Solar America Board for Codes and Standards

Final Report: Inverter Ground-Fault Detection "Blind Spot" and Mitigation Methods

Prepared by

Greg Ball
DNV KEMA
Bill Brooks
Brooks Engineering
Jack Flicker
Jay Johnson
Sandia National Laboratories
Andrew Rosenthal
John Wiles
Southwest Technology Development Institute
Larry Sherwood
Sherwood Associates
Mark Albers
SunPower Corporation
Tim Zgonena
Underwriters Laboratories, Inc.

www.solarabcs.org

INVERTER GROUND-FAULT DETECTION "BLIND SPOT" AND MITIGATION METHODS

Report Overview

This is the final report in the Solar America Board for Codes and Standards (Solar ABCs) "blind spot" series. It concludes a research program into an important safety issue associated with the design of many U.S. photovoltaic (PV) systems. Over the last twelve months, Solar ABCs has led a broad industry- and stakeholder-based working group to research this problem and develop effective mitigation strategies. The current research builds on earlier work **(www.solarabc.org/blindspot)** that provided a basic explanation of the cause of the detection blind spot. It includes results of field research conducted to characterize basic array wiring impedance properties and their effects on ground fault detection, circuit modeling, and analyses of high and low impedance faults that may occur throughout the array. It also includes a technical review of the effects of ground fault detection blind spots on different array topologies (grounded, ungrounded, and grounded through the alternating current connection).

Why the Report is Important

The blind spot safety issue came to light during studies of two well-publicized PV system fires—the first on April 5, 2009, in Bakersfield, California, and the second on April 16, 2011, in Mount Holly, North Carolina. Based on evidence found at these two fires, traditional, fuse-based ground fault protection schemes do not detect certain ground faults that can occur in grounded PV systems. These undetected faults fall within a detection "blind spot" inherent in the design of most U.S. PV installations.

Issues

PV systems may be wired in several different configurations with respect to system grounding. These design factors influence a system's fault tolerance and response to ground faults and add complexity to effective ground fault protection.

PV inverter ground fault protection requirements, methods, and limits have been a significant point of discussion nationally and internationally for some time, and both the *National Electrical Code® (NEC)* and product safety standard requirements are presently under revision. Under requirements of the *NEC*, ground fault protection is required of most PV installations in the United States. (The 2014 *NEC* revision cycle is being finalized and Solar ABCs members were instrumental in developing and building consensus for updating PV ground fault protection requirements in the latest code.)

In addition, the Underwriters Laboratories 1741 standard requires that inverters with ground fault detection be evaluated for compliance with specific ground fault detection and interruption tests unless they are marked to indicate that separate ground fault protection must be installed. When investigations uncovered evidence for persistent but undetected ground faults as a condition leading to some PV fires, concern grew about whether the maximum fault current allowed for grounded PV systems during fault conditions is sufficient to protect PV systems from ground faults.

Key Findings

This report includes recommendations for operational strategies and equipment retrofits that can increase ground fault detection sensitivity and reduce the risk of fire in new and retrofit applications. Early results from large PV systems that have been retrofitted with the recommended protective devices indicate that these devices can substantially reduce the detection blind spot without requiring redesign of the system.

The major mitigation strategies and equipment retrofit options presented in this report include:

- following proper installation techniques with close attention to wire management,
- performing routine preventative maintenance to identify and resolve progressive system damage,
- introducing data acquisition and system monitoring at a level sufficient to determine if system integrity has degraded and unscheduled maintenance is required, and
- installing differential current sensors and PV array insulation monitoring devices that can be incorporated into the data system to alert operators to potential problems in advance of conditions that may lead to fire.

Based on the investigations reported here, it is recommended that PV systems with damaged conductors be identified and repaired as soon as possible. It then becomes the task of system operators to weigh the cost of increased system inspections and retrofit hardware against the potential cost and damage of a fire.

Although losses from fires caused by PV systems have been historically quite low relative to the number of systems in the field, this field experience is not necessarily indicative of future losses. As systems age, ground faults and arc faults can be expected to increase in number and potentially in consequences. Equipped with the knowledge in this report, PV system owners, designers, and installers will be able to more effectively make correct decisions about what measures to employ and when those measures are cost-effective.

For more information please contact

Mr. Larry Sherwood, 303-413-8028,
larry@sherwoodassociates.com.

Download the full report:

www.solarabcs.org/blindspot

About Solar America Board for Codes and Standards

The Solar America Board for Codes and Standards (Solar ABCs) is a collaborative effort among experts to formally gather and prioritize input from the broad spectrum of solar photovoltaic stakeholders including policy makers, manufacturers, installers, and consumers resulting in coordinated recommendations to codes and standards making bodies for existing and new solar technologies. The U.S. Department of Energy funds Solar ABCs as part of its commitment to facilitate widespread adoption of safe, reliable, and cost-effective solar technologies.

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