Eliminating Back-of-Module Temperature Sensors for Reference Modules Using V_{oc} Temperature Measurement

2018 PV Systems Symposium's
10th PVPMC Workshop

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Objective

Problem

- **Reference modules** used for soiling & irradiance measurement
- Module **temperature** needed
- Back-of-module temperature sensors **inconvenient**, add **cost $**

Solution

- Determine module temperature from **Voc**
- Use **equivalent cell temperature** method, modified from IEC 60904-5
- Use I-V sweeps in **soiling & irradiance** monitoring system
- **Lowers system cost**

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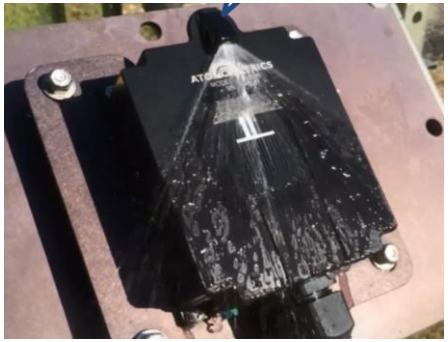
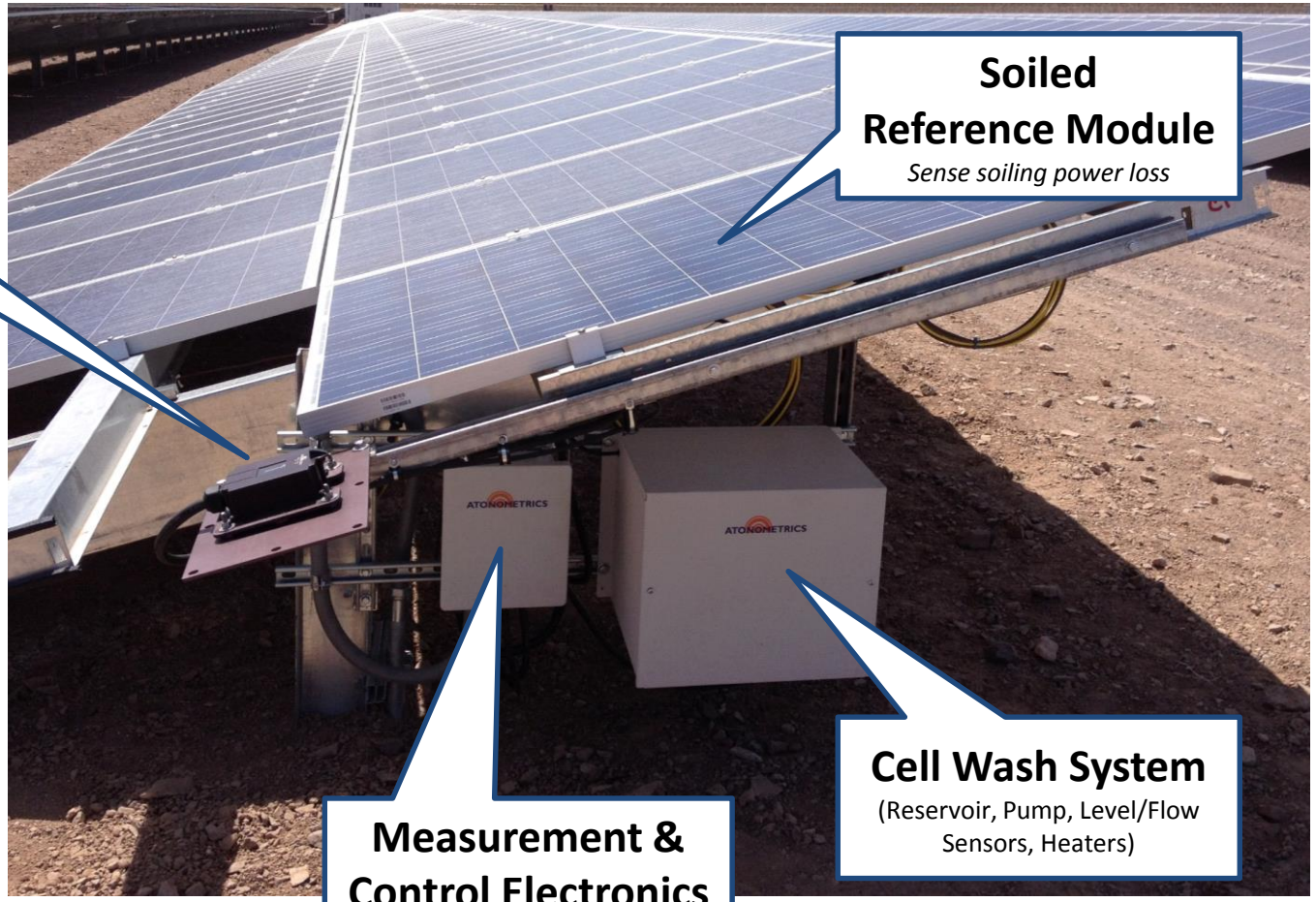
Soiling System with Reference Module

Clean Reference Cell
Measure irradiance

Daily Automatic Washing





Soiled Reference Module
Sense soiling power loss

Measurement & Control Electronics
(Module IV Sweep, Cell Irradiance Measurement, Data Analysis, Wash Control)

Cell Wash System
(Reservoir, Pump, Level/Flow Sensors, Heaters)

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Back of Module Temperature Sensor

SolarPro, May/June 2015

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Atonometrics Voc Temperature Method

Modified Equations Based on IEC 60904-5 (2011):**

$$T = 25\,^{\circ}\mathrm{C} + \frac{1}{\beta}\left[\frac{V_{oc}}{V_{oc,STC}} - 1 - a \cdot ln\left(\frac{I_{sc}}{I_{sc,STC}}\right)\right]$$

$$a = \frac{\frac{V_{oc,NOCT}}{V_{oc,STC}} - 1 - \beta \cdot (T_{NOCT} - 25\,^{\circ}\mathrm{C})}{ln\left(I_{sc,NOCT}/I_{sc,STC}\right)}$$

Equations modified to use **module datasheet parameters for two known irradiance/temperature combinations, **STC** & **NOCT**:

β (V_{oc} temp co.), $V_{oc,STC}$, $I_{sc,STC}$, $V_{oc,NOCT}$, $I_{sc,NOCT}$

Assumes datasheet parameters are accurate.
But can also be field-calibrated by customers / users.

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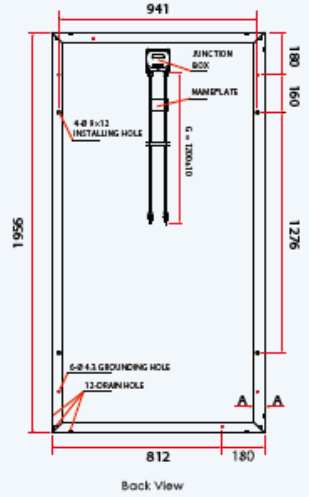
Datasheet

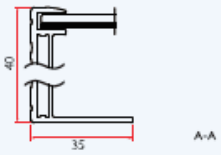
THE Utility MODULE TSM-PD14

DIMENSIONS OF PV MODULE

unit:mm

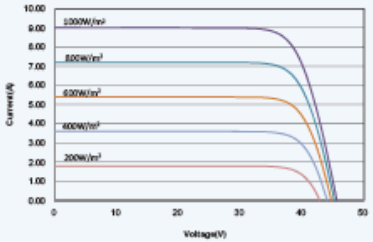


Back View



A-A

I-V CURVES OF PV MODULE(315W)



ELECTRICAL DATA (STC)

Peak Power Watts-P_{MAX} (Wp)	300	305	310	315
Power Output Tolerance-P_{MAX} (%)	0 ~ +3			
Maximum Power Voltage-V_{MPP} (V)	36.2	36.6	37.0	37.1
Maximum Power Current-I_{MPP} (A)	8.28	8.33	8.38	8.51
Open Circuit Voltage-V_{OC} (V)	45.4	45.5	45.5	45.6
Short Circuit Current-I_{SC} (A)	8.77	8.81	8.85	9.00
Module Efficiency η_m (%)	15.5	15.7	16.0	16.2

STC: Irradiance 1000 W/m², Cell Temperature 25°C, Air Mass AM1.5 according to EN 60904-3.
Typical efficiency reduction of 4.5% at 200 W/m² according to EN 60904-1.

ELECTRICAL DATA (NOCT)

Maximum Power-P_{MAX} (Wp)	223	227	231	235
Maximum Power Voltage-V_{MPP} (V)	33.5	33.8	34.1	34.1
Maximum Power Current-I_{MPP} (A)	6.66	6.72	6.77	6.88
Open Circuit Voltage-V_{OC} (V)	42.1	42.2	42.2	42.3
Short Circuit Current-I_{SC} (A)	7.08	7.11	7.15	7.27

NOCT: Irradiance at 800 W/m², Ambient Temperature 20°C, Wind Speed 1 m/s.

MECHANICAL DATA

Solar cells	Multicrystalline 156 × 156 mm (6 inches)
Cell orientation	72 cells (6 × 12)
Module dimensions	1956 × 992 × 40 mm(77× 39.05 × 1.57 inches)
Weight	27.6 kg (60.8lb)
Glass	4.0 mm,High Transmission, AR Coated Tempered Glass
Backsheet	White
Frame	Silver Anodized Aluminium Alloy
J-Box	IP 65 or IP 67 rated
Cables	Photovoltaic Technology cable 4.0mm² (0.006 inches²), 1200mm (47.2 inches)
Connector	MC4 or MC4 Compatible

TEMPERATURE RATINGS

Nominal Operating Cell Temperature (NOCT)	44°C (±2°C)
Temperature Coefficient of P_{MAX}	- 0.41%/°C
Temperature Coefficient of V_{OC}	- 0.32%/°C
Temperature Coefficient of I_{SC}	0.05%/°C

MAXIMUM RATINGS

Operational Temperature	-40~+85°C
Maximum System Voltage	1000VDC (IEC) 1000VDC(UL)
Max Series Fuse Rating	15A

WARRANTY

10 year Product Workmanship Warranty

25 year Linear Power Warranty

(Please refer to product warranty for details)

TSM_EN_Mar_2015_A

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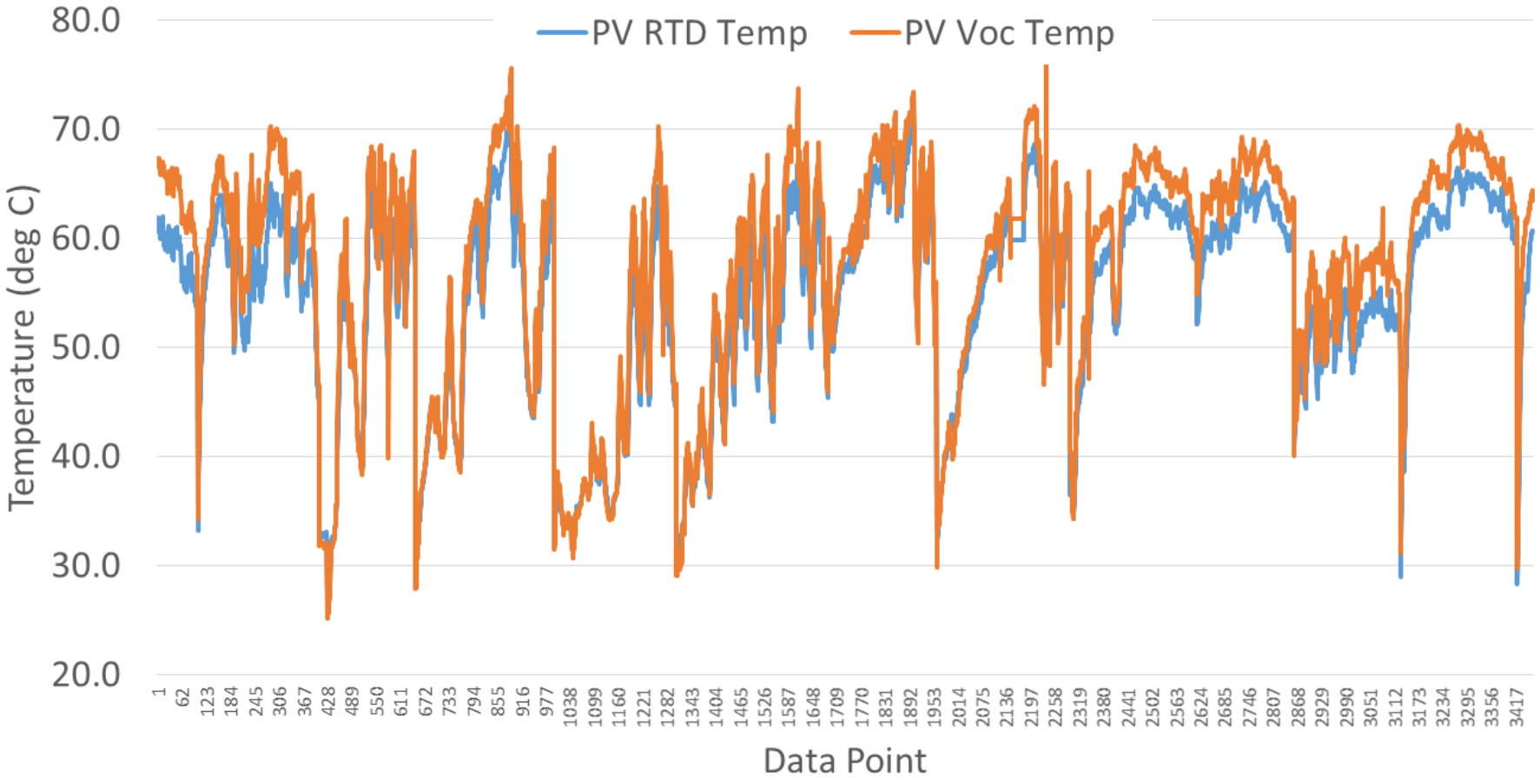
Example Results



Data filtered to irradiance >100 W/m^2

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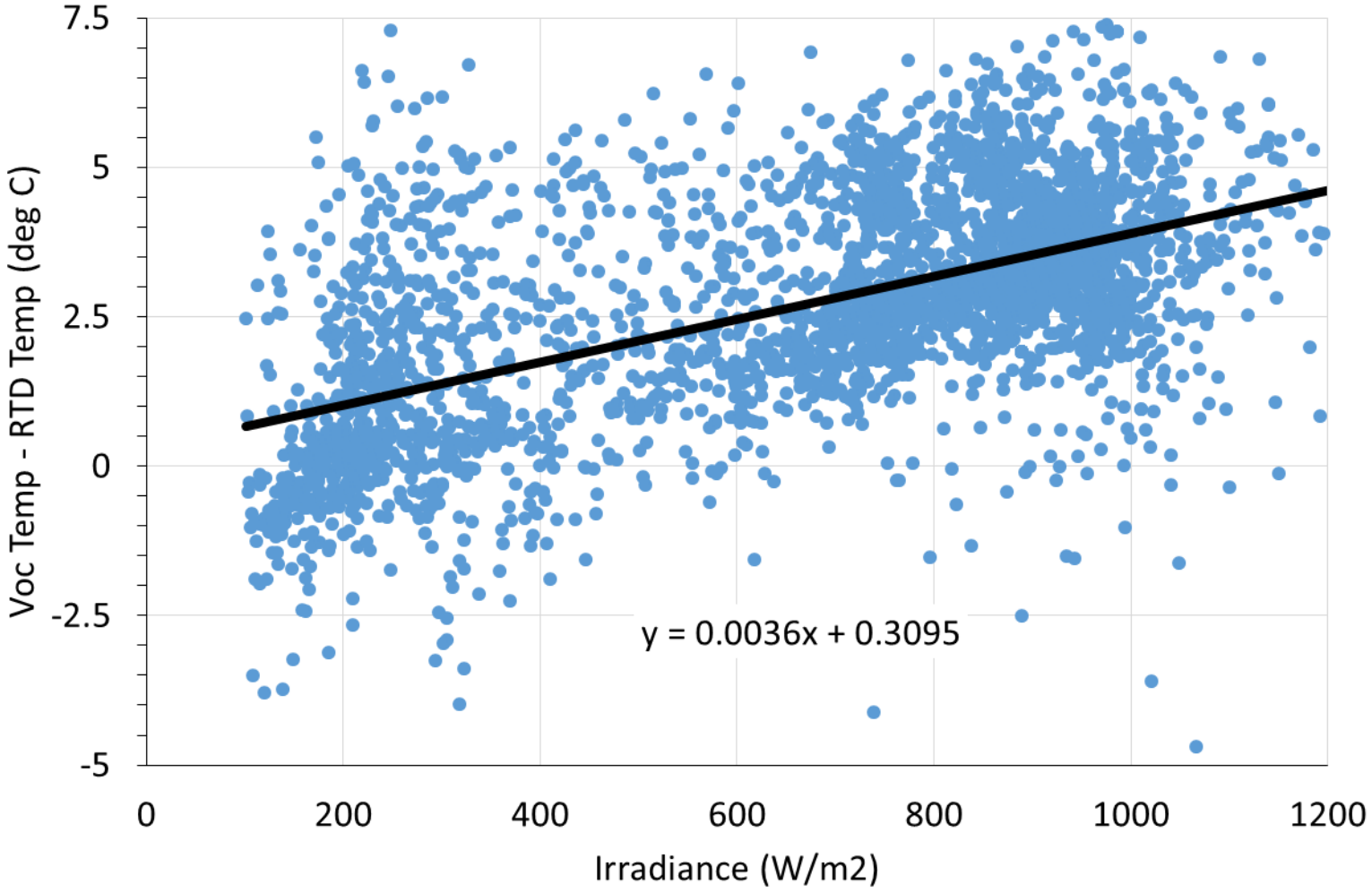
Temperature Difference vs. Irradiance



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Reasons for Temperature Differences

- Accuracy of datasheet values
- Irradiance
  - Cell is hotter than back surface
- Wind speed
  - Cell is hotter than back surface
- Temperature non-uniformity
  - Back surface RTD measures one point only
- RTD thermal mass
  - RTD temperature changes more slowly than cell temp. RTD can be higher/lower depending on cloud movement.

Conclusions

- Voc temperature method can be used to eliminate module temperature sensors
- Atonometrics formulation uses datasheet values
- Advantageous for reference modules:
  - More convenient
  - Lower cost
- Potentially more accurate
  - Irradiance, wind, time lag, and temperature non-uniformities all contribute to back-surface RTD error
- May require an in-field calibration procedure to fine-tune datasheet values

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