

Comparison of 100 WP Monocrystalline Solar Panel Output in Sunny and Cloudy Weather

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ABSTRACT

Solar energy is a highly potential renewable energy source, especially in tropical regions that receive abundant sunlight throughout the year. This study aims to evaluate the performance of a 100 Wp monocrystalline solar panel under clear and cloudy weather conditions to determine the impact of weather changes on electrical energy conversion efficiency. Data were collected over three consecutive days by measuring light intensity using a BH1750 sensor, while voltage and current were recorded through an Arduino Uno-based monitoring system. The results indicate that solar panel performance is optimal during clear weather, whereas efficiency decreases by up to 44.4% under cloudy conditions due to reduced light intensity. These findings highlight the importance of technical strategies, such as energy storage systems and the use of panels adaptive to diffuse radiation, to improve solar energy performance in tropical regions. Additionally, integrating local weather monitoring can support more efficient and responsive energy management.

INTRODUCTION

Global energy demand continues to increase in line with population growth and industrial sector expansion. Reliance on conventional energy sources such as oil, coal, and natural gas has given rise to various problems, ranging from limited reserves and price fluctuations to environmental impacts in the form of carbon emissions that accelerate climate change. To address these challenges, renewable energy is becoming an increasingly relevant and urgent strategic option for development.

Figure 1: Photovoltaics



Source: Internet

Description: Photovoltaics is a technology that directly converts energy from sunlight into electrical energy. Photovoltaic devices consist of a collection of solar cells arranged in series or parallel and combined into solar modules.

One of the most promising forms of renewable energy is solar energy. This energy comes from sunlight radiation, which can be converted into electrical energy through photovoltaic (PV) technology. PV technology has experienced rapid development in recent decades and is now a crucial component of sustainable energy systems. The main advantages of solar energy are its abundant availability, its clean nature, as it produces no greenhouse gas emissions when used, and its flexibility in application at various scales, from household use to large-scale power plants.

Figure 2: Differences between Mono and Poly Solar Panels



Source: Internet

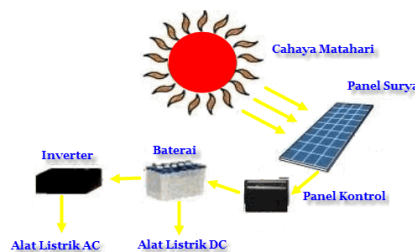
Description: This solar cell is made of silicon that is sliced thinly using a machine. The slices can be thinner and also have identical characteristics because of the use of this cutting machine. This type of solar panel is the most widely used type because it has the advantage of being able to absorb sunlight more efficiently compared to other solar cell materials. The efficiency of converting sunlight into electricity owned by this solar cell material is around 15%. This number is one of the quite large numbers when compared to other solar cell constituent materials even with the same cross-sectional size. And this type of solar panel is a

technology made from silicon rods that are then melted. This panel technology has the advantage of a neater and denser arrangement. For its characteristics, usually this solar cell has a unique appearance because it looks like there are cracks in the solar cell it has. This solar cell technology also has disadvantages that are quite similar to the monocrystalline silicon mentioned previously. Polycrystalline solar panels have disadvantages when used in areas that are prone to and often cloudy. When placed or used in areas like this, their efficiency will decrease. Compared to monocrystalline silicon, polycrystalline silicon has lower efficiency. Therefore, to generate the same amount of electricity, this type of solar cell requires a larger cross-section.

However, the drawback of this type of solar panel is that it requires very bright sunlight. Its efficiency will decrease in cloudy or overcast weather. Monocrystalline silicon solar panels are characterized by their black color and thin shape, as previously mentioned.

Indonesia, as a country located near the equator, has enormous solar energy potential. According to the National Energy Council, the average solar radiation intensity in Indonesia reaches approximately 4.8 kWh/m² per day. If fully utilized, this potential could generate an energy capacity of over 200,000 MW. However, the utilization of solar energy in Indonesia still faces several challenges, one of which is the unstable tropical climate. Despite high sunlight intensity, frequent changes in atmospheric conditions – from sunny to cloudy or rainy within a short period – cause fluctuations in solar panel power output.

Figure 3: How Solar Panels Work



Source: Internet

Caption: This image shows that during the day, solar panels receive sunlight, which is then converted into electrical energy by crystalline cells through a photovoltaic process. The electricity generated by the solar panels can be directly distributed to the load or stored in a battery (accumulator) before being distributed to the load (lamps, radios, TVs, etc.).

At night, when solar panels are not generating electricity, the electricity collected (stored) in the battery can be used to power electrical appliances, especially lighting and other devices.

Solar panels are highly dependent on light intensity to generate electricity. Under clear skies, the panels receive direct radiation, enabling optimal energy conversion. Conversely, under cloudy conditions, the received radiation becomes diffuse, and its intensity decreases significantly, thus decreasing energy conversion efficiency. This phenomenon poses a challenge in maintaining a

continuous energy supply, especially if the system is not equipped with energy storage or adaptive load regulation.

This study aims to quantitatively assess the effect of weather conditions on the performance of a 100 Wp monocrystalline solar panel. The main focus was to compare panel performance under two different atmospheric conditions: sunny and cloudy. Measurements were conducted using a BH1750 light intensity sensor and an Arduino Uno microcontroller-based recording system. Observed parameters included voltage, current, and light intensity over three consecutive days. The obtained data was used to calculate panel efficiency under each condition and evaluate its implications for designing solar energy systems that are more responsive to weather changes.

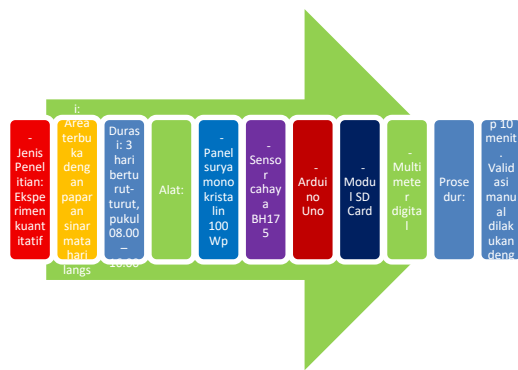


Figure 4: Methodology

Source: Personal Analysis

Caption: This image shows - Type of Research: Quantitative Experiment

- Location: Open area with direct sunlight
- Duration: 3 consecutive days, 8:00 AM–4:00 PM
- Equipment:
 - 100 Wp monocrystalline solar panel
 - BH1750 light sensor
 - Arduino Uno
 - SD Card module
 - Digital multimeter

Procedure:

Light intensity, voltage, and current data were recorded every 10 minutes. Manual validation was performed using a multimeter and visual documentation of sky conditions.

Type of Research

This research employs a quantitative approach using an experimental method. This approach was chosen because the primary objective of the study was to obtain numerical data that could be statistically analyzed to evaluate the performance of solar panels under two different atmospheric conditions: sunny and cloudy weather. The experimental method allows researchers to directly observe the variables that influence energy conversion efficiency and control the measurement environment so that the results can be objectively compared.

The experiment was conducted by observing changes in the output power of a 100 Watt peak (Wp) monocrystalline solar panel under two contrasting weather conditions. In this study, weather conditions (sunny and cloudy) served as the independent variable, while solar panel efficiency, measured through voltage, current, and light intensity, served as the dependent variable.

Research Location and Time

The study was conducted in an open space that allowed direct sunlight exposure without obstruction from surrounding objects such as buildings, trees, or other structures. This location was chosen to ensure that the solar panels received optimal solar radiation during the data collection process. The location was also adjusted to the direction of the incoming sunlight so that the panel's tilt angle could be precisely adjusted to maximize light absorption.

Data collection was conducted over three consecutive days, from 8:00 AM to 4:00 PM each day. This timeframe was chosen because it encompasses the active period of sunlight, when light intensity is relatively stable and representative for measuring solar panel performance. The first two days represented sunny conditions, while the third day was conducted under cloudy conditions.

Figure 5: Solar Panels on Top of a House



Caption: This image shows solar panels on top of a house.

Research Tools and Materials

To support the measurement and data recording process, several electronic devices and components were used, as follows:

- 100 Wp Monocrystalline Solar Panel. This panel was the primary object of the research. The monocrystalline type was chosen due to its high energy conversion efficiency and consistent performance under various lighting conditions

PANEL SURYA CPS-SP100WP 18V

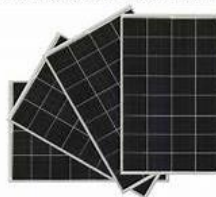


Figure 6: 100 WP Monocrystalline Solar Panel



Caption: This image shows that monocrystalline solar panels (Mono-Si)

Have become one of the most popular technologies in the renewable energy industry, particularly for generating electricity from sunlight. Known for their high efficiency and aesthetic design, Mono-Si solar panels are widely used in a variety of applications, from households to large-scale power generation projects. This article will discuss monocrystalline solar panel technology in detail, its manufacturing process, advantages, disadvantages, applications, and current developments as of May 2025.

The BH1750 Light Sensor is used to measure light intensity in lux. This sensor is known for its high sensitivity and ability to provide real-time lighting data with a high degree of accuracy.

Figure 7: BH1750 Light Sensor

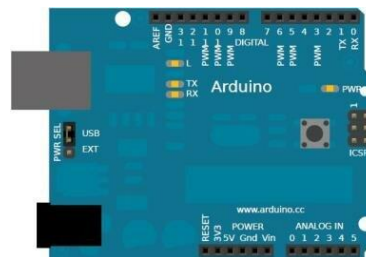


Source: Internet

Caption: This figure shows that the BH1750 is a respected digital light sensor known for its accuracy and ability to communicate over the I2C bus. Its design allows it to integrate seamlessly into a variety of electronic systems. Due to its accuracy and responsiveness to different light levels, the sensor finds its place in a wide range of applications. This article explores the technical specifications and practical uses of the BH1750. This discussion aims to offer a thorough understanding of its operation and significance in the modern technological environment.

- Arduino Uno This microcontroller functions as the control center for the data recording system. The Arduino is programmed to read data from the BH1750 sensor and record the voltage and current generated by the solar panel.

Figure 8: Arduino Uno Microcontroller



Source: Internet

Description: This image shows that the Arduino Uno is a circuit board based on the ATmega328 microcontroller. This IC (integrated circuit) has 14 digital inputs/outputs (6 outputs for PWM), 6 analog inputs, a 16 MHz ceramic crystal resonator, a USB connection, an adapter socket, an ICSP header pin, and a reset button.

- SD Card Module: Functions as an automatic storage medium for measurement data. Data is stored in CSV format for easy processing and analysis using statistical software.

- Digital Multimeter: Used to perform manual measurements of voltage and current to validate the automatically recorded data. The multimeter also serves as a backup tool in case of disruptions to the electronic recording system.

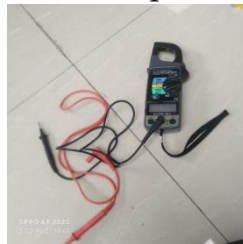
Figure 9: Multimeter



Source: Internet

The measuring instruments used are an ammeter and a sunny web box sensor. The ammeter is used to measure the current and voltage of the solar module and battery. When in operation, the sunny web box sensor is an internet-integrated sensor from SMA, used to monitor irradiance values, module temperature, and ambient temperature in real time for more accurate data collection.

Figure 10. Ampere clamp



(source: personal document)

The ammeter is equipped with two probes that function as workpiece clamps. In addition to clamping, the ammeter can also be used to measure electrical voltage. The ammeter can measure single-phase and three-phase alternating current (AC).

Research Procedure

The steps for implementing this research consist of:

- System Preparation: All devices were connected according to the designed circuit diagram. The solar panel was connected to a light sensor and an Arduino Uno, which was then integrated with an SD card module for data recording. A digital multimeter was prepared for manual measurements and validation.

Figure 10: SD Card Module



Description: The image above shows that the SD (Secure Digital) Card Module is a device used to store and access data digitally.

- **Device Calibration:** Before data collection began, the BH1750 sensor and multimeter were calibrated to ensure measurement accuracy. The solar panels were also tested under initial conditions to ensure there was no physical damage or technical issues.
- **Data Collection:** Light intensity, voltage, and electric current were recorded every 10 minutes during the observation period. The Arduino automatically recorded the data and saved it to the SD Card. Manual measurements using a multimeter were performed periodically to ensure consistency of results.
- **Visual Documentation:** Sky conditions during data collection were documented using a digital camera. This documentation was used as a reference in the correlation analysis between atmospheric conditions and solar panel performance.
- **Data Processing and Analysis:** The collected data was processed using spreadsheet and statistical software. Panel efficiency was calculated using the formula:

$$\text{"Efficiency"} = \left(\frac{\text{"Output Power"}}{\text{"Irradiance"} \times \text{"Panel Area"}} \right) \times 100\%$$

Comparisons were made between measurement results on sunny and cloudy days to determine the impact of weather changes on solar panel performance.

Data Validation and Reliability

To ensure data accuracy, cross-validation was performed between the automatic recording results and manual measurements using a multimeter. If significant differences were found, the system connections and configuration were rechecked. Visual documentation was also used to confirm atmospheric conditions when the data were recorded, allowing for more accurate interpretation of the results.

Data Analysis Techniques

Data were analyzed descriptively and comparatively. Descriptive analysis was used to illustrate trends in changes in light intensity, voltage, and current during the observation period. Comparative analysis was conducted to compare panel efficiency between sunny and cloudy conditions. The results of the analysis were used to develop technical recommendations for developing solar energy systems that are adaptive to weather changes.

Table 1. Comparison of 100 Wp Monocrystalline Solar Panel Output

| Time | Power Output (Bright) | Power Output (Cloudy) |
|-----------|-----------------------|-----------------------|
| 08.00 WIB | 20.12 W | 10.20 W |
| 09.00 WIB | 30.45 W | 15.30 W |
| 10.00 WIB | 38.90 W | 20.10 W |
| 11.00 WIB | 42.30 W | 23.40 W |
| 12.00 WIB | 45.84 W | 25.50 W |
| 13.00 WIB | 45.60 W | 24.80 W |
| 14.00 WIB | 43.10 W | 22.10 W |
| 15.00 WIB | 38.20 W | 18.90 W |
| 16.00 WIB | 30.00 W | 14.60 W |

Note:

- 1) Power output during sunny weather shows an upward trend until midday, then gradually decreases.
- 2) Output during cloudy weather is lower and fluctuates, with a more rapid decline after 1:00 PM.
- 3) The most significant difference occurs at 12:00 PM, with an output difference of 20.34 W.

RESULTS AND ANALYSIS

Solar Panel Power Output Trends

- During the three-day observation period, significant differences in solar panel performance were observed between clear and cloudy conditions. The first and second days were sunny, while the third day was cloudy. The recorded results showed that:
- On sunny days, the power generated by the solar panels increased gradually from morning, starting at 8:00 a.m. Peak production was reached between 12:00 and 1:00 p.m., reaching a peak value of 45.84 watts. After that, power decreased as light intensity decreased towards afternoon.
- On cloudy days, power output showed sharper fluctuations and significantly lower values. Peak output reached only 25.50 watts, and the decline occurred more rapidly due to unstable solar radiation scattered by clouds.

The resulting graphical visualizations confirmed these findings. The power curve on sunny days appeared smooth and symmetrical, reflecting stable solar radiation. In contrast, the curve on cloudy days shows an irregular pattern and tends to decrease sharply, indicating instability of the energy source.

Solar Panel Efficiency Analysis

The energy conversion efficiency of solar panels is calculated using the formula:

$$"Efficiency" = \frac{"Panel Output Power"}{"Solar Radiation" \times "Panel Area"} \times 100\%$$

Bright Conditions:

- Radiation intensity: 800 " ["W/m"] ^2

- Panel area: 0.6 " "m"²
- Total radiant energy: 800×0.6=480" W"
- Power output: 45.84" W"
- Efficiency: $\frac{45.84}{480} \times 100\% \approx 9.55\%$

Cloudy Conditions:

Radiation Intensity: 400" " ["W/m"] ^2

Panel Area: 0.6" " "m"²

Total Radiant Energy: 400×0.6=240" W

Power Output: 25.50" W

Efficiency: 25.50/240×100%≈10.63%

Absolute Efficiency Decrease:

$$\frac{45.84 - 25.50}{45.84} \times 100\% \approx 44.4\%$$

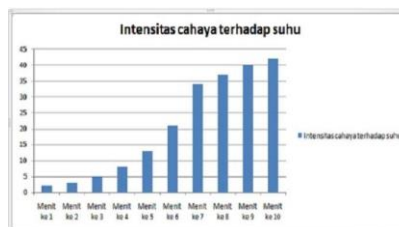
Although the relative efficiency under cloudy conditions appears higher, this is due to a greater decrease in radiation than in power output. In absolute terms, the power output remains significantly lower than under clear conditions.

Impact of Light Intensity on Panel Output

Measurements show that light intensity is the primary factor affecting solar panel performance. When light intensity exceeds 60,000 lux, the panel is able to produce power close to its maximum capacity. Conversely, when light intensity drops below 25,000 lux, power output decreases significantly.

This confirms that solar panels are highly sensitive to changes in lighting. Therefore, solar energy systems implemented in tropical regions must be designed with daily light fluctuations in mind to maintain efficiency.

Figure 11: Impact of Light Intensity on Panel Output



Source: Personal Analysis

Effect of Ambient Temperature on Output Voltage

Air temperature also affects panel performance, although not as significantly as light intensity. When ambient temperatures exceed 30°C, output voltage decreases by 0.6 to 1.0 Volts. This decrease is caused by increased internal resistance in the solar cells due to high temperatures.

However, compared to the effects of lighting, the effects of temperature are moderate and do not cause significant power reduction. Nevertheless, the system still needs to be designed with good ventilation and air circulation to maintain optimal panel temperatures.

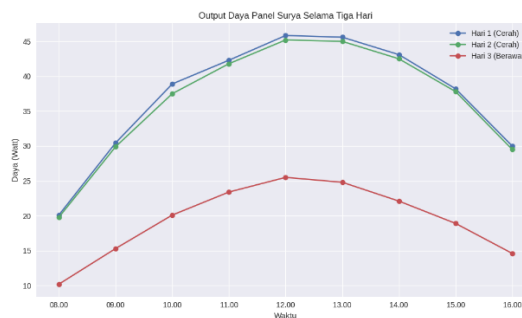
System Design Implications in Tropical Regions

Tropical regions like Indonesia are characterized by highly dynamic weather, with rapid changes between sunny, cloudy, and rainy days. Based on the research results, several technical recommendations can be implemented:

- Integration of MPPT (Maximum Power Point Tracking) technology is crucial for optimizing output power under changing lighting conditions.

- The use of an energy storage system (battery) is highly recommended so that energy generated during sunny weather can be used during unfavorable weather.
- The panel design must take into account the optimal tilt angle and adequate ventilation system, so that the panel continues to work efficiently even at high ambient temperatures.

Figure 12: Solar Panel Power Output Over Three Days



Source: Personal Analysis

CONCLUSION

This study was conducted to assess the performance of a 100 Watt peak (Wp) monocrystalline solar panel under two different atmospheric conditions: clear skies and cloudy skies. Observations were made by recording light intensity, voltage, and electric current for three consecutive days. The results showed a significant difference in energy conversion efficiency between the two conditions. These findings provide important insights into the technical challenges and potential of solar energy utilization in tropical regions with changing weather patterns.

Overview of Findings

Based on the results of measurements and data analysis, it can be concluded that:

- Solar panels show their best performance under clear weather conditions, when light intensity is high and stable. In this condition, solar cells receive direct radiation optimally, producing a peak power output of 45.84 Watts and an energy conversion efficiency of 9.55%.
- On cloudy days, light intensity decreases drastically and becomes more diffused. The power output drops to 25.50 Watts. Although the relative efficiency is recorded at 10.63%, this value does not indicate improved performance, but rather results from a greater decrease in radiation compared to the decrease in output.
- The absolute efficiency decline reaches 44.4%, indicating that changes in atmospheric conditions have a direct impact on solar panel performance. This fluctuation becomes a major challenge in maintaining the stability of energy supply from photovoltaic systems.
- Light intensity is the primary factor affecting panel performance. When the lux value exceeds 60,000, the panel can approach its maximum output. Conversely, when light intensity falls below 25,000 lux, the generated power decreases significantly.

- Ambient temperature also has an effect, although not as significant as light intensity. When the air temperature exceeds 30°C, the output voltage decreases by approximately 0.6–1.0 Volts. However, its impact on total power is relatively small.

Technical and Practical Implications

The findings of this study have several important implications for the development and operation of solar power systems, particularly in tropical regions:

- The implementation of MPPT (Maximum Power Point Tracking) technology is highly recommended to optimize power output under unstable lighting conditions. This technology enables the system to adjust the panel's operating point to continuously generate maximum power.
- Energy storage systems such as lithium-ion batteries or hybrid configurations are essential to store energy generated during clear weather and use it when conditions are less favorable. This is crucial to maintain continuity of electricity supply, especially in remote areas.
- Solar panel design should consider tilt angle and adequate ventilation to ensure efficient operation even under high ambient temperatures. The correct angle maximizes light absorption, while ventilation helps maintain stable panel temperature.
- Integration of solar panel systems with local weather sensors can improve operational efficiency. With real-time weather monitoring, the system can adjust load and energy distribution more responsively to atmospheric changes.

RESEARCH LIMITATIONS

This study has several limitations that should be considered:

- The observation period was relatively short, only three days, so the results do not yet cover extreme weather variations such as heavy rain or fog.
- The system scale was relatively small, involving only a single 100 Wp solar panel, and therefore does not represent the performance of large-scale systems or grid-connected systems.
- Data collection was conducted manually and semi-automatically, leaving some potential for recording errors despite cross-validation efforts.

RECOMMENDATIONS FOR FUTURE RESEARCH

- To expand the scope and deepen understanding, future studies are recommended to:
- Conduct observations over a longer period, covering various seasons and extreme weather conditions, to obtain more representative data.
- Compare the performance of different types of solar panels, such as polycrystalline, thin-film, bifacial, and PERC technologies, under the

same weather conditions to determine the most suitable technology for tropical climates.

- Integrate Internet of Things (IoT)-based monitoring systems to enable real-time data collection and automated analysis, improving accuracy and decision-making efficiency.
- Develop predictive efficiency models based on weather data, which can be used to design more adaptive and intelligent solar power systems.

GENERAL CONCLUSION

- Overall, this study shows that monocrystalline solar panels perform very well under clear conditions but experience significant performance degradation under cloudy weather. Energy conversion efficiency is strongly influenced by light intensity, while ambient temperature provides an additional effect that must be considered. For tropical regions with highly variable weather characteristics, solar power systems need to be equipped with supporting technologies such as MPPT, energy storage batteries, and weather monitoring systems to operate efficiently and sustainably.
- With a deeper understanding of the factors affecting solar panel performance, it is expected that solar energy systems can become a reliable solution in supporting the transition toward clean and sustainable energy in Indonesia and other tropical countries.

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