IoT Assisted Battery Management System for Electric Vehicle

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Abstract— To guarantee the longevity, safety, and efficiency of the battery packs, the introduction of Electric Vehicles (EVs) has required the development of robust Battery Management Systems (BMS). To improve the administration and monitoring of lithium ferrophosphate battery packs used in electric vehicles, this research focuses on integrating IoT technology. The primary aim of this study includes the validation of BMS and battery enclosure standards and regulations, as well as the development of a BMS board with IoT capabilities for real-time data transmission and monitoring. The first step in our study is a thorough examination of the laws and regulations currently in place regarding battery enclosures and BMS, with a focus on safeguarding lithium ferrophosphate batteries. The goal is to guarantee that the battery enclosures and BMS meet all applicable safety and performance standards. The design and implementation of a BMS board utilizing specialized software is the following phase of the proposed work. Key parameters including temperature, C-rate, depth of discharge (DoD), and state of charge (SoC) are all monitored by sensors installed on the BMS board. The development of a specific application for BMS monitoring is the last part of our job. Through the usage of this application, users may view and examine the data gathered by the BMS board, gaining knowledge about the functionality and condition of the battery pack. Moreover, the application has remote monitoring and control capabilities that let users maximize the battery pack's performance.

I. INTRODUCTION

The advent of Electric Vehicles (EVs) has marked a significant transition towards sustainable transportation, offering reduced emissions and lower reliance on fossil fuels[1,2]. However, one of the critical challenges facing the widespread adoption of EVs is the efficient management of their battery systems. Effective Battery Management Systems (BMS) are essential for ensuring the safety, longevity, and optimal performance of EV batteries [3,4]. In this context, the integration of Internet of Things (IoT) technologies offers promising solutions to enhance BMS capabilities. By leveraging IoT, real-time monitoring, remote management, and predictive analytics can be applied to EV battery systems, improving overall efficiency, reliability, and user experience [5]. The techniques for battery balancing contribute to a higher battery life efficiency. The two most often used techniques are passive and active balancing [6-8]. In this paper, a comprehensive approach to developing an IoT Assisted Battery Management System for Electric Vehicles was developed. The primary objective of this paper is to design and implement a BMS solution that integrates IoT capabilities to monitor, analyze, and optimize the performance of EV batteries. The key components and activities of this proposed work include:

- Suitable Standards for Enclosure & BMS
- Enclosure Selection Criteria
- PCB Design
- Application for BMS Monitoring using IoT Platform

These are the main aspects of our paper that aim to contribute towards the advancement of EV technology, fostering greater sustainability and efficiency in the transportation sector. The proposed IoT Assisted Battery Management System has the potential to enhance the performance, reliability, and safety of electric vehicles, thereby accelerating their adoption and contributing to the transition towards a cleaner and greener future.

II. STANDARDS AND NORMS FOR BMS APPLICATION

Battery Management System (BMS), is a system that manages and monitors the performance of rechargeable batteries.

Some of the key standards include:

- ISO 26262: This is an international standard that provides guidelines for the development of safety-critical systems, including BMS for electric and hybrid vehicles.
- IEC 62619: This is an international standard for secondary lithium-ion cells and batteries for use in industrial applications, and provides requirements for the design, construction, and testing of lithium-ion batteries, including BMS. IEC 62109: This is an international standard for the safety of power converters for use in photovoltaic power systems.
- IEEE 1815: This is a standard for electric power systems communications. It provides guidelines for the communication protocols used in BMS and other power systems.
- SAE J2464: This is a standard for electric and hybrid electric vehicle propulsion battery system safety standard. It provides requirements for the design, construction, and testing of battery systems, including BMS.
- UL 1973: This is a standard for batteries for use in stationary, vehicle auxiliary power, and light electric rail (LER) applications. It provides requirements for the design, construction, and testing of batteries, including BMS.

Norms for Battery Management Systems (BMS)

Phase 1 (Effective from December 1, 2022)

- BMS must be microprocessor/microcontroller-based
- BMS must ensure over-charge, over-discharge, over-temperature, overcurrent, and short-circuit protection.
- The charger must have charge voltage cut-off, soft-start function, pre-charge function, input supply variation protection, and earth leakage detection.
- Cells must undergo a minimum of 1 cycle of charge-discharge at C/3 current rate.
- Adequate cell-to-cell spacing distance must be maintained for effective heat transfer and isolation in case of thermal runaway.
- A battery must have an additional safety fuse or circuit breaker.
- Each battery must have a traceability document.
- Adequate protection of cells in the case of regenerative braking must be considered.

Phase 2 (Effective from March 31, 2023)

These norms aim to ensure the safety, reliability, and traceability of EV batteries in India, thereby supporting the growth of the EV industry while prioritizing consumer safety.

- BMS must comply with Electromagnetic Compatibility (EMC) requirements.
- A battery must withstand thermal propagation without resulting in fire or explosion.
- The manufacturing date of battery cells must be visible.
- Cells used must be certified as per IS16893 Part 2 and Part 3.
- A battery must have a pressure-release vent.
- A battery must have active paralleling circuits for parallel connection of strings.
- BMS must log critical parameters of the battery pack for at least one month.

These are the International standards and Norms for the BMS, and based on the needs and requirements, choose the standards.

III. ENCLOSURE SELECTION CRITERIA

Enclosures are protective or housing structures designed to contain and safeguard various components, devices, or systems. They play a crucial role in ensuring the safety, reliability, and performance of sensitive electronic and electrical equipment. Enclosures come in various types, materials, and designs, each tailored to specific applications and environmental conditions. They are commonly used in industries such as automotive, aerospace, telecommunications, and manufacturing, among others.

Overview of NEMA: The National Electrical Manufacturers Association (NEMA) is a trade association in the United States that sets standards for electrical enclosures and other electrical equipment. NEMA standards define the performance and safety requirements for enclosures, ensuring they can withstand various environmental factors, such as dust, moisture, and corrosion, as well as physical damage and hazardous conditions

These are NEMA-based enclosures and their price ranges are discussed in table 1 below and also for Li-Battery enclosures are discussed. The National Electrical Manufacturers Association (NEMA) enclosure types are comprehensively outlined in the table, together with information on their materials, sizes, features, and pricing ranges in Indian Rupees (INR). It divides them into different categories: NEMA 1, NEMA 2, NEMA 3, NEMA 3R, NEMA 3S, NEMA 4, and NEMA 4X. These types offer different degrees of protection against environmental factors both indoors and outside. The enclosure type and characteristics determine the price range; options include simple indoor protection as well as designs that are dust-tight, water-tight, and resistant to corrosion for both indoor and outdoor operations.

Table 1. Price comparison of NEMA 1-4X

NEMA Enclosure Type	Material	Size	Features	Price Range (INR)
NEMA 1	Steel	Various	Basic indoor protection	₹3,500 - ₹14,000
NEMA 2	Steel	Various	Indoor protection with drip-proof design	₹4,900 - ₹18,500
NEMA 3	Steel	Various	Weather-resistant, outdoor protection	₹7,000 - ₹28,000
NEMA 3R	Steel	Various	Weather-resistant, outdoor protection with rainproof design	₹8,400 - ₹31,500
NEMA 3S	Steel	Various	Weather-resistant, outdoor protection with ice and sleet resistance	₹10,500 - ₹35,000
NEMA 4	Steel or Non-metallic	Various	Water-tight and dust-tight, indoor / outdoor protection	₹10,500 - ₹42,000
NEMA 4X	Stainless Steel	Various	Corrosion-resistant, water-tight and dust-tight, indoor/outdoor protection	₹14,000 - ₹56,000

NEMA 6P, NEMA 7, NEMA 9, NEMA 12, and NEMA 12K enclosure types are among the several NEMA (National Electrical Manufacturers Association) enclosure types shown in the table 2. Cast iron, steel, stainless steel, and cast aluminum are some of the materials used to make each variety, and each has unique properties. With pricing ranging from ₹7,000 to ₹1,75,000, these enclosures suit a variety of uses, from dust-tight and drip-tight protection to submersible and explosion-proof capabilities.

Table 2. Price comparison of NEMA 6P-14K

NEMA Enclosure Type	Material	Size	Features	Price Range (INR)
NEMA 6P	Stainless Steel	Various	Submersible, watertight and dust-tight, underwater applications with additional corrosion resistance	₹24,500 - ₹84,000
NEMA 7	Cast Aluminum	Various	Explosion-proof, for hazardous locations with flammable gases or vapors	₹35,000 - ₹1,40,000
NEMA 9	Cast Iron or Cast Aluminum	Various	Explosion-proof, for hazardous locations with combustible dust	₹42,000 - ₹1,75,000
NEMA 12	Steel	Various	Dust-tight and drip-tight, indoor protection	₹7,000 - ₹28,000
NEMA 12K	Stainless Steel	Various	Corrosion-resistant, dust-tight and drip-tight, indoor protection	₹14,000 - ₹56,000

Lithium enclosures are protective casings for lithium-ion batteries, safeguarding them from hazards like short circuits, overheating, and fires. These containers vary in material, size, and features, tailored to specific applications as shown in table 3. They ensure safe battery operation during storage, transportation, and use. The primary role of lithium enclosures is to contain and protect lithium batteries, mitigating risks associated with their volatile chemistry and ensuring safe handling and usage.

Table 3. Price comparison of Lithium Enclosures

Lithium Enclosure Type	Material	Size	Features	Price Range (INR)
Aluminum Battery Box	Aluminum	Various	Lightweight, corrosion-resistant, thermal management features	₹15,000 - ₹60,000
Plastic Battery Case	Plastic	Various	Lightweight, corrosion-resistant, insulation features	₹7,500 - ₹37,500
Stainless Steel Housing	Stainless Steel	Various	Durable, corrosion-resistant, thermal and fire protection features	₹22,500 - ₹75,000
Composite Battery Enclosure	Composite materials (e.g., carbon fiber reinforced polymers)	Various	Lightweight, high strength, thermal management features	₹37,500 - ₹1,12,500

These are various types of Enclosures are available and based on the needs and requirements, choose the enclosure for EV applications.

IV. PCB DESIGN

Eagle is a popular PCB design software developed by Autodesk. It is widely used by engineers, hobbyists, and professionals for designing and creating printed circuit boards (PCBs) for various electronic devices. Eagle offers a user-friendly interface and a comprehensive set of tools for schematic capture, PCB layout, and routing. It supports both single-layer and multi-layer PCB designs, and it provides advanced features such as auto-routing, design rule checking (DRC), and simulation. With its extensive component library and integration with popular electronics distributors, Eagle streamlines the PCB design process, making it easier and more efficient to bring electronic projects from concept to reality.
In this paper, a PCB for the circuit is designed to balance the battery by connecting the battery in series and parallel for balancing the batteries. So that the life of the battery was increased, due to the methodology that adopted in our proposed work was a combination of active and passive balancing of battery. Here we use PCB design for the BMS board which is the main part of the work it has the all connections within the PCB.

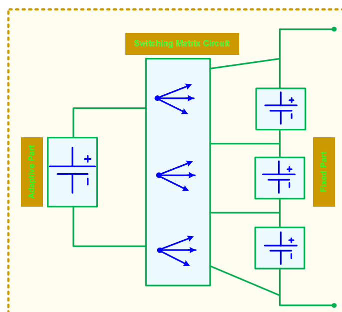

Figure 1: Battery Balancing Circuit

Figure 1 shows that this is the proposed methodology used in our work and the PCB design is implemented using eagle software. The entire setup is enclosed with a switching matrix containing the circuit for balancing the batteries and also monitors the SoC, DoD, Temperature, and C-Rate of the battery and monitors it through the IoT system.

V. APPLICATION OF BMS MONITORING USING IoT PLATFORM

The creation of a Battery Management System (BMS) with an ESP8266-based Node-MCU development board is the subject of this study. To track the battery's temperature and State of Charge (SoC), the system integrates several sensors, including voltage, current, and temperature sensors. Wi-Fi is used to transfer the data that these sensors gather to a BMS application, which then processes and evaluates it. The application offers real-time battery system monitoring and control and was created for desktop, mobile, and online platforms. This study describes the hardware configuration, sensor integration, software development, and BMS application implementation, as illustrated in Figure 2. The relevant hardware components are

1. ESP8266 Development Board: For our proposed work we use an ESP8266-based development board, such as the Node-MCU

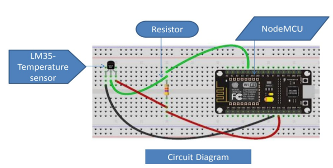

Figure 2. Sensor interfacing with ESP8266

2. Sensors: Depending on our requirements, we may need sensors for measuring SoC temperature, etc. Common sensors include voltage sensors, current sensors, and temperature sensors.

3. BMS: Battery Management System (BMS) plays a crucial role in the system. The battery pack consists of the number of batteries that are connected in series and parallel to deliver the required amount of voltage and current. The output voltage, current, and SoC of the batteries were sensed using an appropriate sensor, and the

data were transferred to the cloud for further analysis.

BMS Application: A BMS application is developed so that it can receive and process the sensor data. The Application can either be a web application, a mobile application, or a desktop application. The user can able to monitor the system anywhere. A Wi-Fi network is built in with the Node MCU. The sensed data is transferred to the cloud using Wi-Fi and it is stored in the cloud for further analysis.

Figure 3. IoT – Battery Management App

In the BMS app we can monitor the parameters from the sensor we get data like SoC, DoD, Temperature, and C-Rate, to receive the data in Node MCU ESP8266 through the controller we can upload it in the Cloud and send it to MQTT then using API integration connect it with Flutter and we are to display it in the mobile app which was specially designed for BMS application.

VI. CONCLUSION

In conclusion, the development of an IoT Assisted Battery Management System (BMS) for Electric Vehicles (EVs) represents a significant step forward in enhancing the efficiency, reliability, and safety of EV battery systems. By integrating Internet of Things (IoT) technologies with BMS, real-time monitoring, and remote management, enabling a more proactive approach towards battery performance optimization. Throughout our paper, we have outlined the key components and activities involved in the development of such a system. Starting from the identification of suitable standards and norms for BMS application to the selection of appropriate enclosures based on NEMA standards, each aspect has been meticulously considered to ensure compliance, safety, and reliability. The importance of PCB design cannot be overstated, as it forms the backbone of the BMS, facilitating efficient communication and control of battery parameters. Additionally, the application of BMS monitoring using IoT platforms opens up avenues for optimized battery performance and extended lifespan. As the world transitions towards sustainable transportation solutions, the adoption of EVs is poised to grow rapidly. However, addressing the challenges associated with EV battery management is crucial for widespread acceptance. The proposed IoT-assisted BMS offers a comprehensive solution to these challenges, promising to accelerate the adoption of EVs while contributing to a cleaner and greener future for generations to come.

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