Performance Comparison of 3 Kwp Solar Panels Between Fixed and Sun Tracking in Palembang - Indonesia

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Abstract. Photovoltaics or also called solar cell is a technology that can be used directly into electrical energy in DC currents. The voltage generated by solar cells on available solar radiation. Photovoltaic systems can be improved by several methods, one of which is by installing solar panels. The pattern is mounting with solar tracking system into a solution to increase energy efficiency. This paper is a case study to analyse and compare the performance of different photovoltaic systems in its mounting pattern. Analysis and comparison of the photovoltaic (PV) system consist of 3 KWp Fixed Mounting Photovoltaic and 3 KWp Sun Tracking Photovoltaic with the same type of silicon monocrystalline. The solar photovoltaic system is located in Plaju Palembang (South Sumatra, Indonesia) where the daily irradiation rate is 4.96 kWh / m2. To find out the power production rate, data collection is done for three months in December 2017, January 2018 and February 2018. During the rainy season like December 2017, Fixed Installation of Photovoltaics has greater than 0.4% Sun Tracker Photovoltaic. In the dry season, Sun Tracker Photovoltaic has 0.5% greater interference than Photovoltaic Fixed Mounting. The maximum efficiency in Photovoltaic Fixed Installation is 12.4%, while the maximum efficiency of Sun Tracker photovoltaic is 13%.

1. Introduction

Energy plays an important role in human life, every day humans use energy to carry out their life activities. In line with the growth in population and the national economy, the rate of energy consumption is increasing. In Indonesia, energy consumption still mainly revolves around fossil energy [1]. The high rate of energy consumption has resulted in an imbalance between the rate of depletion of fossil resources and the speed of finding new reserves, that it is estimated that in the near future fossil energy reserves will run out and Indonesia will depend heavily on imported fossil energy [2].

Indonesia is a country rich in energy resources. Almost all kinds of energy needed are available in Indonesia. The availability of oil is abundant, gas is not hard to find, coal is mountainous, the sun is all year round, rivers are countless, and there are still some other energy sources. Indonesia should be able to retrieve surplus energy if the natural resources are managed well, with the support of government policies, including the issuance of the National Energy Policy which is regulated in the Law of the Republic of Indonesia No. 30 of 2007 on Energy. To meet the increasing energy needs and to handle the issue of global warming caused by the constant use of fossil energy, various alternative energies are developed as a substitute for it, one of which is Photovoltaic [3, 4].
Photovoltaics, also known as a solar cell, is a technology that can convert sunlight directly into electrical energy in DC current. The voltage is immediately generated by the solar cell depending on the sunlight. The generation of current in solar cells, also known as The Photovoltaic effect, involves several processes. If the solar cell is exposed to sunlight, it will result in electrons and holes. The electrons and holes resulted around the PN junction move in a row toward both the n and p layers. So that when the electrons and holes cross the PN junction, a potential difference arises at both ends of the solar cell. If at both ends of the solar cell is given a load, then an electric current is generated, flowing through the load. The combination of several solar cells that are arranged in series or parallel is called a solar panel [5-7].

![Photovoltaics system](image1)

**Figure 1. Photovoltaics system**

2. Materials and Methods
This paper is a case study to analyse and compare the performance of different solar panel in its mounting pattern. Analysis and comparison of the solar panel system consist of 3 KWp Fixed Mounting solar panel and 3 KWp Sun Tracker solar panel with the same type of monocrystalline silicon. The solar panels are located in Plaju Palembang (South Sumatra, Indonesia) where the daily sun radiation rate is 4.96 kWh/m2.

![Fixed Mounting and Sun Tracker solar panels](image2)

**Figure 2. Fixed Mounting and Sun Tracker solar panels**
Table 1. Specification of Solar Panel

| Specification          | Solar Cell Fixed Mounting | Sun Tracker |
|-----------------------|---------------------------|-------------|
| Maximum Power (P\text{max}) | 250 Wp                    | 250 Wp      |
| Total System Power    | 9000 Wp                   | 9000 Wp     |
| The voltage on Pmax (V\text{mp}) | 30.9 Volt               | 30.9 Volt  |
| Ampere on Pmax (I\text{mp})    | 8.12 Amp                  | 8.12 Amp    |
| Open circuit ampere (I\text{sc}) | 8.47 Amp                  | 8.47 Amp    |
| Open circuit voltage (V\text{oc}) | 37.8 Volt                | 37.8 Volt  |
| Amount of photovoltaic cells | 36 cell                   | 36 cell     |
| Cell Efficiency       | 17.12%                    | 17.12%      |
| The dimension of Solar Cell | 1640 x 992 x 40 mm       | 1640 x 992 x 40 mm |
| The weight of Solar Cell | 19.00 kg                 | 19.00 kg    |
| Type of Solar Cell    | Monocrystalline Silicon   | Monocrystalline Silicon |

The performance of a tool in engineering is the ability of a device, machine or system to operate according to its designed capacity. Performance in solar panels is analyzed to determine the rate of power produced by solar panels, and to compare it with the initial design of solar panels. The following is the calculation of input and output by multiplying the intensity of solar radiation received with the solar cell surface area, using the following equation [8-10]:

\[ P_\text{in} = I_r \times A \] ................................................................. \( (1) \)

Description :

\( P_\text{in} \): Input power after sun radiation
\( I_r \): Sun radiation intensity (watt/m\textsuperscript{2})
\( A \): Area of solar cell surface (m\textsuperscript{2})

The value of solar cell power (\( P_\text{out} \)) results from multiplying voltage when opened (Voc), short circuit current (Isc), and Fill Factor (FF) generated by Photovoltaic cell, according to the following formula:

\[ P_\text{out} = V_\text{OC} \times I_\text{SC} \times FF \] ................................................................. \( (2) \)

Description :

\( P_\text{out} \): Power generated by solar cell (Watt)
\( V_\text{OC} \): Voltage of open circuit solar cell (Volt)
\( I_\text{SC} \): Short circuit current solar cell (ampere)
\( FF \): Fill Factor

FF value is obtained using the following formula:

\[ FF = \frac{V_\text{OC} - \ln(V_\text{OC} + 0.72)}{V_\text{OC} + 1} \] ................................................................. \( (3) \)

The efficiency that occurs in solar cells is resulted from comparing the power that can be generated by solar cells with the input energy obtained from solar radiation.

\[ \eta = \frac{Output}{Input} \times 100\% \] ................................................................. \( (4) \)

3. Result and Discussion

The discussion of performance comparison is carried out with two data, including the difference in solar panel production at every hour and the difference in the efficiency of solar panels every day.
3.1. The difference in solar panel production every hour

Daily data collection is carried out every hour for 6 days, from February 13, 2018, to February 19, 2018. The highest power production of Fixed Mounting power and Sun Tracker solar panels is on February 18, 2018. The following is a comparison of the solar panel power production to the solar panel capacity design on February 18, 2018.

![Figure 3. Power comparison chart with a design capacity of Sun Tracker's solar panel on February 18, 2018](image)

![Figure 4. Power comparison chart with a design capacity of Fixed Mounting solar panel on February 18, 2018](image)
3.2. Efficiency difference of solar panel on a daily basis
The calculation of the efficiency ratio of each solar panel is done to determine the system, using the installation pattern of solar panels that have better efficiency in Palembang. The following below are the comparisons and differences in efficiency between Sun Tracker and Fixed Mounting solar panels. The efficiency comparison calculation is carried out for 3 months in December 2017, January 2018 and February 2018. The following below is the graph of efficiency comparison.

**Figure 5.** Graph of differences in the percentage of power production of Fixed Mounting solar panels and Sun Tracker on February 18, 2018

**Figure 6.** The Difference between the efficiency of Fixed Mount solar panels and Sun Tracker on December 2017
Figure 7. The difference in efficiency of Fixed Mount and Sun Tracker solar panels in January 2018

Figure 8. The difference in efficiency of Fixed Mount and Sun Tracker solar panels on January 2018

4. Conclusion
After analysing the charts of solar panel power production and the efficiency ratio, it can be concluded that:

1. Maximum performance of solar panels in generating power is described as:
   a. Sun Tracker solar panel: 80% from the designed capacity (maximum power 2400 W vs 3000 W).
   b. Fixed Mounting solar panel: 66.7% from the designed capacity (maximum power 2000 W vs 3000 W).
2. Sun Tracker solar panel performance duration can last until 6 pm Indonesian Western Time, while the Fixed Mounting solar panel can only last until 5 pm Indonesian Western Time. This occurs
because the Sun Tracker solar panel will always move toward the sun, making its firmness to the direction of the sun maintainable.

3. At low ambient temperatures and high precipitation or cloudy weather in December 2017, Fixed Mounting solar panels have better daily power efficiency and production than that of Solar Tracker, with an average of 0.2 Kwh (0.4% of better efficiency)

4. In sunny weather, the daily power efficiency of solar panels with the Sun Tracker system is better than the solar panel with a Fixed Mounting system, with the following average:
   - January 2018 = 0.6 Kwh (0.5% of better efficiency)
   - February 2018 = 0.6 Kwh (0.5% of better efficiency)

5. Maximum efficiency ($\eta$) in solar panels with Mono-crystalline Silicon type of solar cell installed in Pertamina Corporation Refinery Unit III with the average solar radiation in Palembang of 4.96 kWh/m2 is:
   - Solar Panel Fixed Mounting, $\eta = 12.4\%$.
   - Solar Panel Sun Tacker, $\eta = 13\%$.

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