

COMPARISON OF OUTPUT POWER OF PHOTOVOLTAIC SOLAR PANELS WITH AND WITHOUT CONCAVE ALUMINIUM REFLECTORS AT VARIOUS ANGLES

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ABSTRACT

The increasing demand for energy has encouraged the use of renewable resources, especially solar energy. The efficiency of solar panels is strongly influenced by sunlight intensity and environmental conditions. This study aims to analyze the effect of varying concave aluminum reflector angles on the power output and efficiency of a solar panel and to determine the most optimal configuration. A 50 Wp monocrystalline solar panel was tested using reflector angles of 50°, 60°, 70°, 80°, and 90°, along with a comparison panel without a reflector. Measurements were taken every 10 minutes from 10:00 to 14:00 (WIB), focusing on Voc, Isc, current (mA), and surface temperature. The results show that concave aluminum reflectors can significantly increase Voc, Isc, and output power compared to the panel without a reflector. The 80° reflector produced the highest efficiency at 12,75%, followed by 90° at 12,29% and 70° at 5,57%. Meanwhile, the 50° and 60° reflectors resulted in decreased efficiency at -21,68% and -6,83%. These reductions occur because smaller angles fail to direct reflected sunlight effectively toward the panel surface. Overall, the 80° concave aluminum reflector is identified as the most efficient configuration for improving the performance of the 50 Wp monocrystalline solar panel.

Keywords: Solar Photovoltaic Module, Aluminum Reflector, Panel Surface Temperature, Reflector Angle, Output Power.

INTRODUCTION

Indonesia is one of the most populous countries in the world. The continuously increasing population drives a higher demand for electrical energy. According to data from Badan Pusat Statistik (BPS), electricity consumption in Indonesia has reached 1,084.32 kWh per capita per year. Most of this demand is still supplied by non-renewable fossil energy sources such as petroleum and coal, which contribute to global warming and environmental pollution [1].

As a sustainable alternative, the utilization of renewable energy sources such as solar energy has become an environmentally friendly option. A Solar Power Plant (Pembangkit Listrik Tenaga Surya or PLTS) converts sunlight into electrical energy through photovoltaic (PV) cells that make up solar panels [2]. However, the performance of solar panels is highly dependent on several factors, including solar radiation intensity, the angle of sunlight incidence, environmental conditions, and the mounting angle of the solar panel.

Pontianak, located in a tropical region precisely on the equator, has a high potential for solar energy utilization. Based on data from the Badan Meteorologi, Klimatologi, dan Geofisika (BMKG), the average solar irradiance intensity in Pontianak exceeds 4.5 kWh/m² per day throughout the year. These climatic and geographical conditions strongly support the development of an efficient solar power system. Apart from weather and location, several additional components can be used to enhance the efficiency of solar panels.

One of the effective methods to improve the output power of solar panels is the use of a reflector. A reflector functions to redirect additional sunlight onto the solar panel surface, thereby increasing the light intensity received and improving the power output [3].

Jiang et al. [4] reported that the use of reflectors can increase panel efficiency by up to 20%, depending on the reflector material and installation angle. However, the reflector angle plays a significant role in determining the effectiveness of energy gain, as certain angles can direct more sunlight to the panel surface. Concave aluminum reflectors are considered more efficient than flat reflectors because they can better focus reflected sunlight.

Based on the above background, this research aims to analyze the effect of concave aluminum reflector angle variations (50°, 60°, 70°, 80°, and 90°) on the output power of a solar panel and to determine the optimal angle for maximum performance. The novelty of this study lies in the use of a one-sided concave aluminum reflector with multiple installation angles. This design is expected to concentrate sunlight more effectively, resulting in higher light intensity and improved panel efficiency.

METHOD

This study employed an experimental method by directly testing a 50 Wp monocrystalline photovoltaic (PV) module under two conditions: without a reflector and with a concave aluminum reflector at various angles of 50°, 60°, 70°, 80°, and 90°.

a. Literature Study

The preliminary stage involved collecting theoretical information related to Solar Power Plant (Pembangkit Listrik Tenaga Surya – PLTS) technology, solar panel efficiency, the influence of reflectors, and relevant previous studies to establish the research foundation.

b. System Design

The PV module was installed horizontally (0° tilt), with a one-sided concave aluminum reflector attached at each tested angle. The mounting frame, made of wood with dimensions of 45.1 × 58 cm, was designed to securely hold both the panel and the reflector.

c. Data Collection

1. Determining the testing location that receives direct sunlight exposure and is free from shading.
2. Designing the mounting frame for the solar panel and the reflector with tilt angle variations of 50°, 60°, 70°, 80°, and 90°.
3. Constructing and assembling the testing equipment according to the previously designed electrical wiring configuration.
4. Conducting tests at each reflector angle between 10:00–14:00 WIB, with data recorded every 10 minutes. The experiment is only carried out during clear weather conditions.
5. The tested parameters include: Open-circuit voltage (Voc); Short-circuit current (Isc); Load current; Temperature around the solar panel.
6. Collecting the data, research results, and documentation.
7. Conducting data analysis and processing of the measurement results to determine the effect of reflector angle variations on the performance of the solar panel.
8. Formulating the final conclusions based on the testing results and analysis.
9. The research is declared complete.

d. Data Analysis

The output power was calculated using $P = V \times I$, where V is voltage (V) and I is current (A). The efficiency improvement was determined using Equation (1):

$$\text{Power Improvement (\%)} = \left(\frac{P_{\text{with reflektor}} - P_{\text{without reflektor}}}{P_{\text{without reflektor}}} \right) \times 100\%$$

RESULT AND DISCUSSION

Tool Design Results

The photovoltaic (PV) panel support frame was constructed using galvanized light steel, designed to be detachable for easy assembly, transportation, and maintenance. The structure was specifically built to support one unit of a Mitsuyama 50 Wp monocrystalline solar panel, measuring 45.1×58 cm and weighing approximately 2 kilograms. The design of the tool frame is shown in Figure 12 below.

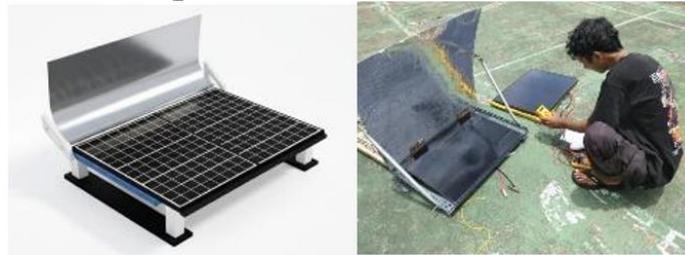


Figure 1 Tool Design

In addition, the frame was equipped with a concave reflector made of aluminum plate coated with aluminum foil to enhance light reflection toward the panel surface. The reflector angle could be adjusted flexibly to 50° , 60° , 70° , 80° , and 90° , according to the optimal solar incidence angle.

Testing Of Solar Panel Output Power With And Without Reflector

The testing of solar panel power output with and without a reflector was conducted to determine how the use of a concave aluminum reflector affects the panel's performance in converting sunlight into electrical energy. The results showed that the addition of a reflector significantly influenced the panel output, depending on the reflector angle used.

At angles of 80° and 90° , the panel produced noticeably higher voltage, current, and power output compared to the condition without a reflector. The 80° reflector gave the most optimal results, as its reflection angle aligned more effectively with the sunlight's incidence angle during testing, allowing light to be distributed more evenly on the panel surface. At 70° , the improvement was present but not as significant, as the reflected rays were not fully directed toward the panel. Meanwhile, at 60° and 50° , the reflected light failed to reach the panel surface efficiently, resulting in lower power outputs than the non-reflector condition. Overall, the findings confirm that the use of a concave aluminum reflector can enhance solar panel performance, with the 80° configuration providing the best efficiency and power output among all tested angles.

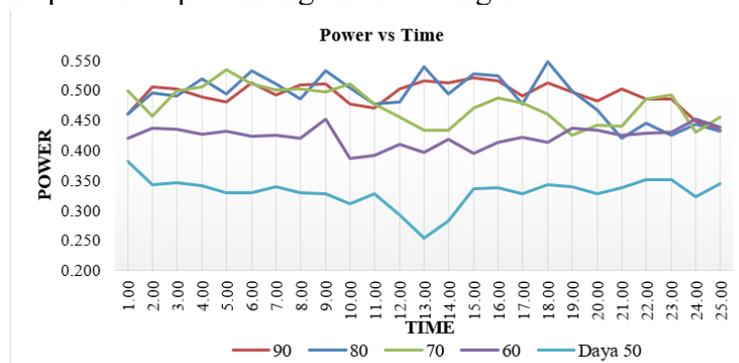


Figure 2 Data Collection

Measurement of Solar Panel Power Efficiency Improvement with Reflector (%)

Each reflector angle produced different effects on the efficiency improvement of the solar panel. Based on the average data, the 80° reflector achieved the highest efficiency increase of 12.75%, followed by 90° (12.25%) and 70° (5.57%). Meanwhile, reflectors with angles of 50° and 60° showed decreased performance, with negative efficiency values of -21.68% and -6.83%, respectively. The detailed results of efficiency measurements are shown in Table 7 below:

Table 1. Measurement of Solar Panel Power Efficiency

Time	Efficiency Reflector 50° (%)	Efficiency Reflector 60° (%)	Efficiency Reflector 70° (%)	Efficiency Reflector 80° (%)	Efficiency Reflector 90° (%)
A vg	-21.68 %	-6.83%	5.57 %	12.75 %	12.29%

The best result was obtained at the 80° reflector angle. This occurred because, at this configuration, the reflector was optimally positioned to direct and concentrate sunlight more effectively onto the panel surface, aligning closely with the sun's incidence angle during the testing hours (10:00–14:00 WIB). At this period, the sun's position was relatively high, allowing the 80° reflector to capture and redirect a larger portion of sunlight directly toward the solar cells. As a result, the solar module received a higher intensity of effective irradiance, which significantly improved both the voltage and current output. Consequently, the overall power generation and conversion efficiency of the system increased notably compared to other reflector angles.

In contrast, reflector angles of 50° and 60° were too shallow, causing the majority of reflected rays to deviate away from the solar panel surface. This misalignment reduced the effective irradiance received by the module, leading to a drop in energy absorption and overall power output. The 70° angle, although better than 50° and 60°, still did not achieve perfect alignment with the sun's rays during peak hours, resulting in only moderate improvements in performance.

Furthermore, the observed hourly fluctuations in efficiency values were influenced by changes in solar radiation intensity caused by the natural movement of the sun, intermittent cloud cover, and atmospheric conditions. These external variations affected both the incoming and reflected irradiance, leading to slight deviations in voltage and current readings over time.

Overall, it can be concluded that the 80° concave aluminum reflector configuration provided the most stable and optimal performance among all tested angles. It maximized light concentration without causing excessive heating on the panel surface, maintained efficient light capture throughout the test period, and effectively improved the panel's energy conversion capability. Reflector angles below 70°, on the other hand, demonstrated less favorable performance and a tendency to decrease the solar panel's overall efficiency due to improper light reflection geometry.

Measurement Of Open-Circuit Voltage And Short-Circuit Current After Determining The Optimal Angle

Previous testing demonstrated that the 80° reflector angle provided the most optimal performance among all tested configurations. At this specific angle, the reflected sunlight was distributed evenly across the solar panel surface, ensuring effective illumination without causing excessive thermal buildup that could negatively affect the photovoltaic (PV) cell efficiency. This optimal balance between light concentration and heat

management allowed the panel to achieve superior energy absorption efficiency, thereby significantly enhancing its overall performance.

The experimental results revealed that under the 80° configuration, the power (watt) consistently ranged between 26.4–51.6 watt, which was noticeably higher compared to the non-reflector condition, where values only reached 14.8–30.5 watt. This voltage improvement indicates that the reflector at 80° effectively redirected and concentrated sunlight toward the active surface of the panel, thereby increasing the irradiance intensity received by the solar cells. As a result, the light-to-electricity conversion process became more efficient, leading to improved output voltage stability and higher electrical potential generation.

In addition, the short-circuit current (Isc) under the 80° reflector setup remained relatively stable throughout the entire testing duration, exhibiting smaller fluctuations compared to measurements taken without the reflector. This consistent current output suggests that the reflected sunlight was uniformly distributed across the panel's active surface, preventing localized heating and minimizing energy loss due to uneven illumination. The even distribution of reflected rays contributed to a stable flow of generated current, which in turn improved the reliability of the power output.

Overall, the combination of higher voltage, stable current, and efficient light reflection under the 80° angle confirmed that this configuration offered the most effective and consistent energy conversion performance. Compared to shallower reflector angles, the 80° setup maintained a superior balance between solar radiation capture and thermal management, maximizing power generation while ensuring long-term operational stability of the solar module.

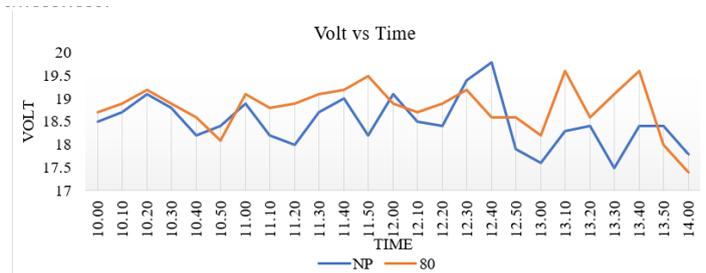


Figure 3 (a) Volt vs Time in Optimal Angle

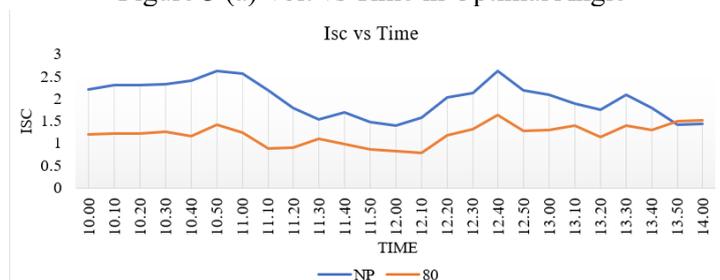


Figure 4 (b) Isc vs Time in Optimal Angle

Additionally, the surface temperature of the panel under the 80° reflector configuration was slightly higher, ranging from 43.8°C to 65.4°C. This temperature increase remained within acceptable limits and did not significantly reduce performance. Instead, it demonstrated that the reflector efficiently directed sunlight onto the panel. Therefore, the 80° reflector angle can be considered the most efficient configuration, achieving the best combination of higher voltage, stable current, and increased overall power output.

CONCLUSION

The variation of concave aluminum reflector angles has a significant effect on the power output of the solar panel. The test results show that the use of a reflector is able to increase the open-circuit voltage (Voc), short-circuit current (Isc), and power output compared to a panel without a reflector. The 80° reflector produced the highest efficiency at 12.75%, followed by 90° at 12.29% and 70° at 5.57%, while the efficiency decreased at 50° and 60°, reaching -21.68% and -6.83%, respectively. This occurs because the more accurate the reflection angle aligns with the direction of incoming sunlight, the greater the amount of light energy received by the solar panel.

Based on the analysis of test data at reflector angles of 50°, 60°, 70°, 80°, and 90°, it was found that the 80° angle is the most optimal. At this angle, the solar panel produced the most stable voltage and current, as well as the highest power output compared to the other angles. This indicates that the concave aluminum reflector at 80° has the best capability in reflecting and focusing sunlight onto the surface of the solar panel efficiently.

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