Solar Panel Performance Improvement using Heatsink Fan as the Cooling Effect

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Abstract. Currently, technological developments in Indonesia are growing very fast, one of which is technology in the field of renewable energy. As a tropical country, Indonesia gets a lot of daylight. National Energy Board data on solar irradiation in Indonesia with irradiation distribution in the Western Region of Indonesia (KBI) around 4.5 kWh / m² / day and in Eastern Indonesia (KTI) around 5.1 kWh / m² / day. We must focus on the development of renewable energy and be a solution to the current energy problems where fossil energy is increasingly depleted of its supplies, especially solar energy with unlimited resources. The problem is if you want to build a solar power plant (PLTS) in a tropical country where the ambient temperature is quite hot if you want to improve the performance of the solar panel you must get the maximum open circuit voltage by maintaining the standard operational temperature of the solar panel. Polycrystalline Sankelux solar panel type SPV 1610-100 with a standard temperature of 25°C will produce a maximum open circuit Voc voltage of 22.94 V. The study was conducted in Palembang between 9:00 a.m. to 3:00 p.m. where the temperature could reach 38°C, the temperature on the surface of the solar panel reached 55°C and solar radiation reached 1447 W / m² at 12:30 a.m. By adding cooling heatsink fan to keep the surface temperature of the solar panel close to the standard operational temperature, the temperature decreased to 15 °C so we could maximize the open circuit voltage.

1. Introduction

One of the abundant sources of renewable energy is solar energy. At present many people have used it to make energy sources substitute for fossil fuel energy sources, especially in areas that have not been reached by the electric current or just to reduce electricity costs every month by using photovoltaic (PV) solar panels. Solar panels consist of several solar cells in a series of panels, usually totaling 36 cells, 48 cells or 72 cells. Solar cells can convert sunlight radiation into electrical energy where the output is voltage and direct current (DC). When the sun rays on the solar cell in the crystal lattice, the sun’s energy is channelled into the lattice, where the atom will turn into a paired electron hole. If this happens outside the p-n junction, the electron hole pair will reunite very quickly. Electron hole pairs around the p-n junction are separated from the local electric field. The results of electrons move to layer n while holes move to the p layer, resulting in a voltage build up in the solar cell. If the load is connected to the solar panel, the current will flow [1, 2].
The basic material of the solar cell is SiO₂ quartz sand where silicon (Si) is produced as the second most common substance in the earth's crust. SiO₂ quartz sand is present in very large quantities. The chemical process of how to get silicon (Si) by adding carbon and heated in a furnace with a large power supply, as follows:

\[
\text{SiO}_2 + \text{C} = \text{Si} + \text{CO}_2 \quad [3]
\]

Although silicon (Si) produced has in this process 98% purity is not enough to make solar cells because additional processes are needed to increase the purity of silicon (Si) near 100%. This silicon (Si) quality is very expensive to produce. This very pure Silicon (Si) is then used to make silicon wafers where the solar cell is finally produced. Silicon wafers can be produced using a variety of techniques, depending on the type needed to make solar cells [3].

If we make solar power plants (PLTS) solar panels are the main component in producing an output voltage in addition to other components such as charge controllers, inverters before they can be used by electronic devices. The open circuit voltage Voc produced by solar panels is influenced by several factors.

The main factors that influence the performance of solar panels are [4].
1. Solar radiation intensity, the greater the solar radiation, the greater the current produced by solar panels, not the other way around, the voltage tends to remain even though the radiation level is higher. At 12:30 a.m. is the highest radiation level up to 1447 W / m², how do you increase the radiation intensity at hours outside of it? Several studies added reflectors in the form of glass on four sides of the solar panel, but the side effect of the surface temperature of solar panels also increased.
2. The angle of solar radiation, the Solar panel will get high radiation when the sun's position is perpendicular to 90 °. Several studies to get the best radiation by optimizing the angle of the solar panel that is adding a solar tracker where the motor is installed to move the solar panel angle following the angle of solar radiation.
3. Solar panel surface temperature, solar panels have a standard operating temperature of 25°C [5]. Temperature can affect how electricity flows through an electrical circuit by changing the speed at which the electrons travel. Also, since solar panels work best at certain weather and temperature conditions [6]. A PLTS in the tropics, of course, the temperature of the area needs to be considered, for example Palembang where the average temperature in the day reaches 38 ° C. Several studies in tropical countries such as Indonesia, India, Morocco, Iraq, and others add a cooling system for solar panels so that the temperature is maintained and is close to the temperature of the operational standard [7].

Some research that has been carried out by several researchers in Indonesia or other tropical countries, in particular, added a cooling system in solar panels, including methods:
1. Water cooling method, by continuously flushing the solar panel surface[8].
2. Heatsink (HS) profile L degree 45 °, 90 °, 135 ° with cooling fan [9] [10].
3. Liquid active cooling [11].
4. Force air stream method, exhaled strong winds to the back of the solar panel [12].
5. Thermoelectric cooling [13].

The above cooling methods can achieve a temperature reduction on the surface of the solar panel between 15° to 15.9°, a voltage increase of 0.28 V - 0.35 V and the efficiency of 10% - 12%.

This paper presents the application of heatsink as the cooling effect to reduce PV panels surface temperature to improve the performance of solar panel applied in a tropical condition.

2. Methods and experiment setup

2.1. Efficiency of photovoltaic (PV)

The strength that can be given by a PV cell or module depends not only on radiation but also how well the consumer is matched. The point of no-load operation with I = 0 mA and the short-circuit operation point with V = 0 V, produces output power P = 0 W according to the formula P = V.I. Between these two operating points, product P = V.I must, therefore, reach the maximum value. This operating point
is referred to as Maximum Power Point (MPP). The maximum power of Pmax a PV cell can convey to consumers is always smaller than the product of the short-circuit current and open-circuit voltage [3].

![Figure 1. PV efficiency graphic.](image)

Factor fill is the quality criteria for solar cells and states the extent to which the characteristics of the IV rectangular approach consist of no-load Voc and short-circuit Isc stresses shown below. Fill factors are calculated using the following equation [14]:

\[
FF = \frac{P_{\text{mp}}}{V_{\text{oc}} \cdot I_{\text{sc}}} \\
= \frac{V_{\text{mp}} \cdot I_{\text{mp}}}{V_{\text{oc}} \cdot I_{\text{sc}}} 
\]

The conversion of efficiency is calculated as the ratio between the maximal generated power and the incident power. The irradiance value \( P_{\text{in}} = 1000 \, \text{W} / \, \text{m}^2 \) for the AM1.5 spectrum has become a standard for measuring the conversion efficiency of solar cells [3]:

\[
\eta = \frac{P_{\text{max}}}{P_{\text{in}}} = \frac{V_{\text{mp}} \cdot I_{\text{mp}}}{P_{\text{in}}} \\
= \frac{V_{\text{oc}} \cdot I_{\text{sc}} \cdot FF}{P_{\text{in}}} 
\]

2.2. **Experiment Setup**

In figure 2 block diagram which describes the research method to produce the desired research results, the results of the study note the measurement results of solar panel surface temperature, solar radiation, and output voltage. It would be compared the surface temperature between the two solar panels that were expected to used heatsink fan could be lower 18 ° to 20 ° so that the output voltage would be greater. Heatsink (HS) as the main additional component to reduce the temperature in this
experiment used aluminum material was expected to absorbed heat and then channelized with the helped of the wind from the fan.

![Diagram showing solar panel and cooling system](image)

**Figure 2.** Block diagram

The key to the success of this research was a cooling system that was attached to a solar panel of an aluminum heatsink to absorbed the heat and wind blowing from the fan so that heat was quickly discharged into the air. Figure 3 described the solar panel with the added cooling and figure 4 illustrated the airflow concept on the heatsink.
Figure 3. PV with heatsink fan

Figure 4. Airflow concept. [15]
In Figure 5 described the devices used for research where solar panels used sankelux SPV 1610 mono crystalline as much as 2 units, the first panel was attached to the heatsink in all cells on the back of the panel and a fan was added to accelerate the disposal of heat circulation. At the solar output, panel was paired each load a DC lamp 24V 100 / 90W where the load would be connected if for Vpm voltage measurement while the DC lamp was off if for Voc voltage measurement. For solar meters measuring instruments for solar radiation in figure 6.

Figure 5. Experiment setup and measurement device.
In this research, the recording was done every 30 minutes with the important point of increasing solar radiation would increase the temperature on the surface of the solar panel and of course it would affect the voltage generated. The cooling system with heatsink fan was very cheap and requires not much energy to turned on the fan and switch at low speed positions throughout the study at 9:00 a.m. to 3:00 p.m. When measuring the Vpm voltage the solar panel needed to be loaded using a 24V DC lamp so that the Vpm voltage could be measured.

3. Results and discussion
The research was conducted in August 2018 in the city of Palembang where the month is still in dry season and the temperature is very hot during the day to 38.7 °C and the surface temperature of the solar panel reaches 55.5 °C. Solar panels that were added with cooling heatsink (HS) fan could make the surface temperature of the solar panel more stable, the wind blows quite tightly in some time recording could make the solar panel surface temperature decreased than before. Research data showed windy weather conditions made the panel conditions cooler.

Solar radiation at daytime (11:30 a.m. - 13:00 p.m) showed the highest point and had an effect on increasing the surface temperature of the panel but at 12:00 p.m – 13:00 p.m when the weather was windy enough to cause the surface temperature to decrease this was due to strong wind blowing could make the panel surface temperature decrease even though solar radiation was high.

![Solar meter for measuring irradiance.](image)

**Figure 6.** Solar meter for measuring irradiance.

![Irradiance vs PV temp.](image)

**Figure 7.** Irradiance vs PV temp.
Figure 7 could be concluded that the high solar radiation regarding photovoltaic solar panels did not automatically raise the surface temperature of solar panels (14.00-15.00), the wind blowing factor actually made the surface temperature more stable and could decrease (12.00 - 13.00). By adding a heatsink (HS) fan, the surface temperature of the solar panel can go down to 15.9 °C.

![Graph showing Voc vs Temperature](image)

**Figure 8.** Voc vs Temperature.

Figure 8 showed the graph of the open circuit voltage Voc measurement compared to the surface temperature of the solar panel with cooling heatsink and without cooling the heatsink. From the results of the study showed the surface temperature of solar panels with cooling heatsink fan was more stable surface temperature than solar panels without cooling, this was due to the influence of the heatsink attached to the rear surface of the solar panel absorb heat and channel it through the ducting and the fan helped accelerate heat dissipation as in figure 3b with the stable surface temperature of the solar panel, photovoltaic produces a higher Voc open circuit voltage because this was a proof according to the technical specifications of the solar panel.

![Graph showing Vpm vs Temperature](image)

**Figure 9.** Vpm vs Temperature
Figure 9 shows a graph of measurement of maximum peak Vpm voltage compared to the surface temperature of solar panels. The difference with Voc here is added load in the form of DC lamp 24 V 100/90 W. The surface temperature of the solar panel is the same as figure 8 and the maximum peak voltage Vpm also shows that the solar panel that is attached to the cooling heatsink is greater than without cooling.

| Tabel 1. Improvement of output Voltage PV+HS. |
|----------------------------------------------|
| Voc PV (V) | Voc PV+HS (V) | Improve Voc (V) | Vpm PV (V) | Vpm PV+HS (V) | Improve Vpm (V) |
| Average    | 20.33         | 21.7           | 1.37       | 16.30         | 19.22           | 2.92            |
| The Highest| 21.00         | 22.20          | 1.20       | 17.20         | 20.40           | 3.20            |

| Tabel 2. Efficiency PV+HS result. |
|-----------------------------------|
| PV Temp (°C) | PV+HS Temp (°C) | Delta (°C) | Efficiency |
| Average       | 47.94           | 36.65       | 11.29       | 23.56%       |
| The Highest   | 55.50           | 39.60       | 15.90       | 28.65%       |

4. Conclusion

SPV 1610-100 solar panels which are cooled by adding heatsinks fans can be concluded to be very effective in reducing the surface temperature of solar panels when compared to the same solar panel without cooling. The research conducted in August 2018 in the city of Palembang can reduce the temperature to 15.9 °C or efficiency reached 28.65%, increase the average output Voc 1.37 V and if added to the load DC lamp 24V 100/90W the Vpm output voltage increases by 2.92V on average.

The results of this study can also be concluded that between 9:00 a.m. and 3:00 p.m. the solar radiation level starts to increase followed by a rise in the linear panel surface temperature, see figure 6 between 09:00 a.m. to 10:30 p.m. but when solar radiation starts to fall the surface temperature of the solar panel did not drop significantly at 1:30 p.m. until 3:00 p.m. actually the strong wind blows could reduce the surface temperature of the panel to drop significantly between 12:00 a.m. to 13:00 a.m.

The output voltage of solar panels in either Voc or Vpm between 09:00 a.m. to 3:00 p.m. is relatively stable because the temperature in the city of Palembang at that hour is also stable between 29 °C to 38 °C and tends to be cloudy and wind blowing.

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