2011/2008/2005 NATIONAL ELECTRICAL CODE SOLAR PV CODE COMPLIANCE REFERENCE

This Reference provides a very comprehensive list of aspects of a solar PV installation that could be reviewed, clarifying what the codes do and do not require. In practice, inspectors or reviewers can use their discretion to focus on key areas for which issues are more likely to occur or which issues have the highest consequences. **Users should note the following:**

1. This Reference is an outline of the general requirements found in the 2005, 2008, 2011 National Electrical Codes (NEC) — Article 690 for Photovoltaic (PV) Power Systems installations. This Reference is only a guide and applies to components used or installed in a PV system (aside from those inside a listed, factory-assembled component). ***As of February 2014, Connecticut abides by the 2011 NEC; other years are provided as reference.***
2. The local authority having jurisdiction (AHJ) or inspector or reviewer has the final say on what is or is not acceptable, within the context of the Connecticut state building codes. This list should be used in conjunction with Article 690 and other applicable articles of the NEC and includes inspection requirements for both stand-alone PV systems (with and without batteries) and utility-interactive PV systems. Where Article 690 differs from other articles of the NEC, Article 690 takes precedence.
3. References in brackets [ ] are to the 2005 and 2008 NEC and other relevant documents. Changes related to 2008 NEC requirements are noted in {brackets}. 2011 differences are in (parenthesis).
4. Access to the 2011 NEC is provided online, for free, by the National Fire Protection Association (NFPA): http://www.nfpa.org/codes-and-standards/document-information-pages?mode=code&code=70

This reference was created by John Wiles, modified only slightly. To access the original reference along with other information about solar PV codes and standards, see the Southwest Technology Development Institute, New Mexico State University, Codes & Standards website: http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/C-S-Resources.html.

1. PV ARRAYS

- PV modules listed to UL Standard 1703 [110.3] {690.4(D)}

a. Mechanical Attachment

- Modules attached to the mounting structure according to the manufacturer's instructions [110.3(B)]
- Roof penetrations secure and weather tight

b. Grounding

- Each module grounded using the appropriate hardware, the grounding point identified on the module and the manufacturer's instructions.
  - **Note:** Bolting the module to a "grounded" structure usually will not meet NEC requirements [110.3(B)]. Array PV mounting racks are usually not identified as equipment-grounding conductors (Note 690.43(C) and (D) in 2011 have additional provisions and allowances for grounding with mounting structure).
- Properly sized equipment-grounding conductors routed with the circuit conductors [690.45] Note differences between 2005, 2008 and 2011 NEC.

c. Conductors

- Conductor type- If exposed: USE-2, UF (usually inadequate at 60°C), or SE, 90°C, wet-rated and sunlight resistant. [690.30(B)] {2008 NEC restricts exposed single-conductor wiring to USE-2 and listed PV/Photovoltaic wire/cable} – If in conduit: RHW-2, THWN-2, or XHHW-2 90°C, wet-rated conductors are required [310.15]
- Conductor insulation rated at 90°C [UL – 1703] to allow for operation at 70°C+ near modules and in conduit exposed to sunlight (add 17-20°C to ambient temperature – 2005 NEC) {see Table 310.15(B)(2) in the 2008 NEC}

- Temperature-derated ampacity calculations based on 156% of short-circuit current (Isc), and the derated ampacity greater than 156% Isc rating of overcurrent device [690.8,9].
  - **Note:** Suggest temperature derating factors of 65°C in installations where the backs of the module receive cooling air (6" or more from surface) and 75°C where no cooling air can get to the backs of the modules. Ambient temperatures in excess of 40°C may require different derating factors.

    (2011 NEC 690.8 substantially updates ampacity calculations to parallel calculations in other sections of the NEC)
- Portable power cords allowed only for tracker connections [690.31 (C), 400.3,7,8]
- Strain reliefs/cable clamps or conduit used on all cables and cords [300.4,400.10]
- Listed for the application and the environment? Fine stranded, flexible conductor cables properly terminated with terminals listed for such conductors (690.31(E))
- Cables and flexible conduits installed and properly marked (690.31(E))
- Exposed conductors in readily accessible areas in a raceway if over 30 volts {690.31(A)}
  - **Note:** Raceways cannot be installed on modules. Make conductors not readily accessible.

2. OVERCURRENT PROTECTION

- Overcurrent devices in the dc circuits listed for dc operation – if device not marked dc, verify dc listing with manufacturer. Auto, marine and telecom devices are not acceptable.
- Rated at 1.25 x 1.25 = 1.56 times short-circuit current from modules [UL – 17093, 690.8, module instructions]
  - **Note:** Both 125% factors are now in the NEC, *but a duplicate 125% remains in the module instructions and should be removed in 2011*. Supplementary listed devices are allowed in PV source circuits only, but branch-circuit rated devices preferred [690.9(C)].
- Each module or series string of modules have an overcurrent device protecting the module [UL-1703/NEC 110.3(B)]
  - **Note:** Frequently, installers ignore this requirement marked on the back of the modules. Listed combiner PV combiner boxes meeting this requirement are available. One or two strings of modules do not require overcurrent devices, but three strings or more in parallel will usually require an overcurrent device. The module maximum series fuse must be at least 1.56 Isc.
- Located in a position in the circuit to protect the module conductors from backfed currents from parallel module circuits or from the charge controller or battery [690-9(A) FPN]
- Smallest conductor used to wire modules protected – sources of overcurrent are parallel-connected modules, batteries, and ac backfeed through inverters [690-9(A)]
- User-accessible fuses in "touch-safe" holders or capable of being changed without touching live contacts [690.16] Strengthened for 2011 to include distance between overcurrent device and disconnect.
- Fuses must be able to be de-energized for service per NEC 690.16(B)

3. ELECTRICAL CONNECTIONS

- Pressure terminals tightened to the recommended torque specification
- Crimp-on terminals listed and installed with listed crimping tools by the same manufacturer [110.3(B)]
- Twist-on wire connectors listed for the environment (e.g. dry, damp, wet or direct burial) and installed per the manufacturer's instructions
- Pressure lugs or other terminals listed for the environment (e.g. inside, outside, wet, direct burial)
- Power distribution blocks listed and not just UL recognized
- Terminals containing more than one conductor listed for multiple conductors
- Connectors or terminals using flexible, fine-stranded conductors listed for use with such conductors? {690.31(F), 690.74}
- Locking (tool-required) on readily accessible PV conductors operating over 30 volts {690.33 (C)}

4. CHARGE CONTROLLERS

- Charge controller listed to UL Standard 1741 [110.3] {690.4(D)}
- Exposed energized terminals not readily accessible
- Diversion controller has an independent backup control method [690.72(B)(1)]

5. DISCONNECTS

- Disconnects listed for dc operation in dc circuits. Automotive, marine and telecom devices are not acceptable
- PV disconnect readily accessible and located at first point of penetration of PV conductors
- PV conductors outside structure until reaching first readily accessible disconnect unless in a metallic raceway [690.14, 690.31(F)]
- Disconnects for all current-carrying conductors of PV source [690.13]
- Disconnects for equipment [690.17]
- Grounded conductors not fused or switched – Bolted disconnects OK.
  - **Note:** Listed PV Centers by Xamtrex, Outback, and others for 12, 24 and 48-volt systems contain charge controllers, disconnects and overcurrent penetration for entire dc system with possible exception of source circuit or module protective fuses.

6. INVERTERS (Stand-alone systems)

- Inverter listed to UL Standard 1741 [110.3] {690.4(D)}
  - **Note:** Inverters listed to telecommunications or other standards do not meet NEC requirements
- DC input currents calculated for cable and fuse requirements. Input current = rated ac output in watts divided by lowest battery voltage divided by inverter efficiency at that power level [690.8(B)(4)]
- Cables to batteries sized 125% of calculated inverter input currents [690.8(A)]
- Overcurrent/Disconnects mounted near batteries and external to PV load centers if cables are longer than 4-5 feet to batteries or inverter
- High interrupt, listed, dc-rated fuses or circuit breakers used in batter circuits. AIR/AIC at least 20,000 amps [690.71(C), 110.9]
- No multiwire branch circuits where single 120-volt inverters connected to 120/240-volt load centers [100-Branch Circuit, Multiwire], [690.10(C)]

7. BATTERIES

- None are listed
- Building-wire type cables used [Chapter 3]
  - **Note:** Welding, cables, marine, locomotive (DLO) and auto battery cables don't meet NEC. Flexible, listed RHW or THW cables are available. Article 400 flexible cables larger than 2/0 AWG are OK for batter cell connections, but not in conduit or through walls. [690.74, 400.8] Flexible, fine stranded cables require very limited specially listed terminals. See stand-alone inverters for ampacity calculations.
- Access limited [690.71 (B)]
- Installed in well-vented areas (garages, basements, outbuildings, and not living areas)
  - **Note:** Manifolds, power venting and single exterior vents to the outside are not required and should be avoided.
- Cables to inverters, dc load centers and/or charge controllers in conduit
- Conduit enters the battery enclosure below the tops of the batteries [300.4]
  - **Note:** There are no listed battery boxes. Lockable heavy-duty plastic polyethylene tool boxes are usually acceptable.

8. INVERTERS (Utility-interactive Systems)

- Inverter listed to UL Standard 1741 and identified for use in interactive photovoltaic power systems [690.4(D), 690.60]
  - **Note:** Inverters listed to telecommunications and other standards do not meet NEC requirements
- Back up charge controller to regulate the batteries when the grid fails [690.72(B)(1)]
- Connected to dedicated branch circuit with back-fed overcurrent protection [690.64]
- Listed dc and ac disconnects and overcurrent protection [690.15, 17]
- Total rating of overcurrent devices supplying power to ac load center (main breaker plus backfed PV breaker) less than load-center rating (120% of rating in residences) [690.64(B)(2)] The 2008 NEC allows the 120% breaker total on commercial installations if the PV breaker is at the opposite end of the busbar from the main utility breaker

9. GROUNDING

- Only one bonding conductor (grounded conductor to ground) for dc circuits and one bonding conductor for ac circuits (neutral to ground) for system grounding [250]
  - **Note:** The dc bonds will generally be located inside inverters as part of the ground-fault protection devices. ON stand-alone systems, the dc bonding jumper may be in separate ground fault detection and interruption device or may be built into the charge controller
- AC and dc grounding electrode conductors connected properly. They may be connected to the same grounding electrode system (ground rod). Separate electrodes, if used, must be bonded together [690.41,47]
  - **Note:** The 2008 NEC in 690.47 allows a combined dc grounding electrode conductor and an ac equipment-grounding conductor, but the conditions and requirements are numerous {690.47} (2011 NEC clarified and combines 2005 and 2008 690.47(C) requirements)
- Equipment grounding conductors properly sized (even on ungrounded, low-voltage systems) [690.43]
- Disconnects and overcurrent in both of the ungrounded conductors in each circuit on 12-volt, ungrounded systems or on ungrounded systems at any voltage [240.20(A)], [690.41]
- Bonding/grounding fittings used with metal conduits when dc system voltage is more than 250V dc [250.97]

10. CONDUCTORS (General)

- Standard building-wire cables and wiring methods uses [300.1(A)]
- Wet-rated conductors used in conduits in exposed locations [100 Definition of Location, Wet]
- Insulations other than black in color will not be as durable as black in the outdoor UV-rich environment
- DC color codes correct – they are the same as ac color codes – grounded conductors are white and equipment-grounded conductors are green, green/yellow or bare. [200.6(A)] Ungrounded PV array conductors on ungrounded PV arrays will *not* be white in color.