Solar America Board for Codes and Standards

ANALYSIS OF FUSES FOR "BLIND SPOT" GROUND FAULT DETECTION IN PHOTOVOLTAIC POWER SYSTEMS

Prepared by

Jack Flicker

Jay Johnson

Sandia National Laboratories

www.solarabcs.org

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Report Overview

This Solar America Board for Codes and Standards (Solar ABCs) report contains portions of a recent Sandia National Laboratories (Sandia) technical report that investigated ground fault detection deficiencies associated with faults occurring on the grounded current-carrying conductor (CCC) of a photovoltaic (PV) power system. This Solar ABCs report and the Sandia technical report characterize ground fault protection limitations in current PV system designs. Sandia developed a functional circuit model of the PV system including modules, wiring, switchgear, grounded or ungrounded components, and inverters. This model was used to analyze the effectiveness of PV system fault detection methods for a range of ground fault fuse sizes to determine the optimal fuse size for improving ground fault detection sensitivity.

Why the Report is Important

The 2012 Solar ABCs publication, *The Ground-Fault Protection BLIND SPOT: Safety Concern for Larger PV Systems in the U.S.*, revealed that undetected faults on grounded PV array conductors were an initial step in a sequence leading to two well-publicized rooftop fires. In that paper, the theoretical detection limits of traditional ground fault protection systems were discussed but not explored in depth. In this study, Sandia developed an analytical and numerical Simulation Program with Integrated Circuit Emphasis (SPICE) model for PV systems that have a fault between the PV array's grounded conductor and the equipment grounding conductor (EGC). This model was used to perform electrical simulations of faults occurring on arrays of various sizes (representing residential, commercial, and utility scale systems) with different fault, cabling, and ground fault protection device (GFPD) impedances.

Issues

A PV array ground fault is an unintentional electrical connection between one or more of the array's conductors and earth ground. Such faults are usually the result of mechanical, electrical, or chemical degradation of PV components or mistakes made during installation. In order to protect the array against continued operation during a ground fault event, a GFPD or ground fault detector/interrupter (GFDI) is used to detect ground fault currents.

Recently, a detection limit, or "blind spot," in traditional ground fault protection systems has been identified for the direct current-grounded, alternating current-isolated PV systems that are the most common PV systems in the United States. This blind spot occurs when the grounded CCC is faulted to the EGC, resulting in a fault current too small to blow the GFDI fuse.

These faults may produce small fault currents that can go undetected by GFPDs. The danger of undetected ground faults in the EGC is twofold:

- an energized EGC can be a shock hazard, resulting in severe injury; and
- if there is a second ground fault, the array can be shorted though the EGC, bypassing the GFPD and allowing fault current to flow through the system undetected and with no means of interruption.

The fires discussed in Bill Brooks' SolarPro article, "The Bakersfield Fire," and his Solar ABCs report, *The Ground-Fault Protection BLIND SPOT: A Safety Concern for Larger Photovoltaic Systems in the United States,* highlight the incomplete protection provided by ground fault fuses in grounded arrays in the United States.

Key Findings

This report presents numerical solutions that determine GFPD current for a range of conditions in which a fault occurs on the grounded CCC of a PV array. The results demonstrated the importance of fault and conductor resistance values on the detectability of different ground faults. In general, blind spot detection is challenging because of the small magnitudes of fault currents in relation to the large resistance values of the GFPD and cabling in the circuit. The SPICE model and analytical results were used to determine trends for various ground fault conditions and to ascertain the potential benefits of reducing the fuse ratings in PV systems.

Although it may not be possible to provide complete detection for the grounded CCC using only a fuse, the simulations indicate that the detection window for fuses used to identify faults can be optimized by:

- minimizing leakage current, because fault current is in the opposite direction of leakage current and large leakage currents will inhibit the detection of negative CCC faults;
- decreasing the fuse sizing for large arrays below current UL 1741 requirements to one amp, because module leakage current will be too small to result in nuisance tripping and it will trip on more ground faults;
- limiting the reduction in fuse size to not less than one amp, because the large internal resistance of smaller fuses prevents the fault current from passing through the GFPD;
- monitoring both GFPD current magnitude and direction (especially for smaller array sizes), because GFPD current can change direction when a fault to the grounded CCC occurs; and
- employing other fault detection tools such as differential current measurement and insulation monitoring.

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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