Working with Inspectors

What Your Checklist Should Include

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Grid-tied photovoltaic (PV) systems can be quite complex—more complex than the typical residential or commercial electrical systems that most inspectors are familiar with. To minimize the time that the actual inspection requires, and to increase the probability that the system passes the inspection, it pays to prepare before you contact an inspector.

The majority of PV systems installed today are utility-interactive (U-I). This *Code Corner* discusses how to smooth the way for the installation of a safe, code-compliant, inspected batteryless U-I PV system.

Permits Can Educate

Although inspectors are generally approachable and usually willing to answer questions about inspections and the *National Electrical Code (NEC)*, most are not PV system designers and aren't familiar with PV equipment. So your first job is to determine how inspections are accomplished in your local jurisdiction. In many jurisdictions, a permit is required to do any electrical work. There also may be requirements that the work be done by a licensed electrical contractor or licensed electrician.

Once you've done this legwork, it's time to pave the way for a smooth inspection. A system installer can use the permitting process to educate the inspector and demonstrate that, on paper, the PV system meets the basic requirements of the *NEC*.

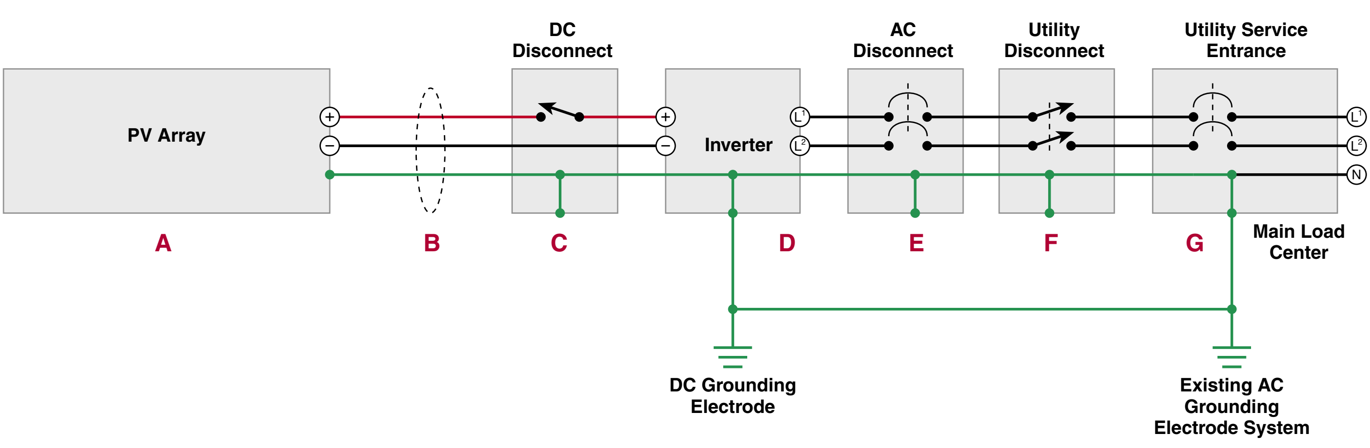
Frequently, an inspector will have more time to check the plans in the office than what is available in the field to perform the actual inspection. For a utility-interactive, residential PV system, giving the inspector the information outlined below during the permitting process or, with no permitting, at least a week before the inspection is scheduled will enable him or her to examine the system's design and maybe even ask a few questions. Some of these items are not necessarily required by your inspector, but will still be helpful.

Your Checklist

Equipment Lists & Specs. Include with the permit a list of the equipment used and the specifications for that equipment. This list includes PV-specific equipment, such as PV modules, inverter, fuses, and circuit breakers. Also include listing/certification and rating information. Factory cut-sheets or pages from instruction manuals are the preferred way to present this information. Giving inspectors copies of the module and inverter instruction manuals for their files may be a way to increase their understanding of how these components should be installed.

The Diagram. While a CAD-generated diagram is not required, present something better than a "back of the envelope" sketch. The red letters in the diagram below indicate information that should appear on or be attached to the plan.

Residential PV System



A. PV Array

Indicate the type and number of PV modules in each series string. The open-circuit voltage (Voc) of each module times the number of modules connected in series, times a cold temperature factor (*NEC* Section 690.7) equals the maximum system voltage. This must be less than the inverter's maximum direct current (DC) input voltage and less than the voltage rating of connected components (wires, overcurrent devices, disconnects). A label on the back of the PV module will give the electrical parameters needed for these code-required calculations.

The ampacity of module interconnection cables, after corrections for conditions of use, must not be less than 1.56 times the short-circuit current (Isc) marked on the back of the module. Due to the exposed, outdoor location and high operating temperatures, all conductors should have insulation rated for 90°C (194°F) and wet conditions (in conduit, THHN/THWN-2 or RHW-2). Exposed conductors (usually USE-2) must also be sunlight resistant.

B. Conduits

Conduits will typically be used throughout the system—usually after the wiring leaves the PV array. They will be installed in various locations, some of which may be in sunlight that will cause them to be hotter than the surrounding air. Be sure to include conductor ampacity calculations for conduit fill and temperature corrections. These correction factors can be found in Section 310.15 of the *NEC*; the temperature correction factors are at the bottom of the ampacity tables (Section 310.16 or 310.17).

C. Module & String Overcurrent Protection; PV DC Disconnect

Overcurrent protective devices (OCPD) in DC circuits may not be required when there are only one or two strings of modules. Three or more strings of modules typically require an OCPD in each string. The current rating of the OCPD, when required, should be 1.56 Isc for that circuit. The voltage rating of the OCPD should be not less than the maximum PV system voltage.

The strings may be combined in parallel in a combiner box ahead of an unfused DC PV disconnect or combined at the output of a fused DC PV disconnect. Appendix J in *PV Power Systems and the National Electrical Code: Suggested Practices* provides detailed calculations on OCPD requirements in DC PV array circuits (see Access). Any OCPD connected in series with a module or string of modules should not have a value greater than the maximum series fuse value marked on the back of the module.

The grounded PV output conductor (commonly the negative conductor) must not be switched by the disconnect. This grounded conductor must be color-coded white. Some PV systems have a positive conductor that is the grounded conductor—it will be color-coded white and will not be switched. In this case, the ungrounded negative conductor will be connected to the switch pole. Future PV systems may not have any grounded PV array circuit conductors. In those instances, both PV output conductors would be switched and neither would be color-coded white.

PV output conductors, after any combining of series strings, should have an ampacity, after corrections for conditions of use, of not less than 1.56 times the module Isc times the number of strings in parallel.

D. The Inverter

The inverter must be listed for utility-interactive (U-I) use. The inverter maximum input voltage must not be exceeded in cold weather (see A).

For PV systems with roof-mounted modules installed on a dwelling, the inverter must have a ground-fault protection device (GFPD). When a GFPD is built into the inverter (which is the case with most batteryless U-I inverters below 10 KW), there should be no bond external to the inverter between the grounded circuit conductor and the grounding system.

AC and/or DC disconnects internal to the inverter are acceptable if they are readily accessible and the inspector deems that only qualified people will service the inverter. Otherwise, external disconnects will be needed. Internal disconnects, if circuit breakers, might not be suitably rated for the ampacity of PV output conductors (the rating may be too high) and an external OCPD may be needed.

E. Inverter AC Output Overcurrent Device & Disconnect

Any OCPD located in the inverter AC output should be rated at 1.25 times the maximum continuous output current of the inverter. The maximum continuous current is specified in the inverter manual or is calculated by dividing the inverter rated output power by the nominal AC line voltage. This OCPD may be a backfed breaker located in the load center—the place where any possible fault currents for the inverter AC output conductor would originate. A backfed breaker in the load center could also be the inverter AC disconnect if the inverter were located near the load center.

F. Utility-Required AC Disconnect

Many utilities require a visible-blade, lockable–open disconnect in the inverter's AC output circuit. This disconnect is usually located within sight of the service-entrance meter so that emergency response people can easily find it. The top terminals (line side) of this disconnect should be connected to the circuit that comes from the AC load center because it will usually be energized by utility voltage. The bottom terminals (load side) should be connected to the circuit from the inverter. This disconnect may be fused or unfused depending on the utility's specific requirements. The utility disconnect must have a minimum current rating that is 1.25 times the inverter's maximum continuous output current (*NEC* Section 690.8).

G. Point of Connection—Load Center

Most smaller residential PV systems make the point of connection with the utility through a backfed breaker in the load center. *NEC* Section 690.64(B) establishes these requirements. If the load center is rated at 100 amps and has a 100-amp main breaker, the maximum rating of all backfed PV breakers would be 20 amps (either or both phases of the 120/240-volt panel). A 200-amp load center with a 200-amp main breaker would be limited to 40 amps of backfed breakers. However, many installations have PV systems that are larger than the 100-amp or 200-amp load centers can accommodate. Other combinations are possible as is a supply-side tap of the service entrance conductors (for more information, see *Code Corner* in *HP112*).

Good Planning Pays

Be sure to include all of the listed information when you're submitting your plans for obtaining a permit for your PV system installation. The more information you provide, the easier it will be for your installer to communicate to the inspector that the system design and component selection meet *NEC* requirements. It is far more cost effective to change the design on paper—before any hardware is purchased and installed. The bottom line is that working with your inspector can, and frequently does, result in a safer, more reliable PV system.

Questions or Comments?

If you have questions about the *NEC* or implementing PV systems that follow *NEC* requirements, call, fax, e-mail, or write to me. For more detailed articles on these subjects, visit the NMSU Web site (see Access). The U.S. Department of Energy sponsors my activities in this area as a support function to the PV industry under Contract DE-FC 36-05-G015149.

Access

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Photovoltaic Power Systems & the 2005 National Electrical Code: Suggested Practices, a downloadable 144-page PDF manual • www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html

2008 *NEC* Proposals PDF • www.nmsu.edu/~tdi/pdf-resources/2008NECproposals2.pdf

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The 2005 *National Electrical Code* 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