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IRRADIATION PERFORMANCE ON SOLAR PV PANELS AT POLITEKNIK UNGKU OMAR

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ABSTRACT

The performance of photovoltaic (PV) panels is highly dependent on solar irradiation, which varies according to location, time of day, and weather conditions. This study investigates the impact of solar irradiation on PV panel performance specifically at Politeknik Ungku Omar, (PUO) aiming to identify the optimal operating conditions for maximum energy yield. This study utilizes experimental setups across different climatic regions to assess the influences of irradiation on key performance indicators such as voltage, current, and power output. A real-time monitoring system was developed using a custom-built data logger integrated with sensor for measuring solar irradiance as well as voltage and current sensors connected to the PV panels. Data were collected continuously over a four-day period under natural outdoor conditions on PUO. Measurements included solar irradiance (W/m²), voltage (V) and current (A), captured at five-minute intervals between 7:00 a.m. and 6:00 p.m. daily. The result of the study shows the sunlight at PUO using optimal panel orientation suitable to produced maximum power output especially at peak hours between 10.00am to 1.00pm. This finding also compared from Universiti Teknologi Petronas (UTP) shown the pattern of power output and irradiation is closely same for both regions which are power output range between 50W to 56W with irradiation approximately 457W/m^2.

1. Introduction

As the global shift toward clean energy continues to gain momentum, solar photovoltaic (PV) systems have emerged as a key technology due to their scalability and growing efficiency. However, one of the main challenges in optimizing PV performance lies in the variability of solar irradiation in real-world environments. Fluctuations caused by cloud covers, atmospheric pollution, and site orientation significantly affect the consistency of solar input, which in turn influences voltage, current, and overall energy output (Asif et al., 2023; Hasan et al., 2022).

This makes it essential to conduct site-specific evaluations of solar potential, especially in regions prone to unpredictable weather conditions. To support this goal, this study employs Arduino-based monitoring tools to capture real-time solar and electrical performance data for PV system assessment.

Extensive research has explored the effects of solar irradiation variability on PV system efficiency, confirming its central role in determining energy yield Asif et al., (2023) emphasize that fluctuations in solar exposure particularly due to shading and cloud dynamics can significantly reduce power output Hasan et al.,(2022) adds that sudden drops in irradiance often result in temporary but substantial losses in system performance. These findings highlight the importance of using real-time monitoring to understand local environmental impacts and system behavior, which is critical for ensuring reliable and efficient PV operation across diverse conditions.

Recent studies have investigated the application of microcontroller-based platforms, such as Arduino, in PV system monitoring. Ahsan et al., (2022) demonstrated their ability to detect faults and monitor system performance using basic electrical parameters, while Akhtar et al., (2024) showed how these platforms could be effectively integrated into academic settings to support renewable energy education. These efforts demonstrate the practical value of microcontroller-based monitoring systems for enhancing PV analysis and fostering hands-on learning in solar energy applications.

This study aims to evaluate how varying levels of solar irradiation impact the power output from the solar PV panels specifically at Politeknik Ungku Omar (PUO) using real-time data collected over four consecutive days. PUO serves as an ideal environment for renewable energy implementation and research. As a technical and engineering academic institution, the integration of solar PV systems can serve dual functions supporting campus energy needs while providing real-time data and practical experience for students. The site offers open rooftops and building facades suitable for panel installation, with minimal shading and adequate exposure to sunlight throughout the day. The scope includes short-term monitoring using low-cost components, offering insights into PV performance under actual environmental conditions. By doing so, this research contributes to a broader understanding of solar feasibility studies in educational. The remainder of this paper is organized as follows: Section 2 outlines the methodology of this study. Section 3 and 4 presents results and discusses the results obtained from analysis, respectively. Finally, Section 5 concludes the paper with key findings and directions for future research.

2. Methodology

2.1 Instrument

This study investigates the relationship between solar irradiation and power output using a custom solar energy monitoring included data logger setup over four consecutive days to see a pattern for solar output either suitable or not for applying solar PV panel in PUO. The system was designed to capture three primary parameters: solar irradiation, voltage, and current. A solar panel was employed to measure voltage and current directly from incident sunlight, while irradiation data was collected using a BH1750 light intensity sensor. To enhance the sensitivity and directional accuracy of the irradiation measurements, a mirror was used to reflect sunlight toward the BH1750 sensor, enabling more consistent data under varying sun positions. These components were integrated into a custom data logger programmed using an Arduino Uno, which handled analogue and digital signal processing as Figure 1. The logger recorded data at approximately 10-second intervals throughout the day, enabling high-resolution tracking of system behaviour. This approach is aligned with prior work demonstrating the effectiveness of Arduino-based systems in solar energy monitoring due to their flexibility and affordability (Ahsan et al., 2022).

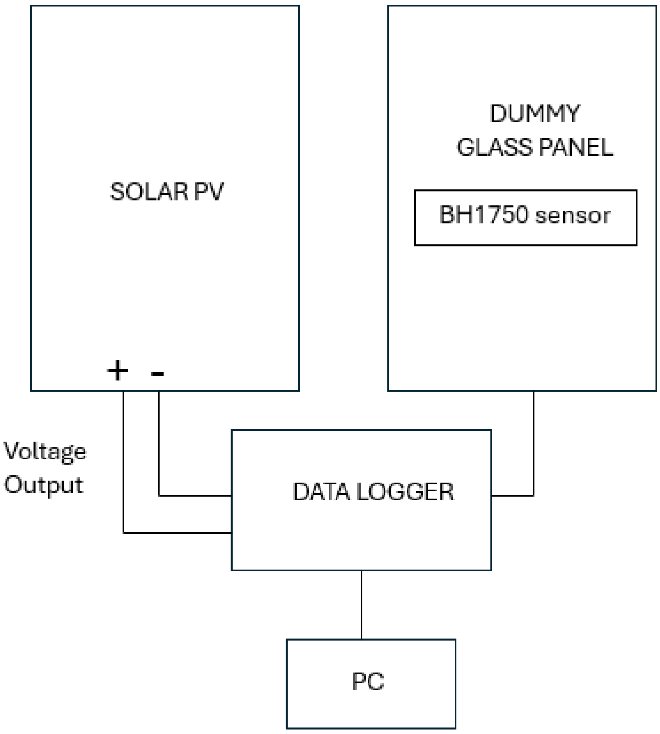

Figure 1 Block diagram setup for Solar PV panel and dummy glass (Sulaiman et al., 2018)

2.2 Data Acquisition

The Arduino Uno data logger was programmed using the Arduino IDE and included routines for reading analog voltage and current from the solar panel and digital irradiance values from the BH1750 sensor. Power output was computed in real time using the formula.

$$P = V \times I$$

Where P is power in watts (W), V is voltage in volt (V), and I is current in ampere (A).

To transfer the collected data to a computer, CoolTerm, a serial port communication software, was used. CoolTerm provided a real-time interface for data capture, saving logs in CSV format for post-processing. The use of the BH1750 sensor for irradiance measurement for enhanced through mirror alignment and offered a cost-effective and reliable method of simulating pyranometer-like behavior, which has been explored in previous research aiming to simplify solar monitoring tools (Hasan et al., 2022).

2.3 Data Analysis

After data acquisition, the CSV files were imported into Microsoft Excel for data analysis. Two time-series plots were generated: one showing solar irradiation and another displaying power output over the same period. Each line on the graphs represents data from one of the four days, color-coded for clarity. The x-axis represents time in HH:MM format, while the y-axis shows the magnitude of the variable where irradiation in watts per square meter (W/m²) and power in watts (W).

The power output plot, however, displayed a relatively stable trend across all four days, which can be attributed to the averaging effect of current and voltage measurements even when irradiance fluctuates. This indicates the PV system's ability to deliver consistent output under dynamic environmental conditions. Such behaviour is commonly reported in field studies of solar performance, where modern modules demonstrate resilience to transient solar variations due to steady-state electrical characteristics (Asif et al., 2023). Additionally, the system's real-time computation of power enabled accurate performance tracking and validated the effectiveness of the BH1750-mirror configuration for estimating irradiation. The methodology aligns with current best practices in low-cost solar energy monitoring and paves the way for expanding this system with other environmental sensors such as temperature or humidity. Integrating this setup with predictive modelling tools, such as machine learning algorithms, would enhance forecasting capabilities of an approach increasingly supported in solar energy research (Alabi et al., 2022).

3. Results

Figure 2 shown sunlight irradiation performance for four days, showing daily and intraday variations. Solar irradiation refers to the power per unit area received from the sun and is a primary input for photovoltaic (PV) energy conversion. From the data, day 1 demonstrates the highest and most stable irradiance throughout the day, peaking above 450 W/m² between 9:00 AM and 1:00 PM, suggesting clear sky conditions. In contrast, October day 2 and day 3 display erratic fluctuations, indicating intermittent cloud cover or shading. Day 4 shows significantly lower and more consistent irradiance, remaining mostly below 150 W/m², likely due to overcast conditions or atmospheric obstructions.

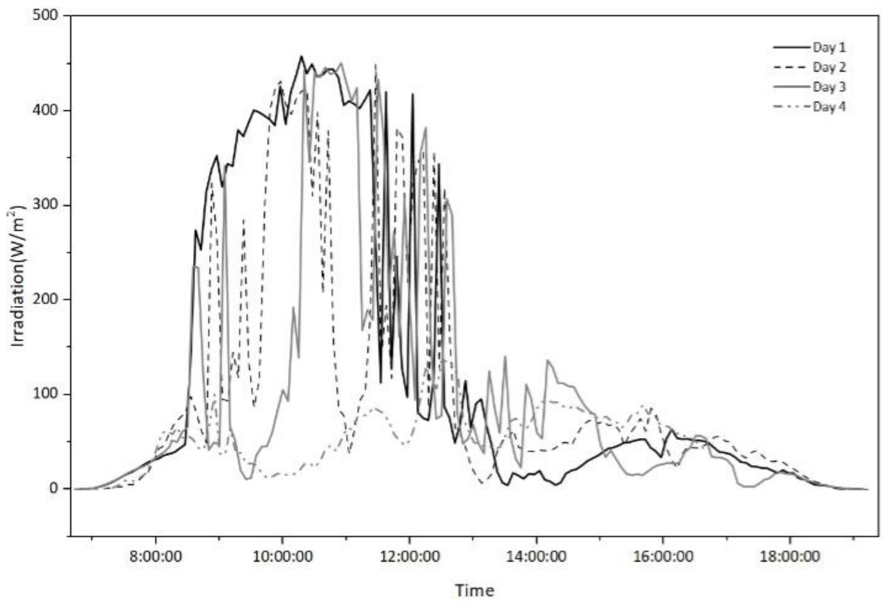

Figure 2. Sunlight irradiation performance for 4 days

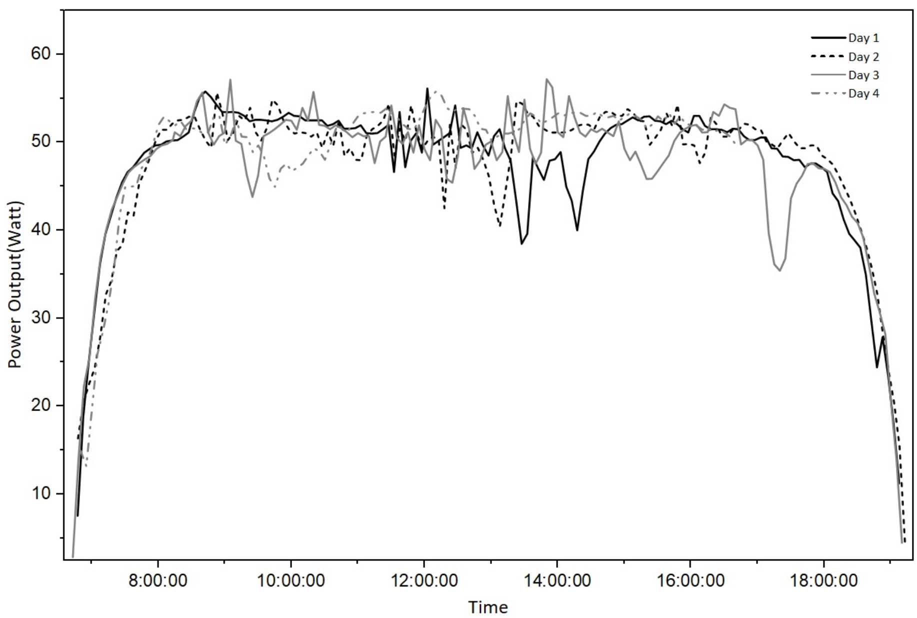

Figure 3. Solar power output of PV panel for 4 days

Figure 3 illustrates the real time power output of a photovoltaic (PV) system across four consecutive days reflects the power output of the PV system during the same period. The x-axis represents time throughout the day, while the y-axis displays power output in watts (W). Unlike the corresponding irradiation graph, the power output appears relatively stable across all four days, with values ranging mostly between 45 W and 55 W, despite fluctuations in solar irradiance.

4. Discussion

The PV panels convert sunlight into electricity based on the photovoltaic effect, which requires sufficient solar irradiance to excite electrons in semiconducting materials (Su, 2015; Watanabe et al., 2023; Zhang et al., 2021). The intensity and stability of irradiation directly affect energy production; thus, understanding irradiance patterns helps predict PV output reliability. In the graph, days like day 1 and day 3 exhibit high peaks (near 450 W/m^2), suggesting optimal conditions, while day 4 shows significantly lower values, likely due to heavy cloud cover or atmospheric interference. Rapid fluctuations on day 2 indicate intermittent clouding. This variability aligns with atmospheric phenomena, such as shifting cloud density and humidity levels, which are known to cause solar input intermittency (Nikolopoulos et al., 2024; Sulaiman et al., 2018). High-resolution forecasting and data logging are therefore essential for managing power quality and system design (Dubois et al., 2021; Schnitzer et al., 2012).

The relationship between solar irradiance and PV power output is inherently nonlinear, particularly under variable environmental conditions. Although irradiance levels are a direct input to PV generation, the efficiency of conversion can be affected by shading, temperature, and the system’s electrical configuration. Studies have shown that even brief reductions in irradiance due to cloud movement can lead to significant drops in power output, with response times depending on module type and circuitry design (Nikolopoulos et al., 2024). This highlights the need for high-resolution monitoring systems capable of capturing rapid irradiance fluctuations that may not be apparent in average daily data.

This variability highlights one of the primary challenges in PV system deployment which is solar resource inconsistency, which can significantly affect energy output and system efficiency. Real-world conditions often deviate from ideal test conditions, resulting in lower-than-expected yields (Asif et al., 2023; Bala et al., 2024). Studies have shown that even short-term reductions in irradiance due to cloud movement can result in measurable performance losses (Hasan et al., 2022; Salim et al., 2013).

The analysis reveals that despite variability in solar input (irradiance), the system maintains a consistent power output due to compensatory mechanisms inherent in PV modules and the electrical circuit design. Factors such as energy storage within the system (capacitive smoothing), the panel's operating point, and the electrical behavior of the load contribute to this stability. Additionally, real-time maximum power point tracking (MPPT) even if not explicitly implemented can mimic this behavior by keeping output within an optimal range despite changes in sunlight (Blaga & Paulescu, 2018; Hasan et al., 2022).

The recorded irradiation data across the observation period revealed significant daily variation. Day 1 registered the highest and most stable irradiance, peaking around 450 W/m^2, whereas Day 2 and Day 3 experienced intermittent declines, likely caused by transient cloud cover or shading. Remarkably, even on Day 4, when irradiance dropped below 150 W/m^2, the system maintained usable energy output between 45 W and 55 W, indicating a high level of operational efficiency. This decoupling effect where variations in solar input do not result in proportional changes in electrical output reflects a well optimized system design. Such behavior is characteristic of modern PV installations that utilize predictive algorithms and power conditioning to stabilize output (Hasan et al., 2022).

When compared to similar performance condition from Universiti Teknologi Petronas (UTP), where irradiation levels averaged around 380 W/m² and power output ranged between 47.05 W and 49.21 W, PUO demonstrates competitive, if not superior, output performance under comparable or even more variable conditions (Sulaiman et al., 2011). This supports the notion that real-time data acquisition, intelligent control systems, and site-specific calibration are crucial for sustaining PV efficiency in fluctuating environmental settings (Korada & Mishra, 2017; Wan et al., 2016). Consequently, PUO's site proves to be both suitable and resilient for solar energy generation.

5. Conclusion

Based on the result and discussion, the solar irradiation levels fluctuated significantly across the observed period, with peak values reaching approximately 450 W/m² during clear days on Day 1, and notably lower levels during overcast days on Day 4. Despite these variations, the power output of the PV panels remained relatively stable, typically ranging between 45 W and 55 W throughout the day. This indicates that the PV system demonstrated a consistent electrical response to fluctuating solar input, reflecting robust performance and system resilience under variable environmental conditions. The performance data from UTP revealed similar patterns in both solar irradiation and power output, which further supports the findings observed at PUO. This comparison reinforces the conclusion that PUO offers suitable environmental conditions for photovoltaic (PV) installation. The consistency in power output, despite variable irradiance levels, demonstrates the PV system’s capability to perform reliably under fluctuating weather conditions. The similarity between the two sites suggests that PUO can achieve energy performance on par with other recognized solar research locations, making it a viable candidate for continued solar energy development.

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Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this manuscript, the author(s) used OpenAI's ChatGPT to assist in improving the readability and language of the text. All content generated by ChatGPT was subject to thorough review, editing, and revision by the author(s) to ensure its accuracy, completeness, and alignment with the research objectives. The author(s) take full responsibility for the integrity and content of the published work. This declaration complies with ICGESD 2025 guidelines on the use of generative AI in scientific writing.

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