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Design and development of 10 WP Solar panel tracking system based on RTC and Arduino

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Abstract
Currently, the use of solar panels in Indonesia is still in a stationary position (static) so that the absorption of sunlight is less than optimal due to frequent weather, cloudy weather, and during the afternoon until the afternoon the sun's light has turn back/or is not parallel to the solar panels. To obtain optimal electrical energy, the solar panel systems must be equipped with a control-systems and equipped with an RTC (Real Time Clock) sensor module which functions to provide real time data/or components to adjust the direction of the surface of the solar panel so that it always faces the sun at a given angle (tracking based on the movement of the earth) so that the energy from the sun's ray can completely fall to the surface of the solar panel. And from the data obtained on December 13, 2021, the output produced by a 10 Wp solar panel tracking system for 9 (nine) hours with a 5 Watt lamp load produces a total power of 3.392 Wh while a non-tracking 10 Wp solar panel produces a total power of 19.658 Wh and the difference between the two 10 Wp solar panels is 15.732 Wh.
Keywords: Solar energy; Solar panel; Servo motor; RTC; Microcontroller

Introduction
Research on the development of using Arduino in detecting sunlight on solar panels with the help of sensors has been carried out by many other researchers. Arduino Uno is also used in the design of electronic devices that work as an automation system that uses a microcontroller. The purpose of using sensors is to maximize the reception of solar energy on solar panels by adding an electric motor to drive the solar panels. RTC is used to monitor the movement time more accurately.The rising and setting of the sun from the earth's surface causes the light received on the surface of the solar panel to be limited. Tracking is an alternative way to get maximum absorption of sunlight on the surface of solar panels. The purpose of this paper is to design a 10 Wp solar panel tracking system based on RTC and Arduino.

Literature Review
The importance of using electrical energy in this world is something to maintain human life. In terms of hardware and software are available in modern times today (Fadhlan Muhammad Nasution and Takdir Tamba, 2018). The sun is an extraordinary source of energy in every country every day which will rise from the east and set on the earth's surface (Situngkir Haposan and M. Fadlan Siregar, 2018). Meanwhile, the utilization of solar energy will not have a negative impact on the environment. (Junial Heri, S.T., M.T., 2012) To that end, the World Bank has published a Country-based Global Photovoltaic Power Potential study, providing expert views on and with solar resources and development potential as a photovoltaic (PV) power plant with a utility scale from the perspective of the country and region (Global Solar Atlas, 2021). Indonesia is a tropical region that has the potential to produce very large solar energy with an average daily insolation of 4.5 - 4.8 KWh/m²/day. So with this solar energy becomes a form of renewable energy with potential that can be developed further (Ari Rahayuningtyas, et. al., 2014).

In general, solar panels are installed horizontally and permanently. So that the installation of a technique like this will cause the morning sun and pain not to be in a position perpendicular to the direction of the sun. Resulting in the amount of electrical energy obtained to be reduced than it should be (Lukman et al., 2020). Therefore, a device design that can be adjusted by the solar panel will always follow the sun's position or perpendicular to the sun using the sun's tracker position so that energy conversion is maximized. Tracking the sun during the day will collect the maximum amount of energy. Steering will generate a significant amount of energy with the help of a tracker built into the PV system (Syafii Ghazali, et. al, 2015).

Tracking the sun's position can be done based on PV thermal expansion (passive trackers) or electrically using DC motors, gear boxes and others (active trackers) (Suci Imani Putri, et.al., 2014). For this reason, microprocessor-based tracking systems have developed in storage and power calculations (Alan L. Vergara, and Harreez M. Villaruz, 2014). So that the proposed microcontroller is in the form of a Real System. Time Clock (RTC) will make the microcontroller conform to its own time and date system (M.N. A.M. Alias, et al, 2019). With the integration of actuators from servo motors and solar trackers, the direction of rotational motion will occur following the sun's rays. solar tracker followed by the feedback received by the sensor. The use of a servo/stepper motor as an actuator on a one-axis or two-axis solar tracker has shortcomings in terms of response and the addition of gear components to the system (Singgih Hawibowo, et. al., 2018).

For solar panels, this is done by direct test method, namely the test results will show the results of the movement of the solar panels following the direction of the movement of sunlight so that will produce maximum electrical energy (Ula et al., 2018). And this tool can be applied to all regions so that it can help the government in efforts to overcome energy problems, especially optimizing alternative energy (Fadhullah, Khalid, 2017). But the performance of solar panels will be greatly influenced by the intensity of sunlight. Therefore, it is necessary to design a solar tracking device that can move the solar panel and the position of the solar panel will always be able to follow the direction of the sun's arrival (Syafii Ghazali, et. al., (2015). On the other hand, solar tracking is one of the generation technologies. future electricity is environmentally friendly and a saving solution for high electricity rates. In its operation, we need a system that can integrate the conversion of solar energy into electrical energy to improve system performance and safety. The need and accuracy of the system will be have (Ali Basrah Pulungan, et. al. .,2020).

For a long period of time the PV system works and obtains a lot of data. The data collection is traditionally manually with conventional instruments such as: multimeters and thermocouples, which takes a long time to process. So the reading is really difficult for the user to obtain because rapidly changing environmental conditions Automatic sensor-based data acquisition (DAQ) system can provide a faster response and accuracy in real time in unifying PV systems and storing data (N Sugiartha, et.al, 2019).

Materials & Methods

The working scheme of the tool is shown in Figure 1.

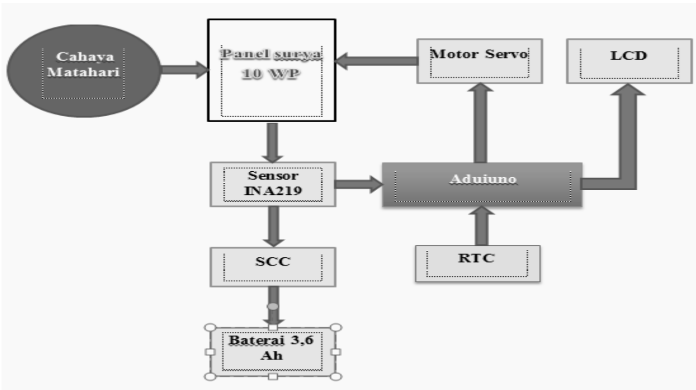

Figure 1. Block Diagram Tool

Figure 1 shows the components in the study including the sun as the main energy source, RTC, solar cells, INA219 sensor, Arduino Uno, LCD and servo motor as the main driver.

Where the sunlight obtained by the solar panel is then sent to Arduino for processing, then the RCT module works according to the command, namely capturing the absorbed light based on time or tracking in a clockwise direction through the help of a servo motor with a maximum working voltage value of 5 volts to move the solar panel. to an angular position perpendicular to the sun.

The LCD display is in the form of a value or output result where the data shows the ADC value of the RTC that gets the most light, in bright and cloudy sun conditions. The data obtained from the test is the output voltage of the solar panel at the intensity of sunlight that changes every time. Furthermore, the measurement data is entered into a table and then the graph of the highest percentage is taken.

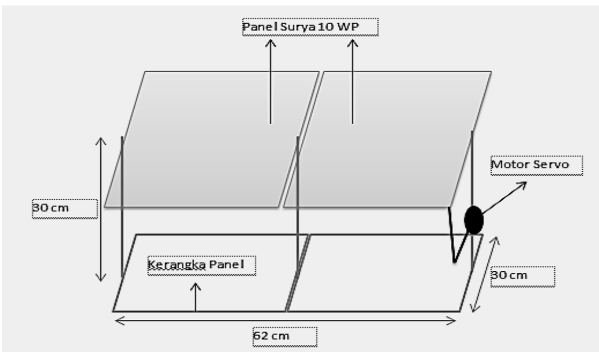

Figure 2. Illustration of Solar Panel Position

The solar panel frame is made of mild steel with a length of 62 cm, a frame width of 30 cm, and a height of 30 cm see Figure 2

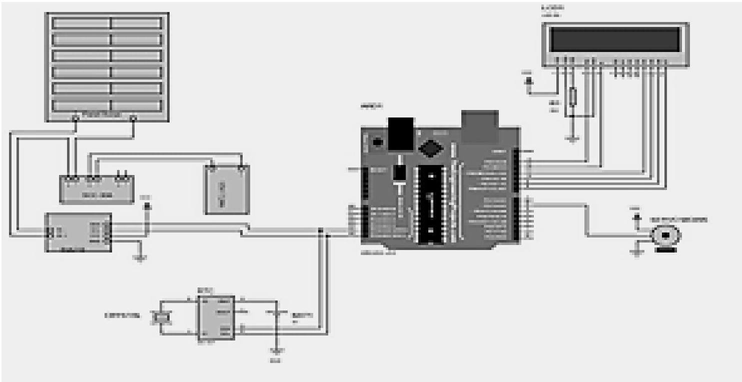

Figure 3. The Overall Set of Tools

The workings of the whole tool are centered on the Arduino UNO as shown in Figure 3. Arduino UNO is a piece of hardware that has an IC program that has been planted with an Arduino boatloader. This IC program will control all activities in the designed control system. Sensor reading, Input, output, and controlling the servo motor in this circuit.

Where a 10 Wp solar panel functions to convert sunlight energy into electrical energy using a principle called the photovoltaic effect. On the solar panel there are 2 (two) pin outs which are connected to the SCC pin and the INA219 sensor pin. The use of this SCC module plays a major role in protecting and automating battery charging. This aims to optimize the system and ensure that battery life can be maximized, besides that SCC can also detect when the battery voltage used is too low, if the battery voltage drops below a certain voltage level the SCC will disconnect the load from the battery so that the battery power does not run out. The circuit above describes the connectivity of the solar panel system including SCC. The battery connected to the positive and negative terminals of the SCC will be charged by the solar panel.

The use of the INA219 sensor functions to measure 2 parameters at once, namely voltage (volts) and current (amperes). The voltage that can be measured is up to 26v while the current is up to 3.2 A, apart from measuring the INA219 sensor it also functions as monitoring the power output generated by the solar panel. In the circuit figure 1.6 the solar panel and SCC pins are connected to IN – and IN + on the INA sensor and the SDA INA output pin is connected to the A4 Arduino Uno pin and vice versa the SCL pin is connected to the A5 Arduino (Hasibuan et al., 2021).

The function of the RTC in this series is to count hours, minutes, seconds, months, days and even years. In this circuit the RTC works to provide time data to the Arduino Uno so that the Arduino can drive the servo motor based on the angle from east to west according to the time read from the RTC. Through the help of a servo motor as a driver and the results of the intensity of sunlight absorbed by the solar panels are more accurate when under the hot sun / or perpendicular to the sun. In this circuit the SDA and SDL pins on the RTC module are connected in series to pins A4 and A5 of Arduino Uno.

The use of a 16x2 LCD serves as a character display, where in this circuit the function of this LCD is as a display to output the current and voltage values generated by the solar panel. The 16x2 LDC uses an I2C module so that the pins connected from the 16x2 LCD pins, namely the RS, E, D4, D5, D6, D7 pins are connected to the Arduino UNO pins, namely pins 13, 12, 11, 10, 9, 10. The use of a servo motor in this circuit functions as a solar panel driver according to the Arduino UNO command which stores data/orders on the RTC module, the pin of the servo motor circuit, namely the VCC pin, is connected to the 5 Volt Arduino UNO pin.

Results and Discussion

From the results of the research conducted, a 10 Wp solar panel tracking system based on RTC and arduino was produced as shown in Figure 4 and 5.

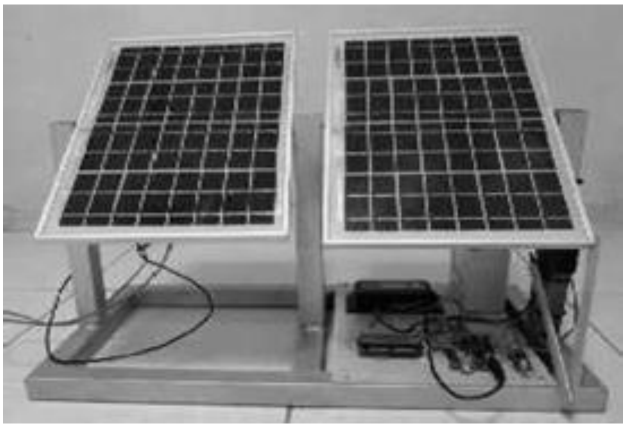

Figure 4. Tool Prototype

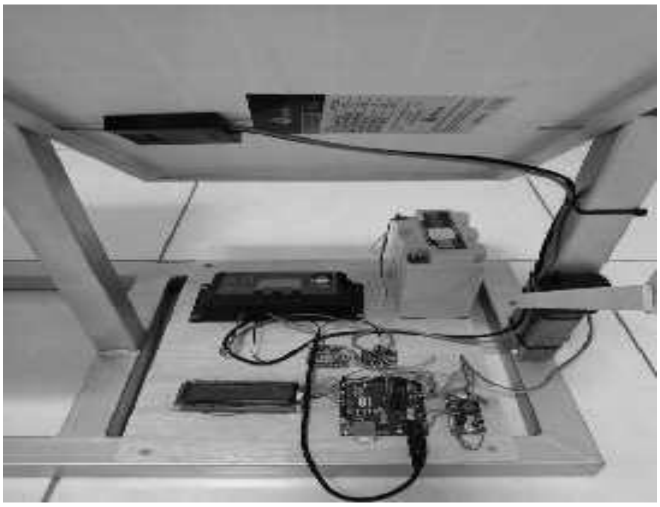

Figure 5. 10 Wp Solar Panel Control System.

The servo motor moves the solar panel by 90 every 1 (one) hour, when in the morning at 07.00 wib the position of the solar panel points to the east and is at the 130^o position. After the rotating time shows 08.00 wib the servo motor will move the solar panel by 9^o and the position of the solar panel is at 139^o. When at sunset the position of the solar panel faces west and is in a position of 211^o.

The position of the solar panels is placed based on the direction of sunrise and sunset, and the angular movement of the servo motor is regulated based on the rotation of the servo motor from east to west of 90^o. In designing the solar panel tracking tool, it works for 10 hours, from 07.00 WIB to 17.00 WIB and when towards 18.00 wib the servo motor moves the solar panel back to its initial position / or returns to its original position.

Solar Panel Measurement Test

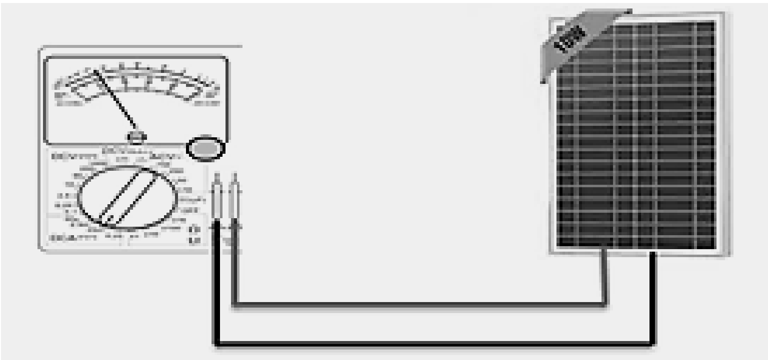

Figure 6. Measurement of Non-Tracking Solar Panel Voc Voltage and Isc Current

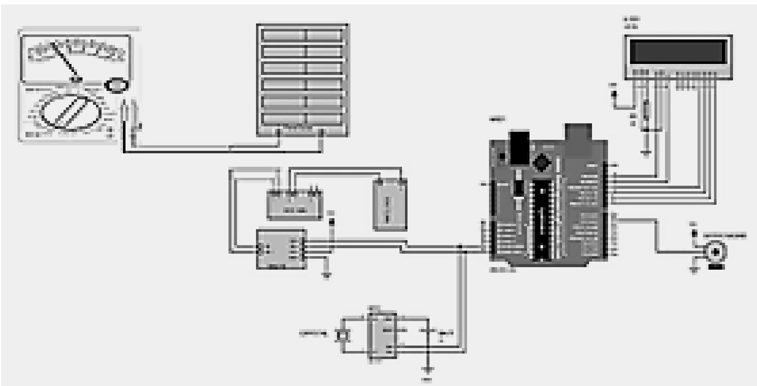

Figure 7. Measurement of VOC Voltage and Isc Current of Solar Panel Tracking System

In the no-load solar panel measurement picture, the solar panel output is not connected to the system see figure 6 and 7. This means that the output absorbed by the solar panel is measured directly using a multimeter to determine how much Voc voltage and Isc current can be emitted by the solar panel when absorbing light intensity.The following is the measurement data for tracking and non-tracking solar panels with no-load conditions.

Table 1. Measurement Data of Tracking and Non Tracking Solar Panels with No Load Conditions on September 13, 2021

Light intensity (Lux)	Time	Solar panel Tracking V_{oc} (Volt)	I_{sc} (Amp)	P_{max} (Watt)	Solar panel Non Tracking V_{oc} (Volt)	I_{sc} (Amp)	Pmax (Watt)
45.560	10.00 am	18.74	0.48	8.99	18.41	0.32	5.89
85.640	11.00 am	18.63	0.64	11.92	18.29	0.48	8.77
85.640	12.00 am	18.95	0.64	12.12	18.60	0.48	8.92
47.400	01.00 pm	18.92	0.64	12.10	18.75	0.35	6.56
44.690	02.00 pm	18.47	0.49	9.05	18.19	0.28	5.09
23.900	03.00 pm	18.16	0.47	8.53	17.76	0.12	2.13
17.670	04.00 pm	18.68	0.30	5.60	17.54	0.08	1.40

In the measurement table 1 the data for solar panels with no-load conditions, it can be seen that there is a tension in the open condition or / Open Circuit Voltage (V_{oc}) and the current when the condition is open or / Short Circuit Curent (I_{sc}) which is produced by the output of the panel. Measurements are made when the weather or the intensity of sunlight is unstable. When at 12.00 am the intensity of the sun is bright, and then at 01.00 pm the intensity of the sun is down/or cloudy, it can be concluded that the solar panel is in no-load conditions or direct measurements are based on the intensity of the light absorbed, if the intensity of sunlight is high then the voltage is high and the current at the solar panel output is high.

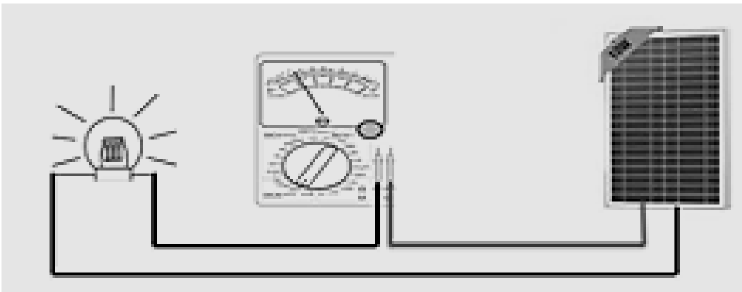

Figure 8. Imp Current Measurement in Non-Tracking Solar Panels

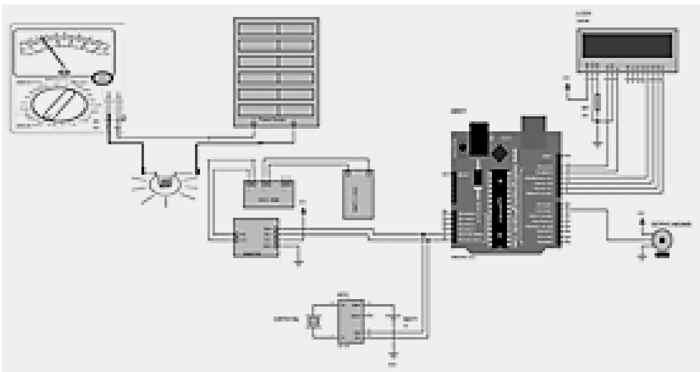

Figure 9. Imp Current Measurement in Solar Panel Tracking System

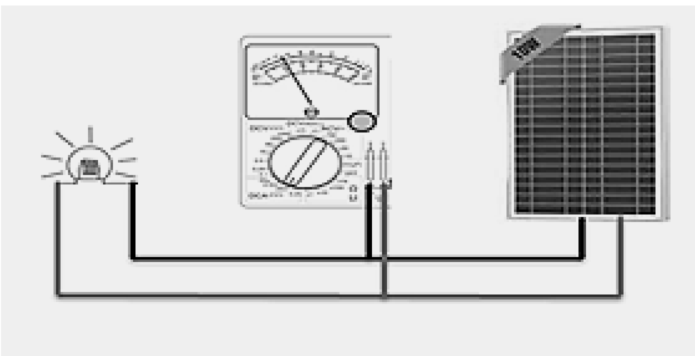

Figure 10. Non-Tracking Solar Panel Vmp Voltage Measurement

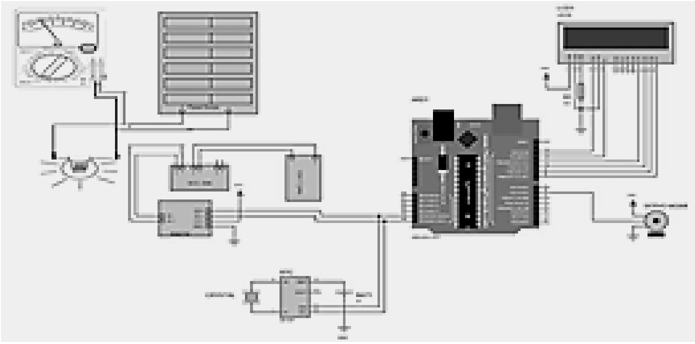

Figure 11. Measurement of Vmp Voltage on Solar Panel Tracking System

Measurements of tracking and non-tracking solar panels under load conditions or/connected to a system called Voltage At Maximum Power (V_{mp}) and Current At Maximum Power (I_{mp}) are carried out as in the circuit shown in Figure 8, 9, 10 and 11. The following is a table of data from the reading of the multitester measuring instrument with the condition of the solar panel being silent, and during the tracking process at 09.00 am - 05.00 pm.

As table 2 can be seen, at 00.00 – 06.00 pm, the data from the measurement of the output voltage of the tracking solar panel is different from the non-tracking panel. The power generated by the tracking panel, the total power obtained is:

$P_{tot}= P_1 + P_2 + P_3 + P_4+ \ldots + P_{14}$

= 2.06 + 1.23 + 2.21 + 7.42 + 7.20 + 5.69 + 4.29 + 4.02 + 1.22

= 35,392 Wh

Meanwhile, the total power generated by non-tracking solar panels is as follows:

$P_{tot}= P_1 + P_2 + P_3 + P_4+ \ldots + P_{14}$

= 1.81 + 1.22 + 1.81 + 6.90 + 4.54 +1.96 + 0.66 + 0.55 + 0.17

= 19,658 Wh

It can be concluded that the total power released by the 10 Wp tracking solar panel for 9 hours produces 35.392 Wh, while the non-tracking solar panel is able to generate 19.658 Wh of power. The test results obtained an average increase in solar cell voltage of 1.98 volts.

Table 2. Measurement Data of Tracking And Non Tracking Solar Panels With 5 Watt Lamp Load On December 13, 2021

Time	Light intensity (Lux)	Solar panel Tracking			Solar panel Non Tracking		
		V_{mp} (Volt)	I_{mp} (Amp)	P_{max} (Watt)	V_{mp} (Volt)	I_{mp} (Amp)	P_{max} (Watt)
09.00 am	43.100	10.86	0.19	2.06	10.65	0.17	1.81
10.00 am	21.300	11.25	0.11	1.23	11.14	0.11	1.22
11.00 am	30.350	11.66	0.19	2.21	11.37	0.16	1.81
12.00 am	110.700	11.78	0.63	7.42	11.50	0.60	6.90
01.00 pm	146.100	15.01	0.48	7.20	13.37	0.34	4.54
02.00 pm	101.400	14.24	0.40	5.69	10.89	0.18	1.96
03.00 pm	78.230	13.43	0.32	4.29	9.55	0.07	0.66
04.00 pm	58.100	13.43	0.30	4.02	9.29	0.06	0.55
05.00 pm	18.160	10.23	0.12	1.22	8.56	0.02	0.17

Table 3. Comparison of Vout of Tracking and Non Tracking Solar Panels

Time	Tracking [V_{out}] (Volt)	Non Tracking [V_{out}] (Volt)	Selisih V_{out} (Volt)
09.00 am	10.86	10.65	0.21
10.00 am	11.25	11.14	0.11
11.00 am	11.66	11.37	0.29
12.00 am	11.78	11.5	0.28
01.00 pm	15.01	11.37	3.64
02.00 pm	14.24	10.89	3.35
03.00 pm	13.43	9.55	3.88
04.00 pm	13.43	9.29	4.14
05.00 pm	10.23	8.29	1.94
Total	111.89	94.05	17.84
Rata - Rata Selisih V_{out}			1.98

Tests on the design results are carried out by comparing the output voltage with the position of the solar panel at test without tracking with the tracking solar panel method. at 13.00 – 17.00 wib, the data from the measurement of the output voltage of the tracking and non-tracking solar panels, there is a large difference in measurements caused by the position of the non-tracking solar panels with their backs to the sun, while the tracking solar panels remain parallel/or perpendicular facing the sun see Figure 12.

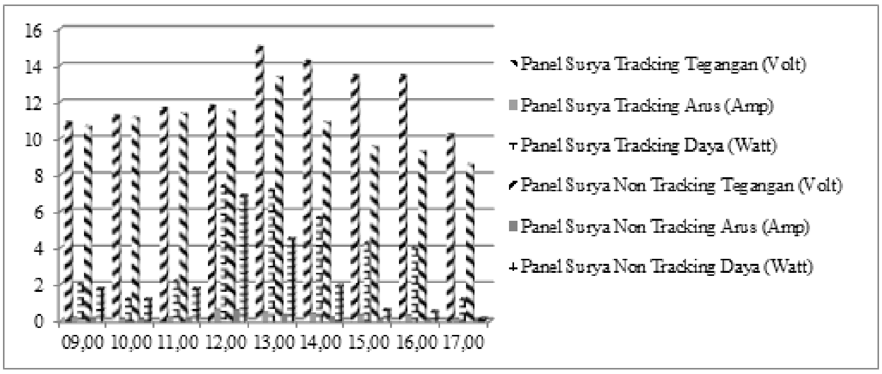

Figure 12. Tracking and Nontracking Solar Panel Measurement Data Chart

Tests on the design results are carried out by comparing the output voltage with the position of the solar panel at test without the RTC sensor and the sensor output voltage after tracking based on the results of calculations and measurement results. In the calculation results, and graphic images and measurement results with measuring instruments, it is obtained that a large light intensity from the value obtained produces a large amount of energy due to the panel's position which always remains perpendicular to the sun. While the graph of the difference between the tracking and non-tracking output voltages are shown in the image below.

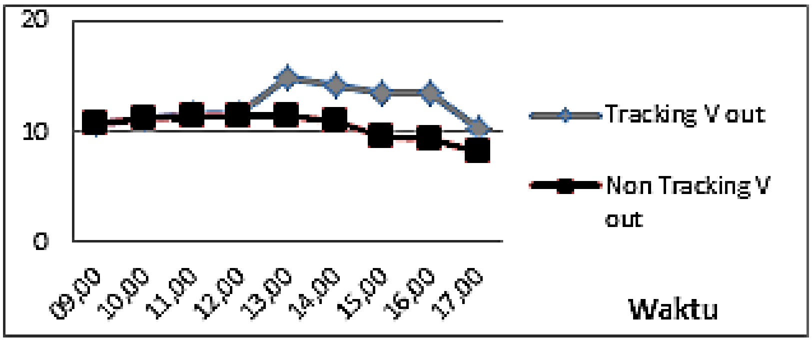

Figure 13. Graph of Voltage Difference Between V_{out} Tracking and Non Tracking

In the graphic image Figure 13, the difference in voltage between Vout tracking and non-tracking can be seen at 09.00 am until 12.00 am, the voltage generated by the tracking and non-tracking solar panels is the same because the solar panels are perpendicular to the sunlight, and at 01.00 pm the solar panel voltage increases because the intensity of sunlight is very bright and remains perpendicular to the sun's rays. Meanwhile, non-tracking V_{out} from 01.00 pm to 05.00 pm decreased because the non-tracking solar panels were not perpendicular to the sunlight or had their backs to the sun. So it can be concluded that solar panels that always face perpendicular to the sun always get an optimal voltage so that the voltage generated is higher than that of non-tracking solar panels and when the sunlight is bright the output generated by solar panels is high, and when the light is bright the sun is cloudy the output produced by the solar panels is low.

Conclusions

Based on the results of the design and testing of tools and discussion, it can be concluded that:

1. That the tracking solar panel has been successfully made and designed with an RTC sensor that rotates ±1200. The solar panels move 90 degrees every hour through the help of a servo motor that can follow the direction of the sun's rays following the time cycle.

2. The power generated by the 10 WP tracking solar panel produces a total power of 35.392 Wh while the non-tracking 10 WP solar panel produces a total power of 19.658 Wh. And the difference in total data between tracking and non-tracking is 15,732 Wh.

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