Comparative Study of the Long-Term Performance and Reliability of three different Photovoltaic Systems installed in Florida

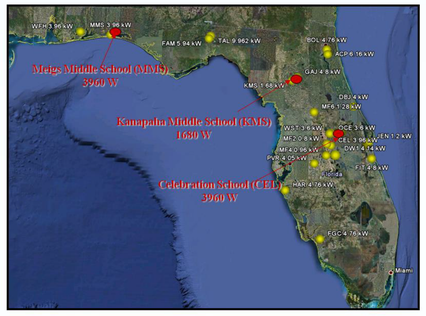
FSEC

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

NREL

Introduction

Accurate and consistent evaluations of photovoltaic (PV) system performance are critical for the continuing development of the PV industry. Scientists from NREL and FSEC developed a strong collaboration in order to improve the operation, sizing, electrical and economical output of photovoltaic power systems and subsystems by analyzing and disseminating information on their performance and reliability, providing a basis for their assessment, and developing practical recommendations. The collaborative project between NREL and FSEC is focusing on utilizing FSEC's existing PV system database to establish degradation rates of the PV modules and validate the energy rating models.



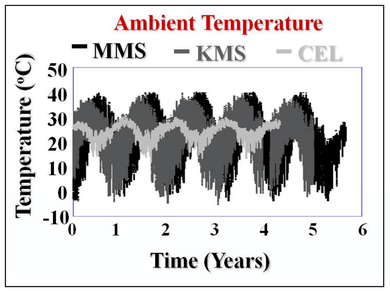
Measurement Selection

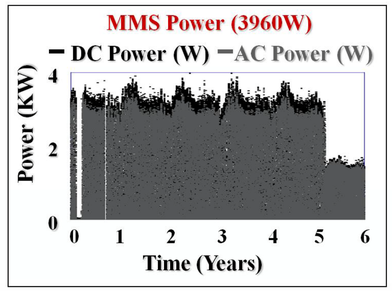
Channel	Description	Low Limit	High Limit
5	Battery Avg DC Voltage, volts	11.80	14.50
6	DAS Internal Temperature, °C	-10.00	50.00
7	Reference Temperature, °C	-10.00	50.00
8	Ambient Temperature, °C	-10.00	40.00
9	PV Array Temperature, °C	-10.00	80.00
10	POA Solar Irradiance, W/m²	-5.00	1300
11	Inverter #1 Avg AC Power, W	0.00	10000
12	Inverter #2 Avg AC Power, W	0.00	10000
13	PV Array #1 DC Current (A)	-10.00	10.00
14	PV Array #2 DC Current (A)	-10.00	10.00
15	PV Array #1 DC Voltage (V)	-600.00	600.00
16	PV Array #2 DC Voltage (V)	-600.00	600.00

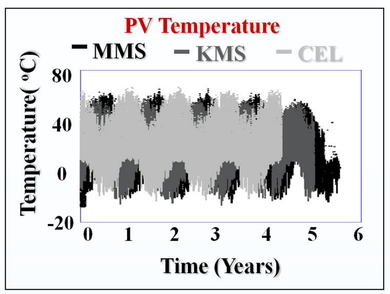
CR10 Datalogger for all PV systems with:
- Type-T Thermocouple wire
- Licor LI200 pyranometer
- Empro current shunt - DC current
- Voltage divider- DC Voltage
- IMS meter with pulse output - AC Power

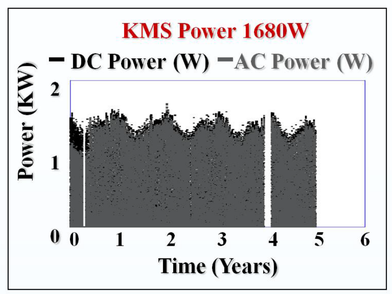
Photovoltaic Systems Characteristics

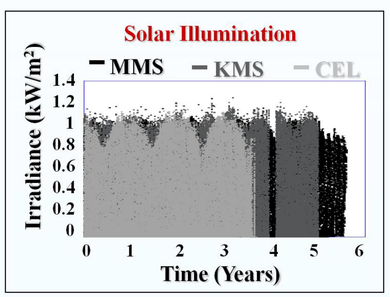
PV System	Location	Size (W)	Technology	Install Date	PV Manufacture	Inverter	Years	Azimuth and Tilt
MMS	Florida	3960	multi Si	2/5/03	Sharp NEQ5E2U	SMA-2500U	6	180° South; 25°
KMS	Florida	1680	mono Si	1/15/04	Shell solar SP 140	SMA-2500U	5	180° South ; 17°
CEL	Florida	3960	multi Si	12/8/03	Sharp NEQ5E2U	SMA-2500U	4	225°West of South ; 15°

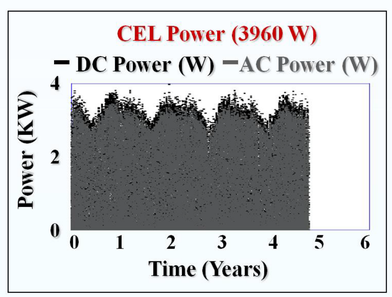












PVUSA power rating analysis (AC, DC)

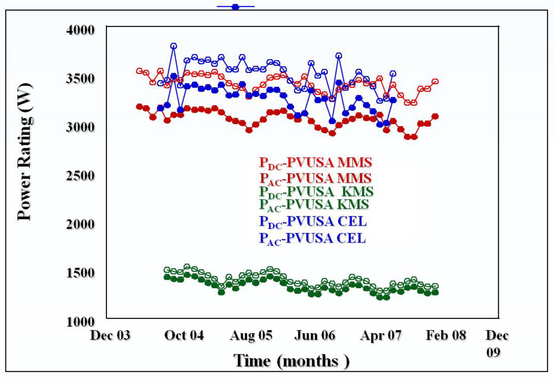
$$P = I_{POA}(a + bI_{POA} + CT_{amb} + dW)$$

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

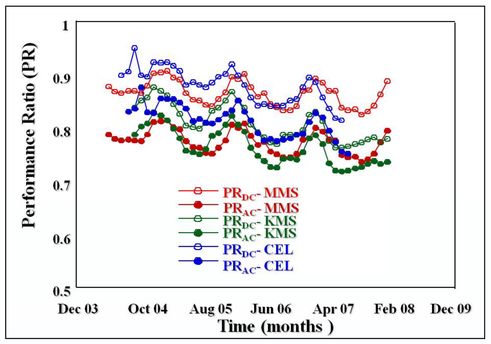
Ignore Data

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



Performance ratio analysis

The performance ratio is defined as the relationship between the actual returns and theoretically potential energy returns of a Photovoltaic system. The performance ratio is an appropriate valuation criterion for determining the quality of the solar system.

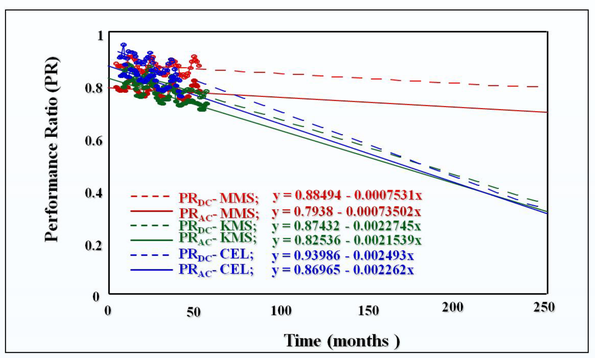


$$Y_f(\frac{kWh}{kW}) = \frac{E_{out}(kWh)}{P_{STC}(kW)};$$

$$Y_r(hours) = \frac{H_{POA}(kWhm^{-2})}{G_{STC}(kWm^{-2})};$$

$$PR = \frac{Y_f}{Y_r};$$

Linear Fit of Performance Ratio

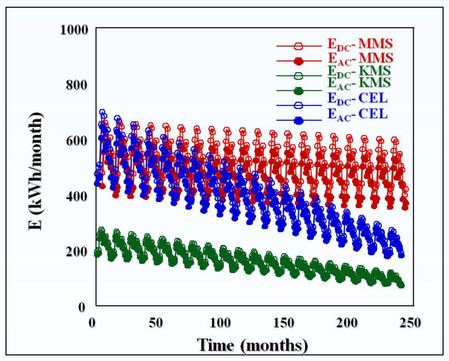


1. D. Myers, *"Evaluation of the performance of the PVUSA rating methodology applied to dual-junction PV technology"*, NREL Conference Paper 550-45376, (2009)
2. B. Marion et al., *"Performance parameters for grid-connected PV systems"*, Proc. 31st IEEE Photovoltaic Specialist Conference and Exhibition, Orlando, (2005)
3. K. Lynn, J. Szaro, W. Wilson, M. Healey, *"A review of PV system performance and life-cycle cost for the SunSmart school program"*, Proceedings of the ASME International Solar Energy Conference 2006, Denver, (2006)

Estimating Energy Output

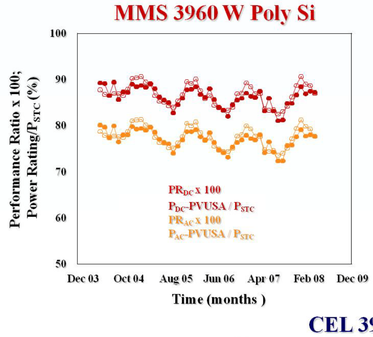
$$E(\frac{kWh}{month}) = H(\frac{KWhm^{-2}}{day})N(\frac{days}{month})P_{STC}\,PR$$

The energy output of each systems has been modeled using a straightforward technique that utilized the PR values and degradation rates established from the experimental results. Equivalent levels of incident solar irradiation are assumed for all three arrays to allow for a fair comparison

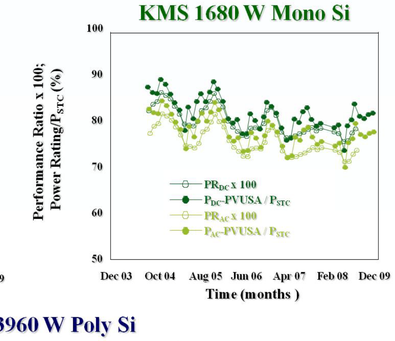


Comparison

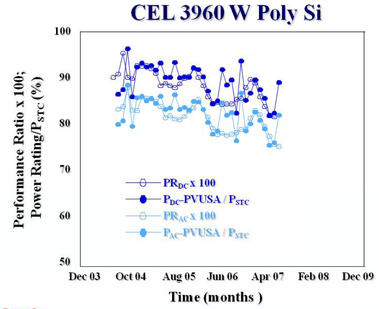
MMS 3960 W Poly Si



KMS 1680 W Mono Si



CEL 3960 W Poly Si



Conclusion

- The analysis of data of the three PV systems from the FSEC database led to increased understanding of the performance and degradation rates - expressed in terms of performance ratio and power rate.
- There is a typical winter power increase for all three systems when using both methods
- Season variation was found to be about 9 % (PR method) and 8 % (PVUSA method)

System	PR Array Degradation (DC)/ year		Total Estimated DC Energy Production 20 Years	PR Array Degradation (AC)/year		Total Estimated DC Energy Production 20 Years	Total DC/ Total AC
	PR	PVUSA		PR	PVUSA		
MMS	-0.49%	-0.89%	126,836 kWh	-0.57%	-0.97%	112,922 kWh	89 %
KMS	-2.34%	-2.54%	39,563 kWh	-2.38%	-2.61%	37,135 kWh	94 %
CEL	-2.28%	-2.28%	97,537 kWh	-2.35%	-2.26%	90,682 kWh	93 %

Acknowledgements

- NREL for funding this project
- Kevin Lynn, William Wilson, Steve Barkaszi, and all our colleagues from the Solar Energy Division at FSEC involved in systems installing and data collections.