Solar PV Surface Cooling Using Small Companion Solar Cell-Blowers

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ABSTRACT Solar PV surface temperature has been shown to affect the performance of Solar PV especially in temperate and dry weather systems. Many innovative solutions have been proposed by researchers to reduce the operating temperature of the solar PV. Most of this solution is more inclined in using active cooling methods as opposed to the passive cooling method. This is because the active cooling method tends to have a better cooling effect as compared to passive cooling method. However, it is also known that active cooling method is expensive due to the underlying maintenance work and drawing power from the main solar PV system. In this paper, a cooling technique based on the forced air-cooling method is proposed and experimented. The companion system is relying on small blowers powered by small independent solar cell; providing forced air cooling based on the intensity of solar radiation at any given time of day. This system was experimented under a halogen lamp in the lab to establish the power-light intensity-temperature relation. Experiment result shows that average solar PV surface temperature was reduced up to 6 °C using 2 blowers while a single blower able to reduce average surface temperature up to 4 °C at 15600 lx by a direct halogen lamp. On average, the solar PV efficiency was increased by 4% especially using a 2-blower configuration. The result of this experiment shows that a small independent solar-powered blower system was able to cool down solar PV surface temperature and increases solar PV efficiency at minimal maintenance effort.

KEYWORDS: PV Temperature, Solar panel, Cooling system, Active Cooling, Efficiency
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INTRODUCTION

We use energy every day of our lives. The places we work using computers, phone networks, security systems and servers, as do our shopping malls, parking lots, sports stadiums, cars, airplanes and so on. All these things require power from fuel. Sources that will be used up or will never be restored produces non-renewable energy Renewable energy is an energy that is collected from resources that can be renewed, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, and geothermal heat. The main component of a solar power system is the solar panel. The main factors that affect the electrical efficiency of the solar panel are operating temperature and solar radiation. Solar panels transformed solar radiation intensity into electricity with an efficiency of 25% in the lab and less than 22.8% commercially today. If the temperature of solar cells increases by 1K, there will be a decrease in electrical efficiency by 0.4 – 0.5% (Bianchini *et al.*, 2017).

In literature, research on the cooling method was done by Venkateswari & Sreejith (2019), Tucci *et al.* (2013), Fouad *et al.* (2017), and Siecker *et al*. (2017). They reported that the solar panel efficiency can be enhanced by considering the basic material used for solar cells. The technological efficiency limit that can be attained for single-band-gap p-n junction silicon solar cells is about 28% although it is continuing to develop (Tucci *et al.*, 2013). The rest of the solar energy received by the solar panel is turned into thermal energy. Siecker *et al*. (2017) stated that the amount of solar energy absorbed by solar panels is less due to the temperature rise. A high temperature will result in low power output and not an efficient way to use energy. Fouad *et al.* (2017) observed the factors that influence the performance of photovoltaic cells. They found those factors include environmental, installation, cost as well as miscellaneous factors. The main factor was the temperature of the solar cell. The higher the temperature of the solar cell, the lower the power output of the solar cell. These findings indicate the need to cool the temperature to increase the power output of the solar cell.

Study identifying the need for a good cooling system were done by Guramun *et al.* (2018), Grubišić-Čabo *et al*. (2016), and Bahaidarah (2013). by Guramun *et al.* (2018) and Grubišić-Čabo *et al*. (2016) have reviewed a few active and passive methods to cool down solar PV surface temperature as each temperature increase would drops efficiency by approximately 0.5%. Bahaidarah (2013) showed that they managed to cool a monocrystalline PV module with an area of 1.24 m^2 from the backside, via closed casing through which a flow of water is established. The maximum increase in efficiency, when compared with the non-cooled module is a total of 2.8% and the decrease of module temperature is 10 °C. Considering the size of the panel, the rise in efficiency is significant.

The active cooling technique with air and water managed to cool down the solar panel. However, existing solutions were using direct connect systems for power supply as a source of energy to run the cooling process. In this research, a small capacity solar cell coupled with blowers were integrated as a companion device to cool down the surface of the solar PV. Thus, the objective of this paper is to investigate the effect of the companion solar cell-blower on the average power output of a small solar PV system.

METHODOLOGY

A companion solar cell-blowers consist of small solar PV wired directly with small blowers attached to a predetermined sized solar PV. The power of the blowers is dependent on instantaneous solar radiation or light intensity; a higher intense solar radiation will produce stronger airflow in the blower. The airflow will change depending on the solar radiation variance of the day. The blowers are located at the bottom of the solar PV in an air straightener to allows cooling air to flow thru the surface of the solar PV as shown in Figure 1.

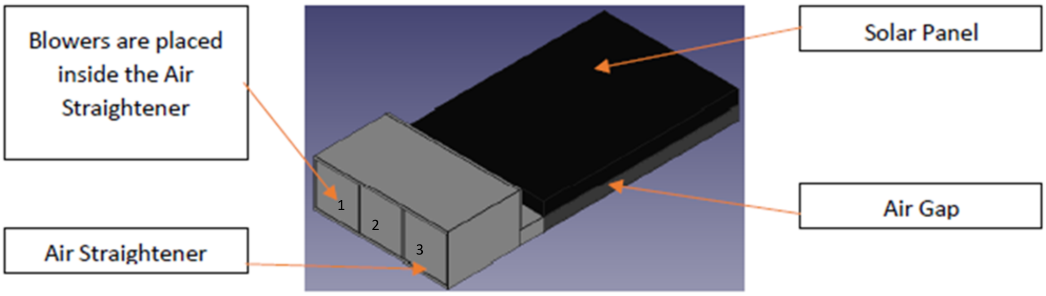

Figure 1. Companion Solar Cell-Blowe

In this experiment, a 60-Watt Mono-crystalline Silicon Solar PV was used as the main panel while a 5-Watt mini solar cell connected to blower functioned as the companion cooling device. To demonstrate the effect of the cooling device, the experiments were done using three setups; a control standalone solar PV, a solar PV connected with one blower and another with two blowers. One blower is placed at inlet 2 of the air straightener in a single blower configuration and a blower is placed on inlet 1 and inlet 3 for 2-blower configuration. A variable halogen lamp rated at 500 Watt was used to simulate light at different intensity (Moria *et al*., 2016). An environment meter Model ET-965 was used to record the light intensity and airflow rate. An infrared thermometer was used to measure the average surface temperature of the solar PV while a digital multimeter was used to measure the volt and current of the solar PV. The experimental setup for the solar PV is as shown in Figure 2.

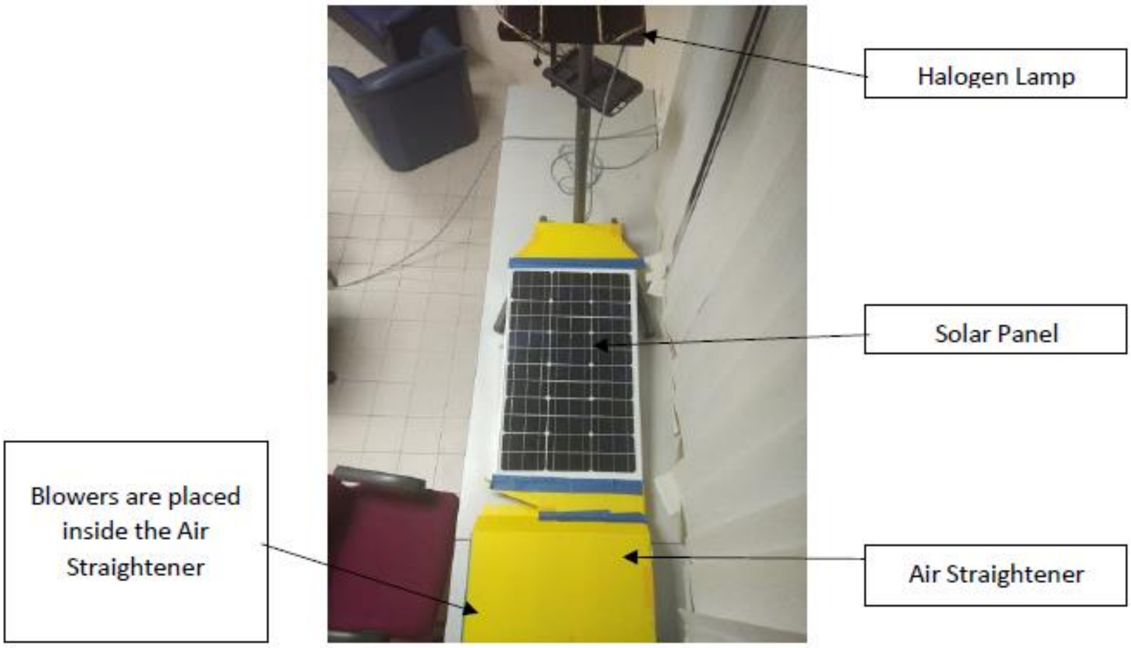

Figure 2. Experimental setup of Solar PV with Companion Solar Cell-Blower

To study the solar panel performance, the power of the solar panel can be calculated by Equation (1) whereas the efficiency of the solar panel is calculated by using Equation (2).

$$P_{pv} = I_{SC} V_{OC} \quad (1)$$

$$\eta_{pv} = \frac{P_{pv} F_f}{P_{in}} \quad (2)$$

P_{pv} is power, V_{OC} open circuit voltage, I_{SC} is short-circuit current, η_{pv} is efficiency, F_f fill factor and P_{in} input power.

RESULT AND DISCUSSION

The experimental work shows two important criteria; the solar PV surface temperature and solar power output.

Solar PV Surface Temperature

The average surface temperature of the solar PV recorded at different lux and three configurations are as shown in Table 1. In general, the increase of the light intensity increases the surface temperature up to 70.4 ^{0}C recorded in the control configuration. Solar PV surface temperature with blowers shows reduced temperature compared with the control configuration being double-blower setup has lower average temperature compared to a single blower setup.

The lowest average cell temperature for no cooling experiment recorded is 63.6 ^{o}C and for cooling with one blower and two blowers are 60.4 ^{o}C and 58.7 ^{o}C. The average temperature decreases about 2- 3^{o}C when the blowers are used. However, using two blowers is higher as compared to using a single blower even though the mass flowrate is lower in all light intensity range. At 15600 lx, 2-blower configuration records 8% in temperature reduction while 1-blower configuration records 5% temperature reduction. The trend can be observed throughout the experiment's radiation range. This is because both configurations use a single solar cell, thus the mass flow rate in a 2-blower configuration is lower compared to a single blower configuration. However, lower temperature reduction observed probably due to better air distribution by the 2-blower configuration due to its placement in the inlet of solar PV.

Table 1. Solar PV Average Surface Temperature at Different Light Intensity

Light Intensity (lx)	Cell Temperature (°C)			Mass Flowrate (kg/s)	
	No Cooling	1 Blower	2 Blowers	1 Blower	2 Blowers
8400	63.6	60.4	58.7	0.01386	0.0099
10800	66.4	62.3	60.1	0.01435	0.01287
13200	68.6	64.7	62.4	0.01485	0.01386
15600	70.4	66.7	64.8	0.01535	0.01485

Solar PV Power Output

The power output of a solar panel generally depends on the value of current and voltage. As the current and voltage data recorded, the power of PV for each experiment was calculated using equation 2. The results are tabled in Table 2. The graph shows the PV power output on the two-blower configuration was higher compared to the control and single blower configuration. The highest value of PV power is 53 W when 2 blowers are used while the value of PV power without cooling is recorded at 51 W.

Table 2. Solar PV Power Output

Light intensity (lx)	Power (W)		
	No Cooling	1 Blower	2 Blowers
8400	47.7	49.4	50.2
10800	48.6	50.4	51.3
13200	50.2	51.7	52.4
15600	51.1	52.2	53.0

PV power increases when 2 blowers are used as the reduced temperature of the solar panel affects the power output. The average temperature is lower when 2 blowers configurations were used compared to when there is no cooling. When the average temperature is low, the power generated by the solar panel is higher, as agreed by existing literature and study. However, a lower average temperature is achieved albeit at a lower mass flow rate probably due to better air distribution from the two-air inlet. This means better surface contact between the air and the solar PV surface promoting better average temperature.

The generated power at different radiation was fitted into a measured daily solar radiation (Rahim, 2019) expressed in the form of light intensity as shown in figure 3. The average generated power for Solar PV without cooling, 1-blower and 2-blower is 48.87W, 50.6W, and 51.5W respectively.

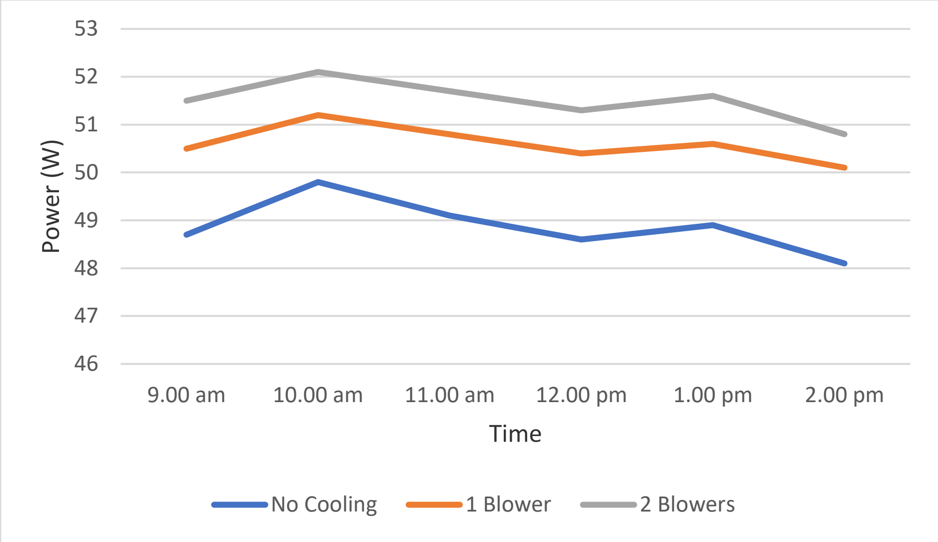

Figure 3. Fitted Solar PV Output

CONCLUSION AND RECOMMENDATION

Forced air cooling is a proven method to cool down the surface temperature of solar PV and produce better power output compared to conventional solar PV. However, traditional forced-air cooling is bulky, consumed a lot of electric energy from the generated power, requires maintenance and expensive. In this paper, an alternative forced air cooling for solar PV based on direct light intensity in a small cheap companion solar cell-blower setup has experimented with.

The experimental results obtained from this research show an improvement of power output in Solar PV with companion solar cell-blower configuration compared to a standalone solar PV. With the current solar cell-blower option, a two-blower setup gives better power output compared to a single blower at no additional power cost to the main system.

The solar power efficiency shows an increase of up to 4% recorded with a two-blower configuration. Although this value is relatively minuscule, the effect of a companion solar cell-blower towards the electrical efficiency of the PV panel was notable.

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