Common Mistakes

& How to Avoid Them

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Designing and installing a PV system that meets the minimum requirements of the *National Electrical Code* (*NEC*) doesn't take any more time, effort, or cost than installing a system that does not meet the code. This Code Corner will outline some of the common errors that are made in the installation of PV systems, and what could have been done to avoid them.

Color Codes

Back in the late 1800s, Tom Edison used DC electrical systems many years before Westinghouse and AC electricity came along. Early versions of the code addressed these DC systems, and DC has continued in the code ever since, although most of the attention has focused on AC systems in recent years. The early code and all subsequent revisions established that all (DC, and then AC) grounded circuit conductors be identified with white or gray colored insulation. Insulation identified with three white stripes along its length is also allowed.

Conductor sizes larger than #6 (13 mm^2) can be identified with white or gray marking at each termination because these conductors are nearly always made with only black insulation. The other frequently used color code is that equipment-grounding conductors be bare (no insulation) or have green or green and yellow insulation. There are no other color codes in the *NEC* that are commonly used in residential and commercial electrical installations. There are no specified color codes for ungrounded conductors, and there are no color codes associated with DC wiring.

Many PV installers throughout the United States feel that the DC wiring in a PV system should have red insulation for the positive conductor and black insulation for the negative conductor. The roots of this misconception may be in the automotive and electronics industries. Inappropriate color coding has been used in numerous PV systems that have grounded conductors and operate at voltages from 12 to 600 volts.

The photo (bottom left) is typical of recently installed systems observed on the East and West Coasts and in Phoenix, Arizona. Any PV junction box with no white conductors probably does not meet the code.

If the PV system were an ungrounded 12 volt PV system, the *NEC* has nothing to say about the color of the insulation on the two ungrounded conductors. Red and black would be perfectly acceptable. However, on grounded 12 volt systems and all higher voltage systems (which are required to be grounded by code), the grounded circuit conductor (usually the negative conductor) is required to be white, gray, or marked with those colors. As a matter of common usage in AC circuits, the first ungrounded conductor is colored black and the second ungrounded conductor is colored red, but these are not code requirements.

The reason why this misuse of color codes continues to exist is not known. For years, *Home Power* has been using

Not to code: improper color coding.

Not to code: grounded conductor switched.

Not to code: disconnect 10 feet in the air.

Not to code: DC250 mounted horizontally.

Not to code: triple whammy.

red and black color codes for readability and to differentiate DC wiring from AC wiring in system schematics. This may have contributed to the problem.

Disconnects—Which Conductors?

Disconnects (safety switches and circuit breakers) should never be installed in the grounded conductor of DC PV circuits. For that matter, they are not usually allowed in the grounded conductors of AC circuits either. When these disconnects are installed in this manner and operated, a grounded conductor from a PV array will become ungrounded and will still be energized when the PV array is sunlit. Since all grounded conductors (marked white) are assumed to be grounded (at earth potential), it may come as a surprising shock when one is touched and it turns out to be energized with respect to ground.

There is a common misconception that when both conductors of a circuit are ungrounded, it is not possible to get shocked by touching ground and one of the conductors. Distributed small leakage paths in PV modules and wiring will generally prevent a truly isolated, ungrounded circuit, and a definite shock potential usually results.

Many of the grounded SMA Sunny Boy and Xantrex PV-series high-voltage systems seem to get disconnects installed with the positive and negative conductors both switched. See the photo labled "not to code: grounded conductor switched" on the previous page. This may come about from the switch manufacturer's tech notes that say: "Use the outer two poles of the three-pole disconnect to achieve the 600 volt DC rating." In our PV systems, the two outer poles should be connected in series and then used to switch only the ungrounded (normally the positive) conductor.

As an aside, Square D has obtained a special listing on their H361/HU 361 30-amp, 3-pole, 600 volt heavy duty safety switch when used with PV systems. (See Access for details.) If the PV string short-circuit current is below about 12 amps, then each of the three poles can be used as a 600 volt disconnect without connecting the poles in series. One H361 (fused) switch could be used for all three PV strings connected to a Sharp 3,500 watt inverter. Up to three Sunny Boy 2500 inverters could use a single HU361 (unfused) disconnect. The Sunny Boy inverter cannot backfeed currents into the PV array, so DC fuses are normally not needed when only one or two strings of modules are connected to the inverters. Therefore, the unfused HU361 disconnect may be used.

Disconnects—Location & Orientation

The rule for mounting many disconnects seems to be "wherever it will fit." The *NEC* requires disconnects (switches and circuit breakers) to be located with the handles in the upper position no more than 6 feet, 7 inches (2 m) above the floor or ground. The manufacturer's instructions on many high current switches and breakers (like those used for large PV system disconnects and battery disconnects) require that they be mounted on a vertical surface and oriented so that the handle also moves vertically rather than horizontally. This must be done so that the internal arc suppression mechanisms function properly (hot arcs rise).

The photo (top right), a triple whammy, shows a disconnect and combiner box using black wires for grounded conductors, switching the grounded conductor, and mounted 10 feet (3 m) above the ground.

Installing PV systems safely and in compliance with the codes is not difficult. It takes some understanding of the requirements. After all, hundreds of thousands of new homes and electrical systems are installed every year throughout the country, and most are in full compliance with the *National Electrical Code.* Why should PV systems be any different?

Access

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Special listing information on the Square D H361/HU361 safety switch: www.squareD.com/us/products/safetysw.nsf/DocumentsByCategory/DD5F1F9416FA236685256D350071EC30 or go to www.sma-america.com and select Tech Updates

The 2002 *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