# Accurately Measuring PV Soiling Losses Using Module Power Measurements

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**Non-uniform PV soiling can't be measured by short-circuit current alone. '**

## Non-Uniform PV Soiling

- In some conditions, soiling may accumulate non-uniformly on PV modules
- Wind, rain, condensation, temperature, and gravity all affect soiling distribution
- Often, soiling is concentrated at module edges

Example of edge soiling on utility-scale tracking system:

From: F. Brill, "EnviroPolitics Blog: PSEG building solar farms--and not just in New Jersey," 16-Nov-2012. [Online].

Examples on ground and roof-mount systems:

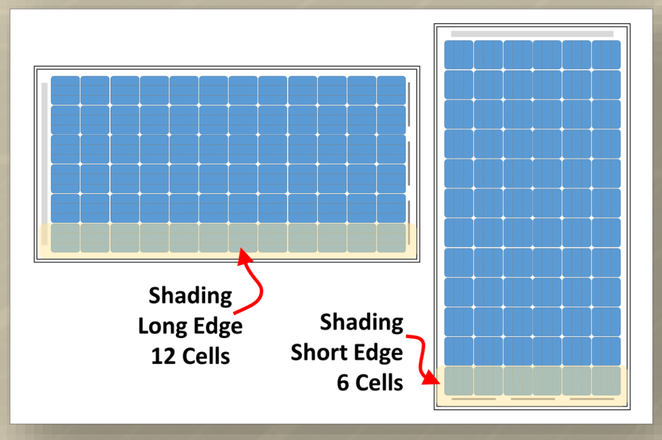

From: E. Lorenzo, R. Moretón, and I. Luque, "Dust effects on PV array performance: in-field observations with non-uniform patterns," *Progress in Photovoltaics: Research and Applications*, 2013.

## Pmax vs. Isc as Soiling Metric

- "Soiling Ratio" (SR) metric can be based on losses in measured current (Isc) or power (Pmax)
- Isc measurement simpler, but only approximates true power loss in case of uniform soiling
- Experiment shows Isc measurements can severely over- or under-estimate true power loss for non-uniform soiling on c-Si PV modules

### Experiment with Simulated Soiling

72-cell c-Si module, two orientations



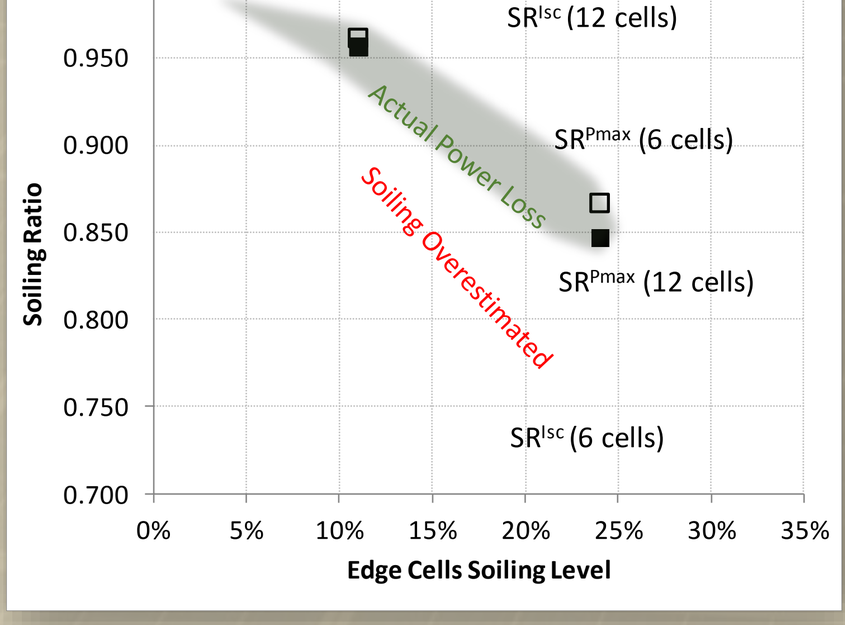

### Soiling Ratio Metrics

$$SR^{Isc} = \frac{\text{Measured Isc Soiled }^{**}}{\text{Predicted Isc Clean}}$$ **Current**

$$SR^{Pmax} = \frac{\text{Measured Pmax Soiled }^{**}}{\text{Predicted Pmax Clean}}$$ **Power**

***Irradiance- and temperature-corrected*

### Results

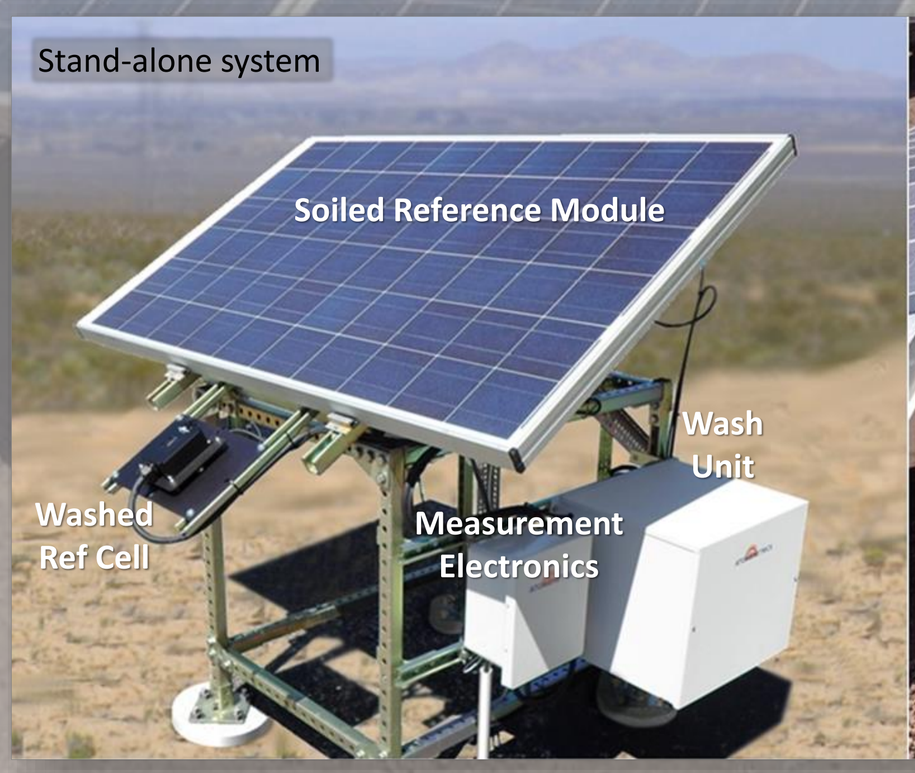


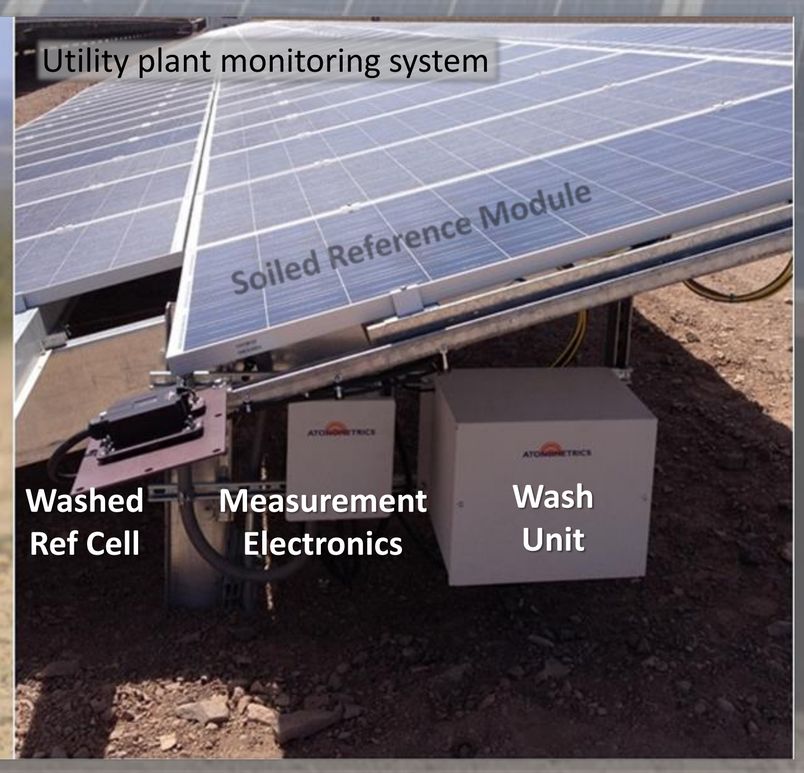

Explanation: Module has 3 internal bypass diodes. Shaded 12-cell string on long edge is bypassed by internal diode, so Isc is not limited by shading; but shading 6 cells across all strings results in the shaded cells controlling and limiting Isc.

From: Gostein, Littmann, Caron, Dunn, Proceedings of the 39th IEEE Photovoltaic Specialists Conference (PVSC), Tampa, FL, June 2013.

## Soiling Measurement System

- Soiling measurement: use "soiled" module and "clean" control
- "Clean" control: may use automatically cleaned reference cell
- For "soiled module" use actual PV module representative of site, to capture module-specific effects and non-uniformities
- <u>Should measure both module current and power</u>




*This poster contains no confidential information. '*

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