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Analysis of the effect of a microcontroller-based solar panel cooling system on temperature and power output

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ABSTRACT

This research addresses the problem of temperature fluctuations affecting the efficiency of solar panels. A cooling system has been developed using a Peltier and a combination of air- and water-cooling methods. The air-cooling system involves placing a Peltier coated with a heatsink under the solar panel, while the water-cooling system uses pumped water on the panel's surface. The study aims to design a solar panel cooling system to reduce temperature and power losses and compare its output to standard solar panels. The system includes a Peltier, DC fan, and heatsink. Results indicate that the air-cooling system reduced temperature losses on the bottom milk of solar panels by 14.5%. However, the surface of solar panels showed no reduction in temperature losses. Additionally, solar panels with cooling systems were able to reduce power losses by 4% compared to standard solar panels. This research suggests that the use of an air-cooling system utilizing Peltier as the cooling medium could be a potential solution to reduce temperature losses and power losses on solar panels.

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1. INTRODUCTION

Solar panel is a device that can convert sunlight energy into electrical energy. Solar panels are made up of a collection of solar modules in which There is a collection of solar cells that experience the photovoltaic effect, thus producing electrical energy [1]. Solar panels are currently one of the most popular means of renewable energy generation due to their easy operation, not requiring large and high rooms, simple maintenance and convenience for various household needs, and offices [2]–[4]. However, the use of solar panels today still has several disadvantages, one of which is related to the cost of electricity with changes in temperature. A sharp increase in temperature leads to a decrease in the efficiency of solar panels. Previous research shows that an increase in temperature every 1 °C can reduce efficiency by 0.4% or will weaken 2-fold every 10 °C increase in temperature [5]–[8].

The issue addressed in this study is the impact of temperature on the output of solar panels. The aim of this research is to use an air-cooling system to mitigate the temperature losses and power losses on solar panels, thus improving their performance by reducing the temperature of the panels and enhancing their efficiency. A cooling system is a system used to cool devices that experience an increase in temperature. In previous studies, the cooling system used on solar panels used an air cooling system, which is a system that uses air to reduce the temperature of solar panels [9]–[12]. In previous research, the air-cooling system used a DC fan. In this study, the use of a DC fan requires a longer time to cool the solar panels. Many applications utilize Peltier as a cooling device, such as cooler boxes, medicine boxes, and others [13]. Peltier is a thermoelectric system that utilizes the Peltier effect to get a temperature difference, namely hot and cold between the two sides when powered by a DC electric current [14].

Based on these problems, the research "Design of cooling system on microcontroller-based solar panel" was conducted. This study uses an air-cooling system as the cooling system. A single axis tracker was chosen to limit the effect of cooling system to its performance. So, with this research cooling systems on solar panels are expected to reduce temperature losses and power losses on solar panels.

2. METHOD

This research aims to design a cooling system on solar panels automatically using a microcontroller to reduce temperature losses and power losses generated by solar panels [15]–[17]. The design uses the air-cooling system method which is equipped with a solar panel surface temperature monitoring system controlled by Arduino Uno and a digital wattmeter for monitoring voltage, current, and power. Meanwhile, to measure underneath the solar panel a thermogenic is used.

In Figure 1 is the flow of the tool control system, if the temperature exceeds 40 °C, the cooling system will be active. whereas if the temperature of the solar panel is below 38 °C, the cooling system will be inactive in the microcontroller system consists of 3 main components, namely the temperature sensor in this case the researcher uses DS18B20 as a temperature sensor, Arduino Uno as a control system, and a relay as an automatic switch for connecting and disconnecting the cooling system electricity. Meanwhile, the air-cooling system is composed of a DC fan, heatsink, and Peltier which are arranged and integrated on the bottom side of the solar panel. The following is the CAD design of the cooling system shown in Figures 2, 3, and 4.

In this paper, 2 solar panels were used as shown in Figure 5, which is a solar panel using a cooling system in the form of an air-cooling system as a solar panel cooling system. While the second solar panel is a solar panel without a cooling system is a reference. Both solar panels will be placed in the same place and conditions as in Figure 5. The data taken is the maximum voltage data (Vm) and maximum current (Im), so the condition of the solar panel with load is required. The load used is a 12 V DC lamp and a 12 V DC motor. The entire data display which includes solar irradiation, maximum output power (Pm) solar panel surface temperature, and solar panel bottom side temperature will be documented simultaneously and will be compared between solar panels with cooling systems and solar panels without cooling systems. Then the maximum power data generated through measurement will be compared with the maximum power calculation using (1) to determine the size of the error [18], [19].

$$Ppv = Pstc.(Gc/Gstc).[1 + k(Tc - Tstc)] \tag{1}$$

Where Ppv is the output power of the solar panel (W), $Pstc$ is the output power of the solar panel at STC (60 W), Gc is the solar irradiation at measurement (W/m^2), $Gstc$ is the solar irradiation at STC (1000 W/m^2), k is the temperature constant (0.011%/°C), Tc is the temperature of the solar panel at measurement (°C), and $Tstc$ is the temperature of the solar panel at STC (°C) [20]–[23].

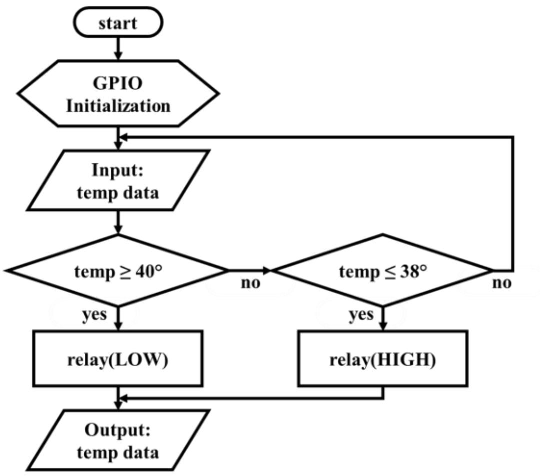

Figure 1. Flowchart of cooling system

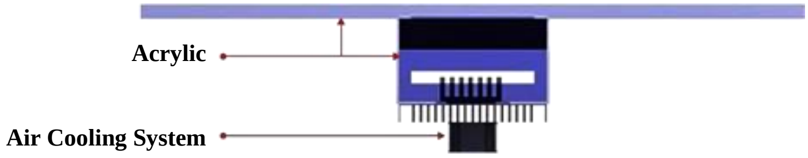

Figure 2. Air cooling system

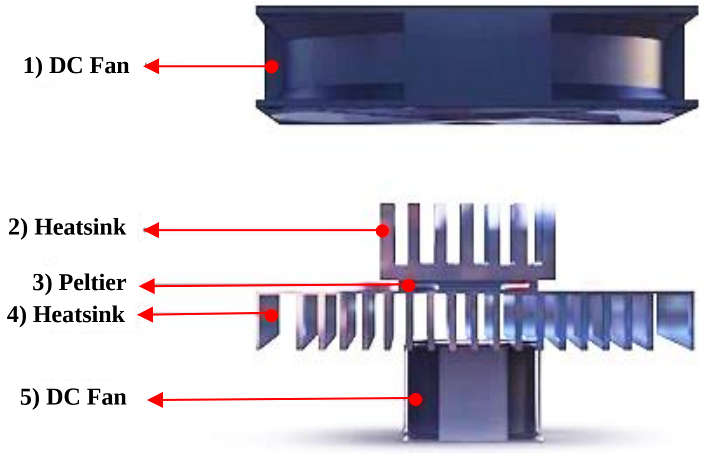

Figure 3. Components of the air-cooling system

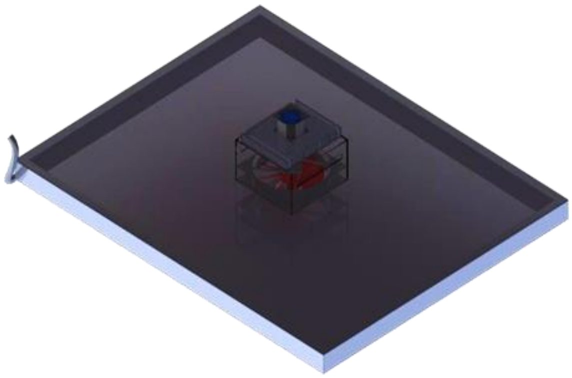

Figure 4. Solar panel integrated with cooling system

Figure 5. Integrated solar panel with cooling system and control system

3. RESULTS AND DISCUSSION

The main objective of the experiment conducted is to design a cooling system on solar panels using a microcontroller and compare it with solar panels without a cooling system, to determine the difference in temperature and power released by solar panels. The research was conducted in the environment of the Kalimantan Institute of Technology Laboratory Building from 09.00 WITA until 15.00 WITA. The solar panel was placed at a tilt angle of 24.6° with the orientation facing north. During the test, the surface temperature of the solar panel, the temperature of the bottom side of the solar panel, the output voltage, output current, output power and solar irradiation were measured every 30 minutes. In Figure 6 the test was conducted by placing the solar panel with a cooling system and standard in the same place and condition. The research used solar panels with specifications that can be seen in Table 1.

Table 1. Simulation results

No	Name	Description
1	Model PV	MS60M-36/MS60M-72
2	Rated Maximum Power (Pm)	111 A (Average)
3	Voltage at Pmax (Vmp)	78 MW (Average)
4	Current at Pmax (Imp)	11.87 kJ
5	Open-Circuit Voltage (Voc)	35.4%
6	Short-Circuit Current (Isc)	3.59 A
7	Normal Operating cell Temp (NOCT)	47±2 °C
8	Operating Temperature	-40 to +85 °C
9	Dimension (mm)	540×680×30 mm

After testing the equipment and collecting data, the results obtained in the comparison graph of surface temperature, bottom side temperature, and output power produced by solar panels with cooling systems and standard solar panels. In the test, the average solar irradiation was 528.615 W/m^2. Then in Figure 7. It can be seen that the use of the cooling system is able to reduce the temperature of the bottom side of the solar panel by an average of 14.5% with the bottom side temperature of the solar panel having an average value of 39.523 °C, while the standard solar panel has an average bottom side temperature of 45.254 °C. Then it is known that the highest temperature ever reached on the bottom side of a standard solar panel is 61.6 °C. While the solar panel with a cooling system on the bottom side of the panel is 50.4 °C. So, it is known that the use of a cooling system is able to cool the bottom side of the solar panel.

The data used in the calculation becomes the basis of reference, as using more days of data will increase the accuracy of the average value. By using (1) based on the value of solar irradiation and the temperature of the solar panel during measurement, the calculated power value can be determined. The comparison of the measured power value and the calculated power from Figures 8 and 9 can then be used to determine the error of the power value. The error in the output power of solar panels with a cooling system is 6%, while in standard solar panels, it is 3.6%. As revealed by [24], the use of an air cooling system method has been shown to increase the solar panel output power by up to 7.8%. This supports the findings of Zaini, 2015 [25], who also demonstrated the effect of temperature on solar panels and the impact of using a cooling system on the output power of solar panels.

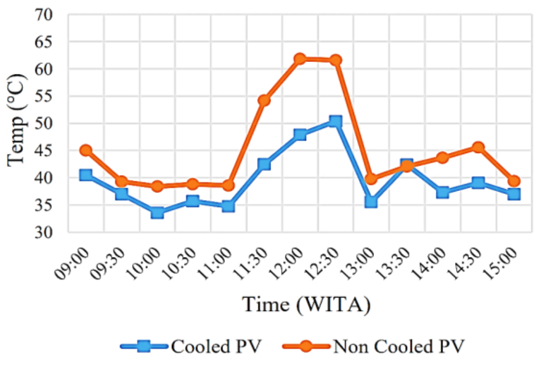

Figure 6. Comparison of solar panel bottom side temperature with cooling system and standard

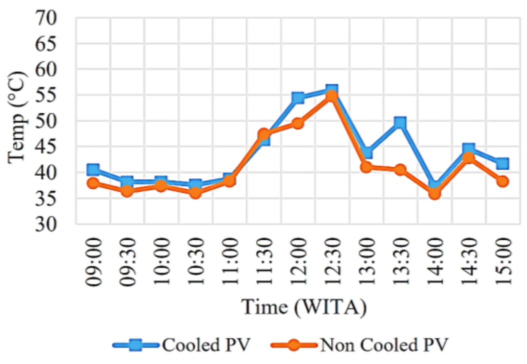

Figure 7. Comparison of solar panel bottom side temperature with cooling system and standard

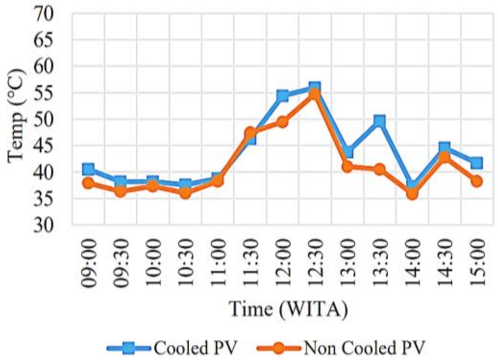

Figure 8. Comparison of solar panel surface temperature with cooling system and standard

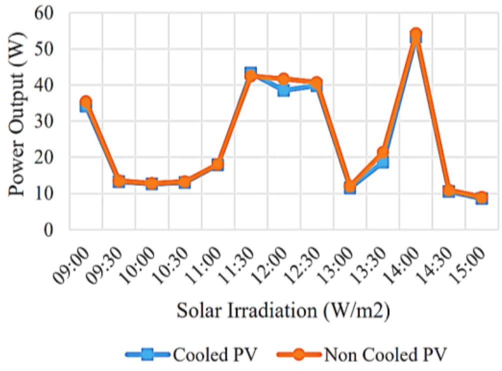

Figure 9. Comparison of solar panel calculation power with cooling system and standard

4. CONCLUSION

Based on the results of the analysis that has been carried out in the study, it is found that the cooling system tool that has been designed has the characteristics of being active when the temperature of the solar panel is more than 40 °C and will be deactivated if the temperature of the solar panel is less than 38°C. Solar panels with a cooling system are able to reduce temperature losses by 14.5% by obtaining the average temperature of the bottom side of solar panels with a cooling system of 39.523 °C and standard solar panels of 45.253 °C. However, the surface temperature of solar panels has not been able to reduce temperature losses. However, the surface temperature of solar panels has not been able to reduce temperature losses, with the average surface temperature of solar panels with a cooling system of 43.605 °C and standard solar panels of 41.23 °C. Solar panels with a cooling system can reduce power losses by 4% with the result that the power generated is greater than that of standard solar panels. In the test results, solar panels with a cooling system get an average power of 25.373 W and standard solar panels of 23.820 W.

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