SEMARAK ILMU PUBLISHING

Semarak Proceedings of Applied Sciences and Engineering Technology

Journal homepage:
https://semarakilmu.my/index.php/spaset/index
ISSN: 3083-9807

Development of Battery Monitoring System for Power Generators: Insights and Experience

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ABSTRACT

The increasing dependence on battery monitoring systems (BMS) by power generators highlights the critical role of the former in ensuring continuous power operation and supply in commercial and residential facilities. This paper details the development of a BMS specifically tailored for monitoring Nickel-Cadmium (Ni-Cad) batteries at Jayalax Resources. The system provides near real-time data on essential metrics such as voltage, current, temperature, internal resistance, and state of charge (SOC) for each individual battery cell, all presented through an intuitive online dashboard. Additionally, the BMS features automated email notifications and alerts for critical conditions, including low voltage, high temperature, and significant SOC drops, ensuring timely intervention for remedial actions. The successful deployment of this system across various commercial and residential buildings in the Klang Valley has minimized the need for frequent manual inspections, reduced human error, and generated significant cost savings for Jayalax Resources. Insights gained from this project underscore the importance of robust monitoring solutions in optimizing battery performance and reliability in generator applications.

Keywords: *Battery monitoring; generator; real-time; SOC; temperature; Nickel-Cadmium*

1. Introduction

A Battery Monitoring System (BMS) is a critical technology for overseeing the performance and health of battery systems across various applications, including transportation, energy storage, emergency power supplies, consumer electronics, and industrial equipment. Its ultimate purpose is to ensure the safe and efficient operation of batteries by providing real-time data on their condition [1]. A BMS continuously tracks several key parameters, including voltage, current, temperature, internal resistance, state of charge (SoC), and state of health (SoH). This enables proactive management and maintenance of battery systems, enhancing reliability and extending battery lifespan, making the BMS an indispensable component of modern energy management [2,3].

In renewable energy systems [4,5], such as solar and wind power, BMS optimizes battery usage and prolongs lifespan by ensuring proper charging and discharging cycles. In electric vehicles (EVs),

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https://doi.org/10.37934/spaset.1.1.165172a

the BMS is crucial for enhancing safety and performance by monitoring battery conditions during operation [6]. Furthermore, BMS is essential in uninterruptible power supplies (UPS) and telecommunications, where dependable battery performance is vital for maintaining uninterrupted service [7].

The use of BMS for generator sets in commercial and residential buildings is becoming increasingly common. Generators serve as backup systems for critical facilities during power outages, making it essential that sufficient battery power is available to start them [8]. Therefore, it is vital to ensure that the battery is in optimal condition as any failure can prevent the generator from starting when it is needed most. Several factors influence the availability and performance of the battery [9-11]. Charging cycles are particularly important; frequent deep discharges can shorten the battery's lifespan and reduce its overall capacity. Temperature is another critical factor as extreme heat can accelerate wear, while extreme cold can impair the battery's power output. Current levels also impact performance; excessive current draw can lead to overheating and damage, while insufficient current may not provide enough power for startup. Additionally, the rate of battery cell degradation increases with a higher current rate (C-rate), even though the charging period is reduced. Therefore, a fast-charging strategy that balances charging speed with battery health is essential [14]. The age of the battery affects its performance, as older batteries typically lose capacity over time. Therefore, regular maintenance practices, including monitoring charge levels and conducting routine inspections, are crucial to maximize battery performance and reliability [12,13]. This paper discusses the development of a BMS specifically tailored for Jayalax Resources, designed to ensure the generator starting system is always ready for use. Towards the conclusion of this paper, the visualized battery metrics displayed on the dashboard are presented and discussed, showcasing the successful implementation of the BMS.

2. Methodology

2.1 Battery Monitoring System Development

The developed Battery Monitoring System (BMS) consists of several key components: cell sensors, a current measurement unit, a data converter, a data transfer unit, and an online dashboard, as visualized in Figure 1. For this project, the BMS is specifically designed for monitoring Nickel-Cadmium (Ni-Cad) batteries used in generators, ensuring optimal performance and health management.

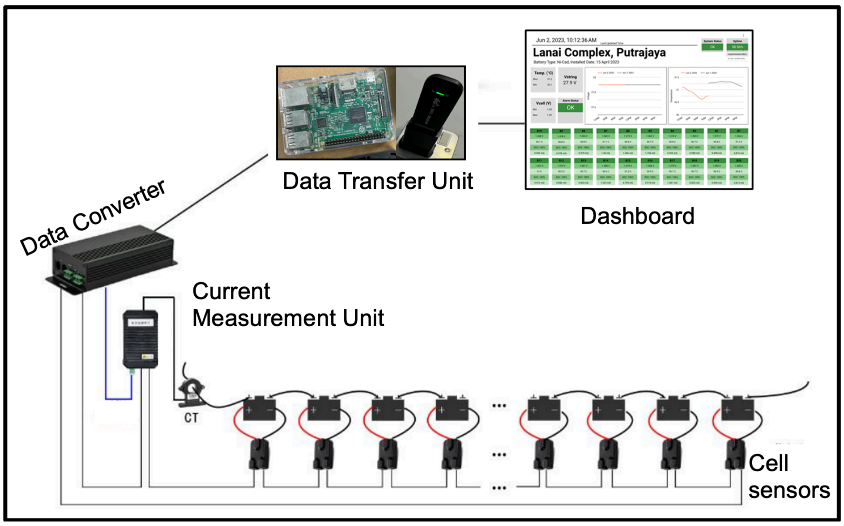


Fig. 1. Example of basic cell metrics visualized in the BMS dashboard

2.1.1 Cell sensors and current measurement unit

The cell sensors are used to measure the voltage, internal resistance, and temperature of each individual battery cell. To effectively monitor the condition of every cell, a dedicated sensor is installed on each one in the system. In the generator set system operated by Jayalax Resources, a total of 20 cell sensors will be installed, with each sensor dedicated to monitoring an individual cell. This configuration ensures comprehensive oversight and effective management of battery performance.

2.1.2 Current transformer (CT) and current measurement unit (CMU)

Both the CT and the CMU unit are applied to monitor the charging and discharging currents of the battery pack. The system incorporates one unit of each component. Additionally, the CMU can also measure the ambient temperature of the room where the battery is installed.

2.1.3 Data converter and data transfer unit (DTU)

The data converter collects information from the cell sensors and the current measurement unit, converting it into the standard Modbus-RTU protocol. In the DTU, the Raspberry Pi processor acts as the brain of the BMS, processing data from the sensors and executing control algorithms. Communication interfaces utilizing a 4G network enable the BMS to transmit data to an external monitoring dashboard. It is important to note that a SIM card is required for the DTU to function fully. The DTU is placed in a hardshell case to provide protection to the unit.

2.1.4 Dashboard

Finally, a user interface, often presented through a web or mobile application, allows operators to visualize battery performance metrics and receive notifications for critical conditions, ensuring timely intervention when necessary. Together, these components form a comprehensive system that enhances the reliability and longevity of battery operations. Details explanation on the dashboard will be covered in the next section.

2.1.5 Installation

The developed BMS is installed on the battery pack, located close to the generator set, as shown in Figure 2 (left). The battery pack typically consists of 20 Nickel-Cadmium (Ni-Cad) batteries connected in series. Individual cell sensors are installed on each battery, allowing them to monitor key parameters from each cell, as illustrated in Figure 2 (right). The sensors are numbered from 1 to 20, with the positive end of the battery pack connected to Sensor No. 1, followed by Sensor No. 2, and so on. The DTU can be seen to be housed in a protective shell, and it will be powered by electricity.

For optimal performance, the cell sensors are installed in suitable locations on the batteries. They are usually affixed directly to the side or front of each battery cell using double-sided adhesive as shown in Figure 3. When attaching the cell sensors to the side, it is recommended to use glass glue for added reinforcement to ensure a secure fit. After all the installation and commissioning work is completed, the tightness of each battery terminal must be checked.

Fig. 2. Battery packs without (left) and with (right) the installed BMS

Fig. 3. Cell sensor attached to the front side of the cell

2.2 Online Dashboard and Notification

The developed online dashboard, illustrated in Figure 4, presents a range of information, including the time and location of the battery pack is located, system status, connectivity duration, and other technical details related to the cells and battery pack. To give users a comprehensive view, the dashboard also visualizes historical voltage and temperature data for the past 12 hours in graphical format.

The technical information for each individual cell is displayed at the bottom of the dashboard. For each cell (B1 – B20), key data such as voltage (V), temperature (°C), state of charge (SoC, %), and internal resistance (mΩ) are presented. The typical nominal operating voltage for a Ni-Cad battery cell is around 1.2 V; however, in this sample, the individual cell voltages range from 1.35 V to 1.39 V. These elevated voltages are normal for fully charged batteries (SoC of 100%) and indicate that each cell is in good condition. It is important to note that during the discharge period, the voltage can drop to around 1.0 V to 1.1 V per cell. Discharging below 1.0 V can potentially damage the battery and shorten its lifespan. Different types of batteries may have varying acceptable operating voltage ranges.

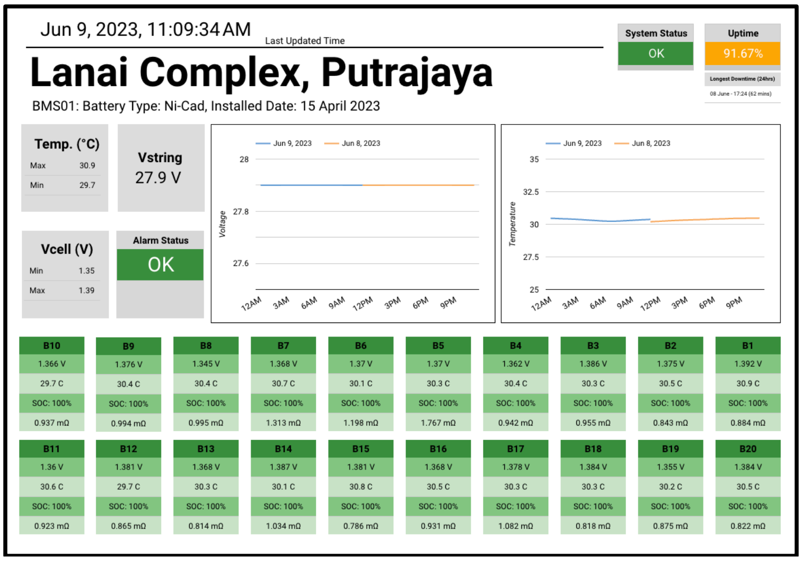


Fig. 4. Example of basic cell metrics visualized in the online BMS dashboard

The temperature of each cell in the sample was measured to range from 29.7 °C to 30.9 °C, remaining consistent over the past 12 hours, as shown in the graphical visualization. This stable temperature range is a positive indicator of normal operation, with no signs of abnormalities. For Nickel-Cadmium batteries, the acceptable operating temperature range is between 0 °C and 40 °C. Therefore, the tested batteries are considered to be in good operational condition. Maintaining a stable temperature within this acceptable range is crucial for maximizing both the performance and longevity of the batteries.

Internal resistance is a critical parameter of a battery, as it reflects the battery's resistance to current flow. In this case, the internal resistance of the battery cells ranges from 0.786 mΩ to 1.767 mΩ, which is considered ideal. For new, well-maintained batteries, values typically fall below 20 mΩ. However, for older or poorly maintained batteries, internal resistance can rise above 30 mΩ, signaling potential performance and efficiency issues. By monitoring internal resistance in real-time, Jayalax Resources can proactively address any increases, helping to mitigate negative consequences for the battery pack.

The BMS, equipped with sensors to measure critical battery parameters, periodically transmits data to the online database, including a timestamp indicating the exact time of data acquisition. A comparison algorithm is employed to identify any discrepancies between the received timestamp and the previously stored timestamp. If the timestamps are identical, it indicates that the online database is reading the same data from its cache, suggesting that there has been no new update from the remote system. This could be due to various reasons, such as network connectivity issues or system failures. By analysing the time difference between the two timestamps, the system downtime can be estimated.

In addition to monitoring the BMS status, the online database also analyses the battery data to ensure that the batteries are operating within acceptable parameters. If the battery parameters are within normal range, the Alarm Status box will display “OK” in green. However, if any abnormalities are detected, such as excessive temperature or drop in voltage, the Alarm Status box will display “Warning” in yellow, indicating a potential issue that requires attention as shown in Figure 5. In general, the dashboard capable to provide real-time updates on the system’s performance, including:

i. Uptime percentage: The percentage of time the system was online within the past 24 hours.
ii. Longest downtime: The maximum duration of continuous offline period recorded
iii. Alarm status: Indicates the battery's system operational status (OK or Warning) and triggers
iv. the email notification.
v. System status: Indicated by green status box with "OK" for an online system and a red status
vi. box with "Offline" for offline system.

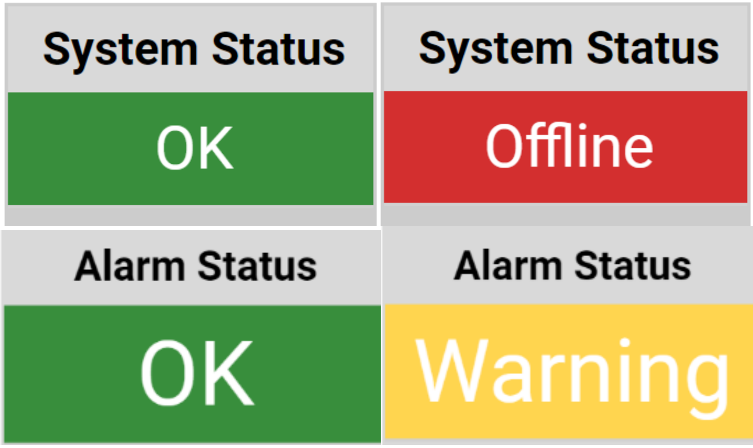
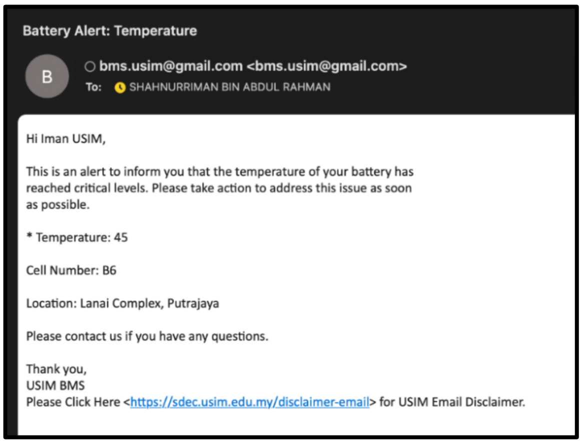


Fig. 5. System and alarm status identification in the dashboard

When the alarm status is activated due to anomalies found in battery, an email notification will be sent to the maintenance personnel or dedicated individual, as shown in Figure 6. In this project, email notifications will be triggered in the following scenarios:

i. **Voltage**: Any cell voltage drops less than 1.25 V.
ii. **Temperature**: Any cell temperature exceeds 40 °C.
iii. **State-of-Charge (SoC)**: Any cell SoC falls below 85 %.

This proactive alerting mechanism enables Jayalax Resources to receive timely notifications, facilitating swift action to address any anomalies and ensure optimal battery performance and safety.


Battery Alert: Temperature

bms.usim@gmail.com <bms.usim@gmail.com>
To: SHAHNURRIMAN BIN ABDUL RAHMAN

Hi Iman USIM,

This is an alert to inform you that the temperature of your battery has reached critical levels. Please take action to address this issue as soon as possible.

* Temperature: 45

Cell Number: B6

Location: Lanai Complex, Putrajaya

Please contact us if you have any questions.

Thank you,
USIM BMS
Please Click Here <https://sdec.usim.edu.my/disclaimer-email> for USIM Email Disclaimer.

Fig. 6. Example of notification received to battery metric limit violation

3. Conclusions

In conclusion, the development and implementation of the Battery Monitoring System (BMS) for Nickel-Cadmium (Ni-Cad) batteries for Jayalax Resources has proven to be a significant advancement in enhancing the reliability and efficiency of generator sets. The BMS not only provides real-time monitoring of critical parameters such as voltage, temperature, state of charge (SoC), and internal resistance but also ensures that users are promptly alerted to any anomalies through a proactive notification system. The integration of an online dashboard facilitates easy access to important data, allowing for informed decision-making and timely interventions by the maintenance personnel. By maintaining optimal battery performance and addressing potential issues before they escalate, the BMS plays a crucial role in ensuring the safety and longevity of battery systems. Overall, the BMS represents a valuable tool for both commercial and residential facilities, paving the way for more efficient and reliable power generators and better battery performance monitoring. As technology continues to evolve, future enhancements to the BMS may further improve its capability and functionality, contributing to the current advancement of battery management solutions.

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