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Design a Two-Axis Sensorless Solar Tracker Based on Real Time Clock Using MicroPython

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Abstract

Since the majority of the electrical energy required to meet consumer demands is still produced by the typical power plant using fossil fuels, the world's electricity supply will eventually approach a critical point due to the steady depletion of fossil fuels. One solution to replacing energy derived from fossil fuels is solar energy. However, the results of energy generation are significantly influenced by the angle of the solar panels to the direction of sunlight. Therefore, in order to optimize the production of electrical energy, a microcontroller system that can track sunlight is developed using MicroPython. This research calculated the azimuth angle and elevation angle to create a solar tracker that can follow the sun's position based on time. The results of this research reveal that solar trackers at 21.30 volts and rooftop solar panels at 20.44 volts when both produce open circuit voltage. With an solar tracker, solar panels may operate up to at a 20% efficiency in sunny conditions, compared to an average efficiency of 18% for rooftop solar panels.

Keywords*: Solar Cell; Solar Tracker; Horizon Coordinates*

1. Introduction

The world's energy crisis is brought on by the scarcity of non-renewable energy sources like fossil fuels. Because the majority of the electrical energy required to fulfill consumer requirements is still provided by the typical national power plant using fossil fuels, this situation will cause Indonesia's electricity supply to cross a crucial threshold over time[1].

The percentage of electricity held by the State of Indonesia up till 2012 was 75.83%. The National Energy Management Blue Print 2005–2025 then sets the goal of raising renewable energy to 5% by 2025[2]. In order to achieve renewable energy diversification in power plants and end the electricity crisis in Indonesia, related parties must prioritize the use of renewable energy while also taking into account a number of crucial factors, including technical, economic, and environmental health and safety[3].

One of the effects of economic expansion and the rising demand for electrical energy is the business of supplying adequate electrical power. An enterprise that deals in the provision of electricity is the generating, transmission, and distribution sector[4].In order to provide a high-quality and sustainable energy supply with attention to electrical safety, it is imperative to have a dependable, safe, continuously operating electric power system. Given these issues, solar energy might be considered as a possible replacement for fossil fuel-based energy[5].

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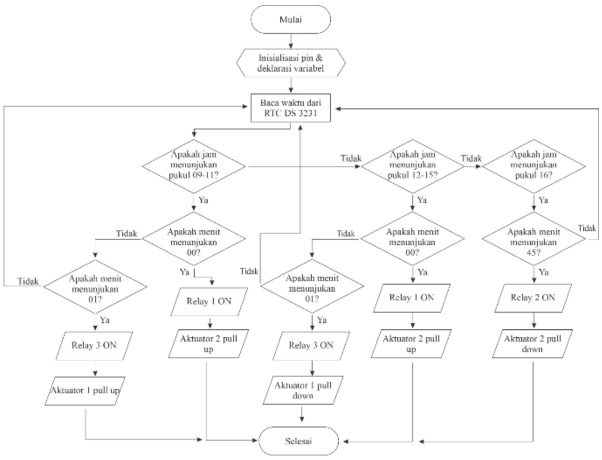
However, the outcomes of the power generation can be impacted by the angle of the solar panels in relation to the direction of sunlight. The intensity of power generation is going to be highest when the panel is positioned perpendicular to the sun[6]. Solar panels are often permanently installed in most government, industrial, and small-scale solar energy generation facilities, including households. Due to the fact that the panel is not always facing directly in the direction of the sun's rays, less than optimum electrical energy is generated.

Furthermore, the electrical energy may be produced as efficiently as possible, an equipment that can track sunlight is required. This final project provides a solar tracker that can follow the path of the sun without the need of a sensor. An ESP32 microcontroller, which has been developed to be able to track by calculating the degree of movement of the sun every half hour, is used to operate the solar tracker in this final project. The actuator arm's predicted movement speed may place the solar panel exactly in the path of the sun, resulting in more efficient electrical energy production. In addition, The ESP32 is programmed using MicroPython, enabling wireless connectivity to communicate real-time data to a network.

2. Methods

The RTC module shifts the linear actuator every hour in this research. The hourly change in azimuth angle and elevation determines how much angular shift there will be. You may use the Andrewmarsh program to calculate the angle shift. This solar tracker can still function correctly even when the amount of sunlight is at its lowest because it is sensorless and independent of the weather.



2.1. Output Solar Cell

The amount of electricity generated by a solar panel is measured in watts (W), which correspond to the panel's optimum sunshine and temperature conditions.

$$P = V \times I \quad (1)$$

2.2. Angles of Elevation and Azimuth

The elevation angle and azimuth angle have an impact on the angular shift of the solar panels. The andrewmarsh website offers an automated elevation angle and azimuth angle calculator. By providing inputs in the form of coordinate points or locations, dates, and times given during data collection, one may obtain the elevation and azimuth values.

2.3. Fill Factor

The fill factor (FF) equation may be used to calculate the solar panels' charging efficiency. The component also includes a comparison of the theoretical and actual capacities of solar cells.

$$\text{Fill Factor (FF)} = (V_m \times I_m)/(V_{oc} \times I_{sc}) \quad (2)$$

2.4. Efficiency of Solar Panel

By comparing the output power (P.out) result with the incoming power (P.in), where (P.in) is the product of Voc, Isc, and FF, it is possible to determine the efficiency of solar panels. The efficiency of solar panels may be determined using the equation while (P.out) is derived from the incident radiation flux in the condition of Standard Test Condition (STC), where it is assumed that the maximum quantity of solar irradiation in this scenario is 1000W / m2.

$$\eta = (V_{oc} \times I_{sc} \times FF)/(1000 \times A) \times 100\% \quad (3)$$

3. Result

3.1. Voltage open circuit (Voc)

Testing the output voltage parameters of solar panels with solar trackers and rooftop solar panels is taken from the readings of the PZEM-051 measuring instrument. The results of the test can be seen in the table 4.1

Table 1 Voltage open circuit

No.	**Time (WIB)**	**Voc (V) (solar tracker)**	**Voc (V) (rooftop)**
1.	08:00	20,78	19,34
2.	09:00	21,30	19,82
3.	10:00	21,25	19,96
4.	11:00	19,15	18,80
5.	12:00	19,86	19,53
6.	13:00	19,67	19,32
7.	14:00	20,27	20,04
8.	15:00	20,16	19,12
9.	16:00	19,45	19,02
Average		20,21	19,44
V max.		21,30	20,04
V min.		19,15	18,80

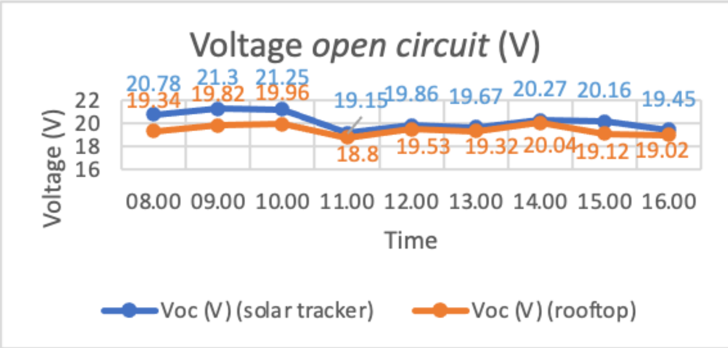


Figure 1 Voltage open circuit

The greatest voltage is known to be 20.44 V for solar panels with a rooftop system and 21.30 V for solar panels with a solar tracker system based on the test results. The lowest voltage, however, is 18.30 V for solar panels with a rooftop system and 19.15 V for solar panels with a solar tracker system. Solar panels attached to a solar tracker system have an average voltage of 20.21 V, whereas solar panels attached to a rooftop system have an average voltage of 19.44 V.

3.2. Current output

The readings of the same measuring device, the PZEM-051 and equipped with a 100Ah VRLA battery, are used to get data on the current output of solar panels with solar trackers and solar panels that are permanently fixed on roofs (rooftop). The findings of monitoring the output current on both panels from 08:00 to 16:00 are as follows.

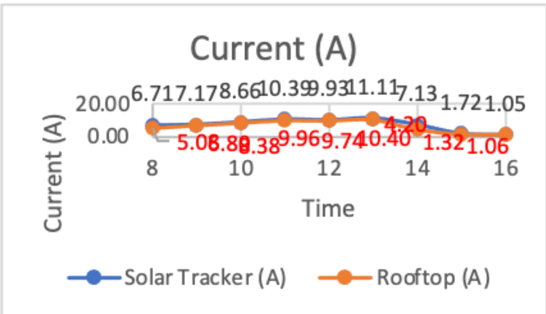


Figure 2 Current measurement data on October 22, 2022

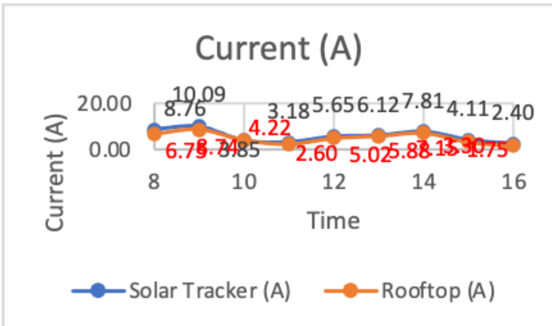


Figure 3 Current measurement data on October 23, 2022

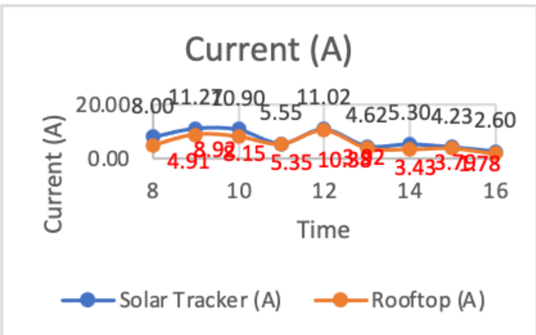


Figure 4 Current measurement data on October 24, 2022

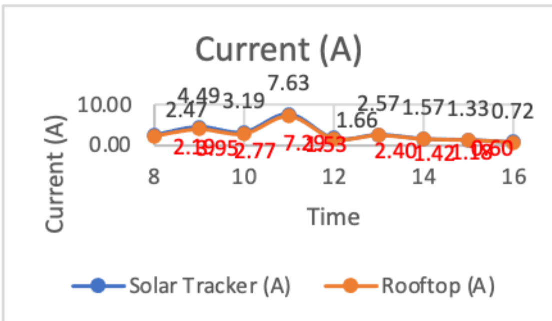


Figure 5 Current measurement data on October 25, 2022

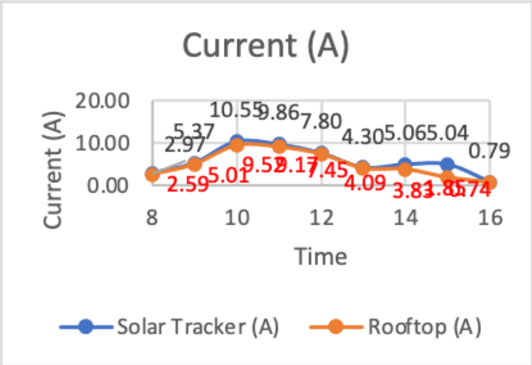


Figure 6 Current measurement data on October 26, 2022

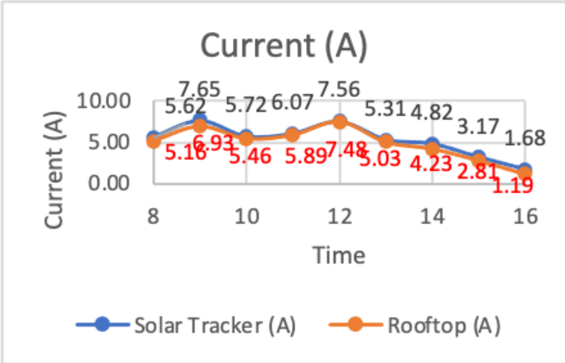


Figure 7 Current measurement data on October 27, 2022

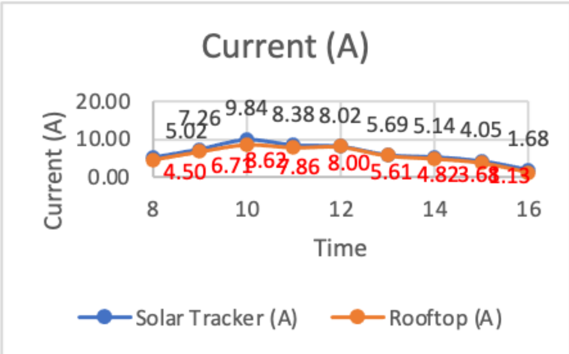


Figure 8 Current measurement data on October 28, 2022

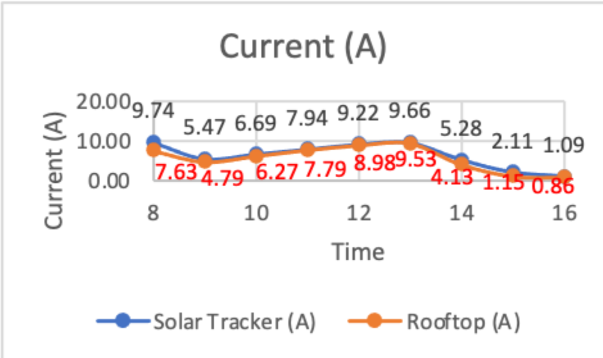


Figure 9 Current measurement data on October 29, 2022

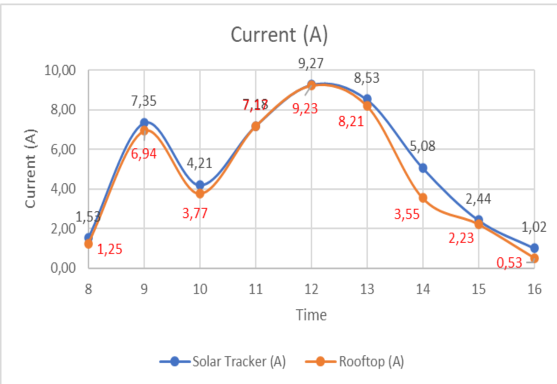


Figure 10 Current measurement data on October 30 2022

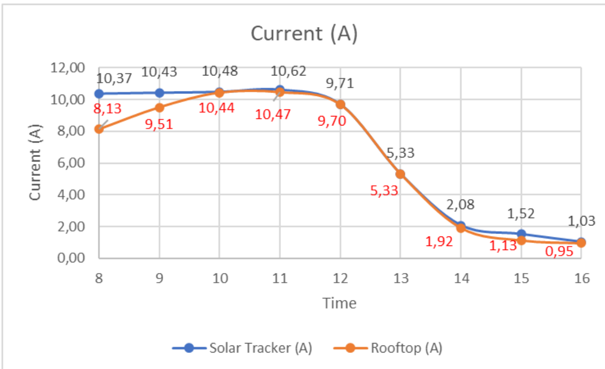


Figure 11 Current measurement data on October 31, 2022

If it's sunny and there is a lot of sunshine, according to the findings of current testing with a 100 Ah battery load, the peak current occurs between 10 and 13 in the morning. With a solar tracker system, solar panels have an average current carrying capacity of 6.21 A. In the meanwhile, a rooftop solar system's average current carrying capacity is 5.19 A.

3.3. Power output

The readings of the same measuring device, the PZEM-051 and equipped with a 100Ah VRLA battery, are used to get data on the power output of solar panels with solar trackers and solar panels that are permanently fixed on roofs (rooftop). The findings of monitoring the output current on both panels from 08:00 to 16:00 are as follows.

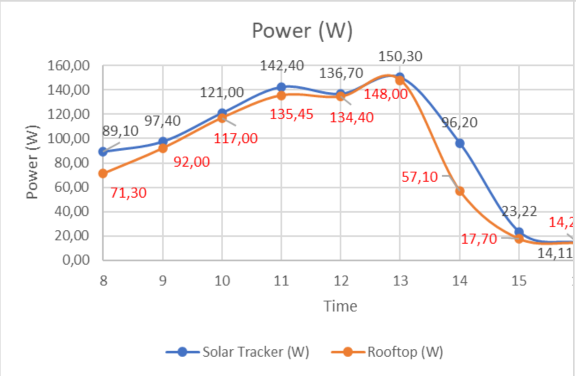


Figure 12 Current measurement data on October 22, 2022

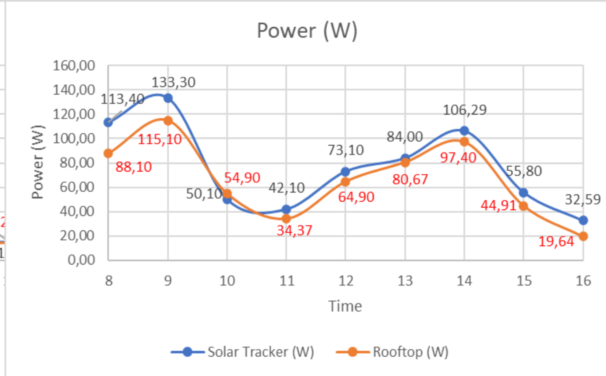


Figure 13 Current measurement data on October 23, 2022

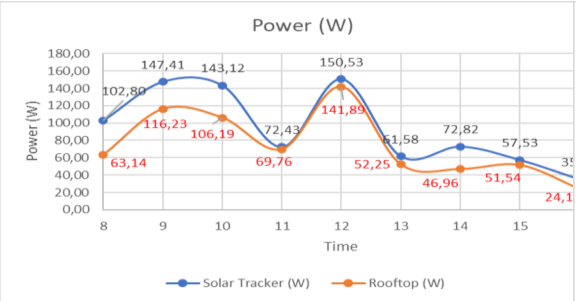


Figure 14 Current measurement data on October 24, 2022

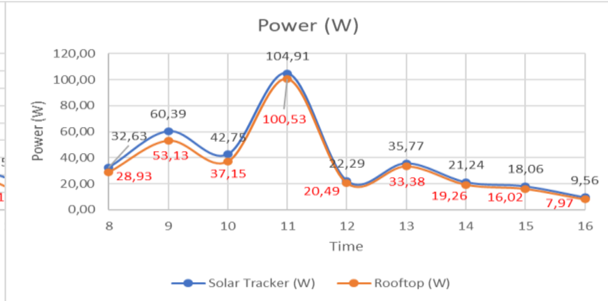


Figure 15 Current measurement data on October 25, 2022

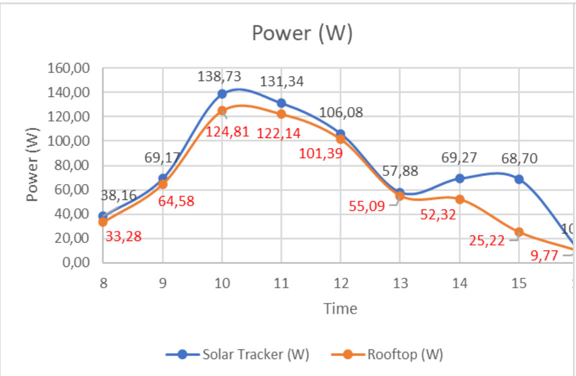


Figure 16 Current measurement data on October 26, 2022

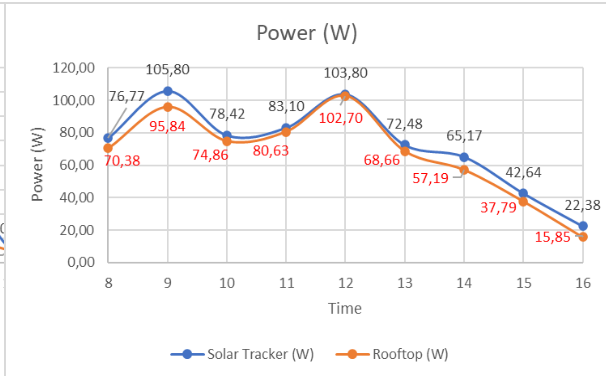


Figure 17 Current measurement data on October 27, 2022

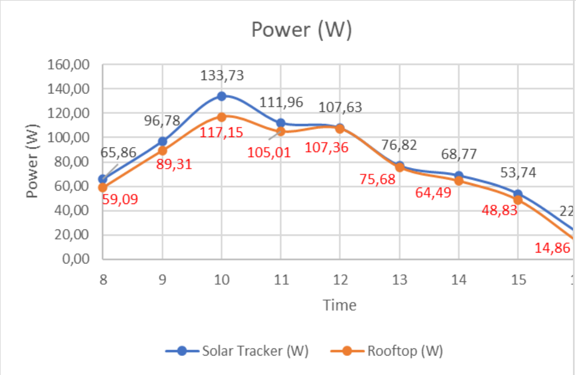


Figure 18 Current measurement data on October 28, 2022

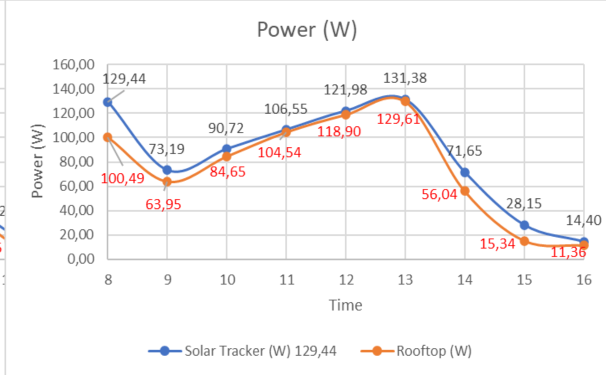


Figure 19 Current measurement data on October 29, 2022

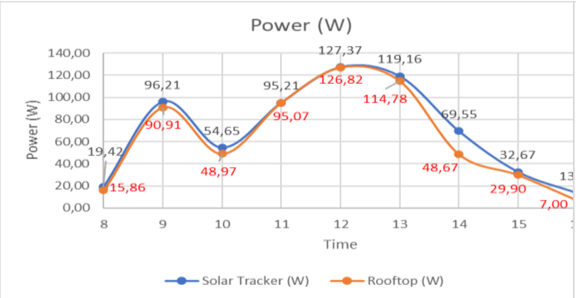


Figure 20 Current measurement data on October 30, 2022

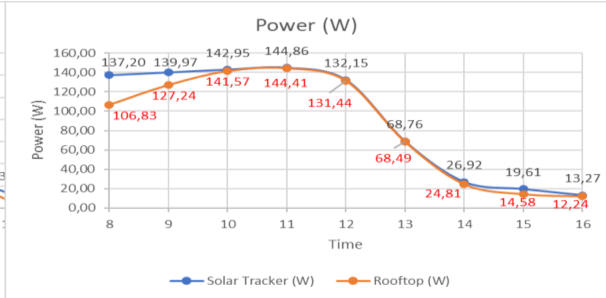


Figure 21 Current measurement data on October 31, 2022

The system utilizing the solar tracker is capable of providing an average daily power of 78.34 W, according to the findings of ten days of power testing. In contrast, it is 69.80 W for rooftop solar panels.

3.4 Energy output

The readings of the same measuring device, the PZEM-051 and equipped with a 100Ah VRLA battery, are used to get data on the energy output of solar panels with solar trackers and solar panels that are permanently fixed on roofs (rooftop). The findings of monitoring the output current on both panels from 08:00 to 16:00 are as follows.

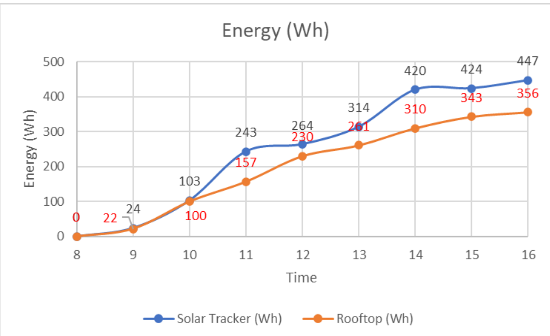


Figure 22 Current measurement data on October 22, 2022

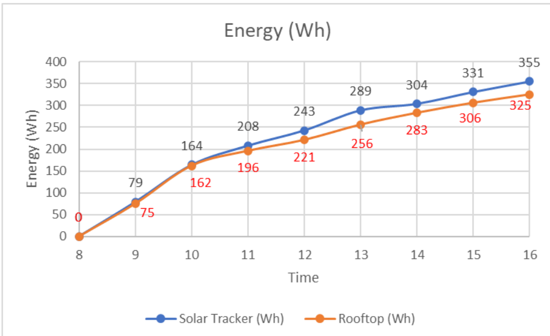


Figure 23 Current measurement data on October 23, 2022

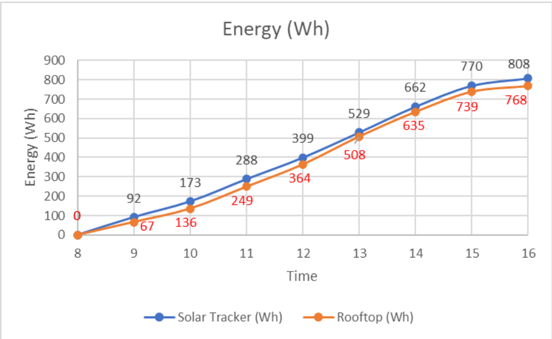


Figure 24 Current measurement data on October 24, 2022

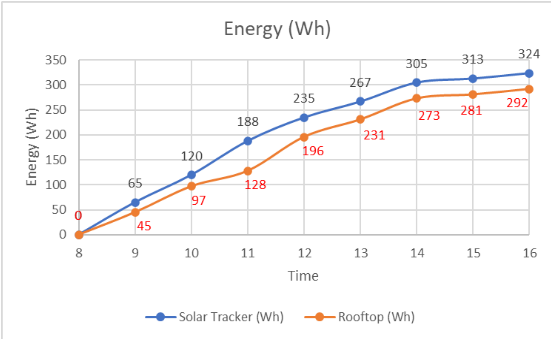


Figure 25 Current measurement data on October 25, 2022

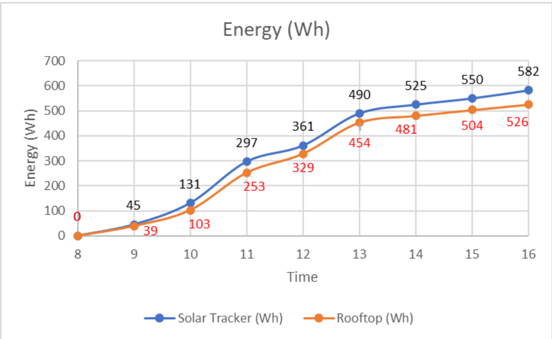


Figure 26 Current measurement data on October 26, 2022

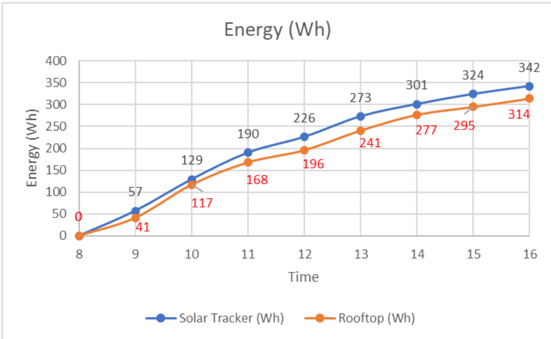


Figure 27 Current measurement data on October 27, 2022

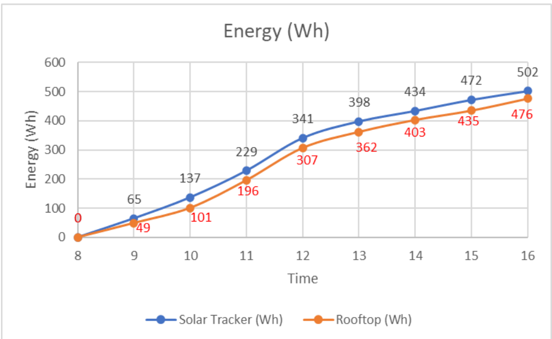


Figure 28 Current measurement data on October 28, 2022

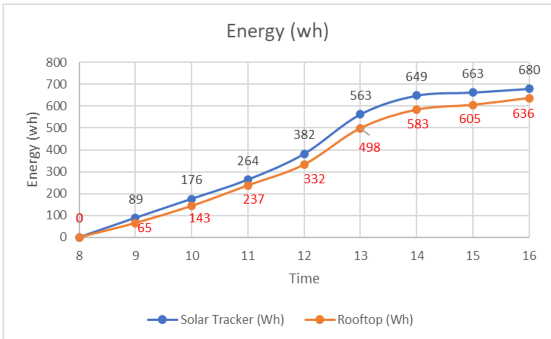


Figure 29 Current measurement data on October 29, 2022

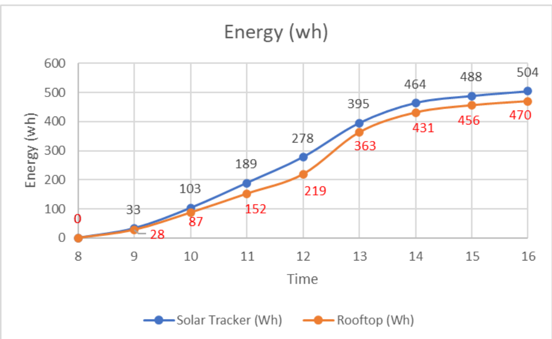


Figure 30 Current measurement data on October 30, 2022

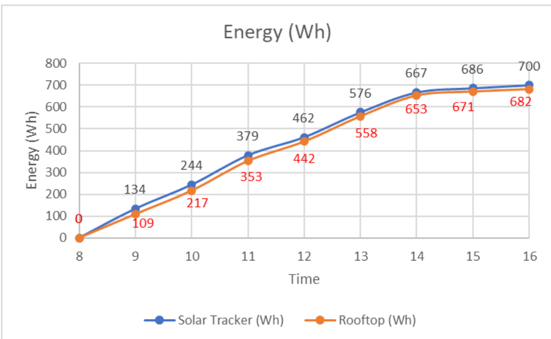


Figure 31 Current measurement data on October 31, 2022

Based on the test, solar panels with a solar tracker can produce a total of 5,244 kWh over the course of ten days, whereas rooftop solar panels may produce 4,845 kWh. Rooftop solar panels have an average daily power generation of 0.485 kWh, compared to 0.524 kWh for solar panels with a solar tracker.

3.5 Maximum Solar Panel Power against Research Time

Solar panels' maximum power for research purposes varies quite a bit. As a result, there is a maximum power that is low and some is high when gathering research data. This is brought on by shifting weather circumstances. The table 4.2 and graphic 4.32 include the observational data.

Table 2. solar panel power

No.	Date	P. max (solar tracker)	P. max (rooftop)
1.	22 October 2022	155,21 W	145,18 W
2.	23 October 2022	138,54 W	119,91 W
3.	24 October 2022	154,85 W	142,10 W
4.	25 October 2022	106,21 W	101,40 W
5.	26 October 2022	144,43 W	130,04 W
6.	27 October 2022	105,80 W	103,45 W
7.	28 October 2022	133,73 W	117,15 W
8.	29 October 2022	132,46 W	129,61 W
9.	30 October 2022	129,50 W	129,04 W
10.	31 October 2022	144,86 W	141,97 W
average		134,55 W	125,98 W

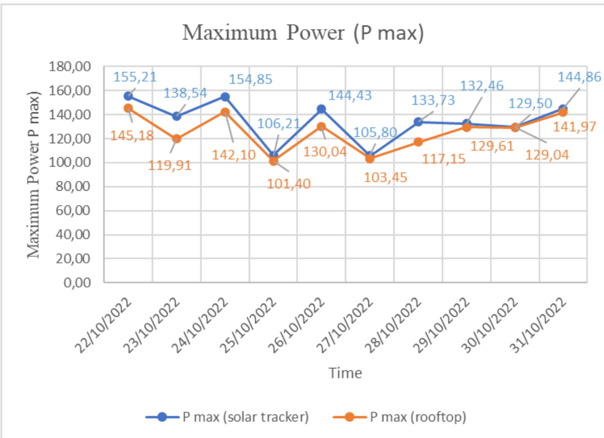


Figure 32 The maximum power of solar panels for 10 days of research

The maximum power value was calculated based on the test using the data that was taken during the peak of the light intensity. During the test, solar panels with a solar tracker system were able to produce an average maximum output of 134.55 W over the course of 10 days. The average maximum power that solar panels on a rooftop system can produce is 125.98 W.

3.6. Elevation and Azimuth Angle

When calculating these numbers, the Andrewmarsh program is used to determine the elevation angle and azimuth angle at the time of the research's execution. The outcomes of the data collection are shown in table 4.3 and 4.4

Table 3 Elevation and azimuth angle on first week

Week-1

Time	Azimuth	Elevation
08:00	88	38
09:00	85	52
10:00	80	67
11:00	59	81
12:00	297	81
13:00	279	66
14:00	274	52
15:00	271	37
16:00	269	22

Table 4 Elevation and azimuth angle on second week

Week-2

Time	Azimuth	Elevation
08:00	91	38
09:00	89	53
10:00	87	68
11:00	76	83
12:00	279	83
13:00	272	66
14:00	274	52
15:00	271	37
16:00	269	22

According to the data collection's findings, it takes 1.2 seconds to alter the degree angle when the linear actuator is moved by a 12 V power. It is well known that the elevation angle shift takes 18 seconds and occurs on average 15 times every hour. It takes 5 seconds to adjust the azimuth angle by 4 degrees on average each hour.

3.7. Solar Panel Efficiency

By comparing the output power (P.out) to the incoming power (P.in), where (P.in) is the product of Voc, Isc, and FF, it is possible to determine the efficiency of solar panels. The incoming radiation flux in the Standard Test Condition (STC), which estimates the maximum amount of sun irradiation in this case is 1000W/m2, is used to calculate (P.out). Figure 4.33 following shows the results of the tests for solar panel efficiency.

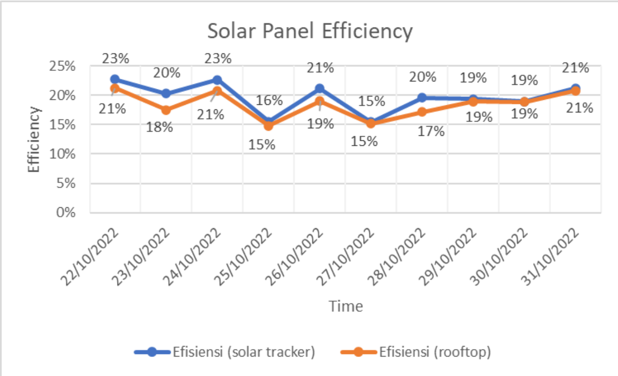


Figure 33 Solar Panel Efficiency

The efficiency of solar panels can be increased by utilizing a solar tracker in comparison to a rooftop system since the tracker has been designed to change the location of the direction of sunlight. With a solar tracker, solar panels may often operate at 20% efficiency in sunny conditions, compared to the average efficiency of 18% for rooftop solar panels.

4. Conclusion

The highest open circuit voltage is 21.30 V for solar panels with a solar tracker system and 20.44 V for solar panels with a rooftop system. Meanwhile, the lowest voltage is 19.15 V for solar panels with a solar tracker system and 18.30 V for solar panels with a rooftop system. The average voltage that can be generated by solar panels with a solar tracker system is 20.21 V, while solar panels with a rooftop system are able to produce 19.44 V. When filled with batteries for 10 days of research, solar panels with solar trackers may create an average voltage of 13.44 V and an average current of 6.21 A. While rooftop solar panels may produce an average voltage of 13.39 V and an average current of 5.19 A. An average of 78.34 W may be produced each day using a system that employs a solar tracker. It is 69.80 W for solar panels on a rooftop installation. Solar panels with a MicroPython-based solar tracker can produce 5,244 kWh of electricity in total over the duration of ten days, whereas rooftop solar panels may produce 4,845 kWh. Rooftop solar panels have an average daily power generation of 0.485 kWh, compared to 0.524 kWh for solar panels with a solar tracker. With a solar tracker, solar panels may often operate at 20% efficiency in sunny conditions, compared to the average efficiency of 18% for rooftop solar panels.

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