Increasing the output power of solar panel by using cooling system

B A Supian*, C Ekaputri and W Priharti
Electrical Engineering Department, Telkom University, Bandung, Indonesia

*budaliasupian@student.telkomuniversity.ac.id

Abstract. Solar panel is a device to convert light energy from the sun into electrical energy, most of solar panel is made from semiconductor such as silicon. Solar panel is still having many disadvantages such as expensive prices, low efficiency, the power output that depended on light intensity and temperature, etc. During the day, solar panel temperature could increase and affect the power output. It is found that temperature would reduce solar panel voltage output that also reduce the power output. In this research, 100WP Monocrystalline solar panel power output will be enhanced by using cooling system to reduce the temperature of the solar panel. Cooling system of the solar panel is applied by flowing the water on the surface of the solar panel using 12V DC water pump. The experiment starts from 11:00 AM to 01:00 PM. The result of this experiment is the power output of the solar panel increased up to 5.79 Watt with the average about 2.96 Watt and the temperature of the solar panel decreased by 20.99ºC. The temperature of the solar panel without cooling is about 52.83ºC and with the cooling system is about 31.85ºC.

1. Introduction
Fossil energy is still a solution today to meet the energy demands of the world because the price is still quite affordable. But fossil energy that exists today will not last long and the world will run out of fossil energy reserves in the near future. Therefore, it is necessary to start utilizing renewable energy whose availability is more guaranteed for a long time. One of them is abundant solar energy for a very long time.

Solar cells are materials that can convert light energy into electrical energy by the photovoltaic effect. Photovoltaic effect is the process of changing the energy of light from the sun into electrical energy [1]. Most of solar panels on the market have an efficiency of around 15% to 20% [2]. But for the efficiency of silicon solar cells is in the range of 13-18% [3]. The output power produced can vary from the STC results due to the difference in temperature at which the solar panel is placed that could affect the output power generated. Output power that produced by solar panel was affected by the atmospheric factors such as solar irradiance and ambient temperature [4]. Ayaz, Nakir, and Tanrioven use mathematical expressions into Simulink which take some actual ambient conditions such as irradiances, cell temperature, and wind speed into consideration. The results showed that cell temperature and wind speed have significant effect on solar panel output power [5]. In solar panels made from monocrystalline it has a temperature coefficient of voltage and power of -0.331% /ºC and -0.444% /ºC [6]. That means for every 1ºC increase in temperature it could cause the voltage drop about 0.331% and power drop about 0.444%. This is due to when the solar panel heats up, causing atoms to vibrate faster and therefore the ability of the "built-in voltage" to separate the electrons and holes is reduced [7].
Some techniques to cooling solar panel temperature has been used. Research by B. Salam using water pump to pump water on the surface of solar panel to reduce the temperature. The result is this method increase the efficiency of solar panel by 7.10% [8]. Another research to cooling solar panel temperature has done by S. Odeh and M. Behina. The result is an increase of the output power by 4-10% and it also found that cooling method by flowing water on the surface of solar panel could increase input radiation due to refraction in water layer [9].

In this research we will optimize the output of solar cell power using a cooling system by pump the water to flow on the surface of solar panel. Then the voltage, current, and power generated will be measured. An increase in power is expected after a cooling system is developed to the solar panel.

2. Specification and fabrication process
In this experiment 2 solar panels will be compared where one solar panel is given a cooling system while the other solar panels are not given a cooler. The load in this experiment is the battery connected to the solar charge controller. The voltage, current, and temperature produced by solar panels are then measured and will be compared.

2.1. Experimental setup
Solar panels are placed fixed with a slope of 10º to the Horizon. This angle was chosen to be able to flow the water, if the solar panel is installed at an angle of 0º to the horizon then the water will not flow, while if more than 10º then the water flows too fast so it cannot cool the panel evenly.

Figure 1. Schematic solar panel with and without cooling system.

In this hardware design, the hose connected to the 12V DC pump. On the pump's water input side is dipped into the water reservoir and the hose connected to the pump's water output side is connected to the top side of the surface of the solar cell. The water output hose on the top side of the surface of the solar cell is perforated according to the number of rows of the solar cell by four points by adding a sprinkler to flatten the water output so that it is able to wet the entire surface of the solar panel.

The component that needed to run the test are as follows.

2.1.1. Solar panel. Solar Panel used for this research had a peak power of 100WP made from monocristalline silicon with a voltage of 18.30V and a current of 5.8A. Monocrystalline is choose because they have the highest efficiency rates since they are made out of the highest-grade silicon [10].
2.1.2. **Battery.** Battery used in this research as load and storage power from solar panel with 12V 20Ah capacity. Another battery also used in this research to power the water pump with 12V 9Ah capacity.

2.1.3. **Solar charge controller.** A solar charge controller used to regulate the power going into the 12V battery from the solar panel.

2.1.4. **Water pump.** Water pump of 12V DC (operating Voltage 9-14V DC) it has flow capacity 3.1 l/m and pressure 70PSI. Water pump used to cool down the solar panel by pump the water to the solar panel surface. The water pump powered by 9Ah 12V Battery that is not connected to the solar panel.

2.1.5. **Controller.** The controller is used to control the sensors and modules needed in this research. Arduino Mega is used as controller for this research.

2.1.6. **Temperature sensor.** Temperature sensor used in this research is DS18b20 which is a digital sensor that is able to read temperatures from -55 to +125°C.

2.1.7. **Voltage and current sensor.** A voltage sensor is used to measure the voltage of the solar panel and current sensor is used to measure the current of the solar panel. Then the power will find by multiplying the voltage and current that has been measured.

2.1.8. **Data logger.** Data logger is device to storage data. In this research, data from sensors such as voltage, current, ad temperature are saved in data logger.

3. **Procedure**

Two solar panel systems were made with one solar panel installed with a cooling system while the other solar panels were not. The cooling system work using a water pump to pump water and then the water will be flowed to the surface of the solar panel as shown in figure 2 to drop the temperature of the solar panel. The parameter measurement data is taken every second and then the measurement data averaged to get the average power output result. The aim is to get more accurate measurement results.

![Cooling system activated](image)

**Figure 2.** Cooling system activated.

The test is carried out for 12 days from 15th to 26th August 2019 in Bandung city, Indonesia. The configuration exchange is carried out on the solar panel and the battery every 3 days. The duration of testing every day is for two hours starting at 11:00 A.M. to 01:00 P.M.
4. Data collection result and analysis
From the measurement in table 1 results can be seen that there are fluctuations in data due to weather changes when doing research that is sometimes sunny and cloudy.

| Date (August 2019) | With cooling | Without cooling | ΔPower (Watt) | ΔTemperature (Celsius) |
|-------------------|--------------|-----------------|---------------|------------------------|
|                   | Power (Watt) | Power (Watt)    |               |                        |
|                   | Temperature (Celsius) | Temperature (Celsius) |               |                        |
| 15                | 73.25        | 71.17           | 2.07          | -21.16                 |
| 16                | 80.51        | 76.68           | 3.83          | -21.84                 |
| 17                | 75.24        | 72.57           | 2.67          | -23.12                 |
| 18                | 71.65        | 70.86           | 0.79          | -19.35                 |
| 19                | 75.65        | 72.04           | 3.61          | -22.70                 |
| 20                | 71.12        | 69.05           | 2.07          | -19.88                 |
| 21                | 77.68        | 75.40           | 2.27          | -20.52                 |
| 22                | 69.97        | 65.82           | 4.16          | -21.43                 |
| 23                | 77.49        | 71.70           | 5.79          | -20.03                 |
| 24                | 73.66        | 69.97           | 3.69          | -20.79                 |
| 25                | 68.67        | 67.06           | 1.61          | -22.38                 |
| 26                | 55.40        | 52.44           | 2.96          | -17.98                 |
| Average           | 72.52        | 69.56           | 2.96          | -20.99                 |
| Min               | 55.40        | 52.44           | 0.79          | -20.03                 |
| Max               | 80.51        | 76.68           | 5.79          | -17.98                 |

4.1. Calculation
Percentage calculation of %ΔPower as follows.

\[ Δ\text{Power} = \text{Power with cooling system} - \text{Power without cooling system} \tag{1} \]

\[ \%\text{Power} = \frac{Δ\text{Power}}{\text{Power without cooling system}} \times 100\% \tag{2} \]

**Average:**
\[ Δ\text{Power} = 72.52 - 69.56 = 2.96 \text{ Watt} \]
\[ \%Δ\text{Power} = \frac{2.96}{69.56} \times 100\% = 4.26\% \]

**Maximum:**
\[ Δ\text{Power} = 80.51 - 71.70 = 5.79 \text{ Watt} \]
\[ \%Δ\text{Power} = \frac{5.79}{71.70} \times 100\% = 8.08\% \]

**Minimum:**
\[ Δ\text{Power} = 71.65 - 70.86 = 0.79 \text{ Watt} \]
\[ \%Δ\text{Power} = \frac{0.79}{70.86} \times 100\% = 1.12\% \]

Average power for 12 days produced by solar panels with a cooling system is about 72.52 Watt while in solar panels without a cooling system obtained an average power of 69.56 Watt. Based on the above calculation it is found that the increase in the average power of the solar panel after being cooled is about 2.96 Watt or 4.26%. It also can be seen that maximum power produced by solar panels is on August 16th 2019. On that day, solar panel with a cooling system delivered power about 80.51 Watt while in
solar panels without a cooling system obtained an average power of 71.70 Watt. Based on the above calculation it is found that the maximum power that increased of the solar panel with cooling system is about 5.79 Watt or 8.08%. Percentage calculation of $\%\Delta$Temperature as follows.

$$\Delta \text{Temperature} = \text{Temperature with cooling system} - \text{Temperature without cooling system}$$

$$%\Delta \text{Temperature} = \frac{\Delta \text{Temperature}}{\text{Temperature without cooling system}} \times 100\%$$

Average:

$$\Delta \text{Temperature} = 31.85 - 52.83 = -20.99 ^\circ \text{C}$$

$$%\Delta \text{Temperature} = \frac{-20.99}{52.83} \times 100\% = -39.72\%$$

Maximum:

$$\Delta \text{Temperature} = 31.66 - 54.78 = -23.12 ^\circ \text{C}$$

$$%\Delta \text{Temperature} = \frac{-23.12}{54.78} \times 100\% = -42.20\%$$

Minimum:

$$\Delta \text{Temperature} = 32.34 - 50.32 = -17.98 ^\circ \text{C}$$

$$%\Delta \text{Temperature} = \frac{-17.98}{50.32} \times 100\% = -35.73\%$$

The average temperature for 12 days produced by solar panels with a cooling system is 31.85°C, while the average temperature produced by solar panels without a cooling system is 52.83°C. From the calculation above, it is found that the average temperature reduction of the panel using a cooling system is about 20.99°C or 39.72%.

In figure 4 can be seen a graph of energy produced by solar panels. Energy is obtained by adding up the measured power produced by the solar panel by testing for 2 hours. It can be seen that the energy produced by solar panels is higher than the energy produced by solar panels without a cooling system. It is proportional to the increase in power that has been previously measured.

**5. Conclusion**

Based on the results of this experiment the output power on the solar panel with cooling system, it can be concluded that there is an increase in power generated when the cooling system is applied to solar panels.
panels, this can be seen based on the results of measurements on solar panels that use a cooling system that produce more power compared to solar panels without a cooling system. Also, solar panels that use a cooling system have a lower temperature compared to solar panels without a cooling system. And also, by keeping the temperature of the solar panel so that it is not too hot also effectively able to extend the life of the solar panel.

References
[1] Jordan H, Kailyn S and Jason D 2019 *Photovoltaic Effect* [Online] Retrieved from: https://energyeducation.ca/encyclopedia/Photovoltaic_effect Accessed on 1 July 2019
[2] Vikram A 2019 *What are the most efficient solar panels on the market? Solar panel efficiency explained* [Online] Retrieved from: https://news.energysage.com/what-are-the-most-efficient-solar-panels-on-the-market/ Accessed on 15 July 2019
[3] Wasfi M 2011 *Solar Energy and Photovoltaic Systems* Member IEEE
[4] Amelia A R, Irwan Y M, Leow W Z, Irwanto M, Safwati I and Zhafarina M 2016 Investigation of the Effect Temperature on Photovoltaic (PV) Panel Output Performance *International Journal on Advanced Science Engineering Information Technology* 6 pp 682-688
[5] Ayaz R, Nakir I and Tanrioven M 2014 *An Improved Matlab-Simulink Model of PV Module considering Ambient Conditions* *International Journal of Photoenergy* 2014 pp 1-6
[6] Dash P K and Gupta N C 2015 *Effect of Temperature on Power Output from Different Commercially available Photovoltaic Modules* *Int. Journal of Engineering Research and Applications* 5
[7] Four Peaks Technologies 2019 *Band Gap Definition* [Online] Retrieved from: http://solarcellcentral.com/junction_page.html Accessed on 17 August 2019
[8] Keron A S, Sikder A B, Sama-E-Shan, Zerin D A and Salam D B 2017 Fabrication and experimental analysis of solar panel water cooling system *International Conference on Mechanical Engineering and Renewable Energy*
[9] Odeh S and Benhia M 2009 *Improving Photovoltaic Module Efficiency Using Water Cooling, Heat Transfer Engineering* 30 pp 499-505
[10] Energy Informative 2019 *Which Solar Panel Type is Best? Mono- vs. Polycrystalline vs. Thin Film* [Online] Retrieved from: https://energyinformative.org/best-solar-panel-monocrystalline-polycrystalline-thin-film/ Accessed on 1 July 2019