Photovoltaic Performance with Heat Sink from Copper and Aluminum Material

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Abstract. Energy becomes a basic human need, so energy reserves are needed. Solar energy is the solution to overcome this problem. Solar energy can be converted into electrical energy through PV panels. However, high temperatures can make PV panels do not work optimally. One way to reduce the temperature is to use a heat sink. The materials used are PV panels without heat sinks, PV panels with aluminum heat sinks, and PV panels with copper heat sinks. This research shows that with the same intensity of 1100 W/m² PV panels without heat sinks, PV panels with aluminum heat sinks and PV panels with copper heat sinks have an efficiency of 8.76%, 10.27% and 11.14%. The result of temperatures 69.7 °C, 60.8 °C and 52.7 °C and the maximum power produced is 35.19 W, 40.17 W and 43.58 W. The results showed that the average working temperature decreased 8.9 °C and 17 °C, thereby increasing output power by 4.98 W and 8.39 W and increasing efficiency by 1.51% and 2.38% without using a heat sink.

Keyword: Photovoltaic; Heatsink; material.

1. Introduction

Energy is a basic need that is inseparable from humans, so energy reserves are needed. Solar energy is a solution for sustainable use because of its abundant amount on earth, one of which is Indonesia. Indonesia is on the equator, which has a daily potential of 4.5 kWh/m² [1]. Solar energy can be utilized to be converted into electrical energy. Solar cells are devices that utilize solar radiation to become electrical energy through the photovoltaic process.

Solar cells have been developed into three generations that have different components in each generation. The most widely used solar cells are first generation made from silicon. The process produced by solar cells has an efficiency of 14% - 20%, the rest is released into the environment and dry. The heat energy generated from solar energy will increase the temperature of solar cells and cause a decrease in efficiency of about 0.4-0.65% every one-degree increase [2].

The temperature of the solar cell that increases will affect the voltage generated because the excitation of electrons in the heat is higher than the excitation in electrical energy for semiconductors. Increased PV panel temperatures can reach 80°C in a blazing region [3]. Excessive increase in the PV panel over the long term will cause damage to the PV panel. Decrease PV panel temperature becomes essential to increase the efficiency and prevent PV panel harm more quickly. Cooling can be divided into two, that passive and active cooling. Active cooling uses additional energy, such as pumps. Passive cooling is the one that can accelerate heat transfer.

The heat sink is one of the passive cooling that can expand heat transfer. Gotmare [4] using an aluminum heat sink with nine holes perforated mounted on the back of the PV panel, the results show...
there is a 5.5% increase in the power produced. Arifin [5] uses ANSYS simulation, with PV panel variations using aluminum heat sinks and not using heatsinks. Their result showed a reduction in temperature in the PV panel reached 10°C. The heat sink can transfer heat from high to low temperatures.

Heat sink undergoes heat transfer by conduction and convection. The rate of heat transfer in a heat sink depends on the constituent material and its geometry [6]. Riupassa [7] analyzes copper and aluminum materials, resulting higher heat transfer rates occur in copper. Heat transfer rates occur better in materials that have high conductivity [7]. The heat sink that will be the object of this research is the material that will be used.

The material will affect to the heat transfer process in the heat sink. The heat sink is mostly made of copper or aluminum [8]. Therefore, this research will use copper and aluminum heat sink material to reduce temperature and improve PV panel performance. The material in this heat sink can increase heat transfer in the PV panel, so the efficiency of the PV panel also increases.

2. Methods

This study aims to determine the effect of copper and aluminum heat sinks on PV panels. The heat sink uses aluminum and copper material. This experiment uses a 50 Wp polycrystalline PV panel with a size of 655 x 670 x 25 mm. Retrieval of data is given a variation of the load on the voltmeter and amperemeter 0, 2.5, 3.5, 4.7, 5.4, 5.8, 6.0, 6.4, 6.6, 6.7, 7.4, 8.5, 13.8, 19.6, 42.5, 111, and 330Ω, obtained the characteristics of the PV panel that forms the I-V curve in each data collection. The intensity of solar radiation data measured using a solar power meter, while the temperature is measured using a thermocouple and then read by the reader.

The heat sink is given an HT-GY260 thermal grease which has a thermal conductivity of 1: 2 W/mK and a thermal impedance <0: 211 C-IN2 / W on the part between the panel and the heat sink. PV panels are limited to intensity at 07.30-16.00 and measured using a solar power meter. The solar power meter is placed following the angle of the PV panel. Data was collected at the Rooftop of Building VI of Engineering Faculty, Sebelas Maret University. The circuit will be shown in Figure 1.

Figure 1. Test Circuit Scheme

This research uses a base heat sink size 620mm x 600mm x 3mm with 10 fins. Dimensions are shown in Figure 2. Heatsink has a base and fin thickness of 3 mm each and a height of 50 mm fin. The material for heat sinks using copper and aluminum and placed at the bottom of the PV panel. The air speed is set at a constant 1.5 m/s.
Figure 2. Dimensions a) Base Heat sink, b) Perforated fins

3. Results and discussion

Data analysis conducted in this study is a PV panel without a cooler, a PV panel with heat sink with aluminum material and a PV panel with heat sink with copper material. Data collection in this study uses quantitative methods. Quantitative data obtained are temperature (T), short-circuit current (Isc), open-circuit voltage (Voc), maximum power (PMPP) and efficiency (η).

3.1. Temperature of Solar Cell

High temperatures on panels can reduce the efficiency of PV panels [2]. Adding the heat sink to the PV panel can reduce the temperature of PV panel. Gotmare and Rahman conducted an experiment that the increase in working temperature was caused by radiation intensity which increased [4,9]. The addition of heat sinks can reduce the working temperature on the panel, due to the rate of heat transfer from the PV panel to the heat sink.

Figure 3. Relationship between radiation intensity and work temperature

Figure 3 shows the relationship between intensity and PV panel temperature. The graph above shows that the temperature rises when the intensity of the radiation also increases, this applies to all variations. The highest temperature when the radiation intensity is obtained at 1100 W/m². PV panels without heat sinks, PV panels with aluminum heat sinks and PV panels with copper heat sinks obtained temperatures
of 63.9 °C, 57.7 °C and 53.5 °C respectively. PV panels that use aluminum heat sinks and copper heat sinks have an average lower temperature value of 6.4°C and 12.4°C than without use of heat sinks. High temperatures are caused by the high intensity of radiation received by the PV panels. The heat sink makes the expansion of heat transfer in the PV panel, making the use of the heat sink more effective in lowering temperature.

3.2. Short-circuit Current (Isc)

Short circuit current (Isc) is the maximum current that a PV panel reaches when the resistance in PV panel is very small. Short circuit current (Isc) is also affected by the size of the intensity of solar radiation to the PV panel [7]. Data from Isc measurement results can be seen in Figure 4.

![Figure 4. Temperature relationship graph with short circuit current (Isc)](image)

Figure 4 shows the relationship of the intensity of solar radiation to Short circuit current (Isc). The graph shows an increase in the value of Isc caused by the increase in the intensity of solar radiation. At an intensity of 1100 W/m², the maximum Isc obtained by each variation without heat sinks, aluminum heat sinks and copper heat sinks are 2.86 A, 2.89 A and 3.18 A. The increased Isc value is caused by the decrease in the photon energy value needed to excite an electron. Excessive excitation will cause the PV panel to increase in temperature [10].

3.3. Open-circuit Voltage (Voc)

Open circuit voltage (Voc) is the maximum voltage obtained by the PV panel when there is no current flowing in the Open circuit voltage (Voc). Open circuit voltage (Voc) will change when there is solar radiation received by the PV panel. Open circuit voltage (Voc) decreases when the intensity of solar radiation and its temperature increase [9].
Figure 5. Graph of relationship between intensity and open circuit voltage (Voc)

Figure 5 shows the relationship between the increasing intensity of solar radiation with the *open-circuit voltage* (Voc) on the PV panel. The graph shows the value of Voc decreases for all variations. At an intensity maximum of 1100 W/m², the Voc value of PV panels with heat sinks, PV panels with aluminum heat sinks and PV panels with copper heat sinks are 19.2 V, 19.6 V and 19.8 V. The decrease in Voc value when the intensity of solar radiation and working temperature increase.

3.4. Maximum Power ($P_{MPP}$)

Maximum Power ($P_{MPP}$) is the amount of energy per unit time. The maximum power in the PV panel is shown on the I-V curve. The maximum power in a PV panel is obtained by multiplying the current and voltage, as shown in equation 1. Data from the calculation of the maximum power is shown in Figure 7 and Figure 8.

$$P_{MPP} = I_{MPP} \times V_{MPP} \quad (1)$$

Figure 6. Curve I-V at an intensity of 1100 W/m²
Figure 6 shows the voltage and current curve obtained from the intensity of 1100 W/m². The maximum temperature obtained using a PV panel without heat sink, PV with aluminum heat sink and PV with copper heat sink are 63.9 °C, 57.7 °C and 53.5 °C respectively. Figure 6 shows that the decreasing working temperature in the PV panel will add to the extent of the curve for the value of the generated voltage.

Figure 7 shows the relationship between the intensity of solar radiation to the maximum power (P_MPP). The graph in Figure 7 shows that the maximum power value (P_MPP) has an effect in increasing the intensity of solar radiation. At an intensity of 1100 W/m² the maximum power obtained in the PV panels of 41.16 W, 43.03 W and 47.47 W.

3.5. Efficiency (η).

Efficiency is comparing the maximum power (P_MPP) to the radiant power received by the PV panel (P_light). Data calculation results to obtain the value of efficiency using equation 2, the calculation results are shown in Figure 9.

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\eta = \frac{P_{MPP}}{I_{light}} = \frac{P_{MPP}}{I_{rad} \times A} = \frac{I_{SC} \times V_{OC} \times FF}{I_{rad} \times A} \tag{2}
\]

Figure 8 shows a graph of the relationship of temperature to the efficiency of solar panels. When the intensity at the maximum point of 1100 W/m² the efficiency obtained by the panel increases. The

Figure 7. Graph of relationship between intensity and maximum output power (P_MPP)

Figure 8. Graph of the relationship of temperature to the efficiency of solar panels
decrease in working temperature affects the efficiency of the PV panel. The increase in efficiency was obtained by aluminum heat sinks of 0.79% and panels with copper heat sinks of 1.63%.

4. Conclusion
Every test that has been carried out uses a PV panel without a cooler, a PV panel with an aluminum heat sink and a PV panel with a copper heat sink. The conclusion from this study is the use of aluminum heat sink and copper heat sinks can reduce the average working temperature of 6.4°C and 12.4°C, increase the output power by 1.87 W and 6.31 W, and increase efficiency by 0.79% and 1.63% from without using a heat sink.

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