Selecting Cables

for PV Systems

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Photovoltaic (PV) modules will supply energy for 40 years or more when illuminated by the sun. The cables and conductors used in PV systems need to be able to carry PV-supplied energy safely for the lifetime of the PV modules without deterioration, or hazardous conditions will arise. Numerous types of conductors, wire, and cables are widely available from a number of sources with a bewildering array of labels and prices. How do we determine that a particular cable is safe for use in a particular application, and that it will remain safe over the many years that our renewable energy systems will be producing energy?

Previous *Code Corner* columns have covered conductor type markings (USE-2, NM, RHW-2, THW, etc.) required on cables to be used in various locations in PV systems. Those columns have discussed the type markings required for environmental conditions, such as exposure to sunlight, temperature levels, and moisture. (See *HP89*, *HP91* & *HP94*.)

Unfortunately electrical cables without these type markings are available from many sources, such as auto parts stores, hardware stores, building supply stores, and welding supply shops, among others. Furthermore, many of these cables do not have any marks or labels to ensure that they have been tested and evaluated for safety. See the table for some of the commonly used conductor type markings and what they indicate.

To ensure the greatest probability of buying and installing safe, durable conductors that meet the requirements of the *National Electrical Code* (*NEC*), you should look for cables that have at least the following markings or labels. First, the type marking (USE-2, RHW-2, THWN-2, etc.) should be on the cable, and that type marking should be appropriate for the particular PV application, such as module interconnections or battery-to-inverter cables.

Second, the mark of a nationally recognized testing laboratory, such as Underwriters Laboratories (UL), should be present. This mark indicates that the cable has undergone extensive testing for that application and has been "listed" for compliance with the appropriate UL standard for that type of cable. The *NEC* and most inspectors require that all equipment used in electrical systems be listed.

At present, UL is the only laboratory that is recognized and accepted throughout the United States for testing and marking cables. Note that cables bearing the CSA (Canadian) and/or CE (European) marks must also have

Conductor Type Designations

Code	Temp.	Characteristics
T	–	Thermoplastic insulation (most commonly PVC)
R	–	Thermoset insulation (synthetic rubber)
W	–	Wet rated
H	75°C	High temperature
HH	90°C	Higher temperature
N	–	Nylon jacket
X	–	Cross-linked polyethylene
-2	90°C	High temperature & wet rated
Wire Type		
THHN	90°C	Dry and damp locations, flame retardant
THWN	75°C	Dry and wet locations, flame retardant
THWN-2	90°C	Dry and wet locations, flame retardant
THW	75°C	Dry and wet locations, flame retardant
RHH	90°C	Dry and damp locations, flame retardant
RHW	75°C	Dry and wet locations, flame retardant
RHW-2	90°C	Dry and wet locations, flame retardant
USE	75°C	Underground service entrance, sunlight resistant
USE-2	90°C	Underground service entrance, sunlight resistant
UF	75°C	Underground feeder
XHHW	90°C	Dry locations, flame retardant
XHHW	75°C	Wet locations, flame retardant
XHHW-2	90°C	Dry and wet locations, flame retardant
NM	60°C	Nonmetallic sheathed cable, flame retardant

the UL mark to comply with U.S. requirements. In the near future, cables marked "CSA (U)" for U.S. standards may be acceptable, and ETL may, at some point, also list cables in the United States to standards established by UL.

UL Standards for Cables

Underwriters Laboratory has two major functions in the electrical energy industry in the United States. The first function is to write, coordinate, and publish safety standards. The second function is to test and evaluate materials and equipment against those standards.

A safety standard is a document that details all of the tests and the results of those tests that a particular type of cable must meet before it can be listed as complying with the standard. For example, UL Standard 44 for "Rubber-Insulated Wires and Cables" was first published in 1917 and has had fifteen major revisions since then. The latest edition was published in 1999 and is now entitled "Thermoset-Insulated Wires and Cables." This standard covers conductor types (such as RHW, THW, XHHW-2, and similar cables) that are acceptable for use as battery cables in PV systems. Numerous companies and other agencies that design, manufacture, sell, install, and inspect cables are involved with keeping the standard current.

This standard is more than 70 pages long, and is updated periodically and completely revised every few years as the technologies change for making, using, and testing cables. In addition to requirements for the types of rubber and synthetic rubber required to make the cable, numerous tests are included in the standard, and these tests are used to verify the quality, durability, and safety of the cables. (Note that each UL standard references other UL standards that must also be met. For cables, additional standards establish requirements for the insulation material and the copper used in the conductors. UL standards provide details on the tests, how they will be conducted, and what results are required for passing.)

Testing to the Standard

The standard is then used by nationally recognized testing laboratories to test the cable. This is UL's second function with respect to cable markings.

A nationally recognized testing laboratory goes through a lengthy evaluation process conducted by special certification agencies to ensure that the lab has personnel with the appropriate educational backgrounds and experience, and sufficient test and evaluation equipment to properly perform the required tests. Test equipment must be calibrated against calibration standards directly traceable to the National Institute of Standards and Technology (previously, the National Bureau of Standards).

A cable is submitted to UL for testing against the standard. UL tests the cable, and if it passes all of the tests in the standard, UL allows the manufacturer to use the UL mark (the letters "UL," sometimes in a circle but more often without) on the cable, indicating that it is a listed product.

UL also visits the manufacturer's facility and determines that the equipment and processes used to make the cable are of sufficient quality to ensure that uniform quantities of the cable can be produced. But the testing does not end there. Any time the cable manufacturer changes the materials used in the cable or the way the cable is made, the manufacturer must notify UL and resubmit the modified cable for evaluation and possible retesting.

Additionally, every three months, UL visits the cable manufacturer and verifies that the materials and production processes are still producing the same cable that was originally tested. UL may pull random samples of cable from the production line or the warehouse and retest them at any time.

To further establish the continuing quality of any listed cable in this highly competitive industry, cable manufacturers routinely test samples of their competitors' cables and protest to UL if the listed cables do not meet the standard in any way.

Other Cables—Usually Not Acceptable

In most major cities, many smaller towns, and certainly through the Internet, you can find a large number of widely varying cable types that are not suitable for use in PV installations. These might have type designations such as DLO (diesel locomotive cable), welding cable, battery cables, Tek cables, etc. These cables may have a very impressive set of markings, such as 600 volts, 1,000 volts, MSHA, IEEE, TVD, CE, 105°C, 200°C, and so forth. These markings have no meaning with respect to the requirements of the *NEC* and PV installations. While they may be superior cables in their intended applications, they have not been tested for use in electrical systems falling under the *NEC* and should not be used.

Best That I Can Find

Although many different cables will meet the minimum requirements of the *NEC*, when I am designing or installing a PV system that may produce potentially hazardous amounts of energy long after I am gone, I try to use the best cables that I can find. If I need exposed module interconnection cables, I use USE-2 conductors made from cross-linked polyethylene (marked XLP or XLPE).

Strictly speaking, USE-2 cables are not tested for use in conduit. Since this cable has no flame retardant, it cannot be used in buildings—even in conduit. I buy cables marked USE-2 with the additional RHW-2 marking, so that I may use them inside conduit in buildings. As far as can be determined based on actual use experiences, utility usage, and data from the manufacturers, these are the most durable cables that we can use in PV systems.

Make an Informed Decision

Yes, you can purchase unmarked or improperly marked wires and cables. They may work quite well in a PV system. But then again, they may not.

How are you to know that a piece of unmarked (no type mark, no listing mark) cable X that you bought yesterday will perform the same as a similar piece of unmarked cable that you bought at the same store a year ago? Is cable X

bought in Arizona the same as cable X bought in California? Will either of these cables withstand the test of time? Did the manufacturer cut costs by making the insulation a little thinner? Did the manufacturer change insulation materials to a type that saves a few pennies, but might crack or catch fire more easily? Were costs reduced by accepting copper with more impurities, which might become brittle or have a higher resistance?

The use of properly type-marked, listed cables ensures that most of these uncertainties are eliminated. With reliable PV modules producing electricity for 40 years or more, it is prudent to buy the proper cables that have been thoroughly examined and tested by trained, experienced personnel, and periodically rechecked. Then you won't have to worry about the uncertainties of using unmarked cables.

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

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