Photovoltaic Module Grounding: Issues and Recommendations

Greg Ball

BEW Engineering

Tim Zgonena, Chris Flueckiger

Underwriters Laboratories, Inc.

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Study Outline

- Address gap in requirements and methods for reliable grounding of PV module frame and mounting components
- Preliminary "lay-of-the-land" Report (BEW) - PUBLISHED 3/2011
  - Summary of existing conditions, problem statement
  - Survey of existing issues and experiences from stakeholders
- UL interim test development (UL) – Presented 6/2011
  - Preliminary testing on corrosion, degradation using methods that go beyond those in existing UL1703 standard.
  - Final report (BEW/UL) - COMPLETED, to be published 11/2011.
  - Recommendations for a set of tests/methods to incorporate into existing/new standards

Final Report

- Recommendations for enhanced current testing in UL 1703
- UL’s accelerated aging and corrosion resistance testing
  - Severe corrosion and failure of tested bonds
  - Dialog around the implementation and interpretation of results
  - Topic left open for more industry involvement
- Update on relevant standards
- Understanding safety aspects under fault conditions
- Summary recommendations for design/installation

UL 1703 Enhanced Current Tests

- Recommendations from ad-hoc group focusing on UL 1703’s grounding/bonding section:
  - Bond path resistance: Existing low-current (30A) test based on string fuse and leakage current.
  - Bonding devices, two high current tests:
    - 4-6 s test, current per UL 467 (based on size of largest allowed ground conductor, e.g. 750 A for #10 AWG.)
    - 5000A until fuse blows
  - Grounding means shall not crack, break, or melt

Accelerated Aging Tests

Evaluate long-term effectiveness of different module grounding methods:

1. copper connections via screw/washer/nut assemblies
2. lay-in lug assemblies
3. grounding clips

Install and age separately using:

1. IEC 61215 damp heat tests
2. IEC 60068-2-11 salt mist tests (similar to ASTM B117)

…With and without current cycling, anti-oxidant compound

ACCELERATED AGING TESTS ON PV GROUNDING CONNECTIONS

Ethan Wang[1], Kai-Hsiang Yen[1], Carl Wang[1], Liang Ji[2], Timothy Zgonena[2]
[1]Underwriters Laboratories Taiwan Co., Taipei, Taiwan
[2]Underwriters Laboratories Inc., Northbrook, IL, USA

ABSTRACT

As many contemporary Photovoltaic (PV) Power systems being installed are designed to produce significant amount of electricity and claimed to operate for 25 years or more, appropriate grounding on PV modules to reduce or eliminate shock and fire hazards becomes a critical issue under high electricity output and long-term use. Although some PV manufacturers have provided technical bulletins to suggest grounding products and methods, not all of them have been carefully evaluated and reviewed by the certification/listing laboratories. In this paper, different types of PV grounding connectors were collected, installed and put into accelerated environmental test chambers. The effects of current cycling, assembly force, anti-oxidation coating application on grounding reliability were evaluated. The grounding failure modes and mechanisms are also discussed in this paper.

INTRODUCTION

Photovoltaic (PV) power systems being installed today are normally designed to produce significant amounts of electricity over an expected operating life of more than 25 years. The high electrical output and long-term reliable performance necessitate robust grounding systems for PV systems to minimize accidental electric shock and fire hazards.

In late 2007, UL issued an Interpretation of UL 1703 on the topic of module field grounding. The Interpretation clarified that the module instruction manual must specify the grounding methods and materials to be used for external field-made grounding connections. These methods and materials are evaluated as part of the module Listing process and will apply to all existing Listed modules and their instructions as they come up for review [1].

A good connection between the grounding hardware and the module frame is essential for a grounding system to function properly. Typically PV manufacturers use copper-alloy for electrical connections and aluminum-alloy for the module frames. The anodization on the aluminum-alloy surfaces is able to provide an oxidized layer to minimize further corrosion of the frames. However, while the anodization of the aluminum-alloy surfaces creates an oxidized layer that minimizes frame corrosion, it also generates a high electrical resistance reducing grounding effectiveness. To overcome this design issue, the grounding hardware must penetrate through the anodization layer to create a direct electric connection. This is normally achieved by one of the following approaches: (1) Installing a self-tapping or self-drilling fastener through the frame, (2) using a stainless steel star (toothed) washer held against the frame by a bolt or nut, or (3) attaching a Listed lug (see Fig. 1) to the marked grounding points after appropriate surface preparation has been accomplished [2] [3].

The differences in these grounding approaches may result in significant performance differences over the course of the product service life. Therefore further study is needed to address the long-term effect and reliability of these different grounding installations.

Figure 1 Lay-in lug Listed for direct burial (DB) and outdoor use.

OBJECTIVE

The objective of this study is to investigate the long-term effectiveness of different PV grounding devices under simulated harsh environmental conditions. By measuring the contact resistance at the junction between connectors and aluminum frames, this scope of this study includes examining the following grounding techniques:

- Attaching lay-in lug to aluminum frame with a lock-nut penetrating the aluminum surface.
- Removing anodization on the aluminum frame and then attaching lay-in lug directly to it. An anti-oxidant compound was applied between the lug and aluminum surface.
- Grounding copper wire to aluminum frame using thread-cutting screw and cup washer.
- Attaching lay-in lug to aluminum frame with a teeth washer laid between the lug and aluminum surface
- Using grounding clips assembly consists of a slider, base, and thread-cutting screw.

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Aging Tests - Salient Results

- Under damp-heat condition, R remained low (<0.05Ω) almost no change over 20 weeks.
- Under salt mist condition most samples corroded severely failed (> 10Ω) in weeks,
- Samples using the anti-oxidant coating lasted longer before failing.
- Lay-in lug with washer (D) and grounding clips (E) with compound lasted > 20 weeks
- Current cycling did not have a significant impact
- Proper torque on the connections improved the performance.
  - Under-torqued connections failed 5 times sooner

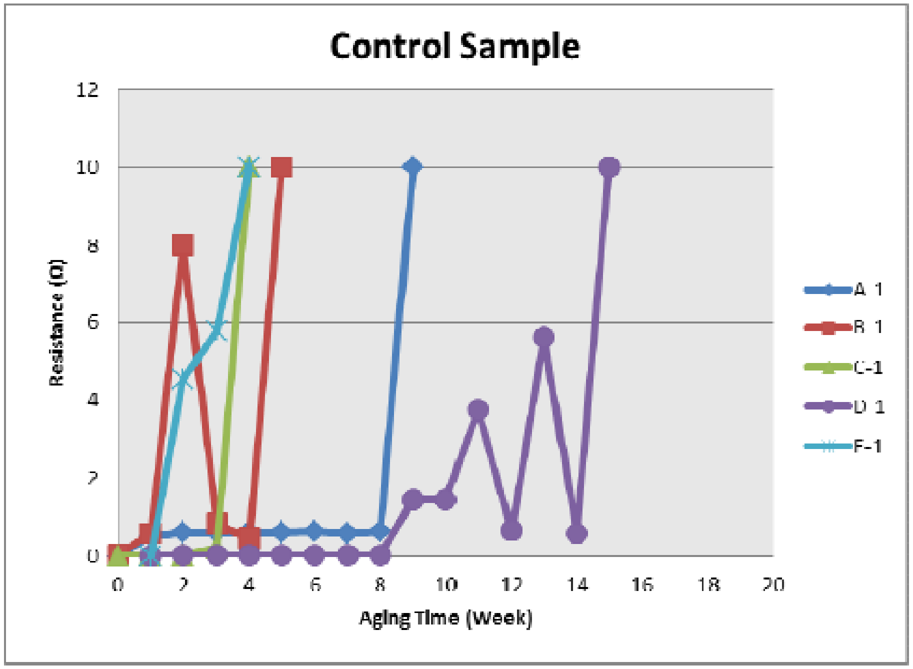
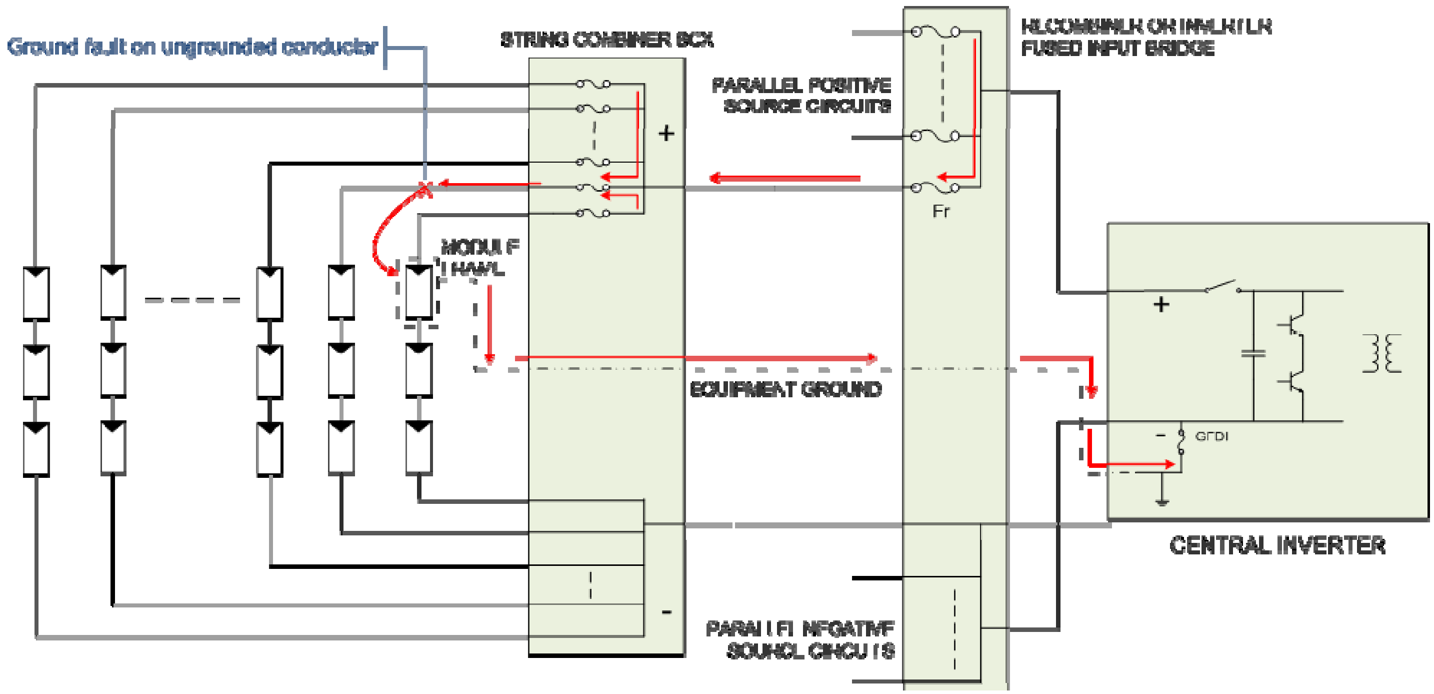


Figure 4 Resistance change for all No.1 connectors under salt mist aging

Update on Applicable Standards

- UL 1703: *Flat-Plate Photovoltaic Modules and Panels*
  - Still the “primary” standard affecting module grounding and devices.
  - Pending changes through Standards Technical Panel (STP)
  - Move towards more categorical evaluation of ground means
- UL 467: *Grounding and Bonding Equipment*
  - General ground component testing.
  - Previously not allowed per UL CRD
  - Recently revised/updated to qualify PV grounding components
- UL 2703: *Rack Mounting Systems and Clamping Devices for Flat-Plate Photovoltaic Modules and Panels*
  - New standard created to address PV module mounting systems
  - Possible to list individual components as well as panelized apparatus

Safety Aspects of Module Grounding



- Illustrative example demonstrating touch hazards with e.g. 2Ω ground path resistance
- Data on safe current thresholds
- Approaches that minimize resistance on large arrays

Recommendations for Design and Installation Related to:

- Listings and instructions
- Equipment selection
- Torqued connections
- Proper handling of and installation of equipment
- Proper sequence and orientation of components
- Avoidance of dissimilar metal combinations
- Other aspects to reduce corrosion risk

What's next

- Publication of final report
- Further digestion of accelerated aging tests, further testing, impact on standards
- Continued improvements to standard via STP process
- Continued iteration based on system grounding advances
- Your continued involvement is welcomed by SolarABCs