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Photovoltaic Electrical Power Systems – Inspector/Installer Checklist

The following checklist is an outline of the general requirements found in the *California Electrical Code (CEC)* current edition – Article 690 for Photovoltaic (PV) Power Systems installations.

The checklist is only a guide and applies to any component used or installed in a PV system other than a listed, factory-assembled component.

The local authority having jurisdiction (AHJ) or inspector has the final say on what is or is not acceptable. Local codes may modify the requirements of the *CEC*.

This list should be used in conjunction with Article 690 and other applicable articles of the *CEC* 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 *CEC*, Article 690 takes precedence. [690.3]

References in brackets [ ] are to the current edition of the *CEC* and other relevant documents.

Note: Structural Calculations may be required.

CHECKLIST FOR PHOTOVOLTAIC POWER SYSTEM INSTALLATIONS

1. PV ARRAYS

PV modules listed to UL Standard 1703 [110.3]

A. Mechanical Attachment

- Modules attached to the mounting structure according to the manufacturer's instructions
- Roof penetrations secure and weather tight

B. Grounding

- Each module grounded using the supplied 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 *CEC* requirements.
- Properly sized equipment-grounding conductors routed with the circuit conductors. [690.45]

C. Conductors

- Conductor type —If exposed: USE-2, UF (usually inadequate at 60°C), or SE, 90°C, wet-rated and sunlight-resistant. [690.31 (B)]—If in conduit:

RHW-2, THWN-2, or XHHW-2 90°C, wet-rated conductors. [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).
- 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]

Suggested temperature derating factors: 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.

- 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.

2. OVERCURRENT PROTECTION

- Overcurrent devices in the dc circuits listed for dc operation. If the device is not marked dc, verify dc listing with the 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-1703, 690.8, module instructions] Note: Both 125% factors are now in the *CEC*. Supplementary listed devices are allowed in PV source circuits only, but branch-circuit rated devices are preferred. [690.9 (C)]
- Each module or series string of modules have an overcurrent device protecting the module. [703/*CEC* 110.3(B)]
  Note: Frequently, installers ignore this requirement marked on the back of modules. Listed combiner PV combiner boxes meeting this requirement are available. SMA Sunny Boy and some other "string" inverters operating at high voltages may not require dc fuses with two strings of modules or less.
- 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 are protected. Sources of overcurrent are parallel-connected modules, batteries, and ac backfed through inverters. [690-9 (A)]
- User-accessible fuses are in "touch-safe" holders or capable of being changed without touching live contacts. [690.16]

3. ELECTRICAL CONNECTIONS

- Pressure terminals are tightened to the recommended torque specification.
- Crimp-on terminals are listed and installed with listed crimping tools by the same manufacturer.
- Twist-on wire connectors are listed for the environment (i.e. dry, damp, wet, or direct burial) and installed per the manufacturer's instructions.
- Pressure lugs or other terminals are listed for the environment (i.e. inside, outside,

wet, direct burial).
- Power splicing blocks are *listed* and not just UL recognized.
- Terminals containing more than one conductor are listed for multiple conductors.
- Connectors or terminals using flexible, fine-stranded conductors are listed for use with such conductors.

4. CHARGE CONTROLLERS

- Charge controller is listed to UL Standard 1741. [110.3]
- Exposed energized terminals not readily accessible.
- Does a diversion controller have an independent backup control method. [690.72(B) (1)]

5. DISCONNECTS

- Disconnects are not required when integrated with the disconnects
- Disconnects are listed for dc operation in dc circuits. Automotive, marine, and telecom devices are not acceptable.
- PV disconnect is readily accessible and located at the first point of penetration of PV conductors.
- PV conductors are outside the structure until reaching the 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 are not fused or switched. Bolted disconnects are okay.

Note: Listed PV Centers by Xantrex, Outback, and others for 12, 24, and 48-volt systems contain charge controllers, disconnects, and overcurrent protection for the entire dc system with the possible exception of source circuit or module protective fuses.

6. INVERTERS (Stand-alone Systems)

- Inverter is listed to UL Standard 1741. [110.3]
  Note: Inverters listed to telecommunications or other standards do not meet *CEC* requirements.
- DC input currents are 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 are sized 125% of calculated inverter input currents [690.8(A)]
- Overcurrent/disconnects are 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 battery circuits. AIR/AIC at least 20,000 amps. [690.71(C), 110.9]
- No multiwire branch circuits used where single 120-volt inverters are 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 do not meet *CEC*. Flexible, listed USE, RHW, or THW cables are available. Article 400 flexible cables larger than 2/0 AWG are OK for battery 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 is 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 is 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 *CEC* requirements.
- Backup 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)]

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 may be located inside inverters or in ground-fault protection devices.
- AC and dc grounding electrode conductors are 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]
- Equipment grounding conductors are 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. [240.20(A)], [690.41]
- Bonding fittings are 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 are used. [300.1(A)]
- Wet-rated conductors are used in conduits in exposed locations. [100. Definition of Location, Wet]
- DC color codes are correct. They are the same as ac color codes—grounded conductors are white and equipment-grounding conductors are green, green/yellow, or bare. [200.6(A)]