Photovoltaic Test and Evaluation

Sandia National Laboratories, Albuquerque, NM

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Sandia National Laboratories

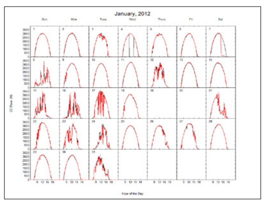
SYSTEMS INTEGRATION

Objectives of Sandia's Test and Evaluation Program

- Unbiased technology assessments
- Support new technology development
- Evaluation of components and integrated systems
- Transfer test technology to industry
- Support development of codes and standards

Small Systems Testing

Outdoor small systems testing is conducted to provide initial performance and reliability assessments under real world conditions and to serve as a test bed for the development and validation of systems analysis tools. A variety of different PV technologies are under tests ranging in length from 1-5 years. Data acquisition systems are designed for high accuracy and sampling rate to facilitate unusually fine measurements. Data from these tests serves several program areas including performance validation, reliability and the development of real-time data analysis tools.



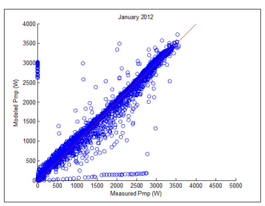


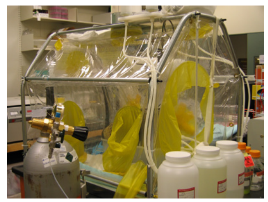
Figure 1: Small system testing and tools developed to analyze and validate PV system performance. a). Building Integrated PV (BIPV) modules installed at Sandia, b). Calendar plot showing system performance over one month of operation, c). Comparison of measured to modeled power.

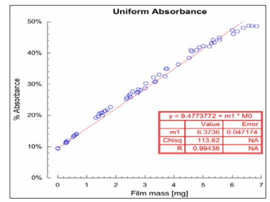
Recent Papers

- Hansen, C., D. Riley and M. Jaramillo, "Calibration of the Sandia Array Performance Model Using Indoor Measurements," *Proceedings, 38th IEEE-PVSC, Austin, TX* (2012).
- Jay Johnson, Jason Strauch, Scott Kuszmaul, Ward Bower and David Schoenwald, "Characterizing PV Arcing Conditions with Impedance Spectroscopy and Frequency Response Analysis," *EU-PVSEC Proceedings* (2011).
- Jay Johnson, Birger Pahl, Charles Luebke, Tom Pier, Theodore Miller, Jason Strauch and Scott Kuszmaul, "Photovoltaic DC Arc Fault Detector Testing at Sandia National Laboratories," *Proceedings, 37th IEEE-PVSC, Seattle, WA* (2011).
- Hansen, C., J. Stein, S. Miller, E. E. Boyson, et al, "Parameter Uncertainty in the Sandia Array Performance Model for Flat-Plate Crystalline Silicon Modules," *Proceedings, 37th IEEE-PVSC, Seattle, WA* (2011).
- Sigfredo Gonzalez, Michael Ropp, Armando Fresquez. Michael Montoya and Nelson Opell, "Multi-PV Inverter Utility Interconnection Evaluations," *Proceedings, 37th IEEE-PVSC, Seattle, WA* (2011).
- Jennifer E. Granata, William E. Boyson, Jay A. Kratochvil, Bo Li, Venkata Abbaraju, GovindaSamy TamizhMani and Lawrence Pratt, "Successful Transfer of Sandia National Laboratories' Outdoor Test Technology to TUV Rheinland Photovoltaic Testing Laboratory," *Proceedings, 37th IEEE-PVSC, Seattle, WA* (2011).
- Pratt, L. and King, D. L., "The effect of uncertainty in modeling coefficients used to predict energy production using the Sandia Array Performance Model," *Proceedings, 35th IEEE-PVSC, Honolulu, HI*, (2010).
- Granata, J. E., Boyson, W. E., Kratochvil, J. A., and Quintana, M. A., "Long-term performance and reliability assessment of 8 PV arrays at Sandia National Laboratories," *Proceedings, 34th IEEE-PVSC, Philadelphia, PA*, (2009).
- Riley, D., Cameron, C., Jacob, J., Granata, J., Galbraith, G., "Quantifying the effects of averaging and sampling rates on PV system and weather data, *Proceedings, 34th IEEE-PVSC, Philadelphia, PA*, (2009).

Simulated Soiling Study

This study is focused on developing a methods to simulate soiling under controlled, laboratory conditions. The objectives are to gaining a deeper scientific understanding of the interaction of incident irradiance with soil of different types. Simulated soil is formulated with NIST traceable components, which can then be applied to a surface via a commercial spray gun. The attenuation effects of soil films applied in this manner are repeatable as light attenuation increases linearly with mass of the applied film. Significantly, both absorption and spectral filtering are dominated by a single component of the simulated soil. These results highlight the potential for the development of more comprehensive soiling derate factors that can account for geographical variations in soil type as well as dynamic changes such as changing solar spectrum.





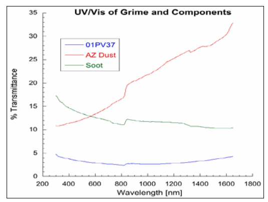
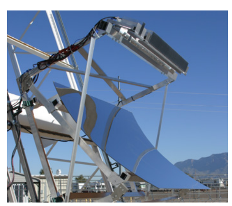


Figure 2: Characterization of simulated soil applied to glass. a). Soil suspended in liquid is applied to glass in a spray booth, b). Absorbance is linear with applied soil mass, c). Transmission and spectral filtering are dominated by a single component

Low-X Concentrating PV Study

This study is aimed specifically at understanding the performance of low-x CPV technologies. These differ significantly from high-x CPV technologies due to their unique optical designs and use of cheaper, less efficient Si receivers. The predominant optical design consists of linear optics that focuses the irradiance onto a strip receiver. This design significantly affects both the angle of incidence (AOI) response and utilization of diffuse light. To enable the necessary measurements to be made, we developed control algorithms for our two-axis trackers to vary angle of incidence along the principal axes of the module while conducting IV curve sweeps. We have also initiated the development of new modeling algorithms that account for use of the diffuse component of the incident irradiance.



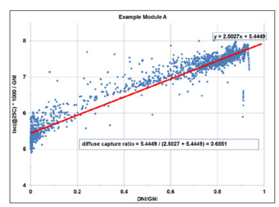
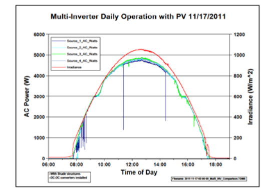


Figure 3: Low-x CPV module under test. a). Example of a Low-X CPV unit employing linear focusing optics, b). The influence of varying the ratio of diffuse to direct irradiance on short circuit current of a Low-x CPV module

Module-Level Distributed Power Electronic Testing

A distributed power electronics (power optimizers) evaluation test bed was developed to analyze and document the interoperability of dc-dc converters with a string inverter. This data is also used to validate PV performance modeling tools being developed to capture the performance enhancements associated with this type of topology. Interoperability evaluations have indicated that the string inverter determines the maximum power point tracking voltage and the dc-dc converters operate at that voltage. Shading tests were conducted to show the main attribute of the distributed power electronic devices.



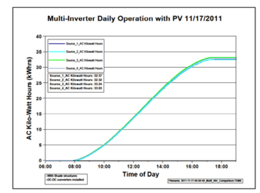
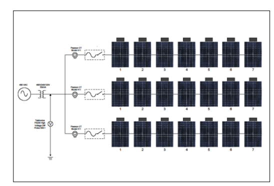
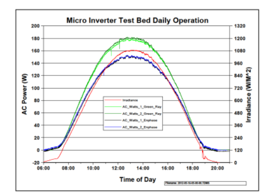


Figure 4: Small system performance analysis with and without power optimizers are being conducted. a). Shade structure covers all strings, b). Output power with shade structure, c). Energy harvest measurements.

Micro-Inverter Implementation Evaluations

The purpose of this study is to quantify the operation of micro-inverters in an array configuration. The micro-inverter topology lends itself well to multiple inverter installations. However, since the micro-inverter is certified as a single device, uncertainty exists with multiple inverter configurations. This is especially true given the possibility of micro-inverters from different manufacturers combined on the same distribution transformer. The power quality, utility compatibility, and loss of utility characteristics will be investigated with this configuration.





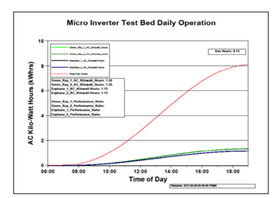


Figure 5: Analyzing the interoperability of different manufacturers tied to the same distribution transformer. a). Micro-inverter test configuration, b). Inverter response (4 inverters), c). Energy harvest measurements (4 inverters).

SunShot U.S. Department of Energy

U.S. DEPARTMENT OF ENERGY

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