Photovoltaic Module Grounding Study
Addendum Report on Corrosion Testing

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Module Grounding Study Overview

- Address issues leading to field failures in module grounding
- Make recommendations to improve standards
  - Achieve better grounding means
  - Improve certification process for manufacturers

- Preliminary "lay-of-the-land" Report (BEW) - PUBLISHED 3/2011
  - Survey of existing issues and experiences from stakeholders
- Accelerated Aging Study (UL) – Presented 6/2011
  - Corrosion/aging evaluation using accelerated salt-spray tests
- Final report (BEW/UL) - PUBLISHED Q1/2012
  - Recommended tests/methods to incorporate into standards
- Solar ABCs Webinar (BEW/UL) – Presented 7/2012
- Corrosion Testing Addendum Report – PUBLISHED 5/2013

Reports and webinar presentation available on Solar ABCs website

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Main Study Findings / Outcomes

- Survey revealed numerous causes of field failures
  - Report includes recommendations for designers/installers
- Recommendations for enhanced current testing
  - Verify integrity of components under field fault conditions
  - Mirrors aspects of UL 467
  - Largely added to UL 2703
- UL’s accelerated aging and corrosion resistance testing
  - Dialog around implementation, interpretation of results
  - Topic left open for more industry involvement
- Identified safety aspects under fault conditions, with examples

Corrosion in Module Ground Connections

- **Corrosion**: chemical reaction process in metals as a result of oxidation, resulting in the gradual destruction of the metals.
- **Galvanic corrosion**: In electrical connections, when two metals of different electrochemical potentials are in contact in some form of electrolyte. Currents flow from one metal (the anode), to the other (the cathode), potentially causing a destructive degradation of the
- **Electrolyte**: the environment of the installation, such as damp, humid air, possibly with salt content (such as near an ocean), dirt, or rain containing acids and alkalis.
- Rate and aggressiveness of corrosion dependent on:
  - Conductivity of electrolyte
  - Difference in electrode potential between metals
  - More severe with DC currents

Accelerated Aging Tests

Evaluate long-term effectiveness of different module grounding methods:

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

Install and age separately using:

IEC damp heat and salt mist tests (similar to ASTM B117)

Under salt mist condition most samples corroded severely failed (> 10Ω) in weeks

ACCELERATED AGING TESTS ON PV GROUNDING CONNECTIONS

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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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Accelerated Aging - New Standards

- IEC 60068-2-11 salt mist tests (similar to ASTM B117)
- Corrosion mechanisms induced by the B117 tests known differ from those found in the field.
- Attempting to accelerate galvanic corrosion is problematic.

- IEC 61701 Ed.2: "Salt mist corrosion testing of photovoltaic (PV) modules"
  - Based on IEC 60068-2-52, widely used in the electronic component field.
  - Test different levels of severity depending on intended environment
  - Better reflects processes seen by PV modules
  - Sequence combines salt fog exposure followed by humidity storage
  - Applicable regardless of frame material.
- IEC 62716, "Ammonia corrosion testing of photovoltaic (PV) modules
  - Companion standard addressing modules operating in corrosive atmospheres involving concentrations of dissolved ammonia (agricultural, near industrial facilities)

UL Activities

- UL 2703 – Surge of applicants for grounding and bonding
  - 300 Series stainless steel passing well (16% Cr min), 400 series not
  - Connections applying torque force faring better than direct force
  - Varying thickness of module frame anodization catching applicants off-guard (device not penetrating successfully).
  - Device failures generally occur in bonding resistance or short-circuit tests after environmental conditioning tests
- Replacing Electrochemical Potential Table
  - Creating new and expanded table for determining acceptable metal combinations
  - Incorporating lessons from 2703 test findings
  - More detailed process for measuring the potential, for metals not included in the table