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A Real-Time IOT Monitoring and Safety Cutoff System for Electric Vehicle Batteries Using the BLYNK Platform

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ABSTRACT

This paper presents the design and implementation of a 58-volt $LiFePO_4$ battery voltage management system for electric vehicles, featuring remote monitoring and control via the Blynk application. The system continuously monitors battery voltage levels and enables control through a Solid-State Relay (SSR) connected to a NodeMCU ESP8266 microcontroller. Through the Blynk interface, users can view real-time voltage readings along with the corresponding battery capacity percentage. The NodeMCU ESP8266 demonstrated reliable performance throughout all test phases, maintaining a stable internet connection. The average voltage measurement deviation displayed on the Blynk application was approximately 0.74%. The SSR is configured to disconnect the vehicle's power supply when the battery voltage reaches around 46.3 volts or when the battery percentage decreases to 0.16%. This disconnection can be triggered manually through the Blynk application or automatically by the SSR. The disconnection process can be carried out through the Blynk application or automatically via the Solid State Relay (SSR). Remote disconnection via the Blynk application serves as an additional safety measure activated when suspicious conditions or activities are detected. This mechanism safeguards the battery from excessive discharge, promoting better performance and extending its service life by cutting off the load at critical limits.

Keywords : *Battery; SSR; Blynk.*

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1. INTRODUCTION

Cars continue to be one of the most widely used means of transportation because of their convenience and comfort. However, increasing worries about air pollution and the surge in fuel costs have drawn significant attention, and the depletion of fossil fuels have encouraged the pursuit of cleaner energy alternatives bringing electric vehicles (EVs) to the forefront as a sustainable solution. Research on electric vehicle development has grown significantly in Indonesia, with a number of studies concentrating on cutting-edge feature integration and creative designs. Battery capacity is still a significant obstacle in the EV industry despite these developments. Battery data is safely stored for later analysis, and state of charge (SOC) estimation is done on the cloud platform. Battery capacity is still a significant issue in the EV industry despite these developments. State of charge (SOC) estimation is done on the cloud platform, and battery data is safely saved for later examination. A smartphone application and a PC-based interface are then used to show the overall battery condition, enabling users to easily monitor battery performance across devices. [1]- [4].

IoT-Based Battery Capacity Monitoring System on Solar Panels in Electric Vehicles" showed how an Internet of Things system could be used to efficiently track the 12-volt system's DC accu capacity. The vehicle's lighting system was powered by a 50 WP photovoltaic system and a 12-volt, 7-amp battery used in the study. The system also had remote control functionality, which let users use the Blynk app to deactivate the battery by just clicking the "Off" button. [5]- [7].

Electric vehicles utilize different types of batteries, such as lithium-ion and lead-acid, each possessing unique properties that influence their performance, efficiency, and durability [8]- [10]. Key battery parameters like current, voltage, heat level, and chemical responsiveness must be continuously monitored in order to maintain optimal performance. These elements offer crucial information about the state of the battery, enabling more precise performance analysis and capacity estimation [11-14]. Effective monitoring and control not only help prevent overcharging and deep discharging but also enhance safety and reliability. Therefore, proper battery management serves an essential role in maintaining the durability, stability, and overall efficiency of electric vehicle systems [15]-[17].

The primary communication channel used by Model A is a Universal Serial Bu serial interface, which enables direct, dependable, and stable communication between system devices. On the other hand, Model B uses the ESP8266 Wi-Fi unit's Message Queuing Telemetry Transport (MQTT) communication to provide wireless internet access [18]. This configuration offers enhanced flexibility, efficiency, and scalability in data transmission across IoT-based networks. Model B enhances data synchronization and overall system responsiveness by implementing MQTT, which facilitates smooth real-time communication between numerous connected devices. As a result, Model B is better suited to contemporary IoT applications that demand the ability to interact remotely and dynamically. [19].

To enhance the progress of electric vehicle development at Polbeng, the integration of a system based on the Internet of Things platform is crucial for effective battery capacity monitoring and control. Such a system will enable users to accurately estimate the remaining driving range by analysing real-time battery conditions. As of 2023, the electric vehicle prototypes being developed lack an integrated battery monitoring and control mechanism, leading to unexpected vehicle shutdowns caused by depleted battery power. To overcome this limitation, this research introduces a project entitled *"IoT-Based Battery Capacity Monitoring System for Electric Cars,"* aimed at improving reliability, safety, and user convenience in electric vehicle operation. Electric vehicle monitoring systems use the NodeMCU microcontroller due to its integrated Wi-Fi connectivity, ease of programming, and compatibility with various sensors. Based on the ESP8266 chip, NodeMCU can wirelessly transmit data such as battery voltage, current, and temperature to IoT platforms like Blynk or Thing Speak, enabling real-time monitoring via smartphone or computer. Its low power consumption makes it appropriate for usage in electric vehicles without compromising battery performance. Furthermore, NodeMCU is low-cost, widely available, and supported by a huge developer community, making it an excellent

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choice for designing and deploying efficient and dependable electric car monitoring systems.

The proposed system is intended to provide users with notifications on the remaining percentage of a battery's capacity and expected running time, as well as continuous monitoring and control via a smartphone interface. A dedicated monitoring feature will categorize battery status based on voltage levels during both the charging and discharging procedure. Data will be collected using a direct current voltage sensor, with the NodeMCU serial number ESP32 serving as the Arduino and IoT gateway to enable internet communication [20]-[22]. Additionally, the system incorporates an automatic control mechanism that disconnects specific loads when the battery reaches a critical threshold to prevent over-discharge. For improved security, it also includes an anti-theft function that can remotely disconnect the battery from the main load, effectively disabling the vehicle in case of unauthorized use.

2. METHODS

In using the Internet of Things to monitor electric car battery capacity management, several critical components contribute to the system's overall operation. The key component is the battery, which serves as the primary power source for the vehicle's electrical system and stores energy received from the PLN (State Electricity Company). The energy storage management system uses a lithium-ion ($LiFePO_4$) battery, which is noted for its high efficiency, stability, and longevity [23]-[24]. Continuous monitoring is performed during the charging and discharging cycles to ensure maximum performance, eliminate damage from overcharging or deep drain, and maximize energy utilization throughout the electric vehicle's operation [25]-[26].

The electric car battery capacity control system is based on the NodeMCU serial number ESP8266 development board, which contains a built-in WiFi unit for remote monitoring and control via the internet. These readings are shown locally on an OLED screen and may also be viewed remotely using a smartphone and the Blynk application. This integration enables customers to easily and efficiently monitor the state of their batteries. The general design and data flow of the Internet of Things-based electric car battery capacity management system are shown in Figure 1.

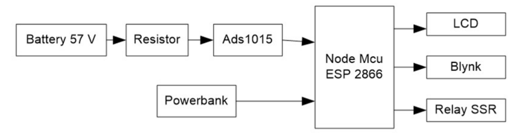

Figure 1. *System Flow Diagram*

This system's successful development requires specific equipment. The design process focuses on the planning and construction of hardware components that meet the control system's technical detail and performance goals, which are designed to track battery status in a PV configuration with the Internet of Things-enabled NodeMCU serial number ESP8266 microcontroller. The development process comprises carefully selecting compatible components such as sensors, relays, and communication modules, as well as designing an effective integration structure to assure steady and accurate functioning. This hardware setup enables continuous monitoring, data transmission, and remote battery status reporting via the internet. The battery capacity used is 48 VDC and 15 Ah. The complete hardware blueprint layout is presented in figure 2.

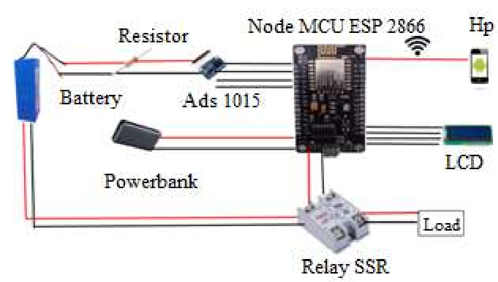

Figure 2. *Physical System Design*

The battery functions as the primary power source for the electric vehicle, supplying energy to all system components. A voltage divider resistor is implemented to lower the battery's voltage to a safe measurement-ready level by the ADS1015 analog-to-digital converter (ADC) unit. The resistor specifications used are 220 kΩ & 10 kΩ. The ADS1015 subsequently transforms the analog voltage signal to digital data, which can be processed by the NodeMCU serial number ESP8266 microcontroller. Powered by a portable battery pack, the NodeMCU serial number ESP8266 transmits control signals to

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the Solid-State Relay, Liquid Crystal Display, and Blynk application. The solid-state relay functions as an electronic switch that controls the connection between the battery and the load when necessary. Table 1 describes the specifications of the SSR. Meanwhile, the Liquid Crystal Display and Blynk app display real-time information on the battery's voltage and remaining charge percentage, allowing users to easily monitor system performance both locally and remotely.

Table 1. *Solid state relay specifications*

No	Explanation	Specifications
1	Working Voltage	Input (3-32 VDC)
2	Maximum Voltage	Output (240 VAC)
3	Maximum Current	Output (40A)
4	Voltage Isolation	2500 VAC
5	Response Time	10 ms

The 48-volt battery voltage is measured using the ADS1015 ADC module connected to the NodeMCU ESP8266. Since the battery voltage exceeds the maximum input range of the ADS1015, a voltage divider circuit is used to scale down the voltage to a measurable level. The raw digital reading from the ADS1015 is then converted into the actual battery voltage using the following equation:

$$V_{battery} = Raw_{Reading} \times \frac{V_{FSR}}{2048} \times \frac{R1+R2}{R2} \quad (1)$$

The ADS1015 gain configuration determines the full-scale range (VFSR), whereas R1 and R2 are the resistor values used in the voltage divider circuit. This formula may convert each digital reading into the actual 48-volt battery voltage. This allows the system to check the battery condition in real time and verify that the voltage is within the electric vehicle's safe operating range.

The software design focuses on creating an application that maintains and analyses electric car battery capacity using the Internet of Things-enabled NodeMCU serial number ESP8266 platform. The approach entails developing computational methods, communication protocols, and interactive dashboards to ensure effective real-time monitoring and control of the internet. The software collects, processes, and transfers data to the Blynk virtual server, where it is visualized and designed for user interaction. Furthermore, the design specifies how the system will react to various conditions, such as activating the SSR relay when the battery hits crucial voltage levels. Figure 3 depicts the overall workflow, module interactions, and user interface layout, demonstrating how the program operates and integrates inside the control and monitoring framework.

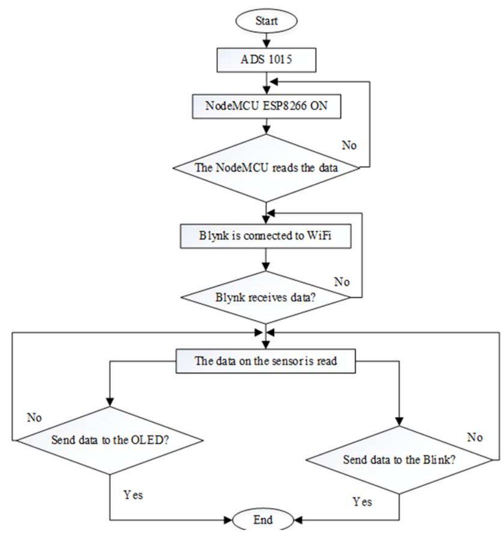

Figure 3. *Flowchart Design*

3. RESULTS AND DISCUSSION

The monitoring device is housed in a compact acrylic enclosure with dimensions of 11 × 7.5 × 4 cm, designed to accommodate all essential system components neatly and securely. The enclosure incorporates a power button to facilitate convenient operation and a terminal block with six dedicated connections to establish a connection between the battery and solar panel, providing stable and coordinated wiring connections. This configuration ensures ease of installation and enhances system reliability by minimizing loose or tangled connections. The acrylic box not only protects the internal components from external factors but also maintains a lightweight and durable structure. A detailed illustration of the device's design, internal arrangement, and key features is presented in Figure 4, highlighting the enclosure's practicality and functionality in supporting efficient battery monitoring.

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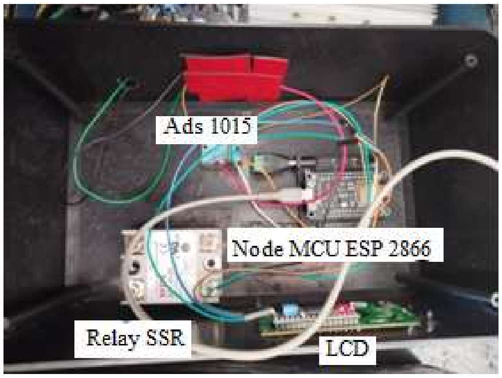

Figure 4. *Device Design Results*

This instrument is designed to monitor a 58-volt DC battery. The voltage is stepped down to 5 V DC using a resistor to transform the analog signal into digital form, allowing it to be detected by the NodeMCU serial number ESP8266. At the same time, the 5 V DC input for the ADS1015 unit, Solid State Relay unit, and Liquid Crystal Display can be taken from the NodeMCU serial number ESP8266. The Blink platform is used to display the data read by the ADS1015 module, enabling battery status monitoring via a smartphone. The wiring configuration of the INA219 sensor unit and NodeMCU serial number ESP8266 can be seen in table 1 and is described as follows:

a. Link the 5V pin on the NodeMCU serial number ESP8266 to the VCC pin on the ADS1015 to provide the necessary power supply for the ADC module. This connection ensures that the ADS1015 receives a stable voltage source, allowing it to accurately perform analog-to-digital conversions of the input voltage signals.
b. Link the GND pin on the NodeMCU serial number ESP8266 to the GND pin of the ADS1015 to establish a common ground reference between the two components. This connection is essential for ensuring stable communication and accurate voltage measurement across the circuit.
c. Link the D1 pin of the NodeMCU serial number ESP8266 wired to the ADS1015 clock pin (SCL). This connection serves as the serial clock line for the I²C communication protocol, enabling the NodeMCU to synchronize data transfer timing with the ADS1015 during analog-to-digital conversion processes.
d. Link the D2 pin on the NodeMCU serial number ESP8266 wired to the ADS1015 data pin (SDA). This connection functions as the serial data line in the IC communication protocol, allowing bidirectional data exchange between the NodeMCU and the ADS1015 for accurate transmission of analog-to-digital conversion results.

This device employs an SSR (Solid State Relay) to control the connection between the battery and the load, with switching operations managed by a program running on the NodeMCU ESP8266. The SSR relay acts as an electronic switch that responds to digital signals from the microcontroller, enabling safe and efficient control without mechanical wear. The wiring configuration of the NodeMCU ESP8266 and the solid-state relay is summarized in Table 2, and the connections are explained as follows:

a. Link the D5 pin of NodeMCU ESP8266 to the VCC pin of the Solid-State Relay. This connection delivers the control signal that triggers the relay, allowing the NodeMCU to handle the battery-to-load connection using the preset logic.
b. Connect the GND terminal of the NodeMCU (ESP8266) to the SSR relay's GND pin. This connection creates a common ground reference between the microcontroller and the relay module, providing appropriate circuit operation and consistent signal transmission for switching control.

Table 2. *Set Up Pin*

NodeMCU ESP8266	Relay
5 V	VCC
GND	GND

Observation using Blynk can be done by installing the Blynk app from the Play Store (Android) or App Store (iOS). Aside from cellular access, Blynk can also be utilized on personal computers through the official Blynk platform and a web browser. This cross-platform interoperability gives customers more freedom and simplicity when managing and monitoring system performance across many devices. Users can observe and operate system functions remotely using the Blynk interface, which also displays continuous statistics such as battery current, voltage, and residual capacity.

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Figure 5 shows the Blynk dashboard interface on a mobile device, demonstrating its user-friendly structure and real-time monitoring features.

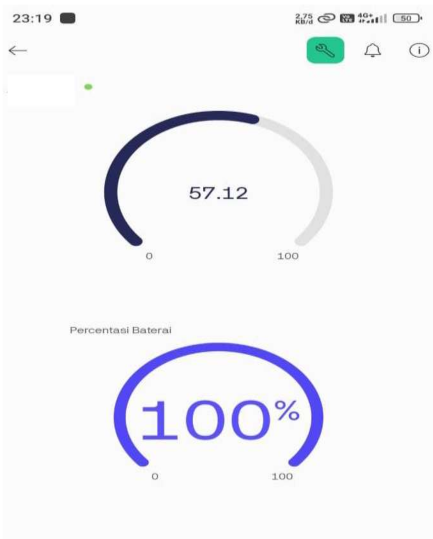

Figure 5. *Data visualization on the Blynk application*

In this study, the Blynk dashboard displays both the battery voltage and the related storage capacity percentage in real time. For example, when the voltage reaches 57.12 volts, the dashboard indicates that the battery is 100% charged. The direct relationship between voltage and capacity allows consumers to immediately determine the battery's charge condition. The interface is designed to provide users with clear, accurate, and immediate feedback on the battery's status, allowing them to make informed decisions about power usage and charging requirements. Overall, the solution improves the user experience by providing accurate, real-time data that enables effective monitoring and management of battery performance.

The goal of this testing is to determine the voltage and battery % during vehicle operation. The trials were carried out on the campus of Bengkalis State Polytechnic. The goal of evaluating these characteristics while in operation is to evaluate the battery's performance and efficiency under actual driving situations. The findings will aid in determining the dependability of the monitoring system and confirming that it provides reliable information for monitoring battery performance. This step is critical for ensuring that the system functions properly and meets the criteria for effective battery management in a real-world setting. The voltage % testing table is depicted in Figure 6.

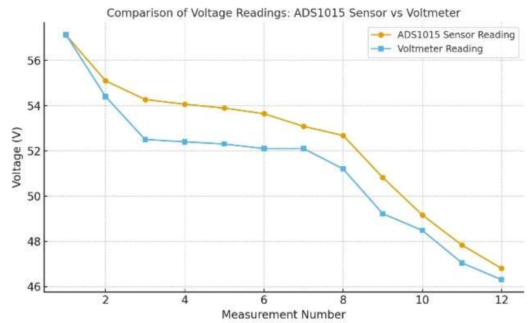

Figure 6. *ADS1015 Sensor Voltage Battery*

The measurement of the voltage percentage display on the Blynk application is presented in Figure 7, which provides a detailed summary of how battery voltage levels are monitored, recorded, and visualized in real time. Figure 7 contains multiple data points gathered during the testing phase, illustrating the correlation between measured battery voltage and the associated percentage value as shown in the Blynk interface. This data is essential for assessing the accuracy, consistency, and responsiveness of the monitoring system. By analysing the results in Figure 7, users can evaluate how effectively the Blynk application reflects actual battery conditions, ensuring reliable performance for real-time voltage observing and overall system monitoring.

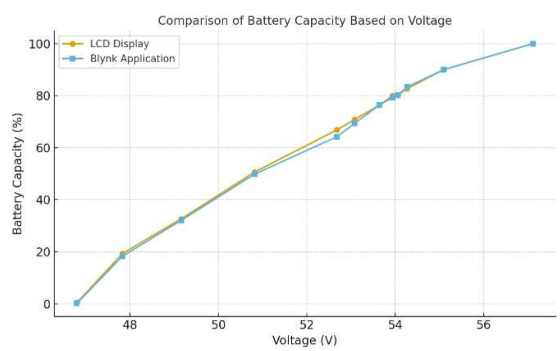

Figure 7. *Voltage Percentage Battery*

According to the statistics given in Figure 7, the battery charge level indicated by the Blynk application closely matches the measurements displayed on the liquid crystal display. The average variance between the two

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measurement outputs is only 0.74%, indicating high accuracy and consistency in data representation. This minor change demonstrates that both the Blynk and Liquid Crystal Display interfaces accurately reflect the current battery condition. Such precision is critical for effective battery management because it provides users with exact, real-time, and reliable information on the battery's state of charge status, allowing for better decision-making in system operation and maintenance.

The voltage-based method for determining the State of Charge (SOC) provides only a rough estimation of the battery's actual capacity. This limitation arises because factors such as temperature, load, and battery chemistry can cause voltage variations that do not accurately reflect the true state of the battery. Therefore, future research should focus on improving SOC accuracy by implementing the coulomb counting (current integration) method, which directly measures the amount of electrical charge entering and leaving the battery. This approach is expected to provide more accurate and representative results of the actual condition of the electric vehicle battery.

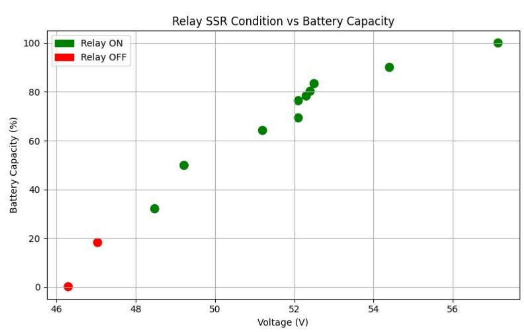

Figure 8. *Relay SSR Condition*

Upon the battery voltage reaching 46.3 volts, the solid-state relay automatically disconnects the power supply from the load to prevent further discharge. This condition corresponds to a battery capacity percentage ranging between 0% and 16%, as displayed in the Blynk application and summarized in Figure 8. Additionally, blinking indicator lights provide a visual alert to signify the battery's low-capacity status. This automated cutoff mechanism ensures that the system safeguards the battery from deep discharge, which could otherwise lead to performance degradation or permanent damage. Through this integrated control and monitoring approach, the system effectively maintains battery health, enhances operational safety, and ensures long-term reliability.

The data value of 46.3 volts represents the lower voltage limit defined as the safe threshold for the battery. At this level, the Solid State Relay (SSR) automatically disconnects the battery from the system to prevent over-discharge, which could damage the battery cells and reduce their capacity permanently. The implication is that the monitoring system functions protectively and responsively under low-voltage conditions, thereby maintaining the safety and lifespan of the battery. This also indicates that the SSR-based control mechanism operates effectively in protecting the main components of the electric vehicle.

CONCLUSION

This research successfully implemented a system capable of monitoring and controlling a 58-volt battery using the Blynk application. The Blynk platform provides real-time data visualization of each of the battery voltage magnitudes and their corresponding capacity percentages. The NodeMCU serial number ESP8266 demonstrated excellent reliability, sustaining a steady internet connection throughout the testing period. The results showed an average voltage discrepancy of only 0.74% between measured and displayed values, confirming the system's high level of accuracy. The SSR relay effectively disconnects the power supply when the battery potential reaches approximately 46.3 volts or when the charge percentage falls to 0.16%, thereby preventing over-discharge and potential damage. This precise control mechanism ensures optimal battery performance and longevity. Overall, the integration of the NodeMCU serial number ESP8266 with Blynk enables accurate, real-time monitoring and control, significantly enhancing the efficiency, safety, and reliability of electric vehicle battery management systems.

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