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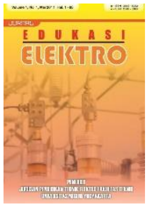

Performance Enhancement of 100WP Monocrystalline Solar Panel using Mirror Reflectors

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Abstract— This research analyzes how the reflection of sunlight intensity affects the power generated by a 100WP monocrystalline solar panel with the addition of various reflector tilt angles. An experimental method was used to conduct this analysis by comparing three tests: a solar panel without a reflector, with a 60° angled reflector, and with a 75° angled reflector. Data was collected at one-hour intervals from 09:00 to 16:00 WIB, measuring parameters such as temperature, intensity, voltage, current, and power. The results showed that the addition of a flat mirror reflector significantly improved the performance of the solar panel. With a 75° tilt angle, the total power generated was 373.32W, compared to the total power generated at 60° of 366.93W and without a reflector of 208.62W. The highest power peak was achieved at 13:00 WIB with the 75° reflector at 69.31W. This research demonstrates that a reflector tilt angle of 75° is the most optimal for increasing the efficiency of monocrystalline solar panels as it distributes sunlight more evenly across the panel surface. The recommendation for future research is the utilization of software-based simulations and IoT integration for real-time monitoring, to strengthen experimental data validation and expand the application of this technology at both industrial and household scales.

Keywords: renewable energy, solar radiation, tilt angle, solar panel, reflector.

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1 Introduction

With the advancement of technology and the growth of the human population, the demand for electrical energy continues to increase daily. The decline in fossil energy production, particularly natural gas, coal, and petroleum, has driven governments to strengthen the role of renewable energy in ensuring energy security and independence [1]–[3]. The growing global energy demand and the depletion of fossil fuels have increased the urgency of adopting renewable energy sources. Solar energy is one of the most promising options because of its abundance and sustainability that solar technologies provide efficient alternatives to conventional energy, while noted their role in meeting rising energy demand in high-irradiation regions [4]–[6]. Solar energy is a renewable, free, reliable, and environmentally friendly source that sustains human life. However, sunlight cannot illuminate the Earth's surface all day long. Solar panels are devices that convert sunlight into electrical energy [7]–[9]**.** When sunlight reaches the panel, the solar cells absorb photons from the light. Factors such as temperature, weather, tilt angle, and shading affect how efficiently a solar panel operates. This is because sunlight varies as the sun moves from east to west. As a result, the power output of solar panels depends on the intensity of light absorbed [10]–[12].

One method to increase the light intensity received by solar panels is by using reflectors or mirrors as additional light reflectors [13], [14]. However, factors such as the angle of incident light, reflection, and the panel's position relative to the light source can affect how effectively the panel absorbs solar energy. Previous studies have shown that the addition of four flat mirror reflectors affects the level of radiation received by polycrystalline solar panels [15]–[17]**.** A 50 WP solar module with two additional reflectors was shown to increase sunlight intensity by 363 (about 50%) and boost power output by 0.0024 or about 7.6% [18]**.** A 10 WP polycrystalline solar panel performs better when directly exposed to sunlight and paired with reflectors positioned vertically at a 90-degree angle [19]**.** Adding flat mirror reflectors and adjusting the reflector angle to 60° and 70° can optimize power absorption. In this research, the reflectors were equipped with a monitoring system using current, voltage, and light intensity sensors [20]**.** The use of reflectors on a 100 WP monocrystalline solar panel at an 83° tilt angle showed a higher power output compared to one without a reflector [21].

Based on the above discussion, this research aims to add flat mirror reflectors to a 100 WP monocrystalline solar panel to achieve more optimal sunlight intensity and power output, as well as to compare the performance between PV systems without reflectors and those with reflectors. It is expected that this research will positively influence the voltage, current, and solar intensity readings, thereby allowing the panel to produce more power through the addition of two reflectors at tilt angles of 60° and 70°.

2 Method

2.1 Research Diagram

The flowchart in Figure **1** explains the research process related to a monocrystalline solar panel with the addition of varying tilt angles on the reflector. The following is an explanation of each stage:

1. Before conducting the research, a literature review is carried out to find relevant reference sources and obtain existing information related to monocrystalline solar panels and reflectors in the research process.
2. Then, all equipment and materials needed for the research are prepared to construct the solar panel system with the addition of reflectors, making it ready for testing.
3. Next is the design and construction of the solar panel system with variations in the reflector tilt angles.
4. Testing and data collection are conducted on the 100WP monocrystalline solar panel from 09:00 to 16:00 WIB, with data taken at 1-hour intervals.
5. Once the data is collected, calculations and data processing are carried out, followed by analysis and discussion of the results.
6. The research findings are presented in conclusion, along with suggestions for future research or further applications.

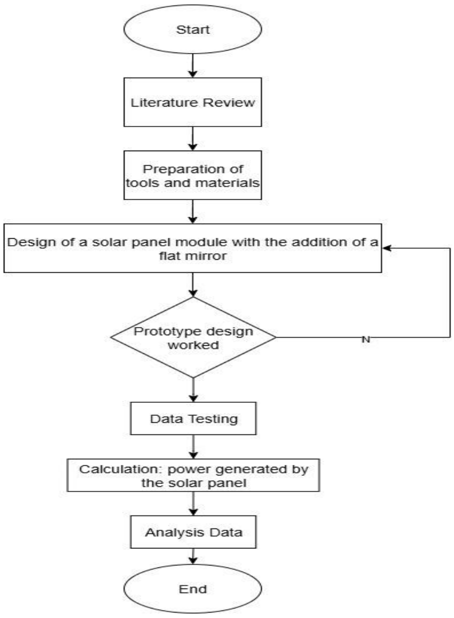

Figure 1. Solar panel with flat mirror reflector

2.2 Design of a Solar Panel with Flat Reflector Mirrors

The following is the solar power system circuit with flat mirrors, as shown in the Figure 2. The components used in the solar power system (PLTS) research with the addition of flat mirrors are as follows:

1. Solar Panel Support Frame
2. 100 WP Monocrystalline Solar Panel
3. Flat Mirror (35 cm x 97 cm)
4. DC Watt Meter 100A
5. 30A Solar Charge Controller
6. 12V/34Ah Battery

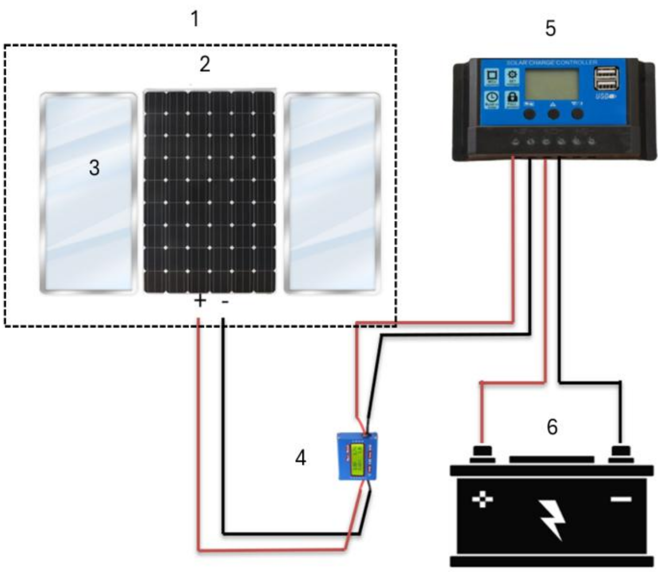

Figure 2. Solar panel with flat mirror reflector

3 Results and Discussion

The solar power system (PLTS) with the addition of flat mirror reflectors demonstrated improved power conversion efficiency from solar energy to electricity. Testing with tilt angle variations of 60° and 75° produced different results. At a 75° tilt angle, the reflected sunlight was more evenly distributed, leading to a greater and more optimal increase in power output from morning to evening. In contrast, at a 60° angle, the reflected sunlight was less evenly distributed across the surface of the solar panel.

Figure 3. Monocrystalline solar panel without reflector and at tilt angles of 60° and 75°

Figure 3 presents a comparison of the results from three testing scenarios conducted on the monocrystalline solar panel: without a reflector, with a reflector installed at a 60° tilt angle, and with a reflector at a 75° tilt angle. The purpose of this test is to evaluate the effectiveness of each configuration in absorbing and converting solar energy into electrical energy. The solar panel was mounted on a specially designed support frame with reflectors installed on both sides of the panel, allowing reflected sunlight to be redirected onto the panel surface. All three configurations were positioned with the same orientation and in the same location to ensure uniform solar exposure, enabling a more accurate comparison of the power output produced. Thus, the analysis of these test results can help identify the most optimal reflector configuration for improving the overall performance of the solar panel.

3.1 Solar Power Output Tests

The testing and data analysis in this research were conducted through a series of systematic experiments involving the use of flat mirrors and variations in the reflector tilt angles. The performance of the monocrystalline solar panel was then evaluated to determine the highest total power output among the three test configurations. The comparison results of the monocrystalline solar panel without a reflector, with a 60° reflector, and with a 75° reflector can be seen in Table 1, Table 2, and Table 3, respectively.

Table 1. Monocrystalline solar panel without reflectors

Time	Monocrystalline Solar Panel Without Reflector					Weather (Sunny/Cloudy)
	Temperature (°C)	*Light Intensity (Lux)*	*Voltage (V)*	*Current (A)*	*Power (W)*	
09.00	26.4	329	11.26	1.24	13.96	Sunny
10.00	27.2	457	11.84	1.56	18.47	Sunny
11.00	27.6	616	12.19	1.65	20.11	Sunny
12.00	29.8	924	13.54	3.39	45.9	Sunny
13.00	30.4	951	13.65	3.72	50.77	Sunny
14.00	29.1	803	12.32	2.56	31.53	Sunny
15.00	27.9	752	11.91	1.63	19.41	Sunny
16.00	25.3	148	10.87	0.78	8.47	Cloudy
Total Power (W)					208.62	
Average Power (W)					26.07	

Table 2. Monocrystalline solar panel with 60^0 reflectors

Time	Monocrystalline Solar Panel With 60^0 Reflector					Weather (Sunny/Cloudy)
	Temperature (°C)	*Light Intensity (Lux)*	*Voltage (V)*	*Current (A)*	*Power (W)*	
09.00	30.1	598	12.91	2.22	28.66	Sunny
10.00	32.3	1004	13.63	3.31	45.11	Sunny
11.00	33.7	1156	14.89	3.58	53.3	Sunny
12.00	35.1	1288	15.53	4.17	64.76	Sunny
13.00	35.5	1362	15.77	4.34	68.44	Sunny
14.00	33.1	1019	13.95	3.56	49.66	Sunny
15.00	30.7	867	13.66	2.74	37.42	Sunny
16.00	28.9	266	12.32	1.59	19.58	Cloudy
Total Power (W)					366.93	
Average Power (W)					45.86	

Table 3. Monocrystalline solar panel with 75^0 reflectors

Time	Monocrystalline Solar Panel With 75^0 Reflector					Weather (Sunny/Cloudy)
	Temperature (°C)	*Light Intensity (Lux)*	*Voltage (V)*	*Temperature (°C)*	*Power (W))*	
09.00	30.2	602	09.00	30.2	29.37	09.00
10.00	32.4	1011	10.00	32.4	45.79	10.00
11.00	33.8	1152	11.00	33.8	54.31	11.00
12.00	35.1	1282	12.00	35.1	65.81	12.00
13.00	35.7	1387	13.00	35.7	69.31	13.00
14.00	33.2	1024	14.00	33.2	50.88	14.00
15.00	30.8	871	15.00	30.8	37.86	15.00
16.00	29.2	275	16.00	29.2	19,99	16.00
Total Power (W)					373.32	
Average Power (W)					46.66	

Based on the data presented in Table 1, Table 2, and Table 3 regarding the total power calculations for each test configuration, it can be concluded that there is a significant difference in the power output generated by the monocrystalline solar panels. The first test, conducted without using a reflector, showed a total power output of only 208.62W. Meanwhile, the second test, with the addition of a reflector installed at a 60° tilt angle, showed a significant increase with a total power output reaching 366.93W. Furthermore, the third test using a reflector at a 75° tilt angle produced the highest total power output of 373.32W.

From these three results, it is evident that the use of reflectors on solar panels generally enhances performance and efficiency in absorbing and converting solar energy into electricity. In particular, the reflector with a 75° angle proved to deliver the most optimal results compared to other configurations, whether with a smaller angle reflector or without any reflector at all. Therefore, it can be concluded that the addition of a reflector, especially at a 75° tilt angle, significantly increases the total power output of the monocrystalline solar panel under the testing conditions conducted.

3.2 Comparison Graph of Power Output from Solar Panels

The graph presenting the results of the three tests on the monocrystalline solar panel shown in Table 1, Table 2, and Table 3 reveals a significant difference in key parameters such as Light Intensity, Voltage, Current, and Power Output between tests using reflectors and those without. The graph clearly shows that the use of reflectors, at both 60° and 75° tilt angles, consistently produces higher values for each parameter compared to the configuration without reflectors.

This increase occurs because the reflectors help redirect more sunlight onto the panel surface, thereby increasing the light intensity received by the panel. With higher light intensity, the panel generates greater voltage and current, which ultimately results in higher power output. The reflector at a 75° tilt angle even shows the most optimal performance among the three, marked by the highest peak values on the graph, especially at 13:00 WIB when the sun is at its highest position.

Therefore, it can be concluded that the use of reflectors, particularly at angles aligned with the incoming sunlight, significantly improves the performance of the monocrystalline solar panel. This graph serves as a visual confirmation that reflectors enhance the efficiency of solar energy absorption and its conversion into electrical energy.

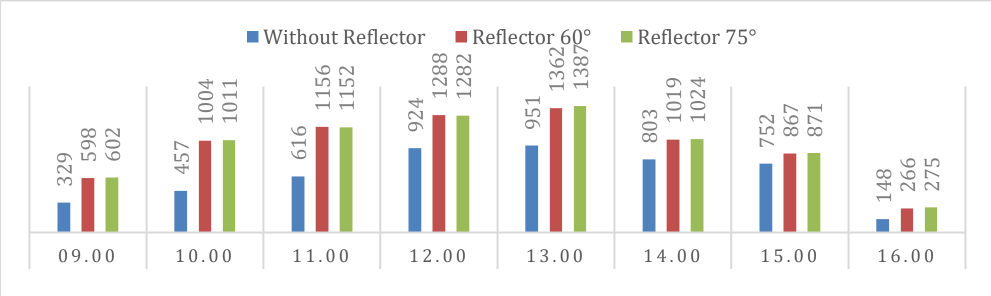

Figure 4. Light intensity comparison graphic

Based on Figure 4, which shows the light intensity graph on the monocrystalline solar panel measured using a Lux Meter, the highest light intensity occurred at 13:00 WIB with a 75° reflector, reaching 1387 Lux. Meanwhile, the lowest light intensity was recorded at 16:00 WIB without a reflector, with a value of 148 Lux. The results indicate that the light intensity received by the monocrystalline solar panel with a reflector is greater compared to without a reflector.

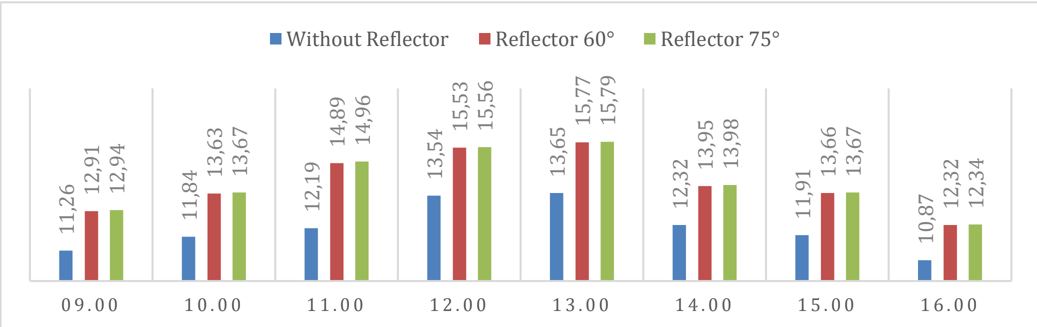

Figure 5. Voltage comparison graphic

Based on Figure 5, which displays the voltage graph measured using a DC Wattmeter and supported by a Multimeter, it can be seen that the addition of a reflector to the monocrystalline solar panel at a tilt angle of 75° resulted in a voltage value of 15.79V at 13:00 WIB. Meanwhile, the lowest voltage value occurred without a reflector at 16:00 WIB, with a value of 10.87V. These results indicate that the voltage generated by the monocrystalline solar panel with a reflector is higher compared to that without a reflector.

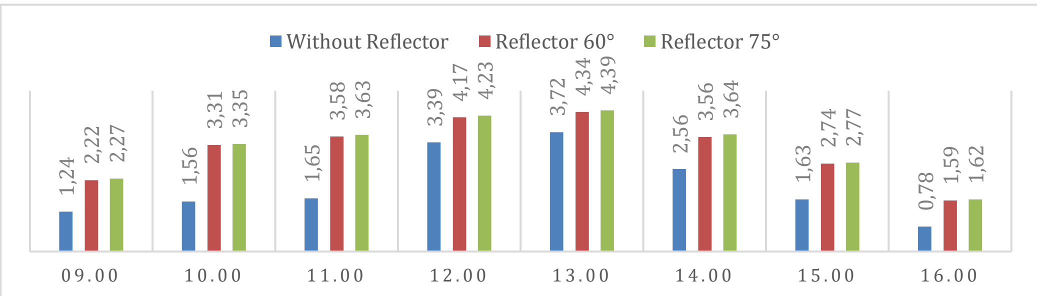

Figure 6. Current comparison graphic

Based on Figure 6, which displays the current graph of the monocrystalline solar panel measured using a DC Wattmeter and supported by a Multimeter, it can be observed that the highest current occurred at 13:00 WIB using a 75° reflector, reaching 4.39A, while the lowest current occurred at 16:00 WIB without a reflector, with a value of 0.78A. These results show that the current generated by the monocrystalline solar panel with a reflector is greater compared to that without a reflector.

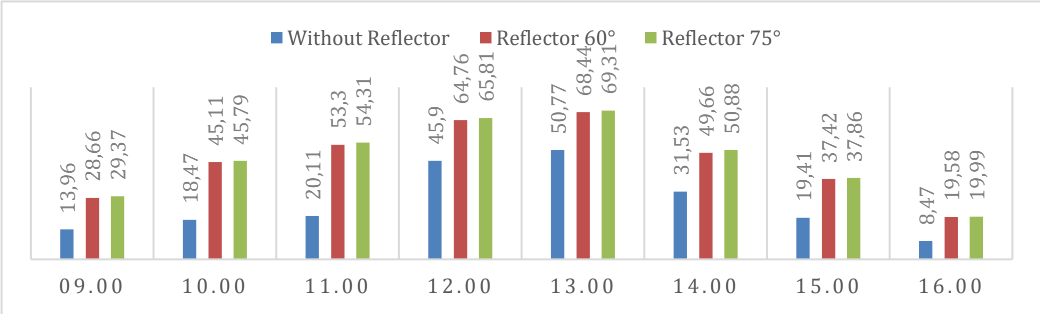

Figure 7. Power comparison graphic

Based on Figure 7, which displays the power output graph of the monocrystalline solar panel, the highest power output occurred at 13:00 WIB using a 75° reflector, reaching 69.31W, while the lowest power output occurred at 16:00 WIB without a reflector, with a value of 8.47W. These results show that the power generated by the monocrystalline solar panel with a reflector is greater compared to that without a reflector.

This research demonstrates that the use of flat mirror reflectors in PV systems can significantly improve the efficiency of solar energy conversion into electricity. Under three test conditions, the total power generated without a reflector was only 208.62 W, while with a 60° reflector it increased to 366.93 W, and with a 75° reflector it reached 373.32 W. The more even sunlight distribution at a 75° tilt angle also resulted in the highest peak power of 69.31 W at 13:00 WIB. These findings are consistent those reported an improvement of up to 9% in PV performance with reflectors at various tilt angles, although the improvement in this study was more significant due to the optimization of the 75° angle [22]. Furthermore, Kim confirmed that a higher reflector angle, approaching 75°, delivers optimal PV performance through more efficient light distribution [23]. Similarly, Arslan stated that solar panels at the optimal angle achieve peak power during midday when solar radiation is at its maximum [24]. Therefore, compared to previous studies, this research highlights that a 75° reflector configuration not only increases total power output but also provides more stable solar radiation distribution throughout the day. Thus, an optimal reflector angle can be recommended as an effective strategy to enhance the energy efficiency of monocrystalline solar panels.

4 Conclusion

This research analyzes a 100WP monocrystalline solar panel with variations in reflector tilt angles. From the three test variations, the total power generated without a reflector was 208.62W, with a reflector at a 60° tilt angle was 366.93W, and with a reflector at a 75° tilt angle was 373.32W. The results indicate that adding a flat mirror reflector enhances the panel's performance compared to using no reflector. Furthermore, the 75° tilt angle proved to be the most optimal, producing a maximum power output of 69.31W at 13:00 WIB, as it was able to distribute sunlight more evenly across the panel surface throughout the day. Additionally, it was found that the increase in light intensity positively correlates with the increase in voltage, current, and power output. The highest values typically occurred at 13:00 WIB, while the lowest values were observed at 16:00 WIB. Future work could include the use of simulation-based modeling to predict performance under various weather and seasonal conditions, as well as the integration of Internet of Things (IoT) technology for real-time monitoring and control.

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