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Analysis and study of PV Module on the Effect of Dust and Temperature

S. Parthasarathy[1], K. Srinivasan[2],
[1]Research Scholar, Maharishi University of Information Technology, Lucknow, E-mail: spsarathy_au@yahoo.co.in
[2]Professor, Tagore Engineering College, Chennai-India-600 127,E-mail: omsrivas@yahoo.co.in

ABSTRACT- This paper investigates the environmental effects (temperature and dust) on photovoltaic module performance. The degradation of the PV performance owing to an increase of temperature and dust density is investigated. A test of the PV module at standard test conditions (STC) was analyzed. Then, the effects of temperature, wind speed and several type of dust accumulation on the PV performance were examined. The depositions of red soil, sand and white soil dust were used in the study. I-V characteristics were determined for various intensities of dust. The evolutions of the short circuit current, the open circuit voltage, and the maximum power for the several cases were examined. The results show that the PV voltage and power is affected significantly by pollutant type and deposition level.

Keywords: dust effect; irradiance; PV generation; solar panel testing; temperature effect.

Introduction

More recent attention has focused on the use of PV power systems on the distribution networks as well as the degradation effects of PV on the distribution system stability, power losses and reliability. Al-Maghalseh [1-5] investigated the differential impact of renewable energy distribution generation on the system performance and stability. PV system performance can be affected by several conditions such as temperature, weather conditions, dust, wind speed. The research has been conducted into two phases for two time periods. Drawing on an extensive range of sources, the authors identifies the challenges of future research and the appropriate cleaning/maintenance cycle of the PV systems. Batra et al [7], investigate the effects of Badarpur, fly ash, and rice husk on the PV performance. He found that the rice husk has the highest effects on the PV performance. El-Shobokshy and Hussein[3, 4]carried out both experimental and numerical study in order to investigate the effect of dust on PV performance. The study has shown that the short circuit current was reduced significantly with dust deposition. Further, the finer particles have a greater effect on the PV performance compared to that of courser particle. Kymakis et al.[5] examined the effect of dust deposition on the power losses of a grid connected PV park. It was found that the PV efficiency has reduced by 0.3%-0.45% per the increase of temperature (C). Schwingshackl et al.[7] numerically investigated the effect of wind on the PV Module temperature. Several techniques are investigated, and it was found that the wind cooling effects plays an important role for the power estimation. The performance of a photovoltaic cell depends on manufacturing technology and the operating conditions under Standard Test Conditions (STC)[8]. The photovoltaic cell of terrestrial solar power modules is tested in order to measure and explain its I-V curve characteristic and to compare the performance of different solar power modules under uniform operating conditions. These performance conditions are at incident sunlight of 1000 W/m², a cell temperature of 25°C (77°F) and an AM (air mass) of 1.5. The air mass determines the radiation impact and the spectral combination of the light arriving on the earth's surface [8]. With the increasing use of the PV systems, it is vital to know the effects that active meteorological parameters such as humidity, dust, temperature, wind speed have on their efficiency. This paper investigates the effect of temperature and dust on the PV system performance and parameters such as light intensity or irradiation, tracking angle, temperature, air velocity and dust. Through the photovoltaic parameters like open circuit voltage, short circuit current, maximum output power, fill factor and efficiency are generally affected by the above environmental parameters.In this paper, the influence of different values of temperature and the accumulation of dust types on the efficiency of solar the PV panels is assessed by using artificial materials. A constant radiation condition is used by a sun simulator to overcome the variation of the sunlight.

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2. EXPERIMENT SET-UP

Basically, the system comprised a multi-crystalline photovoltaic module. This module is a 10W, 21.08V, 0.59A, 1.5 kg and 415×268×22m3 the PV module. The PV module is connected to the sun simulator to control the radiation by autotransformer. The performances of the PV module are monitored by digital multimeters, temperature sensors and dust sensors. In this research, indoor experiments are conducted to investigate the effect of uniform dust, wind speed and temperature on the PV performance, so the experiments are divided into four sections: (i) The PV module at STC, (ii) the impact of temperature on the PV performance, (iii) the impact of uniform dust on the PV performance, and (iv) the impact of wind speed on the PV module. Fig. 1 shows the experimental block diagram and procedure.

Firstly, in order to determine the impact of the different selected dust on the PV module performance, an experimental procedure was carried out in order to compare the voltage output of the PV module under different dust deposition conditions at constant radiation (1000W/m2) and a temperature of 30°C. The experimental procedure was carried out indoors and at least 30 measurements were recorded within the time period 110s. The experimental analysis was conducted in the Renewable Energy Laboratory. The dust deposition density was measured in mg/m3 by using dust sensor GP2Y1010AU0F. Then different types of dust were monitored by an Arduino controller to record the values on an Excel sheet and draw the curves. The dust was uniformly distributed on the PV surface using a fan. Secondly, to determine the effect of temperature on the PV module, the experimental procedure was carried out indoors at a constant radiation (1000W/m2), varying the value of temperature from 25°C to 55°C, and then taking the mean value of 50 measurements for each value of temperature. In this section, the Arduino microcontroller was connected with the temperature sensor to observe and record its values. In the wind speed effects on the PV experiments, an anemometer was used to measure the value of wind speeds. Also, we used a multispeed fan in order to obtain several wind speed values.

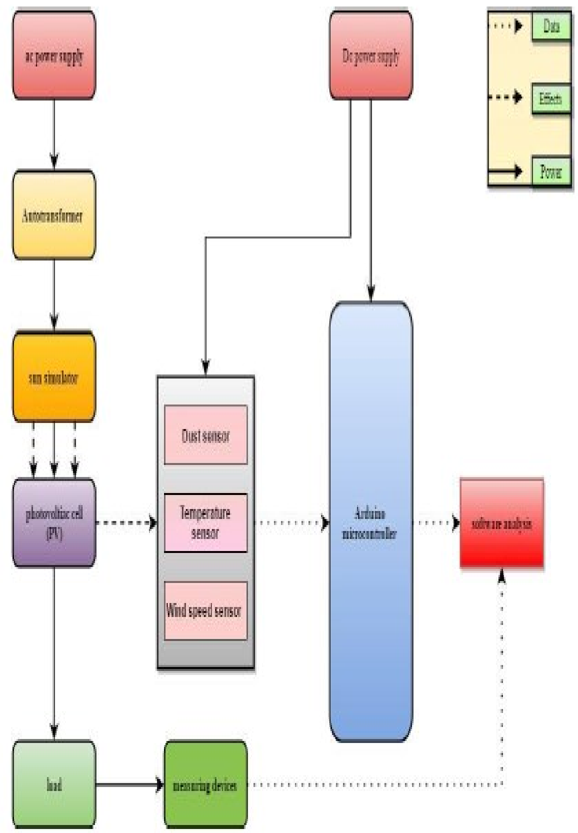

Figure 1: Experiment Block diagram and procedure

3. Results and discussions

3.1. Photovoltaic module at standard test conditions.

Fig. 2 illustrates the I-V and P-V curves for the PV cell under STC conditions (1000W/m2, 25°C, A.M 1.5). In this case, the short circuit current (Isc) was 0.6A and open circuit voltage 20.7V. Under STC the maximum power that could be obtained from the PV module was 9.352W and the efficiency was 9.396 %.

3.2. The effect of temperature change on the PV module.

In this section, the performance of the PV module at different temperature levels was investigated. The analysis considers the effect of temperature on the open circuit voltage (Voc), the short circuit current (Isc), maximum power and efficiency of the PV module.

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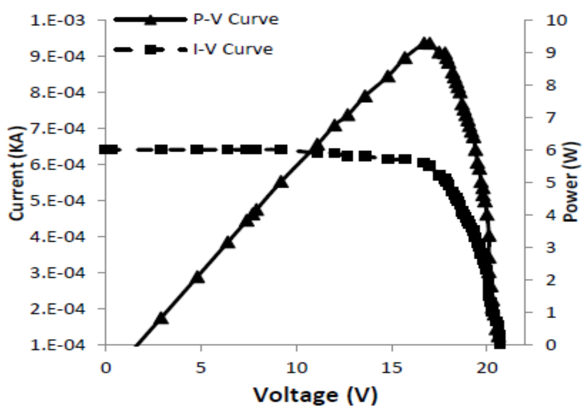

Figure 2: I-V and P-V curves of the PV module at STC.

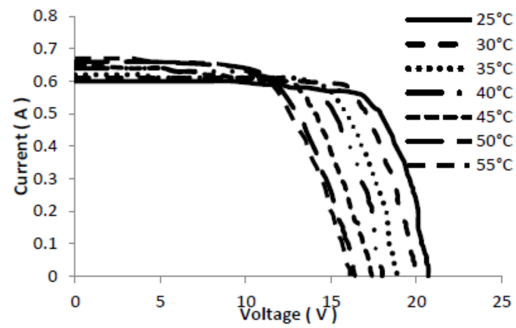

Figure 3: I-V curves of the PV module at different temperature.

Figures 3and 4 illustrate the I-V and P-V curves at different temperatures of the PV. It can be seen that when the temperature of the PV increased to 30, 35, 40, 45, 50 and 55°C, the open circuit voltage (Voc) decreased to 20, 18.9, 18, 17.4, 16.4 and 16.1V respectively. While the short circuit current (Isc) increased slightly to 0.61, 0.62, 0.64, 0.65, 0.66 and 0.67A respectively. In other words, Voc was decreased by 3.89% per 5 °C above 25°C and Isc was increased by 2% per 5°C above 25°C.

The P-V curves of the PV showed that maximum power (PMax) that could be generated from the PV decreased to 9.263, 8.584, 8.208, 7.611, 7.02 and 6.786W, when the temperature of the PV was raised to 30,35, 40, 45,50 and 55°C. Also, the efficiency of the PV decreased to 9.263%, 8.584%, 8.208%, 7.611%, 7.02% and 6.786% respectively. From these results it can be concluded that PMax and η were decreased by 5% per 5°C above 25 °C (STC). In case of the temperature of the PV below 25°C, Voc increased to 21 V and Isc was decreased to 0.56 A. The maximum output power (PMax) and the efficiency (η) generated from the PV was decreased to 8.823W and 8.86%, respectively. The results agreed well the previous work of [11-14].

The effect of temperature change on maximum output power of the PV module is demonstrated in Fig. 5. From the figure below we can obtain a mathematical expression that describes the relation between PMax and temperature of the PV (T). The PMax of the PV is a function of temperature

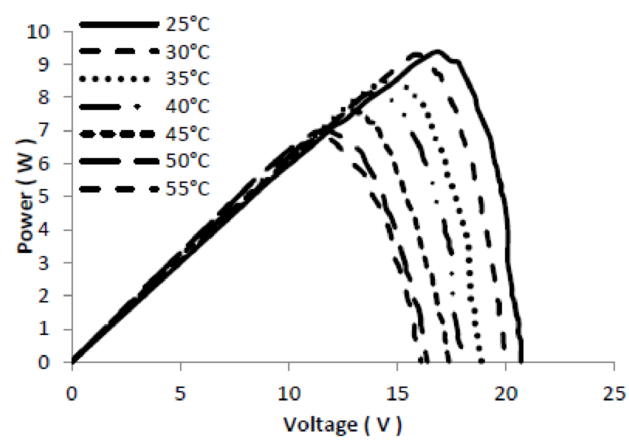

Figure 4: P-V curves of the PV module at different temperature.

3.3. The effects of dust density on the PV module

In this section, the effect of dust on the PV performance was investigated. It was found that the short circuit current (Isc) was strongly decreased as the dust density increased. Also maximum output power and efficiency decreased significantly as the dust density increased. However, different dust types with different densities did not vary greatly in their effect on the open circuit voltage (Voc).

Figures 6-7 show the effect of red dust on the I-V curve, power, and efficiency of the PV module. The results show that the short circuit current (Isc) was decreased from 0.61 to 0.56, 0.64 and 0.48 A for dust densities of 25, 30 and 35mg/m3, respectively, while the open circuit voltage (Voc) was slightly increased to 20.1 and 20.3V for dust densities of 30 and 35mg/m3.

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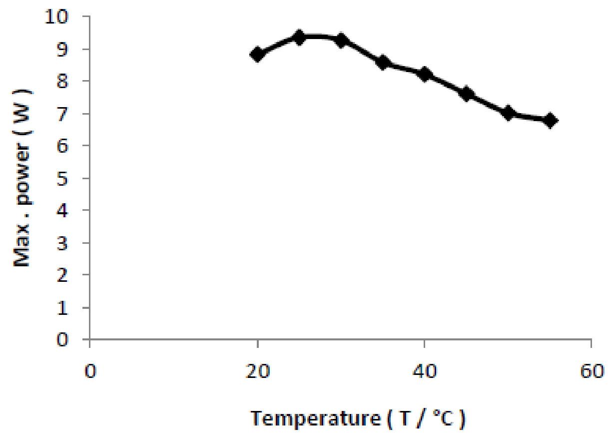

Figure 5: The maximum output power of the PV module at different temperature.

3.3.1. Effect of soil dust on the PV module

In other words, Isc was decreased by 2.4% and Voc increased by 0.15% per 5 mg/m3 of red dust density. Furthermore, the PMax of the PV module was decreased as the red dust densities increased. It can be seen that without any dust on the PV module, the maximum power was 9.263W, but where red dust densities were 25, 30 and 35mg/m3, the maximum power varied between 8.036, 7.56 and 7.26W respectively. It can be concluded that the maximum power of the PV is decreased by 13.24%, 18.38%, and 21.62% for the cases of 25, 30, 35mg/m3 respectively. In other words, the maximum power of the PV was decreased by 3% per 5mg/m3 of dust.

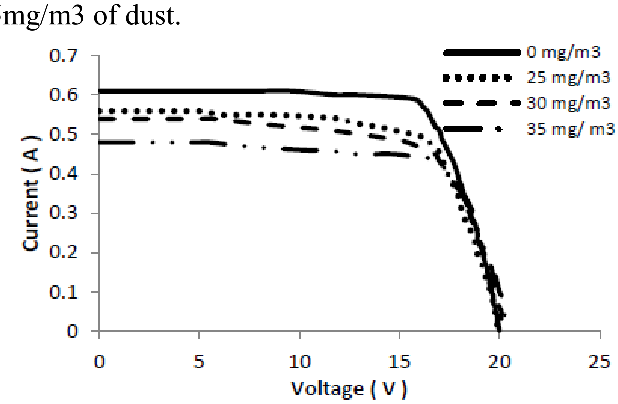

Figure 6: I-V curves at 30°C and different red soil dust densities.

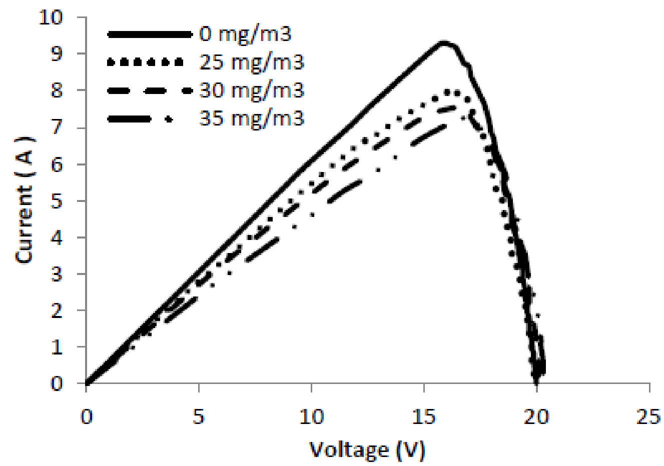

Figure 7: P-V curves at 30°C and different red soil dust density.

4. CONCLUSION

The effects of dust, wind speed and temperature on the mono-crystalline PV module were investigated at constant radiation (G=1000W/m2). A series of experiments were conducted in order to investigate the effect of several types of dust. The results showed that a significant effect was observed on both module current and short circuit current. However, they were dramatically decreased as the dust density increased. On the other hand, the dust density did not have a significant effect on the module maximum output voltage and the open circuit voltage. The effect of temperature on the PV module was also investigated. It was observed that the open circuit voltage (Voc) was decreased by 4%/5°C, while the short circuit current (Isc) was slightly increased by 2%/5°C. Consequently the maximum power (PMax) and efficiency dramatically were decreased.

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