Automatic Cooling System for Efficiency and Output Enhancement of a PV System Application in Palembang, Indonesia

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Abstract. Active cooling system technique which flows a thin layer of water on the surface of the PV panels can significantly reduce the panel surface temperature compared to normal use. From experiments conducted in Palembang, Indonesia on August 2018 used two polycrystalline PV panels 100 WP manufactured by Sankelux, can reduce the average surface temperature of PV panels by 18.7°C. The output voltage of the water-cooled PV panels increases by average 1.5 volts when loaded with a 1.5 ohms DC lamp compared to the normal panels. From the experiment, PV panel will work effectively from 8.30 AM to 3.30 PM. Increasing of panel temperature does not significantly affect the output current. The average output power on the water-cooled panel is 31.5 watts, has increased compared to the normal panel 34.2 watts. The overall average output power increase 2.7 watts. The cooling system can also increase the efficiency of the output power. Between 8.30 AM to 3.30 AM, the lowest efficiency enhancement occurred at 9.30 AM is 5.01% and the highest is 13.06% occurred at 2.30 PM, and overall average efficiency enhancement of output power is 8.6%.

1. Introduction

Renewable energy is the energy produced from natural resources that can be continually renewed. There are several types of renewable energy, one of them is solar energy. The PV system is one of the renewable energy that can generate electricity directly without causing environmental impacts when exposed to solar radiation [1].

Solar energy has big potential to be developed as renewable energy and can be as alternative energy to replace fossil energy. Fossil energy is not environmentally friendly and the amount is getting smaller because this energy cannot be renewed [2]. Humans must find alternative energy to replace fossil energy [3]. Solar energy has become an important part and it is very influential on human life, especially for utilization as a source of electricity [4].

The performance of PV panels is very dependent on the operating temperature. Most of the energy absorbed by PV panels is changed to heat. Generally, PV panels only change 4-17% of solar radiation into electrical energy. More than 50% of solar energy is converted to heat and then the temperature of PV panels will increase. Increasing the panel temperature will eventually reduce the output of...
electrical energy and reduce the electrical efficiency of the PV panel, besides that there is also the possibility of permanent structural damage due to thermal stress that is continuously received by the panels [5]. Increasing of temperature causes a decreased output voltage, output power and Fill Factor and output power, but on the other hand short circuit current increases slightly [7]. For this reason, researchers and scientists need to make a PV panel cooling system that can effectively remove heat so the optimum temperature will be obtained [8].

The increasing of temperature will reduce semiconductor band gap energy. A reducing in band gap energy can be interpreted as an increasing electron energy in the semiconductor material. Therefore, the increasing of temperature will decrease band gap energy, only a small amount of energy is needed for moving electrons. Increasing of temperature in PV cells affects open-circuit voltage (Voc), short-circuit current (Isc), output power maximum (Pmax) and Fill Factor (FF) [10] [11]. Hot PV panels will cause a decreased efficiency of electrical energy conversion, so the panel surface must be cooled. Cooling PV panels can generally be divided into 2 types, active and passive cooling. Passive cooling discharges heat from a PV panel naturally or with certain techniques without requiring energy. Active cooling uses equipment and controllers that requires additional energy to activate the equipment and controller [6].

Media for cooling PV panels basically is water and air. In passive cooling heat is taken from the PV panels and discharged into the surrounding. The structure uses air ducts, heat pipes or additional heat dissipation fins or heat sinks behind the PV panels to make easy the natural circulation of air or liquid [13]. Discussion about passive cooling by using several different methods such as air flow channels, heat pipes, liquids, thermo-electric devices, and Phase Change Materials (PCM) can be seen in the journal [14]. In a simulation, the PCM technique uses a water storage tank is connected with the pipe to the back surface of the PV panel. From the simulation, the increasing of output electricity was 13.7% [13]. Besides passive cooling, some researchers have developed a technique named radiative cooling technique, which uses a colorless and transparent silicon layer on the surface of the PV panel to produce thermal radiation and reduce the surface temperature of the PV panel. From the simulation, the PV panel operating temperature decreased by 18.3°C [15].

Active cooling is generally used to get a better electrical energy conversion efficiency. The structure of design is heat dissipating by using a device such as a fan to force air, or a water pump to drain water on the panel surface and also in the back of the surface PV panel, or by placing a PV panel on top of a metal pipe that drains cooling water. Water spraying can also be used for cooling PV panels, especially in dry or desert areas are also by floating PV panels above the water surface [16]. A study with Mediterranean environmental and climate conditions using water cooling systems on both sides of the PV panel can increase electrical power by 16.3%. Active cooling techniques that use water as cooler have high potential to be implemented [13].

Hybrid Photovoltaic/Thermal or PV/T solar system is one of popular PV cooling panel systems. Water or air is passed over the surface for cooling PV panels, water or air flow will become warm that can be used for other purposes such as warm water for household and others [12].

The efficiency of PV panels will decrease if the temperature exceeds the critical temperature. It is necessary to maintain the temperature of PV panel or the cell has to be below this critical temperature. One way to improve efficiency is to flow the surface of the PV panel a thin layer of water. Krauter [17] is one of the researchers who uses a thin layer of water which is flowing on the surface of the PV panel to reduce heat due to solar radiation. He said the reflection of solar radiation on PV panels could reduce the efficiency of electrical energy conversion by [9].

Tang 2010 [18] has conducted a study using Solar Panel Cooling system, named Novel Micro Heat Pipe Array. Heat pipes can transfer heat from the PV panels to air or water, it can increase efficiency of PV panel by 2.6%. When using water as a cooler can reduce the temperature of PV panel up to 8°C and can increase efficiency of PV panels by 3%. Therefore, cooling with water is more effective than cooling using air.
The medium which usually used in passive and active cooling systems are air and water. But the thermal air character makes it less efficient as a cooling medium. Therefore, air cooling is not suitable for absorbing heat energy of PV panels in very hot areas. More electricity is needed to operate the fan to achieve the same performance as water cooling. But in places where water is limited, air cooling may still be an option. Active cooling systems can also work together with passive cooling to get more effective results. Therefore, the choice of cooling techniques and cooling media depends on the design of the PV system and the conditions under where the system operates [14].

Many literatures have explained water as a cooler, more effective than air. The Purpose of this paper is how to build a PV panel cooling system using water to find and solve of hot PV panel problem when operating with an optimum water and energy consumption to operate electric pump. It is necessary to conduct research to determine of the PV panel temperature that have the optimum electrical efficiency and how long it will take to cool the panel [16].

This paper proposes an automatic cooling system for efficiency and output enhancement of a PV system by letting the water flows on the surface of a PV panel. 2.5 liters of water per minutes are flowing on the PV panel surface all the times from 06.00 AM - 06 PM by using the 4-watt electric water pump. PV panel output data are taken per half an hour, and data result is compared with the normal application of PV panel at the same condition and location. The data comparison will show the output and efficiency enhancement of the proposed active cooling system.

2. Methodology

2.1 Efficiency PV cell

Fill Factor or FF is the ratio of PV cell maximum power ($P_{MPP}$) with $V_{oc}$ and $I_{sc}$, and all of the parameters can be seen in Figure 1 [10].

\[ FF = \frac{P_{MPP}}{V_{OC} \cdot I_{SC}} = \frac{V_{MPP} \cdot I_{MPP}}{V_{L} \cdot I_{SC}} \]  

(Figure 1. Fill Factor of a PV cell.)

The Fill Factor or FF of a PV cell is given by:
The efficiency of a PV cell is given by:

$$\eta = \frac{P_{MPP}}{E \cdot A} \times FF \times V_{MPP} \times I_{MPP}$$

(2)

$P_{MPP}$ is the maximum power point, $E$ is Irradiance of solar, and $A$ is the surface area of PV cell.

2.2 Experimental setup

This research was conducted in Palembang, Indonesia (2° 59'27.99 "S and 104 ° 45'24.24" E), using two polycrystalline PV panels 100 WP Sankelux brand. The first panel is installed normally and the other is cooled by flowing 2.5 liters of water per minutes on the PV panel surface all the times from 06.00 AM to 06.00 PM by using the 4-watt water pump.

**Figure 2.** Diagram of experiment system setup.

**Figure 3.** The left side photograph of the experimental system setup.
2.3 Specification of PV panels
The experiment uses two polycrystalline PV panels 100 WP Sankelux brand with the specification:

| Parameters                        | Variable | Value   |
|-----------------------------------|----------|---------|
| Nominal Maximum Power             | Pmax     | 100 W   |
| Optimum Operating Voltage         | Vpm      | 18.74 V |
| Optimum Operating Current         | Ipm      | 6.20 A  |
| Open Circuit Voltage              | Voc      | 22.04 V |
| Short Circuit Current             | Isc      | 6.57 V  |
| Maximum System Voltage            |          | 1000 V  |
| Maximum Series Fuse Rating        |          | 10.00 A |

3. Results and Discussion
This experiment was conducted in Palembang on August 2018 with average clear weather. The first analysis is the effect of irradiance and air temperature compared to PV panel temperature. Figure 5 shows the surface of panel temperature at 9:00 AM which is installed normally has started to increase significantly to 50°C and the difference of temperature between the two panels is 17.4°C, the highest panel temperature is 64.1°C at irradiance 1081 W/m². Irradiance gradually dropped to 486 W/m² at 3:30 PM, and temperature normal panel is 46.3°C. Cloudy happened at 12:30, so irradiance and panel temperature also dropped. The average temperature of the water-cooled panel surface is 36°C, this temperature is not too much different from the average temperature of air in surrounding 36.3°C. The highest difference of temperature between the two panels is 26°C and the average difference of temperature between the two panels is 18.7°C.
Effect of PV panel temperature to output Current can be seen on figure 6. when a 1.5 ohms load (DC lamp) is connected to the terminal each PV panel. The average output current is stable around 1.8 Amperes from 9.00 AM to 3.30 PM. Figure 6 shows the heat difference in surface of both PV panels does not significantly affect the output current. There was a slight increase in the output current on the normal PV panel installed. PV panels produce electrical currents effective from 8.30 AM to 3.30 PM, we named it efficient point.

Figure 7 shows the effect of PV panel temperature to output voltage when a 1.5 ohms load (DC lamp) is connected to the terminal each PV panel. The output voltage of normal panels increases significantly at 8.30 AM, changing from 2 volts to 17.4 volts when Irradiance reaches 533 W/m². The output voltage will be stable until 3.30 PM when Irradiance starts to drown. We can see output voltage is affected or will decrease in the presence of clouds. The average output voltage in water-cooled PV panels is 18.9 volts in a range between 8.30 AM to 3.30 PM. There is an increase in voltage compared to the average output voltage on a normal panel that is 17.3 volts. Overall average enhancement output voltage is 1.5 volts.
Figure 7. The PV panel temperature’s effect is compared to output Voltage

Figure 8 shows effect of PV panel temperature of output power when a 1.5 ohms load (DC lamp) is connected to the terminal PV panel. Output power tends to be stable at 8.30 AM until 3.30 PM even though there is cloudy influence at 12:30 AM. In a times range between 8.30 AM to 3.30 PM, the average output power of water-cooled panels are 31.5 watts, has increased average output power compared to normal panel 34.2 watts. Overall average enhancement output power is 2.7 watts.

Figure 8. Effect of PV panel temperature compared to output Power
Figure 9. Enhancing efficiency of output power cooled PV panel compared to normal PV panel

Figure 9 shows efficiency enhancement of the output power of water-cooled PV panels compared to normal PV panels in a range of time between 8.30 AM to 3.30 PM. The lowest efficiency enhancement occurred at 9.30 AM is 5.01% and the highest is 13.06% occurred at 2.30 PM, overall average efficiency enhancement is 8.6%.

4. Conclusion
Active cooling system technique which flows a thin layer of water on the surface of the PV panels can significantly reduce the panel surface temperature compared to normal use. From experiments conducted in Palembang, Indonesia on August 2018 used two polycrystalline PV panels 100 WP manufactured by Sankelux, can reduce the average surface temperature of PV panels by 18.7°C. This technique can increase the average output voltage of a PV panel about 1.5 volts when it is loaded with a 1.5 ohms DC lamp compared to normal panel. From the experiment in Palembang, we can see that the PV panel would work effectively at 8.30 AM to 3.30 PM. There is no significant influence on the output current with increasing heat in the panel. The output voltage of the water-cooled PV panels increases by average 1.5 volts when loaded with a 1.5 ohms DC lamp compared to the normal panels. Increasing of panel temperature does not significantly affect the output current. The average output power on the water-cooled panel is 31.5 watts, has increased compared to the normal panel 34.2 watts. The overall average output power increase 2.7 watts. The cooling system can also increase the efficiency of the output power. Between 8.30 AM to 3.30 AM the lowest efficiency enhancement occurred at 9.30 AM is 5.01% and the highest is 13.06 % occurred at 2.30 PM, and overall average efficiency enhancement of output power is 8.6%. From observations of the experiment, the water pump is one of the important parts of the system. Because this is an active cooling system so it takes energy to drive the motor pump to cool the panel surface. To obtain optimum efficiency, the water pump must work only at a certain temperature by installing a thermostat, and the configuration of the system can be seen in Figure 2. The temperature setting is 36°C which is the average temperature of the water-cooled panels. The water pump will only turn on if the panel temperature reaches 36°C.

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