Validation of In-Situ I-V Measurement Device for PV System Monitoring Applications

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ATONOMETRICS

Acknowledgements

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Introduction

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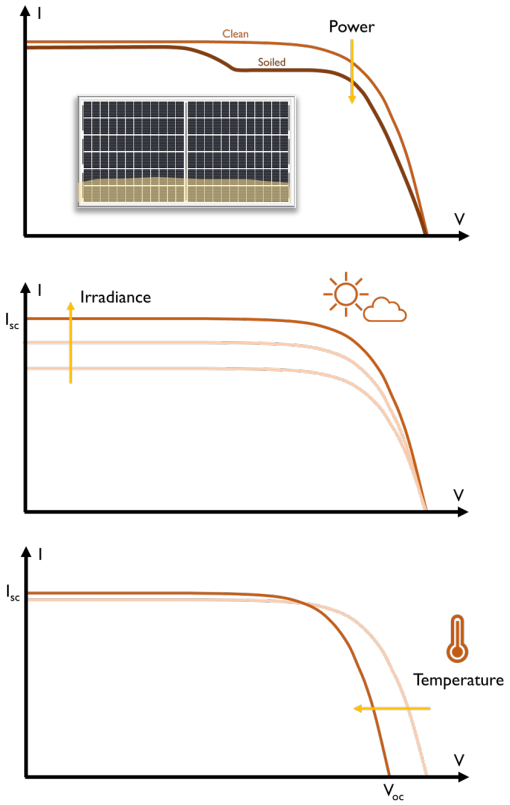
IV sweeps are useful for system monitoring



Soiling

Irradiance (including bifacial effective irradiance)

Degradation

Temperature

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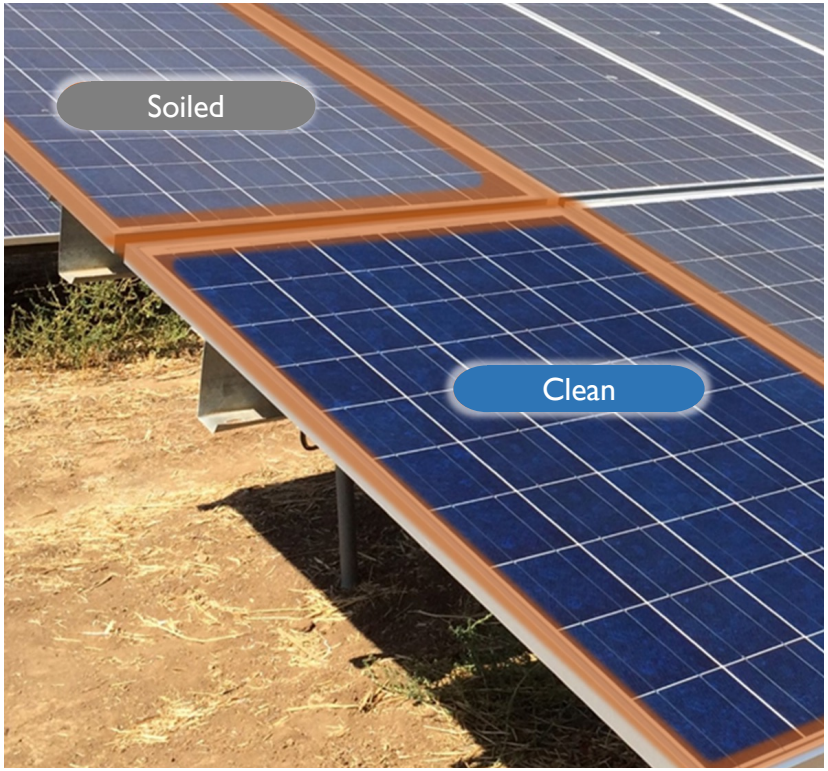
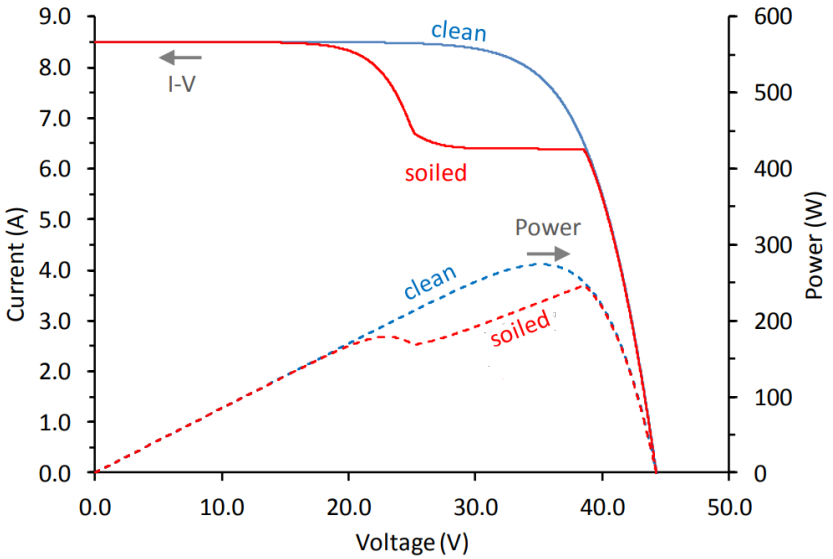
A clean and dirty module can be used to calculate soiling loss





Gostein, M. & Duster, T. & Thuman, C. PVSC 2015
Accurately Measuring PV Soiling Losses With Soiling Station Employing Module Power Measurements.

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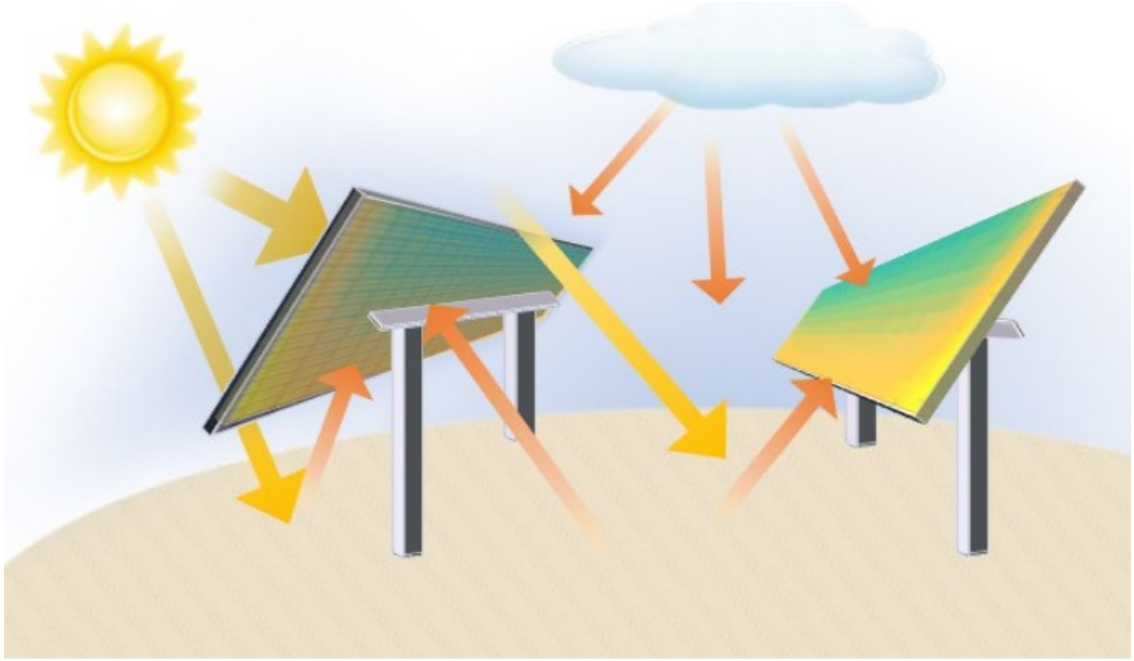
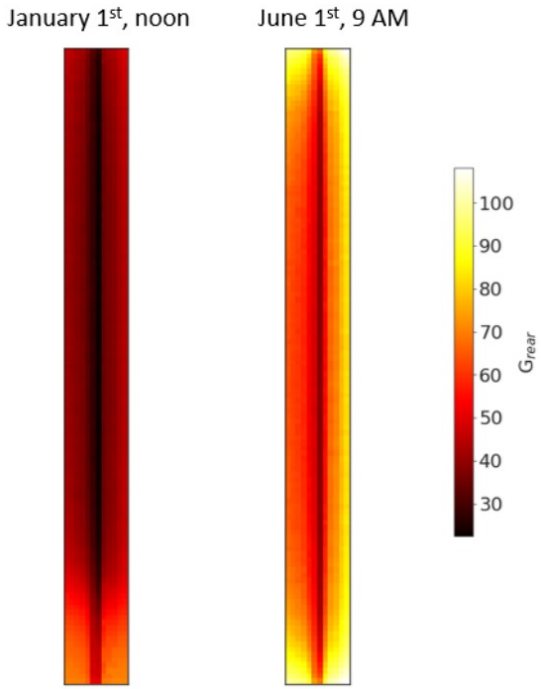
Bifacial rear side irradiance is non-uniform





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Gostein, Michael & Ayala Pelaez, Silvana & Deline, Chris & Habte, Aron & Hansen, Clifford & Marion, Bill & Newmiller, Jeff & Sengupta, Manajit & Stein, Joshua & Suez, Itai.
Measuring Irradiance for Bifacial PV Systems. PVSC 2021

Bifacial reference modules measure total front + rear irradiance

AREA 7: STRATEGIES FOR PERFORMANCE MONITORING AND RATING

Chair/Organizer: Keith McIntosh, Kevin Anderson

204 B

1:30 **Effective Irradiance Monitoring Using Reference Modules**

Jennifer L. Braid[1], Joshua S. Stein[1], Bruce H. King[1], Christopher Raupp[2], Jaya Mallineni[2], Justin Robinson[3], Steve Knapp[3]. *[1]Sandia National Laboratories, Albuquerque, NM, USA.[2]SOLV Energy, San Diego, CO, USA.[3]GroundWork Renewables, Holladay, UT, USA*

1:45 **Intelligent cloud-based monitoring and control digital twin for photovoltaic power plants**

Andreas Livera[1], Georgios Paphitis[1], Loucas Pikolos[1], Ioannis Papadopoulos[1], Javier Lopez-Lorente[1], George Makrides[1], Juergen Sutterlueti[2], George E. Georghiou[1]. *[1]PV Technology Laboratory, FOSS Reseacrh Centre for Sustainable Energy, Department of Electrical and Computer Engineering, University of Cyprus, Nicosia, *, Cyprus.[2]Gantner Instruments GmbH, Schruns, *, Austria*

2:00 **Best Student Presentation Award Finalist - Measuring Irradiance with Bifacial Reference Panels**

Nicholas Riedel-Lyngskar[1], Jan Vedde[2], Peter B. Poulsen[1], Sergiu Spataru[1]. *[1]Technical University of Denmark, Department of Photonics Engineering, Roskilde, *, Denmark.[2]European Energy A/S, Soborg, *, Denmark*

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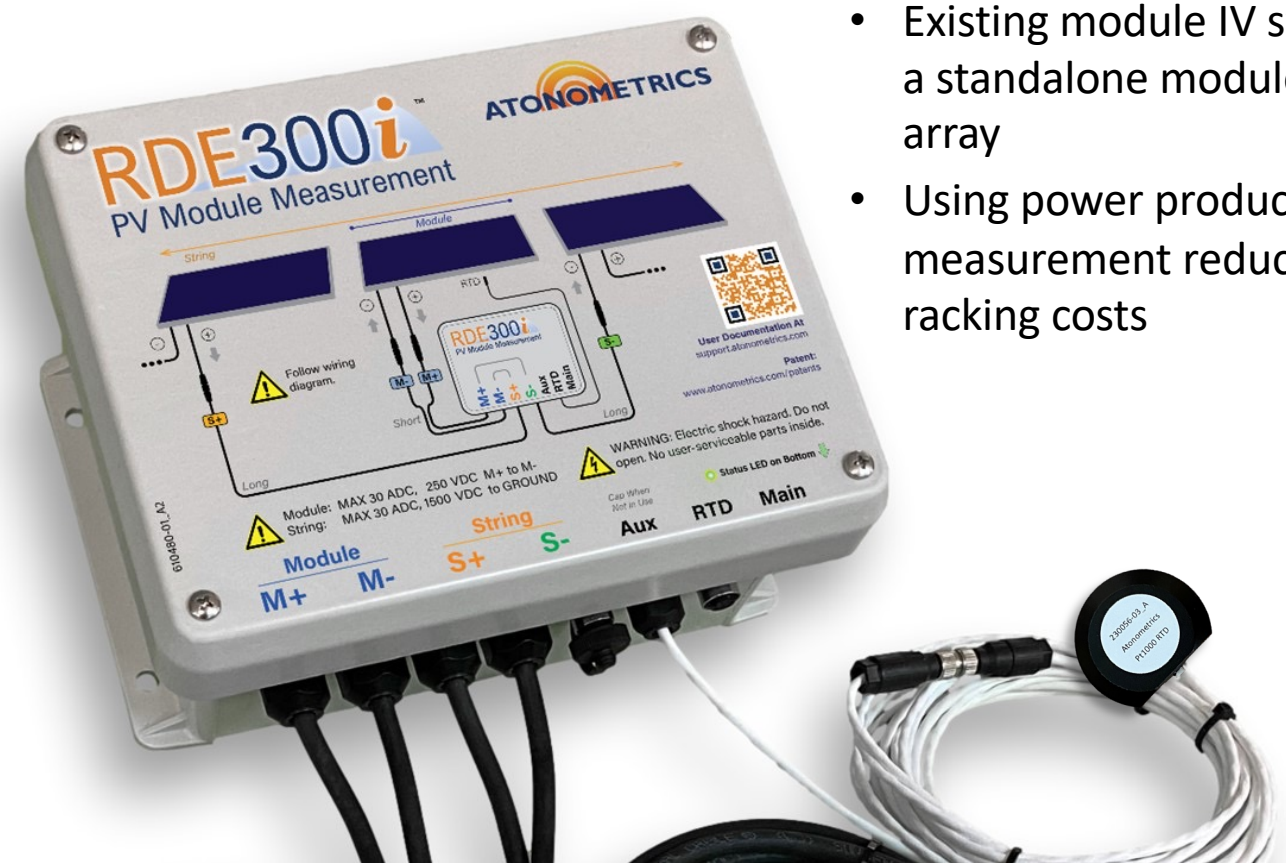
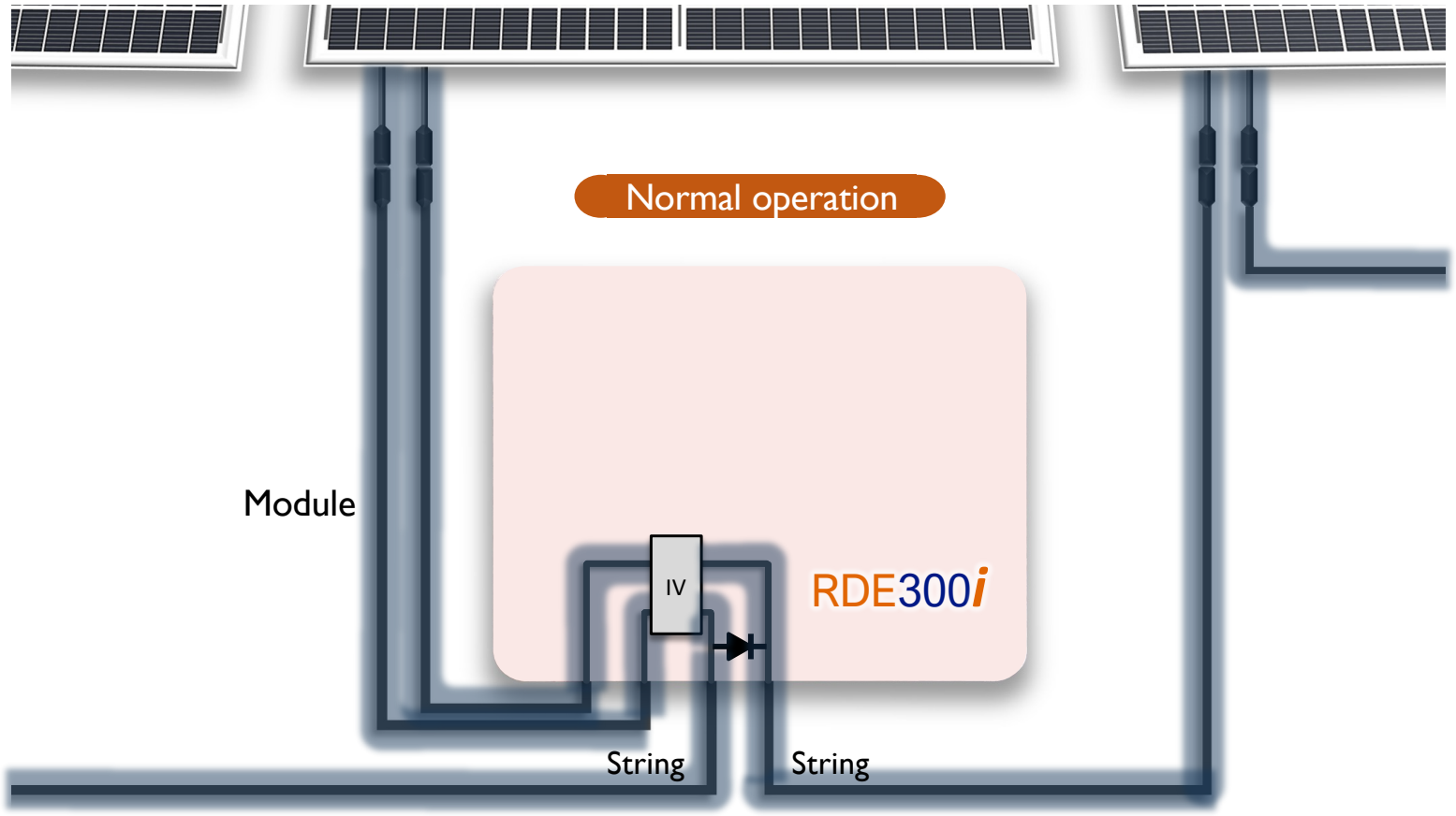
RDE300i provides in-situ IV curves for any module in an array



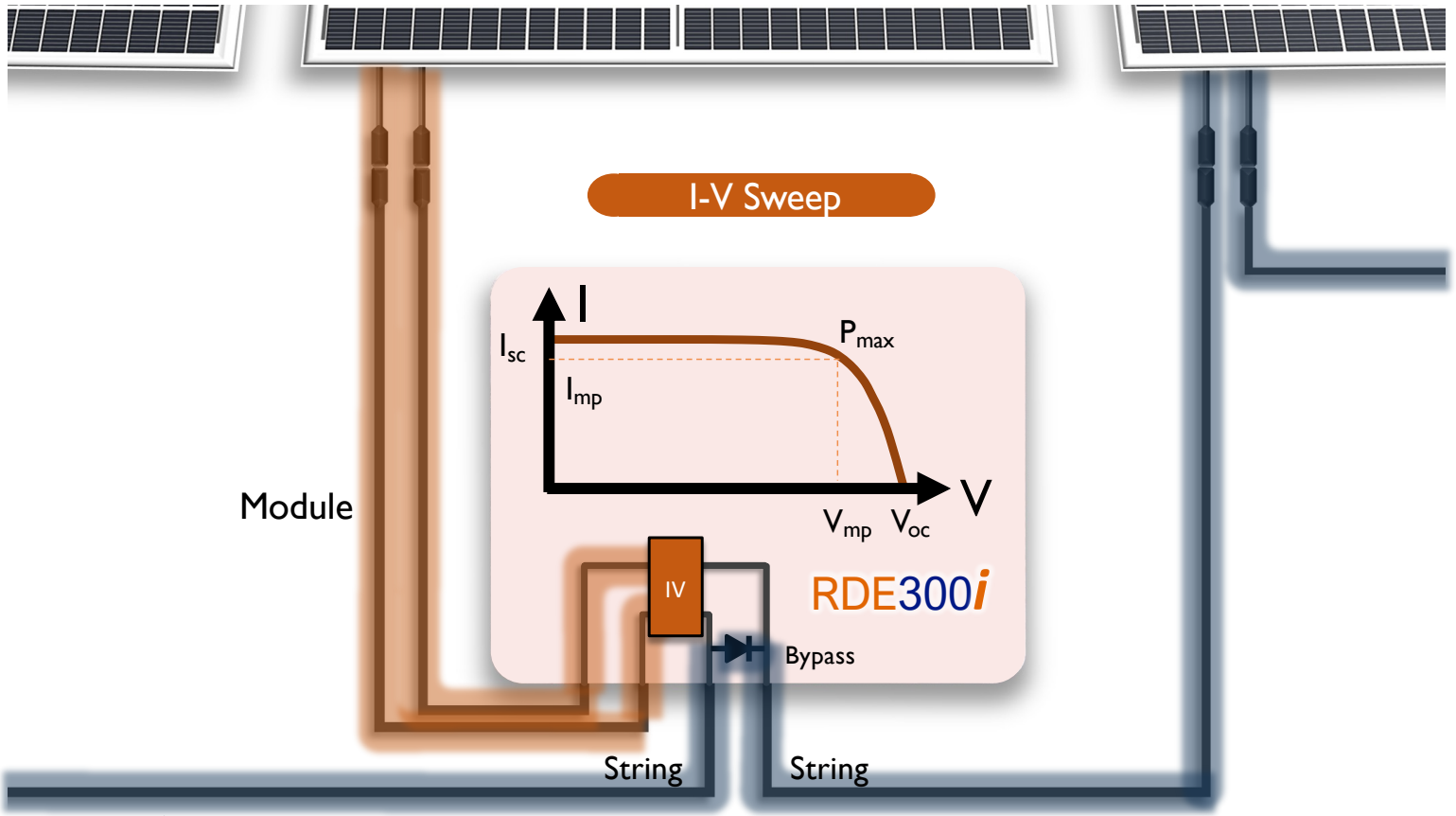
- Existing module IV sweep units require a standalone module alongside the array
- Using power producing modules for measurement reduces engineering and racking costs

Connect RDE300i between target module and array

During normal operation string current passes through RDE300i

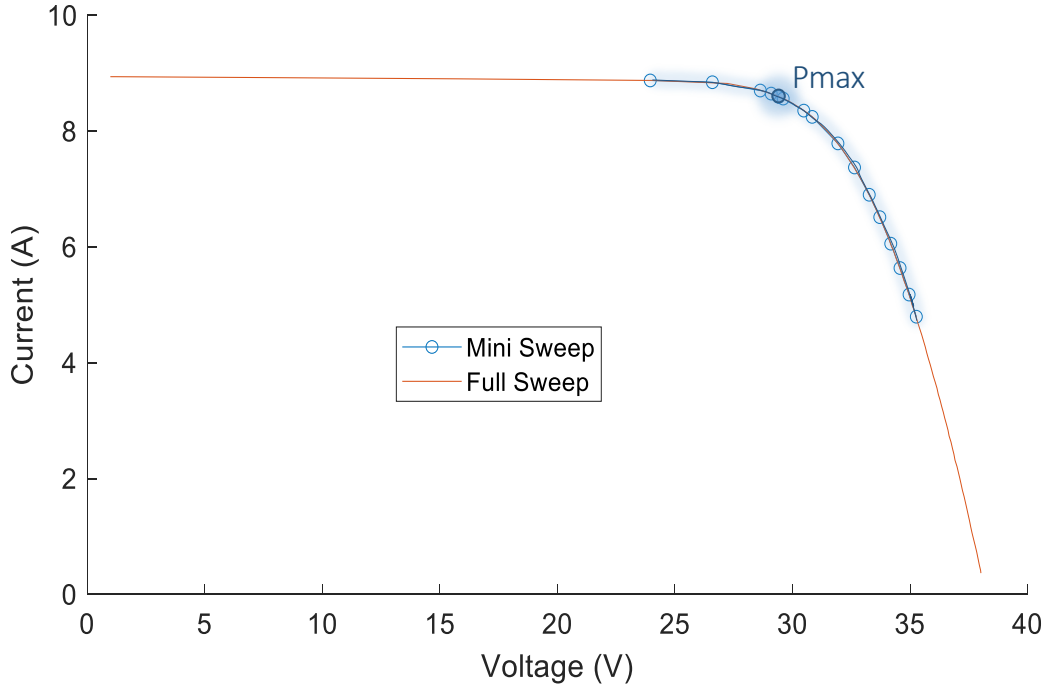


During full IV sweeps string current bypasses RDE300i



Mini-sweep mode measures Pmax without disconnecting

- Allows for more frequent measurements (10 seconds instead of 1 minute)
- Measured module continuously produces power



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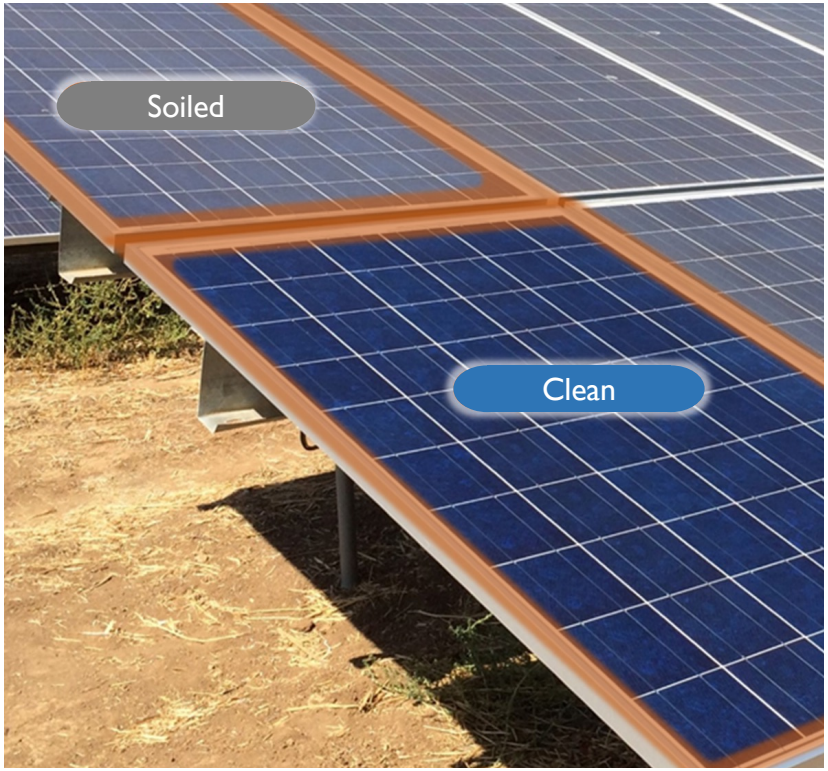
A clean and dirty module can be used to calculate soiling ratio



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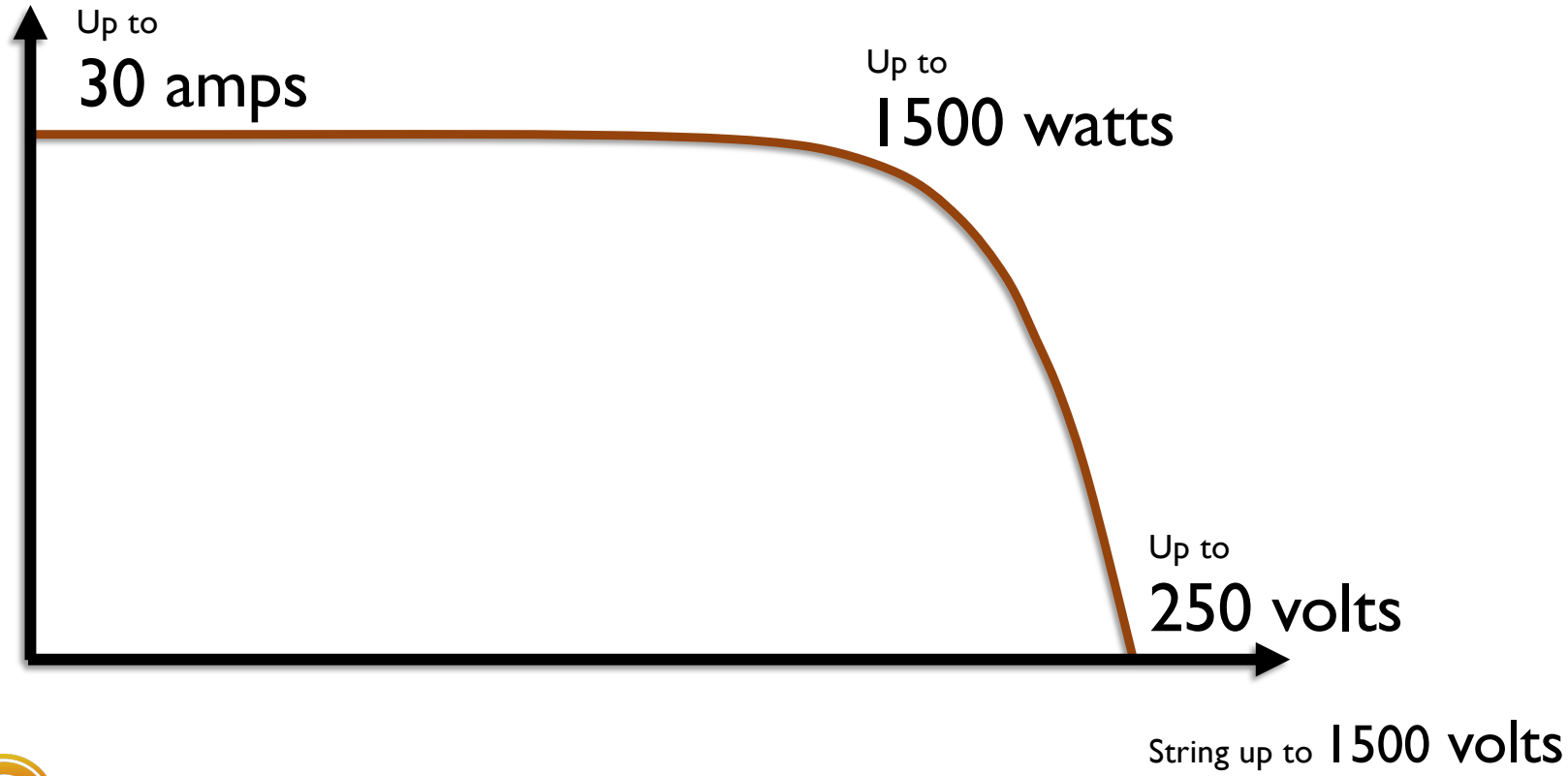
Use a reference module to get total effective bifacial irradiance

RDE300i is rated for the new generation of PV modules



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Validating RDE300i at Sandia National Labs

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Sandia provided a number of systems for testing

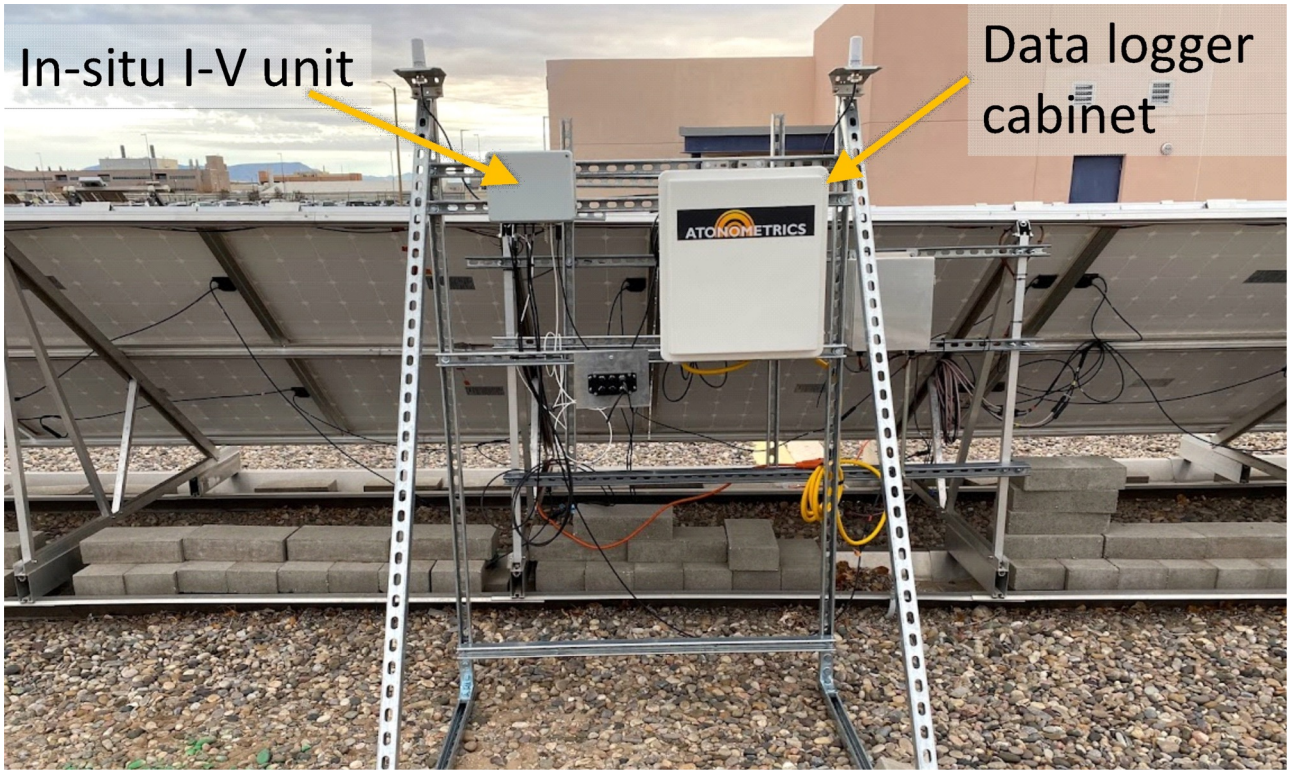
- Used 5 different arrays
  - Monofacial and bifacial silicon modules
  - Various string level inverters from different manufacturers
- Strings selected for testing have output power up to 4.8 kW

Test beds at Sandia National Laboratories Photovoltaic Systems Evaluation Laboratory (PSEL) in Albuquerque, New Mexico

Photo from Sandia National Laboratories

ATONOMETRICS

RDE300i installed on a test rack at Sandia National Labs



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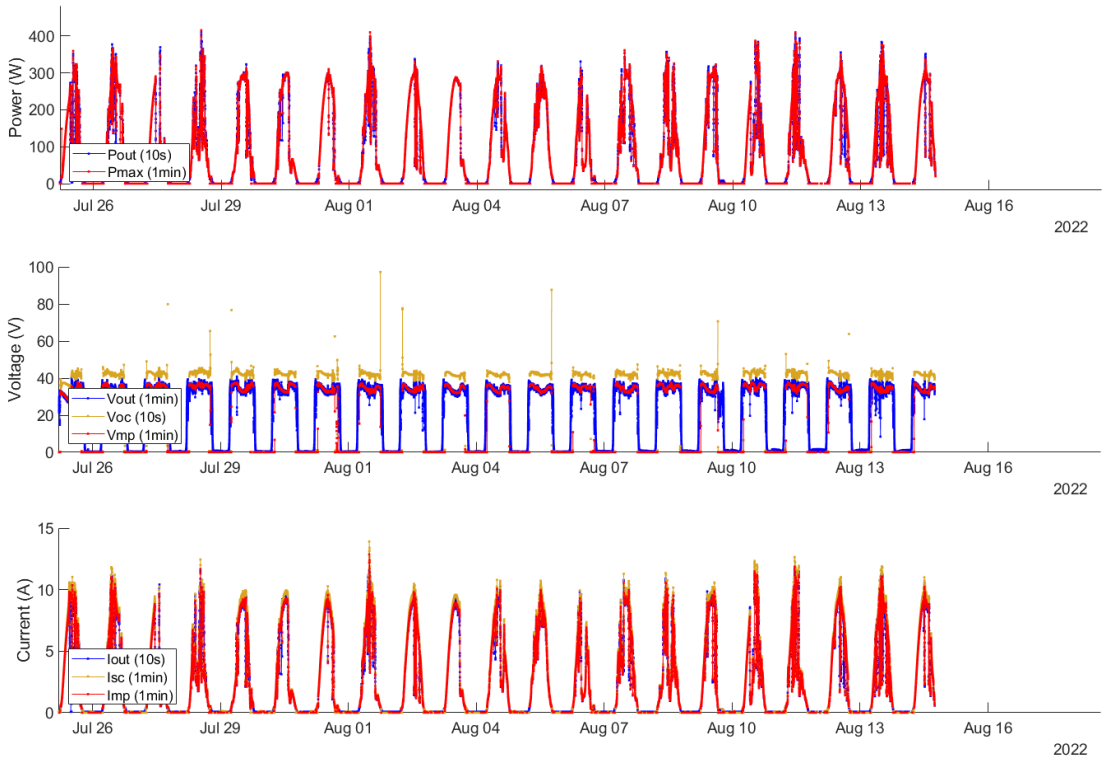
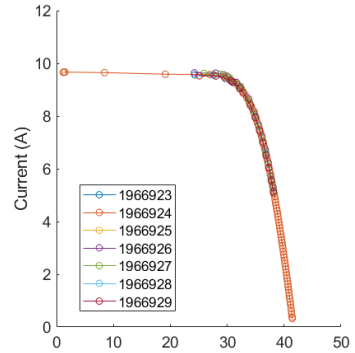
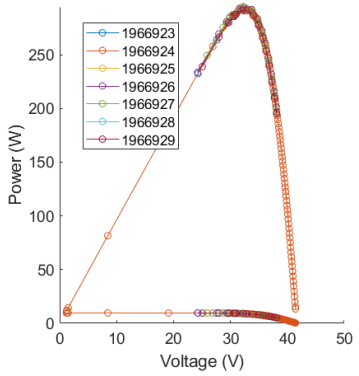
RDE300i measures Isc, Voc, Pmax, Vmp, Imp, Vout, and Iout







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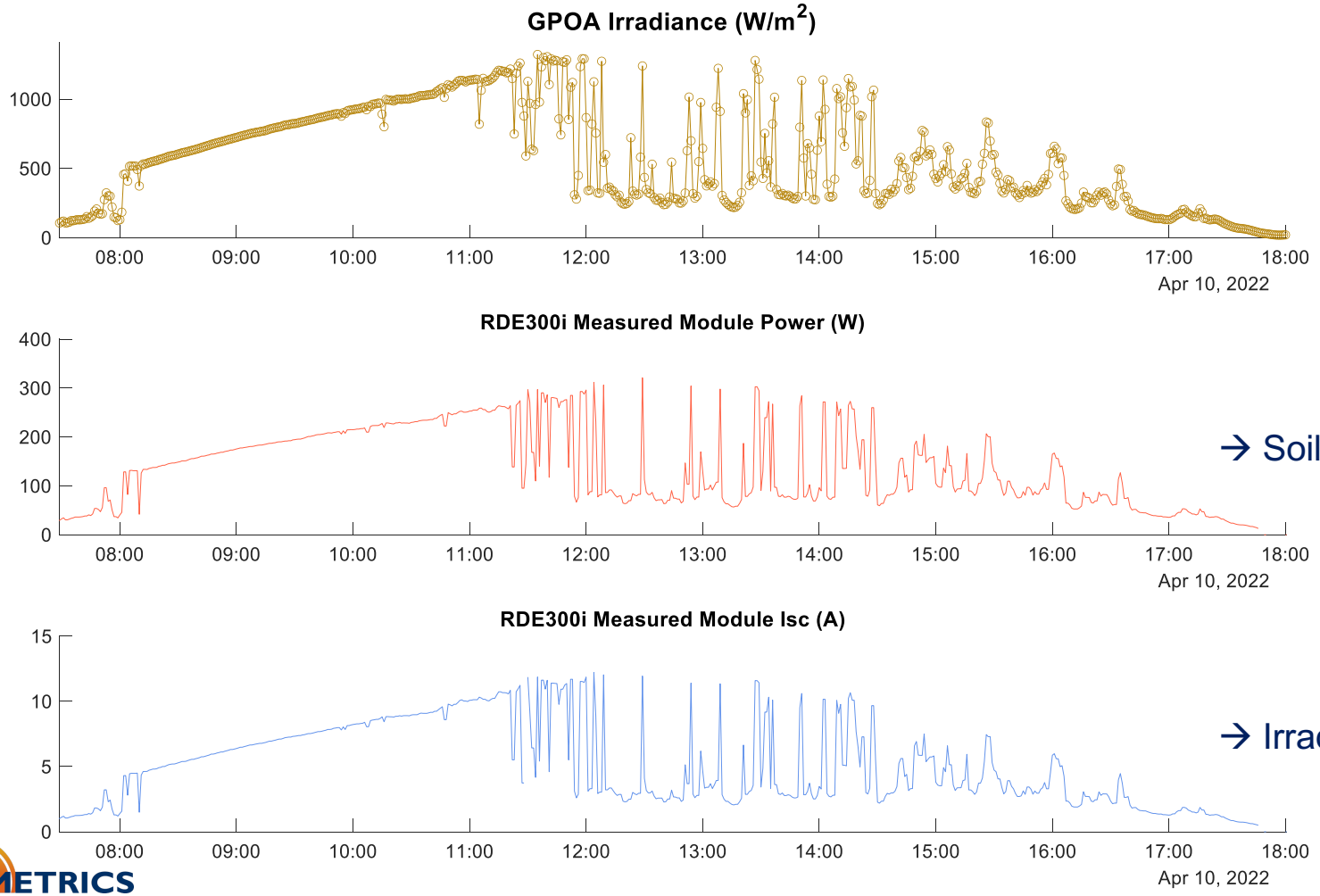

→ Soiling

→ Irradiance

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Test Protocol

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Inverter operation must not be disturbed by RDE300i

Testing goals:

- Verify RDE300i functionality
- Ensure no inverter faults
- Ensure inverter follows MPP Tracking
- Quantify any impact on inverter energy output

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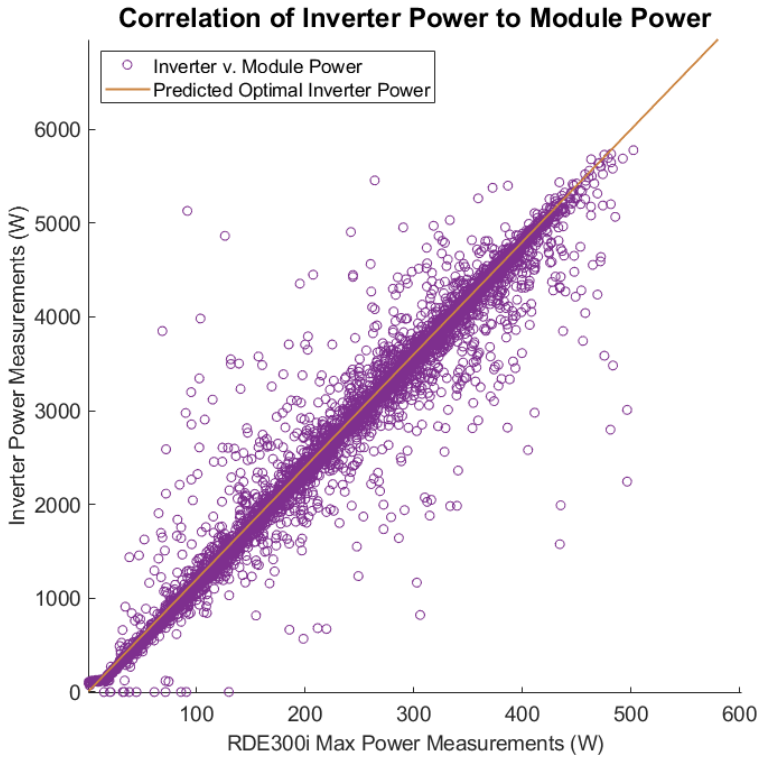
Functionality Test: ensure no inverter fault events

- Objective: Inverter functions are not interrupted
  - Data is monitored for irregularities indicating faults
  - Module power is correlated with the power measured at the inverter input
  - Quantify spikes to string Voc at the inverter
- Objective: Measured Pmax correlates with system behavior
  - The module's potential P_{max} and actual operating point are compared



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Energy Harvest Test: ensure no inverter power loss

- Compare two strings to calculate a Performance Index
  - String 1 does not have RDE300i inserted
  - String 2 has RDE300i inserted after an intial set of data is collected
- Baseline comparison included to account for differences between the strings
- We expect PI to be very close to 1

$$PI = \frac{(\sum P_2 \ / \ \sum P_1)_{after}}{(\sum P_2 \ / \ \sum P_1)_{before}}$$

RDE300i has been inserted into String 2

No RDE300i, baseline comparison

Power of String 2

Power of String 1

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Uncertainty due to fluctuations in irradiance, temperature, etc.

- Performance Index (PI) is calculated from all collected data

$$PI = \frac{(\sum P_2 \,/\, \sum P_1)_{after}}{(\sum P_2 \,/\, \sum P_1)_{before}} + \text{uncertainty}$$

- Data is separated into single days to calculate uncertainty
  - The "before" and "after" days are paired
    - Day 1, day 2, …, day k, …, day N
- A Performance Index PI_k is calculated for each day pair k
- Final uncertainty $\sigma_N = \frac{\sigma}{\sqrt{N}}$
  - σ = Standard deviation of the set of PI_ks: (PI_1, PI_2, …, PI_N)

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Data collection and filtering

- During this testing the RDE300i unit was performing mini-sweeps once every 10 seconds and full sweeps once every 60 seconds
- No filtering when searching for faults
- For calculating PI, data were filtered to exclude days with low insolation
- Inverter data provided by Sandia from dedicated inverter monitoring system
- Sandia also provided irradiance

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Results

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No excess power loss from inserting RDE300i

- No inverter faults observed in any system
- Observed power loss in line with expected power loss from series resistance and sweep duty cycle
- No adverse effect on inverter

System	Hours of Collected Data	Minutes of Inverter Fault	Performance Index
System 1	916	0	0.9984 ± 0.0017
System 2	648	0	0.9983 ± 0.0017
System 3	570	0	0.9963 ± 0.0009
System 4	1080	0	1.0026 ±0.0009
System 5	384	0	0.9945 ±0.0012

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Test results indicate RDE300i is well suited for PV plant deployment

- We developed a protocol for validating in-situ I-V tracing equipment
  - Identify any fault conditions caused by I-V sweeps
  - Quantify any power losses due to adverse impact on inverter MPP tracking
- Test results showed no faults or impact on inverter power production
- RDE300i enables efficient use of PV reference modules for system monitoring applications
  - Utilize power producing modules for measurements

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Thank you!

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