WEBSITE DESIGN FOR THE IMPLEMENTATION OF IOT TECHNOLOGY UTILIZING SOLAR PANELS FOR ILLUMINATING REGIONAL SIGNBOARDS IN MERUYA SELATAN

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ABSTRACT

This research proposes and designs a regional signboard lighting system in Meruya Selatan that utilizes solar panels as the primary energy source and integrates Internet of Things (IoT) technology as an automatic control system, supported by a website platform for remote monitoring and management. The system is developed to support renewable energy initiatives and the advancement of smart urban infrastructure. Solar panels are employed to generate self-sustained and environmentally friendly electrical power, thereby reducing dependency on the national electricity grid (PLN). The IoT system is designed to monitor key parameters such as illumination levels, battery status, power consumption, and to detect system faults or failures in real-time through a microcontroller connected to various sensors. Complementing the hardware system, the website is developed using a modern framework that enables the visual representation of sensor data, including light intensity graphs, charging status, and historical energy usage. The website also offers manual control features such as lamp activation scheduling and automatic notifications to operators in case of anomalies. The user interface is designed with a focus on accessibility and responsiveness across multiple devices. Field testing conducted in the Meruya Selatan area demonstrates that the system operates in a stable, efficient, and weather-adaptive manner. By integrating renewable energy, IoT, and digital platforms, this system significantly contributes to energy efficiency, operational effectiveness, and maintenance cost reduction in the management of public lighting infrastructure.

Keywords: Signboard, Solar Panel, Internet of Things (IoT), Website.

1. INTRODUCTION

Meruya Selatan Urban Village is one of the administrative regions located in Kembangan District, West Jakarta. Strategically positioned in the western part of the capital city, Meruya Selatan exhibits a high level of urbanization and is supported by continuously developing social, economic, and educational infrastructure. Based on demographic data from 2016, the population of this area reached 34,361 residents across 10,882 households, indicating a high population density and dynamic social structure. These conditions demand the availability of efficient, modern, and technologically adaptive environmental support infrastructure. (https://barat.jakarta.go.id/kelurahan/meruya-selatan)

Along with the rapid growth of infrastructure and increasing community mobility, the need for clear area identification systems, such as regional signboards, has become increasingly important. Signboards serve not only as location markers but also as tools to enhance regional visibility and institutional identity particularly for government, education, and public service sectors. However, one major challenge in implementing lighting systems for outdoor signboards is the limited access to electricity, especially in locations distant from the main PLN (State Electricity Company) distribution grid. This issue is exacerbated by growing demands for energy efficiency and environmental awareness, which encourage a transition toward renewable energy sources. (S. Shanmugasundaram et.al,2017)

As a response to these challenges, this study proposes a design for a solar-powered regional signboard lighting system integrated with Internet of Things (IoT) technology and a web-based monitoring platform. This approach aims to develop an energy-independent, operationally efficient, and remotely manageable lighting system. Solar panels are employed as the primary renewable energy source, harnessing sunlight to generate electricity and storing it in batteries. The IoT framework enables real-time data acquisition from sensors embedded in the lighting system, such as light intensity sensors, battery voltage sensors, and microcontroller modules for dynamic lamp control.

From the software perspective, the system is complemented by a cloud-based website that serves as a remote monitoring interface. This platform is designed to visualize data related to solar panel conditions, battery status, energy usage history, and to issue fault notifications via an early warning system. This enables users—such as local government officials or educational facility managers—to monitor and manage the lighting system efficiently through digital devices such as laptops or smartphones.

As a case study, the system was implemented at PKBM Amari, a non-formal education center in Meruya Selatan actively engaged in community empowerment. PKBM Amari has a growing need to improve the visibility of its institution through sustainable signboard lighting, while also serving as a medium for educating the community on renewable energy and IoT technologies. Through this project, students and local residents are introduced to the concepts of smart energy, solar power utilization, and web-based monitoring systems. This initiative is expected to enhance technology literacy and directly contribute to community empowerment. https://pkbmamari.sch.id/

In conclusion, the system design proposed in this study not only addresses the technical demands for reliable and efficient outdoor lighting, but also fosters social impact by integrating advanced technology into education and community development. This solution holds the potential for wider replication in the development of smart infrastructure powered by renewable energy in other urban regions.

2. METHOD

This research adopts a prototyping approach to design an integrated hardware and software system. In the initial stage, a system block diagram was formulated, outlining the main components—including the solar panel, charger, battery, microcontroller, sensors, and display module—along with a system workflow flowchart and a wiring diagram detailing the interconnection scheme among devices. Based on this framework, both hardware and software components were subsequently developed in parallel.

2.1. Design of the Hardware System

The hardware design includes several key components. A 100 Wp solar panel serves as the main energy source, connected to a charge controller and a 12V VRLA battery. A 12V charge regulation module is used to manage the battery charging process, ensuring stable power delivery to the LED load. The battery stores backup energy for nighttime illumination. A voltage divider circuit and an analog-to-digital converter (ADC), such as the ADS1115, are used to accurately measure the battery voltage level. This data is essential for monitoring the charging condition and preventing over-discharge. For ambient light detection, a light intensity sensor—such as an LDR or a digital module like the BH1750—is used to measure environmental lighting conditions. These readings enable automatic LED control, such as turning the lights on when the surroundings become dark. The central processing unit of the system is the ESP32 microcontroller, which features integrated Wi-Fi connectivity. The ESP32 collects data from all sensors (voltage and light) and controls the LED module. One of its advantages is its ability to handle wireless communication without requiring additional modules. The LED control module consists of a driver, such as a MOSFET or relay, connected to the output of the ESP32 to regulate current flow to the signboard LEDs. The LEDs installed on the Meruya Selatan regional signboard function as the load, which is turned on or off based on the control logic implemented in the microcontroller

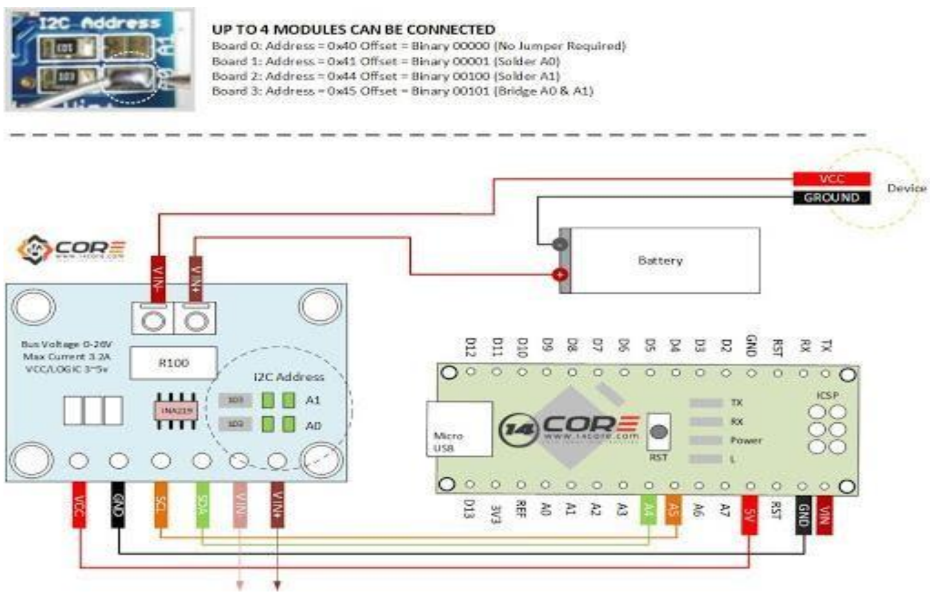

Figure 1. Illustration of ESP32 with Current Sensor (Annisa Tyas Muzazanah, 2020)

2.2. Design of the Software System

The software consists of two main components: the firmware running on the ESP32 and the web server application. The core function of the firmware, developed using Arduino IDE and C++, is to periodically read data from voltage and light sensors. The microcontroller processes the acquired data, activates the LED module as needed, and prepares data packets containing sensor values and system status for transmission to the server. Data communication with the server can be carried out using the HTTP POST protocol (REST API) or the MQTT protocol for real-time data transmission. The ESP32 sends data to the server via a Wi-Fi internet connection. For instance, the ESP32 can issue an HTTP POST request to a PHP script on the server, which then logs the sensor data into a MySQL database. This approach is commonly used in web-based IoT monitoring systems. A front-end interface is built using PHP and CSS, allowing real-time visualization of sensor data. The MySQL database stores the historical readings of the sensors and the system status. The web page displays charts or tables of battery voltage readings, light intensity levels, and LED status, enabling users to remotely monitor the system's performance.

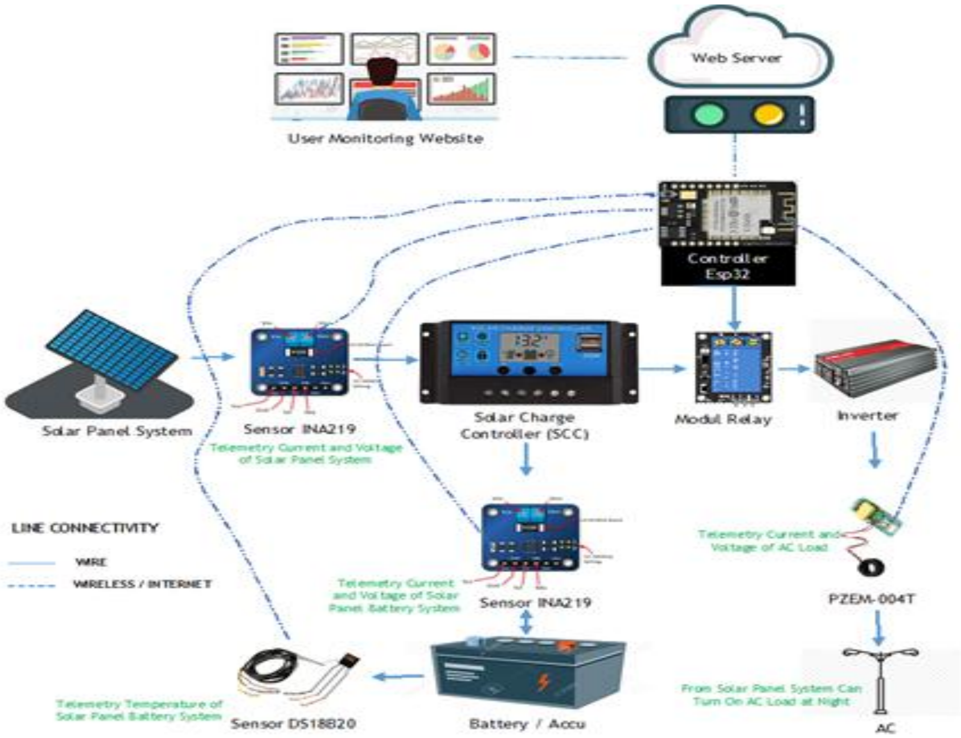

Figure 2. System Integration Illustration (Muzazanah, Annisa Tyas (2020)

2.3. System Integration and Data Flow

The system integration is explained through the following sequence of data flow. First, energy harvesting: the solar panel is installed facing the sun, delivering power to the charge controller and battery. The LED lamp for the Meruya Selatan signboard is connected to the battery's output voltage (either directly at 12V or via an inverter) and is controlled through a driver module. Second, sensor acquisition: a voltage sensor reads the battery level via an analog-to-digital converter (ADC), while a light sensor measures the ambient light intensity. The ESP32 microcontroller sequentially retrieves both values at defined time intervals (e.g., every 1 to 5 minutes). Third, LED control: based on the light intensity value, the ESP32 determines the LED operating state. The LED control logic is implemented in the firmware, which may range from simple on/off switching to dimming functionality if required. Fourth, IoT data transmission: sensor data (voltage and light) along with LED status is encapsulated in a data packet and transmitted to the server via a Wi-Fi network. Supported communication protocols include HTTP POST to a PHP endpoint (via REST API) or publishing to an MQTT broker, ensuring data delivery to the server. Fifth, server-side storage and visualization: the web server receives incoming data, executes PHP scripts to store it in a MySQL database, and updates the user interface accordingly. Stored data can later be retrieved for analysis or reporting purposes. This technique follows the standard practice of IoT monitoring systems, where sensor information is displayed and recorded on a web page in real time.

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2.4. System Implementation and Testing

The prototype was tested comprehensively to evaluate the performance of each system component. Testing began with the measurement of voltage and current output from the solar panel under standard lighting conditions using a multimeter. From this data, the actual output power of the panel was calculated and compared to its rated capacity. Subsequently, each sensor was tested and calibrated against reference measurement instruments. Voltage sensor readings were compared with those from a multimeter, while light sensor measurements were validated using a standard luxmeter. This testing ensured data accuracy, as supported by literature which emphasizes the importance of comparing sensor outputs to standard instruments (such as multimeters and ammeters) to verify reliability. The next phase involved testing the responsiveness of the web interface by observing how quickly the latest sensor data appeared after transmission. Various test scenarios were conducted, including simultaneous user connections and stability checks of data visualization. A successful outcome was defined as the appearance of real-time sensor data on the website with no significant latency. Finally, if the system includes a notification feature (e.g., low battery alerts), its reliability was evaluated. Critical conditions were simulated—such as the battery voltage dropping below a predefined threshold—and the timeliness of notifications (via email or Telegram bot) was measured. Prior studies have demonstrated that web-connected solar monitoring systems are capable of sending email alerts to operators, such as those at PKBM Amari, when specific conditions are detected.

3. RESULTS AND DISCUSSION

3.1. Website Interface Design Results

The login page serves as the entry point before accessing the main dashboard, requiring the operator to input a valid username and password. *Figure 3* shows the initial login interface. On this page, users are prompted to enter their credentials into the provided form fields. Authentication is performed by sending the input data to the server via the POST method, where the system validates the credentials against the user database. If the entered data is correct, the user is redirected to the main dashboard; otherwise, an error message is displayed as feedback.

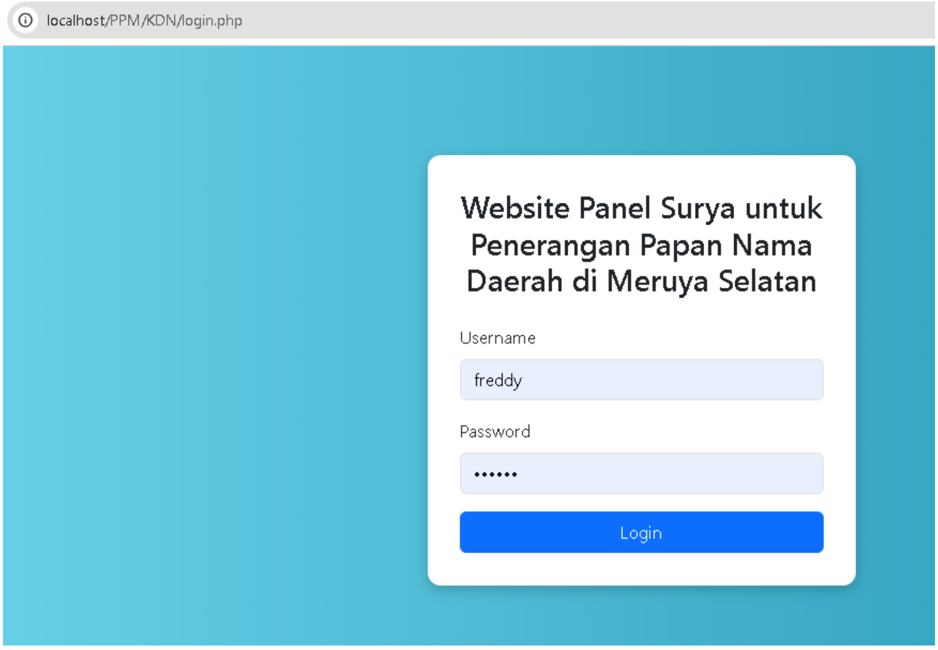

Figure 3. Login Page Display

From a security perspective, the login page is designed with consideration for data protection and user privacy. All login data transmissions are conducted over the HTTPS protocol to prevent information theft. In addition, the system implements password encryption and limits the number of login attempts to mitigate brute-force attacks. Consequently, only authorized and registered operators are granted access to critical features within the application, thereby ensuring the integrity and security of the data. Once an operator successfully logs in, the interface transitions to the IoT monitoring dashboard, as illustrated in *Figure 4*.

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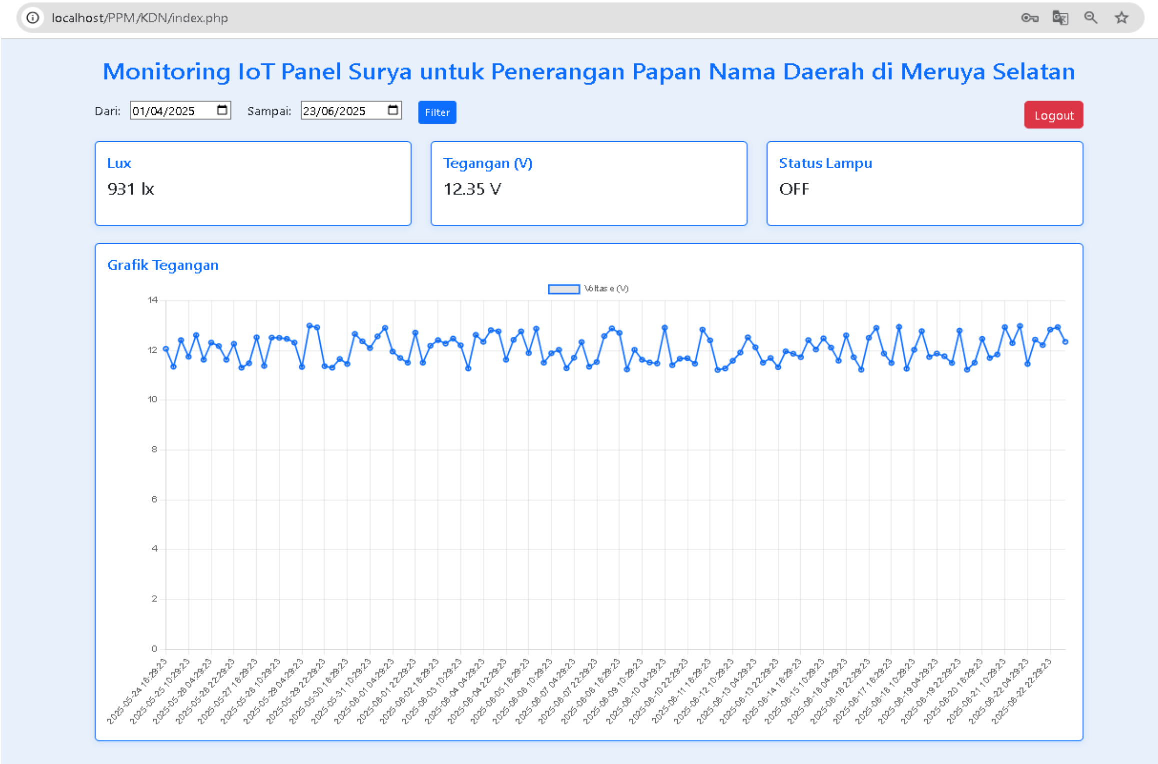

Figure 4. Website Dashboard Display

The website dashboard is designed to display three key parameters in real-time: Lux data, Voltage, and Lamp Status, which are critical in the IoT-based solar panel monitoring system for regional signboard lighting. The Lux data represents the light intensity measured by the sensor, enabling operators to assess whether the lighting generated by the solar panel meets the environmental requirements. The displayed Voltage (V) value reflects readings from the solar panel's voltage sensor, visualized both numerically and graphically to facilitate trend analysis and accurately detect fluctuations or performance degradation in the electrical system. Additionally, the Lamp Status provides direct information about the operational state of the lighting system—indicating whether the lamp is ON or OFF—which is essential to ensure proper functionality of the illumination system. Equipped with a time-range filter feature, the dashboard also enables users to conduct historical data analysis, supporting informed decisions regarding maintenance or repairs. The integration of these three parameters within the IoT-based dashboard enhances monitoring efficiency and allows for faster responses to potential issues in the field.

3.2. Physical Design Results of the Solar Pane

The solar panel system installed at PKBM Amari has been properly assembled, qualifying it as a **Solar Power Plant (PLTS)**. This designation is due to the complete integration of key components, including the inverter, battery, and charge controller. The solar panel operates by converting sunlight into direct current (DC) electricity through the photovoltaic effect. The inverter then converts the DC electricity into alternating current (AC), which can be utilized to power electrical devices at the site. The battery functions as an energy storage unit, ensuring a continuous power supply during periods of insufficient sunlight, such as at night or during cloudy weather conditions.

Figure 5. Solar Panel Design Result

In addition, the installation of the solar power system (PLTS) at PKBM Amari includes supporting components such as conductor cables and a **mounting system** that ensures the solar panels are positioned at an optimal angle to maximize sunlight capture. The use of a **charge controller** is crucial for regulating battery charging, preventing overcharging or overdischarging, which could damage the battery and shorten its lifespan. With proper assembly and the integration of these components, the solar power system at PKBM Amari is capable of operating efficiently and reliably, providing a sustainable and environmentally friendly source of electricity.

3.3. System Handover to PKBM Amari

The handover ceremony of the solar power system (PLTS) at PKBM Amari, held on Saturday, June 14, 2025, proceeded smoothly and was met with great enthusiasm. This event not only served as a symbolic moment of delivering the final product but also represented a strong collaboration between academics, university students, and the local community.Faculty members and students from the Electrical Engineering Department of Universitas Mercu Buana were present to provide a direct explanation of the PLTS system's operational mechanisms and conducted a brief training session for the PKBM Amari staff and local residents on how to operate and maintain the equipment. The presence of the Head of Meruya Selatan Urban Village and PKBM Amari officials added significance to the event, reflecting the support of both the local government and community in promoting renewable energy development within their environment.

Figure 6. Handover Ceremony between PKBM Amari and Mercu Buana University

The installed solar power system (PLTS) has proven to be effective in fulfilling the electricity needs for the illumination of the PKBM Amari signboard, significantly enhancing the visibility and safety of the area. The lighting connected to the solar panel system operated optimally, demonstrating that the integration of the solar panel, inverter, battery, and controller components was successfully implemented. This achievement serves as tangible evidence that renewable energy technologies can be practically and sustainably applied in educational and community settings, while simultaneously providing positive social and environmental benefits.

Figure 7. Workshop by Lecturers

Moving forward, the PKBM Amari management, together with local residents, have committed to maintaining and preserving the PLTS system to ensure its long-term functionality. They also plan to conduct regular monitoring and report any technical issues to the Universitas Mercu Buana team for prompt follow-up. This initiative represents a critical first step in raising awareness and building local capacity for the adoption of clean energy, with the expectation that similar technologies may be replicated in other areas of Meruya Selatan and surrounding regions.

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4. CONCLUSION

This community service initiative successfully designed and implemented a regional signboard lighting system powered by solar energy and integrated with Internet of Things (IoT) technology, along with a real-time web-based monitoring platform. The system serves as an innovative solution to the limitations of electricity access in the Meruya Selatan area. Not only is the system energy-independent and operationally efficient, but it also enhances environmental visibility and safety through data-driven monitoring support. With the reliable physical assembly of the solar power system, responsive monitoring features, and active community participation in the operation and maintenance of the system, the project demonstrates significant potential for the practical application of renewable energy technologies in supporting smart infrastructure and local community empowerment. The collaboration between academic institutions and local residents-through the handover and training activities—further amplifies the social impact of the project and opens up opportunities for replication in other urban areas facing similar challenges.

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