Performance Analysis of Dynamic Systems Using Solar Trackers to Improve Solar Panel Efficiency

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Abstract. This paper presents the design and performance analysis of solar panel dynamic systems using a solar tracker to improve output power efficiency. The majority of the solar panels are still static, which results in inferior solar energy receiving. to create a perpendicular angle between the solar panels and the direction of the sun's rays in order to maximize the absorption of solar energy. By altering the time of the solar module, this research creates a prototype solar tracker that is capable of producing more energy overall than solar modules that are static. For automatic solar module storage, these prototypes used two light sensors are employed, along with an actuator and the controller. It is expected that by using this technology, solar energy usage can be maximized and a cost-effective electronic control system can be created.

Keywords: Solar Panel, Dynamic System, Solar Tracker, Efficiency Improvement.

1 Introduction

Nowadays, electrical energy is very important for human life. One of the causes of global energy problems is the reduced supply of fossil fuels which are non-renewable energy sources. This phenomenon also has an impact on the global electrical energy market, which is on the verge of a crisis because most of the world's electrical energy needs are still being met by fossil fuel power plants. Meanwhile, the rural electrification ratio has not yet reached the target of 100 percent. In addition to supply problems, fossil fuels such as coal and oil are also not environmentally friendly because they release pollutants that can damage the ozone layer [1].

The potential of renewable energy as a source of energy is very high. Considered in lightof the fact that the cost of fossil fuels is currently rising together with the environmental issuesbrought on by the usage of conventional fuels, employing renewable energy sources as a producer of electrical energy is a different approach. Many people who want to be electrically independent

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now choose to use renewable energy, especially solar power generation systems with solar cell modules as the main component.

Solar energy is the most promising type of renewable energy, and its availability is abundant. However, solar energy has some drawbacks, namely intermittent availability and high level energy costs (LCOE) [2]. Solar cells are the main source of converting solar energy into electricity. There are several important things that affect the process of converting energy from the sun, namely the quantity, quality, and time availability of solar radiation [3]. The continuous movement of the sun in the sky throughout the day causes fixed PV panels placed at optimal tilt angles to not work effectively [4]. Currently, the most installed solar panels are static and do not take into account the optimal point of sunlight. As a result of this condition, the received solar energy is less than optimal [5]. To increase the efficiency of solar panels, we need to use a solar tracker to get the optimal point of solar radiation according to the direction of the sun's rays. The solar tracking system follows the movement of the sun so it can increase the input of solar radiation. Solar energy tracking systems work by increasing the angle of inclination to obtain the maximum available radiation [3], [5], [6].

The purpose of this research is to apply an automatic solar tracker to solar panels with a single-axis system. This is done to increase the efficiency of solar cells by changing the direction of the solar panels from east to west automatically following the direction of the sun's movement.

2 Literature Review

Renewable energy is also known as clean energy because it is a form of energy that does not produce harmful emissions, does not endanger human health or ecosystems, and does not harm the environment. The switch from burning fossil fuels to renewable energy sources will reduce the amount of carbon that is created in the atmosphere as CO_2 gas. One of these renewable energy sources is solar energy.

The sun's light and heat, which are both forms of solar energy, are used to heat and power buildings, schools, businesses, and perhaps even automobiles in the future. The devices known as photovoltaic cells, sometimes known as solar cells, are what convert solar energy into electrical energy. Without using any mechanical parts, these devices produce power directly from electromagnetic radiation, specifically light. A photovoltaic cell generates an electric current by collecting photons, the energy units of solar radiation, which subsequently eject electrons from the material inside the cell. Silicon and other semiconductor materials are excellent for converting photon energy into electric current.

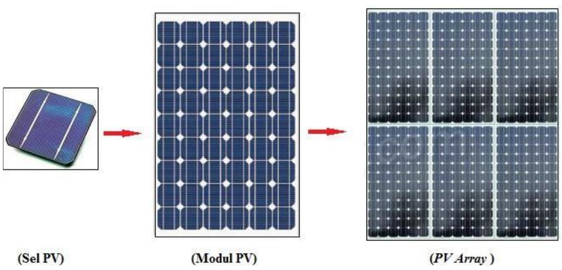

Fig. 1. The types of solar modules.

Several PV cells that are stacked and connected in series or parallel make up this PV module. As illustrated in Figure 1, installing PV modules to create a PV mini-grid system with a specific capacity will also require many PV modules that are also arranged and connected in series or parallel to build a PV array. The greater the intensity of sunlight captured by the solar panel, the greater the electrical power generated. Therefore, it is necessary to create a system that can make the solar cell always follow the direction of the sun's movement, namely the solar tracking system [5].

Through testing, it was found that on the same day, the energy output of the non-tracking solar panel system was 829.6 Wh and that of the tracking system was 1742.88 Wh. It can be concluded that solar panels with a tracking system get almost double the energy obtained without a solar tracking system [3]. From the results of the solar cell test, by using a solar tracker, solar energy can be absorbed more optimally than without using a solar tracker (static). The maximum power absorbed at 12.00 by static solar panels is 16.62 watts, while that absorbed by dynamic solar panels is 25.72 watts [7]. Based on the literature study that has been done, we will design a tool that can help increase the absorption of sunlight by using a single-axis sun tracker system to increase the output power of dynamic solar panels by using solar panels that are able to follow the direction of the sun's rays.

3 Methods

3.1 Method and Design of the Device

The research was conducted using the following methodology: Initially, a literature review was conducted to comprehend the ideas included in the investigation. The following step entails experimental testing, planning, and tool creation. From the location of the solar panel, experiments were conducted on the dynamic mechanical system of the frame. In order for the solar panel control method to achieve the intended result, which is for the solar panel's surface to be perpendicular to the incoming sunlight, mechanical system design, electrical system design, and program design are three broad categories into which the design of the sun tracker system can be divided.

Fig. 2. The design of solar panel dynamic system.

3.2 Solar Tracker

To maximize the sun's absorption by the solar panels, a solar tracker is a device that can detect the direction of sunlight and adjust the position of the solar panel so that it is perpendicular to the sun's beams. For the solar panel to move at a predetermined time, solar trackers can be divided into two categories. The first is the type based on time, in which the sun's path has been calculated according to time. The second category is the type where the solar panel will respond directly to sunlight. The one-axis Solar Tracker utilized in this investigation (single-axis).

A single-axis solar tracker is a tracking device that can only track the direction of the sun's rays when it rotates on one axis, either vertically (from east to west to west to east), horizontally (from north to south to north), or tilted (from northwest to southeast to southeast to northwest) or from northeast to southwest to southwest to northeast) [4]. Two light sensors are mounted on one side of the solar panel in the single-axis solar tracker system, which also includes one motor to move the solar panel. One of the two light sensors will be shaded and the other will be lit depending on how much sunlight is there. When one light sensor is exposed to more intense sunlight than the other, the motor will receive a command from the controller to move the solar panel in the direction of the light sensor. The solar panel is perpendicular to the sun's rays if the two light sensors measure the same amount of sunlight.

3.3 Tools and Material

The tools used in this research are:

1. Solar Power Meter
2. Thermo Gun
3. AC/DC Analyzer

The materials used in this research are:

1. Solar Panel
2. MPPT
3. Inverter
4. VRLA Battery
5. Single Axis Solar Tracker
6. Microcontroller

4 Result and Discussion

4.1 Output Power Analyze

The research was carried out for five days, from August 22 to August 26, 2022, on the roof top of the Electrical Engineering Laboratory, Faculty of Engineering, Universitas Negeri Medan. It involved 5 days of measuring the dynamic solar panel solar tracker single-axis research, which was done from 10.00. to 17.00 western indonesia time. The objective of the research was to determine the variable voltage open circuit (Voc), current of short circuit (Isc), surface temperature (°C), and solar radiation intensity (W/m^2) of solar panels. Table 1 shows the average of the total measurements, and Figure 3 shows the Dynamic Solar Panel with Solar Tracker.

Fig. 3. Dynamic solar panel with solar tracker.

Table 1. The average of solar panel dynamic system measurment.

Time	Solar Radiation (W/m^2)	Solar Panel Dynamic System with Solar Tracker				
		Temp (^oC)	Voc (V)	Isc (A)	FF	Power
10:00	1130	52,66	21,5	5,6	0,82	96,42
10:30	664	48,34	20,36	3,32	0,81	54,78
11:00	1006	50,62	20,99	4,98	0,81	85,15
11:30	988	49,36	21,11	4,89	0,82	84,16
12:00	856	41,88	20,77	4,25	0,81	71,78
12:30	965	43,74	20,96	4,79	0,81	81,76
13:00	829	43,92	20,95	4,12	0,81	70,29
13:30	773	41,48	20,84	3,85	0,81	65,28
14:00	971	41,66	21,18	4,81	0,82	83,11
14:30	662	36,98	20,86	3,31	0,81	56,19
15:00	637	36,12	21,72	3,19	0,82	56,75
15:30	702	40,64	21,24	3,50	0,82	60,67
16:00	690	40,02	21,14	3,44	0,82	59,31
16:30	613	40,46	21,08	3,07	0,82	52,75
17:00	497	36,40	21,16	2,51	0,82	43,32
Average	799	42,95	21,03	4,72	0,81	80,88

The characteristics of open voltage (Voc), short circuit current (Isc), solar panel surface temperature, and solar radiation intensity (W/m^2) from dynamic solar panels with a single axis solar tracker are shown in Table 1 based on measurement findings of monocrystalline solar panels. Using the equation, determine how much energy solar panels produce:

$$Pout = Voc\ x\ Isc\ x\ FF \quad (1)$$

The Fill Factor (FF) value is searched using the equation:

$$FF = \frac{Voc - \ln(Voc + 0{,}72)}{Voc + 1} \quad (2)$$

Using the following details, analyze the dynamic solar panel output power at 15:00 :

Voc = 21.72 V
Isc = 3.19A

So the Fill Factor value use equation (2) is:

$$FF = \frac{21.72 - \ln(21.72 + 0{,}72)}{21.72 + 1}$$
$$FF = \frac{21.72 - 3.111}{22.72}$$
$$FF = \frac{18.609}{22.72}$$
$$FF = 0.819$$

And the output power of dynamic solar panels using a solar tracker use equation (1) is:

$$Pout = 21.72\ x\ 3.19\ x\ 0.819$$
$$Pout = 56.75\ W$$

Analysis of the overall power output of solar panels and FF can be seen in Table 1.

4.2 Efficiency Analysis

Solar panel efficiency can be calculated using the equation:

$$\eta_p = \frac{P_{out}}{G\ x\ A}\ x\ 100\% \quad (3)$$

A is cross-sectional area of solar panels. This research use solar panels with a section of 1x0.67 m^2.Table 1 shows that the solar panel's output power is 56.75 Watt on the 15:00. with incoming sunlight intensity (G) of 637 W/m^2. in order for dynamic solar panels to have the following efficiency at 15.00:

$$\eta_p = \frac{56.75}{637\ \text{x}\ (1 \times 0{,}67)}\ x\ 100\%$$
$$\eta_p = \frac{0.089}{0{,}67}\ x\ 100\%$$
$$\eta_p = 0.133\ x\ 100\%$$
$$\eta_p = 13.3\%$$

The voltage of the solar panel is shown in Figure 4. From the graph, it can be seen that there is an increase in the value of the voltage on the solar panel with a solar tracker compared to static solar panels, where the increase is 4.78% or 0.96V, for solar panels with a single axis solar tracker.

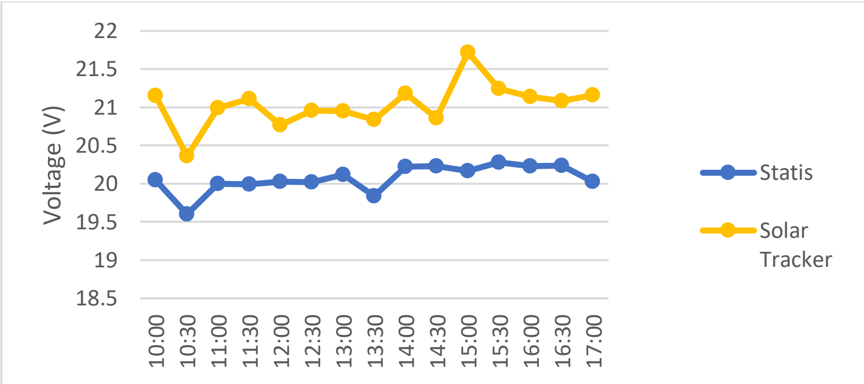

Fig. 4. Voltage graph of static and solar tracker system.

The power comparison graph of static and dynamic solar panels is shown in Figure 5. At 15.00, a static dynamic solar panel's efficiency value was determined to be 13.3%. On all dynamic solar panels, this calculation is done at the time between 10:00 and 17:00. Figure 6 shows the graph of power and efficiency.

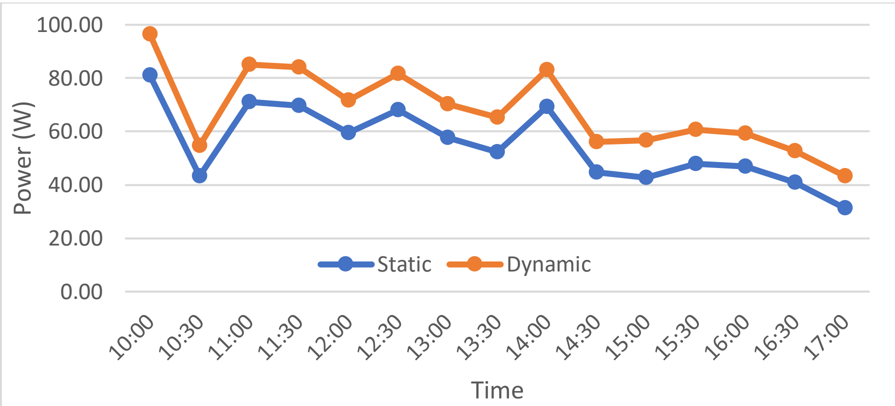

Fig. 5. The power comparison graph.

The highest power is obtained at 10:00, which is 96.42 W, the second highest at 11:00 is 85.15 W, and the last at 14.00 is 83.11 W, according to the efficiency and output power statistics. While the best efficiency is attained at 15.00, where it is 13.30%, the second is at 17.00, where it is 13.00%, and the final one is at 15.30, where it is 12.91%. In the comparison graph, we can see that a solar dynamic panel is better at generating power than a static solar panel.

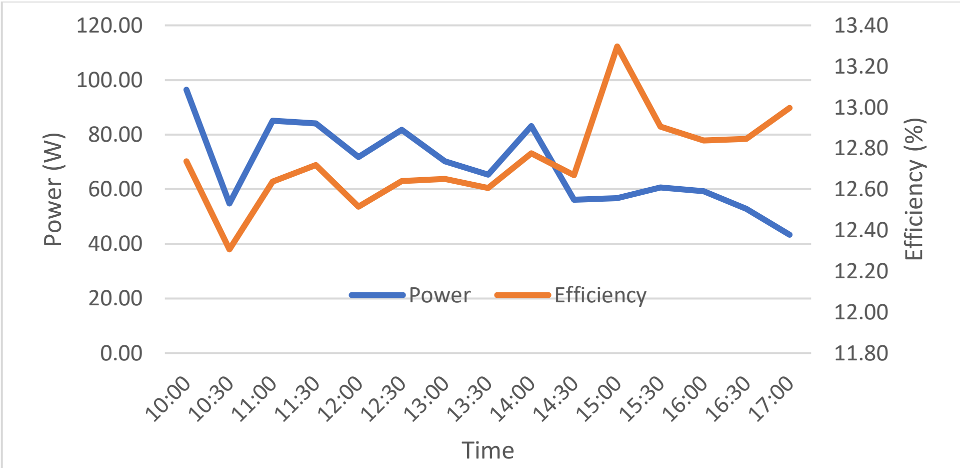

Fig. 6. Graph of power and efficiency of dynamic solar panel.

5. Conclusion

Based on the reasearch's results and discussions the final product has been finished. The highest power is obtained at 10.00, which the power is 96.42 W. And the best efficiecy is attained at 15.00, which the percentage is 13.30%. Solar panels with solar trackers have increased output power compared to static systems. The use of a solar tracker on solar panels can increase the value of the open circuit voltage and short circuit current of the solar panel.

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