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The Effect of Filtered PV on Its Efficiency Performance

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ABSTRACT

Photovoltaic (PV) involves the conversion of solar energy to electricity. However, the performance of a PV module depends significantly on its operating temperature due to the solar radiation that is not converted into electricity; thus, causing heat generated in the PV system. In order to preserve PV efficiency, the running PV temperature can be controlled by applying a range of water-cooling methods. The main objective of this research is to study the performance of PV using water filter as a cooling method to eliminate the unconverted wavelengths, such as UV and Infrared. The performance of unfiltered PV and 10mm filtered PV using a water filter were compared, and the results show that the PV module with a water filter achieved a higher efficiency of 10.24% than the unfiltered PV module, which had an efficiency of 8.82%.

Keywords: *Photovoltaic (PV), PV efficiency, Water-cooling method*

1. INTRODUCTION

Global demand for energy, particularly electricity, has become an excellent opportunity for the utilization of renewable energy resources; since non-renewable energy sources, such as fossil fuels (coal, petroleum and natural gas) are continually depleting. Solar radiation, intercepted here on earth, is many times greater than the present rate of all energy consumption (which is about 1.8 x 10^{11} MW) (Parida et al., 2011). Photovoltaics is one of the best ways to harness solar energy. Photovoltaic systems have a number of merits and unique advantages over conventional power-generating technologies. PV systems can be designed for a variety of applications and operational requirements and can be used for either centralized or distributed power generation. PV systems have no moving parts, are modular, are easily expandable and in some cases, are even transportable. Energy independence and environmental compatibility are two attractive features of PV systems. The fuel (sunlight) is free, and no noise or pollution is created from operating PV systems. In general, PV systems that are well designed and adequately installed require minimal maintenance and have long service lives. Even though PV technology has excellent potential for the future, unfortunately, it depends significantly on operating temperature. PV efficiency is proved to be a function of operating temperature (Lee & Tay, 2012; Skoplaki & Palyvos, 2009). The outdoor performance of photovoltaic (PV) modules suffer from the high temperatures that are reached under high irradiation and the efficiency of a PV panel to convert solar radiation into electricity drops significantly.

The water-cooling method is one approach applied by researchers. Various designs have been applied using this method. For example, the operation of a water spray system every five minutes, with the assistance of a water pump, could reduce the PV temperature by 10ºC (Kordzadeh, 2010). Then, the simulation of a water spray system every 10 minutes indicates that the inlet water temperature is an important parameter to be controlled. A lower temperature of inlet water, which is around 20ºC, could obtain a PV efficiency of approximately 12.06%. However, PV efficiency drops by 2.18% once the PV panel reaches 45ºC. This proves that the temperature of a PV panel affects the performance of the PV panel. One of the suggested ways for improving the system's operation is by using a thin film of water. This study intends to investigate the performance of PV with a 10mm water filter using an unfiltered PV panel. The primary function of the water filter is to eliminate the components of solar radiation, such as UV and Infrared since the PV module converts selected wavelength bands; precisely 0.35 to 0.82 µm (Baradey et al., 2016; Hawlader et al., 2012).

2. EXPERIMENTS

A setup was designed to investigate how the operating temperature of PV affects efficiency. Figure 1 shows the schematic of the experimental setup for a 10mm water filter. For unfiltered PV panel experiments, the water filter was removed so that the PV panel was exposed to direct incident solar radiation. Thermocouple wire is attached at the top and the bottom of the PV panel to measure temperature. Next, other parameters, such as output voltage, short circuit current, and solar radiation, were recorded using multimeter and pyranometer.

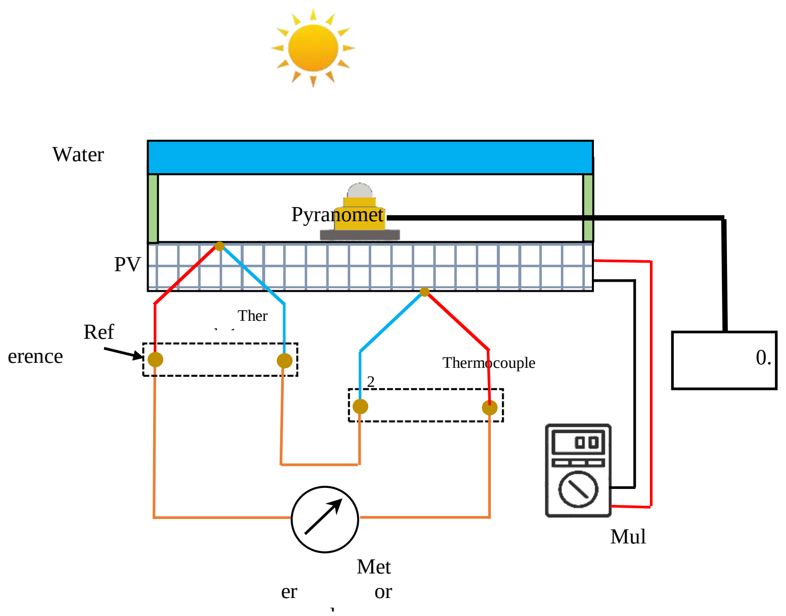

Fig.1: The schematic of an experiment setup for a 10mm filtered PV panel with water

3. THE EXPERIMENTAL RESULTS

3.1 Results of Unfiltered PV Panel

The experiments of an unfiltered PV panel was conducted for approximately 45 minutes. The highest irradiation during this experiment was recorded at 985.6 W/m^2, while the lowest irradiation was 534.6 W/m^2. Figures 2 and 3 show the relation of solar irradiation towards the output voltage and current generated by the PV module. Based on the results, the highest voltage was 19.74V and the lowest voltage was 18.8V. Meanwhile, the maximum current generated was 5.92A and the minimum current was 2.62A. The temperature at the bottom of the PV panel was higher than at the top of the PV panel. The maximum temperature (at the top of the PV) was 51ºC and the minimum temperature (at the top of the PV) was 47.8ºC. Meanwhile, the maximum temperature (at the bottom of the PV) was 53.8ºC and the minimum temperature (at the bottom of the PV) was 49.5ºC. The average voltage, current, irradiation and temperature for both sides of the (unfiltered) PV panel were calculated and are summarized in Table 1. Next, based on the data, the efficiency of the PV module was calculated to be equal to 8.82%. Figure 4 demonstrates how the increase of PV temperature affects PV efficiency.

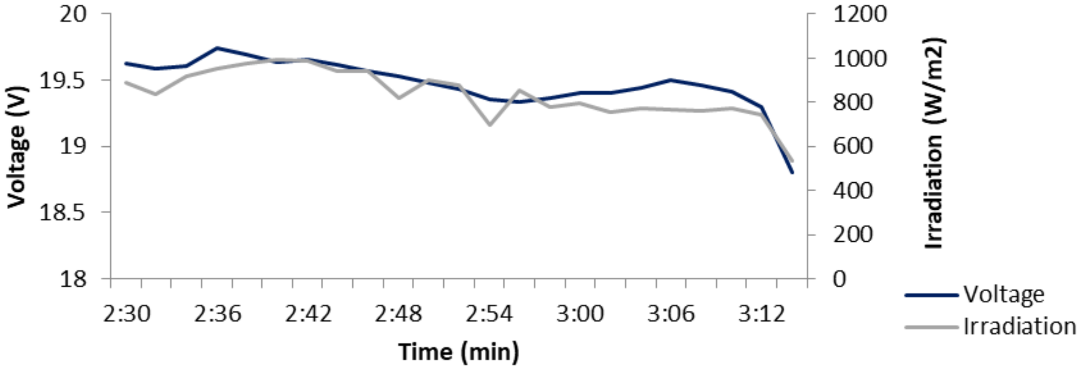

Fig.2: Transmitted irradiation and voltage vs time (unfiltered)

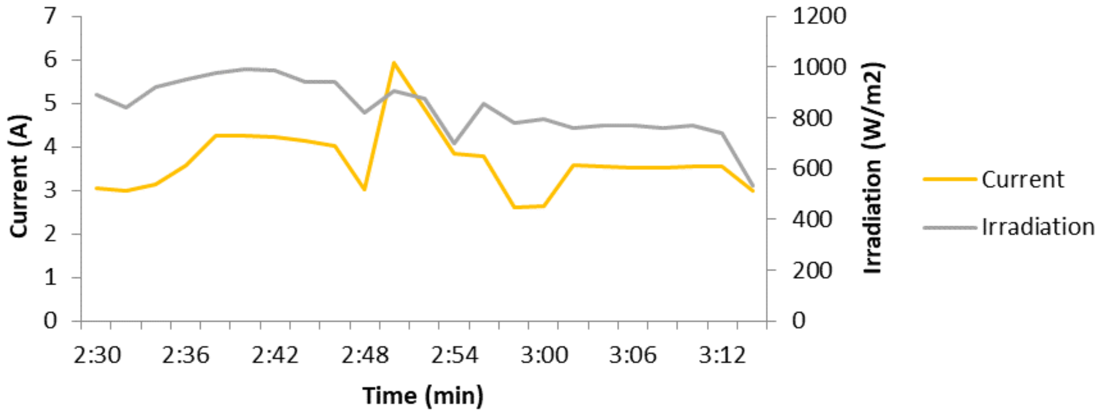

Fig.3: Transmitted irradiation and current vs time (unfiltered)

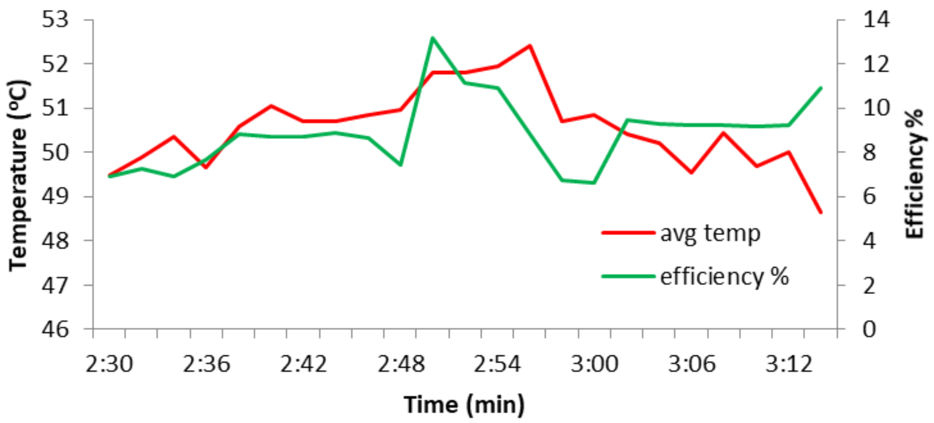

Fig.4: Average temperature and PV efficiency vs time (unfiltered)

3.2 Results of 10mm Filtered PV Panel with Water

A water container was added to the filtered PV experimental setup. The experiment was conducted with a similar time range of approximately 45 minutes. The highest transmitted irradiation was found to be 672 W/m^2, while the lowest transmitted irradiation was 619 W/m^2. Figures 5 and 6 show the effects of the amount of transmitted irradiation towards the output voltage and current generated. The highest voltage found was 19.72 V and the lowest voltage was 18.85V. Meanwhile, the maximum current generated was 3.49A and the minimum was 2.94A. As shown, the temperature at the bottom of the PV panel was higher than the temperature at the top of the PV panel. Next, the average filtered PV efficiency (with water) was measured based on the data gathered. The efficiency of 10mm filtered PV with water was higher than the efficiency of unfiltered PV by 1.42%. Referring to Table 1, the average temperatures at the top and bottom of the filtered PV panel with water were higher than the unfiltered PV panel; because filtered PV acquired higher transmitted irradiation. However, filtered PV generated higher efficiency at around 10.24%; because the water filter eliminated unconverted solar radiation. Furthermore, the water filter was capable of maintaining the PV temperature so that the performance of the PV module could maintain a high rate (as shown in Figure 7).

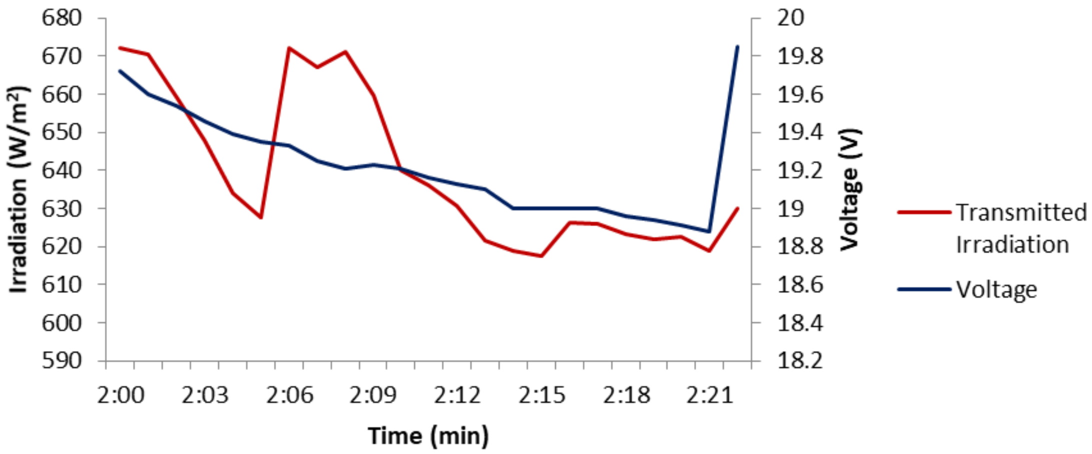

Fig.5: Transmitted irradiation and voltage vs time (10mm filtered PV with water)

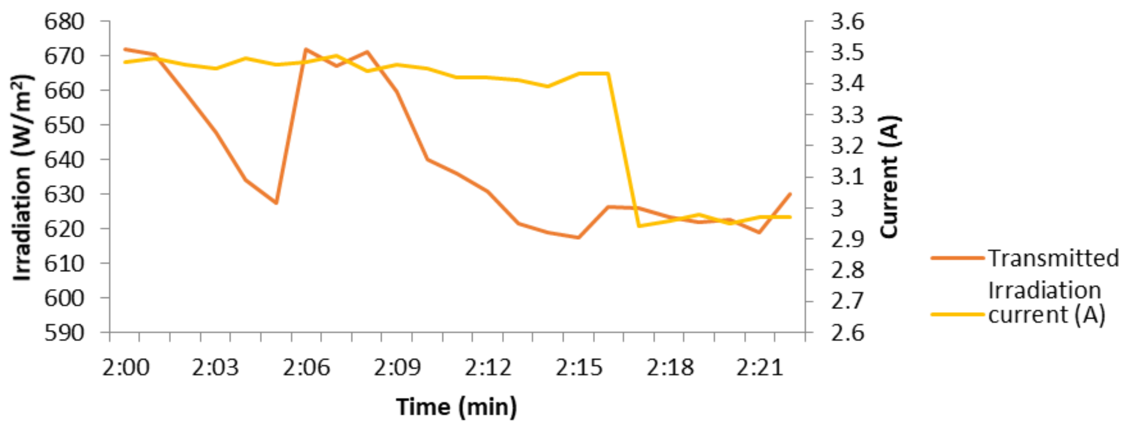

Fig.6: Transmitted irradiation and current vs time (10mm filtered PV with water)

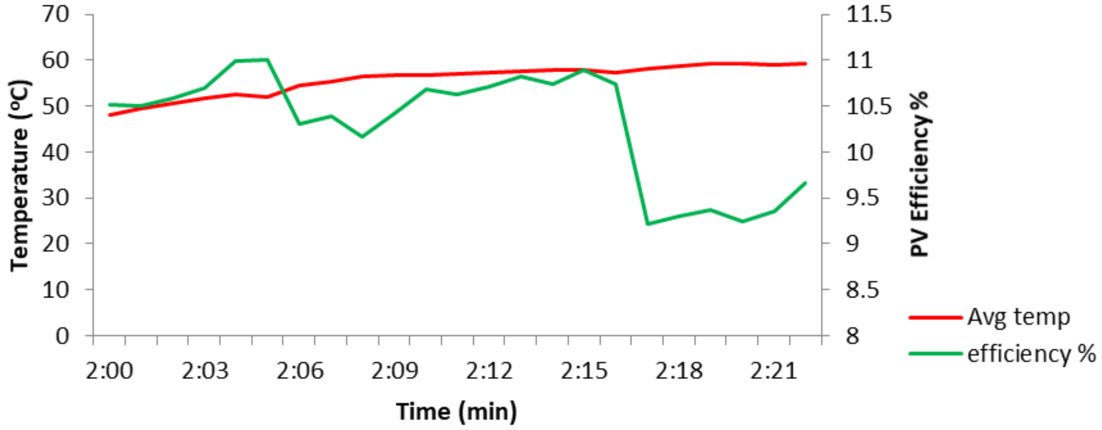

Fig.7: Average temperature and PV efficiency vs time (10mm filtered PV with water)

Table 1 Results for unfiltered PV and 10mm filtered PV panels

Results / Conditions	Unfiltered PV	10mm Filtered PV with water
The average temperature at the top of the PV panel (°C)	49.49	56.9
The average temperature at the bottom of the PV panel (°C)	51.61	58.59
The average current generated (A)	3.66	4.44
The average voltage generated (V)	19.47	18.84
Average incident irradiation (W/m^2)	837.82	1030.25
Average transmitted irradiation (W/m^2)	675.45	844.5
PV efficiency (%)	8.82	10.24

4. CONCLUSIONS AND FUTURE RECOMMENDATIONS

Based on the calculated results, the performance of a 10mm filtered PV panel with water obtained higher efficiency than the unfiltered PV panel, due to waters capability of filtering unwanted solar wavelength and absorbing more excess heat. However, there is one parameter that should be considered; how long can the water filter be used to sustain a higher PV efficiency? Therefore, future research on the relation of water temperature in the container with PV performance should be investigated.

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