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Design of Solar Panel Cooling System Based on Natural Circulation Using Ground Source Energy

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ABSTRACT

The performance of solar panels is greatly affected by high temperatures, so a cooling system is required to improve their efficiency. Various cooling methods have been explored, including passive cooling, active cooling, and hybrid cooling systems. This research applies the passive cooling method by designing a solar panel cooling system based on natural circulation using ground source energy. This method relies solely on natural cycles so that the system can operate sustainably. The design of this system uses an experimental method to observe the effect of the cooling system made on the surface temperature and output power of the solar panel. Analysis was conducted to compare the power output generated by solar panels with a cooling system using ground source energy and solar panels without a cooling system. The test results show that the cooling system made is able to reduce the surface temperature of solar panels with an average temperature of 41.23 ºC compared to solar panels without a cooling system with an average temperature of 42.87ºC. In addition, the solar panel cooling system using ground source energy is able to obtain an average power of 72.07 Watt/day with an average efficiency of 7.6%.

1. INTRODUCTION

Solar power generation is a renewable energy source that belongs to the type of clean and environmentally friendly energy [1]. With the depletion of non-renewable energy resources such as petroleum and other fossil energies, the development of renewable energy is a must [2]. The development of renewable energy is an effective solution to address current energy needs [3]. Renewable energies available today include solar energy, wind energy, water energy, geothermal energy, and other energies[4], [5] . However, solar energy is the most promising renewable energy for power generation as a clean and sustainable energy source that is not harmful to the environment [6]. Currently, there are many solar energy systems available such as PV/Trombe walls [7], [8].Floating Solar Power Plant [9], Solar collector [10], and rooftop solar PV [11], [12]. The biggest obstacle in power generation from solar panels is the increase in temperature on the surface of solar cells which is influenced by the ambient temperature and operating temperature. This results in a decrease in the efficiency and performance of the photovoltaic process of solar panels [13]. For this reason, a cooling system is needed to keep the solar panel at the optimal temperature [14].

In principle, there are two types of solar panel cooling systems that is active cooling and passive cooling. Active cooling methods can be considered as methods that continuously consume power to cool solar panels. Most active cooling methods are based on air or water cooling. Therefore, the main components used are pumps or fans needed to keep the liquid or air circulating [15]. Amelia et al conducted a practical experiment to use a number of DC fans directed towards the back of the cell to cool it. The results showed that using one fan increased the power generated by 12.93%. When the number of fans was increased to 2, 3, and 4, the power increased to 37.17%, 41.28%, and 44.34% respectively [16]. Ananda et al tested a solar panel cooling system using the water spray method based on the Arduino Uno microcontroller and DHT22 sensor. When the surface temperature of the solar panel exceeds 41ºC, the pump will activate and then spray water on the surface of the solar panel. The test results show that the cooling method using the water spray method is able to reduce the surface temperature of the solar panel with an average

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temperature of 38.67ºC and obtain a power efficiency of 36% [17].

Passive cooling methods rely on natural heat dissipation mechanisms such as convection and conduction to remove excess heat from solar panels [15]. This method does not require electrical power to operate. This method is represented by the natural cooling process with water or with air [18]. Cuce et al conducted an experimental study on polycrystalline PV cells under controlled conditions. Two PV cells were used: one with aluminum fins as heat sink and one without heat sink. The results showed that the PV cell with cooling fins was able to increase the power efficiency by 20% [19]. Mehrotra et al conducted an experiment to cool PV solar cells by immersing them in water with different depths. The results proved that the greater the water depth, the lower the surface temperature of the PV solar cell, and thus the PV cell efficiency increased. The highest efficiency obtained was 17.8% [20].

Research related to the design of solar panel cooling systems based on natural circulation using ground source energy has been carried out previously. Mahdi et al. conducted simulations for a solar panel cooling system based on natural circulation using ground source energy. Simulation results show that the proposed cooling method achieves an impressive temperature reduction of about 28% compared to the conventional cooling method. In addition, the PV panels with ground source cooling were able to gain 15.55% efficiency on power output, reaching a maximum of about 88 W [6]. Ansyah et al conducted research for solar panel cooling systems using air circulation in underground pipes. The air is sucked by a compressor with a variation of air velocity of 1, 2, and 3 m/s. The result obtained is that the greater the air speed blown, the better it is to reduce the temperature of the solar panel. [21].

There is little research on the utilization of ground air circulation to cool solar panels. Most of the previous studies concentrated on the use of water for the cooling system, which may not be feasible in many areas especially areas with limited water resources. Therefore, this study aims to create a cooling system using a natural cycle by utilizing natural circulation using ground source energy. For comparison, tests were conducted with solar panels without a cooling system to determine the difference in solar panel surface temperature, output voltage, output current, and power generated by each system.

2. METHODOLOGY

This research uses the experimental method [22], [23] with the aim of observing the effect of the cooling system made on the surface temperature and output power of the solar panel.. The research flowchart can be seen in Figure 1.

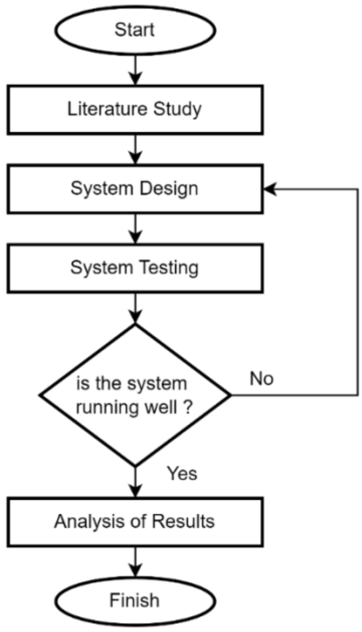

Fig. 1. Research Flowchart

2.1 *System Design*

Figure 2 shows the design of the solar panel cooling system based on natural circulation using ground source energy. The buried pipe is made of PVC material with a diameter of 4 inches, a length of 6 meters, and a depth of 1,5 meters from the ground. The height of the pipe hole from the ground is 70 cm. The solar panel is placed above the output pipe.

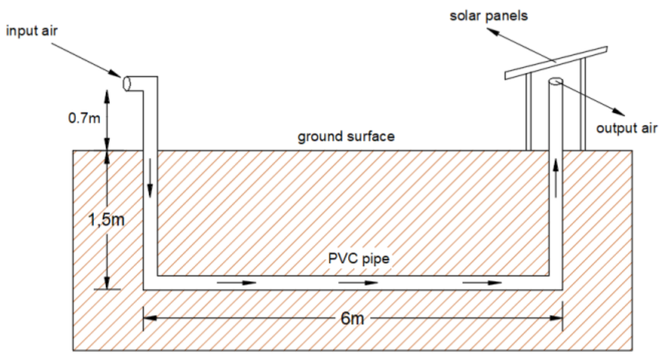

Fig. 2. Design of Solar Panel Cooling System

Based on Figure 2, air will enter through the input pipe by utilizing the natural pressure from the wind blowing in the direction of the input pipe hole. As the air flows inside the pipe, it releases its heat to the pipe wall and the surrounding ground so that the air temperature will be reduced to cooler. The air flows up to the output pipe to blow cooler air towards the solar panel.

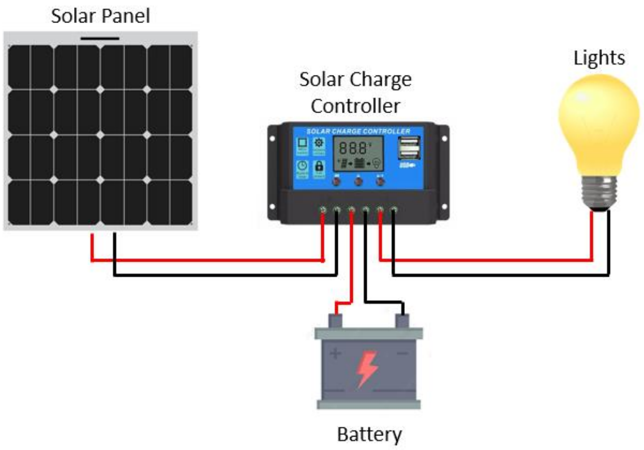

Fig. 3. Solar panel circuit schematic

Table 1. Specifications of solar panel

Parameters	Value
Type	Polycrystalline
Maximum Voltage	18 Volts
Maximum Current	1,11 A
Maximum Power Output	20 Watts
Dimensions	450 x 350 x 15 mm

Based on Figure 3, the solar panel functions to convert sunlight into DC current electricity. The DC electricity generated by the solar panel flows to the Solar Charge Controller (SCC) for voltage and current regulation before charging the battery. Furthermore, the battery receives electric current from the SCC and stores the electric charge. A 12Volt DC/18W lamp is used for experimental loads in measuring the voltage and current output of the solar panel. System efficiency can be calculated using the equation [24].

$$\text{Efficiency} = \frac{(\text{Pwith} - \text{Pwithout})}{\text{Pwithout}} \times 100\% \quad (1)$$

where Pwith is the power from the solar panel with the cooling system, and Pwithout is the solar panel without the cooling system.

2.2 Experiment Setup

The experiment was conducted in the environment of Swadaya Gunung Jati University (7GCW+C9) Sunyaragi, Cirebon City, West Java, Indonesia. The test was conducted for three consecutive days from July 7 to July 9, 2024 at 09:00 to 16:00 in sunny and cloudless weather with an average wind speed of 2 m/s and an average ambient temperature of 32ºC. The solar panel was in a static position with an angle of 15° and facing north. The surface temperature of the solar panel was measured using a thermo gun, while the output voltage and current of the solar panel were measured using a multimeter. Figure 4 shows the results of installing the pipe in the ground. The length of the pipe is 6 meters with a depth of 1.5 meters below ground level. The height of the pipe from the ground is 70 cm..

Fig. 4. Pipe Installation

Figure 5a shows a model of a solar panel system with a cooling system using ground source energy, while Figure 5b shows a solar panel without cooling.

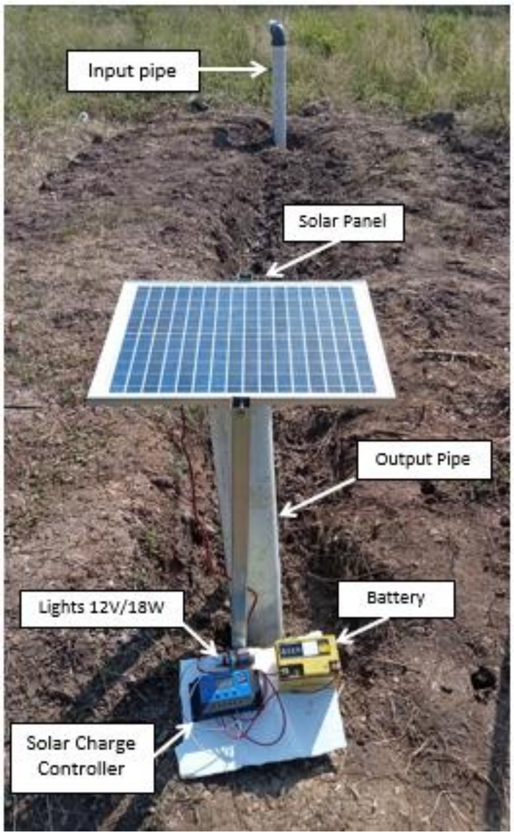

Fig. 5a. Solar panel with cooling system using ground source energy

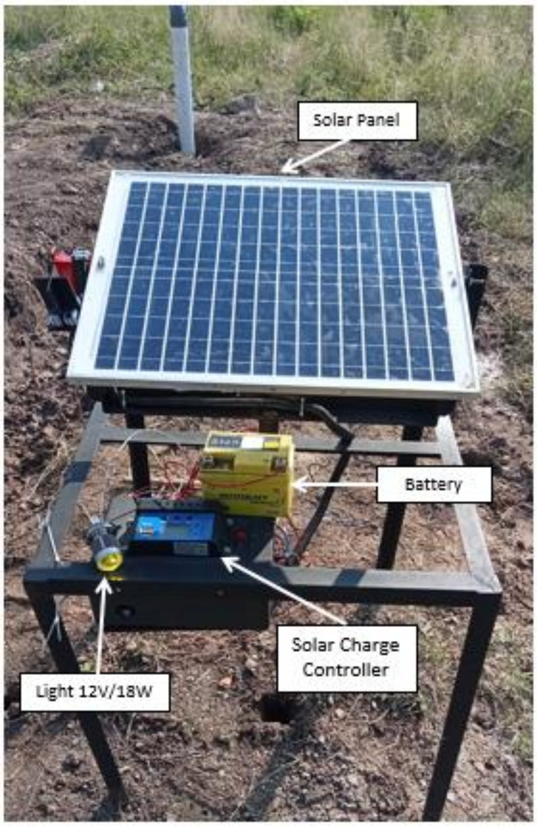

Fig. 5b. Solar panel without cooling system

3. Result and Discussions

Testing of solar panels with a cooling system using ground source energy and solar panels without a cooling system has been carried out. From the test results, the hourly average values of the surface temperature, voltage, and current produced by the solar panel were obtained for three days from 09:00 to 16:00. The average values are then made in the form of graphs presented in Figures 6, 7, and 8.

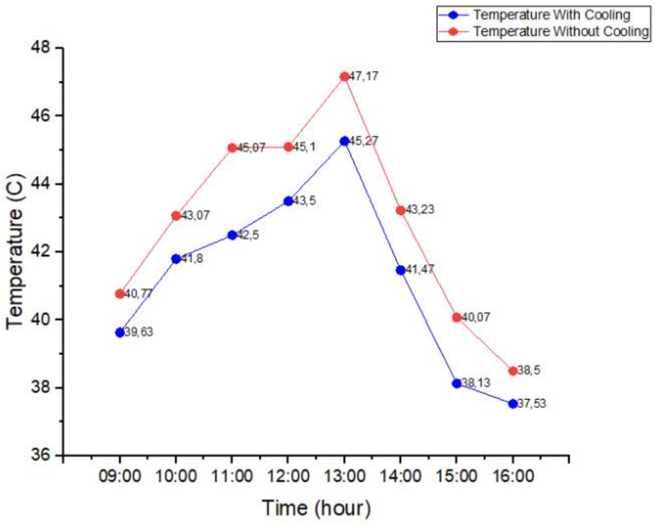

Fig. 6. Comparison graph of solar panel surface temperature

Based on Figure 6, the average daily surface temperature of solar panels with cooling systems is 41.23 ºC, while the average daily surface temperature of solar panels without cooling is 42.87 ºC.

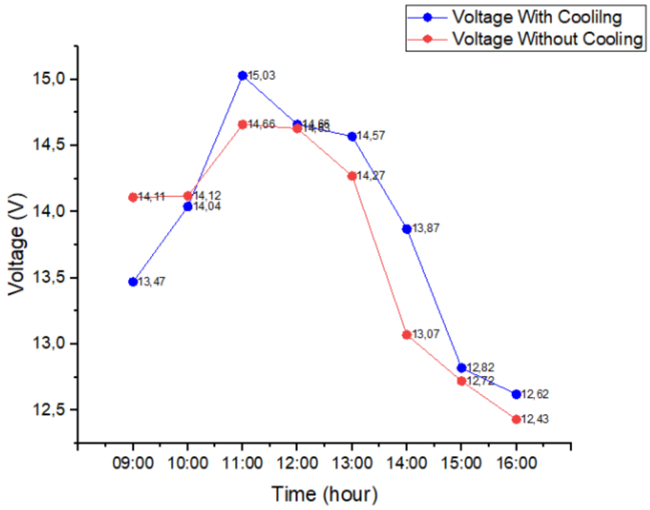

Fig. 7. Comparison graph of solar panel voltage

Based on Figure 7, solar panels with a cooling system obtain a daily average voltage of 13.89 V, while solar panels without cooling have a daily average voltage of 13.75 V.

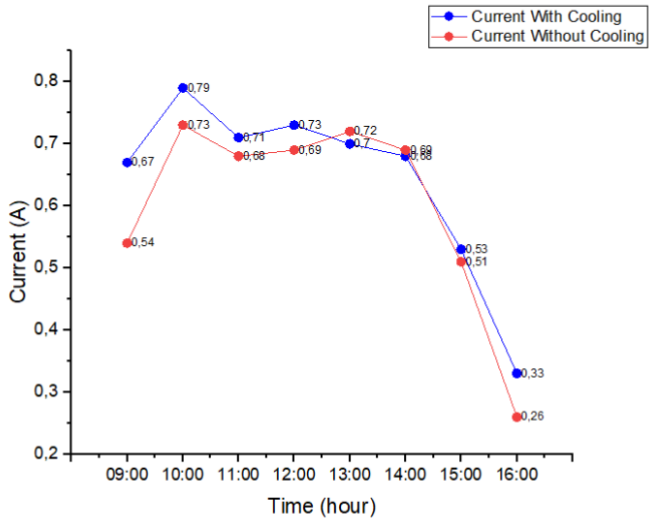

Fig. 8. Comparison graph of solar panel current

Based on Figure 8, solar panels with a cooling system obtain a daily average current of 0.64 A. While solar panels without cooling have a daily average current of 0.60 A..

Based on the average voltage and current values every hour for 3 days, the average hourly power value can be obtained by multiplying the voltage and current values presented in table 2. So that the total power obtained is the total average power for 3 days.

Table 2. Average hourly power value for 3 days

Time	Power With Cooling (W)	Power Without Cooling (W)
9.00	9,05	7,62
10.00	11,05	10,26
11.00	10,62	9,98
12.00	10,66	10,10
13.00	10,21	10,34
14.00	9,43	8,98
15.00	6,84	6,45
16.00	4,21	3,27
Total	**72,07**	**66,98**

Based on Table 2, Solar panels with a cooling system obtained an average power of 72.07 Watt/day, while solar panels without a cooling system obtained an average power of 66.98 Watt/day. Furthermore, the calculation of power efficiency is based on equation 1. The result is that the solar panel cooling system using ground source energy is able to obtain an average power efficiency of 7.6%.

When compared to research conducted by Ananda et al [17] who tested the solar panel cooling system with the air cooling method using a fan, the air cooling method using a fan was able to obtain an efficiency of 16,19%. However, the use of fans certainly requires electrical power to turn on the fan. The solar panel cooling system based on natural circulation using ground source energy offers simplicity and cost effectiveness because this method only relies on natural cycles without the need for power consumption..

4. CONCLUSION

The design of solar panel cooling system based on natural circulation using ground source energy was successfully made. The test results show that the cooling method of solar panels based on natural circulation using ground source energy is able to reduce the temperature of solar panels with an average temperature of 41,23ºC compared to solar panels without a cooling system with an average temperature of 42.87ºC. By comparing the average power of each system, the solar panel with a cooling system using ground source energy obtained an average efficiency of 7.6%.

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