SolarWave IR, Inc. Set! Contest Technical Assistance Request

Why Module-level Durability Diagnostics?

The cost competitiveness of solar energy relies strongly on solar modules requiring minimum maintenance and having an operational lifetime of more than 25 years. Maintaining power generation above a certain level throughout this long lifetime, typically above 80% of the initial power, is required to protect the value of the large initial capital investment associated with PV projects and achieve the necessary rate of return for profitability and future bankability. *How can we be sure that new panels will last?*

Based on interviews with PV R&D specialists, solar manufactures and solar power plant operators, we have identified that current module monitoring technologies have limited use. Module degradation is typically factored into financial and performance models as a linear annual percent loss in power generation efficiency, which is often assumed to lay below 0.8 %/year. Nevertheless, this rate is highly dependent on the bill of materials of the module, as well as in changes in the environmental conditions of the operating modules.

Current State of the Art

Moisture exposure has been implicated in a range of PV failure mechanisms, ranging from corrosion to encapsulant and backsheet delamination to potential-induced degradation. Accelerated testing, like humidity-freeze and damp heat tests, has reinforced a relationship between moisture content and degradation. Available module monitoring technologies only detect ongoing module-level electrical malfunction – losses which already are incurring financial penalties, especially in the case of systemic defects. Based on our interviews, we identified unmet needs for: (1) Quality-control screens for materials used for encapsulation to be performed by solar panel manufacturers and PV R&D engineers, and (2) Module-level projections of performance losses that can be used to determine the adequacy of a module prior to installation and as an additional monitoring tool for solar operators and installers.

SolarWave IR's Technology and Technical Assistance Requested

SolarWave IR's goal is to provide a robust analytics system that includes hardware and software tools to *predict* module durability, based upon accurate assessment of underlying risk factors – such as its interaction of moisture. We envision R&D engineers using our products to develop improved materials and designs for modules, manufacturers using them to perform quality control, and project developers using them to screen for defective parts prior to installation and for remediation in the case of early detection of performance degradation.

To date, SolarWave IR has developed patent-pending technology (PV WaRD) to probe the moisture content of the encapsulant layers in operating solar modules quantitatively with no need to make contact to the module. We are building analytics that complement our moisture detection tool to give consistent projections on device performance losses. From literature reports and our preliminary data, we have established a link between moisture uptake in solar modules and increased degradation. We envision developing close partnerships with the national lab network to achieve our objectives, including through the use of vouchers.

Technical Request

We seek technical assistance to accomplish two objectives to achieve our technical goal:

Objective 1. Establish causal relationships between moisture exposure and power loss in fielded systems

Objective 2. Develop and validate physics-informed prediction algorithms based upon the root causes of power loss over time.

Toward the first objective, we note that Sandia National lab and NREL have extensive, instrumented outdoor module installations with long operating history. We have established a growing network of collaborators at each. Partnering with the labs, we will perform detailed analyses on modules subject to degradation under field-operating conditions and under controlled accelerated tests.

Based upon our analysis of product market fit, we expect to (A) develop, test, and demonstrate a rugged tool for measuring modules in a manufacturing or fielded environment and (B) expand the range of materials for which we have validated our PV WaRD technology.

To achieve A, we plan to conduct field studies together with Sandia National lab to validate and standardize PV WaRD performance tests on field-deployed modules. Specifically, we would like to partner to:

- Conduct moisture measurements on solar modules extracted from field-deployed at different US DOE test centers.
- Performance characterization on these modules using electroluminescence, infrared spectroscopy, ultra-violet fluorescence and current-voltage characterization.
- Validate the incorporation of WaRD test in Sandia Labs portfolio of baseline characterization

To achieve B, we plan to work together with the National Renewable Energy Laboratory to calibrate our tool to estimate the degradation rates of silicon solar cell modules under accelerated testing environments for different module materials. We would request to:

- Perform moisture measurements on commonly used cell architectures (Al BSF, PERC) with a variety of encapsulants (EVA, POE, silicones).
- Conduct complimentary performance characterization of these devices.
- Estimate the degradation rates of the tested devices in accelerated test conditions

These analyses are devised to feed predictive models used to provide risk assessment functionality.

Toward the second objective, we have an open ask. One avenue is to develop our network in the PV community, including amongst the Duramat Consortium to leverage recent efforts in applying data science to durability prediction. A unique path that we seek to take is to use physics-informed modeling that leverages experimental measurements and constraints in modeling. This is a technical area where subject expertise within and beyond the traditional PV network may be of value.

Finally, we are working with component vendors to move from our current lab prototype to a minimal viable product that best matches the needs of our customers, which will require some optical and electronic OEM engineering. We expect to use Set! prize money toward meeting this technical need.