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Monitoring Solar Tracker System Dual Axis Based on The Internet of Things to Improving Solar Panel Performance

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***Abstract*— Building a monitoring solar tracker system dual axis based on the Internet of Things (IoT) to monitor the performance of the solar tracker which can be viewed through computers and smartphones. A solar tracker is a device that allows solar panels to follow the movement of the sun to maximize sunlight reception. Through this project, the implementation of sensors that can measure important parameters such as light intensity, temperature, tilt angle, current, voltage and power generated by solar panels. The collected data is then processed and analyzed to effectively monitor the performance of the solar tracker. The NodeMCU component is used to send sensor data to thingspeak. From the test results, it was obtained that the percentage increase in light intensity was 76.1%, the current produced increased by 136.6% and the voltage also increased by 6.4%. The percentage increase in solar panel temperature was 3.07%, the voltage of solar panels decreased by 1.35%. The use of a solar tracker system dual axis that makes the position of the solar panels perpendicular to the sun increases the total power produced by the solar panels by 8.72%. The test data showed that the increase in the intensity of sunlight received by the solar panels increased the current and voltage produced, while the increase in temperature from the solar panels reduced the voltage produced by the solar panel**

***Keywords*— Solar Tracker, Solar Panel, Internet of Thing, Thingspeak.**

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I. INTRODUCTION

Based on the Climate Transparency Report 2022, electrical energy sources from renewable energy are still minimal in Indonesia[1]. The source of electricity from renewable energy in Indonesia only reached 19% in 2021. Of this proportion, hydropower accounts for the largest source of electrical energy, which is 8%. Then, followed by biomass and waste 5.3%; geothermal (geothermal) 5.1%; wind energy in coastal areas 0.1%; and solar energy (solar) by 0.1%. On the other hand, fossil fuels dominate the source of electrical energy in Indonesia. The report noted that 81% of electrical energy in the country comes from coal, petroleum, and natural gas. In detail, 62% of electrical energy sources in Indonesia come from coal. Then, followed by natural gas 18% and petroleum 2%.

Therefore, it is necessary to increase the portion of renewable energy power plants even more, such as installing solar panels. Solar panels can provide electrical energy by harnessing sunlight. However, the energy produced by solar panels depends on several factors, such as the intensity of light and the angle of incidence of light; the higher the intensity of solar radiation (irradiation) hitting the solar cells, the greater the electrical power it generates[2]. In addition, the temperature of the solar panel also affects the power that will be generated by the solar panel[3]. The optimization of sunlight reception by these solar panels is carried out so that the solar panels can generate sufficient power to supply electrical energy according to the planned load usage.

So that the total load to be used does not exceed the power that the solar panels can produce, it is necessary to monitor the performance of the solar panels. By monitoring the solar panels, users will receive data on the intensity of light received, the angle and temperature of the solar panels, as well as the voltage and current values generated by the solar panels. The ESP8266 type microcontroller can be used as a node consisting of light sensors, current sensors, voltage sensors, and a computer to monitor the condition of the solar panels[4]. With this data, users will be able to measure how efficient the solar panels are in tracking the movement of the sun, the performance of the solar panels under various weather conditions, and how significant the impact of the tracking system is on the solar panels

II. METHOD

A. Internet of Thing

The Internet of Thing or IoT is a network of interconnected devices that connect and exchange data with other IoT devices and the cloud. The term IoT (Internet of Things) began to be known in 1999 and was first mentioned in a presentation by Kevin Ashton, cofounder and executive director of the Auto-ID Center at MIT[5]. Another similar meaning, the Internet of Things (IoT) is a framework in which objects are provided with a unique identity and the ability to transmit data over a network without requiring bidirectional communication between humans, that is from source to destination or human-to-computer interaction[6]

B. Solar Panel

Solar panels are devices that are used to convert light into electricity. This conversion process occurs thanks to the photovoltaic cells embedded in the panels. Photovoltaic cells, also often referred to as solar cells, use a thin layer of a semi-conductive material called silicon. When light particles strike the solar cells in the solar panel, the electrons in the silicon atoms are released and initiate a chain reaction. These released electrons will move one after another in a continuous flow into a direct current (DC) that can be used as a source of electrical energy.

A single solar panel typically consists of 28 to 36 solar cells with a total voltage generated of 12 volts under standard irradiant conditions (Air mass 1.5). Air mass 1.5 is a term used in the context of solar energy to describe the thickness of the atmosphere that sunlight passes through before reaching the earth's surface. The Mono Crystalline 100 Wp solar panel has a maximum power power of 100 W. The short-circuit current used is around 4.94A and the maximum power current is 4.39A. In addition, the open circuit voltage is 26.48V and the maximum power voltage is calculated at 22.8V. The high power output and highest conversion efficiency on this type of solar panel is 16.51%[7].

C. Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the ATmega328P microcontroller. These boards are often used to design and manufacture electronic devices as well as software. The function of Arduino UNO in this final project is as the brain or control center of the system. The Arduino UNO is connected with a variety of sensors to collect data such as sunlight intensity, the power generated by the solar panel, the tilt angle and temperature of the solar panel, as well as the operation of a servo motor and linear aquarium to move the solar panel so that it faces the direction of sunlight optimally.

The Arduino UNO has 14 input and output pins, of which 6 of the 14 pins can be used as PWM outputs. Each of the 14 digital pins on the arduino uno can be used as input and output, using the pinMode(), digitalwrite(), and digitalRead() functions. These functions operate at a voltage of 5 volts. On the Arduino UNO there are also SCL (Serial Clock) and SDA (Serial Data) pins which are used for Inter Integrated Circuit (I2C) communication. I2C communication is a synchronous serial protocol for connecting devices such as sensors or modules with microcontrollers. The SCL pin is a clock path that regulates when data is read or written. On the Arduino UNO the SCL pin is located on the A5 pin and near the SDA pin. SDA pins are data paths used to send and receive data. On the Arduino UNO the SDA pin is on the A4 pin and near the AREF pin. Arduino provides a "wire" library to facilitate I2C communication.

D. NodeMCU

NodeMCUs (Node Micro Controller Units) are open-source software and hardware development environments built around inexpensive System-on-a-Chip (SoC) called ESP8266. ESP8266 use a standard voltage of 3.3V to be able to function. Unlike AVR microcontrollers and most Arduino boards that have a TTL voltage of 5 volts. Even so, the NodeMCU can still connect to 5V but through a micro USB port or Vin pin provided by the board. ESP8266, designed and manufactured by Espressif Systems, contains essential elements of the computer: CPU, RAM, network (WiFi), and even modern operating systems and SDKs. In terms of functionality, this module system is similar to the system module platform, but what distinguishes it is that it is dedicated to Connected to the Internet[8].

IoT refers to a network of physical devices that are connected to the internet, allowing to send and receive data. Meanwhile, Arduino is an electronic platform consisting of hardware and software that is easy to use. The integration of Arduino and IoT can create a monitoring system that can collect data from sensors, process it and transmit that information to users over the internet

E. Thingspeak

Thingspeak is an internet of things platform in the cloud where you can send and receive data with the HTTP protocol and can also display data through the given dashboard. Thingspeak provides a free dashboard that allows you to monitor the values of data sent by IoT devices.

From the image above, you can see that Thingspeak acts as a data collection center from various node devices, especially sensors connected to the internet. The thingspeak platform is able to connect with sensors spread across multiple locations, allowing data collection from multiple sources. In addition to sensors, the thingspeak platform can also collect data from other software. This can provide flexibility in integrating data from multiple sources

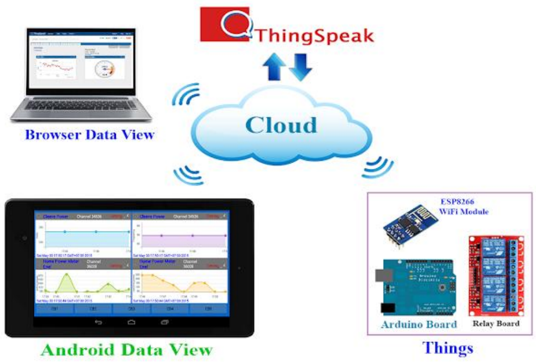


FIGURE 1. Monitoring Thingspeak (Source : androidcontrol.blogspot.com)

.Thingspeak allows users to set up notifications based on the data received. The platform also supports device control, which allows users to take direct actions based on the data they have received. ThingSpeak allows the creation of logging apps, location tracking apps, and social networks with status updates[9]. Using ThingSpeak, one can create a censorship logging app, a location tracking app, and a social network of everything connected to the internet with status updates.

F. System Design

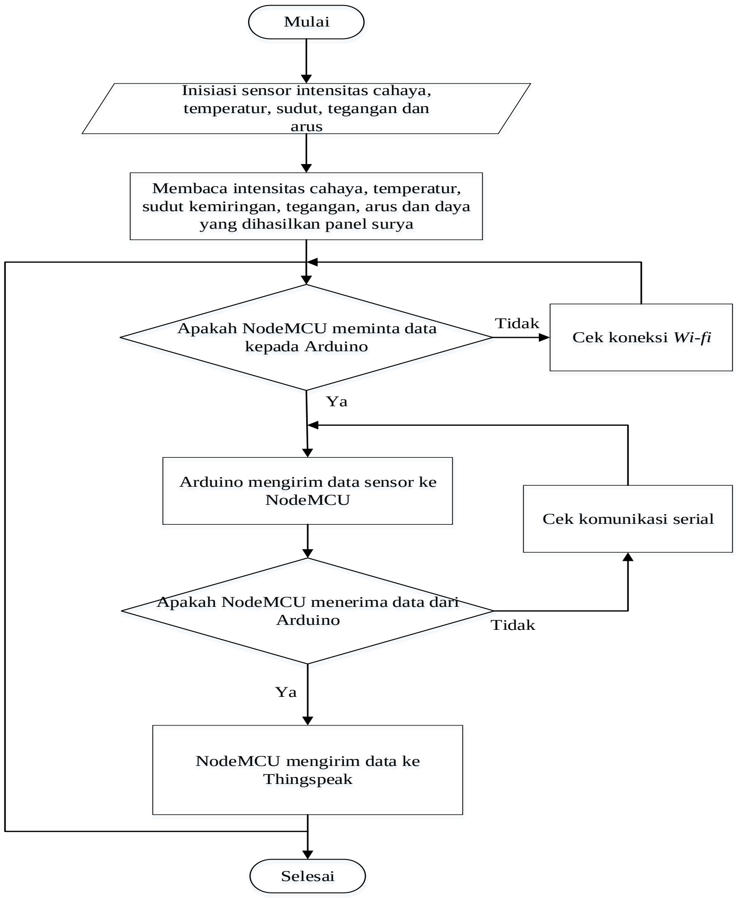


FIGURE 2. Flowchart

From figure 2. 2 above, which is a flowchart of this final project, which can explain how the tool works, namely using several sensors as monitored data input. Data from light intensity, temperature and tilt angle sensors are read by Arduino UNO, while voltage, current and power sensor data is read by NodeMCU. In order for all the data from the sensors used to be connected to the internet, Arduino needs to send sensor data to the NodeMCU. The Arduino sends data to the NodeMCU when the NodeMCU requests data to the Arduino. This is done because when the Arduino sends data too fast or too slow, the NodeMCU will reset.

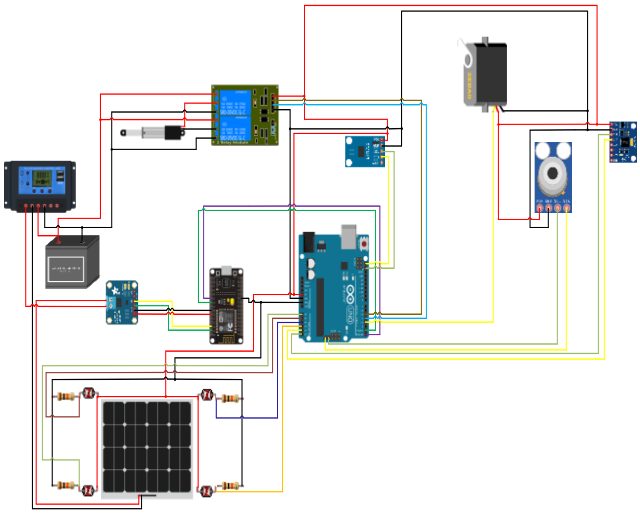


FIGURE 3. Wiring Diagram

From figure 2.3 above, it explains the overall solar tracker monitoring diagram. In the picture there are Arduino UNO and NodeMCU microcontrollers, LDR sensors, INA219, BH1750, MPU6050 and MLX90164, resistors, servo motors, 5v 2 channel relays, linear aquariums, batteries, solar charge control and solar panels.

III. Result And Discussion

A. Testing Using Solar Tracker Systems

The dual axis solar tracker system test was carried out on August 4, 2024 from 08.30 to 15.15 WIB. At 08.30 to 12.00 WIB the weather is sunny, but at 12.00 to 15.15 WIB the weather conditions tend to be cloudy. The data from monitoring can be seen in table 1

TABLE I
Solar Tracker Monitoring Results

No	Time	Voltage (V)	Current (mA)	Power (W)	Temperature Solar Panel (°C)	Ambient temperature (°C)	Light intensity (lux)	Angle X (°)	Angle Y (°)
1	08:30	12.74	698.4	8.89762	27.23	28.59	15920.83	-18.45	24.47
2	08:45	12.98	723.7	9.39363	27.73	29.11	16240	-18.82	24.84
3	09:00	13.312	990.5	13.18554	28.63	29.59	22240	-23.26	24.98
4	09:15	13.396	1055.1	14.13412	28.53	29.21	23833.33	-10.07	21.91
5	09:30	13.924	1837.8	25.58953	28.99	31.05	42959.16	-10.36	20.64
6	09:45	14.58	3200	46.656	35.93	38.67	54612.5	-9.83	17.38
7	10:00	14.632	3200	46.8224	34.33	37.43	54612.5	-8.98	5.47
8	10:15	14.104	2460.3	46.9376	38.89	39.75	54612.5	-9.29	5.92
9	10:30	14.352	3023.3	43.3904	32.75	33.11	54612.5	-9.14	5.37
10	10:45	13.616	1548.9	21.08982	33.99	33.05	38496.66	-8.89	5.46
11	11:00	13.496	1453.9	19.62183	35.69	35.17	39336.66	-8.94	-2.06
12	11:15	13.568	1770.4	24.02079	35.99	34.35	49915	-9.6	-2.12
13	11:30	14.776	3200	47.2832	36.25	35.15	54612.5	-2.87	-2.11
14	11:45	14.548	3200	46.5536	42.03	38.33	54612.5	-3.96	-2.08
15	12:00	14.152	3200	45.2864	37.93	34.95	44799.16	-2.59	-1.93
16	12:15	13.256	1432.6	18.99055	36.29	34.91	33739.16	0.24	-1.94
17	12:30	14.732	3200	47.1424	40.93	38.91	54612.5	-8.01	-2.47
18	12:45	14.708	3200	47.0656	42.61	39.87	54612.5	-9.47	-10.03
19	13:00	14.708	3200	47.0656	42.63	39.35	54612.5	-1.68	-32.73
20	13:15	13.252	1662.2	22.02747	37.43	35.11	39761.66	-0.43	-31.99
21	13:30	12.948	1218.9	15.78232	36.93	35.15	26800	-1.44	-31.64
22	13:45	14.684	3200	46.9888	43.83	39.91	54612.5	11.67	-33.22
23	14:00	14.172	3200	47.3504	37.21	36.29	54612.5	17.89	-34.92
24	14:15	14.688	3200	47.0016	42.01	37.73	54612.5	21.93	-34.92
25	14:30	14.444	3200	46.2208	43.57	38.73	54612.5	20.66	-35.48
26	14:45	13.392	1899.3	25.43543	38.43	36.01	48897.5	21.32	-34.98
27	15:00	12.6	766.6	9.65916	33.91	32.81	19112.5	20.3	-35.06
28	15:15	12.376	351.1	4.34521	31.11	30.79	8867.5	21.14	-34.22

B. Testing Without Using a Solar Tracker System

The test without using a dual axis solar tracker system was carried out on August 5, 2024 from 08.30 to 15.15 WIB. At 08.30 to 15.00 WIB the weather conditions were sunny, but at 15.15 WIB the weather conditions had begun to be cloudy. The position of the solar panel is facing North with an angular slope of 38° to the ground. The monitoring data can be seen in table 3. 2

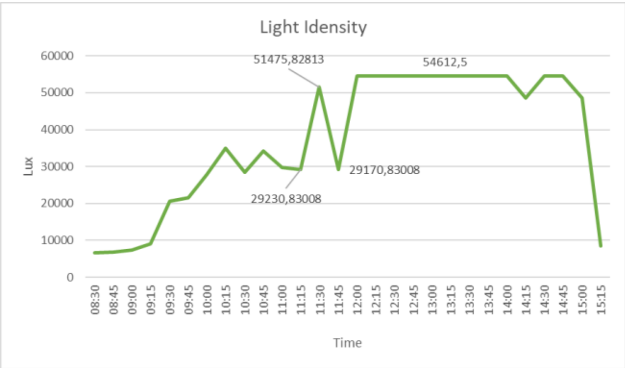
TABLE II
Monitoring results without using a solar tracker system

No	Time	Volt (V)	Current (mA)	Power (W)	Temperature Solar Panle (°C)	Ambient Temperature (°C)	Light Intensity (lux)	Angle X (°)	Angle Y (°)
1	08:30	12.264	288.1	3.53326	27.11	27.91	6596.67	6.37	-37.02
2	08:45	12.296	308.3	3.79086	28.69	35.83	6728.33	4.87	-39.03
3	09:00	12.368	377.1	4.66397	30.87	37.61	7350.83	5.35	-38.54
4	09:15	12.488	552.4	6.89837	32.31	38.37	9037.5	5.67	-38.56
5	09:30	12.744	879.7	11.2109	31.19	33.01	20645.83	5.6	-39.26
6	09:45	12.848	963.6	12.38033	31.97	33.11	21476.67	5.4	-38.65
7	10:00	13.16	1253	16.48421	33.11	34.29	27810	5.39	-39.07
8	10:15	13.692	1627	22.27825	32.77	34.09	34918.33	5.74	-38.89
9	10:30	13.492	1267	17.09436	33.29	33.93	28443.33	5.35	-38.49
10	10:45	13.64	1521	20.7519	34.51	35.55	34262.5	5.82	-38.99
11	11:00	13.448	1336	17.97191	35.29	33.73	29821.67	5.34	-38.68
12	11:15	13.452	1321	17.77413	34.31	34.45	29230.83	6.11	-38.66
13	11:30	14.328	3127	44.80222	36.69	36.35	51475.83	5.58	-38.97
14	11:45	13.192	1201	15.84491	37.17	35.35	29170.83	5.87	-37.97
15	12:00	14.504	3200	46.4128	42.49	40.45	54612.5	4.71	-38.75
16	12:15	14.484	3200	46.3488	45.41	42.67	54612.5	5.84	-38.77
17	12:30	14.64	3200	46.848	44.33	40.65	54612.5	4.81	-39.14
18	12:45	14.504	3200	46.4128	45.07	42.19	54612.5	5.45	-38.91
19	13:00	14.796	3200	47.3472	43.51	42.17	54612.5	4.82	-38.83
20	13:15	14.596	3200	46.7072	45.93	42.77	54612.5	5.32	-38.85
21	13:30	14.76	3200	47.232	43.31	38.57	54612.5	5.05	-38.13
22	13:45	14.5	3200	46.4	45.89	42.91	54612.5	5.85	-38.39
23	14:00	14.64	3200	46.848	41.91	38.25	54612.5	5.61	-38.23
24	14:15	13.348	2903	38.7439	38.77	35.71	48570.83	5.05	-38.26
25	14:30	14.12	3200	46.1184	47.03	42.13	54612.5	5.48	-38.65
26	14:45	14.28	3200	45.696	41.01	38.09	54612.5	4.94	-38.7
27	15:00	13.088	2359	30.86805	37.25	35.05	48657.5	5.42	-38.36
28	15:15	12.344	348.4	4.30065	33.11	31.31	8565.83	5.26	-37.72

C. Data Analysis

Based on the monitoring data in table 3.1, table 3.2 can find out what factors affect the performance of solar panels, as well as the comparison of power produced by solar panels between the use of solar tracker systems and those who do not use solar tracker systems.

From figure 4, there is an increase in light intensity from 29,230.83 lux to 51,475.82 lux. At the same time, the current produced by the solar panel also increased from 1.3 A to 3.1 A. In addition to the current, the voltage value of the solar panel also increased, from 13.4 V to 14.3 V. With a percentage increase in light intensity of 76.1%, the current produced by the solar panel increased by 136.6% and the voltage of the solar panel increased by 6.4%. The value of light intensity is directly proportional to the value of current and voltage from the solar panel. Although light intensity affects the current value and voltage of the solar panel, the effect of light intensity is greater on current than voltage. This happens because of the number of photons that reach the surface of the solar cell. As the intensity of light increases, more photons are available to release electrons, thus increasing the amount of current produced.



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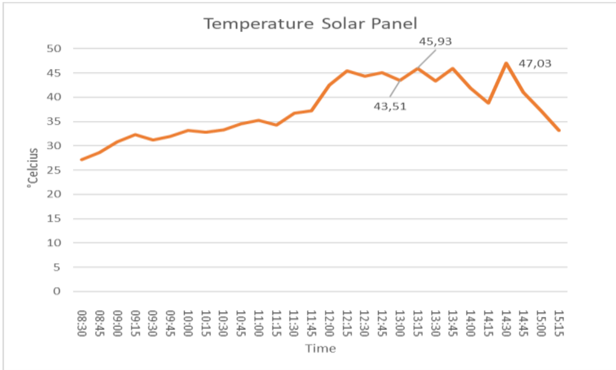

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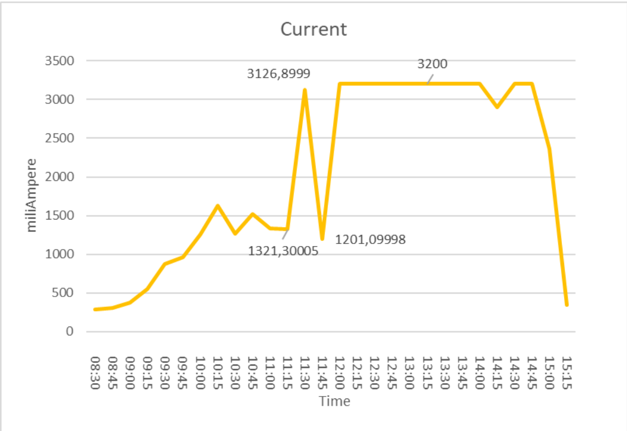

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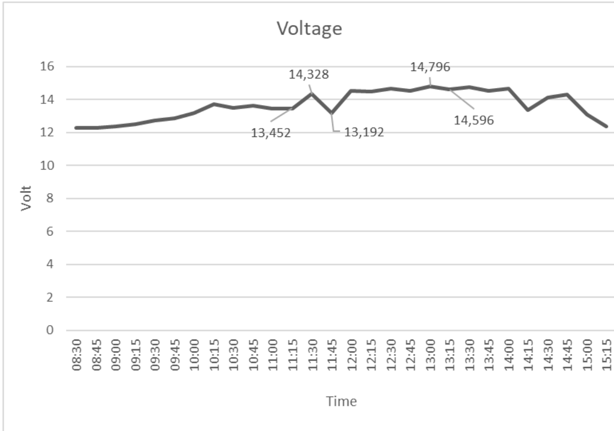

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FIGURE 4 Graph of the relationship between light intensity, solar panel temperature, generated current and voltage against time

In addition, when the light intensity was stable at 54612.5 lux, the temperature value of the solar panel increased from 43.51°C to 45.93°C. At the same time, the voltage of the solar panel decreased from 14.79 V to 14.69 V. With a percentage increase in the temperature of the solar panel of 3.07%, the voltage of the solar panel decreased by 1.35%. The temperature value of the solar panel is inversely proportional to the voltage of the solar panel. This happens because the increase in temperature causes excessive thermal energy in the semiconductor material in the solar cell, reducing its efficiency in generating voltage.

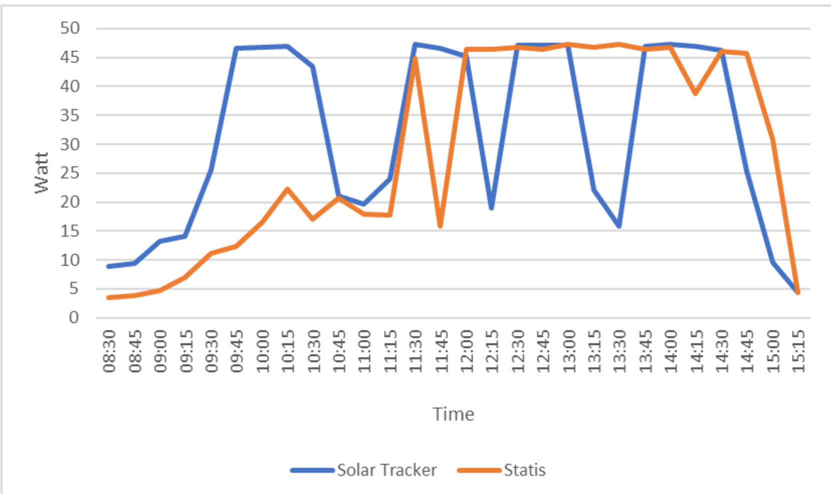

FIGURE 4. Comparison of the value of the power produced by solar panels

From the comparison chart of the use of the tracker system with static on the solar panel above, there is a difference in the value of the power produced. From the power data measured every 15 minutes from 08:30 WIB to 15:15 WIB, the total power produced by solar panels without using the solar tracker system is worth as little as 801.76 watts, while the total power produced by using the solar tracker system is worth 871.7 watts. There is an increase in the power produced by solar panels by 8.72%. The use of a solar tracker system on solar panels can make the power generated increase early. This condition indicates that when the sun's rays are perpendicular to the surface of the solar panel, the absorption of solar energy runs optimally.

IV. CONCLUSION

1. The solar tracker monitoring system can display the sensor data in the form of a graph of values from temperature, light intensity, angular slope, voltage, current, and power to time on the thingspeak.com page. With the help of the Wi-Fi module found in the NodeMCU, it connects the sensor data to the internet.
2. Changes in sunlight intensity, solar panel temperature, and the angle of incidence of sunlight can affect solar panel performance. A 76.1% increase in light intensity resulted in a 136.6% increase in current, and a 6.4% increase in voltage. A 3.07% increase in solar panel temperature resulted in a 1.35% decrease in voltage. When sunlight is perpendicular to the surface of the solar panel, solar energy absorption is maximized.
3. The total power generated by solar panels facing north at a 38° angle to the ground is 801.76 watts. The use of a dual axis solar tracker system on solar panels can increase the power produced to 871.7 watts. There was an increase in power of 8.72% using a dual axis solar tracker system

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