Checklist

For Designing & Installing a PV System

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Planning a PV system? The checklist below, while not all-inclusive, lists items that should go into the planning and design process. It is similar to a checklist that is used by some electrical inspectors when inspecting PV systems. References to the *National Electrical Code (NEC)* are presented in brackets so you can look at the actual code requirements. Detailed explanations can be found at the Southwest Technology Development Institute Web site (see Access) where you can download past *Code Corner* columns.

Installation Checklist

PV Array

- ☐ Are the PV modules listed to UL Standard 1703? [110.3]
- ☐ Are the modules attached to the mounting structure according to the manufacturer's instructions?
- ☐ Are roof penetrations for mounts secure and weathertight?
- ☐ Is each module grounded using the supplied hardware, the grounding point identified on the module, and the manufacturer's instructions?
  Note: The installer must always use the hardware and instructions supplied with the module except when that hardware or the instructions are inadequate or do not meet the requirements or intent of the code. In addition, bolting the module to a "grounded" structure usually will not meet NEC *requirements.*
- ☐ Are equipment-grounding conductors routed with the circuit conductors?
- ☐ Are the equipment-grounding conductors properly sized? [690.45]
- ☐ Has the correct PV array conductor type been used? If exposed, types USE-2, UF (usually inadequate at 60°C; 140°F), or SE may be used. They must be rated for 90°C (194°F), wet-rated, and sunlight-resistant. [690.31(B)]. If in conduit, types RHW-2, THWN-2, or XHHW-2 may be used. They must be rated for 90°C, and be wet-rated conductors. [310.15]
- ☐ Is the PV array conductor insulation rated at 90°C (194°F) [UL-1703] to allow for operation at 70°C (158°F) or higher, near modules and in conduit exposed to sunlight?
- ☐ Were temperature-derated ampacity calculations, based on 156 percent of short-circuit current (I_{sc}), used? [690.8]
  Note: A temperature derating factor of 65°C (149°F) is suggested in installations where the backs of the module receive cooling air (mounted 6 inches or more from the mounting surface) and a derating factor of 75°C (167°F) is recommended where little or no cooling air can get to the backs of the modules. Ambient temperatures in excess of 40°C (104°F) may require different derating factors.
- ☐ Is the derated ampacity for the PV array conductors greater than the rating of any overcurrent device (156 percent I_{sc})? [690.9]
- ☐ Were portable power cords used only for tracker connections? [690.31(C), 400.3,7,8]
- ☐ Were strain reliefs/cable clamps or conduit used on all cables and cords, and are they listed for the application and the environment? [300.4, 400.10]

Overcurrent Protection

- ☐ Are all overcurrent devices in the DC circuits listed for DC operation? If a device is not marked DC, verify its DC listing with the manufacturer. Auto, marine, and telecom devices are not acceptable.
- ☐ Has overcurrent protection been rated at 1.56 times (1.25 x 1.25) the short-circuit current from modules? [UL-1703, 690.8, module instructions]
  Note: Both 125 percent factors are now in the NEC. *Supplementary listed devices are allowed in PV source circuits only, but branch-circuit rated devices are preferred. [690.9(C)]*
- ☐ Does each module or series string of modules have an overcurrent device protecting the module or string? [UL-1703/NEC 110.3(B)]
  Note: Frequently, installers ignore this requirement, which is marked on the back of modules. Listed PV combiner boxes meeting this requirement are available. SMA Sunny Boy and some other "string" inverters may not require DC fuses with two strings of modules or fewer.
- ☐ Are overcurrent devices 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]
- ☐ Is the smallest conductor used to wire modules protected? Sources of overcurrent are parallel-connected modules, batteries, and AC backfed through inverters. [690-9(A)]
- ☐ Are user-accessible fuses in "touch-safe" holders or capable of being changed without touching live contacts? [690.16]

Electrical Connections

- ☐ Have pressure terminals been tightened to the recommended torque specification?
- ☐ Are crimp-on terminals listed and were they installed with listed crimping tools by the same manufacturer?
- ☐ Are twist-on wire connectors listed for the environment (dry, damp, wet, or direct burial) and were they installed per the manufacturer's instructions?
- ☐ Are pressure lugs or other terminals listed for the environment (inside, outside, wet, direct burial)?
- ☐ Are power splicing blocks listed, and not just UL recognized?
- ☐ Are terminals containing more than one conductor listed for multiple conductors?
- ☐ Are connectors or terminals using flexible, fine-stranded conductors listed for use with such conductors?

Charge Controllers

- ☐ Is the charge controller listed to UL Standard 1741? [110.3]
- ☐ Are exposed, energized terminals readily accessible?
- ☐ If the charge controller is a diversion controller, does the system have an independent backup control method? [690.72(B)(1)]

Disconnects

- ☐ Are all disconnects in DC circuits listed for DC operation? Automotive, marine, and telecom devices are not acceptable.
- ☐ Are PV disconnects readily accessible and located at first point of penetration of PV conductors? [100, Definitions: Accessible, Readily & 690.14(C)(1)]
- ☐ Are PV conductors kept outside of the structure until reaching the first readily accessible disconnect, unless in a metallic raceway? [690.14, 690.31(F)]
- ☐ Are there disconnects for all current-carrying conductors of PV source? [690.13]
- ☐ Are there disconnects for equipment? [690.17]
- ☐ Are grounded conductors *not* fused or switched? Bolted disconnects are OK.

  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 module-protective fuses.

Inverters (Stand-Alone Systems)

- ☐ Is the inverter listed to UL Standard 1741? [110.3]

  Note: Inverters listed to telecommunications or other standards do not meet NEC *requirements.*
- ☐ Have DC input currents been calculated for cable and fuse requirements? Input current equals the rated AC output in watts, divided by lowest battery voltage, divided by inverter efficiency at that power level. [690.8(B)(4)]
- ☐ Are cables to the batteries sized at 125 percent of calculated inverter input currents? [690.8(A)]
- ☐ Are overcurrent/disconnects mounted near the batteries and external to PV load centers if the cables are longer than 4 to 5 feet (1.2–1.5 m) to the batteries or the inverter?
- ☐ Have high interrupt, listed, DC-rated fuses or circuit breakers been used in battery circuits? Is the amps interrupt rating (AIR; usually applied to fuses) or the amps interrupt capability (AIC; usually applied to circuit breakers) at least 20,000 amps? [690.71(C), 110.9]
- ☐ Have multiwire branch circuits been eliminated when single, 120-volt inverters are connected to 120/240-volt load centers? [100–Branch Circuit, Multiwire], [690.10(C)]

  Note: A multiwire branch circuit is a three-wire circuit with a shared neutral for two, 120-volt branch circuits.

Batteries

Note: No batteries are UL listed.

- ☐ Have building-wire-type cables such as USE, RHW, and THW been used? [Chapter 3; see Table 310.13 for a complete list.]

  Note: Welding cables, marine, locomotive (DLO), and auto battery cables don't meet NEC *requirements. Flexible, Article 400 cables (in sizes #2/0; 67 mm² and greater) and flexible RHW or THW cables are available, but these cables require very limited, specially listed terminals. When the battery conductors leave the battery enclosure, the conductors must be of a type listed for use in conduit (RHW or THW)—Article 400 cables are not. [690.74, 400.8] See Inverters (Stand-Alone Systems for ampacity calculations.*
- ☐ Is access to the batteries limited? [690.71(B)]
- ☐ Are batteries 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.
- ☐ Are cables to inverters, DC load centers, and/or charge controllers in conduit? [300.4]
- ☐ Does conduit enter the battery enclosure below the tops of the batteries?

  Note: There are no listed battery boxes. Lockable, heavy-duty plastic polyethylene toolboxes are usually acceptable.

Inverters (Utility-Interactive Systems)

- ☐ Is the inverter listed to UL Standard 1741 and identified for use in interactive photovoltaic systems? [690.4(D), 690.60]

  Note: Inverters listed to telecommunications and other standards do not meet NEC *requirements.*
- ☐ Is there a charge controller to regulate the batteries (if present) when the grid fails? [690.72(B)(1)]
- ☐ Is the inverter connected to a dedicated branch circuit with backfed overcurrent protection? [690.64]
- ☐ Have listed DC and AC disconnects and overcurrent protection been used? [690.15,17]
- ☐ Is the total rating of the overcurrent devices *supplying* electricity to the AC load center (main breaker plus backfed PV breaker) less than the load center's rating (120 percent of the load center's rating in residences)? [690.64(B)(2)].

Grounding

- ☐ Has only one bonding conductor (grounded conductor to ground) for DC circuits and one bonding conductor for AC circuits (neutral to ground) been used for system grounding? [250]
  Note: The DC bonds may be located inside inverters or in ground-fault protection devices.
- ☐ Are 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]
- ☐ Are equipment grounds properly sized (even on ungrounded, low-voltage systems)? [690.43]
- ☐ Have disconnects and overcurrent devices been used in both of the ungrounded conductors in each circuit on 12-volt, ungrounded systems? [240.20(A)], [690.41]
- ☐ For inverters with a system voltage more than 250 VDC, were bonding fittings used if metal conduits were used? [250.97]

Conductors (General)

- ☐ Were standard building-wire cables and wiring methods used? [300.1(A)]
- ☐ Were wet-rated conductors used in conduits in exposed locations? [100 Definition of Location, Wet]
- ☐ Are the DC color codes 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)]

Summary

This checklist is not intended to replace a working knowledge of the code. If you are contemplating designing and installing a PV system, by all means, get a copy of the current edition of the *National Electrical Code* for your area. Some parts of the country are still using the 1999 and 2002 editions of the *NEC.*

Access

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The 2005 *NEC* and the *NEC Handbook* are available from the National Fire Protection Association (NFPA), 11 Tracy Dr., Avon, MA 02322 • 800-344-3555 or 508-895-8300 • Fax: 800-593-6372 or 508-895-8301 • custserv@nfpa.org • www.nfpa.org