Sandia National Laboratories

Energy, Climate, & Infrastructure Security

SANDIA NATIONAL LABORATORIES' PHOTOVOLTAIC RELIABILITY PERFORMANCE MODEL

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Sandia National Laboratories' Photovoltaic Reliability Performance Model is an analytical tool to help mitigate risks associated with large PV plant design and operation

Vision

To enhance the nation's security and prosperity through sustainable, transformative approaches to our most challenging energy, climate, and infrastructure problems.

As new technology helps bring photovoltaic (PV) output costs closer to those of traditional power generation sources, plant operators are looking for ways to increase operations and maintenance (O&M) efficiencies to increase PV's profitability. Sandia National Laboratories (Sandia) recognizes a need to design more reliable and efficient PV systems and has developed a PV Reliability Performance Model (PV-RPM) to test strengths and weaknesses of different PV plant configurations and O&M procedures. With PV-RPM, Sandia delivers a valuable scenario-based predictive tool that helps owners, operators, risk managers, and financiers simulate planned PV projects to avoid costly system weaknesses before development. Sandia developed PV-RPM with industry partners on behalf of the Solar Energy Technologies Program of the U.S. Department of Energy (DOE).

Developing a Comprehensive Evaluation Tool

To date, PV reliability studies have focused on components much more than entire systems. As PV installation size continues to grow and profit margins continue to shrink, the PV industry recognizes the need to better understand how component reliability affects overall system performance. Sandia's PV-RPM provides risk-management experts with a rich visualization tool to simulate detailed PV plant operational scenarios using a hypothetical lifespan typically set at 30 years. PV-RPM represents a plant as a hierarchal system of components (e.g., modules, combiner boxes, trackers, inverters). This hierarchal system restricts each component's failure to affect availability only on those elements that are immediately "downstream" from the failed component. PV-RPM assigns to each component stochastic parameters that include failure modes, a time-based failure rate, repair time, and a time-based repair cost. Multiple iterations of PV-RPM thus produce a system-level, stochastic distribution of possible energy production and cost trends over the life of the PV system.

PV-RPM calculates hourly simulated plant life cycle data including energy production and component availability. System availability—a fraction of the system that is available to supply energy—is calculated as a function of time. For each simulation month, PV-RPM calculates estimated positive

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and negative cash flow based on theoretical sale of produced energy and energy loss due to component failure respectively. The predictive tool also estimates O&M costs (e.g., debt servicing, repair costs, preventative maintenance) in the final cash flow calculation. PV-RPM also evaluates the value of string-level monitoring, which increases installation costs but allows integrators to identify and fix string-level failures shortly after they occur.

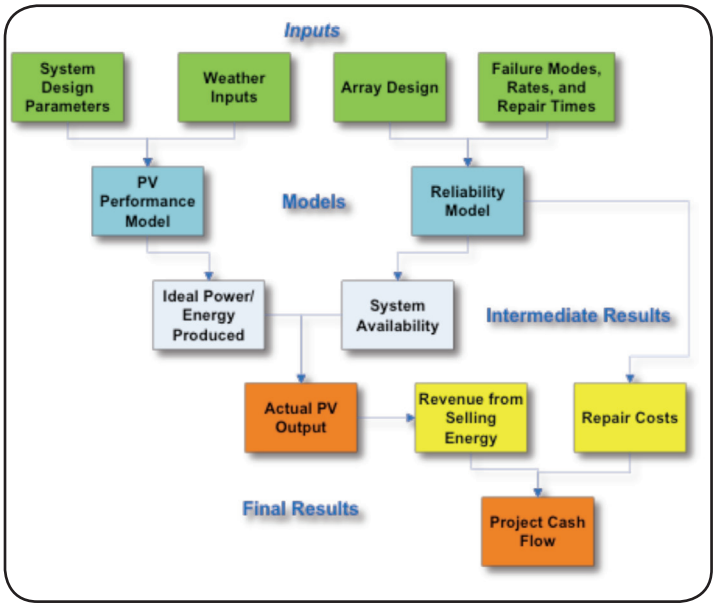


Fig. 1 PV-RPM Conceptual Flow Diagram

PV-RPM functional highlights include:

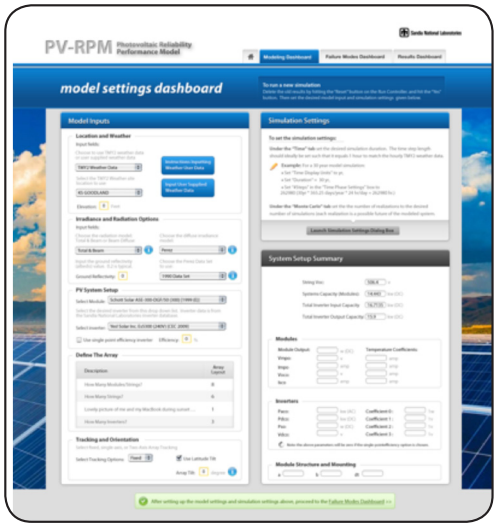
- Component-based reliability assessments using Failure Modes and Effects Analysis procedures that are coupled with Sandia's PV Array Performance Model
- A simple financial cash flow models that includes dynamic (i.e., failure event driven) O&M
- Performance evaluations that factor in uncertainty (e.g., inter annual weather variability, uncertain performance coefficients); levelized cost of energy calculations that factor in reliability (e.g. module and inverter failure modes and rates), and potential trade-offs (e.g., value of increased component reliability, value of detailed monitoring, maintenance strategies)
- Correlation between operational reliability and weather conditions (e.g., role of temperature, humidity, or UV exposure on failure modes and rates)

A Simulation to Inform Real World Applications

Sandia conducts PV-RPM as part of the lab's research to integrate emerging PV and other renewable technologies into new and existing electricity infrastructures. PV-RPM allows stakeholders to assess different system configurations and O&M strategies for operational effects and value. To improve its effectiveness, Sandia uses site performance data from its own Reliability Accelerated Testing program and from several industry and government partners.

Sandia has a long history of trusted expertise in fundamental sciences and applications. The lab is recognized as a leader in solar PV research and technical expertise. Through support from DOE as well as industry partnerships, Sandia addresses complex issues and barriers to high penetration of PV in the United States and around the world.

Sandia Photovoltaics and Distributed Systems Integration Program manages the lab's PV-RPM efforts.



Example interface for PV-RPM model

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