Case Study: Soiling Assessment
Turn Modules into Soiling Sensors with IV DAQs

1. Problem Statement

Ensuring optimal yield of photovoltaic power plants requires optimization of maintenance activities such as cleaning. It is important to know WHEN to send crews to perform site cleaning which requires knowing how much energy production is lost to soiling. The amount of generation that can be recovered is difficult to ascertain and can be regionally dependent within a site.

2. Our Approach

In-field curve tracers can be used to measure module IV curves, *taken in isolation from the rest of the field*, to assess the level of soiling on individual modules. IV DAQs are distributed in a strategic manner such that chosen modules are representative of different portions of the field. This system captures both the IV curve and the operating point of the instrumented modules, as shown in Figure 1.

The recorded IV curve contains a variety of information such as the short-circuit current (Isc), and the maximum power point (Pmp). This information can be used to calculate soiling as outlined in IEC 61724. The short-circuit current (Isc) parameter is directly impacted by soiling with the drop in current being proportional to the amount of light blocked by soiling. Comparing the Isc of two modules, a cleaned control and a test module that is soiled, we determine **the actual performance loss due to soiling.**

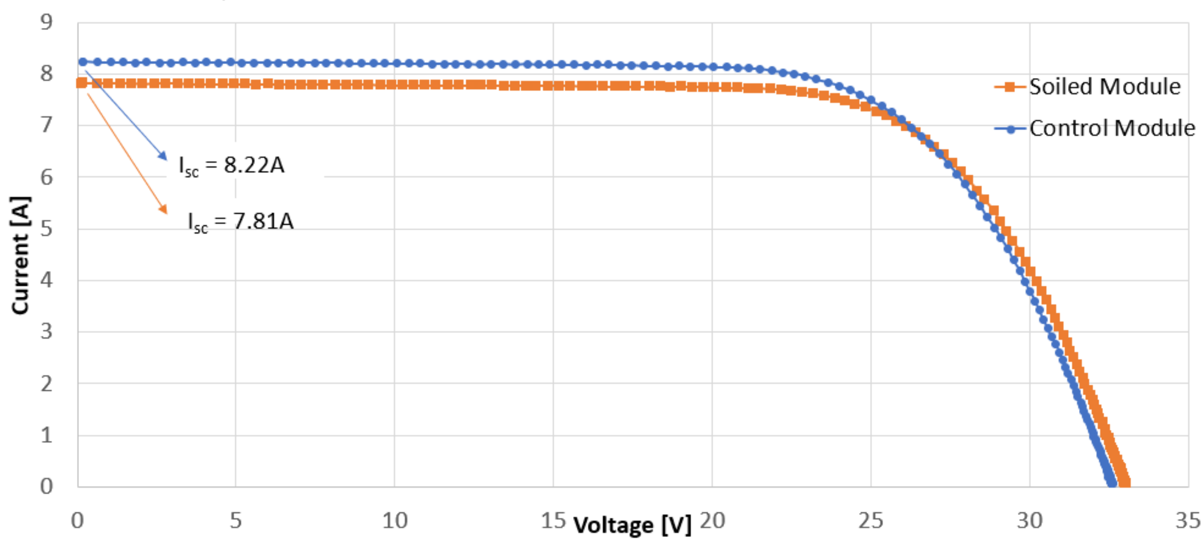

Figure 1: . Sample IV curve traces of a control cleaned module and a soiled module. The short-circuit current (Isc) point is highlighted, showing a 5% difference in current generation.

Prior to analysis, data is filtered to ensure that it is not affected by transient phenomena such as clouds or shading, for longitudinal analysis data is selected for high irradiance times near solar noon.

3. Results

In order to assess soiling on operational modules they were compared to a control module cleaned weekly. This enables us to differentiate recoverable energy from module degradation. Soiling trends over time can be observed in Figure 2, which depicts the power loss due to soiling vs time over a period of several months on several modules distributed across a field. Notably, soiling losses as high as 8% are recorded multiple times through the observation period. Some modules, shown below in green and blue, experience larger loss rates than others. Steps in the losses are due to the control module gradually soiling between weekly cleanings.

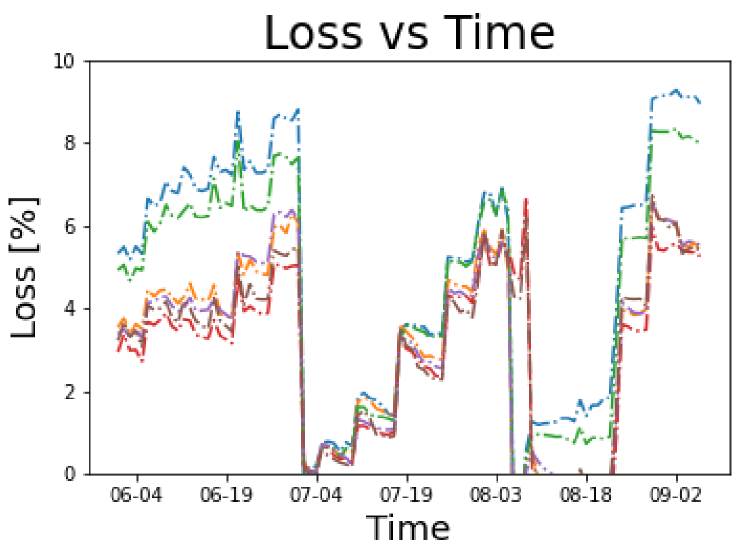

Figure 2: Soiling loss of of 6 modules over July and August 2022

Performance recovery, where loss falls back to near zero for all test modules, is visible during cleaning events in earlier July and early August, further supporting that the losses depicted were caused by soiling.

4. Deeper Analysis

Positional Dependence of Soiling

IV DAQs can be strategically placed across a solar field to assess how soiling rates are influenced by different variables. With widely spaced IV-DAQs one can observe the impact of location on soiling across a specific field, allowing for assessment of the effect of nearby forests, farms or roads. Placing IV-DAQs across a rack, for example from end to end, or top to bottom, can help identify more local sources of soiling such as runoff from upper modules to lower modules on a rack. These insights can be extrapolated to inform cleaning schedules and future site design.

To collect the data for Figure 2 (see above), IV DAQs were distributed to observe differences in end-to-end performance of modules across a string and rack. While the primary goal was to observe potential-induced degradation over time, we are also able to see soiling variations across racks. Figure 3 (see below) shows soiling from the above data, where we have averaged the soiling losses by position on rack. It is evident that the left end of the rack soils significantly faster than the middle or right edges. This is visible with the larger loss experienced by the left end in late June, as well as a steeper rate of loss leading again to larger soiling losses by late July.

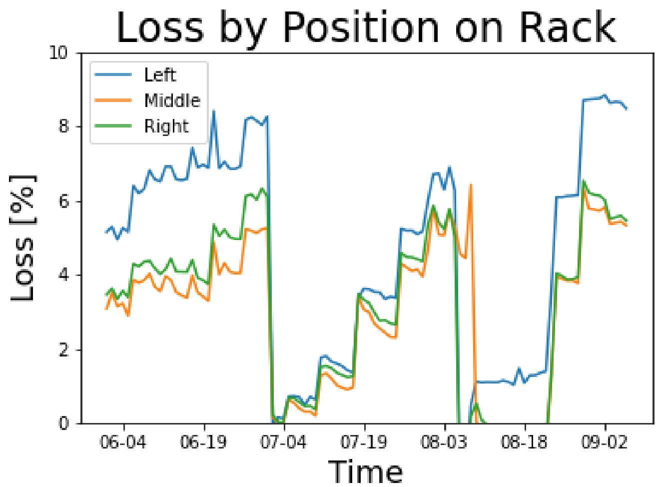

Figure 3: Soiling losses by position on rack

The overall performance of a field is dependent on and encumbered by the worst soiling conditions across each of the strings. Identifying the most-soiled locations and continually collecting soiling measurements at those locations is a vital step to quantify how much energy can be recovered.

Measuring Soiling with Machine Learning

The IV-DAQ enables Morgan Solar to collect a large quantity of data consisting of millions of IV curves and module operating points across a variety of weather conditions. These enormous datasets make it possible to apply big data machine learning models that can extract more insights from the information. In Figure 4 we see a machine learning model trained to extract module soiling values; the model is trained on just irradiance data and a soiled module's Isc.

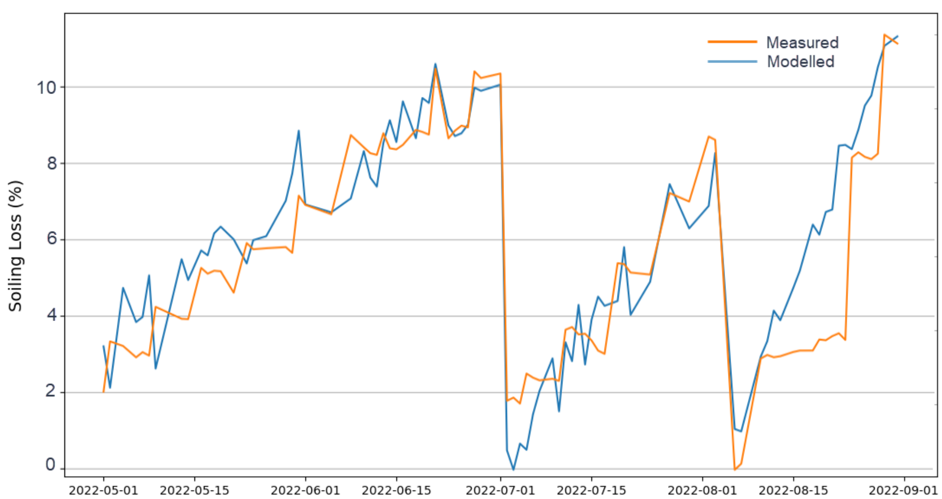

Figure 4: Comparison of extracted soiling values from the direct comparison of clean and soiled modules in orange, and a machine learning model in blue. The machine learning model operates without requiring data from a control module.

The Measured Loss (orange curve) shows the direct comparison between a test module and a cleaned control as outlined above- this serves as a baseline for comparison. The Modeled Loss (blue curve) depicts soiling loss predicted by the machine learning algorithm, showing good agreement with the measured losses, with similar soiling rates and absolute soiling level with the advantage of not requiring cleaned controls.

5. Implications and Significance

Actual performance over a field's lifetime is highly dependent on the worst soiling conditions across each of the strings. Quantifying soiling loss and its impact on energy generation is an important factor in obtaining the best returns on a site. IV DAQs can be strategically deployed to isolate and understand soiling variation across a field, down to a per-string level. Insights from IV DAQ soiling tests can be used to design cleaning plans that maximize site performance and minimize expenses—for example, plans can call for partial cleaning along roadsides which have been proven to soil quickly instead of scheduling full site cleanings.

Morgan Solar has built the world's largest weather-correlated IV curve database. Utilizing this data we have begun to train machine learning algorithms to reliably predict module soiling.

Further, understanding where soiling is largest and ensuring that the measurements occur at those locations will enable the best optimization. Losses can be highly geographically dependent and assessing this variability is critical to ensuring the best ROI on PV module cleaning.