the following wording:

    **RAPID SHUTDOWN SWITCH FOR SOLAR PV SYSTEM**
  - White lettering, red background, reflective

- Minimum 3/8 inch capitalized letters
- Required on all system types, including microinverters

- **690.56(C)(1), Rapid Shutdown Type**
  - The type of rapid shutdown must be indicated by one of the two following labels
  - This label must be on or within 3 feet of the service disconnecting means to which the PV systems are connected and shall indicate the location of all identified rapid shutdown switches if not located at the same location

  For systems that shut down conductors within and leaving the array:
  - Black lettering, yellow background
  - Minimum 3/8 inch capitalized letters

  **SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN**

  For systems that shut down only the conductors outside of the array boundary:
  - White lettering, red background
  - Minimum 3/8" capitalized letters

  **SOLAR PV SYSTEM IS EQUIPPED WITH RAPID SHUTDOWN**

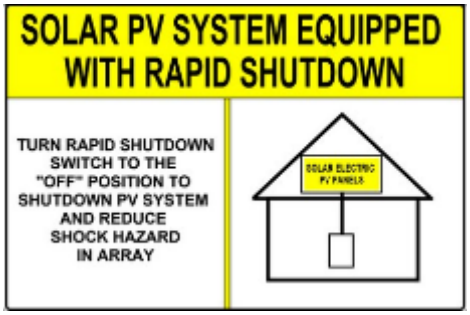


*Figure 8. Array-level rapid shutdown label requirement, often used with dc-dc converter and microinverter systems*

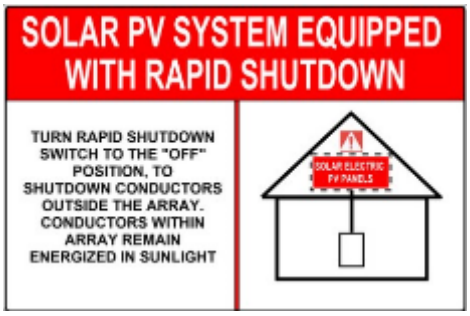


*Figure 9. Array boundary rapid shutdown label, can be used for installations prior to January 1, 2019. See Article 690.12(B)(2) for further details.*

- **690.53, Direct Current PV Power Source**
  - The requirements have been reduced and simplified for 2017.
  - A permanent label with the following properties to be installed at each DC disconnect:
    - **Maximum voltage**
    - **Maximum circuit current**
    - **Maximum rated output current of the charge controller or dc-to-dc converter (if installed)**

- **690.54, Interactive System Point of Interconnection**
  - No changes from 2014
  - All points of interconnection shall be marked at an accessible location at the disconnecting means as a power source and with:
    - **Rated AC output current**
    - **Nominal operating AC voltage**


*Figure 10. Example of "multiple sources" label for load-side connection equipment*

- **705.12(B)(3), Load-Side Connection Marking**
  - No changes from 2014
  - Equipment shall be marked to indicate the presence of all sources
  - Example text:

**WARNING:**
**DUAL POWER SOURCES**
**SECOND SOURCE IS**
**PHOTOVOLTAIC SYSTEM**

- **705.12(B)(2)(3)(b), Do Not Relocate**
  - No significant changes from 2014
    - The word "inverter" has been replaced with "power source."


*Figure 11. Example of "do not relocate" label for backfed overcurrent device when Article 705.12(B)(2)(3)(b) is utilized*

  - When the primary overcurrent device and a backfed PV circuit breaker exceed the busbar rating (by no more than 120%), the PV breaker must be at the opposite end and contain the following or equivalent wording:

**WARNING:**
**POWER SOURCE OUTPUT CONNECTION;**
**DO NOT RELOCATE**
**THIS OVERCURRENT DEVICE**

- **705.12(B)(2)(3)(c), "AC Combiner" Warning Label**
  - No changes from 2014
  - If a panelboard is used to combine multiple inverter outputs, a warning label must be installed that indicates (1) it is fed from multiple sources and (2) not to add additional loads.


*Figure 12. Example of label required for "AC combiners" indicating multiple sources, and not to add loads*

- **690.56(B), 705.10, Plaques or Directories**
  - No changes from 2014
  - A permanent plaque or directory denoting the location of all electric power source disconnecting means, shall be installed at each service equipment location and the location of the PV system disconnect


*Figure 13. Example of a directory indicating the location of all disconnects*