# Grounding & UL Standard 1703

**by John Wiles**

One of the most important elements to long- and short-term PV safety is grounding. Environmental conditions, using copper conductors to ground aluminum module frames, and the daily thermal cycling that terminals, combiners, and modules are subjected to will eventually cause a breakdown in insulation or in the electrical connections. That means proper grounding is a must. Here's why.

Grid-tied residential, commercial, and utility-scale PV systems operate with DC voltages from 50 to 600 volts—and higher. AC voltages start at 120 V and some larger systems, such as premises wiring in large commercial and industrial facilities, can hit 23 kV. Exposed circuits operating at more than 30 V (DC or AC) in wet locations are considered a shock hazard by Underwriters Laboratories (UL), which helps establish safety standards for various products. [See also *National Electrical Code* sections 690.31(A) and 690.33(C).]

PV system current ranges from less than 10 A (DC and AC) to about 2,400 amps DC on some of the larger inverters. Consider this: In the right material, an arc at only 1 amp can start a fire. Modules commonly used in residential PV systems range from 20 to 320 W—considerably more than 1 A. PV modules can produce dangerous voltage and current throughout their 40- to 50-year life expectancy. USE-2 cables and the new PV cables are some of the toughest cables available—when properly installed, USE-2 cables have been reported to still be in good shape after two and half decades of service. But what about a less-than-outstanding installation after 30 or 40 years?

**The module bonding screw and the braided copper is touching the aluminum frame, causing corrosion. Tinning the copper does not help.**

## Grounding Problems Reported

There is significant confusion among module manufacturers, installers, and inspectors concerning how to properly ground PV modules. Inspectors are finding improper grounding techniques, and improper grounding instructions are appearing in listed PV module instruction manuals.

Unfortunately, it is difficult grounding PV modules and racks in a manner that will yield a low-resistance connection and will last for 50 or more years. Inspections and tests have found that in some cases, module-grounding connections have deteriorated in as little as three years.

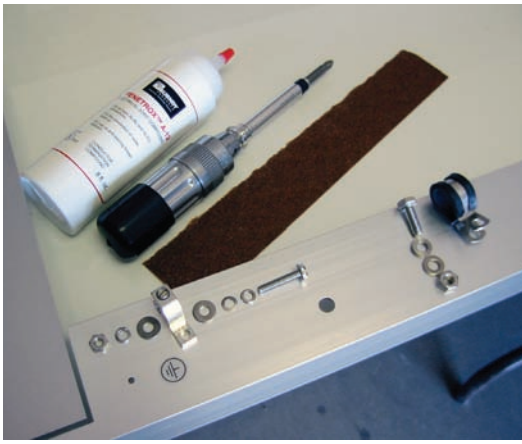
## Bonding vs. Grounding

The current edition (2002) of UL Standard 1703 (PV Flat Plate Modules) devotes a single section to bonding and grounding. Bonding refers to the *factory-made* electrical connections between the four or more sections of the aluminum frame. Grounding refers to the *field-installed* electrical connection between the aluminum module frame and the equipment-grounding system (usually copper conductors).

Bonding uses specific materials and methods to attain a durable electrical connection between the frame pieces. Any failure in module or conductor insulation may result in all pieces of the frame receiving equal voltage. When the module frame is properly field-grounded at one of the marked and tested points, factory bonding also ensures that the entire module frame is maintained at the ground potential under fault conditions. All bonding fasteners are precisely torqued to specification by automated equipment or trained technicians. During the listing process, the factory's bonding materials and methods are evaluated for low resistance and durability. If the manufacturer changes any of the bonding materials or methods, the changes must be reevaluated by the listing agency.

Contrast this precisely controlled and evaluated system with the field-grounding techniques used to connect a copper equipment-grounding conductor to the aluminum module frame. Grounding PV modules is haphazard at best. Many

module manufacturers don't acknowledge the importance of this connection to the system's overall safety. Many instruction manuals and hardware (sometimes supplied) show techniques that may not provide good electrical connections. Further, field-made connections using a threaded fastener are rarely torqued to the specified value—even when that value is given in the module instruction manual—because few PV installers have torque screwdrivers. Inspectors may not inspect the grounding connection and they are rarely tested for overall continuity. Also, since the PV system can operate without trouble for many years, there is little motivation to inspect these connections after the original installation. But possibly the most critical factor is that the UL Standard 1703's bonding/grounding section does not clearly distinguish the differences.



**When other good methods are unavailable, use surface preparation and a tin-plated copper lay-in lug listed for direct burial, and a torque screw driver for accurate tightening.**

## Instruction Inconsistency

In late 2007, UL issued an "Interpretation" of UL 1703 that focused on module field-grounding to be used by module manufacturers and certification laboratories to evaluate and possibly revise the grounding methods, hardware (if any), and instructions supplied with the modules. Modules are supposed to be reevaluated every five years (when the listing must be renewed). Unfortunately, it is not possible for the laboratories to review all existing modules.

For example, some instructions specify lock washers, star washers, and other critical grounding hardware that is found at hardware stores that lack control over the quality of the supply. Others recommend thread-cutting or thread-forming screws, but the UL interpretation states that all threaded fasteners must be installed and removed 10 times without damage to any threads—nearly impossible to do with aluminum module frames.

The UL 1703 interpretation contains a chart showing the compatibility of various metals—electrolytically incompatible metals are clearly shown. For instance, copper and aluminum should not come in contact—if they do, the aluminum at the contact point will suffer galvanic corrosion, destroying the connection. (Inadvertent contact between the copper grounding conductor and an aluminum module frame or rack does not pose problems because the small amount of aluminum that may be corroded is part of the electrical contact.) But some module manufacturer instructions call for isolating the copper conductor from the aluminum frame by using a stainless steel washer—without specifying surface preparation of the oxidized, anodized, and/or clear-coated aluminum module frame. Done properly—that is, *with* surface preparation—the presumption is that the mechanical fastener (screw and nut) and the stainless steel washer would carry the fault currents. However, these devices have not been evaluated and listed for carrying current.

To further confuse the situation, it appears that the high currents, steel plates, and test methods used in UL Standard 467 for evaluating and listing grounding devices may not be applicable to evaluating grounding devices for PV modules and racks where the currents are low and the aluminum surfaces are oxidized, anodized, or clear-coated.

UL is developing specific UL Standard 1703 requirements for PV module grounding that will appear at some future date. The requirements will cover methods and hardware supplied by the module manufacturers, as well as third-party grounding devices.

For now, when the grounding instructions furnished by the module manufacturer are inadequate or contradict *NEC* or UL requirements, the PV installer and the inspector must work out an acceptable module grounding method and hardware. One method used by utility companies for many years to connect copper conductors to aluminum bus bars in an outdoor environment uses surface preparation and a tin-plated copper lay-in lug listed for direct burial. It may be found in the Burndy instructions for installing lay-in lugs and in Appendix G of the *NEC/PV Suggested Practices* manual. Both may be found on my Web site (see Access).

**Although this copper ground appears installed per the module's instruction manual, the copper is touching the aluminum frame which will corrode the aluminum and destroy the electrical contact.**

## Access

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