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Effect of Temperature Reduction on Produced Power Performance of Solar Panels

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Abstract

The performance of solar panel system applying water cooling system was studied in this research. In the experiment, the solar panels were 2 40-watt Monocrystalline silicon panels; a control panel and a tested panel. The control panel was the panel without the cooling system and the tested panel was the panel with the cooling system using water. Water was sprayed on the front surface of the panel and was controlled the temperature to be in the range of 25 – 30 °C. The results showed that temperature reduction at the front surface of the panel would affect the produced voltage of the panel but the produced current was affected more by the solar radiation. In comparison, during the testing time of 9 am to 3 pm, the produced voltage and the produced current of the tested panel had higher value than that of the control panel in the range of 4.57% – 11.05% and 3.52% - 6.11%, respectively. In conclude, the temperature reduction at the front surface of the panel would result in the produced power performance of solar panels in which affected more at voltage production process than current production process.

***Keywords**:* Solar panel, temperature reduction, water cooling, voltage, current.

1. Introduction

Solar energy is widely used in many applications. Sun light can be used directly as heat and solar radiation can be converted and used as electricity. There are many technologies that convert solar energy into another form, for example, solar heating, solar thermal, and photovoltaic (PV). Photovoltaic is the equipment that made of semiconductor, such as silicon, to use for converting solar radiation into electricity. Photovoltaic can also be called as solar cell.

When sunlight strikes on solar cell, electron would be excited and ready to move. Electrical power was generated after the system was connected into circuit. The performance of solar cell depended on several factors, such as solar radiation, working temperature, and dust. There are many studies that report the effects of those factors to the performances or efficiency of solar cell. The study of [1] stated that the average photon energy and module temperature affected the performance of amorphous silicon, polycrystalline and hetero-junction PVs. The experiments were carried out in Thailand and revealed that the polycrystalline and hetero-junction PVs depended almost only on a module temperature while amorphous silicon PV mainly depended in average photon energy. [2] also reported that the PV module performance was sensitive to working temperature but offered an acceptable efficiency behavior over the irradiance range. They also said the PV efficiency decreased with temperature and air-mass.

The attempt to reduce the working temperature of solar cell in order to increase its efficiency was made in several ways and techniques. Cooling technique using water was introduced by [3] and followed by others [4-8]. Those techniques used water flow over the front surface of solar panels to absorb the accumulative heat and to cool down the working temperature. The other benefit of using water was having clean solar panel. The obstacles on the front surface would shadow the solar cell and then sunlight could not go through and hit the cell. There were many studies reported that dust or dirt affected the efficiency of solar panel. For example, [9] reported that dust could reduce the efficiency of solar panel for 22% and [10] stated that accumulation of dirt could reduce the PV performance by up to 85%.

In this study, performance of solar panel was investigated after applying the cooling system using water. Water was sprayed on the front surface of solar panel and was scheduled to operate. The comparisons of electricity production between solar panel that operates at normal condition and solar panel that has the cooling system were carried out and analyzed.

2. Methodology

The 40-watt monocrystalline silicon solar panel was used in the experiment. The experiment was set up at Faculty of Engineering, Mahasarakham University, Maha Sarakham province, Thailand. The best condition of getting the maximum solar radiation at the location was having the solar panel faced south with 16 degree inclined from the horizon [11]. There were 2 set of solar panels in the experiment, control panel and tested panel. The control panel was the solar panel that operated in normal condition and the tested panel was the solar panel that installed the spraying water system. The water was sprayed over the front surface of panel in order to reduce the working temperature (Fig.1). The spraying water technique was chosen regarding to the experimental results from previous work [12-13]. In [12], the result comparison was made between 2 techniques. In [13], the temperature of spraying water wasn’t controlled and was about the same as the environment temperature. As a continuing research, the temperature of water was controlled to be in the range of 25 – 30 °C in order to investigate results. Those panels were placed on the steel frame and tested at the same location. Thermocouple type K was used to measure the temperature. They were attached on the front surface of those solar panels. The attached areas of interest were spread out uniformly on the front surface.

Fig. 1 Water was sprayed over the front surface of tested panel

The testing time was 9 am – 3 pm. Cooled water was pumped and sprayed for 3 minutes at every 15 minutes during the testing time period. The temperature data and solar radiation data were collected and stored by data logger. The short circuit current (I_{sc}) and the open circuit voltage (V_{oc}) of solar panels were also measured and recorded. All data were measured every 15 minutes.

The specification of the Monocystalline Silicon that used in this research was shown in table 1. Those measurements were made under the standard test conditions (STC) of 1000 W/m^2 solar radiation, 1.5 spectrums of Air Mass, and 25°C module temperatures.

Table. 1 Specifications of solar panel at standard test conditions (STC)

STC condition measurements	
Output power (peak W)	40
Working voltage, V_{op} (V)	17.2
Working current, I_{op} (A)	2.33
Open voltage, V_{oc} (V)	21.5
Short circuit current , I_{sc} (A)	2.50
Current temperature coefficient	+0.10% / °C
Voltage temperature coefficient	-0.38% / °C
Power temperature coefficient	-0.47% / °C

3. Results and Discussions

The experiment was carried out for 20 days during the month of February – April, 2015. The data of 10th of March, 2015 was selected to represent the results.

3.1 Solar Radiation

Solar radiation data was measured by pyranometer at the site of experiment and collected via data logger. Pyranometer was 16 degree angled from the horizontal, the same position as the solar panels.

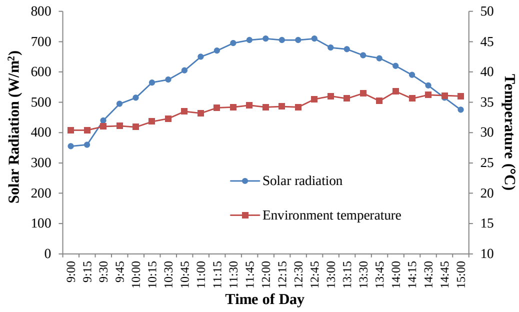

Fig. 2 Solar radiation and environment temperature during the testing time

The results showed that the solar radiation was increased from 9 am until 12.45 pm and then decreased. The maximum value of 710 W/m^2 was occurred at 12 pm and 12.45 pm. The environment temperature tended to increase from the beginning of the experiment through the end, even though the solar radiation was decreased. Since the heat from the sun was accumulated during the day, then the environment temperature was reasonably increased.

3.2 Temperature on the front surface

There were 5 points of temperature measurement on the front surface as shown in Fig.3. Both control panel and tested panel had the same positions of those 5 points of temperature measurement.

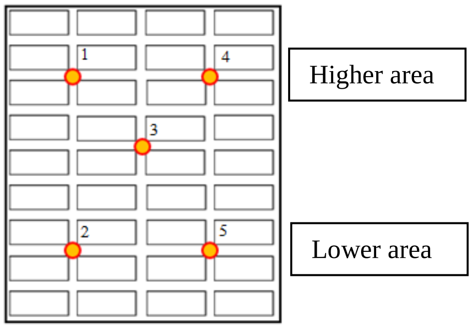

Fig. 3 Temperature measurement positions on the front surface of solar panel

Since the panel was 16 degree angled from the horizon, the results showed that the higher area (point 1 and 4) of control panel had the highest values of temperature while all points of the tested panel had almost the same temperature values (Fig. 4). The highest temperature of the control panel was 64.5°C at higher area and the temperature of all points was above 45°C during the testing time. The environment temperature was increase from 30.4°C at the beginning of the experiment and reached the highest at 36.8°C at 2 pm. For the tested panel, the temperature was in the range of 26 – 32°C during the testing time. There were temperature drops at 12.30 pm and 1.30 pm for both control panel and tested panel. From observation note, there was a strong wind for a short moment at the experimental site. It resulted in temperature drop at the front surface of both panels.

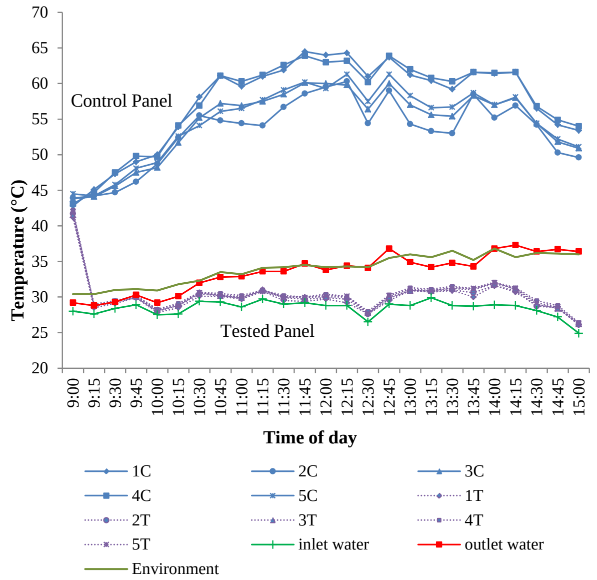

Fig. 4 Control panel and tested panel temperatures during the testing time

Water was sprayed on the front surface of the tested panel in order to remove heat. Since the cooling system was schedule to operate every 15 minutes for 3 minutes duration with the flow rate of 2 L/m, the temperature data of tested panel were slightly fluctuated. The inlet water temperature was kept to be in the range of 25 – 30°C. It turned out that the temperature of the tested panel was in the range of 26 – 32°C which could be resulted from the inlet water temperature.

3.3 Short circuit current (I_{SC})

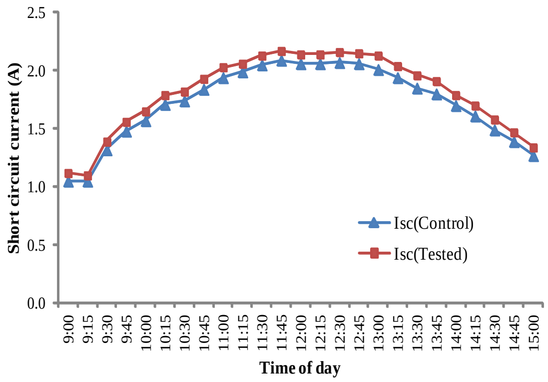

Fig. 5 Short circuit current (I_{SC}) of control and tested panels during the testing time

Short circuit current is the current of solar panel when the voltage across the solar cell is zero. The I_{SC} data of control and tested panels were measured manually via multi meters every 15 minutes. The results showed that I_{SC} of tested panel had higher value that that of control panel during the testing time. The highest I_{SC} of tested panel and control panel were 2.17 A and 2.09 A, respectively.

The maximum I_{SC} values of control panel and tested panel were just slightly different. In [14-15] explained that as the temperature increased, more incident energy is absorbed because electrons could travel more from valence band to conduction band, then the short circuit current would increase. However, the I_{SC} of the tested panel, which having lower temperature, had higher value that the control. It could be explained as the temperature still played certain role in current production process. Moreover, the current had the similar trend line as the solar radiation trend line (Fig. 2), which indicated that I_{SC} was depended significantly on the solar radiation.

3.4 Open circuit voltage (V_{OC})

Open circuit voltage is the voltage of solar panel when the current across the solar cell is zero. The V_{OC} data of control and tested panels were measured manually via multi meters every 15 minutes. The results showed that V_{OC} of tested panel had considerably higher value that that of control panel during the testing time. The highest V_{OC} of tested panel and control panel were 21.3 V and 19.3 V, respectively.

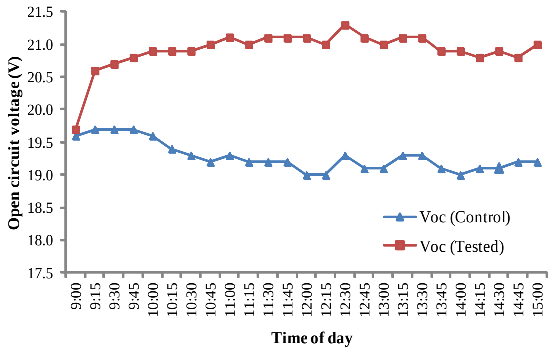

Fig. 6 Open circuit voltage (V_{OC}) of control and tested panels during the testing time

The voltage results looked different than the current results. V_{OC} data trend line wasn't follow solar radiation data; it was inversely proportional to working temperature instead. For tested panel, V_{OC} values seemed constant in the range of 20.6 – 21.3 V. V_{OC} values of control panel was decreased while the temperature of the panel was increased (Fig. 4). The fluctuation V_{OC} data of both panels during 12.30 - 13.30 pm happened accordingly with the temperature drops in Fig 4.

The results showed that V_{OC} was depended on the temperature of the solar panel more than the solar radiation. As the temperature increases, the band gap of the semiconductor would shrink and then the open circuit voltage would drop [14-15]. Thus, the tested panel which had lower working temperature would produce more V_{OC} that that of control panel.

3.5 Comparison between control pane and tested panel

The I_{SC} and V_{OC} differences between control panel and tested panel were calculated and compared in Fig. 7.

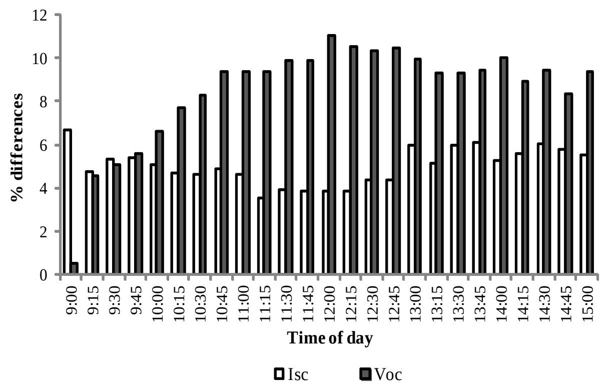

Fig. 7 The I_{SC} and V_{OC} differences between control panel and tested panel during the testing time

In Fig.7, the results showed that the control panel produced less I_{SC} and V_{OC} than that of the tested panel. The I_{SC} differences were in the range of 3.25% - 6.11% and the V_{OC} differences were in the range of 4.57% - 11.05%. It was obvious that high working temperature affected the V_{OC} than the I_{SC}. Solar panel could produce electricity better when the water cooling system was used. There were several studies that reported similar results [3-8].

4. Conclusions

The attempt to reduce working temperature of solar panel was carried out in order to improve the electricity production performance. The cooling system using water was applied and tested. Water temperature was controlled to be 25 – 30°C. Cool water was scheduled to be sprayed on the front surface of the tested panel every 15 minutes.

The temperature of solar panels would behave related to solar radiation traits. The results showed that temperature reduction at the front surface of the tested panel would affect the produced voltage of the panel but the produced current was affected more by the solar radiation. In comparison, during the testing time of 9 am to 3 pm, the V_{OC} and the I_{SC} of the tested panel had higher value than that of the control panel in the range of 4.57% – 11.05% and 3.52% - 6.11%, respectively. In conclude, the temperature reduction at the front surface of the panel would result in the better produced power performance of solar panels in which affected more at voltage production process than current production process.

5. Acknowledgement

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