Quantify degradation rates and mechanisms of PV modules and systems installed in Florida through comprehensive experimental and theoretical analysis

FSEC

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Nicoleta Sorloaica-Hickman, Kris Davis, Florida Solar Energy Center - UCF
Sarah Kurtz, Dirk Jordan, National Renewable Energy Laboratory

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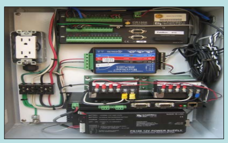
Introduction

The economic viability of photovoltaic (PV) technologies is inextricably tied to both the electrical performance and degradation rate of the PV systems, which are the generators of electrical power in PV systems.

Over the past 15 years, performance data has been collected on numerous PV systems installed throughout the state of Florida. The following parameters are recorded using various data monitoring instruments:

- **Array current and voltage (DC) - electrical power produced directly from incident sunlight by electrically connected modules**
- **Inverter power (AC) – power converted to AC by inverter and sent to home, building, or utility grid**
- **Plane-of-Array irradiance – amount of light (flux) incident on array**
- **Module temperature – measured from the back of modules**



Photovoltaic Systems Characteristics

PV System	Location	Size (W)	Technology	Inverter	Years	Azimuth and Tilt
MMS	Florida	3960	multi crystalline Si	2500U	5	180 ° South; 25 °
KMS	Florida	1680	mono crystalline Si	2500U	5	180 ° South ; 17°
DW	Florida	2840	amorphous Si	2500U	5	180 ° South ; 17°

Research strategy

Field Experience
Performance and metrological tests (5 or more years)

⇩

Real Time measurements
Performance and metrological tests, visual inspection, IR pictures

⇩

Life time Prediction

REFERENCES

1. Dunlop, Photovoltaic Systems, 2007
2. Marion et al, "Performance Parameters for Grid-connected Photovoltaic Systems", 31st IEEE Photovoltaic Specialist Conference, 2005
*3. Ruther, Livingston, "Seasonal variations in amorphous silicon solar module outputs and thin film characteristics", Solar Energy Materials and Solar Cells, **36**, 29, 1994*

PVUSA power rating analysis (AC, DC)

$$P = I_{POA}(a + bI_{POA} + CT_{amb} + dW)$$

Collect $T_{Ambient}$, Irradiance, DC and AC Power on all PV Systems data one-month blocks of 15-minute intervals

↓

500 W/m² < Irradiance < 1200 W/m²
-10 °C < T_a < 60°C
P_{AC} > (75% of the P_{STC}) *Irradiance

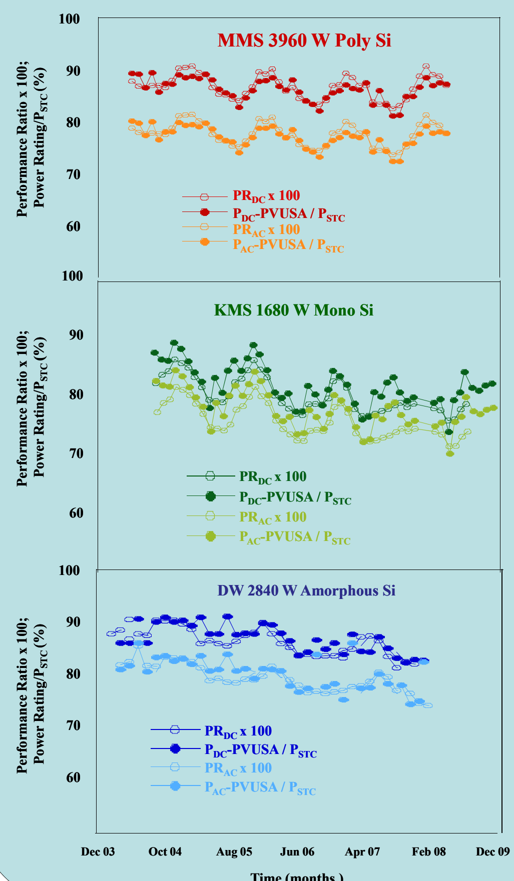
→ **Ignore Data**

↓

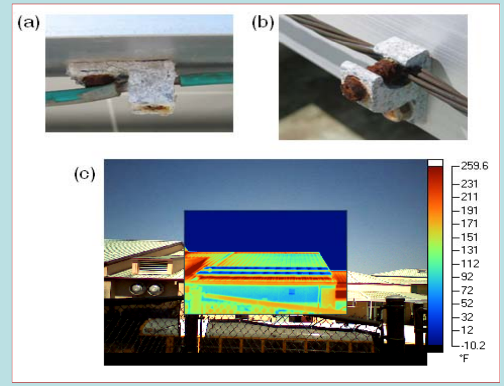
Calculate the regression coefficients and the Power Rate (W) at Illumination of 1000 W/m² and temperature of 20°C

Performance ratio analysis

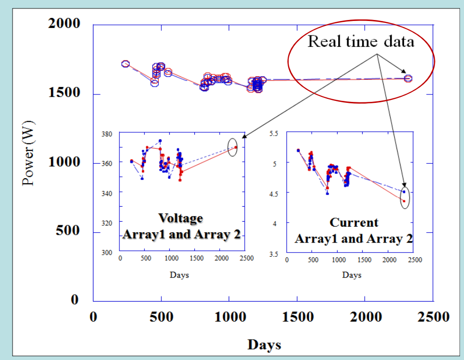
$$Y_f\left(\frac{kWh}{kW}\right) = \frac{E_{out}(kWh)}{P_{STC}(kW)}; \quad Y_r(hours) = \frac{H_{POA}(kWhm^{-2})}{G_{STC}(kWm^{-2})}; \quad PR = \frac{Y_f}{Y_r};$$



MMS 3960 W PV System Real time Measurements (2010) and inspections



(a) and (b) corroded grounding lungs; (c) zoomed out IR image



Conclusions

System	Array Degradation (DC) / year		Estimated DC Energy Production (20 years)	Array Degradation (AC) / year		Estimated AC Energy Production (20 Years)	PVUSA Uncertainty: PVUSA AC (500 – 1200 W/m²)	PVUSA DC (500 – 1200 W/m²)	PVUSA AC (800 – 1200 W/m²)	PVUSA DC (800 – 1200 W/m²)
	PR	PVUSA		PR	PVUSA					
DW	-0.57%	-0.48%	449.42 kWh	-0.68%	-0.69%	409.80 kWh	±100.36 W	±152.61 W	±180.96 W	±229.71 W
KMS	-1.14%	-1.26%	272.91 kWh	-1.16%	-1.13%	262.00 kWh	±67.240 W	±68.971 W	±63.510 W	±65.802 W
MMS	-0.33%	-0.75%	626.74 kWh	-0.40%	-0.82%	505.74 kWh	±142.19 W	±161.00 W	±139.77 W	±159.96 W

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