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Characterization of Daily Solar Radiation Intensity Based on In-Situ Data Using the BH1750 Sensor

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Abstract

This study aims to characterize the daily solar radiation intensity using in-situ data obtained from the BH1750 sensor. The measurement system was designed using the BH1750 light sensor, with data transmitted wirelessly to the ThingSpeak cloud platform for storage and analysis. Data collection was carried out over two consecutive days in an open area with a recording interval of one hour. The measurement results show that the intensity pattern on the first day reached its peak (approximately 62 kLx) at 12:00 noon. This pattern exhibits a nearly symmetric distribution, representing relatively clear and stable weather conditions around midday. In contrast, the second day's peak intensity (around 65 kLx) occurred earlier, at 11:00, and rose again at 13:00, indicating sharp intensity fluctuations. These fluctuations resulted in two distinct local peaks before the intensity declined to zero at sunset. The differences in peak timing and daily fluctuation patterns highlight the need for further analysis using machine learning approaches to accurately model the complex and non-linear relationships within solar radiation data.

Keywords: Radiation intensity; Sensor BH1750; Machine learning

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INTRODUCTION

The global energy crisis and the escalating challenges of climate change have heightened public awareness of the urgency to adopt cleaner and more sustainable renewable energy sources [1-5]. Solar energy stands out as one of the most promising renewable resources due to its abundance, zero emissions, and applicability across a wide range of geographical regions [6-10]. However, the effective utilization of solar energy requires well-designed planning and operational systems that rely heavily on the availability of accurate solar radiation data. In addition, reliable forecasting of radiation fluctuations is essential to ensure the stability and continuity of energy production [11].

The amount of solar radiation reaching the Earth's surface is strongly influenced by atmospheric variability such as cloud cover, water vapor, and aerosols which causes substantial temporal fluctuations [12-14]. These uncertainties pose challenges for integrating solar energy into power systems, particularly for both grid-connected and off-grid applications [15]. Such variability is even more pronounced in tropical regions like Indonesia, where rapid atmospheric dynamics and frequent cloud formation demand forecasting methods that are not only accurate but also responsive to local conditions.

Accurate data are fundamental to producing reliable solar radiation forecasts. Generally, these data can be obtained from three primary sources: satellite-based observations, measurements from meteorological stations, such as ground-based solar radiation data provided by the Indonesian Agency for Meteorology, Climatology, and Geophysics (BMKG) [16], and sensor-based in situ measurements [17,18]. Satellite-derived data offer broad spatial coverage and long-term temporal records; however, they often suffer from limitations in spatial resolution [19]. As a result, satellite data may be less suitable for detailed characterization of small-scale local regions [20]. Conversely, meteorological station data provide high accuracy for local-scale characterization, though their limitations include the relatively small number of stations and the high cost associated with installation and operation [21]. Consequently, measurements from meteorological stations represent only the conditions specific to their immediate surroundings.

METHODS

The methodology employed in this study involves the development of a solar radiation measurement system utilizing multiple light sensors operating in parallel, microcontroller-based data processing, and cloud-integrated data transmission for real-time monitoring and storage. The system architecture is illustrated in Figure 1.

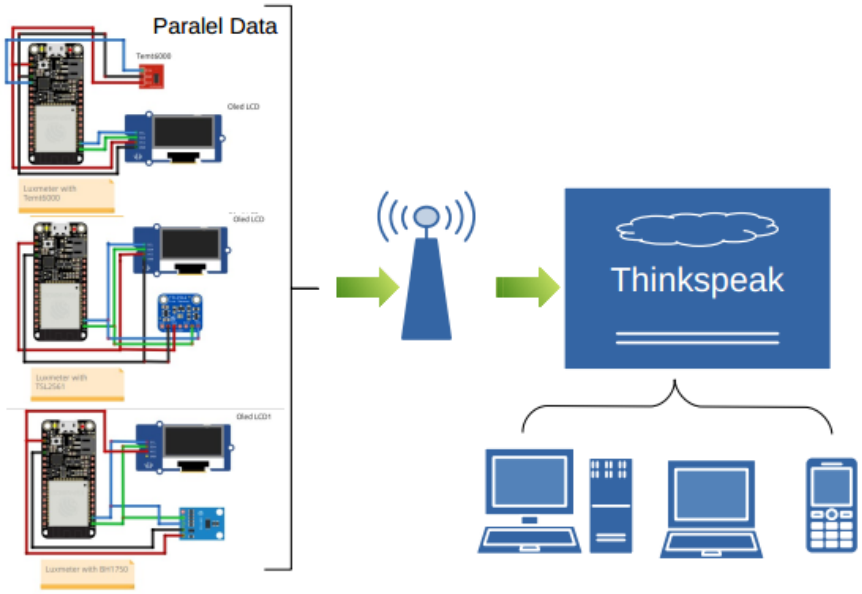
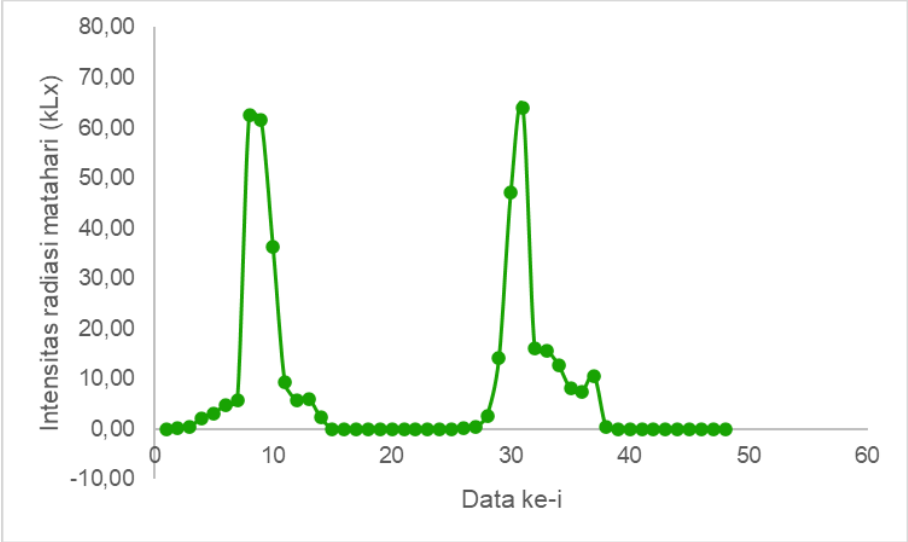


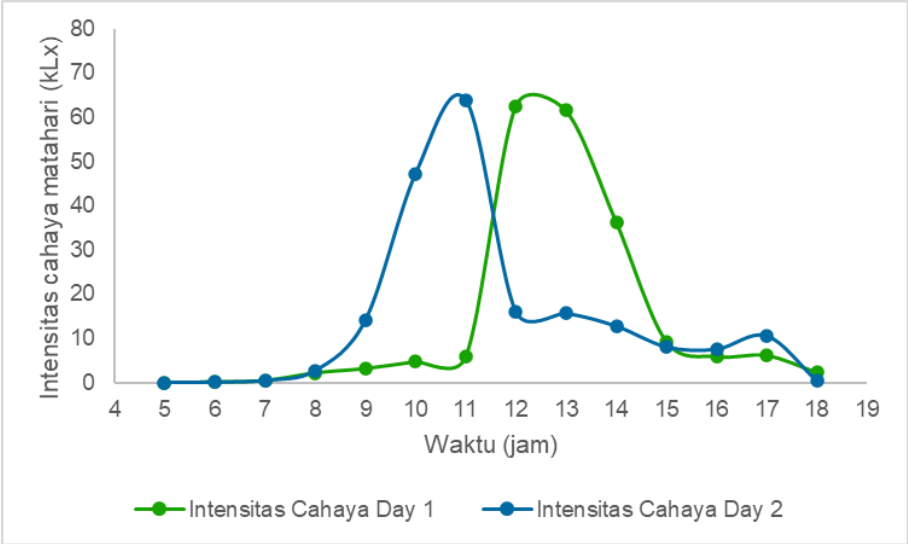
Figure 1. System block diagram for solar radiation intensity measurement

RESULTS AND DISCUSSION

Preliminary data analysis was conducted to characterize the daily patterns of solar radiation intensity obtained from the in-situ measurements.



(a)



(b)

Figure 2. Daily solar radiation intensity plots: (a) distribution of radiation intensity over the two-day period, (b) comparison of radiation fluctuations.

Figure 2 presents the daily solar radiation intensity profiles recorded over two consecutive observation days. Figure 2(a) displays the distribution of solar radiation intensity (kLx) as a function of data index (i) across the full two-day period, revealing two distinct peak-intensity intervals. Figure 2(b) further compares the temporal fluctuations in light intensity (kLx) with respect to time (hours) for Day 1 and Day 2.

Based on Figure 2(b), a clear daily variability in solar radiation intensity is observed.

Day 1 Intensity Pattern (Green Curve): The solar radiation intensity reaches its peak (approximately 62 kLx) at 12:00. The profile exhibits a near-symmetric distribution, indicating relatively clear and stable atmospheric conditions around midday.

Day 2 Intensity Pattern (Blue Curve): The peak intensity (approximately 65 kLx) occurs earlier, at around 11:00. Following this peak, a pronounced decrease is observed before the intensity rises again at approximately 13:00. This behavior suggests sharp fluctuations on Day 2, likely driven by transient cloud cover. These fluctuations generate two distinct local maxima before the intensity gradually decreases toward zero at sunset.

The contrasting daily patterns between Day 1 and Day 2 highlight the strong influence of short-term atmospheric variability on solar radiation intensity. Days with stable sky conditions produce smooth and symmetric curves, whereas days with rapidly changing atmospheric conditions yield more irregular and fluctuating patterns. Understanding these variations is essential, particularly for solar energy applications.

CONCLUSIONS

Based on the recorded solar radiation intensity data, it is evident that each day exhibits distinct peak patterns and fluctuations. The first day demonstrates a more stable profile with a peak occurring around 12:00, whereas the second day shows an earlier peak at approximately 11:00 accompanied by sharper variability. The differences in peak timing and daily fluctuation patterns underscore the need for more advanced analytical approaches—such as machine learning, which serves as the primary focus of this study—to accurately model these complex and non-linear relationships.

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AUTHOR CONTRIBUTIONS

Author 1 (Jesi Pebralia) supervised the overall research design, coordinated the project execution, and ensured the integration of instrumentation, data processing, and forecasting components. Author 2 (Yoza Fendriani) provided expertise in computational physics and supported the development of IoT-based data acquisition and processing modules. Author 3 (Muhammad Ficky Afrianto) contributed expertise in instrumentation physics and led the design and development of the IoT-based solar radiation measurement system. Author 4 (Frastica Deswardani) contributed expertise in renewable energy materials and assisted in the analysis and interpretation of solar radiation characteristics. Author 5 (Alrizal) contributed expertise in theoretical and computational physics and was responsible for developing the machine-learning forecasting algorithms.

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