# Performance Analysis of a 150 WP Portable Solar Power Plant (PLTS) in the Tarutung District Area

**Ronaldo Saurdot Simanjuntak, Pristisal Wibowo, Siti Anisah**

## Abstract

This study aims to analyze the performance of a 150-WP portable solar power plant (PLTS) in Tarutung District. The analysis was conducted based on output power parameters, system efficiency, and the influence of solar radiation intensity and environmental conditions. The research method included measuring voltage, current, and power under daily operational conditions. The results showed that the performance of the 150-WP portable PLTS was affected by weather and the position of the solar modules. This study is expected to be a reference for the use of portable PLTS in the area. The research results show that the solar panel voltage (open circuit) is 18.85 V – 19.90 V, peak voltage (19.90 V) at 14:00 the highest light intensity (49,200 Lux at 12:00) there is a correlation between the decrease in light intensity (caused by the weather) and the decrease in panel voltage, when charging the battery (Close Circuit) the battery voltage is lower than the panel voltage, the highest charging current (3.16A), May 23 there was a fluctuation due to cloudy conditions, when testing the load (battery discharge), the total discharge time was 5.6 hours (experiment 1), 4.1 hours (experiment 2, and 3 hours (experiment 3). These results indicate that the Off Grid PLTS in Tarutung District is very feasible to be implemented both technically and environmentally

**Keywords:** Solar Power Plant (PLTS), Performance, 150 WP Portable, Tarutung

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## Introduction

In rural areas of Indonesia, limited access to electricity remains a crucial issue hampering social and economic development. Tarutung District, as one area likely facing similar challenges, requires reliable and affordable energy solutions. Dependence on fossil fuels is often accompanied by high price fluctuations and negative environmental impacts, making the need for renewable energy alternatives urgent [15].

Portable solar power plants (PLTS), particularly those with relatively small capacities such as 150 Watt peak (WP), offer flexibility and ease of installation, making them suitable for households or small-scale communities in areas not yet connected to the state electricity grid [2].This technology enables the provision of electricity for essential needs such as lighting, charging communication devices, and operating simple household appliances, significantly improving the quality of life and productivity of communities [14].

Theoretically, solar PV power plant performance is highly dependent on various environmental and technical factors, including solar radiation intensity, solar module operating temperature, panel tilt angle and orientation, and the efficiency of system components such as charge controllers and batteries [4]. A thorough understanding of the interactions between these factors is crucial for optimizing energy output and ensuring the long-term operational reliability of solar PV power plants.

Geographically, Tarutung District is located in North Tapanuli Regency, North Sumatra Province, which is located in a tropical region near the equator. Indonesia generally has relatively high solar radiation intensity throughout the year due to almost even daily sunlight exposure. The average solar radiation in Indonesia ranges from around 4–5 kWh/m² per day, thus offering good potential for solar energy development.

Several previous studies have investigated solar PV power plant performance in various locations with varying geographic and climatic conditions. For example, research by [22]. demonstrated the influence of microclimate variables on energy production of household-scale solar PV power plants on the north coast of Java. Meanwhile, a study by [9] analyzed the effect of solar module degradation on the efficiency of solar power plants in humid tropical areas, highlighting the need for regular maintenance.

In the context of electricity generation, solar energy is converted using photovoltaic technology, which directly converts light energy into electrical energy. This makes solar energy an alternative solution for providing environmentally friendly electricity [3].

[11] This study analyzed the performance of small-scale off-grid solar power systems with capacities below 500 watts per square meter. The results showed that the main factors influencing system performance were solar radiation intensity and module temperature. The obtained performance ratio (PR) values ranged from 0.70 to 0.85, depending on environmental conditions. This study is relevant because it also examines small-scale solar power systems and key performance parameters.

[16] This study was conducted in North Sumatra, focusing on analyzing solar energy potential and the performance of household solar power plants. The results showed that average daily solar radiation ranged from 4 to 5 kWh/m²/day and significantly influenced energy production. This study is relevant because it shares a similar geographic location with Tarutung District.

Thus, this study aims to analyze in depth the performance of a portable 150 WP solar power plant in Tarutung District, evaluate the influence of environmental and operational parameters on system efficiency, and provide applicable technical recommendations to support increasing access to sustainable electrical energy for rural communities.

## Literature Review

Solar energy is energy derived from solar radiation that can be utilized as a source of electrical energy through an energy conversion process. This energy is classified as a renewable energy source, abundant and sustainable. The use of solar energy is becoming increasingly important as energy demand increases and fossil fuel reserves dwindle [21]).

In the context of electricity generation, solar energy is converted using photovoltaic technology, which can directly convert light energy into electrical energy. This makes solar energy an alternative solution for providing environmentally friendly electrical energy [3].

In an off-grid solar power plant (PLTS) system, several key components work together to generate and store electrical energy without being connected to the PLN grid. In general, these components include:

Table 1. Main Components of Off-Grid Solar Power Systems

| No | Component | Function |
|---|---|---|
| 1 | Solar Module (Solar Panel) | Converts solar radiation energy into electrical energy in the form of direct current (DC). Module performance is greatly influenced by solar radiation intensity, temperature, and installation orientation. |
| 2 | Solar Charge Controller (SCC) | SCC regulates the flow of electricity from the solar module to the battery to prevent overcharging or overdischarging. It also extends battery life. |
| 3 | Battery | A storage device for electrical energy generated by solar panels. This energy is used at night or when sunlight is low. Battery capacity is crucial for the reliability of an off-grid system. |
| 4 | Inverter | converts DC current from a battery into alternating current (AC) for use by household appliances. Inverter efficiency also affects the overall performance of the system. |

| | | |
|---|---|---|
| 5 | Load | electrical equipment that uses energy from the solar power system, such as lamps, televisions, and other electronic devices. |
| 6 | Protection and Support System | These components include cables, MCBs (Miniature Circuit Breakers), fuses, grounding, and panel mounting structures. Their function is to maintain system safety, reliability, and stability. |

**Research Methodology**

The implementation method of activities that have been carried out in the program "Performance Analysis of 150 Wp Portable Solar Power Plants (PLTS) in the Tarutung District Area" through secondary data analysis in the form of measurement data from the PLTS with household electricity consumption data, which is then processed to obtain technical calculation results in the Tarutung District area.

A. Design of a 150 Wp Portable Solar Power System

The 150 Wp portable solar power system is designed to generate electrical energy from sunlight for flexible use. The system's main components include:

- 150 Wp Solar Panel
- Solar Charger Controller (SSC)
- Battery (80 AH)
- 1000-watt Pure Sine Wave Inverter
- Load (Lights/Electronic Equipment)

B. Solar Panel Flowchart

The flowchart of the 150 Wp Portable PLTS System can be explained as follows:

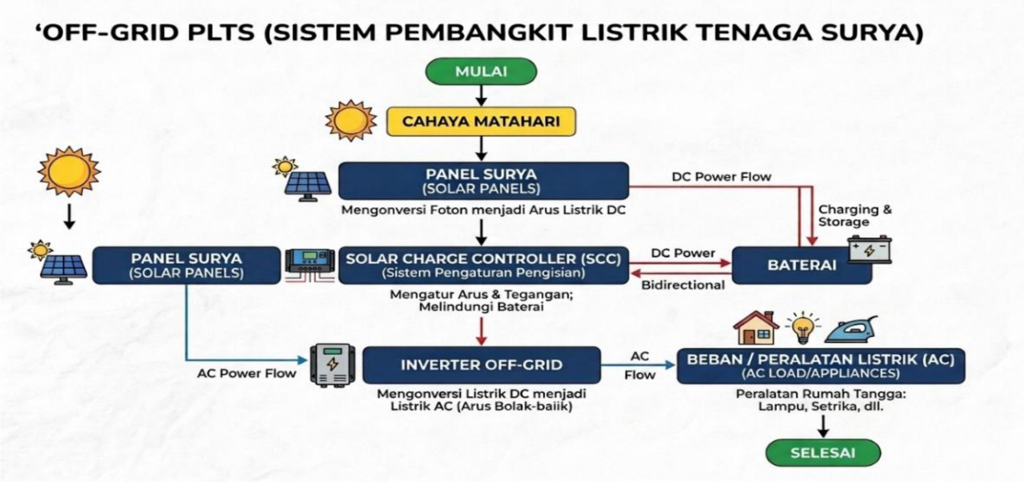



Figure 1. Flowchart of how solar panels work

Explanation:

• Solar panels receive sunlight (energy source)

• The charger controller regulates charging and prevents overcharging, then evaluates the battery calculations.

• Once the battery is fully charged, the electrical energy is supplied to the inverter.

• The inverter then converts the DC current to AC and supplies the electrical current to the load.

• The power absorbed by the load is then measured.

• The battery calculations are then evaluated (discharged).

• Completed.

C. Research Tools and Materials

1. Tools

The equipment used in this research is as follows:

• Multimeter

• Clamp Meter (Ampere Clamp)

• Laptop (for data processing in Microsoft Word and Excel)

2. Materials

The materials used in this research are:

• 150W Solar Panel

• Solar Charger Controller

• 80 AH Dry Battery

• 1000-watt Inverter (Pure Sine Wave)

• Cables and Connectors

• Load (Lights & Electronic Equipment)

D. Data Collection

The data collection method used was a direct experimental method by taking measurements on the solar power plant system.

The data collected included:

- Voltage (Volts)
- Current (Amperes)
- Power (Watts)
- Sunlight Intensity
- Measurement Time

Measurements were conducted periodically, every 30 minutes, starting from 10:00 a.m. to 3:00 p.m., which is the peak solar intensity.

## Results

4.1 Solar Panel Voltage Measurement (Open Circuit)

Measuring sunlight intensity using a Lux meter and measuring panel voltage using a multimeter.

Table 2. Solar Panel Voltage Measurement

| ***14 Mei 2025*** | | | |
|---|---|---|---|
| **No.** | **Pukul (WIB)** | **Tegangan Panel (V)** | **Intensitas Penerangan (Lux)** |
| 1 | 10.00 | 19 | 36.000 |
| 2 | 11:00 | 19,85 | 34.800 |
| 3 | 12:00 | 19,73 | 49.200 |
| 4 | 13:00 | 19,56 | 38.000 |
| 5 | 14:00 | 19,90 | 42.500 |
| 6 | 15:00 | 19,76 | 40.000 |
| ***15 Mei 2025*** | | | |
| **No.** | **Pukul (WIB)** | **Tegangan Panel (V)** | **Intensitas Penerangan (Lux)** |
| 1 | 10:00 | 18,9 | 35.000 |
| 2 | 11:00 | 18,92 | 37.000 |
| 3 | 12:00 | 19,26 | 40.000 |
| 4 | 13:00 | 19,43 | 38.200 |
| 5 | 14:00 | 19,11 | 40.000 |
| 6 | 15:00 | 18,85 | 38.300 |

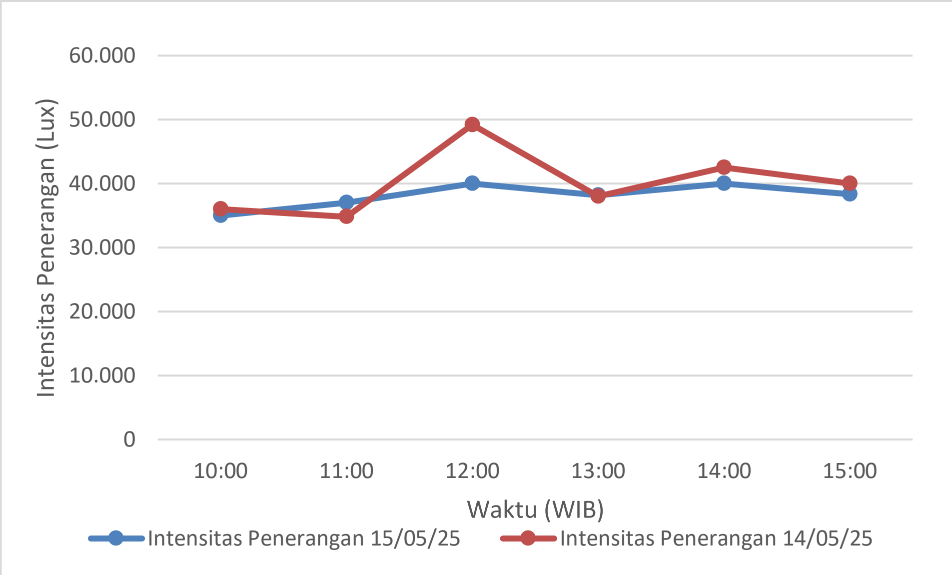



Figure 2. Lighting Intensity Graph

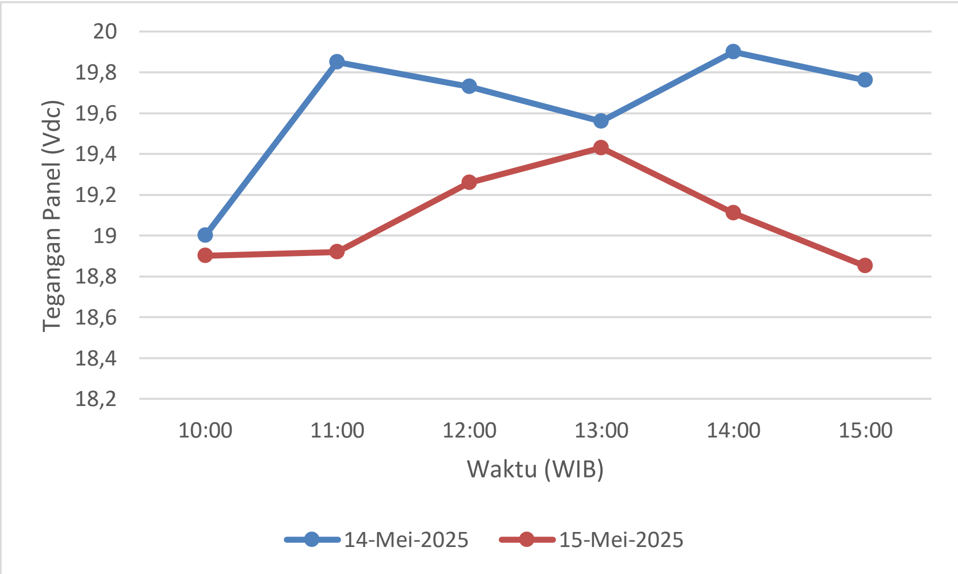



Figure 3. Panel Voltage Graph

In the two-day test, the highest light intensity value can be seen in table 2 which was recorded at 12.00 on the first day with a light intensity of 49,200 Lux and produced a voltage on the Solar Panel of 19.73 V, while the Peak voltage on the Solar Panel was produced on the First Day at 14.00 with a Voltage Value of 19.90 Volts.

4.2 No-Load Battery Measurement (Closed Circuit)

Measurements were conducted periodically, every 30 minutes, starting at 10:00 a.m. WIB and continuing until 3:00 p.m. WIB.

Table 3. No-load battery charging measurement results

| | | ***14 Mei 2025*** | | | | |
|---|---|---|---|---|---|---|
| **No.** | **Pukul (WIB)** | **Tegangan Panel (V)** | **Tegangan Baterai (V)** | **Arus Pengisian Baterai (A)** | **Suhu Baterai (℃ )** | **Intensitas Penerangan (Lux)** |
| 1 | 10:00 | 12,9 | 12,8 | 1,87 | 32 | 36.000 |
| 2 | 10:30 | 12,95 | 12,86 | 1,7 | 31,5 | 34.700 |
| 3 | 11:00 | 13,13 | 12,96 | 1,73 | 31,9 | 34.800 |
| 4 | 11:30 | 13,19 | 13 | 2,75 | 33,8 | 40.000 |
| 5 | 12:00 | 13,28 | 13,06 | 3,16 | 36,4 | 49.200 |
| 6 | 12:30 | 13,14 | 13,01 | 1,91 | 32,5 | 39.600 |
| 7 | 13:00 | 13,13 | 12,97 | 1,95 | 32,4 | 38.000 |
| 8 | 13:30 | 13,23 | 13,08 | 1,90 | 33,5 | 39.000 |
| 9 | 14:00 | 13,36 | 13,17 | 2,97 | 34,4 | 42.500 |
| 10 | 14:30 | 13,54 | 13,3 | 3,06 | 35 | 48.200 |
| | | ***15 Mei 2025*** | | | | |
| **No.** | **Pukul (WIB)** | **Tegangan Panel (V)** | **Tegangan Baterai (V)** | **Arus Pengisian Baterai (A)** | **Suhu Baterai (℃ )** | **Intensitas Penerangan (Lux)** |
| 1 | 10:00 | 13 | 12,9 | 1,75 | 28 | 35.000 |
| 2 | 10:30 | 13,6 | 13,4 | 1,73 | 29,1 | 34.000 |
| 3 | 11:00 | 13,75 | 13,5 | 1,89 | 30 | 37.000 |
| 4 | 11:30 | 13,6 | 13,47 | 1,81 | 31,8 | 37.300 |
| 5 | 12:00 | 14,1 | 13,94 | 2,69 | 32,1 | 40.000 |
| 6 | 12:30 | 14,24 | 14,1 | 1,8 | 31 | 38.000 |
| 7 | 13:00 | 14,98 | 14,8 | 1,84 | 31,7 | 38.200 |
| 8 | 13:30 | 14,77 | 14,65 | 1,81 | 31,8 | 38.000 |
| 9 | 14:00 | 14,31 | 14,12 | 2,71 | 32,5 | 40.000 |
| 10 | 14:30 | 14,29 | 14,10 | 2,55 | 33,2 | 39.800 |

| | | 23 Mei 2025 | | | | |
|---|---|---|---|---|---|---|
| No. | Pukul (WIB) | Tegangan Panel (V) | Tegangan Baterai (V) | Arus Pengisian Baterai (A) | Suhu Baterai (℃) | Intensitas Penerangan (Lux) |
| 1 | 10:00 | 13,51 | 12,85 | 2,23 | 31,5 | 30.400 |
| 2 | 10:30 | 13,56 | 12,93 | 2,79 | 34,1 | 40.200 |
| 3 | 11:00 | 13,10 | 12,83 | 2,10 | 30 | 22.000 |
| 4 | 11:30 | 13,01 | 12,82 | 1,95 | 29,8 | 18.000 |
| 5 | 12:00 | 12,98 | 12,84 | 1,81 | 29 | 12.000 |
| 6 | 12:30 | 12,92 | 12,82 | 1,94 | 28,9 | 10.000 |
| 7 | 13:00 | 13,10 | 12,90 | 2,38 | 29 | 13.000 |
| 8 | 13:30 | 13,17 | 13,05 | 1,23 | 29 | 12.500 |
| 9 | 14:00 | 13,31 | 13,18 | 1,73 | 33,2 | 39.000 |
| 10 | 14:30 | 13,47 | 13,45 | 3,00 | 33,8 | 42.000 |
| 11 | 15:00 | 13,25 | 13,14 | 1,54 | 31,5 | 10.000 |
| 12 | 15:30 | 13,20 | 13,13 | 1,66 | 30 | 12.100 |
| 13 | 16:00 | 12,93 | 12,92 | 0,04 | 24,5 | 1.200 |
| 14 | 16:30 | 13,06 | 13,00 | 0,75 | 25,3 | 5.700 |
| 15 | 17:00 | 13,05 | 13,03 | 0,34 | 25,1 | 3.460 |

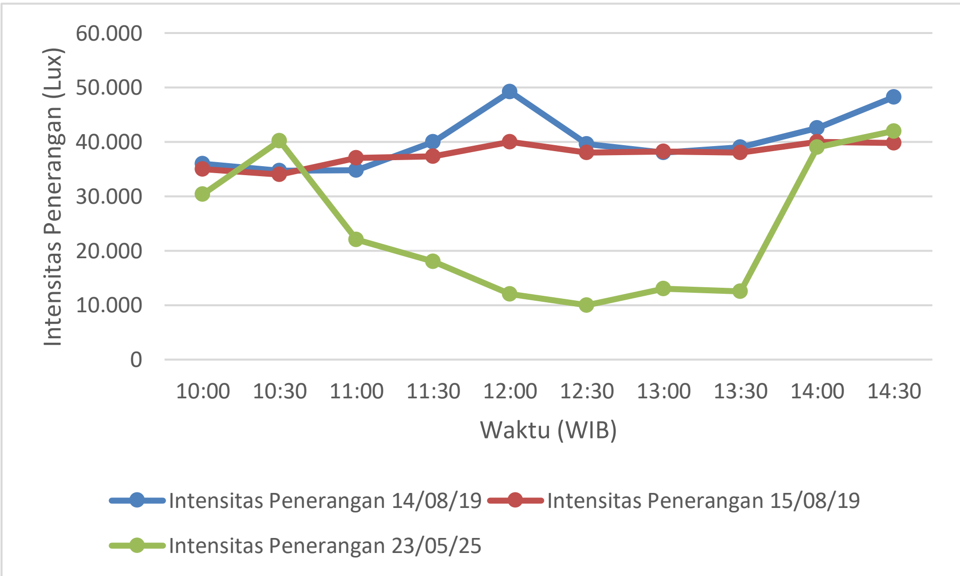
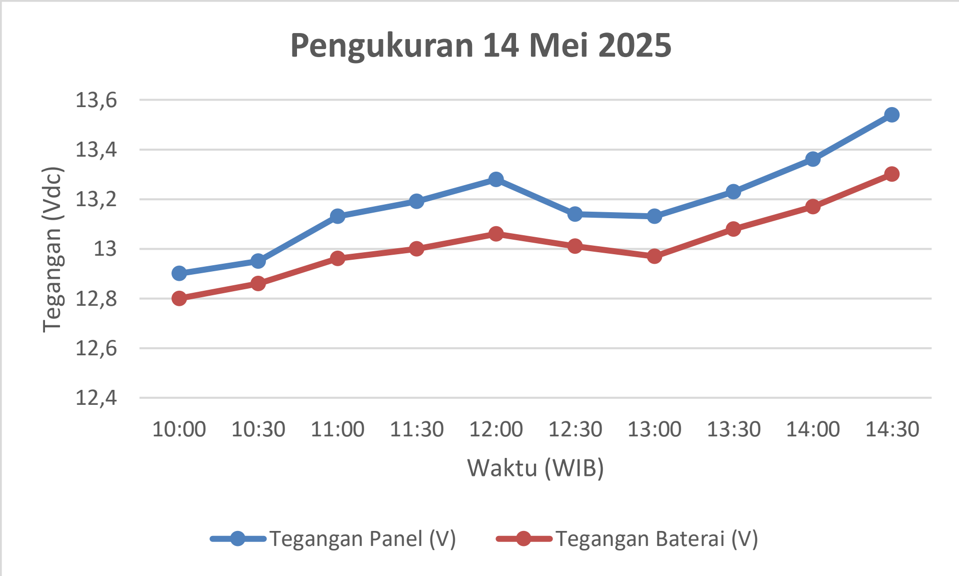
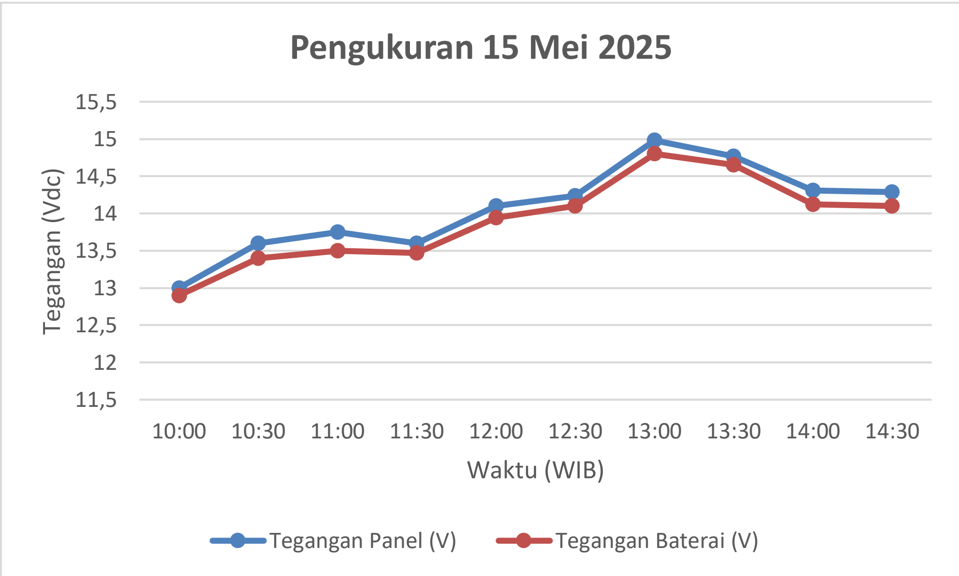



Figure 4. Comparison graph between time and lighting intensity

In Figure 4. Shows a graphic comparison between time and Lighting Intensity, The graph shows that it cannot be guaranteed that the later in the day there will always be an increase in Lighting Intensity. This can be seen in Table 2. Measurements made on May 23, 2025 (Green Line) from 10:30 to 12:30 there was a very significant decrease in lighting intensity, the main factor causing this decrease in lighting was the weather factor.



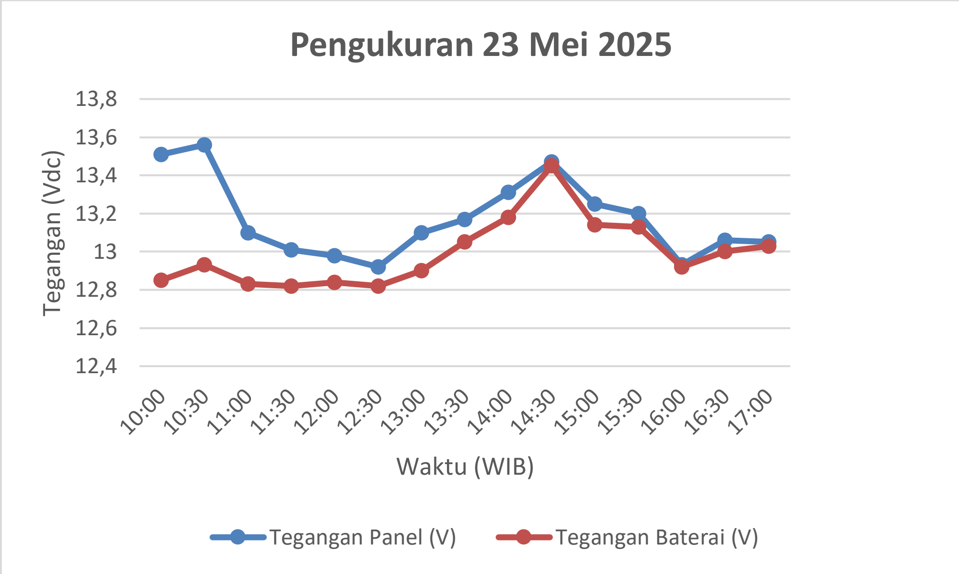



Figure 5. Graph of Panel Voltage and Battery Charging Voltage on May 14, 15 and 23, 2025

Meanwhile, this test also obtained a comparison between the Panel Voltage and Battery Voltage as seen in Figure 5 above. The conclusion that can be drawn from the test results is that the Battery Voltage never exceeds the Panel Voltage, while the decrease in Voltage value that occurs in each measurement is caused by a decrease in Lighting Intensity.

4.3 Tool Testing/Battery Discharging

- ✓ Experiment 1 was conducted on May 16, 2025

Table 4. Testing the tool when the battery is loaded/discharged

| **No** | **Beban** | **Jumlah** | **Daya (Watt)** | **Waktu (WIB)** | **Tegangan Baterai** | | **Arus Beban (A)** | **Ket** |
|---|---|---|---|---|---|---|---|---|
| | | | | | **Awal (V)** | **Akhir (V)** | | |
| 1 | Rice Cooker | 1 | 300 | 11:50-12:15 (25 menit) | 12,85 | 12,44 | 1,43 | Masak |
| 2 | Speaker Aktif | 1 | 40 | 12:35-13:50 (75 menit) | 12,9 | 12,87 | 0,42 | Hidup |
| 3 | Charger Laptop/HP | 1 | 50 | | | | | |
| 4 | Lampu Penerangan | 2 | 18 | 14:15-18:15 (240 menit) | 12,40 | 11,74 | 0,43 | Hidup |
| 5 | Kipas Angin | 1 | 60 | | | | | |
| **Total lama pengosongan baterai** | | | | 340 menit (5,6 jam) | | | | |

✓ Experiment 2 was conducted on May 19, 2025

| No | Beban | Jumlah | Daya (Watt) | Waktu (WIB) | Tegangan Baterai | | Arus Beban (A) | Ket |
|---|---|---|---|---|---|---|---|---|
| | | | | | Awal (V) | Akhir (V) | | |
| 1 | Rice Cooker | 1 | 300 | 16:00-16:25 (25 menit) | 12,8 | 12,39 | 1,42 | Masak |
| 2 | Setrika | 1 | 300 | 16:35-17:20(45 menit) | 12,4 | 11,2 | 1,46 | Hidup |
| 4 | Lampu Penerangan | 2 | 23 | 17:30-21:30 (180 menit) | 12,2 | 11,2 | 0,45 | Hidup |
| 5 | Charger Laptop/HP | 1 | 50 | | | | | |
| **Total lama pengosongan baterai** | | | | 250 menit (4,1 jam) | | | | |

✓ Experiment 3 was conducted on May 23, 2025

| No | Beban | Jumlah | Daya (Watt) | Waktu (WIB) | Tegangan Baterai | | Arus Beban (A) | Ket |
|---|---|---|---|---|---|---|---|---|
| | | | | | Awal (V) | Akhir (V) | | |
| 1 | Setrika | 1 | 300 | 15:45-16:45 (60 menit) | 12,15 | 11,95 | 1,42 | Hidup |
| 2 | Lampu Penerangan | 1 | 20 | 15:45-17:45 (120 menit) | 12,61 | 12,25 | 0, 35 | Hidup |
| 3 | Lampu penerangan | 1 | 18 | | | | | |
| 4 | Charger Laptop/HP | 1 | 45 | | | | | |
| **Total lama pengosongan baterai** | | | | 180 menit (3 jam) | | | | |

The test results in table 4 above were obtained if the load was not applied simultaneously and the test was carried out indoors without sunlight.

4.4 Safety Rating

This overload protection device functions as a circuit breaker, preventing overcurrent and short circuits. The maximum load this device can supply is 768 watts. The following is the calculation for determining the safety rating for this device:

Formula: $P = V.\ I$ ……………………………………..…………(1)

$$I = \frac{P}{V}$$

$$I = \frac{768\,Watt}{220\,V} = 3{,}49\ \text{A}$$

Based on the calculation above, the required Ampere Circuit Breaker is 4A.

4.5 Sine Wave Testing

Tests using an oscilloscope yielded the following results:

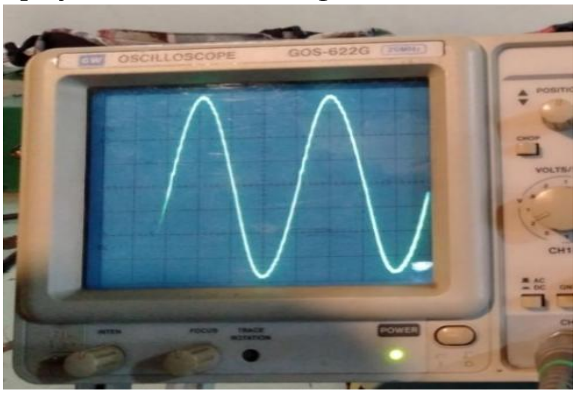



Figure 6. Sine Wave Testing using an Oscilloscope

As in the image above, the waveform produced by the inverter is a Pure Sine Wave, the test results were carried out by reducing the voltage from 220 Volts to 24 Volts using a stepdown transformer. The voltage was reduced to 24 volts because the Oscilloscope cannot measure 220 volts, the results on the Oscilloscope can be calculated using the formula to determine Veff (Voltage Efficiency):

$$\text{Veff} = \frac{Vmax}{\sqrt{2}} \quad \text{……………………………………………………………………(2)}$$

$$= \frac{3{,}8 \times 10 \times 2\ Volt/Div}{\sqrt{2}} = 53{,}74\ \text{Volt}$$

The voltage result obtained from the oscilloscope is 53.74 Volts.

4.6 Battery Charging Test

Table 5. 50 Wp Solar Panel Specifications

| **Parameter** | **Nilai** |
|---|---|
| Modul Type | SP-50-M36 |
| Rated Max Power (Pmax) | 50 watt |
| Open Circuit Voltage (VOC) | 22,4 V |
| Short Circuit Current (ISC) | 3,04 A |

| | |
|---|---|
| Current at Pmax (Imp) | 2,85 A |
| Voltage at Pmax (Vmp) | 17,4 V |
| Normal Cell Temp (NOCT) | $-45^0$C - $+80^0$C |
| Maximum System Voltage | 700VOD |
| Max Series Fuse Raiting | 10A |

Based on the existing formula or theory, the length of time for charging the battery according to the solar module specifications is as follows:

$$P_{max} = V_{max} \times I_{max} \quad \text{……(3)}$$

$$P_{max} = 17{,}4 \text{ V} \times 2{,}85 \text{ A}$$

$$P_{max} = 49{,}59 \textit{ Watt Peak} \text{ or } 50 \textit{ Watt Peak}$$

With a battery capacity of 12 V; 80 AH,

then P = 12 V x 80 AH = 960 Wh

Therefore, the charging time until the battery is fully charged is

$$t = \frac{Ah\ baterai}{It} + 20\,\% \times \frac{Ah\ baterai}{It}$$

$$t = \frac{80\ Ah}{8{,}55\ A} + 20\% \times \frac{Ah\ baterai}{It}$$

$$t = 9{,}35 + 1{,}87$$

$$t = 11 \text{ Jam}$$

From the calculation above, the battery charging time takes 11 hours, if divided by 1 day and 5 hours of exposure (10:00-15:00 WIB), the battery will be fully charged in 2.2 days.

## Conclusion

1. Dry-cell batteries require simpler maintenance, even minimal maintenance.
2. Charging the battery using three 50 Wp solar panels is faster, taking 11 hours.
3. Charging for 5-6 hours per day will fully charge the battery in two days. The inverter in this device produces a sine wave output similar to that of the PLN electricity supply.
4. With a maximum power of 700 watts, it can handle resistive, inductive, and capacitive loads.
5. In this application, it is recommended not to handle loads exceeding 700 watts.
6. Increasing the capacity of the battery and inverter increases the battery's power storage and the inverter's output power.

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