

# A Progressive Look at PV Module Grounding

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Mr. Thomas Bowes, Assistant Director of the Detroit Electrical Industry Training Center, has recently published an article entitled “A Critical Look at PV Module Grounding”, which is available at <http://www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/Codes-Stds.html>. This article answers the questions raised there and clarifies the use of newer grounding products with PV modules.

The WEEB (Washer, Electrical Equipment Bond) is a new invention developed specifically to ground PV arrays. Wiley Electronics LLC has filed a patent application for the technology and parts have been developed for most PV modules and mounting systems.

The code requirement to be met is article 690.43, which states “Exposed non-current-carrying metal parts of module frames, equipment and conductor enclosures shall be grounded in accordance with 250.134 or 250.136(A) regardless of voltage.” In the past, installers have generally used article 250.134 and attached an equipment ground conductor separately to each PV module and metal mount. This is a labor intensive method and suffers from other problems which will be detailed in following sections. We feel a better approach is to use article 250.136.

Article 250.136 states that “... metal parts of the equipment shall be considered effectively grounded when ... in electrical contact with a metal ... structure provided for its support and grounded by one of the means indicated in 250.134.”

As a specific example, for roof mounted PV arrays, PV modules are mounted on aluminum anodized rails. WEEB grounding clips can be used to establish the electrical contact between the modules and rails, and WEEB lugs can be used to connect the rails to an equipment ground conductor, which is grounded in the usual manner. If one accepts the electrical contacts (to be discussed later), then it is pretty obvious that this system satisfies the code.

Note that the code does not require the mounting rails to be equipment ground conductors, but according to article 250.118, “the equipment grounding conductor shall be ... aluminum ... conductor ... in the form of ... a busbar of any shape”, which accurately describes a mounting rail and therefore would allow it to be used as an equipment ground conductor if one so desired. By considering the rail as a conductor, one can evaluate whether the rail is a low impedance connection, and therefore a good ground. The rail of smallest cross-section that I am aware is 2.63 cm<sup>2</sup>, which is approximately equivalent to 20 wires of 6 AWG. The material is structural grade aluminum manufactured to ASTM standards and therefore will be consistently of high quality material. This will make a very good ground conductor indeed! Add to that the fact that there are generally multiple rails which could conduct in parallel and the overall structure has very low impedance.

Let us now discuss the electrical connection. Mr. Bowes comments, "It is difficult to establish and maintain a solid, low-impedence grounding connection between electrical devices and their associated mounting racks." We concur and it is precisely this problem that our invention solves. Since this is a new invention, we could only test it to existing standards. UL1403, Standard for Safety for Flat-Plate Photovoltaic Modules and Panels, is clearly not applicable, and moreover only requires ground testing to be done at a current level of twice the module fuse rating. Most fuses are only 5 or 10 Amperes. UL467, Standard for Grounding and Bonding Equipment, comes from grounding for AC systems and therefore deals with much higher currents. Our WEEB products are certified to carry a current of 1530 Amps for 6 seconds. The WEEB is therefore several orders of magnitude better than is required for PV applications. These results have been tested by Intertek ETL, a Nationally Recognized Testing Laboratory (NRTL).

Note that there still seems to be some confusion about NRTLs. For code purposes, all NRTLs are equivalent and even though some standards are maintained by Underwriter's Laboratories (UL), testing at UL is no better or worse than at any other NRTL. From a scientific standpoint this makes a lot of sense. If results cannot be independently duplicated, then the tests you are performing are inherently flawed.

In developing our product, we also tested a method which is commonly accepted throughout the industry. This method is to attach an off-the-shelf lay-in lug to each PV module using a thread forming stainless steel screw. Note that the first problem with this lay-in lug method is that the lug is not listed for use with such a screw and therefore this method does not meet code. There is nothing in the code which allows use of a stainless steel screw as a conductor as it is used here and for good reason because stainless steel is a relatively poor conductor. We agree with Mr. Bowes that it is unfortunate that the agencies listing this part do not enforce its proper use. Our testing found that when evaluated against UL467, the lay-in lug method should not be used with any wire size greater than 10 AWG.

Mr. Bowes voices concern about the long term reliability of the WEEB connection when exposed to the environment. Since there are no applicable standards to which the connection could be tested, we were forced to develop our own. High temperature accelerated lifetime tests, thermal cycle tests and cycled exposure to salt water environment tests have been performed on the WEEB and indicate exceptional reliability. This makes sense when one examines the mechanism of the connection. In assembling the WEEB, a mechanical deformation occurs which results in a gas-tight connection between stainless steel and aluminum. In comparison, the lay-in lug method requires drilling, which exposes bare metal to the environment. In our salt water tests, corrosion resulted in the lay-in lug completely falling off the rail after 95 cycles, while the WEEB has endured over 200 cycles without measurable degradation.

The WEEB connection is also superior in that it has a much larger surface of contact than the lay-in lug method which even under the best circumstances only has two threads of contact and under field conditions has a propensity to strip out so that very minimal contact is present. Mr. Bowes suggests scraping the anodizing off in the field and using anti-oxidizing compounds. While our tests have shown this can be a reliable method in the laboratory, the WEEB connection represents a much more repeatable operation under real world field conditions and is therefore the more reliable connection.

Mr. Bowes makes an interesting suggestion that equipment ground connections be a “first-make last-break” type. This is a common practice when using current carrying conductors, but it is not generally used with equipment grounds and is nowhere to be found in the National Electrical Code or in any existing standards. This would therefore not seem to be a reasonable consideration in deciding whether to use new equipment such as the WEEB products.

Mr. Bowes brings up some good questions in his concluding sections. While they do not seem to have any direct application to our WEEB products, we welcome his ideas and would like to suggest that Mr. Bowes join a standards committee so that he can participate in the development of future PV standards.