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Performance Evaluation of a 1.5-kW a-Si PV Array Using the PVUSA Power Rating Method at NREL's Outdoor Test Facility

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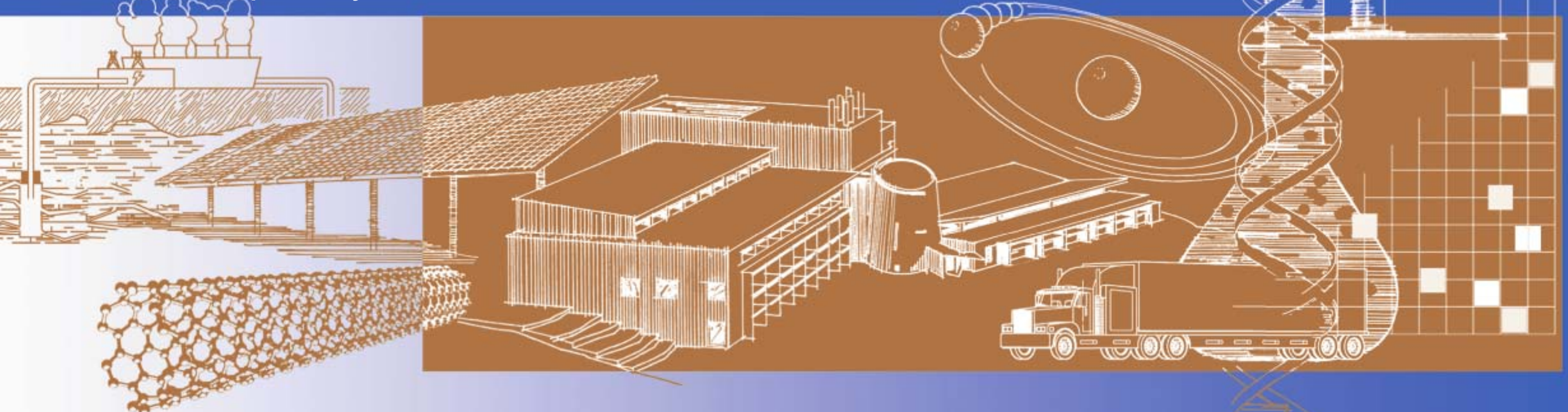

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ABSTRACT

As part of the work conducted in the PV Systems Reliability & Performance R&D Task, a 1.5-kW_{dc} photovoltaic (PV) array consisting of 36 Solarex MST-43MV dual-junction a-Si modules was installed and its performance monitored for almost six years (September 1999 through May 2005) at the National Renewable Energy Laboratory (NREL) Outdoor Test Facility (OTF). This paper describes the system and its performance based on the PV for Utility-Scale Applications (PVUSA) power rating method.

1. Objectives

NREL's OTF has the capability to do long-term performance testing of PV modules and arrays under real-world conditions. As part of the work conducted in the PV Systems Reliability and Performance R&D Task, a 1.5-kW_{dc} photovoltaic (PV) array of Solarex MST-43MV dual-junction a-Si modules was installed and its performance monitored for almost six years (September 1999 through May 2005) at the OTF (Fig. 1). This paper describes the system and its performance based on the PVUSA power rating method.

Fig. 1. 1.5-kW Solarex OTF Roof array.

2. Technical Approach

The PV array consisted of 36 Solarex MST-43MV modules. These were glass-on-glass modules with full frames. The array was held at its maximum power point, P_{mp}, using a grid-tied Omnion Series 2400 2.2-kW inverter. The inverter accepted a positive and negative input from the array. The dc rating (at STC) of each module was 43 W_p. The rating of the positive and negative sub-arrays was 774 W_p for a total array rating of 1548 W_p. Each sub-array consisted of nine parallel strings of two series-connected modules. The array was rack-mounted on the roof of the OTF facing south at a 40˚ latitude tilt. PV system data were collected using 15-minute averages using a Campbell Scientific data acquisition system (DAS). Measured parameters included dc voltages, dc currents, ac voltage, ac current, ac power, array temperatures and ambient temperature. Wind speed was collected in one-minute averages from the Reference Meteorological and Irradiance System in the OTF array field, just east of the building. The DAS was calibrated annually.

The PVUSA rating method calculates expected power from a PV system by normalizing to PVUSA test conditions (PTC), where PTC are defined as 1000 W/m^2 POA irradiance, 20°C ambient temperature and 1 m/s wind speed.[1] One-month blocks of 15-minute average observations are used to calculate a best-fit correlation to the following equation:

$$P_{dc} = I_{POA} (a + bI_{POA} + cT_{amb} + dW) \qquad (1)$$

where P_{dc} = power, kW
I_{POA} = POA irradiance, W/m^2
T_{amb} = ambient temperature, °C
W = wind speed, m/s
a, b, c, d = regression coefficients derived from operational data.

The four coefficients, a, b, c and d, are then used to predict the system power at PTC conditions.

LabVIEW programs were used to combine the Solarex array data with the RMIS wind speed data and to perform the linear regression. LabVIEW's general linear fit function was used to determine the set of linear coefficients using the least chi-square method. Monthly power ratings were then plotted to show the system performance versus time.

3. Results and Accomplishments

Results of the PVUSA power rating analysis indicate that the Solarex array experienced a 7.3% degradation in power during its initial year of operation (September 1999 – August 2000), followed by an oscillating power output that increased during the summer and decreased during the winter (Fig. 2). The data were filtered based on the irradiance being greater than 800 W/m^2 and the array dc power being greater than 1100 W. Following the one-year "stabilization" period, a linear fit for the almost 5-year period (August 2000 - May 2005) indicates that the array dc power rating decreased by 23.2 W (1.7%) per year.

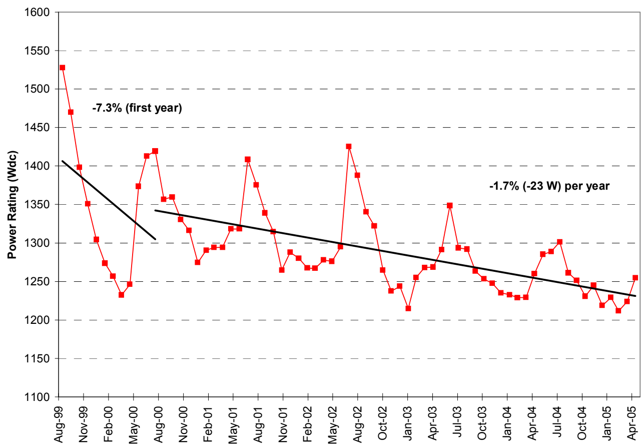

Fig. 2. Solarex OTF Roof system - PVUSA dc power rating versus time (Irr > 800 W/m^2 and P_{dc} > 1100 W).

This behavior is typical of a-Si modules. In a paper summarizing performance characterization of a-Si modules from several manufacturers, researchers at Sandia National Laboratories found that previously unexposed a-Si modules showed an initial rapid degradation in power over the first six months and reached a "stabilized" power level, about 20% below the initial (1st day) power, after about one year. Seasonal oscillation is usually ±4% from the "stabilized" level.[2] The output from a-Si arrays typically varies seasonally: operating a-Si modules at elevated temperatures, such as during hot summers months, can cause self annealing, partially reversing light-induced degradation.

Following August 2000, the mean-power rating for the Solarex system was 1285 W with a maximum power rating of 1425 W in July 2002 and a minimum power rating of 1215 W in March 2005. These equate to oscillations of +10.9% and -5.5% from the mean-power rating.

4. Conclusions

Ultimately, data gathering ended and this system was dismantled because BP Solarex stopped producing thin-film modules in November 2003. By the end of the test period, the back glass on six of the modules had cracked. Following the one-year "stabilization" period, a linear fit for almost a 5-year period indicates that the array dc power rating decreased by 1.7% per year.

Presently, the PV Systems Reliability & Performance R&D Task continues monitoring and reporting on eight PV arrays at the OTF.

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