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Power Enhancement of Monocrystalline Solar Panel with Passive Cooling

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Abstract. *The need for energy every year both in the domestic and global increases. Indonesia's energy needs are predicted to increase by 5% each year. Indonesia has renewable energy potential from solar, hydropower, wind, and geothermal sources. The potential of new renewable energy amounted to 442 GW. Of the 442 GW, the greatest potential is owned by 207 GW of solar energy. The high potential of solar energy in Indonesia is because Indonesia is located in the tropics which experiences sunshine time of approximately 6-8 hours per day and the sun continues to shine throughout the year. However, the length of irradiation also has an impact on increasing the temperature of solar panels. The higher the temperature of the solar panel, the output power will decrease and the life of the solar panel is reduced. The use of passive cooling from reference has a lower efficiency increase than active cooling. However, its installation requires lower costs, minimal maintenance, and no additional power requirements. This research will use 20WP monocrystalline solar panels with three cooling variations, namely: 1) with the addition of a thin aluminum plate and Vortex generator 2) By giving a tub of water under the panel 3) the Addition of aluminum fin. The three variations are compared with solar panels without cooling. The results on the first day showed a decrease in temperature of 2.30C with aluminum fin and an increase in power of 6.97% when using a water container. On the second day, a temperature decrease of 2.90C and a power increase of 5.81% when using aluminum fin coolers were recorded.*

Keywords *- monocrystalline; passive cooling; solar panel*

INTRODUCTION

A. Solar Energy Potential

The need for energy every year both in the domestic and global increases. Indonesia's energy needs are predicted to increase by 5% each year [1] .Current energy needs are met mostly from non-renewable fossil fuels. In addition to being non-renewable, fossil resources produce emissions, pollution and increase the greenhouse effect which can increase the earth's temperature. Therefore, countries that are members of the G20 have gradually agreed to reduce carbon emissions, one of which is by increasing the utilization of renewable energy.

The potential for renewable energy in Indonesia is tremendous. Indonesia has renewable energy potential from solar, hydropower, wind, to geothermal sources. This enormous energy potential must continue to be developed by the government. The potential of new renewable energy amounted to 442 GW. Of the 442 GW, the greatest potential is owned by 207 GW of solar energy, 94.3 Gw of water energy, and 60.6 GW of wind energy [2]. Most of the EBT is used for power generation, and the rest is in the form of transportation and industry. The high potential of solar energy in Indonesia is due to the fact that Indonesia is located in the tropics which experiences sunshine time of approximately 6-8 hours per day and the sun continues to shine throughout the year. The duration of this irradiation exceeds the ideal 4-5 hours. One of the utilization of solar energy is by using Photovoltaic. The government encourages the installation of solar panels on the roof to increase the achievement of EBT targets so that carbon emissions can be reduced and utilize vacant land on the roof of the building/house.

B. Photovoltaic Type

Monocrystalline photovoltaics consist of pure silicon that is produced by slicing it into thin crystalline pieces. It is this difference in material that distinguishes monocrystalline and polycrystalline. The efficiency of monocrystalline solar panels ranges from 15-20% while polycrystalline is 13-15%.[3].

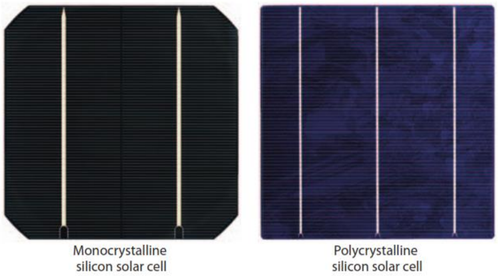


Figure. 1 comparison of monocrystalline and polycrystalline [4]

The backside of solar panels is generally coated by polymers of various types but the most commonly used are PP, PVF, and PET as they offer varying degrees of thermal stability, physical protection, and UV resistance but do not conduct heat well so that the surface of the solar panel can be continuously increased.

The average solar irradiation is 6-8 hours per day. The temperature of the solar panel is certainly affected by the length of irradiation, ambient temperature, and sunlight intensity. From data [5] the average temperature in East Java in 2020 reached 28.2C and the highest temperature reached 35.6C with 74% solar irradiation.

C. Previous Research

The increase of PV cell surface temperature causes the circuit resistance to increase, and this limits the electron velocity, which directly affects the open circuit voltage and greatly affects the cell material [6]. Figure 2 shows the effect of increasing temperature on the output power of various solar cell materials. There is a voltage drop of about 0.12 V, and thus the temperature coefficient is 0.12V/C for every 1 C increase in cell temperature in polycrystalline PV [7]. Excessively high panel temperatures can also reduce the lifespan of solar panels.

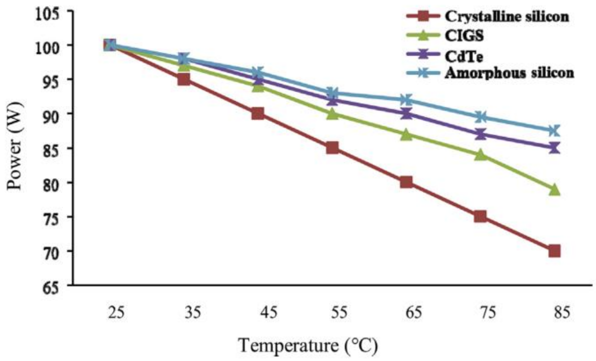


Figure 2. Effect of temperature on power[7]

There are several solar panel cooling methods generally divided into active and passive cooling. [8] adds PCM cooling & PCM with additives methods as shown in Figure 3.

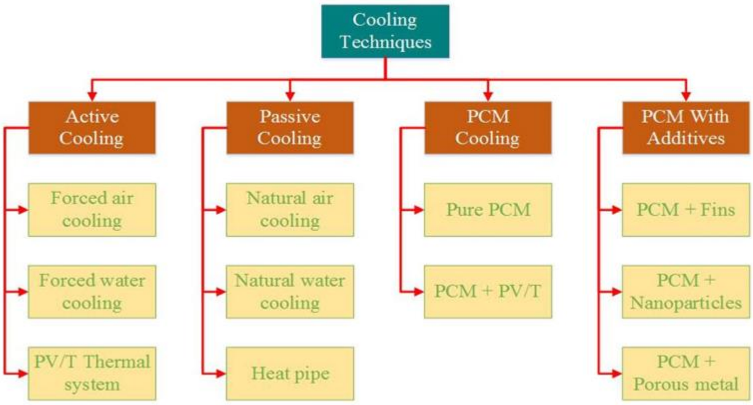
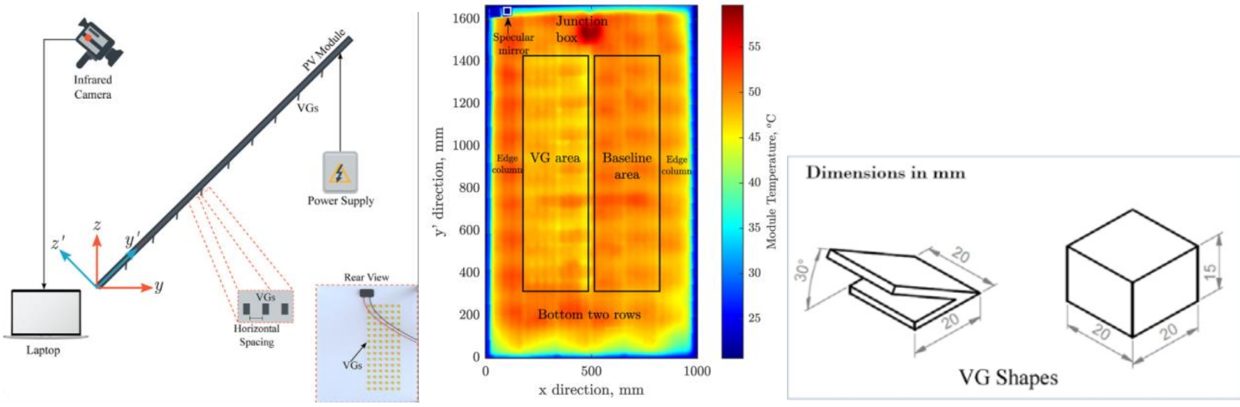


Figure 3. Solar panel cooling type [8]

The addition of fin aims to expand the heat transfer area. Some researchers who use aluminum fin include [9];[10]; [11]; and [12]. Fin with aluminum material has a high thermal conductivity, the price is cheap, easy to shape and easy to find. Fin with copper and aluminum materials researched by [10]as shown in Figure 5 to compare the increase in efficiency, the result is an increase in efficiency of copper fin by 4.07% and aluminum by 2.17%. Although able to increase efficiency higher than aluminum, but copper has a higher price.

Other researchers used metals with shapes other than fins for passive cooling. [9] compared passive cooling of fin and circular threaded fin shapes with an increase in efficiency of 14.5 and 13.2%. [13] used mesh with iron and aluminum materials which were able to increase the efficiency of 0.11% and 1.44% and were able to reduce 4.35C for iron mesh and 6.56 C for aluminum mesh. The addition of a vortex generator on the back of the panel was carried out by [14]with the CFD simulation method being able to reduce the temperature of the solar panel up to 3C for the rectangular wing type. Vortex generator is a device that can increase the heat transfer coefficient through delaying sparation, accelerating turbulence growth [15]. In addition to the utilization of fins and heat-conducting metals, [16] compared the increase in output power between the addition of fins and the installation of panels in floating conditions in water, the result was an increase in output of 14.31% in the addition of fins and 30.54% in the installation of floating panels above water.

Comparison of output power using passive cooling with aluminum plates plus vortex generators, solar panels floating on water and solar panels with the addition of aluminum fins is very interesting to study because it is economical, easy to apply, and the increase in output power is predicted to be quite high with a decrease in heat loss.



A B C

Figure 4. [14] (a) VG arrays on solar panels (b) temperature comparison on solar panels with VG and without VG (c) VG shape

Photovoltaic technology is increasingly developing as seen from the increasing efficiency of solar panels, one type of solar cell that has high efficiency is the monocrystalline type which has an efficiency of around 15-20%, while pollycristalline solar panels have a lower efficiency. The efficiency of solar panels is also determined by the temperature conditions of the solar panels. There is a linear decrease in power efficiency as temperature increases (Amr et al., 2019).

Based on previous research, active cooling can increase efficiency higher than passive cooling. However, active cooling requires additional energy and large maintenance costs. The use of active cooling by [17] and [18] requires pumps and circulating water to cool the panel surface.

Aluminum is used as a passive coolant because it is easy to find, easy to shape, has a cheap price but has great thermal conductivity. The increased temperature of the panel causes the output power and panel life to be reduced. Therefore, this research is very important to give an overview of which passive refrigerants are effective. The research used 20WP monocrystalline solar panels with three cooling variations: 1) adding thin aluminum plates and Vortex generators 2) adding aluminum fin 3) giving water container.

METHOD

A. Location and Time.

The research was conducted experimentally by taking the panels temperature, light intensity, current, and voltage for 2 days on August 22-23 2023 commencing at 08.00-16.00 GMT +7. Data gathering was done every 10 minutes in light and cloud situations. Tests are intended to be carried out on the rooftop of the ISDB Bio Engineering

Building, located at coordinates -8.162664, 113.721337. Tests were carried upon the roof to acquire fundamental light without covered shadows from trees/buildings that could lower output power.

Based on data from https://globalsolaratlas.info/ The best annual slope of solar panels is 12°. With the solar panel facing north. Following the benchmark data, the solar panel will later be tilted 12^0 and oriented north so that it may indicate the electricity it can generate for a year. Given the solar panels used on roofs more type fixed without utilizing solar tracker.

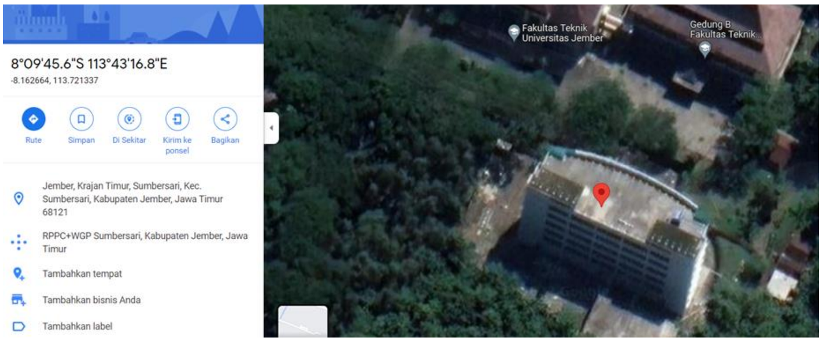


Figure 5. Experiment Location

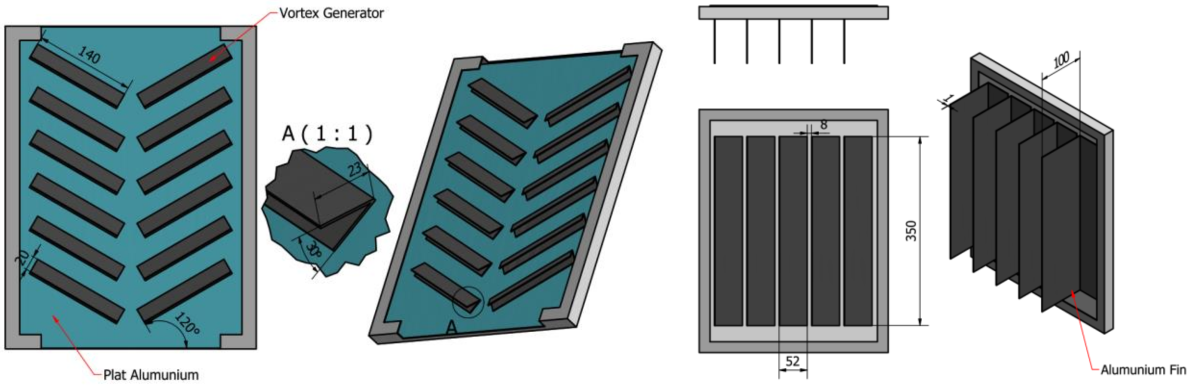
B. Experimental Setup

The monocrystalline solar panels that will be used in this study are 4 units with a power of 20WP each panel. The four solar panels are installed simultaneously to get a comparison of the same solar condition data. The fin is joined to the underneath of the panel with thermal paste.

Figure 6. Experiment Setup

Picture description:

1. Solar panel with the addition of water in a container under the solar panel
2. Solar panel with aluminum fin extended surface cooling
3. Solar panel with the addition of aluminum plate and vortex generator rectangular fin
4. Solar panel without cooling
5. Lux meter
6. Water Container
7. Thermocouple reader
8. Avometer
9. Ambient temperature monitor



(A) (B)

Figure 7. (a) aluminum sheet+ VG configuration (b) Aluminum fin configuration

RESULTS

A. Solar panel power distribution

From the results of experimental studies conducted for 2 days, it was found that the effect of power changes on the variation of cooling types. The rise and fall of power on solar panels depends on light intensity. Figure 8 shows that the highest power on the first day of 28.288W was achieved at 10:50 am using a water container cooler. At 10:50 am, the passive cooling power was sequentially 28.288W with water container cooling, 27.797W with aluminum fin cooling, 27.324W with aluminum sheet +VG cooling, and the smallest 26.445W without cooling.

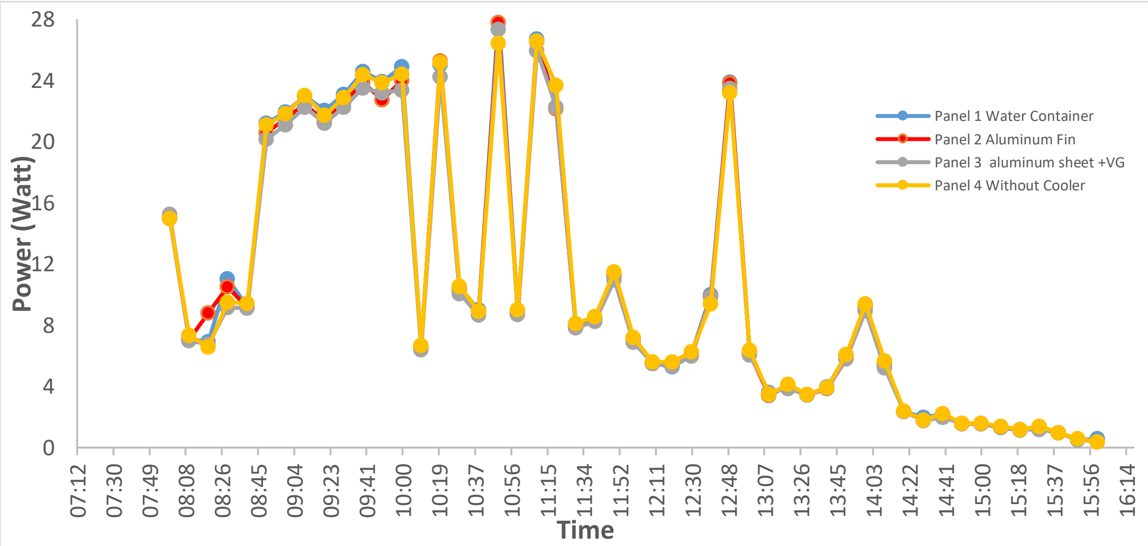


Figure 8. Effect passive cooling on solar panel Power, Day 1

In Figure 9, which shows the effect of passive cooling on solar panel power on the second day, the aluminum fin cooler at 10:50 am produces the highest power of 26.412 W followed by the water container cooler and aluminum sheet + VG. From the results of the first and second day of testing there was an increase in power compared to without cooling. From the results of the first and second day of the experiment, there was an increase in power compared to without cooling. On the first day there was an increase in power of 6.97% when using a water container cooler. On the second day there was an increase in power of 5.81% when using aluminum fin coolers.

The findings of this experimental research with the addition of various types of passive cooling on solar panels can increase the output power compared to without cooling, especially when the sun intensity is high. The power output of solar panels with aluminum fin and water container cooling tends to be higher than that of aluminum sheet + VG. This can be caused by the tilt of the solar panel by 12^0 inhibiting wind flow from the front side.

Cooling using a water container is similar to the application of a floating solar panel system that is widely applied to lakes or calm waters that can contribute to generating electricity and reducing water evaporation. Research by adding a water container cooler as a passive cooler has never been done before using monocrystalline type solar panels. However, research on floating polycrystalline type solar panels has been conducted by Chico et al. [16] .The presence of water under the solar panel can increase the power of the solar panel up to 30.54% Chico et al. [16]. Compared to the study of Chico et al. the power increase in this study was lower. The increase in power cannot be as high as Chico et al. possibly because Chico et al. used a water container size that has a larger area than the solar panel area. Increasing humidity with the addition of ultrasonic humidifier and fin as active cooling was done by Ephraim et al. [19], with an increase in humidity behind 30 W polycrystalline panels can help increase power up to 12.51% with a water requirement of 0.015 L/hour. Aluminum fin passive cooling is able to increase power up to 5.81%, this result is lower than Khuram P.A et.al [9] which is able to increase power up to 14% on 50W polycrystalline solar panels.

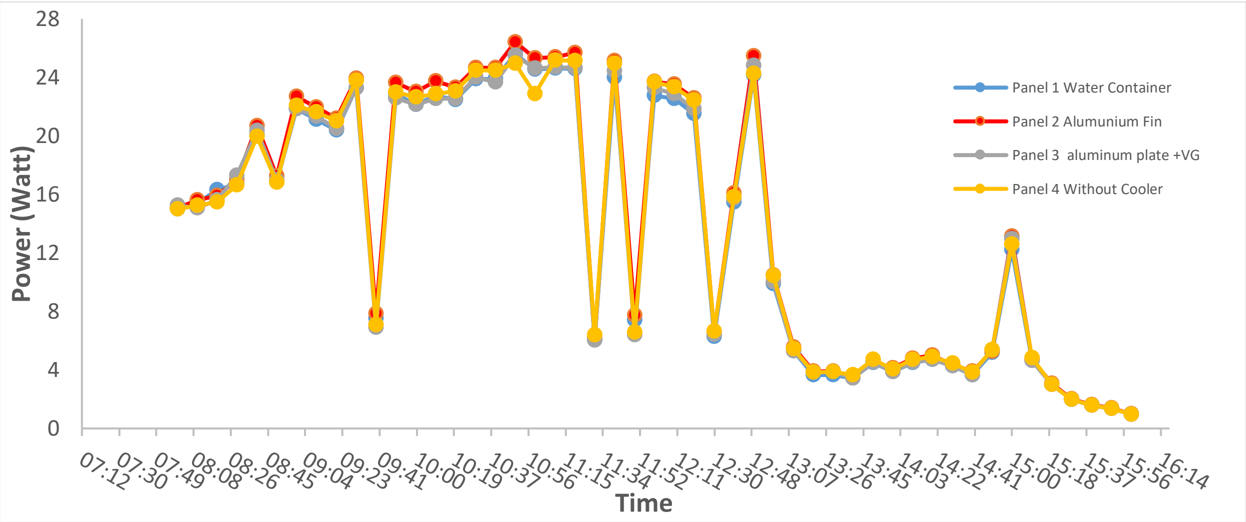


Figure 9. Effect passive cooling on solar panel Power, Day 2

B. Solar panel surface temperature

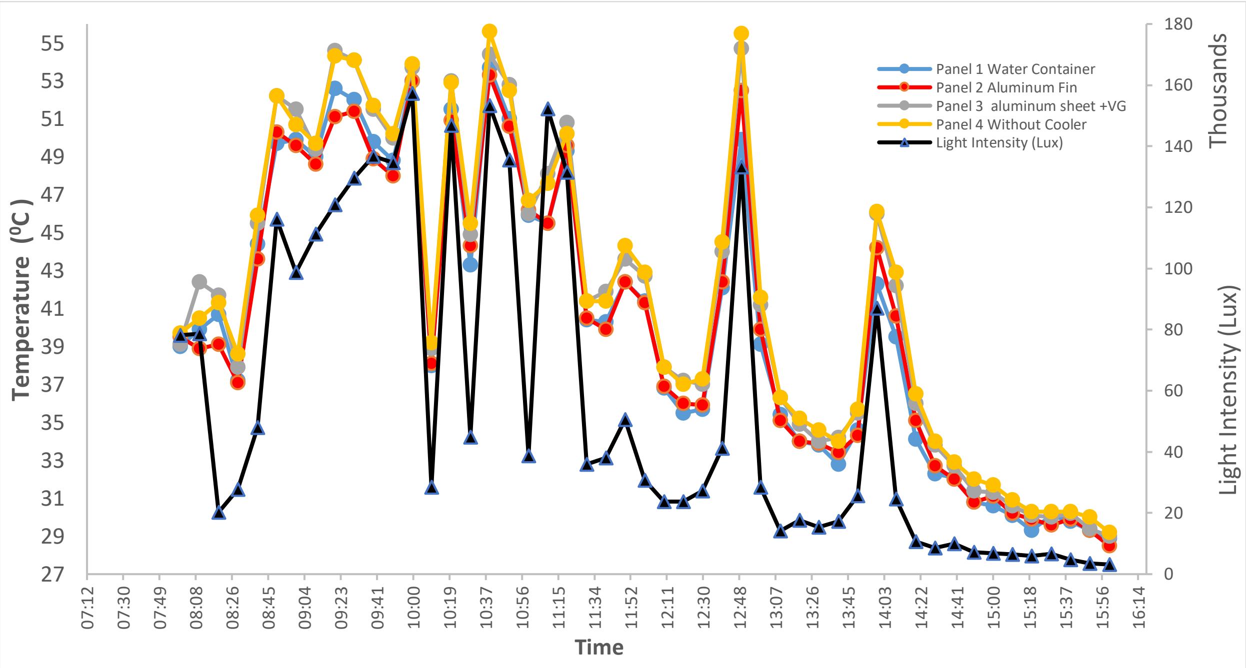


Figure 10. Effect passive cooling on solar panel surface temperature, Day 1

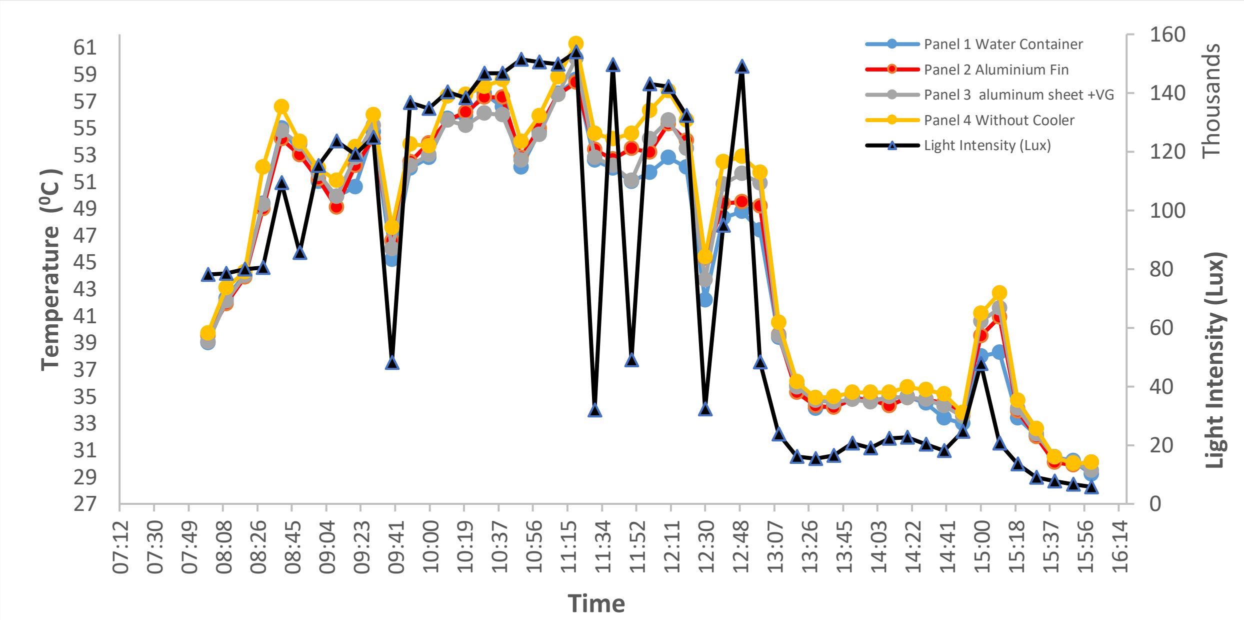


Figure 11. Effect passive cooling on solar panel surface temperature, Day 2

The effect of adding passive cooling on the temperature of the solar panels is demonstrated in Figures 10 and 11. On the first day, the greatest panel temperature was attained at 10:40 am which had a light intensity of 153300 Lux on the panel without cooler with a temperature of 55.6 ^{0}C and the lowest by utilizing a passive cooler Aluminum fin 53.3 ^{0}C so there was a temperature difference of 2.3^{0}C. The temperature increase on solar panels relies on the light intensity. The longer the light intensity is high, the higher the surface temperature. On the second day, the greatest temperature was recorded at 11:20 am with a temperature of 61.3^{0}C in the condition without cooler, and the lowest temperature and temperature at 11:20 am of 58.4 ^{0}C such that the temperature difference between passive cooler aluminum fin and without cooler was 2.9 ^{0}C.

The decrease in temperature affects the power output. The decrease in temperature with the use of passive cooling in this study implied an increase in output power. The addition of heat transfer area with the addition of aluminum fin can reduce the temperature of the solar panel. Aluminum was chosen because it has a high thermal conductivity k = 205 $W.m^{-1}K^{-1}$.

The temperature reduction in passive cooling with aluminum fin is lower than copper fin as has been done by Parkunam et.al[10] .When using aluminum fin Parkunam et.al was able to reduce the maximum temperature of 1.9 ^{0}C and 9.5 ^{0}C when using copper fin. this is due to copper fin has thermal conductivity twice as large as aluminum. The higher the temperature on the surface of the solar panel caused by an increase in solar intensity, the greater the potential for reducing the panel temperature with the addition of passive cooling. Khuram P.A et.al [9] was able to reduce the temperature of his panel by 6°C from 64°C to 58°C. Zainal Arifin et.all [20] conducted a numerical study of the effect of adding aluminum fins and wind speed of 1.5m/s and irradiance of 1000W/m^2, the result was a temperature drop of 12.5°C.

CONCLUSIONS

Modifications aimed at cooling solar panels are carried out in this study. Cooling the solar panel in addition to increasing the power also aims to increase the life of the solar panel itself. The addition of a passive cooler that does not require additional power was tested in a study conducted over 2 days. On the first day, the highest power of 28.288W was achieved at 10:50 am using a water container cooler. The use of Aluminum fin passive cooler can reduce the temperature up to 2.3^{0}C. On the day showed aluminum fin cooler at 10.50 am produces the highest power of 26.412 W. And at 11:20 am 58.4C so that the temperature difference between the aluminum fin passive cooler and without cooler by 2.9 ^{0}C. Of the three pasive coolers used in outline passive coolers from the best in order, namely aluminum fin coolers, water containers, and finally aluminum sheet + VG. For the next researcher will examine the effect of wind speed and the addition of wind direction to increase the cooling temperature of solar panels.

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