SAND2020-8325R

Research Performance Progress Report (RPPR-1)

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c. Project Title	PV Performance Modeling and Stakeholder Engagement	
d. Principal Investigator	Joshua S. Stein jsstein@sandia.gov	
e. Business Contact	Inna Kozinski	
f. Submission Date	July 15, 2020	
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i. Project Period	**Start:** 10/1/2018	**End:** 9/30/2021
j. Reporting Period	**Start:** 1/1/2020	**End:** 6/30/2020
k. Report Term or Frequency	Biannual (twice a year)	
l. Submitting Official Signature		

Major Goals & Objectives:

The objectives of this project are as follows:

1. Reduce uncertainty in PV performance models by developing and validating new and improved models and submodes.
2. Create and manage an open source repository of modeling functions and data.
3. Build and grow the PV Performance Modeling Collaborative
4. Represent the US in the IEA PVPS Task 13 Working group.

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Project Results and Discussion:

Task 1. Technical development work in the areas of module thermal modeling, dynamic soiling prediction, degradation analysis methods, and data management planning for IEC 61853 test results.

Subtask 1.1 Integrate Degradation Tools into PVLIB

This task is intended to publicize and disseminate new methods being used to estimate performance degradation of PV systems. Work in this task was completed in Q1 of FY20. A tutorial and a set of python examples were developed to demonstrate four different methods that can be applied to normalized PV performance data to calculate a degradation rate. This calculation is difficult because the normalized data still contains diurnal and seasonal biases that can cause simple trend fitting methods to have significant uncertainties. Specifically, we provided examples for (1) linear regression with ordinary least squares (simple method), (2) classical seasonal decomposition, (3) seasonal and trend decomposition using locally weighted scatterplot smoothing (LOWESS), (4) Holt-Winters triple exponential smoothing, autoregressive integrated moving average (ARIMA) and robust principal component analysis (RPCA). A detailed summary of the calculation process is included along with linked jupyter notbooks with calculation examples. The content is available here: https://pvpmc.sandia.gov/pv-research/pv-lifetime-project/pv-degradation-modeling/ .

We have also made an investigation into how different degradation profiles can affect plant economics related to module cleaning schedules. Typical O&M practices assume a fixed cleaning frequency per year for a particular location. Although this is usually considered as an adequate first approximation, such assumptions do not take into account that the value of recovered energy changes with time, due to the system's health state and, in particular, degradation. Therefore, due to the lower energy yield with time, revenues will also be reduced making the impact of cleaning less effective, considering also that the economic parameters will also change (e.g. inflation). Furthermore, it should be considered that, in some geographical locations, the electricity price is subject to a daily market-based competition. This means that the price of electricity sold by the PV system producer to the grid may vary over time, depending on supply and demand. In these markets, an escalation in the price of electricity can, at least partially, counterbalance the effects of degradation and rise in cleaning costs, increasing revenues, and therefore incentivize the cleanings. Taking these factors into account, along with the influence of discount rate, one could expect that the optimum cleaning schedule that maximizes the revenues and minimizes the costs would vary with the year of operation. In order to verify this hypothesis, a sensitivity analysis was performed to investigate the impact of different PV degradation rate patterns on the profitability of cleaning schedules taking into account the variability of economic parameters and soiling profiles extracted from a 1 MW PV plant in Spain [1]. The economic parameters were realistically modeled to vary annually, and the effects of their variation was thoroughly discussed. Different degradation rate patterns were considered enabling the cleaning schedule optimization over time using the levelized cost of electricity (LCOE) and net present value (NPV) metrics as criteria. An example is shown in the Figure below, where the revenue per cleaning is demonstrated for different degradation rate scenarios. The cleaning frequency should be increased (i.e. becomes profitable) when the revenue per cleaning is greater than the cost of cleaning.

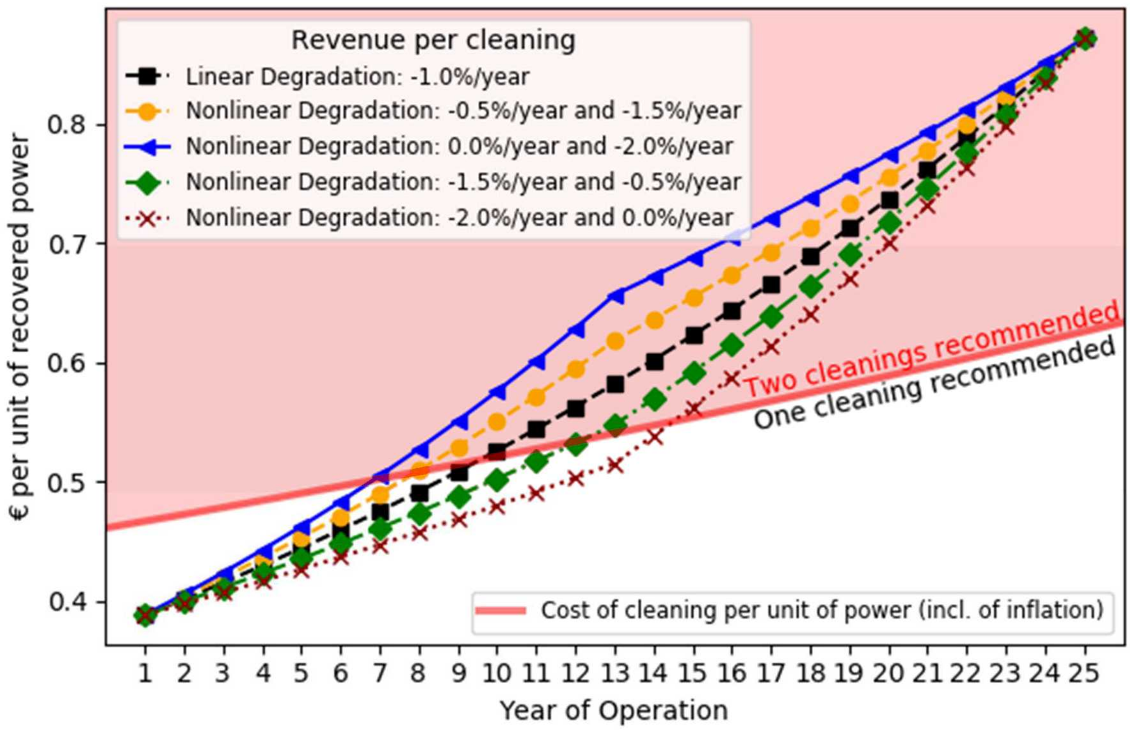


Figure 1. The optimum cleaning frequency for a PV system varies with the time of operation. The profitability of each cleaning is affected by the pattern of PV degradation rate and the variability of electricity price and cleaning costs.

Subtask 1.2 Manage and standardize IEC 61853 module characterization data warehouse

Sandia and contractor PV Performance Labs Germany have been working to develop open source standard data formats and functions to work with data measured for compliance with IEC 61853-1, 2, 3, and 4. This set of standards defines how to measure PV module performance over a range of irradiance and temperature conditions, how to measure angle of incidence and spectral sensitivities and apply these data to energy ratings in a number of climates that are included in the standard.

We have acquired IEC 61853-1 matrix data from a set of nine modules that are included in the PV Lifetime project. This data is being used to illustrate and demonstrate the tools being developed in this task. These same modules are currently being tested at CFV Labs for angle-of-incidence characteristics and temperature behavior following test protocols in IEC 61853-2. Results of these tests will be made public along with the results of IEC 61853-1, which are available on the PVPMC website (https://pvpmc.sandia.gov/pv-research/pv-lifetime-project/pv-lifetime-modules/).

We completed a Sandia report (Driesse and Stein, 2020) that describes recommendations for using the IEC 61853 power measurements matrix data to simulate PV performance. It includes useful and practical observations on how to interpolate and extrapolate using these data while maintaining high levels of accuracy. We include a performance and accuracy comparison of different published methods and provide a description of a newly developed method that improves on the previously published models, especially in predicting performance at very low light levels, where many of the previously published models fail to perform well. We have prepared a manuscript to submit to a peer reviewed journal but have not submitted it yet.

Calibration of the Sandia Model from the IEC 61853-1 Performance Matrix

Introduction:

PV module electrical performance ratings are most commonly represented by a single set of values for current, voltage and maximum power given at standard test conditions (STC) of 25°C, 1000 W/m^2 and AM1.5 spectrum. These are typically determined indoors on a solar simulator under controlled conditions. Traditionally, point measurements are translated to other operating conditions using simple, linear translation models such as PVForm [2] or PVWatts [3]. The IEC 61853-1 [4] performance matrix expands upon this point measurement to include 21 additional points in irradiance/temperature space. While covering a wider range of operating conditions, a challenge still exists in the choice of translation method for this matrix. Driesse and Stein [5] illustrate these challenges by applying a variety of translation methods to a series of matrices.

In contrast, outdoor measurements tend to encompass a continuum of operating conditions rather than the tidy, discrete points prescribed by IEC 61853-1. In addition to irradiance and temperature, these measurements also commonly span a range of other variables affecting PV performance, principally spectrum, solar incident angle and wind speed. The Sandia Array Performance Model [6], a semi-empirical set of four principal equations, was originally developed to reduce outdoor data into a set of coefficients that represent module performance at STC and to perform energy predictions or ratings under arbitrary weather conditions. Here, we have demonstrated the applicability of the Sandia Model to fit IEC 61853-1 matrix data from indoor testing and translate it to arbitrary operating conditions.

Sandia Array Performance Model Overview:

The Sandia Array Performance Model consists of four primary equations describing short circuit current, open circuit voltage, current at MPP and voltage at MPP. Since the performance matrices were generated indoors on a flash tester, the impact of variable environmental conditions that would ordinarily be seen in outdoor testing can be eliminated from the model. Specifically, terms for solar spectrum (air mass), reflection losses (AOI) and wind speed can be eliminated. Further, as indoor testing was performed in a temperature chamber under isothermal conditions, the back-of-module to cell temperature translation may also be eliminated.

The equation for short circuit current is the core component of the model

$$I_{sc} = I_{sco}\left[\frac{G_{poa}}{G_0}\right]\left[1+\hat{\alpha}_{Isc}[T_c - T_0]\right]$$

Effective irradiance, used for all remaining calculations, is given by

$$E_e = \frac{I_{sc}}{I_{sco}\left[1+\hat{\alpha}_{Isc}[T_c - T_0]\right]}$$

The remaining primary equations then are;

$$V_{oc} = V_{oco} + N_s\delta(T_c)\ln(E_e) + \beta_{Voc}[T_c - T_0]$$

$$I_{mp} = I_{mpo}[C_0E_e + C_1E_e^2]\left[1 + \hat{\alpha}_{Imp}[T_c - T_0]\right]$$

$$V_{mp} = V_{mpo} + C_2N_s\delta(T_c)\ln(E_e) + C_3N_s[\delta(T_c)\ln(E_e)]^2 + \beta_{Vmp}[T_c - T_0]$$

where $\delta(T_c)$, the thermal voltage per cell, is given by

$$\delta(T_c) = \frac{nk[T_c + 273.15]}{q}$$

Data Sets:

Nine PV Lifetime modules were characterized at CFV Solar under contract to Sandia. Additionally, data for one CdTe module previously characterized at CFV was extracted from a publicly available report published by First Solar [7]. Characterization was performed indoors on a Halm AAA+ flash solar simulator with integral isothermal temperature control. Results included the full IEC61853-1 matrix, plus five additional points at low irradiance/high temperature. The reported results also included temperature coefficients determined separately at 1000W/m^2, between 15 – 75°C in 5°C increments.

Model Calibration Method:

The original calibration method for the Sandia model relied on piecewise solution of each primary equation, using data sets tightly constrained to specific outdoor environmental conditions. Separate thermal tests were required to determine temperature coefficients prior to calibrating the primary equations. The newer and preferred method utilizes simultaneous solution of each primary equation via multivariate regression analysis and does not require a separate thermal test [8]. In this method, all coefficients of each primary equation are solved without constraint. This method is well-suited to demonstrate calibration and translation of the IEC 61853-1 matrix with no additional inputs.

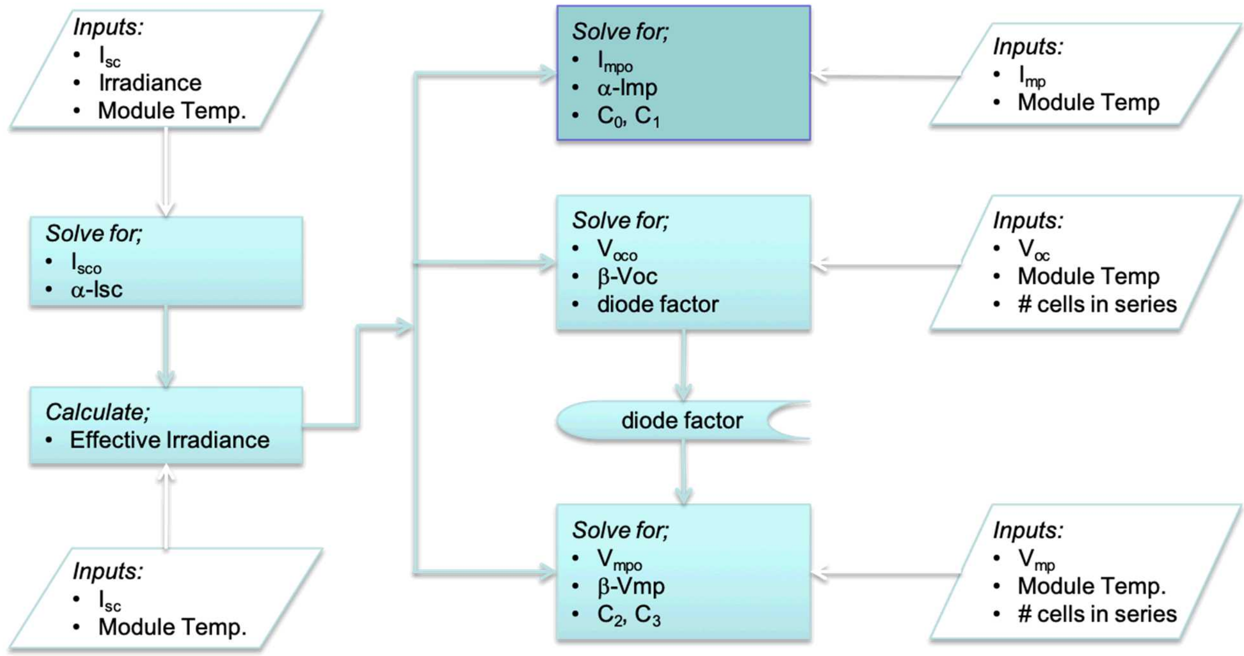


Figure 2. Schematic representation of the simultaneous solution method to the Sandia Array Performance Model. At each solution point, model coefficients are determined without constraint to specific environmental conditions, i.e. STC.

Model Calibration Results:

Sandia applied in-house calibration tools to fit the matrix data to the SAPM, with no assumption of STC values or temperature coefficients. Output was compared to values reported by CFV in accordance with IEC standards. Select STC values are shown below in Table 1.

Table 1. SAPM model parameters at STC compared with measurements

Manufacturer	Canadian Solar			Panasonic			First Solar		
Model	CS6K-275M			VBHN325SA 16			FS-4112-3		
Source	Meas	SAPM	% Diff	Meas	SAPM	% Diff	Meas	SAPM	% Diff
Pmp [W]	277	276	-0.36	322	323	0.31	118	118	0.00
Isc [A]	9.30	9.24	-0.65	5.90	5.92	0.34	1.81	1.80	-0.55
Voc [V]	38.3	38.3	0.00	70.2	70.2	0.00	90.3	90.4	0.11
Imp [V]	8.81	8.75	-0.68	5.51	5.52	0.18	1.65	1.65	0.00
Vmp [V]	31.5	31.5	0.00	58.5	58.5	0.00	71.6	71.6	0.00
δ Pmp [%/°C]	-0.42	-0.41	0.01	-0.30	-0.29	0.01	-0.29	-0.31	-0.02
α Isc [%/°C]	0.04	0.04	0	0.03	0.03	0	0.06	0.06	0
β Voc [%/°C]	-0.31	-0.31	0	-0.24	-0.24	0	-0.28	-0.29	-0.01
α Imp [%/°C]	-0.02	-0.01	0.01	0.00	0.00	0	0.03	0.04	0.01
β Vmp [%/°C]	-0.40	-0.40	0	-0.29	-0.29	0	-0.32	-0.34	-0.02
n	-	1.10	n/a	-	1.08	n/a	-	1.33	n/a

FF [%]	77.9	77.9	0.00	77.8	77.7	-0.1	72.3	72.5	0.2

With one exception (Panasonic) STC ratings were biased negative when determined from SAPM compared to the single point values. Differences in power were generally 0.5% or less (1-2 watts for most modules in this study). Differences in voltage were negligible. Most of the differences in power were attributable to differences in current. Temperature coefficients were nearly indistinguishable.

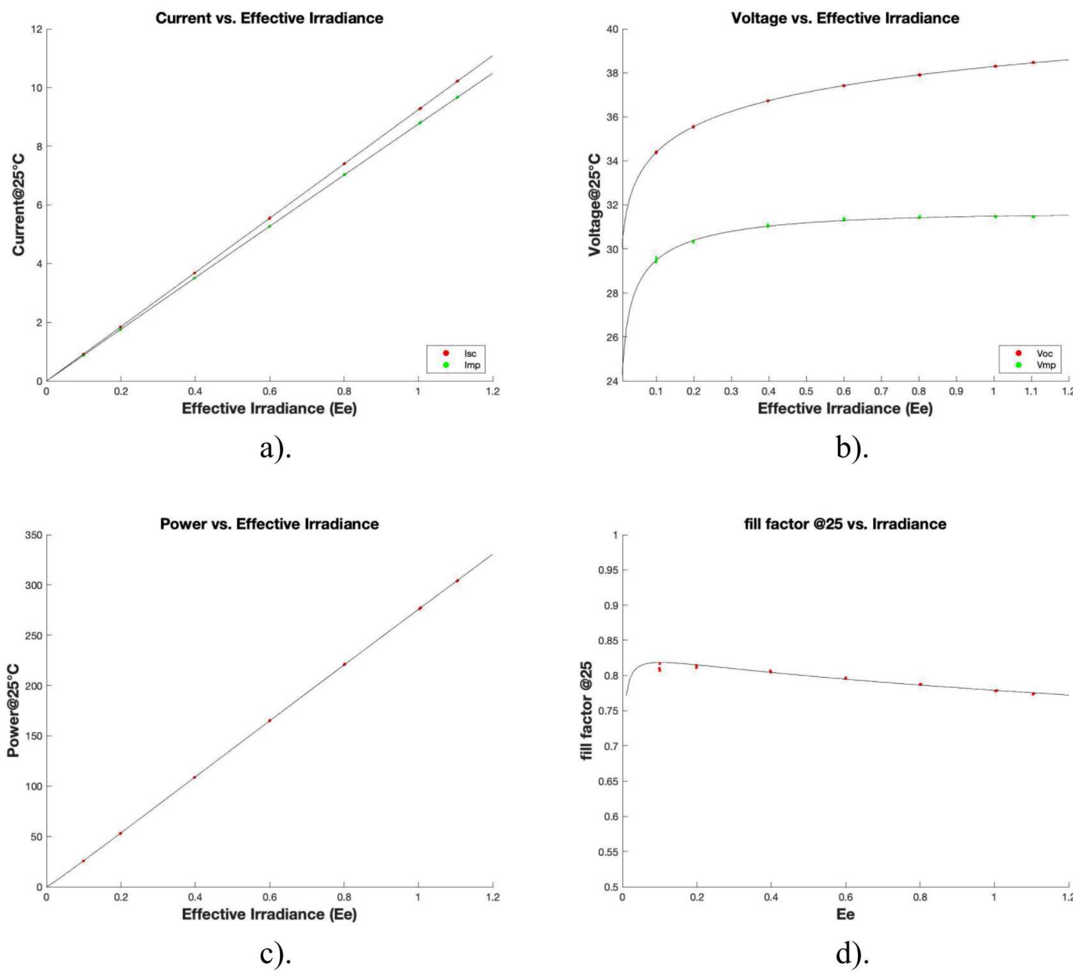
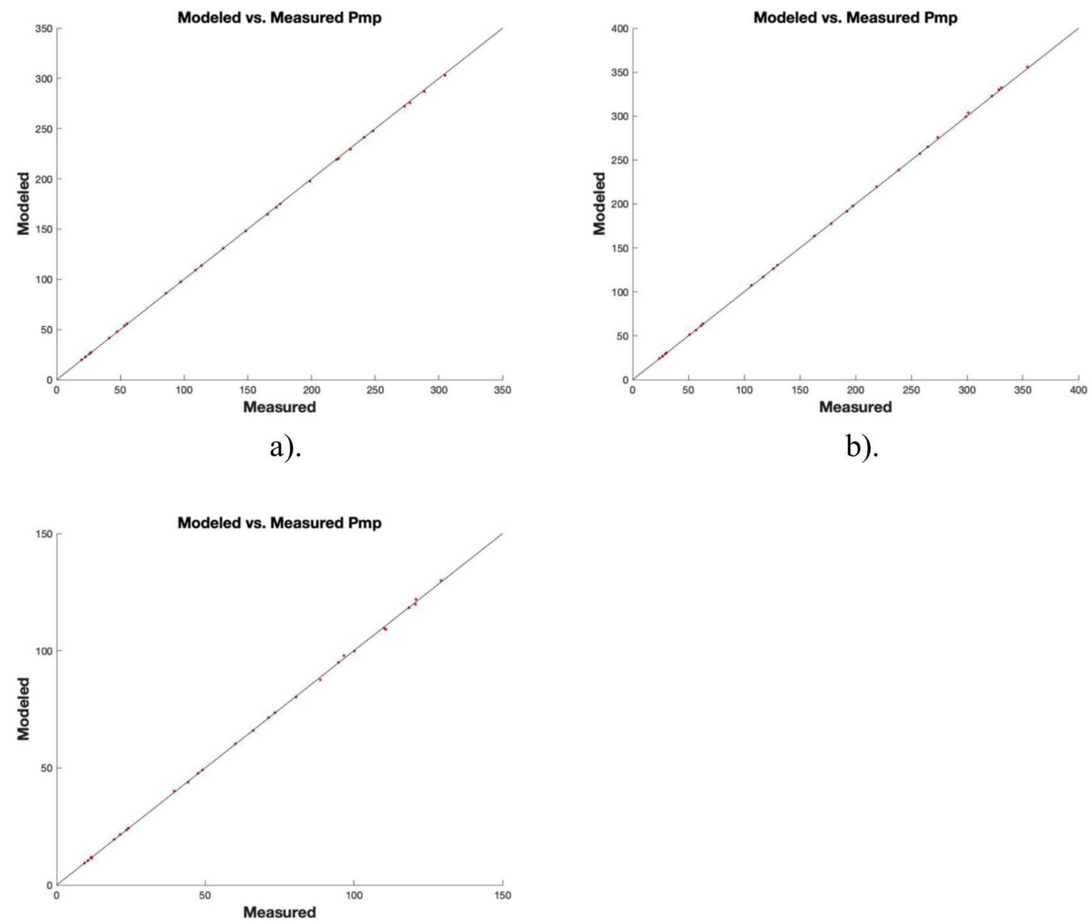


Figure 3. Typical summary plots for one module (CS6K-275M) showing measured data (dots) translated to 25°C compared to model fits (solid lines). a). and b). are direct model output while c) and d) are calculated quantities.



c).

Figure 4. Measured vs. Modeled power for three example modules included in Table 1. a). Canadian Solar, b). Panasonic, c). First Solar.

Subtask 1.3: Support new test standard for module thermal response coefficients

The project team has participated in the working group led by Kyumin Lee of Array Technologies in the revision of IEC61853-2, which includes procedures for measuring and analyzing module thermal response coefficients. Initially we met for monthly calls starting in the summer of 2019. These calls have stopped in the past quarter due to the working group leader changing jobs.

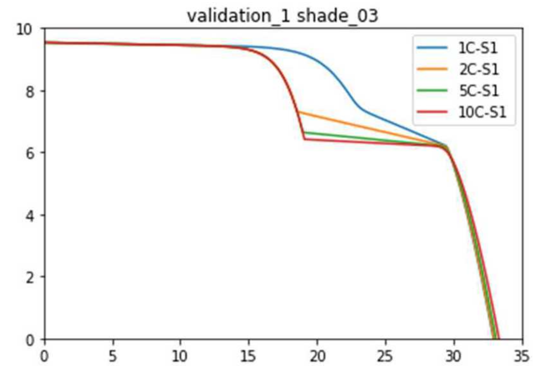
Subtask 1.4: Develop and validate open-source, transient module temperature model

This task was completed during the last reporting period. We developed a simple transient module temperature model that only requires parameters that are available on a standard module spec sheet. The model is based on a weighted moving average of steady-state temperature calculations where the weighting is influenced by the current wind speed and the specific area mass of the module (kg/m^2). This relationship was established using detailed thermal finite element models. The model is validated against field measurements and has been published in the Journal of

Photovoltaics (Prilliman et al., 2020). In addition, NREL's System Advisor Model is implementing the model in its next release.

Subtask 1.5: Develop and validate open-source, module technology specific shade response model

We have made good progress on this task. Building on a new pvlib-python function: singlediode.bishop88_v_from_i(), we have developed a simulation package that can easily simulate effects of shade, partial shade, and other IV related losses on cells, modules, and strings. We are in the process now of validating the model by applying controlled partial shading to individual cells in a module (using a neutral density transparent film) and measuring IV curves using our Spire 4600 SPL flash simulator. The figure to the right shows a sample of modeled IV curves from shading 1, 2, 5, and 10 cells in a module (all same cell substring).



We will compare these results to flash test measurements and report the results in the next quarter. This model will allow us to simulate module specific shade responses more accurately (e.g., half-cell, shingled cells, thin-film, etc.).

Subtask 1.6: Dynamic soiling and snow models added to PVLIB

At WCPEC in 2018, Humboldt State University researchers Liza Boyle and Merissa Coello presented a soiling model which uses particulate matter (PM) concentrations in air (specifically PM 2.5 and PM10) to model the amount of particulate deposited upon PV modules at a given tilt angle. These data are available for certain locations from the Environmental Protection Agency. PV soiling models have long been desired by modelers to predict losses in energy due to soiling. To popularize soiling models and encourage further soiling model development, we validated the Humboldt State soiling model with data collected by Sandia and implemented the Humboldt model in MATLAB. The model was added to the MATLAB version of PVLIB after several reviews. The Humboldt model is now part of the official PVLIB MATLAB code base and is available on GitHub.

Following the model being added to PVLIB MATLAB, a contributor coded up the model and added it to pvlib-python. Subsequently, we discovered that they had made several errors in translating the code and we submitted two pull requests to fix the problem and provide new tests and a tutorial example (*Figure 5*). These will be included in the next release.

- M. Prilliman, J. S. Stein, and D. Riley, "Transient Weighted Moving Average Model of Photovoltaic Module Back-Surface Temperature," *Journal of Photovoltaics,* vol. 10, no. 4, pp. 1053-1060, 2020, doi: 10.1109/JPHOTOV.2020.2992351.
- A. Driesse and J. S. Stein, "From IEC 61853 power measurements to PV system simulations," Sandia National Laboratories, 2020, vol. SAND2020-3877.
- L. Micheli, M. Theristis, D. L Talavera, F. Almonacid, J. S. Stein, E. F. Fernández, "Photovoltaic cleaning frequency optimization under different degradation rate patterns," in preparation for Elsevier, Renewable Energy, 2020.

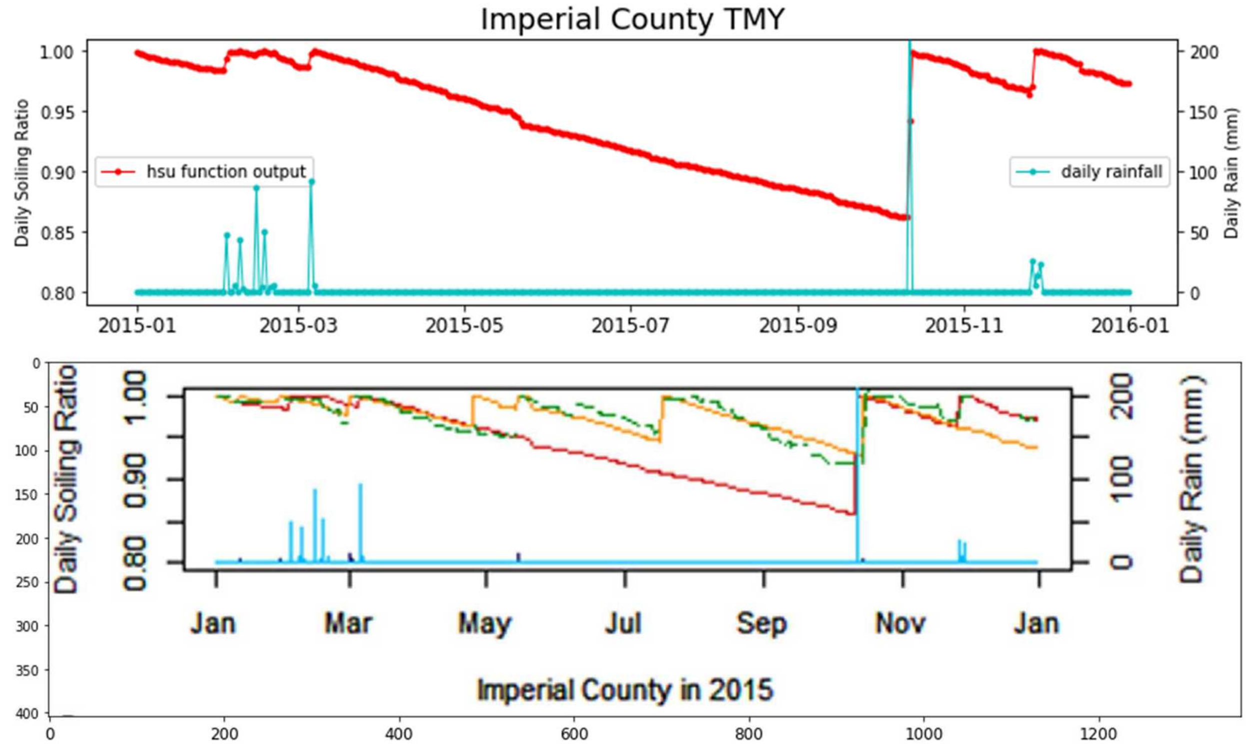


Figure 5. Top figure shows daily soiling ratio and rainfall output from the soiling.hsu() model. Bottom figure is from Coello and Boyle (2019). The red-line scenarios match perfectly, which indicates that the model implementation is correct.

We continue to investigate and compare a variety of commercial soiling sensors in New Mexico (Kipp and Zonen's DustIQ, Atonometrics' Mars, and Fracsun's Ares units). We are currently investigating some problems with the data from some of the units.

Task 2: Stakeholder Engagement Activities

Subtask 2.1: PVPMC Website

The PVPMC website continues to provide key information about PV performance modeling and events. We added new datasets of IEC 61853-1 Performance results for a set of nine PV modules that are part of the PV Lifetime project as well as a tutorial on calculating PV system degradation rates using a variety of trend fitting methods. We also added a list of papers that cite or use PVLIB MATLAB and pvlib-python. We continue to maintain the site and add new information for the community.

Subtask 2.2: PVPMC Workshops

The 14th PVPMC Workshop (cosponsored by GroundWork Renewables and to be held in Salt Lake City on May 19-20, 2020) had to be canceled due to the COVID-19 pandemic. Instead, Sandia, GroundWork Renewables and CFV Labs have begun hosting a PVPMC Webinar series to allow speakers who were scheduled to present at the canceled live event an opportunity to present their modeling results in a timely manner.

The first webinar in this series covered Solar Resource Assessment topics and was held on June 24, 2020. We had a consistent audience of ~300 attendees for the entire two-hour session. Talks were prerecorded to minimize the risk of technical problems and then speakers joined as panelists to provide live question and answer sessions after each of the five talks. The webinar was recorded and is available to view on the PVPMC website (https://pvpmc.sandia.gov/resources-and-events/events/2020-pvpmc-webinars/). PDFs of the slides presented are also available for download.

The next webinar will be help on August 5, 2020 and the topic will be PV Performance Modeling Method Updates. We plan to continue these webinars approximately every month through the summer and fall of 2020.

Subtask 2.3: PVLIB Support.

PVLIB for Matlab and pvlib-python are managed on GitHub. Most of the current development has been focused in the pvlib-python package. We had two code releases in the current reporting period: 0.7.1 (January 17, 2020) and 0.7.2 (April 22, 2020). These releases included several enhancements that are related to this project:

(1) singlediode.bishop88_v_from_i() implements a PV cell IV model that includes reverse bias cell behavior that allows modeling of partial shading of PV module and arrays along with other mismatch effects.
(2) soiling.hsu() implements the Humbolt State University soiling model. This was contributed by someone outside the project and we subsequently found several errors in the implementation. We have submitted two pull requests that will be included in the next release. They fix the errors in the first release and add additional documentation and examples for using the function.

Cliff Hansen from Sandia is one of the main developers and maintainers of pvlib-python. A recent look at the GitHub repository shows that there are 25 pull requests, the repository is used by 118 other repositories, is being watched by 73 people, and has been forked 376 times. The project is also a NumFocus affiliated project.

We compiled a list of 257 references that cite or use PVLIB or pvlib-python in the literature and posted the list by year of publication on the PVPMC website (https://pvpmc.sandia.gov/applications/pv_lib-toolbox/). This is direct evidence of the impact that this open source code is making on the field. We plan to update the list each year.

Subtask 2.4: Represent US at Task 13 meetings

Dr. Stein is the Subtask 1 leader for the IEA PVPS Task 13 Experts group. In this role he oversees working groups in the following areas:

1. New Module Concepts, Designs, and Materials
2. Bifacial Photovoltaic Modules and Concepts
3. Performance of New Photovoltaic System Designs
4. Service Life Prediction

During the latest reporting period Dr. Stein presented at the Spring virtual meeting as the in-person meeting planned in Pietå, Sweden in March 2020 was canceled due to the COVID-19 pandemic. The Fall 2020 meeting in Korea has also been canceled and will be help virtually September 29 to October 1, 2020. Sandia will also participate in an IEA PVPS Task 13 Workshop being held as a parallel event of the EU PVSEC virtual conference to be held on September 10, 2020.

For Subtask 1.1, Dr. Stein and Dr. Gernot Oreski have been organizing an international report entitled: "Designing New Materials for Photovoltaics: Opportunities for Lowering Cost and Increasing Performance through Advanced Material Innovations" which will be ready for IEA review during the Fall of 2020. We have arranged for several important contributions to the report from US DOE funded projects (e.g., DuraMAT).

For Subtask 1.2, Dr. Stein has compiled a complete draft of a report entitled: "Bifacial Photovoltaic Modules and Systems: Experience and Results from International Research and Pilot Applications". Technical contributions for this report will be reported for Sandia's bifacial project.

For Subtask 1.3, Dan Riley has contributed a report section on characterizing and modeling AC modules. He will present this content at a virtual workshop being held in September as part of the EU PVSEC.

For Subtask 2.3, Bruce King and Joshua Stein have contributed several sections to the report entitled: "Climatic Rating of Photovoltaic Modules: Different Technologies in Various Operating Conditions."

For Subtask 3.2, Joshua Stein has done reviews for sections related to UVF imaging.

Subtask 2.5: Enhance PV Performance Model Validation Data

This task is planned to start later in FY20.

Participants and Collaborators:

- Joshua S. Stein PhD., Principle Investigator, Sandia National Laboratories
    - Technical lead for the PVPMC workshops
    - Representative to the IEA PVPS Task 13 (Subtask 1 lead)
- Daniel Riley, Technical Staff, Sandia National Laboratories
    - Lead researcher on the PV soiling model development for MATLAB and python.
- Marios Theristis, Postdoctoral Researcher, Sandia National Laboratories
    - PV degradation modeling
- Cliff Hansen, Technical Staff, Sandia National Laboratories
    - PVLIB package management and maintenance.
- Cameron Stark, Technologist, Sandia National Laboratories
    - Cameron left our group in June 2020 for another department at Sandia.
- Anton Driesse, Contractor, PV Performance Labs Germany
    - IEC61853 module database and function development
- Matthew Prilliman, Graduate Student Intern (ASU), Sandia National Laboratories
    - Transient module temperature model development and validation

- Liza Boyle, Professor, Humboldt State University
    - She volunteered her time to review our implementation of her soiling model in MATLAB and python.
- Merissa Coello, Undergrad, Humboldt State University
    - She translated her soiling model to PVLIB MATLAB
- Sophia Archibeque, Undergrad Student Intern (UNM), Sandia National Laboratories
    - She has just joined the team and is working on python data analysis and documentation of PV performance model validation data.
- Karen Yang, Undergrad, Student Intern (UI-CU), Sandia National Laboratories
    - She has been validating satellite irradiance datasets for sites in the US including RTC locations.
- Michael Hopwood, Undergrad Student Intern (UCF), Sandia National Laboratories
    - He has developed an IV simulation module in python that allows modeling IV curves with losses (e.g., shading, Rs, Rsh, etc.)

Publications this period:

- M. Prilliman, J. S. Stein, and D. Riley, "Transient Weighted Moving Average Model of Photovoltaic Module Back-Surface Temperature," *Journal of Photovoltaics,* vol. 10, no. 4, pp. 1053-1060, 2020, doi: 10.1109/JPHOTOV.2020.2992351.
- A. Driesse and J. S. Stein, "From IEC 61853 power measurements to PV system simulations," Sandia National Laboratories, 2020, vol. SAND2020-3877.
- L. Micheli, M. Theristis, D. L Talavera, F. Almonacid, J. S. Stein, E. F. Fernández, "Photovoltaic cleaning frequency optimization under different degradation rate patterns," in preparation for Elsevier, Renewable Energy, 2020.

Plans for Next Reporting Period:

- Prepare and submit IEC 61853 modeling comparison to journal
- Publish more model validation datasets to PVPMC website
- Prepare PVLIB tutorial to present at PearlPV Training School in October.
- Participate in virtual IEA PVPS Task 13 meeting in September
- Continue to organize PVPMC Webinars
- Complete editing and reviewing assignments for IEA PVPS Task 13 Reports

Changes/Problems:

We would like to add a new task to this project that aims to improve the way that satellite irradiance products are validated against field measurements. We obtained satellite data from Solargis for the RTC sites, NREL, and Livermore, CA. We have two summer interns working to develop better methods for comparing this data to ground truth. We intend to publish a report with results by the fall of 2020.

References:

[1] L. Micheli, M. Theristis, D. L Talavera, F. Almonacid, J. S. Stein, E. F. Fernández, "Photovoltaic cleaning frequency optimization under different degradation rate patterns," in preparation for Elsevier, Renewable Energy, 2020.

[2] D. F. Menicucci, “PVFORM: A new approach to photovoltaic system performance modeling,” in *18th IEEE Photovoltaic Specialists Conference*, 1985.

[3] W. Marion and M. Anderberg, “PVWATTS - An Online Performance Calculator for Grid-Connected PV Systems,” *Proceedings of the ASES Solar Conference*, 2000.

[4] IEC 61853-1: Photovoltaic (PV) module performance testing and energy rating – Part 1: Irradiance and temperature performance measurements and power rating (2011)

[5] A. Driesse and J. S. Stein, "From IEC 61853 power measurements to PV system simulations," Sandia National Laboratories, 2020, vol. SAND2020-3877

[6] D. L. King, W. E. Boyson, J. A. Kratochvil, “Photovoltaic Array Performance Model,”, Sandia National Laboratories, SAND2004-3535, 2004.

[7] “Third Party Validation of First Solar PAN Files,” First Solar, Inc, 2016

[8] B. H. King and Charles Robinson, “Simplifying methods to calibrate the Sandia Array Performance Model,” 6th PV Performance Modeling Workshop, 2016.