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Sandia National Laboratories



DOE SunShot Systems Integration R&D Program at Sandia National Laboratories

Summary of Accomplishments and Impacts for FY15

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U.S. Department of Energy

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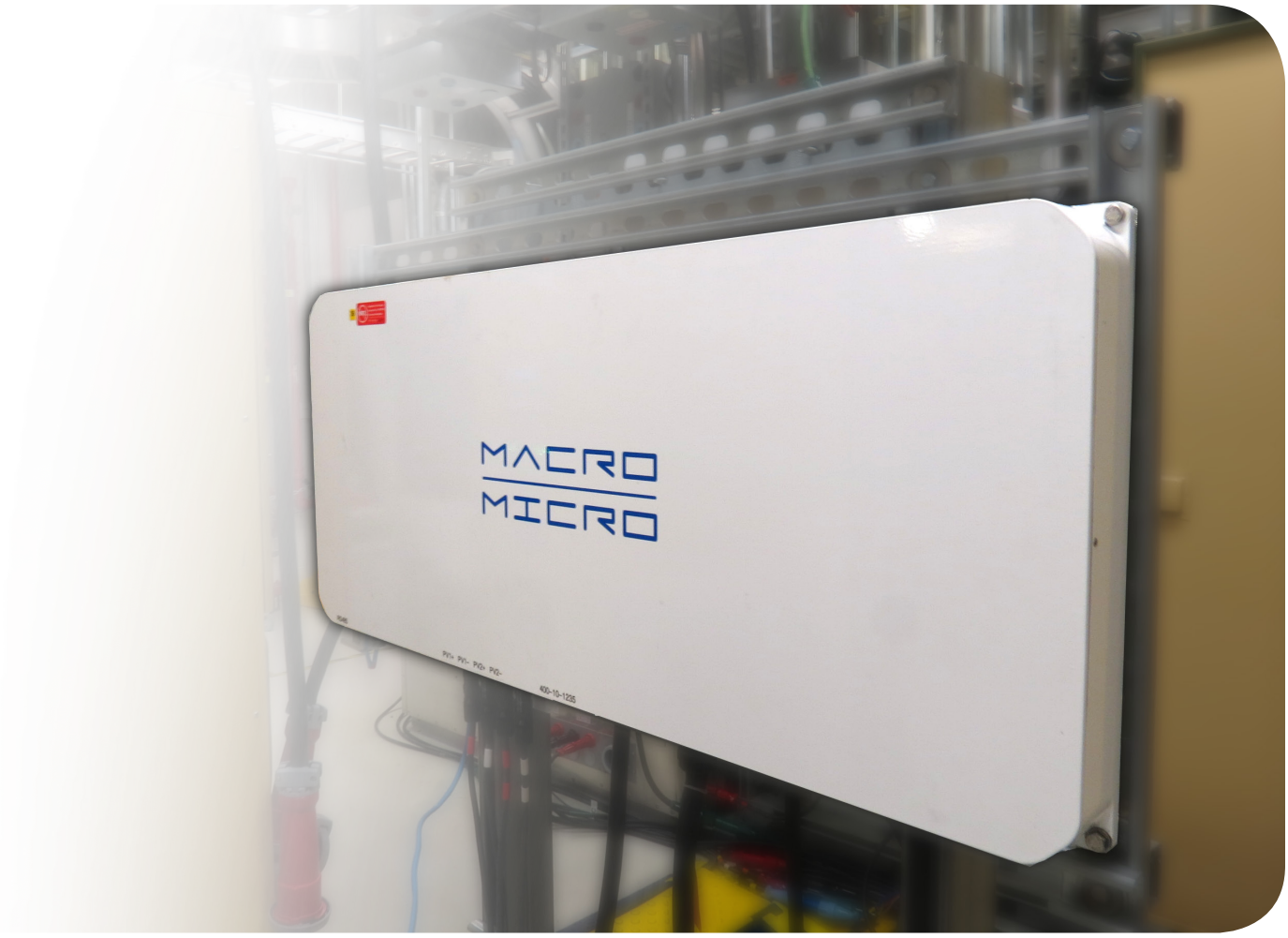


Introduction

During FY15, Sandia National Laboratories executed research and development (R&D) work on a portfolio of 16 SunShot Program Systems Integration (SI) agreements, with a total FY15 budget of $13.2 million. This document summarizes the impact of the Sandia contributions based on Sandia's direct contributions in the following categories identified by DOE:

- New Cooperative Research and Development Agreements (CRADAs), Strategic Partnership Programs (SPPs), and funded collaborative projects with external organizations that are a result of or related to the SunShot SI funding, including details on the organizations, dates, Sandia PIs, and funding amounts
- Patents and licenses applied for and those awarded
- Peer-reviewed journal publications with full citation information
- Conference publications with citation information
- Significant external professional honors received by the principal investigators

Partnerships

During this reporting period, the Sandia SI activities leveraged a total of eight formal external partnerships (CRADAs and SPPs), with $298k coming in to Sandia in FY15. The value including partner in-kind contributions is significantly higher, as detailed on page 5. In addition to these items, Sandia made continued progress on three Laboratory Directed Research and Development (LDRD) projects on SI-related related topic areas.

Intellectual Property

Sandia's efforts have produced a number of patent applications and technical advances, on topics including PV system fault detection and prognostics, photovoltaic module performance model parameters, variability sensors, and virtual power plant control methods. One patent application, one provisional patent application, and eight technical advances have been filed. A listing of intellectual property items is provided on pages 7 and 8.

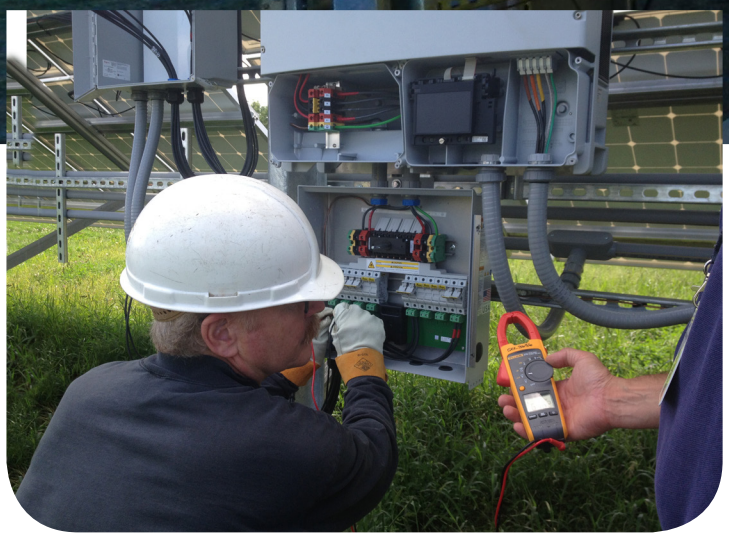
Publications

Sandia researchers produced a large number of SI-related publications, including 11 published and in-press peer-reviewed journal papers, 36 conference publications, 12 Sandia technical publications, and 6 trade journal articles, book chapters or technical reports published elsewhere. A list of publications is provided on pages 10 through 15.

External and Professional Honors

During this period, Sandia SI researchers also participated in numerous workshops, led stakeholder groups on research and standards, and received individual recognitions. These and other notable impacts are listed on page 17.

Industry Partnerships



Funded Industry-Collaborative Projects

The tables below summarize formal industry partnerships (CRADA, SPP, or funded collaborative projects) that were active in FY15 and directly leveraged the SunShot SI program.

CRADA and SPP Collaboration Funding

Type	Partner	Start-End	Sandia PI	Topic
CRADA	EPRI	FY12-15	R. Broderick	Screening Distribution Feeders: Alternatives to the 15 Percent Rule
CRADA	EPRI	FY14-15	R. Broderick	Power Research Collaborations
CRADA	EPRI	FY14-15	A. Ellis	SUNRISE: Transmission and Distribution Grid Integration
CRADA	EPRI	FY14-16	J. Johnson	Standard Inverter Interface and Compliance Framework
SPP	HI-PUC	FY13-15	A. Ellis	Technical Assistance, Hawaii Public Utilities Commission
SPP	Fraunhofer	FY13-15	L. Burnham	Plug-and-Play SunShot Project
SPP	DOE/DOS	FY12-16	J. Johnson	Smart Grid International Research Facility Network (SIRFN)
SPP	DOW Chemical Co.	FY15-16	B. King	DOW Solar Module Characterization
SunShot Incubator Project	RPC	FY-15	S. Gonzalez	Developing the RPC Micro-Macro modular inverter

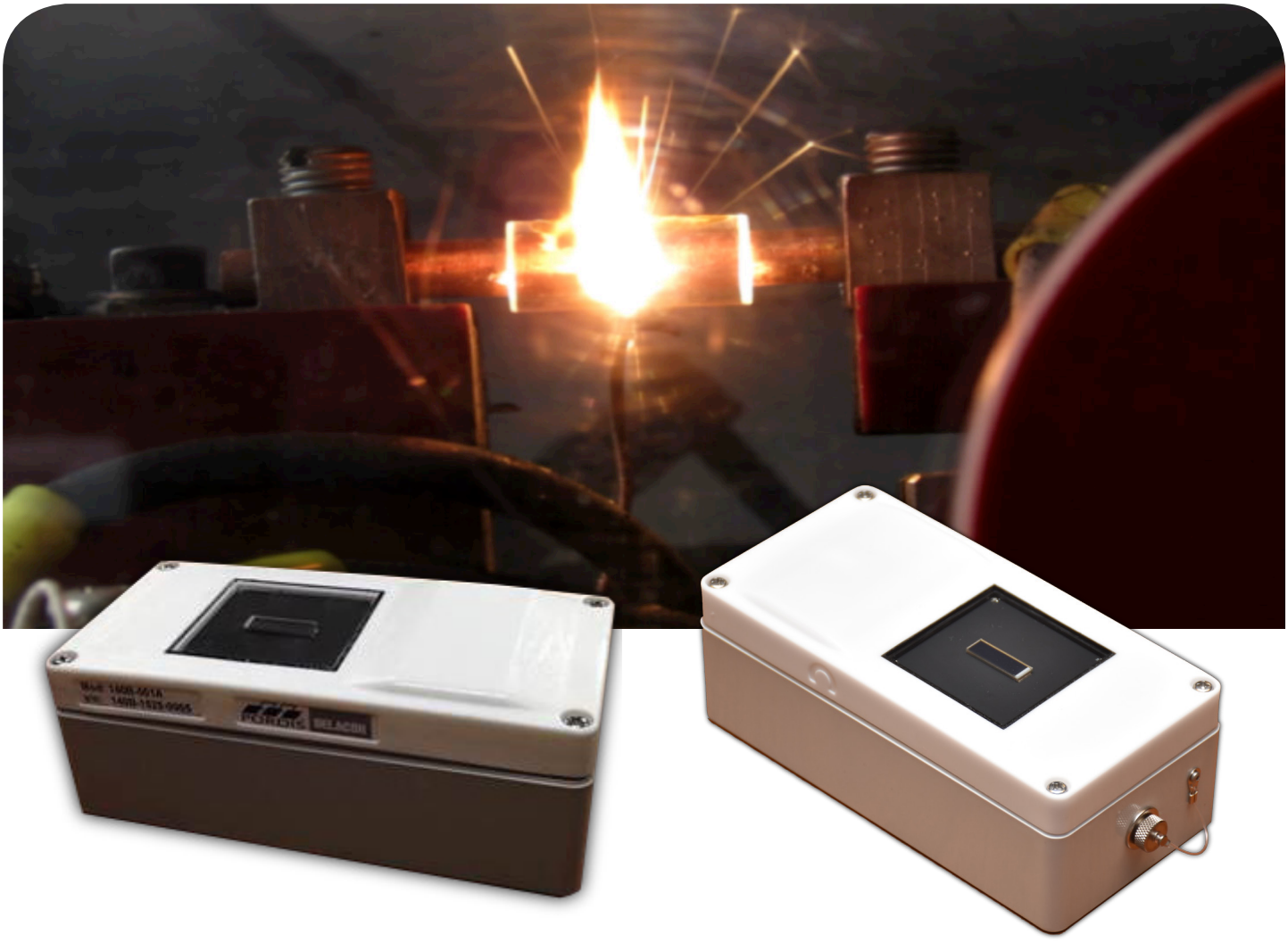
Note: Total DOE funding for these partnerships over their period of performance equals approximately $1.5M. Total partner contributions (in kind) is estimated to be $1M.

MOU and CRADA Collaboration Funding

Type	Partner	Start-End	Sandia PI	Topic
MOU	Soitec	FY14-18	J. Stein	Regional Test Center
MOU	Stion	FY14-18	J. Stein	Regional Test Center
MOU	Prism	FY15-19	J. Stein	Regional Test Center
MOU	ENKI	FY14-18	B. King	Regional Test Centers
MOU	Silevo	FY15-18	J. Stein	Regional Test Centers
MOU	SolarWorld	FY15-18	J. Stein	Regional Test Centers
MOU	SunPower	FY15-18	J. Stein	Regional Test Centers
MOU	Renewable NRG	FY15-18	J. Stein	Regional Test Centers
MOU	PVMC	FY15-18	J. Stein	Regional Test Centers
CRADA	Maxim	FY14-18	J. Stein	Regional Test Center
CRADA	Cogenra (SunPower)	FY15-19	J. Stein	Regional Test Center
CRADA	HelioVolt	FY13-15	J. Stein	Regional Test Center

Note: Total DOE funding for these partnerships over their period of performance equals approximately $5M. Total partner contributions (in kind) are estimated to be $2M.

Intellectual Property



Intellectual Property: Patents, Licenses, and Technical Advances

- U.S. Patent Application 14/643,032, Filed March 10, 2015, "Detection of Arcing Location on Photovoltaic Systems Using Filters" (J. Johnson).
- U.S. Provisional Patent Application Number 62/134,413, filed March 17, 2015, entitled "Methods for Estimating Photovoltaic Module Performance Model Parameters."
- Technical Advance "Low Cost Trackerless Spectral Sensor Development" (Ken Armijo) – This TA proposes the development of a novel low-cost (<$1.5k) spectral sensor that is suitable for outdoor use and will accurately monitor the solar spectrum to optimize solar power generation and better predict PV performance. Moreover, to further reduce its cost and ubiquitous adoption, the design is made to operate without the need for an expensive tracker, where it can record accurate spectral irradiance measurements from any non-shaded location. Commercial-off-the-shelf items will be utilized to keep materials cost low, and novel custom software will be developed to process data for optimizing solar PV and thermal applications. The low-cost spectral sensor also has other applications such as ambient background measurement for optical detection techniques, weather and air quality measurements, visibility data for airports, spectral calibration for satellite imaging systems, and climate change research for accurate, ubiquitous adoption and monitoring. Weather forecasting can also greatly be aided by this device as it can help address radiative forcing impacts which directly affect the weather by airborne particulates such as pollution and dust. Finally, to improve the crop yields the U.S. Department of Agriculture (USDA) has previously shown interest in this type of device through their research studies noting that the quality of light at certain bands can impact crop production. Discussions are currently underway to use this device for spectral-light research management for enhanced foliage crop productions.
- Technical Advance "All-Inclusive Photovoltaics Characterization Room" (Ken Armijo) – This TA is for an automated characterization system that is designed to perform rapid and accurate analysis of PV devices in order to readily identify failure modes that can profoundly affect the reliability and bankability of PV systems. This innovative system will enable operators to not only perform a fast electrical performance check on a production line, but also to remove individual devices or samples from a production run to perform a detailed analysis, to troubleshoot defects or to perform device failure analysis. Current methods of PV indoor characterization testing employ serial operations of connecting and disconnecting devices between a variety of testing platforms requiring significant material movement, test set up times and costs. This novel system allows multiple tests to be run with considerably less test device and software set-up time. The system comprises a light-tight, air tight dark room that serves as an environmental chamber housing a fully-modular electrical performance and imaging suite of various test platforms that are scalable and customizable for various applications. This system comprises radiant wall and floor heating with convective air support to facilitate uniform temperatures throughout the chamber. It also consists of a

multiple-axis vertical, highly-versatile module holder, with a novel, non-obvious designed clamping system that can hold every type of module in the PV market. These innovative clamps can also be equipped to hold cells for enhanced high inspection. Commercial-off-the-shelf materials will be used to keep the costs low, with robotic components to enhance the operator's control and operation of various characterization techniques. This all-encompassing design also has other applications such as materials failure forensics and reliability applications within a multitude of industries (i.e. automotive, aerospace and biomechanical health industries).

- Technical Advance (process started in FY15 and will be completed in FY16) "Multi-Parameter Thermal Plasmas Arc-Fault Generation and Data Acquisition System" (Ken Armijo) – This TA presents an electrical arc discharge system for study of arcing characteristics and effects on photovoltaic devices and materials. The system combines rigorous control and multi-faceted characterization of arcing behavior and materials degradation between two current carrying conductors. Integrated and automated capabilities include optical spectroscopy for determination of arc plasma temperature and materials degradation products; electrical current spectral analysis for obtaining arc signatures and micro-arc detection; and thermal measurements for obtaining temperature profiles of arcing materials or devices. This system has been demonstrated for study of aging impact on the arc fault risk of balance of systems PV connectors and for development of novel arc-resistant PV materials.
- Technical Advance "PV System Fault Detection and Diagnostics using LAPART" (Birk Jones) – This TA offers adaptive and automatic oversight of PV systems. The LAPART learning algorithm works with existing data collection devices and can identify sub-system faults that otherwise go unnoticed. It also diagnosis the fault so that operations staff can easily deploy maintenance staff in a cost effective manner.
- Technical Advance "Variability Sensors" (Matt Lave) – This TA is for a solar variability datalogger, which is a low-cost, integrated solution (built in measurement, data storage, device power, and communications) to measure solar variability. The device significantly reduces the cost required to measure solar variability, so will encourage ubiquitous deployment to greatly increase the number of locations at which solar variability is known. This is valuable IP because it fills a need in the solar industry for low cost measurements, and high demand for these devices is anticipated once we have demonstrated their value in operation.
- Technical Advance "Virtual Power Plant Control Methods" (Jay Johnson) – This TA presented two approaches for providing ancillary services with distributed energy resource (DER) control strategies. These control strategies enable renewable and other DER assets to support the electricity grid by providing contingency reserves. The first control method was designed to provide accurate power generation with an aggregation of DER resources using feedback controls attached to individual DER resources. The second control method was designed to use a combination of distributed and centralized controls to quickly provide accurate power production from the aggregation.

Publications

Peer-Reviewed Journal Publications

- M. K. Alam, F. Khan, J. Johnson, and J. Flicker, "A Comprehensive Review of Catastrophic Faults in PV Arrays: Types, Detection, and Mitigation Techniques," *IEEE Journal of Photovoltaics*, vol. 5 (3), pp. 982-997, 2015. DOI: 10.1109/JPHOTOV.2015.2397599.
- P. D. Burton, L. Boyle, J. J. M. Griego, and B. H. King, "Quantification of a Minimum Detectable Soiling Level to Affect Photovoltaic Devices by Natural and Simulated Soils," *IEEE Journal of Photovoltaics*, vol. 5, pp. 1143-1149, 2015.
- P. D. Burton, B. H. King, D. Riley, "Predicting the spectral effect of soils on high concentrating photovoltaic systems," *Solar Energy*, vol. 112, pp. 469–474, 2015.
- J. Flicker, J. Johnson, and M. Albers. (Issue 8.6 November/December 2015) "Resolving Fire Hazards from the Ground-Fault Detection Blind Spot." *SolarPro Magazine*. 2015.
- M. Lave, W. Hayes, A. Pohl, C. W. Hansen, "Evaluation of Global Horizontal Irradiance to Plane of Array Irradiance Models at Locations across the United States," *IEEE Journal of Photovoltaics*, vol. 5, no. 2, 2015.
- M. Lave, M. J. Reno, and R. J. Broderick, "Characterizing Local High-Frequency Solar Variability and its Impact to Distribution Studies," *Solar Energy*, vol. 118, pp. 327-337, 2015.
- F. Munoz, A. Mills, "Endogenous Assessment of the Capacity Value of Solar PV in Generation Investment Planning Studies," *IEEE Transactions on Sustainable Energy*, vol. 6, no. 4, pp. 1574-1585, October 2015.
- J. Neely, J. Johnson, R. Byrne, R. T. Elliott, "Structured Optimization for Parameter Selection of Frequency-Watt Grid Support Functions for Wide-Area Damping," *International Journal of Distributed Energy Resources and Smart Grids, DERlab/SIRFN Special Issue on Pre-standardisation Activities in Grid Integration of DER*, vol. 11, no. 1, pp. 69-94, 2015.
- J. D. Patrick, J. L. Harvill, C. W. Hansen, "A Semiparametric Spatio-Temporal Model for Solar Irradiance Data," Renewable Energy 87(1), 15-30, March 2016.
- D. Riley, C. W. Hansen, "Sun-Relative Pointing For Dual-Axis Solar Trackers Employing Azimuth and Elevation Rotations," *ASME Journal of Solar Energy Engineering*, vol. 137, 2015.
- K. J. Sauer, T. Roessler, C. W. Hansen, "Modeling the Irradiance and Temperature Dependence of Photovoltaic Modules in PVsyst," Journal of Photovoltaics 5(1), 152-158, January 2015.

Conference Publications

Applied Power Electronics Conference (APEC)

- J. Neely, A. Ellis, S. Gonzalez, J. Johnson, "Integration of Advanced Inverters for Increased PV Penetration"; Alternative Energy Industry Session Presentation; Applied Power Electronics Conference (APEC 2015); Charlotte, NC; March 18, 2015.
- J. Neely, J. Johnson, S. Gonzalez, J. Delhotal, M. Lave, "Evaluation of PV Frequency-Watt Function for Fast Frequency Reserves," Applied Power Electronics Conference and Exposition (APEC 2016), Thirty-First Annual IEEE; Long Beach, CA; 20-24 March 2016.

- S. Perlenfein, M. Ropp, J. Neely, S. Gonzalez, and L. Rashkin, Subharmonic Powerline Carrier (PLC) Based Island Detection, Applied Power Electronics Conference (APEC 2015), March 2015.

European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC)

- A. Driesse, W. Zaaiman, and J. S. Stein (2015). Indoor and Outdoor Evaluation of Global Irradiance Sensors. European Photovoltaic Solar Energy Conference and Exhibition (EU PVSEC 2015). Hamburg, Germany.
- D. Rosewater, J. Johnson, M. Verga, R. Lazzari, C. Messner, R. Bründlinger, K. Johannes, J. Hashimoto, and K. Otani, International Development of Energy Storage Interoperability Test Protocols for Renewable Energy Integration, EU PVSEC, Hamburg, Germany, September 2015.

42nd IEEE Photovoltaic Specialists Conference (PVSC)

- L. Boyle, P. Burton, H. Flinchpaugh, V. Danner, C. Robinson, K. Blackwell, B. King, and M. Hannigan, Initial Results of a Five Site Study Comparing Spatial Variability of Soiling and Ambient Particulate Concentrations, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- P. D. Burton, A. Hendrickson and B. H. King, Macro- and Microscale Particle Size Effects of Soil on Photovoltaic Surfaces, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- A. Driesse (PV Performance Labs), J. S. Stein, D. Riley, C. Carmignani, Monitoring Current, Voltage and Power in Photovoltaic Systems, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- J. Flicker, J. Johnson, M. Albers, and G. Ball, Recommendations for Isolation Monitor Ground Fault Detectors on Residential and Utility-Scale PV Systems, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- S. Gonzalez, J. Johnson, J. Neely, Electrical Power System Support-Function Capabilities of Residential and Small Commercial Inverters, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- C. W. Hansen, K. A. Klise and J. S. Stein, Data Requirements for Calibration of Photovoltaic System Models Using Monitored System Data, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- W. F. Holmgren (Department of Atmospheric Sciences, University of Arizona), R. W. Andrews (Heliolytics), A. T. Lorenzo (College of Optical Sciences, University of Arizona), J. S. Stein, PVLIB Python 2015, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- J. Johnson, K. M. Armijo, M. Avrutsky (Tigo Energy), D. Eizips (Tigo Energy), S. Kondrashov (Tigo Energy), Arc-Fault Unwanted Tripping Survey with UL 1699B-Listed Products, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.

- C. B. Jones, J. S. Stein, S. Gonzalez, and B. H. King, Photovoltaic System Fault Detection and Diagnostics using Laterally Primed Adaptive Resonance Theory Neural Network, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- B. King, D. Riley, C. Robinson, and L. Pratt, Recent Advancements in Outdoor Measurement Techniques for Angle of Incidence Effects, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- B. King, G. TamizhMani, S. Tatapudi, V. Rajasekar, and S. Boppana, Regional Soiling Stations for PV: Design, Calibration and Installation, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- K. A. Klise, C. W. Hansen, and J. S. Stein, Dependence on Geographic Location of Air Mass Modifiers of Photovoltaic Module Performance Models, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- M. Lave, M. J. Reno, J. S. Stein, and R. Smith, Low-Cost Solar Variability Sensors for Ubiquitous Deployment, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- M. Lave, A. Ellis, and G. Nail, Solar Power Simulations for a Renewable Integration Study in New Mexico Using Sparse Input Data, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- B. G. Potter, Jr., C. Hansen, J. H. Simmons, and B. King, Incidence-angle dependent external quantum efficiency: laboratory characterization and use in irradiance-to-power modeling, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- J. E. Quiroz, J. S. Stein, C. K. Carmignani, and K. Gillispie (Stratasense LLC), In-Situ Module-Level I-V Tracers for Novel PV Monitoring, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- D. Riley, Performance Model for Characterizing AC Modules and Predicting Their Power, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- M. Ropp, S. Perlenfein, D. Schultz, C. Mouw, S. Gonzalez, J. Neely, and M. Mills-Price, Practical Considerations in Application of Correlation-Based Islanding Detection with Synchrophasors, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- E. Schindelholz, B. Yang, K. Armijo, B. McKenzie, J. Taylor, N.R. Sorensen, and O. Lavrova, Characterization of Fire Hazards of Aged Photovoltaic Balance-of-Systems Connectors, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- J. Seuss, M. J. Reno, R. J. Broderick, and S. Grijalva, Maximum PV Size Limited by the Impact to Distribution Protection, 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.
- J. Sutterlueti (Gantner Instruments Environment Solutions GmbH), S. Ransome (Steve Ransome Consulting), J. Stein, and J. Scholz (Gantner Instruments Environment Solutions

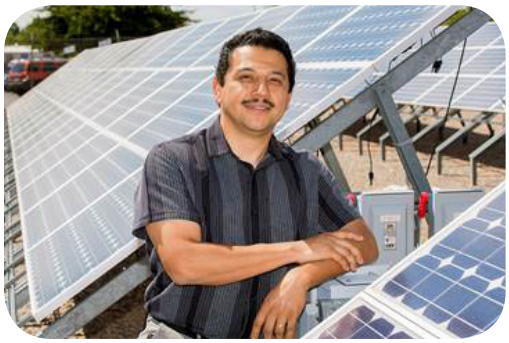
GmbH), Improved PV Performance Modelling by Combining the PV_LIB Toolbox with the Loss Factors Model (LFM), 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.

IEEE Power & Energy Society Transmission and Distribution Conference and Exposition

- R. J. Broderick, K. Munoz-Ramos, and M. J. Reno, "Accuracy of Clustering as a Method to Group Distribution Feeders by PV Hosting Capacity", IEEE PES T&D Conference and Exposition, 2016.

IEEE Power & Energy Society General Meeting

- R. Concepcion, R. Elliott, M. Donnelly, and J. Sanchez-Gasca, On Extended-Term Dynamic Simulations with High Penetrations of Photovoltaic Generation, submitted to IEEE Power & Energy Society General Meeting, July 2016.
- R. T. Elliott, A. Ellis, P. Pourbeik, J. J. Sanchez-Gasca, J. Senthil, and J. Weber, Generic Photovoltaic System Models for WECC – A Status Report, (WECC Renewable Energy Modeling Task Force), IEEE Power and Energy Society General Meeting, Denver, CO, 2015.



- J. J. Sanchez-Gasca, A. Ellis, P. Pourbeik, J. Senthil, and J. Weber, Generic Wind Turbine Generator Models for WECC – A Second Status Report, (WECC Renewable Energy Modeling Task Force), IEEE Power and Energy Society General Meeting, Denver, CO, 2015.
- J. Seuss, M. J. Reno, R. J. Broderick, and S. Grijalva, Improving Distribution Network PV Hosting Capacity via Smart Inverter Reactive Power Support, Albuquerque, NM and Atlanta, GA, IEEE Power & Energy Society General Meeting, July 2015.

INFORMS Annual Meeting

- C.A. Silva-Monroy, J. P. Watson, F. Munoz, and A. Mills, Capacity Planning in Power Systems with High Solar Energy Penetration using Stochastic Programming, INFORMS Annual Meeting, November 2014.

International Conference on Concentrating Photovoltaics

- D. Riley, Mapping HCPV Module or System Response to Solar Incident Angle, International Conference on Concentrating Photovoltaics, April 2015.

PV Solar Resource Workshop

- C. W. Hansen, GSIP Verification and Validation: Preliminary Results, 2015 PV Solar Resource Workshop, February 2015.

Utility Variable-Generation Integration Group (UVIG) Fall Technical Workshop

- C. A. Silva-Monroy, J. P. Watson, Stochastic Unit Commitment Tutorial, UVIG Fall Technical Workshop, October 2014.

World Conference on Photovoltaic Energy Conversion

- C. W. Hansen, K. A. Klise, J. S. Stein, Y. Ueda, and K. Hakuta, Photovoltaic System Model Calibration Using Monitored System Data, World Conference on Photovoltaic Energy Conversion, November 2014.

Sandia National Laboratories Technical Publications

- C. Carmignani, Regional Test Center (RTC) Commissioning Report: Stion 12.32 kWDC Fixed Latitude Tilt Ground Mounted Photovoltaic System, August 2015, SAND2015-8096.
- A. Driesse, J. S. Stein, D. Riley, and C. Carmignani, Sampling and Filtering in Photovoltaic System Performance Monitoring, 2014, SAND2014-19137.
- C. W. Hansen, Estimating Parameters for the PVsyst Version 6 Photovoltaic Module Performance Model, SAND2015-8598.
- C. W. Hansen, Parameter Estimation for Single Diode Models of Photovoltaic Modules, SAND2015-2065.
- C. W. Hansen and C. E. Martin, Photovoltaic System Modeling: Uncertainty and Sensitivity Analysis, SAND2015-6700.
- C. W. Hansen, C. E. Martin, and N. Guay, Analysis of Global Horizontal Irradiance in Version 3 of the National Solar Radiation Database, SAND2015-8023.
- R. Hill, G. T. Klise, and John R. Balfour, [High Performance PV], Precursor Report of Data Needs and Recommended Practices for PV Plant Availability, Operations and Maintenance Reporting, SAND2015-0587.
- M. Lave, Comparison of Errors in Solar Power Plant Variability Simulation Methods, January 2015, SAND2015-0156.
- M. Lave, Albedo and Diffuse POA Measurements to Evaluate Transposition Model Uncertainty, October 2015, SAND2015-8803.
- J. Peppanen, M. J. Reno, Robert J. Broderick, and Santiago Grijalva, “Distribution System Secondary Circuit Parameter Estimation for Model Calibration,” 2015, SAND2015-7477.
- M. J. Reno and K. Coogan, “Grid Integrated Distributed PV (GridPV) Version 2,” 2014, SAND2014-20141, 2014.
- D.M. Riley, C.W. Hansen, M. Farr, A Performance Model for Photovoltaic Modules with Integrated Microinverters, 2015, SAND2015-0179.

Edited Trade Journals, Book Chapters, and External Technical Reports

- J. Flicker, Ph. D., R. Kaplar, Ph. D., “Reliability of Power Conversion Systems in Photovoltaic Applications” chapter in *Reliability of Power Electronic Converter Systems* 1st ed. Stevenage, UK: IET Research, 2015. In Press.
- “Alternatives to the 15% Rule: Final Project Summary,” EPRI, Technical Report 3002006594, 2015.

- "Alternatives to the 15% Rule: Modeling and Hosting Capacity Analysis of 16 Feeders," EPRI, Technical Report 3002005812, 2015.
- "Alternatives to the 15% Rule: Modified Screens and Validation," EPRI, Technical Report 3002005791, 2015.
- J. S. Stein and M. Green, Novel Strategies for PV System Monitoring. PV-Tech Power, London, UK, Solar Media, 02, 2015.
- J. S. Stein, chapter contribution: Energy Prediction and System Modeling, in PV from Fundamentals to Applications, Wiley, In Press, 2015.

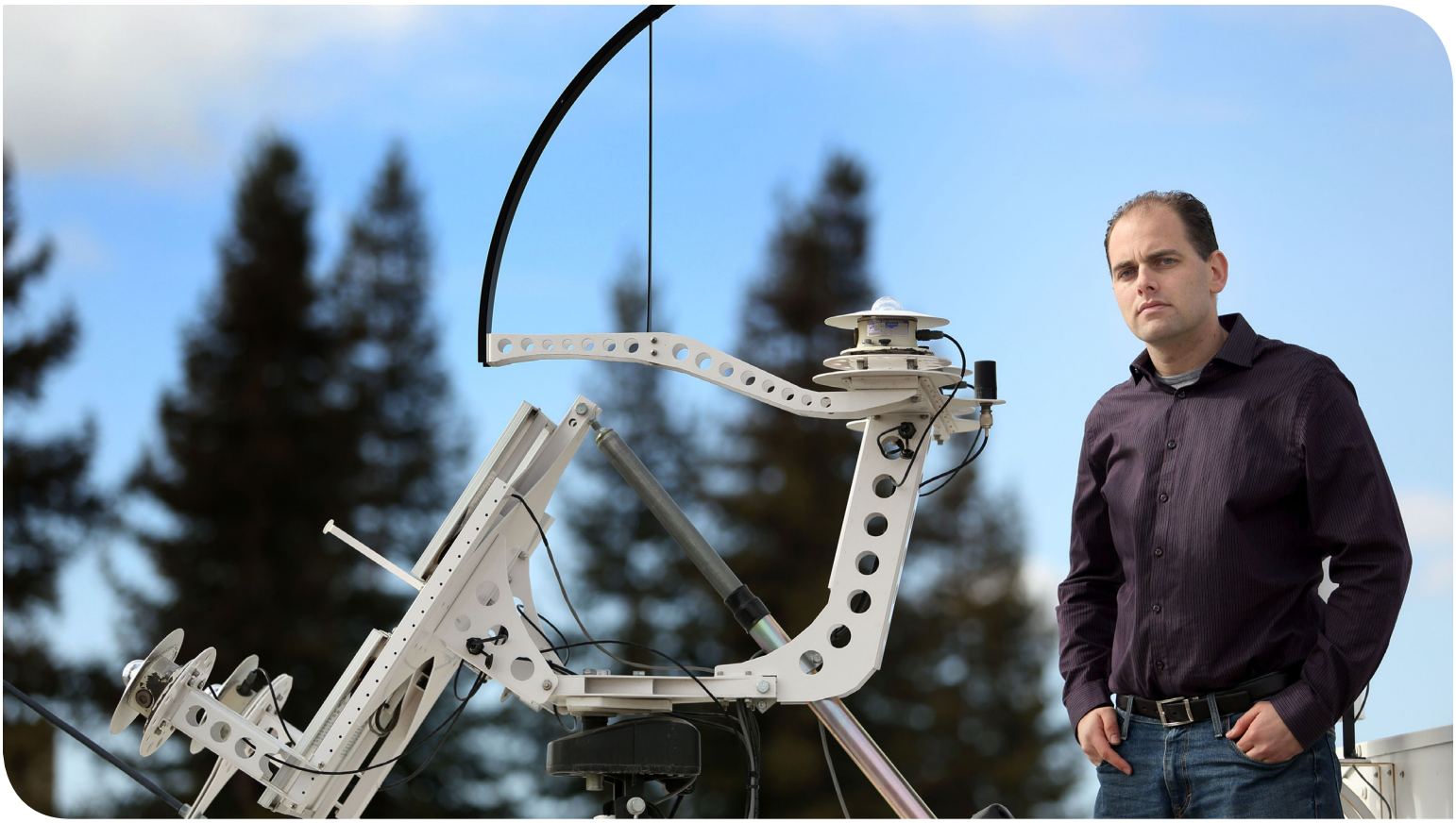
Significant External Professional Honors and Notable Impacts

Significant External Professional Honors

- Journal Article: "Characterizing Local High-Frequency Solar Variability and its Impact to Distribution Studies," selected as "Best Paper 2014-2015" in the "Solar Resource" topic area of the Solar Energy Journal.
- Conference Paper: 15PESGM0126 – Generic Wind Turbine Generator Models for WECC: A Second Status Report, was selected as one of four "Best of the Best" Conference Papers submitted to the 2015 PES General Meeting.
- Conference Paper: Photovoltaic System Model Calibration Using Monitored System Data, was selected for the Best Paper award (Areas 7 and 8), Clifford Hansen, et al., World Conference on Photovoltaic Energy Conversion, November 2014.
- Hispanic Engineer and Information Technology Magazine, Top Professional in Energy (Ken Armijo), Fall 2014.
- 42nd IEEE PVSC Best Poster Award, Area 11: PV and System Reliability, 2015.
- C. W. Hansen was the Area 9 Chair for the 42nd IEEE Photovoltaic Specialist Conference, New Orleans, LA, June 2015.

Other Notable Impacts (Partial list)

- PV Performance Modeling Tutorial taught at the World Conference on Photovoltaic Energy Conversion (WCPEC-6) by Joshua S Stein in Kyoto, Japan, November 2014.
- PV Performance Modeling Tutorial taught at the 42nd IEEE Photovoltaic Specialist Conference in New Orleans, LA by Joshua S Stein, Cliff Hansen, and Daniel Riley, June 2015.
- 4th PV Performance Modeling and Monitoring Workshop, Cologne, Germany. Sandia organized the event with cohosts TÜV Rheinland and IEA PVPS Task 13, 215 participants, October 2015.



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