Development and design of the effect of adding a heatsink as a coolant on improvement output power on solar panels

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ABSTRACT

This study discusses the use of solar energy as a clean and widely available alternative. The performance of solar panels is influenced by various factors including solar radiation, module, temperature, and distribution of the sunlight spectrum. Temperature issues in solar panels can be addressed through passive cooling, such as installing a heatsink. A passive cooling system is implemented by installing a heatsink with four layers of fins on the body panel of the solar module. The advantage of passive cooling with constellations is that it does not require additional energy from outside, while a large number of fins can achieve the best passive cooling constellation. Each heatsink utilizes eight fins with a total of three heatsinks, manufactured from aluminum. Vector values of wind speed, humidity, and temperature are studied through direct measurements. A 100 W polycrystalline solar module at a standard temperature of 25 °C produces an open circuit voltage of 22 +V.

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1. INTRODUCTION

Several approaches exist for harnessing solar energy, such as thermal and photovoltaic methods [1], [2]. However, researchers in photovoltaics encounter challenges with these methods, including the inability to convert all sunlight into electrical energy and the high costs associated with solar energy collection and storage systems. Thus, innovative methods are necessary to design solar panels that enhance efficiency and reduce production and maintenance expenses. Solar panel performance is generally influenced by factors like solar irradiation, module temperature, and sunlight spectrum distribution. Temperature variations affect voltage and current in solar panel generators. Although air temperature may not have a significant impact, reducing solar panel temperature can enhance efficiency by up to 2%, while solar radiation and wind speed play significant roles [3], [4]. Irradiation values can vary based on location, time, and weather conditions, as noted by Gakkhar *et al.* [5]. Solar cells are essential components for converting solar energy into electrical energy, and they can be combined into photovoltaic panels and modules. Photovoltaic systems require protective mechanisms to enhance reliability, stability, efficiency, and safety [6].

Solar cells operate by converting solar energy into electrical energy using photovoltaic phenomena, but they face efficiency limitations due to various losses. Monocrystalline and polycrystalline solar cells generally have longer lifespans than thin-film solar cells, although their performance decreases as temperature rises [7]–[9]. Various cooling methods, including air cooling, liquid cooling, immersion cooling, and heat pipes, aim to improve solar panel module efficiency. There are two types of solar cell cooling systems: active and passive cooling. Active cooling systems utilize electrical energy to drive fans, while passive cooling systems, such as heat sinks, reduce solar panel surface temperatures to enhance efficiency. Heat sinks are crucial for reducing temperatures and increasing solar panel surface efficiency, with thermal resistance indicating heat sink capability. Airflow rate and heat sink geometry influence thermal resistance [10].

Solar modules perform optimally at normal temperatures around 25 ℃, with wind speed playing a significant role in cooling solar cells to maintain this temperature [11], [12]. Temperature increases above normal levels negatively impact solar cell voltage generation, with every 1 ℃ increase resulting in a 0.5% reduction in total power production [13], [14]. Thus, controlling solar module temperatures within permissible limits is crucial for maximizing output power [15]. Elevated solar cell temperatures reduce conversion efficiency and can cause damage, emphasizing the importance of effective temperature control and heat dissipation [16]–[19]. Cooling techniques transfer heat from solar cells to water or air to maintain or reduce temperatures to ideal levels. Heat sinks with symmetrical shapes on both sides have been studied, but those with fins on all four sides are not well-documented. Basic heat sinks can lower solar cell temperatures by about 15 °C, increasing power output by 6% [20], [21].

2. METHOD

The heat sink is a cooling device used to reduce the temperature of an electronic component by transferring heat from the component to the air through metal fins connected to a flat base [22]. Heat sinks are usually used in electronic components that require cooling, such as CPUs, GPUs, and solar panels [23], [24]. Factors that affect heat sink efficiency, such as heat sink size, shape, amount of airflow, and thermal conductivity [25]. The larger the heat sink's size and the airflow amount, the better the heat sink will perform [26]. Thermal conductivity also plays an important role in heat sink efficiency, with better materials having higher thermal conductivity [27].

Figure 1 illustrates the working principle of a heatsink in transferring heat from the source on the installed electronic components to the surrounding environment through conduction, convection, and radiation [28]. Conduction is the process of transferring heat through the materials that make up the heat sink. Heat will flow through the material from hot to cold spots [29]. Convection transfers heat by moving fluids, such as air or liquids. In this case, air is heated by the surface of the heat sink and moves out of the heat sink away from the electronic components. Radiation is the process of transferring heat through electromagnetic waves. Heat sinks made of materials with good reflectivity levels can minimize heat transfer through radiation. By removing heat from electronic components, heat sinks help ensure component temperatures remain stable and within safe operating limits [30]. This ensures optimal performance and efficiency of electronic components and extends component life. To calculate the quantity of heat, the (1) is used.

$$Q = h.A\,(T_s - T_{amb}) \tag{1}$$

Where Q: quantity of heat (W), h: heat transfer coefficient (W/m²K), A: surface area (m²), T_s: surface temperature (°C), and T_{amb}: ambient temperature (°C).

2.1. Solar module cooling design

This research experiment uses a passive heat sink because it has several advantages in natural air cooling without the help of other equipment. passive heat sinks are a component that removes heat from a heat source without using a fan or an active cooling system. Passive heat sinks are designed with a shape and structure that increases surface area to maximize heat transfer to the surrounding air. Usually made of a material with high thermal conductivity, such as aluminum or copper, passive heat sinks work by using heat conduction and radiation.

Passive heat sinks transfer heat by conduction, where heat is transferred from the heat source to the wider surface of the heat sink. Then, the heat will spread evenly across the surface of the heat sink. After the heat is distributed in the heat sink, it will be transferred to the surrounding air through conduction and radiation. Passive heat sinks take advantage of the temperature difference between the heat source and the ambient air to facilitate efficient heat transfer. It may occur on an active heat sink. However, the effectiveness of a passive heat sink is highly dependent on the surrounding environmental conditions, such as adequate air circulation.

2.2. Block diagrams

Cooling planning solar panels are used to transfer heat from this source to the heat sink, which acts as a cooler. The heat ink is designed so that the heat received from the heat source can be distributed evenly and quickly across its surface so that it can be immediately absorbed by the air flowing around it. This air acts as a cooling medium that carries heat from the heat sink and then discharges it to the surrounding environment so that heat from the solar panels can be removed or recycled effectively.

It can be seen that the solar panel must reach the maximum point of the body, which causes the generated voltage to decrease; it is connected to the heat sink, which will receive the heat. The heat sink will distribute heat throughout its surface so that the air flowing around it can absorb it immediately. This air will then dissipate heat to the surroundings to cool the heat source effectively.

The cooling scheme in Figure 2 illustrates the method of cooling solar panels using a heatsink, which aims to keep the temperature of the solar panels low to enhance their efficiency and performance. In this scheme, the solar panels are placed on top of the heatsink, which acts as a passive cooler. When the solar panels are exposed to sunlight and warm up, the heatsink absorbs the heat generated by the solar panels. Subsequently, the heat absorbed by the heatsink is dispersed through air convection via contact with the surrounding air, effectively lowering the temperature of the solar panels. Thus, this scheme utilizes the concept of passive cooling without requiring additional energy. This can help improve the efficiency and lifespan of solar panels by maintaining their operating temperature stable and optimal, especially in hot weather conditions or high workload situations.

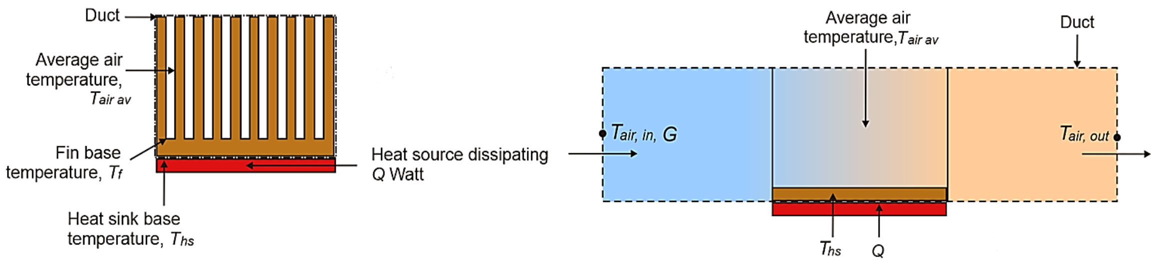
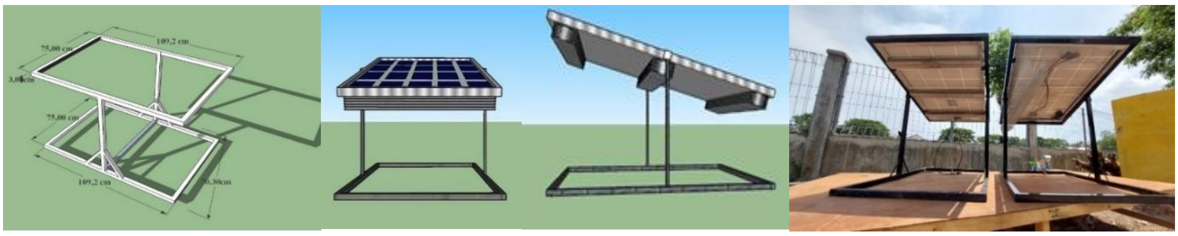


Figure 1. Volume control heatsink

Figure 2. Diagram of a solar panel cooling block

2.3. Tool design

The tool is designed to test the performance of heat sinks on solar panels with various variations of sunlight intensity. The main components of this tool are solar panels, heat sinks, solar light intensity gauges, wind speed gauges, and temperature gauges. The mechanical design of this study contains design drawings of solar panels equipped with coolers. The design can be seen in Figures 3(a)-3(d).



(a) (b) (c) (d)

Figure 3. Design of solar panel in this study: (a) frame dimension, (b) front view, (c) side view, and (d) bottom view

3. RESULTS AND DISCUSSION

Polycrystalline-type solar modules, by adding a heat sink behind the module, can reduce the surface temperature of the solar module very effectively when compared to without adding a heat sink cooler. Based on the comparison graph in Figure 4, it can be observed that the use of a heatsink cooler significantly reduces the device temperature compared to the condition without a cooler at various hours within the observation period. The temperature comparison between the two conditions indicates that the heatsink cooler is effective in reducing the temperature, as evidenced by the consistent temperature difference between them. The temperature tends to increase from morning to afternoon and then decrease again towards the evening. Thus, it can be concluded that the heatsink cooler is an important component in maintaining the performance and lifespan of electronic devices by effectively reducing the temperature.

Based on the power comparison data in Table 1, it can be seen that at each hour, the power generated by the solar panel with a heatsink cooler tends to be higher than that without a cooler. This indicates that the heatsink cooler has a positive impact on improving the performance of the solar panel by reducing its operational temperature. Additionally, it can be observed that the difference in power generated between the two conditions varies from one hour to another. For example, the most significant difference occurs at 12:00, where the solar panel with a heatsink cooler produces 120.73 W, while without a cooler it only generates 99.1 W. However, at 15:00, the power difference between the two conditions becomes smaller, at only about 9 W. This suggests that the cooling effectiveness of the heatsink may be more pronounced at higher temperatures. Furthermore, the general pattern of the data indicates that the power generated by the solar panel tends to increase from morning to afternoon, peaking around 12:00, and then begins to decrease towards the evening. Based on these results, it can be concluded that the use of a heatsink cooler can increase the power generated by the solar panel by reducing its temperature.

Based on the voltage comparison data in Table 2, it can be observed that at each hour, the voltage measured in the system with a heatsink cooler tends to be higher than the system without a cooler. This indicates that the use of a heatsink cooler has a positive effect on increasing the voltage in the photovoltaic system. Additionally, it can be noted that the voltage difference between these two conditions varies from one hour to another. For example, the largest voltage difference occurs at 12:00, where the system with a heatsink cooler has a voltage of 20.15 V, while without a cooler it is only 1 V. However, at 17:00, the voltage difference between the two conditions becomes smaller, at only about 0.2 V. This suggests that the cooling effect of the heatsink may be more pronounced under certain conditions, such as when the environmental temperature is higher. Based on these results, it can be concluded that the use of a heatsink cooler can increase the system voltage by reducing its operational temperature, although the voltage difference between the two conditions varies depending on the time and environmental temperature.

Research conducted in April in the city of Lhokseumawe can reduce the surface temperature of solar modules so that the average value decreases from a high value to a low value with increased efficiency, with an average output voltage of 1 V and power reaching a value of 120.75 W. The results of this research experiment can be concluded between 09:00 and 17:00 with a level of sunlight of 670 W/m^2 at 09:00, and 407.9 W/m^2 at 17:00. In this research experiment, the result of adding a heat sink cooler behind the solar module was a decrease in temperature. The test results show increased output voltage, current, and power on the solar module. The temperature of the solar module can be seen in the figure and table, both without cooling the heat sink and with cooling the heat sink.

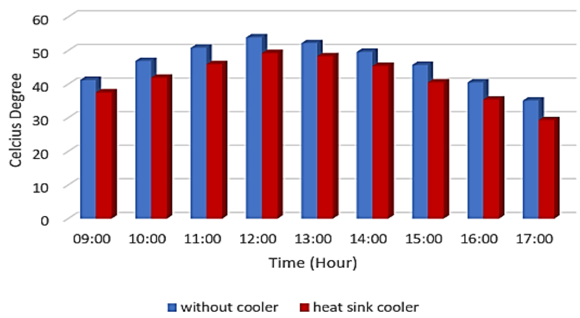


Figure 4. The comparison of photovoltaic temperature

Table 1. The comparison of power output

Time (hour)	Without cooler (Watt)	Heat sink cooler (Watt)
09:00	73.71	80.43
10:00	83.48	97.10
11:00	92.91	107.13
12:00	99.71	120.73
13:00	97.67	111.72
14:00	90.25	100.88
15:00	80.63	91.30
16:00	75.73	85.54
17:00	71.10	75.53

Table 2. The comparison of voltage output

Time (hour)	Without cooler (Voltage)	Heat sink cooler (Voltage)
09.00	18.20	18.75
10.00	18.47	18.92
11.00	19.00	19.55
12.00	19.55	20.15
13.00	19.15	19.60
14.00	19.00	19.40
15.00	18.75	19.15
16.00	18.47	18.85
17.00	18.00	18.20

4. CONCLUSION

Polycrystalline GH 100 P–18 type solar module is always influenced by working temperature. The working temperature of a solar module can be stabilized by providing passive heat sink cooling. Providing a heat sink layered with 4 fins can increase the temperature reduction process. The results of direct measurements at the research location show that the 4-fin layered heat sink can reduce the temperature to an average value of 12 °C, with a voltage with an average voltage output of 1 V and power reaching 120.75 W.

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