The Consideration of Heat Reduction Hourly Schedule on Front Surface of Photovoltaic Module to Improve Efficiency

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Abstract

The efficiency of the Photovoltaic (PV) are depended on many things, one of them is the accumulative heat on the front surface which related to the operating temperature. The attempt to improve PV efficiency was carried out by reducing the heat on the front surface. The Monocrystalline silicon photovoltaic was used in the experiment. There were two sets of system, control system and test system. The control system was the PV that operated in normal condition. The test system was the PV that operated with the heat reduction equipment in which spraying water on the front surface. The results showed that the test system had better output than the control system in overall. The output was considerably different during 11:00 to 14:00 hours. On the other hand, there were not much of the differences in the morning and late afternoon. The highest value of the improvement efficiency was 15%. It was shown that the time schedule of spraying water in order to reduce heat on the front surface of the PV could be arranged instead of having heat reduction system ran all day long.

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Introduction

Solar energy is one of the most powerful energy in the world. There are many different applications that change the form of solar energy into other types. Solar cell or photovoltaic (PV) is the tool that transforms solar energy into electrical energy. The use of electricity has been increasing every year in everywhere in the world. For Thailand, the Electricity Generating Authority of Thailand (EGAT) had energy sales of 155,507.26 x 10^6 kWh in 2011 comparing to the energy sales of 97,412.45 x 10^6 kWh in 2001 [1]. The electricity production mainly uses natural gas as the fuel. From the overall energy resources for electricity generation in Thailand, renewable energy was used only 1.44% to produce electricity [2]. Since the renewable energy is considered to be unreliable resources due to the nature of it, the cost of electricity from this resource is high. Therefore, the improvement of conversion efficiency of the electricity production from renewable energy has been studied and implemented.

Solar energy is one of the renewable energy. The conversion efficiency of solar cell of photovoltaic depends on the material, the production technology, and operating conditions. Typical crystalline silicon photovoltaic has the efficiency of 15-22% [3]. There are many factors that could reduce the efficiency of PV such as high working temperature, dust, relative humidity and air velocity [4][5][6]. It was reported that the operating temperature caused a reduction of electrical power output of 0.4 – 0.5 % for mono and multi crystalline silicon PV [7].

There were many studies that tried to increase the efficiency of the PV by reducing the operating temperature. The use of natural air flow [8], cooling ducts [9], and water flow [7][10][11] were experimentally done to improve the efficiency of PV. Water is a good candidate for the reducing operating temperature operation. Not only water could reduce the heat but also could reduce the reflection of the radiation on the front surface of PV [7]. The increase of 10.3% in efficiency was obtained by using the water flow operation over the front surface of PV [7]. Another technique of using water cooling was water tricking configuration on the upper surface of the panel. It could increase about 15% in system output in peak radiation conditions [11]. The spraying water over the front surface of PV experiment was performed in order to investigate the possibility of improving the performance of PV [10]. The results showed that this system could improve the total efficiency of 1.35%. The experiment of passing water over the back of the module was performed by Wilson [12]. The result of this study was 12.8% increase in PV efficiency.

In this research, water was used as a coolant in order to reduce the operating temperature of the PV and then the efficiency of PV was examined. The heat would accumulate on the PV during the operation. Typically, the cooling system would be set to constantly run during the testing time. Thus, this study was aimed to investigate and recommend the cooling system time schedule. The efficiency of the PV was brought into account and reported. The experiment was carried out at Maha Sarakham, Thailand.

Methodology

The monocrystalline silicon photovoltaic module was used in the experiment. The experiment was set up at Maha Sarakham province, Thailand. The best condition of getting the maximum solar radiation at the location was having the PV faced south with 16 degree inclined from the horizon [13]. There were 2 set of PV in the experiment, control PV and test PV. The control PV was the PV that operated in normal condition and the test PV was the PV that installed the spraying water system. The water was sprayed over the front surface of PV in order to reduce the operating temperature. Those PVs were placed on the steel frame and tested at the same location. Thermocouple type K was used to measure the temperature. The thermocouples were attached on the front surface of those PV modules. The attached areas of interest were spread out uniformly on the front surface.

Fig. 1 The front surface of control PV with attached thermocouples.

Fig. 2 The test PV with attached cooling system .

The testing time was 9:00 to 15:00 hours and the experiment was run from August to October, 2012. The resistant loads were connected in the circuit for measuring current and voltage. The module temperature data were collected and stored by data logger (Wisco AI2010). The operating current and the operating voltage of modules were also measured and recorded. All data were measured every 15 minutes.

Analysis

Power output of the PV was considered from the measured current and the measured voltage from the experiment.

$$P = I \cdot V \qquad (1)$$

P = Power output (W)
I = Current (A)
V = Voltage (V)
Efficiency of the PV was considered from the power output from PV, the front surface area of PV and the solar radiation.

$$Efficiency = \left(\frac{P}{A \cdot G}\right) x100\% \qquad (2)$$

P = Power output (W)
A = Area (m^2)
G = Solar radiation (W/m^2)

Results and discussions

The data was collected during August – October, 2012 for 30 days. All measured data were averaged over the testing period and presented in this study.

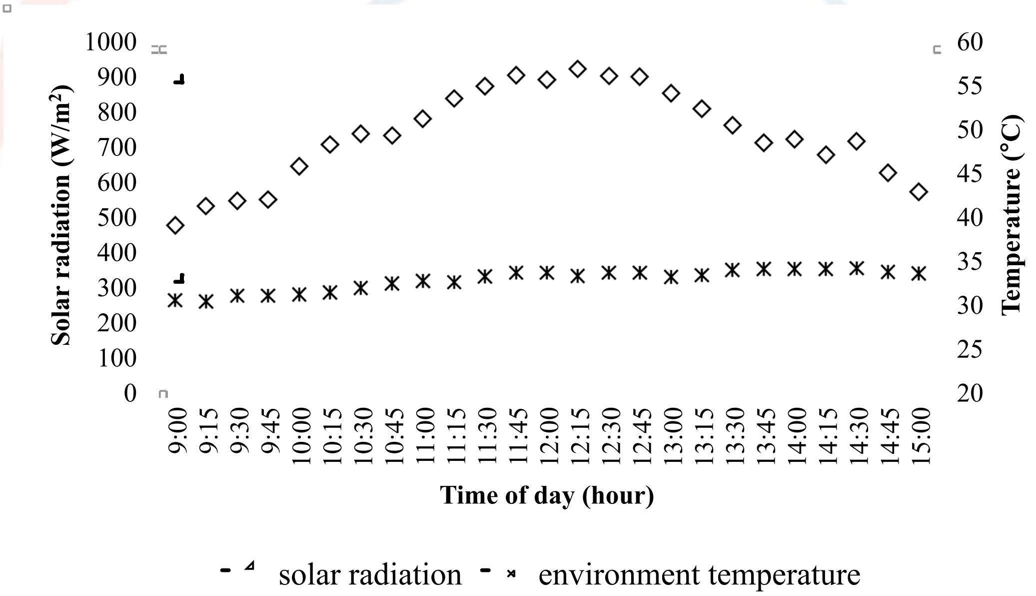

Fig.3 The relationship between daily solar radiation and environment temperature and time of day

The solar radiation and the average environment temperature were shown in Fig.3. For the testing period, the highest solar radiation value was 916.2 W/m^2 and the high solar radiation values were considerably occurred during 11:00 – 14:00 hours. The environment temperature was gradually increased during the day and it was ranged 30 °C – 35 °C.

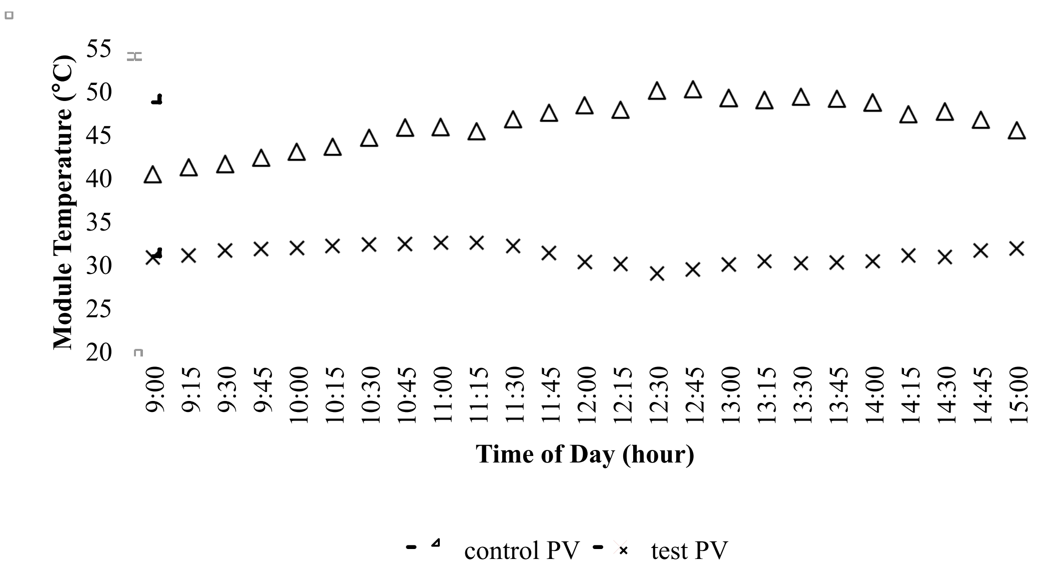

Fig.4 The module temperatures of the control PV and the test PV

In Fig.4, the module temperature of control PV and test PV were compared. The module temperature of the control PV was higher than that of the test PV for the entire testing time. The highest module temperature of the control PV and the test PV were 50.0°C and 32.4°C, respectively. When the sunlight hit the front surface of the PV, not only the PV started working but also the heat was accumulated. Therefore, the module temperature would increase. Since the test PV was installed the water spraying system, the water could reduce the heat on the front surface of the test PV and then the module temperature was decreased. During 11:00 – 14:00 hours, the module temperature of the control PV was high because the solar radiation was high (Fig.3) and also the heat was continuously accumulated since the beginning of the day. In contrast, the module temperature of the test PV was lower, comparing to the control PV. It was maybe because the water was continuously sprayed which gradually reduced the heat. Therefore, the module temperature of the test PV was slowly decreased. At the point that the module temperature of the test PV was close to the environment temperature along with the solar radiation value was high, the heat was accumulated again and then the module temperature started to increase.

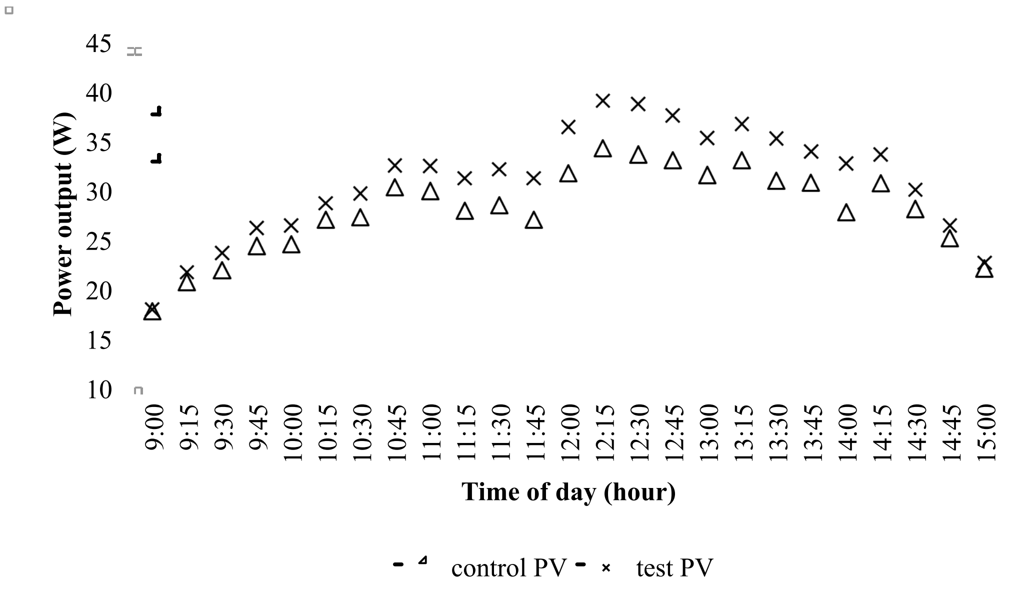

Fig.5 The power output of the control PV and the test PV

The power output of PV was calculated from the current and voltage in which produced from the PV (Eq.1). In Fig.5 showed that the power output of the test PV was higher than that of the control PV. It was also shown that reducing module temperature affected the ability to produce power output of the PV. With lower module temperature, the test PV could produce more power output. During 11:00 – 14:00 hours, the difference of the power output between the control PV and the test PV was considerably high comparing to the rest of the testing time. The average power output that the control PV and the test PV could produce during the testing time were 27.94 W and 30.83 W, respectively. In average, the test PV had the better result of 10.34% comparing to the control PV.

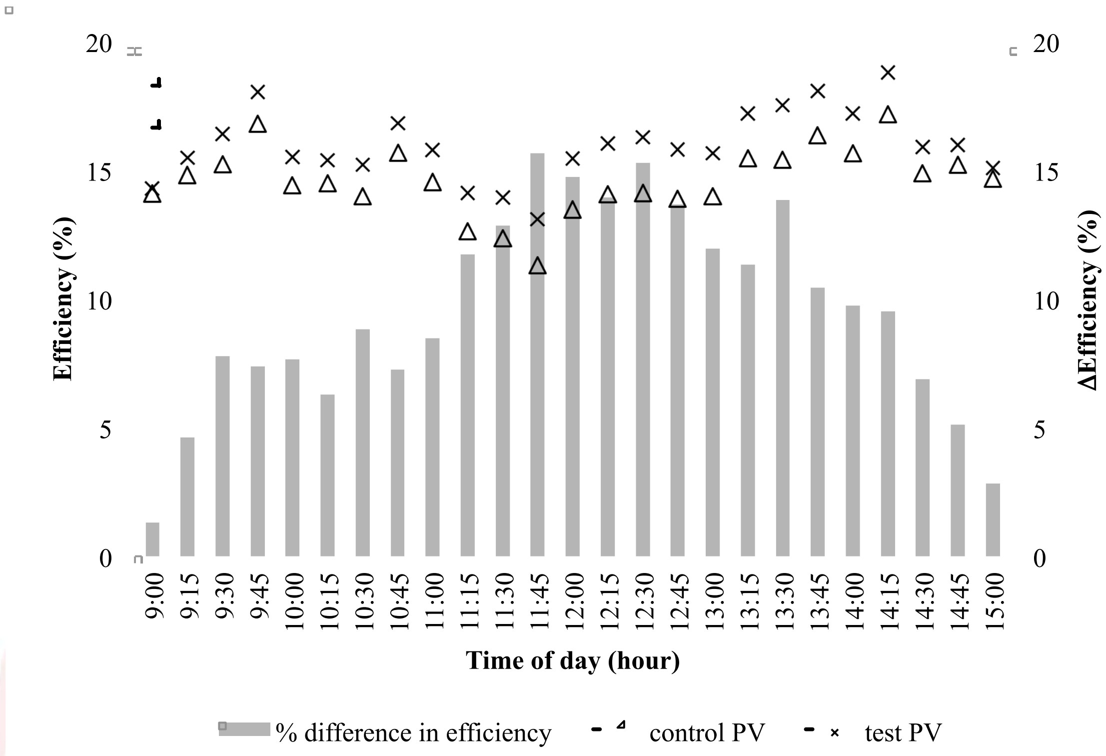

Fig.6 The comparison of the efficiencies and the difference in efficiency between the control PV and the test PV

With Eq. 2, the efficiencies of those PV were calculated. The comparison of the efficiency was made between the control PV and the test PV (Fig. 6). The difference in percentage described that the test PV had better output results. The efficiency of the test PV was improved because the module temperature was reduced. The highest improvement in efficiency that could be achieved was 15.7% during noon time. This number was higher comparing to the results of other techniques [7][10] and was slightly different comparing to the results of other similar water techniques [11]. In overall, it was confirmed that the temperature reduction system could effectively improve the efficiency of the test PV.

From Fig.6, the efficiency of the control PV and the test PV were in the range of 14% - 17% and 14% - 19%, respectively. The differences in efficiency between those PV were above 10% during 11:00-14:00 hours in which solar radiation values were high (Fig.3). The data also showed that the efficiencies between the control PV and the test PV weren't much different in the morning and late afternoon. Therefore, the consideration of setting up the time schedule for the heat reduction system could be implemented.

The PV cooling system could be scheduled to operate at the time that the difference in efficiency was above 10% according to Fig.6. Therefore, the cooling system could start to operate at 11:00 am and end at 14:00 hour instead of operating all day long. Additional observation from the experiment was also noted here. When the spraying water system started to run, the temperature of the test PV was reduced immediately and kept steady afterward (Fig.4). Hence, the investigation of efficiency improvement after implementing the heat reduction schedule during 11:00 – 14:00 hours on front surface of photovoltaic module will be carried out as the future work.

Conclusions

The cooling system for reducing the module temperature of the PV in order to improve the efficiency of the PV was implemented using spraying water technique. There were the control PV which operated at normal condition and the test PV which installed the cooling system. The water was sprayed over the front surface of the test PV while it was operating. The results showed that reducing module temperature affected the efficiency of the PV. The power output of the test PV was higher than that of the control PV. The highest efficiency improvement occurred during noon time of about 15%. The comparison between the control PV and the test PV showed that the cooling system could improve the efficiency in the range of 5% - 15% during the day. The improvement was peak from 11:00 to 14:00 hours. Thus, the schedule for the heat reduction system could be employed for that period of time instead of running the system all day.

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