Characterization of Fire Hazards of Aged Photovoltaic Balance-of-System Connectors

Eric Schindelholz[1], Benjamin Yang[2], Kenneth Armijo[1], N. Robert Sorensen[1], Olga Lavrova[1]

[1] Sandia National Laboratories, [2] Georgia Tech Research Institute

Overview of Research

This work investigates balance of systems (BOS) connector reliability from the perspective of arc fault risk. Accelerated tests were performed on connectors for future development of a reliability model. Thousands of hours of damp heat and atmospheric corrosion tests found BOS connectors to be resilient to corrosion-related degradation. A procedure was also developed to evaluate new and aged connectors for arc fault risk. The measurements show that arc fault risk is dependent on a combination of materials composition and design geometry. Thermal measurements as well as optical emission spectroscopy (OES) were performed to further characterize the arc plasma. Together, the degradation model, arc fault risk assessment technique, and characterization methods can provide operators of photovoltaic installations information necessary to develop a data-driven plan for BOS connector maintenance as well as identify opportunities for arc fault prognostics.

Significance of Work

Arc faults are a low-probability but high-consequence hazard in photovoltaic systems. The rate of arc faults is expected to increase as the worldwide installed capacity of photovoltaic systems continues to grow. In the US alone, there have been a number of high profile fires caused by arcing in PV systems. Some of these incidents have been traced to balance of systems (BOS) connectors, with risk and prevention being identified as a critical area to address. The reliability of BOS connectors has been relatively uncharacterized beyond qualification tests.

Current & Future Work

Work is currently underway to further characterize the arc fault risk of aged connectors. Alternate corrosion test environments are being explored, such as simulated marine atmospheres. We are actively developing methods to extract additional information from optical emission spectroscopy (OES) measurements, such as electron plasma temperature. Further work is being conducted to explore the physics of failure of connector arc fault.

Motivation and Approach

Motivation

What is the impact of corrosion degradation on arc fault risk?

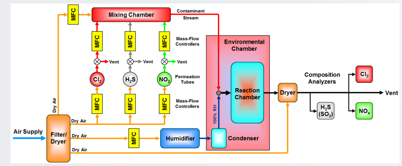
- contact corrosion
- pin & socket materials incompatible
- cyclic mechanical stress on wire/contact
- manufacture/install defect
- foreign debris interferes with connection
- constant mechanical stress results in wire creep

Experimental Approach

- 3 Connector Makes
  - Accelerated Test: Damp Heat; Temp. Cycle; Mixed Flowing Gas
  - Field Test: Outdoor Exposure; Collection of Aged Connectors
- Arc Fault Generation; ΔΩ - Joule Heating
- Arc Fault Risk

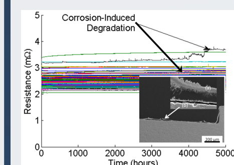
Results: Contact Resistance

Mixed Flowing Gas Exposure



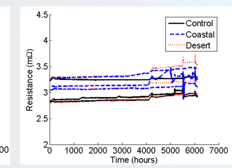
Field Test at SNL, NM

Battelle Class II



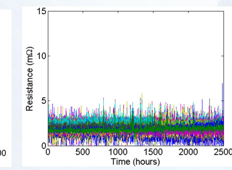
Corrosion of plating, but connectors overall robust to accelerated tests

85°C/85%RH Damp Heat



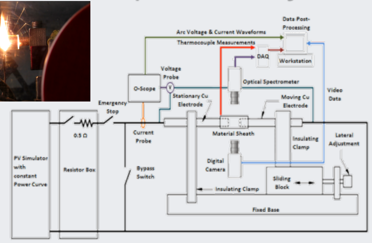
No discernable difference between non-contaminated (control) and coastal or desert-simulating contaminants

Field Test

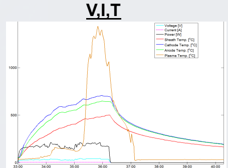


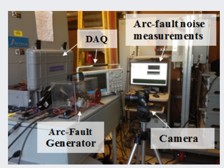
No failures observed in 2500 hours of 51 connectors; test is on-going

Arc Fault Experimental Platform

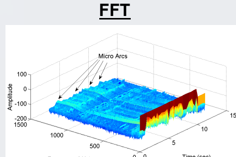


V,I,T

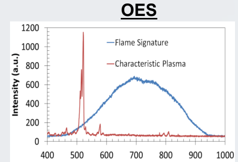




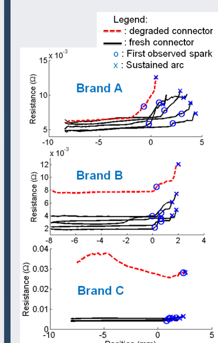
FFT



OES

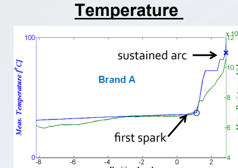


Results: Arc Fault Generation



Connector separation distance prior to arc serves as a proxy for arc fault risk.

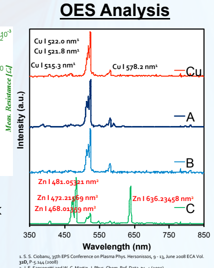
Temperature



Temperature increases measurably between first spark and sustained arc

Materials and electrode geometry likely have significant influence on arc fault risk

OES Analysis



Spectra can identify connectors with similar composition (A and B) vs. one containing other elements (C). Can potentially measure electron plasma temperature

Conclusions

- BOS connectors robust to corrosion-related accelerated tests examined thus far
- Procedure to evaluate arc fault risk of connectors established
- Arc fault risk likely dependent on several factors, such as geometry and composition
- Temperature and emission spectrum analysis can reveal additional information about underlying degradation and arc fault processes

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND Number: SAND2015-1225 C