

Contract Report

Outdoor Monitoring and High Voltage Bias Testing of Thin-Film Photovoltaic Modules

Year 4, Annual Report (Partial for Uni-Solar)

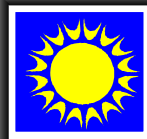
FSEC-CR-1732-07

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NREL, UCF/FSEC Account # 2012 8071

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Introduction

Outdoor monitoring and High Voltage Bias Testing of Thin-Film Photovoltaic Modules has been undertaken through the project funded by NREL. This report briefly summarizes the results of the study for Uni-Solar modules.

The work consisted of the study of outdoor testing and monitoring of thin-film photovoltaic (PV) modules in the hot and humid climate of Florida. The Uni-Solar modules were divided in two sets. The modules in these sets were connected in series so as to build maximum open circuit voltage of less than +600 V or -600 V with respect to ground with a load resistor and a current measuring shunt. The negative terminal of one of the two sets of each type was connected to the ground and thus the modules in these arrays were at a positive bias with respect to the ground potential. These arrays were deployed on the FSEC outdoor test facility as a positive array. The positive terminal of the other sets of each type was connected to the ground and thus the modules in these arrays were at a negative bias with respect to the ground potential. These arrays were deployed at the FSEC outdoor test facility as a negative array. The data was collected using a data acquisition system. The data was taken every 15 seconds and an average value over 15 minutes was recorded and stored.

Regression analysis:

Performance Test Condition (PTC) power values for the have been calculated for both positive and negative arrays using the LABVIEW program, and the corresponding plots are provided in Figure1 and Figure 2. These plots indicate almost no variation in performance of these module arrays over a period of 34 months.

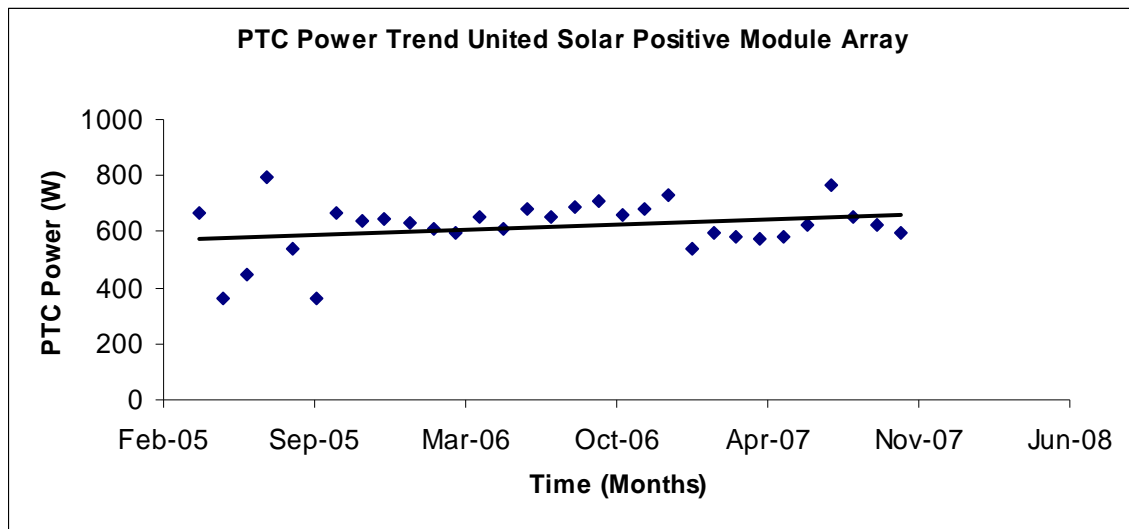


Figure 1: Plot of PTC power values for Uni-Solar positive module array

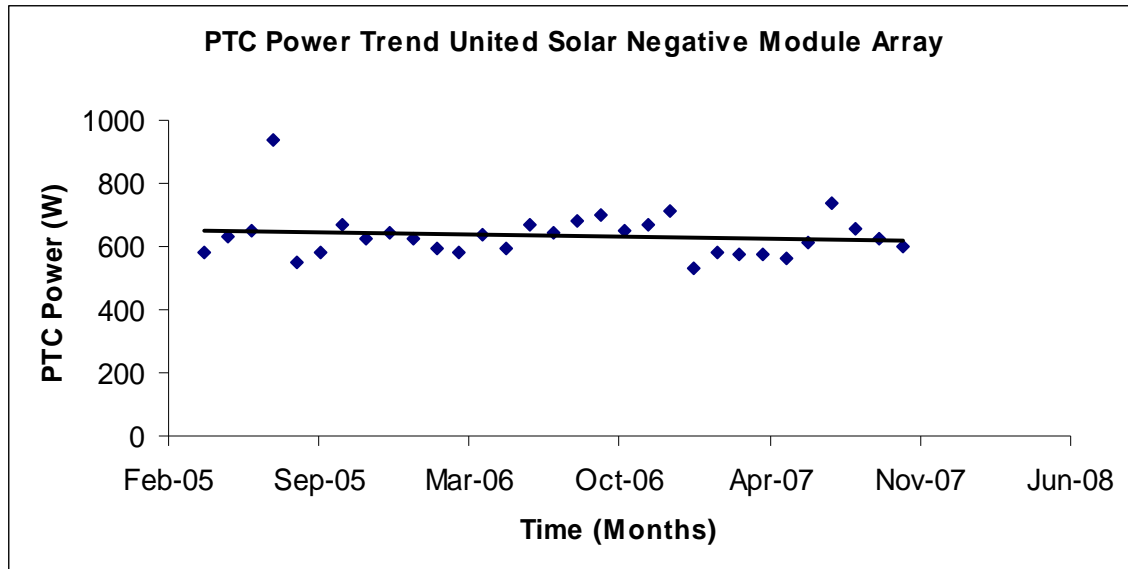


Figure 2: Plot of PTC power values for Uni-Solar negative module array

Study of Current-Voltage (I-V) Characteristics:

A complementary study of current-voltage (I-V) characteristics is carried out for comparison with the outdoor data monitoring of the module arrays. Current voltage characteristics of the module arrays taken on a regular basis provide important PV parameters such as short circuit current, open circuit voltage, fill factor, peak power, etc. The I-V data is used to plot bar charts (Figure 3- Figure 5). Only peak power values are normalized at 1000 W/m^2 , $25 \text{ }^\circ\text{C}$ since the module temperature coefficient values are available only for this parameter. This is done by calculating the power values at 1000 W/m^2 and then multiplying them with the known values of module temperature coefficient. I-V characteristics of the module arrays taken at regular intervals serve as a supplement to the information obtained through continuous data monitoring.

Table I: Comparative Chart of Peak Powers of PV arrays since Feb-2005

Peak Power Ppk@1000 W/m ² , 25 deg. C	US+	US-
Feb-05	603.6	610.2
Jul-05	623.1	612.3
Sep-05	-	-
Dec-05	598.8	612
Mar-06	600.1	659.8
May-06	625.6	625.9
Jun-06	608.8	634
Jul-06	625.8	639.9
Aug-06	629	606.8
Sep-06	621.3	636.3
Oct-06	608.6	609.1
Dec-06	600.3	610.5
Jan-07	606.7	608.6
Feb-07	594	604.2
Apr-07 (A)	620.3	620.8
Apr-07 (B)	594	604.2
Nov-07	564.7	583.6

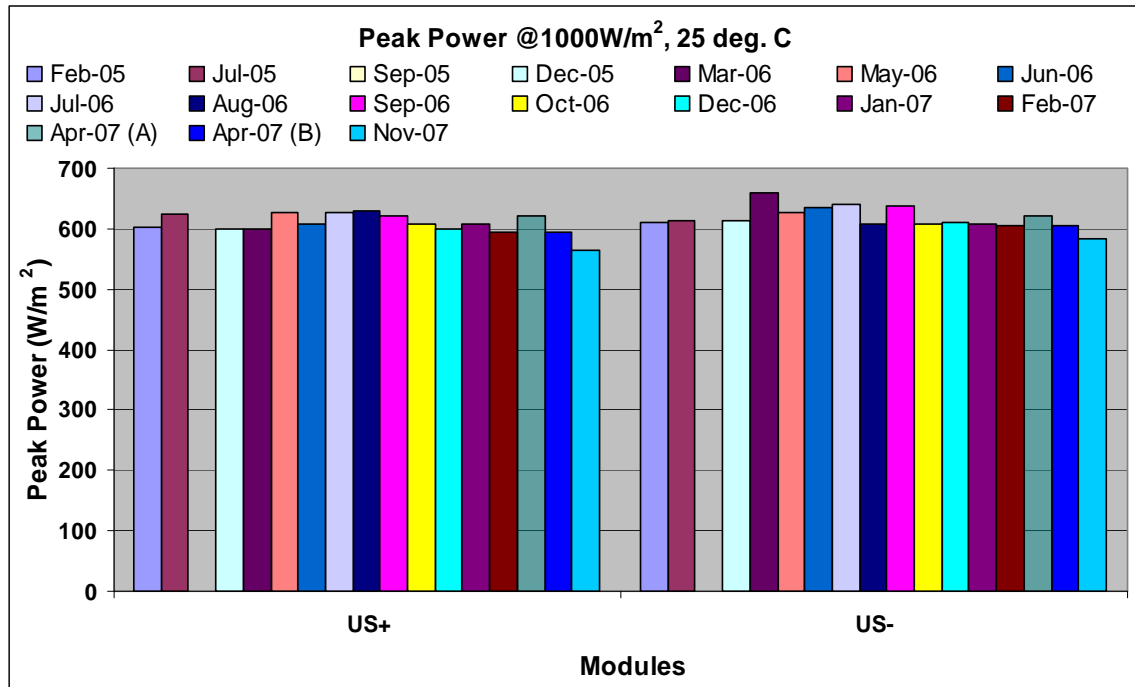


Figure 3: Graphical representation of the Peak Power in Table I

Table II: Comparative Chart of open circuit voltage (V_{oc}) of PV arrays since Feb-2005

Voc	US+	US-
Feb-05	436	437.2
Jul-05	388.6	383.9
Sep-05	-	-
Dec-05	434.4	431.4
Mar-06	407.6	405.3
May-06	402.5	405
Jun-06	401.8	404.6
Jul-06	393.5	392.5
Aug-06	391.9	390.7
Sep-06	392.5	391.5
Oct-06	413.9	412.8
Dec-06	431.9	433
Jan-07	427.2	425.1
Feb-07	424.5	421.7
Apr-07 (A)	395.9	404.2
Apr-07 (B)	424.5	421.7
Nov-07	413.9	410.0

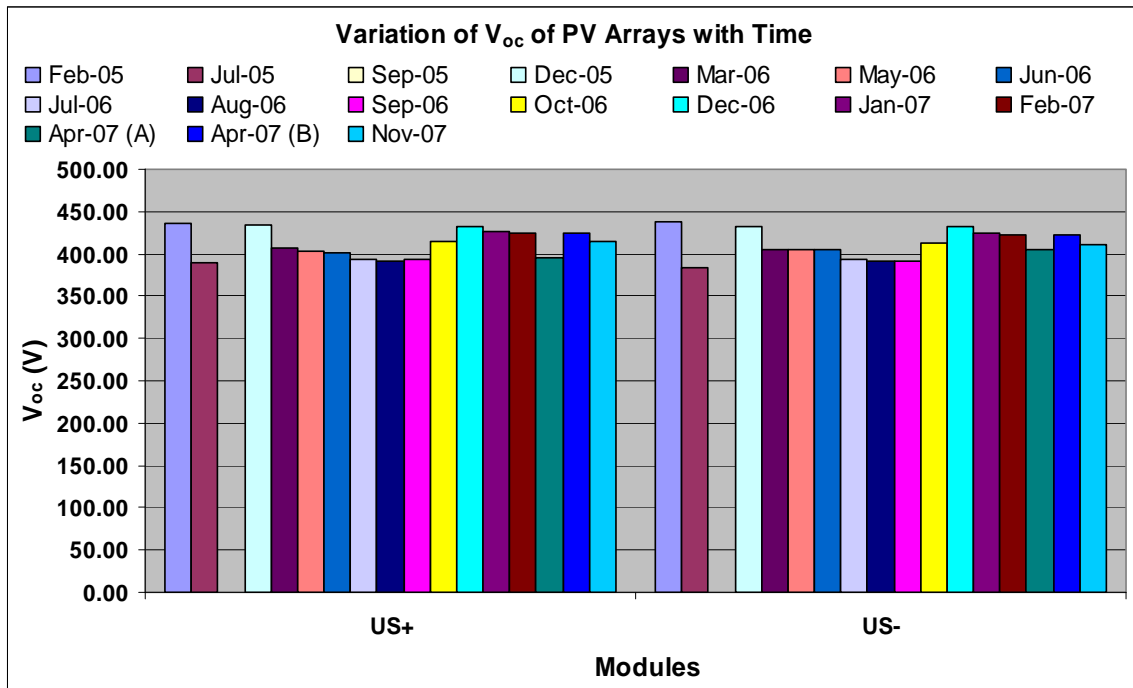


Figure 4: Graphical representation of V_{oc} in Table II

Table III: Comparative Chart for Fill Factors of PV arrays since Feb-2005

FF (%)	US+	US-
Feb-05	55.7	55.5
Jul-05	57.8	58
Sep-05	-	-
Dec-05	56.6	55.9
Mar-06	56.4	57.5
May-06	57.3	57.2
Jun-06	57.2	57
Jul-06	57.7	57.6
Aug-06	57.6	57.7
Sep-06	57.1	57.8
Oct-06	56.6	57.1
Dec-06	55.6	55.4
Jan-07	55.9	55.9
Feb-07	56.8	56.5
Apr-07 (A)	56.7	55.9
Apr-07 (B)	56.8	56.5
Nov-07	57.4	57.9

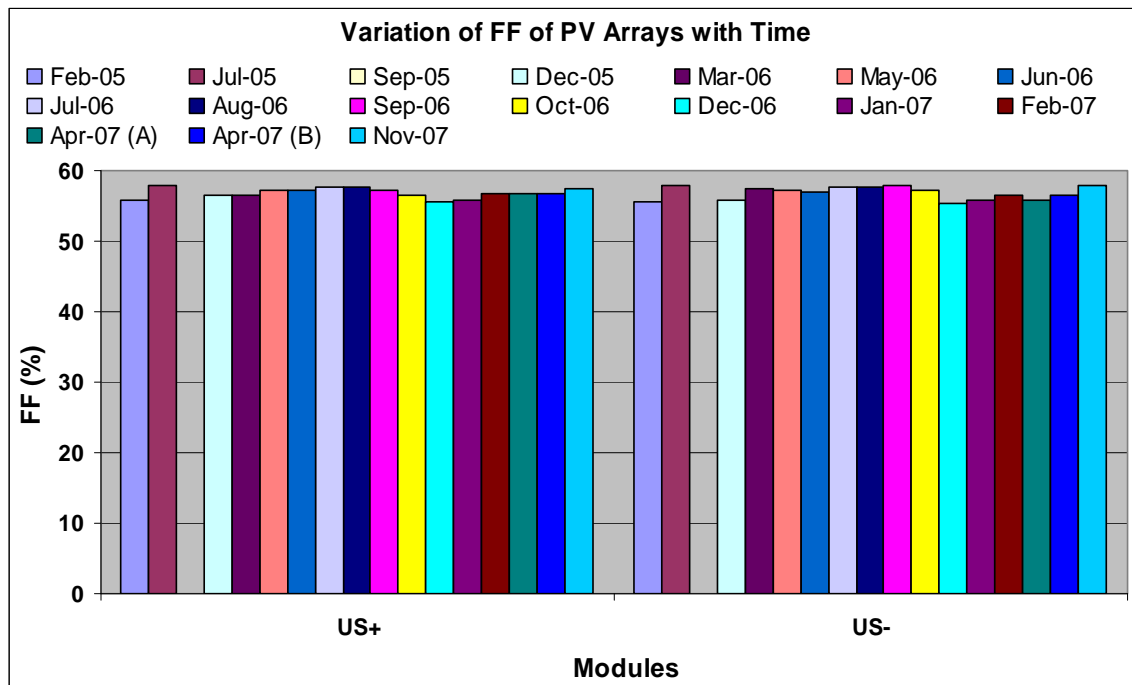


Figure 5: Graphical representation of Fill Factor data in Table III

Open circuit voltage (V_{oc}) and fill factor values are not normalized, since the corresponding module temperature coefficient values are not available. Therefore, the observed pattern of their variation with time might not follow the same trend as that followed by peak power. Hence they are not very helpful in terms of closer comparison on month to month basis. However, it does provide a picture about consistency in the data over a period of time. PTC and I-V analyses do not show any signs of degradation in the module arrays.

Development of Hurricane Protectors:

As part of this project a hurricane resistant sturdy structure was designed and built. This was a major improvement as compared to the wooden structure used in earlier work where there have been issues of severe sagging of wood.

During the hurricane season of 2004 which was noted as the worst in over 100 years, considerable amount of data was lost due to time-consuming process of removing and remounting the PV module arrays as well as the data acquisition system. For this reason, appropriate hurricane protectors were designed and built to eliminate the requirement of complete unmounting of PV modules and reduce the number of days on which the data is lost. During the hurricane Wilma in the year 2005 the hurricane protectors were successfully used. This resulted in minimal loss of data. Moreover, there was no damage to the PV modules.

Development of Human Resources through this project:

During the course of this project a total of ten graduate students completed their graduation. Out of the ten students seven have continued their work at FSEC towards achieving their doctorate degree. Through the work carried out under this project students have gained extensive experience and knowledge in PV systems and reliability issues involved in PV modules.

Current Status:

Recently, the modules were returned to NREL for measurements. At present, the Outdoor Facility is being improved and refurbished. After the NREL measurements are completed, it is hoped to continue this effort with the support of Uni-Solar.