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An Analysis Of Solar Power Plan Optimization With Solar Reflector Angle Variation Based On IOT

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ABSTRACT
This study analyzes the optimization of solar power generation by varying the angle of solar reflectors based on the internet of things (iot). The research aims to determine the most effective reflector angle to maximize the efficiency of solar energy absorption in solar power plants. By utilizing iot technology, real-time monitoring and adjustment of the reflector angles can be achieved to enhance energy capture throughout the day. The methodology involves both experimental and simulation approaches to compare different angles under various environmental conditions. The results of the study indicate that optimal reflector angles significantly improve the overall efficiency of solar power generation. This research contributes to the development of more efficient and sustainable solar power systems by leveraging iot for precise and responsive control mechanisms.

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INTRODUCTION

In this modern era, the need for clean and renewable energy is increasing along with global awareness of the negative impacts of fossil fuel use on the environment. One source of renewable energy that has great potential is solar energy. Utilization of solar energy through Solar Power Plants (PLTS) is a promising solution to reduce dependence on conventional energy sources and reduce greenhouse gas emissions. The global energy crisis and increasing awareness of the environmental impacts of fossil fuel use have encouraged efforts to find alternative energy sources that are cleaner and more sustainable. Among the various renewable energy sources, solar energy stands out because of its abundant availability and great potential to be converted into electricity. Solar Power Plant (PLTS) technology has developed rapidly and become one of the main solutions in facing today's energy and environmental challenges.

PLTS utilizes solar radiation which is converted into electrical energy through solar panels. The efficiency of solar panels in converting solar energy into electricity is greatly influenced by various factors, one of which is the angle of sunlight. Optimizing this lighting angle can increase the efficiency of solar energy absorption, thereby increasing the electrical output produced by PLTS.

However, the efficiency of PLTS is still a major challenge that needs to be overcome. Solar panels, as the main component of a solar power plant, have conversion efficiency that is affected by various factors, including sunlight intensity, temperature, and the angle of incidence of sunlight. In this context, optimal solar panel angle settings or the use of solar reflectors are key to maximizing solar energy absorption.

In an effort to optimize solar power plant performance, the use of Internet of Things (IoT) technology is becoming increasingly relevant. IoT enables the integration of various devices and sensors to collect, analyze, and manage data in real time. By combining IoT technology with a solar power plant system, various parameters such as sunlight intensity, temperature, and solar panel angle can be monitored and optimized automatically to improve energy efficiency.

A solar reflector is a device used to reflect sunlight towards a solar panel, increasing the amount of radiation received by the panel. Variations in the angle of the solar reflector can significantly affect the amount of reflected energy and, ultimately, the overall efficiency of the solar power plant system. Thus, proper angle settings are important to increase the electrical output of a solar power plant.

Previous studies have shown the great potential of solar panel angle settings and the use of solar reflectors in increasing solar power plant efficiency. However, there is still a gap in the application of IoT technology to dynamically optimize the angle of solar reflectors. This study aims to bridge this gap by developing and analyzing a solar power plant system equipped with solar reflectors.

This study focuses on the analysis of the optimization of solar power plants with variations in the angle of solar reflectors based on IoT. Solar reflectors are tools used to reflect sunlight onto solar panels, thereby increasing the amount of solar radiation received by the panels. With the right angle setting, solar reflectors can maximize the absorption of solar energy by solar panels.

On the other hand, the development of Internet of Things (IoT) technology offers great opportunities to overcome this challenge. IoT enables real-time data collection, processing, and analysis, as well as automatic control of various devices. By implementing IoT technology in the solar power plant system, the setting of the angle of the solar reflector can be automated based on changing environmental conditions, such as sunlight intensity and temperature. This not only increases system efficiency but also reduces the need for manual intervention and operational costs.

Literature Review

Solar Power Plants

A power plant is a series of machines and equipment used to generate electrical energy and go through various stages of energy transformation with different energy sources such as water, coal, sun and others. There are two types of power generation sources, namely non-renewable sources and renewable sources. Non-renewable sources are sources that will run out in time which come from fossils and coal, while renewable sources are sources whose availability will not run out or in other words will continue to exist. An example of a renewable energy source is the sun with its application in the form of a Solar Power Plant.

PLTS or Solar Power Plant is a power plant whose energy source is obtained from sunlight by using solar panels as a medium that functions to absorb solar energy to produce electrical energy. In PLTS there is an important component, namely solar panels. Solar panels are devices that can convert solar irradiation into electrical energy with the principle of the Photovoltaic Effect. The Photovoltaic Effect is an event that occurs due to the presence of electrical voltage due to the relationship between two conductors that are connected to the system when obtaining light energy. Therefore, solar cells are often referred to as Photovoltaic Cells.

Electric current appears because the received light energy successfully releases electrons in the N-type and P-type semiconductor connections to flow. Just like a Photodiode, Solar Cells have - and + legs that are connected to a circuit that requires a power source. Solar Power Plants (PLTS) are generators that do not emit emissions during their generation process. Basically, the installed PLTS system is divided into two systems, namely the on-grid system and the off-grid system, here is an explanation of the PLTS system.

The on-grid PLTS system is a type of Solar Power Plant that can be directly connected to the power plant so that it can be connected to the network, can directly send electrical energy obtained from solar panels to the load and the rest will be supplied to the network. This type of PLTS is usually used as a power aid for other large power plants, especially those that use diesel as their source. The off-grid PLTS system is a generating system that is not connected to the PLN network. Usually this PLTS system is used for remote or rural areas that are not covered by the PLN network due to many factors. The off-grid PLTS system is usually used for residential or housing scale, in terms of the off-grid PLTS system it is not much different from the on-grid

Energy Efficiency

Energy efficiency is the ratio between the energy output produced and the energy input used in the energy utilization system. Energy utilization is defined as the activity of using energy either directly or indirectly from an energy source. The success parameter that can be measured from energy efficiency is the ratio between energy use and the product produced.

Energy efficiency in Solar Power Plants is found in the solar panel installation system, including fixed mounting and solar trackers. Fix Mounting is one of the solar panel installation technologies that is generally used in PLTS and its elevation angle cannot be changed. This makes the absorption of solar radiation less than optimal because the sun is always moving. Radiation absorption will be maximized if the solar panels are always perpendicular to the direction of the sun's movement. Solar Tracker is a device that directs the payload towards the sun. The payload that can be moved by the solar tracker is in the form of solar panels, lenses, or other optical devices.

Solar trackers are divided into two types based on their driving motors, namely SAST and DAST. SAST (single axis solar tracker) is classified based on its horizontal and vertical

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axis of movement. Horizontal single axis has a rotation axis of movement towards the north and south, while vertical single axis has a rotation axis of movement towards the east and west. DAST (dual axis solar tracker) functions to change the position of the solar panel to adjust to the azzimuth angle and the zenith angle of the sun. The position of the sun uses a horizontal coordinate system on earth determined by the altitude / elevation angle, azzimuth angle and zenith angle.

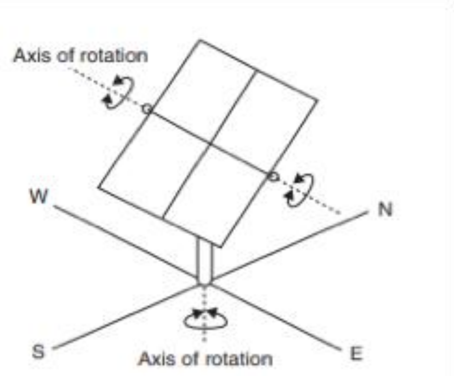

Figure 1. Horizontal Single Axis Solar Tracker

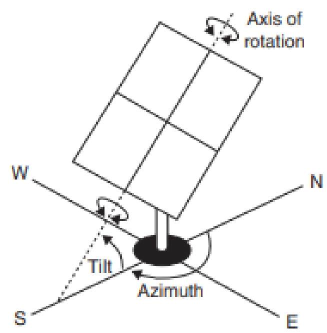

Figure 2. Vertical Single Axis Solar Tracker

It can be said that the era of modern solar trackers began during the oil and energy crisis in the early 1970s. ARCO (Atlantic Richfield Oil Company) as an oil and gas company saw this opportunity to start producing PV modules. In 1983, ARCO had built two PVs connected to the power plant network in the Carrizo Plain in California. Both ARCO plants use trackers controlled by a computer system to maximize sunlight absorption. However, in a study conducted by Akmal Faizal on the analysis of energy output produced by PLTS with a fixed mounting and solar tracker installation system, there was a difference in output at certain hours. For example, at 15:00 the energy produced by fixed mounting is greater than that of a solar tracker. However, the average energy produced in one day using a solar tracker is still greater than that of fixed mounting.

According to Vina Widiawati in a study entitled Optimization of solar cell energy based on IOT, it discusses the influence of current, temperature and voltage values. In this study, the current value is influenced by the light intensity value on the solar cell. The condition of the solar panel during sunny weather will increase the irradiation value of the solar cell, thereby increasing the current value on the solar cell and the voltage value varies every hour. The current, temperature and voltage values have different values since the beginning of data collection starting from 08:00-16:00. The condition of the solar panel during sunny weather increases the temperature of the solar cell, thereby reducing the voltage value. Temperature affects the power value produced. The higher the temperature value, the smaller the power value produced by the module than the maximum power value on the solar panel module.

Based on the results of the research that has been carried out in this experiment, namely the solar tracker system built based on a microcontroller using a light sensor obtains a maximum light intensity value and produces a large current when the temperature is in accordance with the optimum temperature value listed on the solar module.

Solar Panels

Solar panels are the main component of a PLTS system. Solar panels function to convert solar energy into electrical energy. The technology that functions to convert solar energy into electrical energy is Photovoltaics. Solar panels are generally composed of several solar cells arranged in series or parallel into solar panels, which function to increase the current and voltage obtained so that it is sufficient for system use to the load. To obtain maximum electrical energy output, the surface of the solar panel must face the sun.

The electrical power produced by solar panels when receiving light is obtained from the ability of the solar panel device to produce voltage and current through the load at the same time. This ability is represented in the current-voltage (I-V) curve as in Figure 3.
The characteristic curve of solar panels as in Figure 3 occurs when the solar panel gets a constant temperature and Irradiance value at the highest value, so that a curve with maximum current and voltage values is obtained.

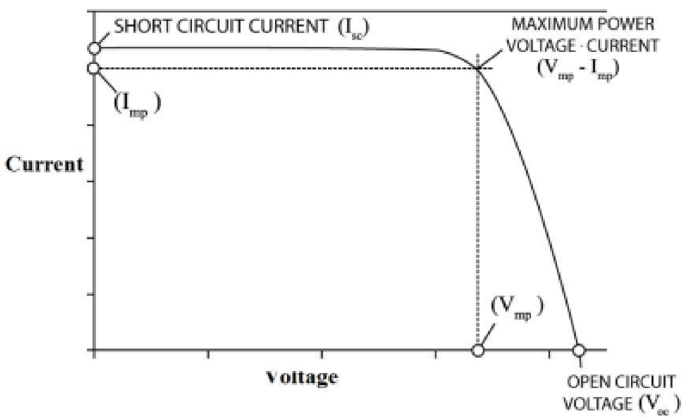

Figure 3. I-V Characteristic Curve of Solar Panel

Based on the curve above, it is known that the intersection point between (Im) and (Vm) is called (Pmpp) of the solar panel, where the maximum peak power (Pmpp) of a solar panel is the result of the multiplication of Im and Vm. The curve is greatly influenced by the amount of sunlight received, so the greater the sunlight received, the greater the voltage (Vm) and current (Im) of the solar panel, so that the power (Pmpp) is also greater.

Description:

Pin: Input power due to solar irradiance (Watt)

Ir: Solar radiation intensity (Watt/m2)

A: Surface area of the solar panel (m2) $W = V \, x \, I \, x \, t$

To find out the power value received by the solar panel, multiply the intensity of solar radiation received by the area of the solar panel with the equation:

Pin = Ir x A

Developed by previous researchers to obtain solar cell devices that have high efficiency and are easy to manufacture. Solar cells based on their development are divided into several generations, namely

a. Monocrystal Silicon (Monocrystaline silicon)

Is an efficient panel, its efficiency is 12-15%. This panel can produce the highest electrical power in unit area, but its price is also relatively more expensive. This panel is made of single crystal silicon obtained from silicon melting. The disadvantage of the monocrystal silicon type panel is that it does not function well in places with a lack of sunlight and panel efficiency can drop drastically during cloudy weather. This type has the characteristics of a plain bluish color without spots.

Efficiency = $Pout$ x 100% Pin

Efficiency = $Pout$ x 100% $Ir \ x \ A$

Pout: Energy produced by solar panels (watts) Pin: Energy captured by solar panels (watts) A: Area of solar panels (m2)

Ir: Intensity of solar radiation (watts / m2)

Over time, there have been several types of solar cells that have succeeded

Figure 4. Monocrystalline Silicon Solar Panel

b. Polycrystalline Silicon (Polycrystalline Silicon)

This type of silicon is made of silicon crystals. It has a random crystal structure, bluish in color with light blue and dark blue spots. This type is widely used in the solar cell industry.

This material has a relatively high efficiency, which is 10-13% and is cheaper. This type requires a larger field area when compared to the monocrystalline type to produce the same electrical output, but can produce electricity when it is cloudy or overcast.

Figure 5. Polycrystalline Silicon Solar Panel

Reflector

Reflector or often known as a reflector is a device that functions as a light reflector which is usually made of glass, metal, plastic and others. There are several types of reflectors including mirrors. One of the uses of mirrors as reflectors is the use of reflectors on solar panels to optimize PV performance so that the intensity of sunlight irradiation captured by the PV can be greater.

Based on the results of the research that has been done in this experiment, there is a difference between the output power of the panel without a reflector and the output power of the panel with a reflector with the same reflector angle, which is 7.025%. During the test carried out with direct sunlight, the average output power increased by 6.83%.

According to Tania Astari T. et al. in a journal entitled Monitoring System for the Effectiveness of Solar Panel Performance with the Addition of Microcontroller-Based Reflectors. In this study, a research method was carried out by testing the solar panel module using three treatments, namely the first to test the output results of the solar panel without using a reflector and using reflectors with angles of 45 ° and 75 °. This test was carried out on all design components in 3 days with the same time, namely 09:00-15:00 WIB.

In the study of the effect of reflectors on solar panel performance, research has been carried out on three conditions, namely two using the addition of reflectors and one without using a reflector. The aim of this study is to determine the value of power efficiency in the use of data recording and monitoring devices on solar panels. In the first value-taking experiment, the voltage and current without a reflector obtained the smallest output power value at 08:00 and 15:00 WIB of 1.49 Watts and the largest output power occurred at 13:00 WIB of 10.75 Watts. In the second value-taking, the solar panel with the addition of a reflector at an angle of 45° obtained the smallest output power value at 15:00 WIB of 2.43 Watts and the largest output value at 13:00 WIB of 12.57 Watts. In the third value-taking, the solar cell with a reflector at an angle of 75° obtained the smallest output power value at

15:00 WIB of 2.44 Watts and the largest output value at 12:30 WIB of 16.41 Watts. The efficiency value of the impact or effect of the reflector on the performance of the solar panel was 1.06%.

Based on the results and discussion of optimizing the reception of sunlight intensity on the surface of solar panels (solar cells) using mirrors, it can be concluded that the increase in temperature is due to an increase in irradiance, where each time irradiance increases, variables such as temperature, current, voltage also increase, so the output power also increases. However, the addition of a mirror reflector can cause a decrease in the output of the current and voltage of the solar panel because the intensity of light received by the solar panel can be blocked by the reflector itself.

Based on the graphic data of the measurement results between the 50 WP solar cell module without a reflector with the addition of a reflector, there is a fairly large difference in value. The reflection of light from the reflector increases the intensity of sunlight obtained by the 50 WP solar cell module by 363 or around 50%. So that the resulting voltage has an increase of 2.25 or around 12.7%. While the measurement results on the current are inversely proportional to the voltage, namely there is a decrease in value of 0.00007 or around 4.3%.

In this study, the author will use a solar panel with a maximum power of 50 WP while for the reflector, a flat mirror is used. In the test, the author will use two solar tracker prototypes to compare the output results between solar trackers without reflectors and with reflectors with varying reflector angles, namely 300, 450 and 600.

METHOD

The research methods that will be implemented in this study are as follows: Literature study is conducted to obtain a theoretical basis for general insight related to the research to be conducted. The theory comes from various references or other scientific sources such as scientific journals, theses, or books related to this research. After conducting a literature study and guidance with a supervisor, the next step is to determine the components and tools needed to be used in designing a solar panel solar tracker with the addition of a reflector. At this stage, the components and tools that have been obtained are then assembled according to the circuit. After the tool has been assembled, the next step is to test the sunlight that shines on the solar panel and take data that will later be processed and analysed.

This stage functions to write down the results that have been obtained and as a means of accountability for the final assignment that has been carried out. The report is divided into two stages, namely the initial report used for the proposal seminar and the final report used for the results conferences as for the research in this paper can be described through a block diagram of the design of a single axis solar tracker consisting of a 100 Wp solar panel, the use of current and voltage sensors, temperature sensors, light intensity sensors or lux and data loggers that function to store measurement results. Arduino which functions as a microcontroller, a source from a power bank that functions as an input voltage.

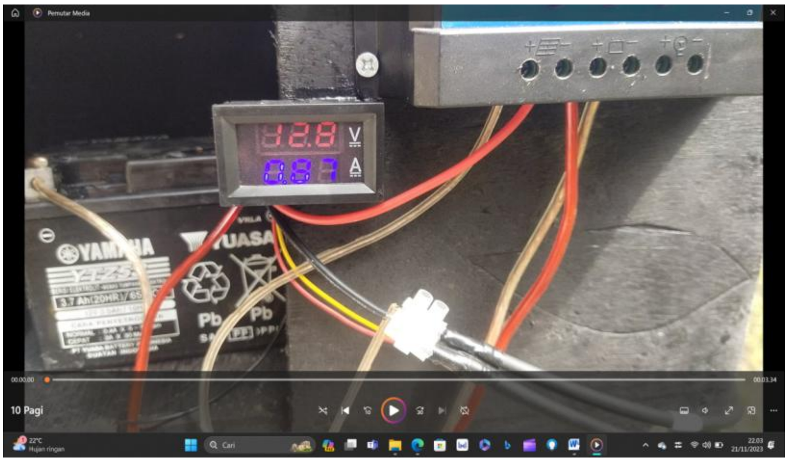

Figure 6. device controlling

The output from the solar panel passes through the current and voltage sensors and is then checked with a multimeter whether there is incoming voltage or not. If there is no incoming voltage or current, the components in the circuit will be checked. If the voltage and current enter, they will be read by the microcontroller and the sensor components used. In addition to measuring current and voltage, the temperature of the solar panel is also measured with a temperature sensor. The temperature sensor used is DHT11. Measurement of light intensity is also carried out to determine the value of the light intensity received. The sensor used is BH1750. Then the data from these sensors will enter the data logger via the RTC which already has a micro SD card in it which functions to store data.

ANALYSED AND RESULT

Result System

The system testing stage is carried out with the aim of knowing the results of the tool design. Testing this tool consists of several stages, starting from testing the suitability of the materials and components used, as well as testing the system as a whole. From the results of this test, researchers can analyze the performance of each tool component contained therein. And for overall system testing, the aim is to find out the comparison of PLTS output power using aluminum foil reflectors and direct sunlight.

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Figure 7. Design Equipment

The current and voltage in solar power plants using reflectors and without using reflectors will be tested to determine the power produced by solar cells. Testing was carried out over two days and data was collected every hour starting from 09:00 in the morning and ending at 16:00 in the afternoon.

Table1. Current and Voltage Test Results Data on Solar Panels Without Using Reflectors

Day	Time	Weather	Temperature	Voltage (Volt)	Current (Ampere)	Power (Watt)
First	09.oo	Cloudy	28.4 °C	12.2	0.19	2.31
	10.00	Bright	32°C	12.8	0.87	11,13
	11.00	Bright	31°C	13.4	1.40	18.76
	12.00	Bright	45°C	14.4	2.02	29.08
	13.00	Bright	60.4°C	12.8	1.89	24.19
	14.00	Bright	35°C	13	1.20	15.6
	15.00	Cloudy	27°C	12.3	0.31	3.81
	16.00	Bright	33°C	12.5	0.57	7.12
Second	09.00	Bright	31°C	13	1.60	20.8
	10.00	Bright	35°C	12.6	0.92	11.59
	11.00	Cloudy	29°C	12.1	0.20	2.42
	12.00	Bright	43°C	13.5	1.50	20.25
	13.00	Bright	37°C	12.7	1.90	24.13
	14.00	Bright	40°C	14.1	2	28.2
	15.00	Bright	34°C	13.6	1.35	18.36
	16.00	Cloudy	28.2°C	12	0.20	2,4

Figure 8. Using Reflector.

In measurements without a reflector, it can be seen in the picture above that the reflectors on both sides of the panel cannot reflect sunlight towards the panel so that the only light that the solar panel can convert into electrical energy is from direct sunlight.

Average Values of Current and Voltage in PLTS Without Reflectors

Average value $V\ panel = \frac{V\ total}{16}$

$= \frac{207}{16}$

Average V = 12.93 V

Average value $I\ panel = \frac{I\ total}{16}$

$= \frac{18,12}{16}$

I average =1.13 A

Power (P) = V x I

= 12.2 x 0.19

= 2.31 watts

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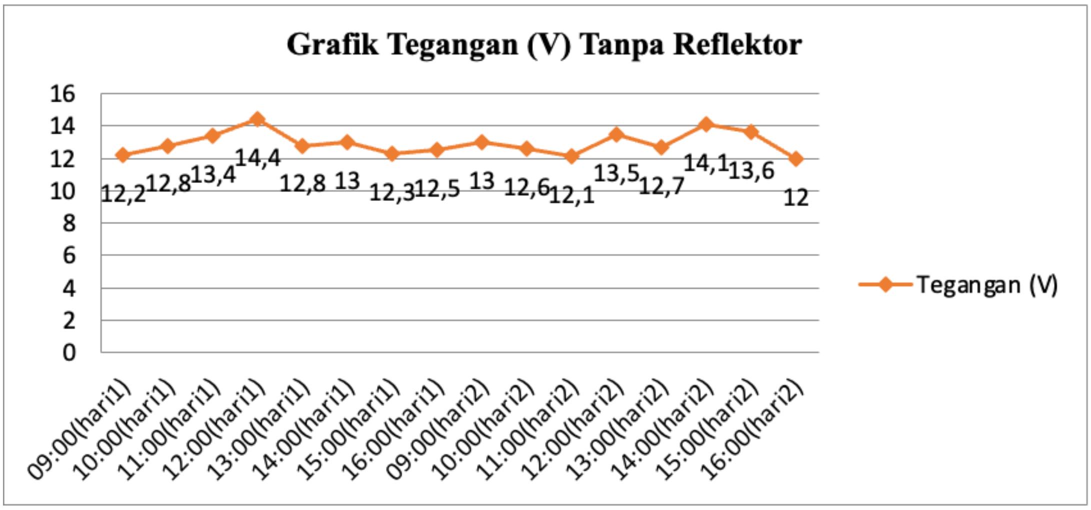

Figure 9. Graph of Output Voltage on PLTS Without Reflectors

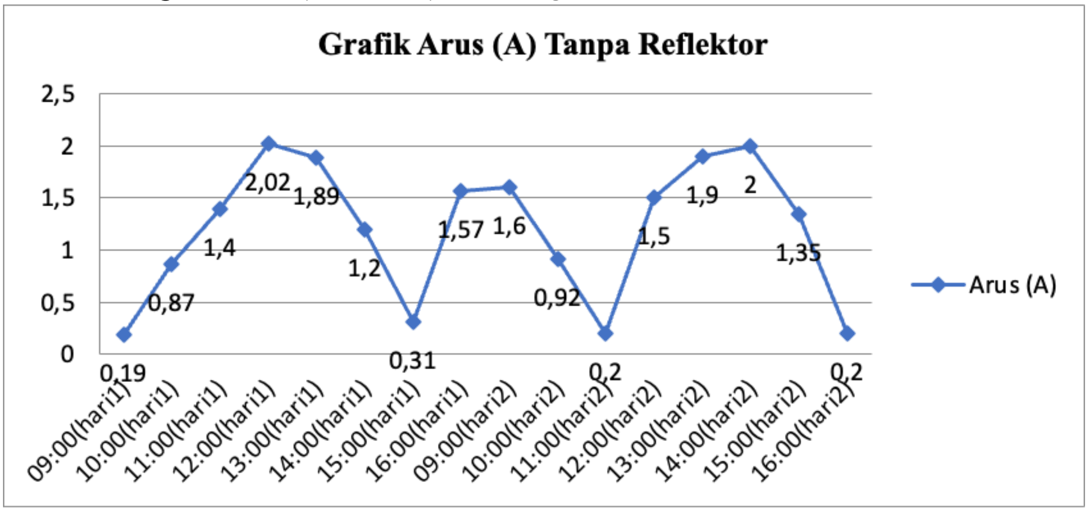

Figure 10. PLTS Without Reflectors

Current and Voltage Test Results Data on Solar Panels Using Reflectors

Testing was carried out within 2 days and data was collected every hour starting from 09:00 in the morning and ending at 16:00 in the afternoon. In testing using this reflector, only one part of the reflector is used while the other part of the reflector is in the off position and the reflector position must be facing towards the sun during the test.

Table 1. Results Data on Solar Panels Using Reflectors

Day	Time	Weather	Corner	Temperature	Voltage (Volt)	Current (Ampere)	Power (Watt)
First	09.00	Cloudy	∠700	28.8°C	12.2	0.20	2.44
	10.00	Bright		34°C	13.0	1.20	15.6
	11.00	Bright		33°C	13.4	1.53	20.50
	12.00	Bright		47°C	14.6	2.39	34.89
	13.00	Bright		62.1°C	12.9	2.13	27.47
	14.00	Bright		37°C	13.2	1.40	18.48

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Day	Time	Weather	Corner	Temperature	Voltage (Volt)	Current (Ampere)	Power (Watt)
	15.00	Cloudy		27°C	12.3	0.31	3.81
	16.00	Bright	∠900	35°C	12.5	0.67	8.37
	09.00	Bright		32°C	13.5	1.72	23,22
	10.00	Bright		37°C	13	1.22	15.86
	11.00	Cloudy		29°C	12.1	0.20	2.42
Second	12.00	Bright	∠700	44°C	14.1	1.65	23.26
	13.00	Bright		39°C	13	2.13	27.69
	14.00	Bright		43°C	14.5	2.40	34.8
	15.00	Bright		36°C	13.9	1.60	22.24
	16.00	Cloudy	∠900	28.2°C	12.1	0.20	2.42

In measurements using this reflector, the position of one reflector must be facing in the direction of the sun and the position of the other reflector must be in the off state as in Figures 4.6 and 4.7 so that the maximum light reflected by the sun can reach the solar panel without any interference. Both reflectors can only be used at 12:00 with an angle of each reflector of 70° due to the vertical position of the sun with the position of the solar panels.

In research using this reflector, there are two reflector angles used by researchers, namely 70° and 90°, this is because after conducting the research the author realized that the maximum reflector angle for reflecting sunlight is not the same at all times. The correct angle of 70° is used to get maximum power from the solar panels from 09:00 to 15:00, while at 16:00 the correct angle to use is 90° because in providing sunlight to the reflector the angle of the sun itself is very influential.

Average Values of Current and Voltage in PLTS Using Reflectors

Average value $V\ panel = \frac{V\ total}{16}$

$= \frac{210}{16}$

Average V = 35.05 V

Average value $I\ panel = \frac{I\ total}{16}$

$= \frac{20,95}{16}$

I average =1.30 A

Power (P) = V x I

= 12.2 x 0.20

= 2.44 watts

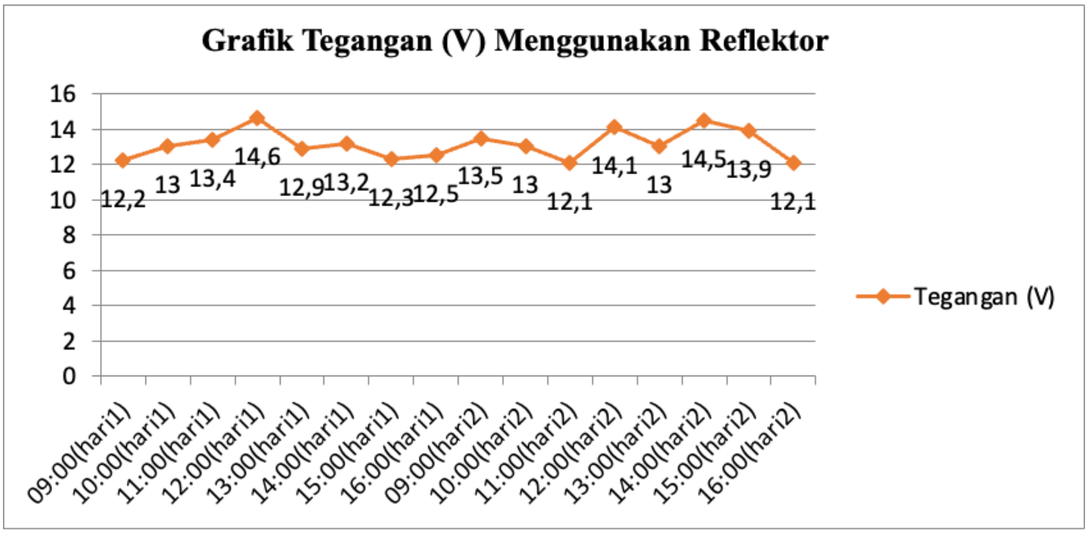

Figure 11. Graph of Output Voltage in PLTS Using Reflectors

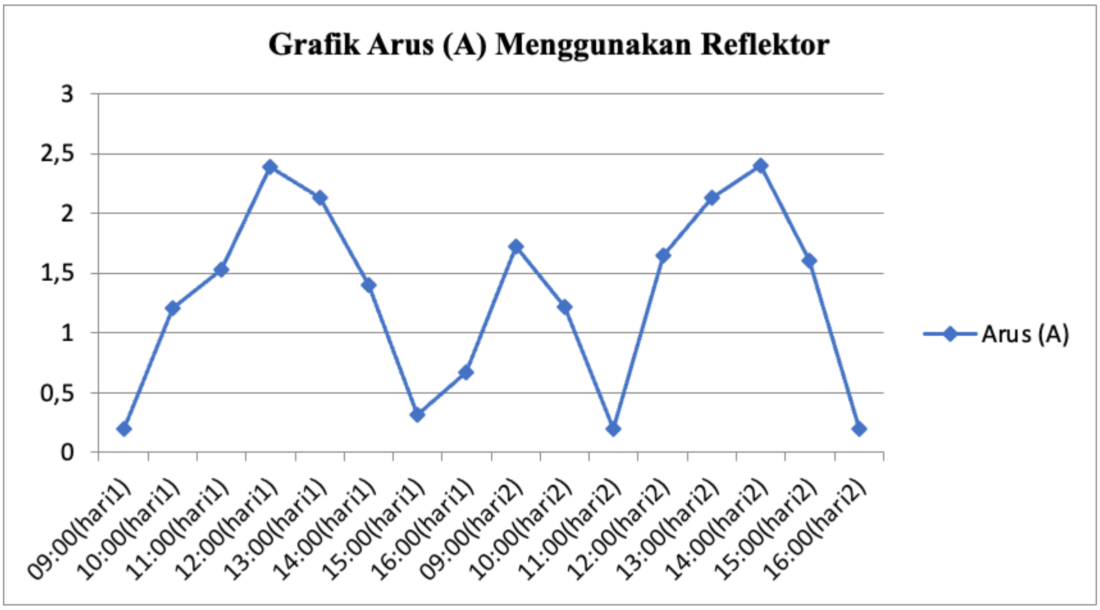

Figure 12. Current Graph in PLTS Using Reflectors

CONCLUSION

In this research, the author has carried out an in-depth analysis of the Solar Power Generation (PLTS) system with a focus on the use of aluminum foil reflectors. Based on the results of the research and discussion that the author has conducted, the author has reached the following conclusions: The results of the research show that the output power produced by PLTS when using a reflector has increased quite significantly compared to when not using a reflector. This can be seen from the graphic image of the comparison of power using a reflector and without a reflector. The results of this research verify the positive potential of Solar Power Plants (PLTS) that use aluminum foil reflectors as a solution to increase the efficiency of using renewable energy. In this research, the reflector used was an aluminum foil reflector, which is much cheaper than other types of reflectors. However, after conducting research, the author realized that this reflector is also very likely to be damaged because the material is elastic and thin, so the author concluded that this type of aluminum foil reflector requires more vigilance so that the condition of the reflector is maintained properly.

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