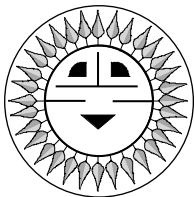


AWG, RHW, CNN, USE-2, THHN, THW, XLPE, #@%*&!



John Wiles

Sponsored by the Photovoltaic Systems Assistance Center, Sandia National Laboratories

Don't understand the designations, types, and sizes of conductors used in PV systems? Read on. In the next several issues of *Code Corner*, we will deal with the wires, cables, and conductors used in a PV system. Wind power installers should also take note: the conductor requirements for wind systems are very much like those for PV systems and any other electrical systems.

Conductors, Wires, Cables—What's the Difference?

Many people use the terms “conductor,” “wire,” and “cable” interchangeably. I do too. The *NEC* uses the terms in specific ways, but it also uses the terms interchangeably. Here are some definitions found in Article 100 of the *National Electrical Code*® (*NEC*®).

Conductor

Bare A conductor having no covering or electrical insulation whatsoever.

Covered A conductor encased within material of composition and thickness that is not recognized by this Code as electrical insulation.

Insulated A conductor encased within material of composition and thickness that is recognized by this Code as electrical insulation.

Premises Wiring (System) That interior and exterior wiring including power, lighting, control, and signal

circuit wiring together with all of their associated hardware, fittings, and other devices, both permanently and temporarily installed, that extends from the service point of utility conductors or source of power such as a battery, a solar photovoltaic system, or a generator, transformer, or converter windings to outlet(s). Such wiring does not include wiring internal to appliances, fixtures, motors, controllers, motor control centers, and similar equipment.

Service Conductors The conductors from the service point to the service disconnecting means.

Service Cable Service conductors made up in the form of a cable.

Section 800-2 (Communications Circuits) has the following definition:

Cable A factory assembly of two or more conductors having an overall covering.

Other sections of the Code mention single conductor cables—the Code does not always define a cable as two or more conductors grouped together. Multiple-conductor cables may or may not have an outer jacket depending on their use and the applicable code requirements. For example, the power cable on an electric drill may have three conductors and be required to have an outer jacket, such as conductor type SOW. On the other hand, a type USE underground service entrance cable may also have three conductors; two are insulated, one is bare, and there may not be a requirement for an outer jacket in some installations.

Section 300-3(a) of the *NEC* says that single conductors specified in this code must be installed as part of a code-recognized wiring system. The process of obtaining listing by Underwriters Laboratories or other testing laboratories poses similar constraints on the use of these cables.

Conductor Properties

The *Properties of Common Conductors* table lists some commonly used conductors and a few of their characteristics. These have been extracted from *NEC* Table 310-13.

The first column (Type) shows the conductor type designation. The second column (Temp. °C/°F) shows temperature rating of the insulation in degrees Celsius/degrees Fahrenheit. The third column (Moist.) shows the highest moisture condition allowed at this temperature. The fourth column (Conduit) indicates whether or not the conductor must be installed in some sort of conduit or raceway. The last column (Sunlight Res.) shows whether the conductor is inherently sunlight resistant (with no marking) or not, or whether it must be marked sunlight resistant if applicable. In some

Properties of Common Conductors

Type	Temp. °C/°F	Moist.	Conduit Req.	Sunlight Res.
THHN	90/194	Damp	Yes	No
THWN	75/167	Wet	Yes	No
THWN	90/194	Dry	Yes	No
THWN-2	90/194	Wet	Yes	No
THW	75/167	Wet	Yes	No
THW-2	90/194	Wet	Yes	No
RHW	75/167	Wet	Yes	No
RHW-2	90/194	Wet	Yes	No
RHH	90/194	Damp	Yes	No
USE	75/167	Wet	No	Yes
USE-2	90/194	Wet	No	Yes
UF	60/140	Wet	No	Marked
SE	75/167	Wet	No	Yes

cases, the conductor has insulation rated at more than one temperature. A second entry for the same cable type shows the secondary temperature/moisture data (see THWN).

By this time, your eyes are crossed, you have a headache, and I'll bet at least some of you are wondering about the alphabet soup. The *Wire & Cable Types* table has the insider's info on what all those letters stand for in the *Properties of Common Conductors* "Type" column.

Many conductors will be marked as two or more types, indicating that they meet the listing requirements for each type. An example is a conductor marked "THHN or THWN-2". This dual or triple marking indicates that the conductor has the properties of both types and can be used in the worst-case environment specified for either (for example, 90°C (194°F) and wet). Another example is a conductor marked "USE-2 or RHW-2". Because they have no flame retardant, conductor types marked with just "USE-2" cannot be used in conduit inside buildings. However, conductor type RHW-2 does have the flame retardant, so the dual-marked cable can be used outside in sunlight, underground, and in conduit inside buildings.

Section 690-31 of the *NEC* allows single conductors in types UF, USE, USE-2 (will be in the 2002 *NEC*), and SE to be used for connecting PV modules where the conductors are exposed in free air and subject to those outdoor sunlit and wet conditions. PV module junction boxes may operate as hot as 75°C (167°F). From the above chart, types SE, USE, and UF should be ruled out for most installations, and only used in very cold climates. A dual-marked conductor such as "USE-2 or RHW-2" is one of the best conductors to use for connecting PV modules since it can also be run through conduit to interior locations.

Multiconductor Cables

There are several multiconductor, sheathed cables that do not have to be installed in conduit for protection if they are afforded physical protection by the location of the installation. The first cable is the very common nonmetallic sheathed cable, type NM, commonly sold as standard Romex®. It has two or three insulated conductors and a bare equipment-grounding conductor enclosed in an outer jacket or sheath. This cable is approved for use in residential, dry locations (as in the walls of a house), and has a final temperature rating of 60°C (140°F). It is not sunlight resistant and cannot be used in damp or wet locations.

A second multiconductor sheathed cable is type UF that also must be installed with physical protection in mind. It is frequently marked "sunlight resistant" and usually has a temperature rating of 60°C (140°F). This cable can be installed outdoors as long as it is out of the sunlight and solar heating areas. It might be used for wiring from a PV combiner box mounted in the shade on the roof to a PV power center located in the house.

Summary

So, where do we use which? Conductors in conduits or raceways can be used for nearly any wiring in a PV system. Local codes may require that conduit be used in commercial installations. As mentioned above, modules may be connected to each other and to nearby combiner boxes by using certain types of exposed single-conductors (USE-2). Wiring inside buildings may be made with the sheathed cables (NM and UF).

Battery and inverter conductors tend to be rather large in size and relatively stiff. Conductor types RHW and THW are available in fine-stranded varieties that are considerably more flexible than the normal conductors available at the local building or electrical supply store. Dealers and distributors in the PV industry stock or can get these flexible conductors.

Wire & Cable Types

Type	Description
T	Thermoplastic insulation
H	75°C (Note: lack of "H" indicates 60°C)
HH	90°C
N	Nylon jacket
W	Moisture resistant
R	Rubber insulation
U	Underground use
USE	Underground Service Entrance *
UF	Underground Feeder *
SE	Service Entrance *
-2	90°C and wet

* May be either single conductor or multiple conductor cable

In the next *Code Corner*, I will address the ampacity and sizing of the conductors used in renewable energy systems.

Questions or Comments?

If you have questions about the *NEC* or the implementation of PV systems following the requirements of the *NEC*, feel free to call, fax, email, or write me. Sandia National Laboratories sponsors my activities in this area as a support function to the PV Industry. This work was supported by the United States Department of Energy under Contract DE-AC04-94AL8500. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy.

Access

Author: John C. Wiles, Southwest Technology Development Institute, New Mexico State University, Box 30,001/ MSC 3 SOLAR, Las Cruces, NM 88003
505-646-6105 • Fax: 505-646-3841 • jwiles@nmsu.edu
www.nmsu.edu/~tdi

Sponsor: Sandia National Laboratories, Ward Bower, Department 6218, PO Box 5800 MS 0753, Albuquerque, NM 87185-0753 • 505-844-5206
Fax: 505-844-6541 • wibower@sandia.gov
www.sandia.gov/pv

National Electrical Code® and *NEC*® are registered trademarks of the National Fire Protection Association. The 1999 *NEC* and the *NEC Handbook* are available from the 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

