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Experimental Investigation of the Photovoltaic Performance Using Porous Media based Cooling System

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Abstract

Cooling photovoltaic panels (PV) is considered one of the most important ways to enhance its performance. Photons with wavelength above the threshold are converted into heat in the PV cells. The ambient temperature acts a key base in the photovoltaic conversion process, where the output power decreases with increasing the temperature than the ambient temperature. In this study, experiment is conducted to study the cooling effect of using a porous material on the electrical performance. The temperature of the front surface of the PV panel is measured at the twenty-eight points without cooling and with cooling. It is found that the temperature decreases when compared to PV panel without cooling. The maximum decrease in the temperature is 9.8%. In addition, the electric current of the PV increases with cooling. The maximum increase of the measured electric current is 16.4 % at a specific voltage, 19.6V. Furthermore, the maximum gain of the output power is about 15 %.

Key words: Cooling PV panel, Ambient Temperature, Porous Material, Electrical Power.

1. Introduction

At the end of 1980, the price of crude oil reached 19 times what it had been just 10 years earlier. In addition, the pollution from fossil fuel burning has become significant in recent years. Moreover, oil has already started to its peak. Therefore, the world looks at renewable energy such as solar energy.

Cooling techniques are used to decrease the operating temperature of the Photovoltaic (PV) solar panel to enhance its electrical performance. Gardas and Tendulkar studied a hybrid solar system to study the heat transfer and electrical performance [1]. Nehari et al. [2] presented a 2D numerical model to study the phase change material effect on the temperature of a PV panel. Dubey et al. [3] showed that the performance ratio of the PV panel decreases with latitude due to the temperature. Three cooling experiments were carried out in [4] and it was noticed that the cooling temperature of the PV module was lower up to 16, 18, 25^0 C for the film cooling module, back cooling module and combined film – back cooling module, respectively, compared to the module without cooling. Tang et al. [5] used a novel micro heat pipe array for cooling a solar panel. Air-cooling and water-cooling techniques were used using natural convection conditions. The photoelectric conversion efficiency increased by 2.6% compared to the solar panel without cooling. Biwole et al. [6] presents a numerical investigation for the usage of a Phase Change Material (PCM) to control the temperature of a PV panel and make it close to the environmental temperature at a constant solar radiation of 1000 W/m^2. It was shown that adding a PCM to the back of the PV panel maintained the operating temperature of the PV lower than 40^0 C for 2 hours. Hashim et al. [7] experimentally investigated a PV/thermal system for thermal energy rate reduction. They developed a cooling technique using a heat exchanger and water pipes, which were placed at the back of the PV panel. A decrease in the temperature was achieved and an increase in the electrical efficiency to 9.8% was achieved. Ronmielid et al. [8] conducted measurements on the performance of string modules of a solar cell with low concentrating reflectors. Four methods of cooling were studied to reduce the reduction in efficiency associated with the high temperature of the PV panel. The actively cooled PV module was the best technique, which had 2.2 times the output of the reference PV module. Chen et al. [9] Conducted comparative experimental study on PV panels without and with fin cooling. They investigated the effect of the inclination angle, wind speed, solar radiation, and ambient temperature on the PV output power and electrical efficiency. It was observed that the average electrical efficiency increased in case of cooling with fins by 0.3-1.8 %. The output power in case of using fins was higher than the case of without cooling by 1.8-11.8%. These results were achieved at various conditions. The above methods to cool solar panels increase the cost of PV panels and consume power. Therefore, this paper investigates a cooling method by natural convection which is cheap and easy to fix.

2. Experiment

Two experiments are carried out to investigate the effect of adding porous material to the PV panel on the operating temperature and electrical performance. The two experiments are carried out at the same time to make sure that the solar radiation intensity and atmospheric conditions did not significantly change. The time interval between the two experiments is almost negligible. Figure 1(a) shows the PV panel with the measuring devices where PV panel specifications are (Model: Ysp-80M)

Rated Max Power (pmax)	80W
Power Tolerance Range	(%) 0/+3
Voltage at pmax (Vmp)	18V
Current at pmax (Imp)	4.44A
Open-circuit Voltage (Voc)	22.32 A
Short-circuit Current (Isc)	4.49A
Normal Operating Cell Temp (NOCT)	50^0C

The temperature is measured at white twenty-eight locations as shown in Figure 1(a) and the PV panel was in the horizontal plane. A porous material was then added to the back of the PV panel to study its effect on the heat transfer process as shown in Figure 1(b). The PV cooling system that is used in this paper consists of four layers of porous aluminum sheets as shown in Figure 1(c). The thermal conductivity of the porous material is 204 W/m.K at 20^0 C. The squared dimensions of the hole of the porous material are 2 mm x 2 mm. The temperature is measured by the k-type thermocouple. The voltage and current of solar panel are directly recorded by the voltmeter and ammeter after loading the PV panel by connecting electric resistances to the electric circuit as shown in Figure 1(b). Furthermore, the open circuit voltage (Voc) and short circuit current (Isc) were measured. Uncertainty of measurements are shown in table 1.

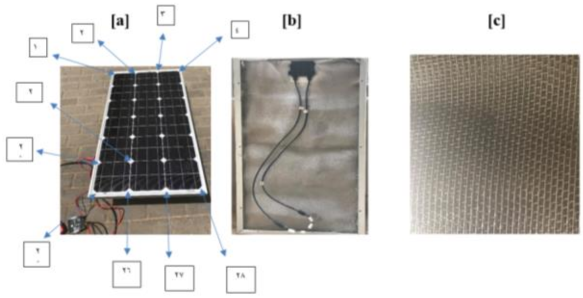

Figure 1 (a) The PV panel without the porous material (b) With the porous material (c) The porous material

Table 1 the uncertainty analysis

Measured Quantity	Uncertainty
Temperature (ESM-3710-N)	$\pm$ 2.2 % ^{0}C
Voltage, Multimètre (UNI-T UT)	$\pm$1.2 % V
Electric current, Multimètre (UNI-T UT)	$\pm$ 2 % A

3. Results and discussion

The PV panel absorbs only 16% of the incident solar energy which is converted into electricity, but the remaining solar energy absorbed is transformed into heat which increases the temperature of solar panel. Therefore, the porous based cooling technique contributes to decrease the PV panel temperature which leads to increase the output power generated from the PV system. Figure 2 demonstrates the temperature distribution on specific locations of the PV front surface, shown in Figure 1(a), with and without porous material. It is clearly noticed that adding the porous material to the back of the PV panel decreases the temperature of the front surface. The maximum temperature reduction is 9.8% at location 2. This implies that adding the porous material enhances the heat transfer process. This shows that the temperature of the front surface for both experiments is a location dependent.

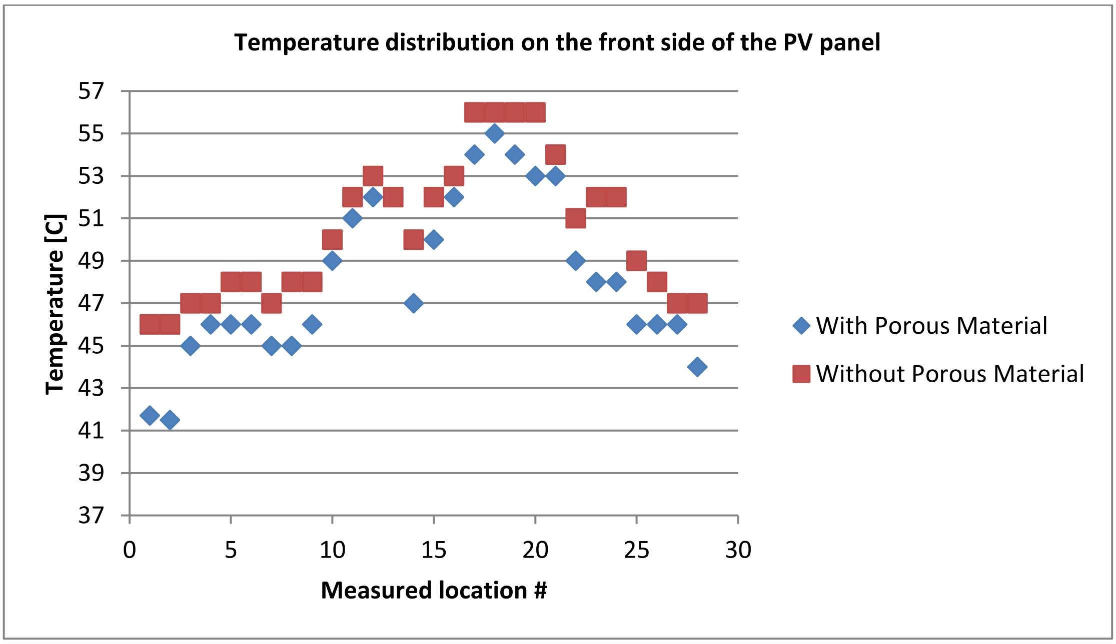

Figure 2 Temperature measurements at white twenty-eight locations on the PV front surface.

Figure 3 illustrates the V-I curve of the PV panel with and without using porous material. It is obvious that adding the porous material increases the current at any voltage level. At the voltage level of 19.6V, the maximum increase in the current is 16.4 %.

Furthermore, from Figure 4, it is clearly seen that adding the porous material increases the output power of the PV panel. At the voltage level of 19.6 V, the maximum increase of power is about 15 %.

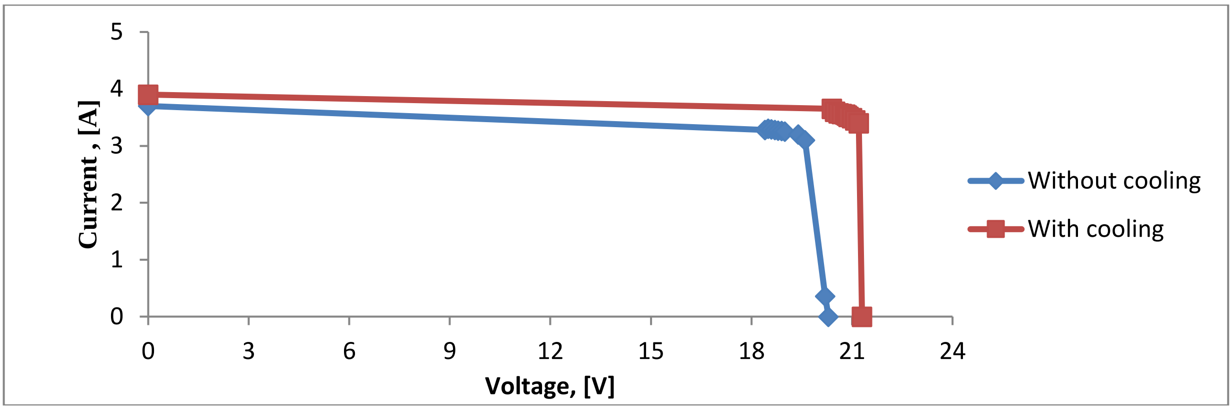

Figure 3 The Voltage - current curve of the PV panel for cooling and without cooling cases

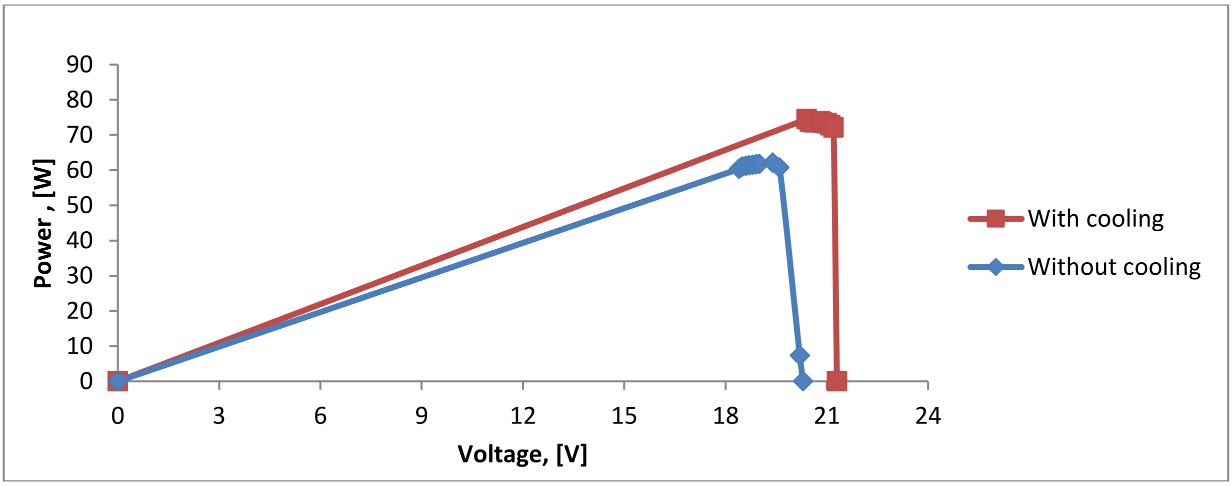

Figure 4 The Voltage - Power curve of the PV panel for cooling and without cooling cases

4. Conclusion

The increase in the efficiency and output power from PV panels depends largely on reducing the temperature limit. Two experiments are conducted on a PV panel to study the effect of adding a porous material to the back surface of the panel to work as a heat sink. From the results, the main conclusion can be summarized in the following points:

- Adding a porous material to the back surface of the PV panel decreased the temperature measured on the front surface of the panel. The maximum temperature reduction is 9.8%.
- At a specific voltage, the PV current is increased by 16.37 % due to adding the porous material. This shows that decreasing the front surface temperature of the panel increases the current, which also led to an increase in the output power about 15 %.
- The porous material works as a good heat sink as it enhances the heat transfer by conduction, cheap and easy to fix .

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