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# Battery Management System for EV Vehicle

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**Abstract:** *The automotive industry is moving forward with green technology, which is Electric Vehicles. A battery is one of the critical components in an Electric Vehicle. With the rapid growth in the EV market, BMS and burning prevention systems are essential for ensuring the safety and reliability of EVs. The BMS functions encompass several key aspects, including cell balancing, state-of-charge(SoC) estimation, state-of-health (SoH) monitoring, temperature management, and protection against overcharging, over-discharging, and short circuits.*

*By having proper monitoring and a balanced cell, it can prolong and maintain the performance of the battery. The purpose of this work is to adopt a passive cell balancing during the charging of a Lithium Ion Polymer battery. By continuously monitoring individual cell voltages, currents, and temperatures, the BMS facilitates the balancing of capacities, thereby maximising the overall utilisation and extending the battery pack lifespan..*

**Keywords:** Electric Vehicles, state-of-charge(S0C), state-of-health (SoH), BMS

## I. INTRODUCTION

The electric vehicle( EV) as a green energy result has formerly become a popular and accepted relief for the inside combustion machine( ICE) vehicle. According to the Bloomberg NEF (BNEF) 2019 Electric Vehicle Outlook, EVs will regard for 55 percent of all new passenger buses worldwide by 2040. also, compared to the ICE vehicles, EV motors are more effective and reply snappily with high necklace. The performance of the EV is nearly related to the design of the battery pack that powers the vehicle's machine and must be suitable to give enough current for the motor over an extended time. Since one battery cell provides relatively low voltage and capacity, in an EV, numerous cells are connected periodical and in resemblant to give the needed voltage and amp hours. For case, a robust EV a bit like the Tesla Model S has 7,104 battery cells. The Li- ion battery has high power viscosity and energy viscosity. Each kind of vehicle has specific power conditions. A number of them bear a rapid-fire charging, while others make long distances between charges, but a standard point is the longest battery life- time. also, the battery is told by factors like temperature, depth of discharge and thus the operation current. This textbook contains the parameters of chemical cells that ought to be taken under consideration during the planning of the battery for a named operation. This is frequently particularly important because the batteries are not duly matched and should wear precociously and beget an redundant cost. The tactic of opting the proper cell type should take preliminarily bandied features and operating characteristics of the vehicle into account. Also there has been described an illustration of the battery parameters selection supported design hypotheticals of the vehicle and the anticipated performance characteristics. opting proper battery operating parameters is vital thanks to its impact on the profitable results of investments in electric vehicles. The state of charge of batteries during a battery operation system is just like the energy cadence during a conventional energy auto. The main function of the SoC is to speak the spontaneous battery state to the driving force and at an original time, avoid problems like overcharge and over-discharge. Also, the State of Charge( SoC) is important to indicate residual charge. Testing battery packs and modules may involve covering the individual cell voltages and/ or temperatures. Thermocouples or thermistors could also be used to cover cell temperature with an external chamber. Cell Voltage is measured through OP- AMP Differential Circuit.

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## II. LITERATURE SURVEY

Harish et al.,( 2019) IOT Based Battery Management System, Battery is the most essential element of any vehicle. So perfect conservation of any battery is veritably important essential for it to serve duly. Lead Acid batteries which are more generally usedin the vehicular batteries, need to be efficiently covered, for it to perform better under all circumstances. So, a more methodical battery operation system needs to be enforced so that the performance of the battery can be covered continuously. When it comes to battery, the two most important parameters are the State of Charging( SoC) and State of Health( SoH) of the battery. There are several coherent styles to calculate these parameters. But these styles can not give correct results, as the battery accoutrements , atmosphere girding the battery, the cargo put on to the battery, will affect these parameters. fleecing of the battery leads to emigration of feasts like Hydrogen, Oxygen etc. This Battery Management System( BMS) aims at detecting the emigration of these feasts from the battery, when it's overcharged, and monitors the other introductory parameters similar as Voltage, Current, Temperature of the battery using STM regulator and detectors. It's also equipped with GPS module, which enables shadowing of vehicles. Also these values are displayed in Cloud, which brings the conception of Internet of effects ( IoT).

Dayal Chandra et al.,( 2021) IoT Grounded Battery Management System for Electric Vehicles Using LoRaWAN A Review, This paper describes the operation of Internetof- effects ( IoT) in covering the performance of electric vehicle battery. It's clear that an electric vehicle completely depends on the source of energy from a battery. still, the quantum of energy supplied to the vehicle is dwindling gradationally that leads to the performance declination. system is able to descry demoralized battery performance and sends announcement dispatches to the stoner for farther action. Reliable battery operation is necessary for safety purposes. There are several reasons that beget battery breakdown similar as deterioration of battery and design blights. Homemade battery monitoring system are like normal battery monitoring system which means that it does n't save the data into the database. But only show the data collected in real time. thus, it's essential to ever cover battery systems using wireless technology

Bharathi S.H1et al., The application of Web of- effects(IoT) in checking the preface of electric vehicle battery. Doubtlessly an electric vehicle completely depends upon the wellspring of energy from a battery still, the proportion of energy gave to the vehicle is reducing constantly that prompts the donation debasement This is a critical concern for battery produce. In this work, noticing the show of the vehicle using IoT methodologies is proposed, so the checking ought to be conceivable easily. The proposed IoT- grounded battery checking system is contains of ESP 32 TV and voltage detector. These days, electric vehicle( EV) is getting well known since the energy costs getting more expensive. As a result of these circumstances, colorful vehicle directors looking for druthers of energy sources other than gas. The operation of electrical energy sources may ameliorate the terrain since there's lower pollution.

Mohammad Asaad et al., The Internet of effects( IoT) technology has immense implicit for operation in enhancement and development of Smart Grid. The rising number of distributed generation aging of present grid structure and appeal for the metamorphosis of networks have sparked the interest in smart grid.The need for energy storehouse system primarily the electrical energy storehouse systems is growing asthe prospects for their operation is getting more compelling. Dynamic electrical energy storehouse system , Electric Vehicles( EVs) are fairly standard due to their excellent electrical parcels and inflexibility but the possibility of damage to their batteries is there in case of overcharging or deep discharging and their mass penetration profoundly impacts the grid. To circumvent the possibility of damage, EVs' batteries need a precise state of charge estimation to increase their lifetime and to cover the outfit they power. Grounded on ease of perpetration and lower overall complexity, this paper proposes a real- time Battery Monitoring System( BMS) using coulomb counting system for SoC estimation and messaging grounded MQTT as the communication protocol. The proposed BMS is enforced on tackle platform using applicable seeing technology, central processor, interfacing bias and the knot- RED terrain.


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## III. METHODOLOGY

The methodology of the proposed Battery Management System (BMS) for electric vehicles outlines how the system is designed, implemented, and operates to ensure real-time monitoring, safety, and optimal performance of lithium-ion batteries.

### A. Block Diagram Description

The Battery Management System (BMS) is designed to ensure the safe, efficient, and reliable operation of the battery pack by continuously monitoring and controlling important parameters such as voltage, current, temperature, and state of charge. The system consists of a battery pack formed by connecting multiple cells in series and parallel combinations to achieve the required voltage and capacity. Sensors are used to measure individual cell voltage, pack current, and temperature, and these analog signals are fed into the data acquisition system, where they are converted into digital signals using an analog-to-digital converter. The digital data is then processed by a microcontroller, which acts as the central control unit and continuously analyzes the battery parameters to calculate the State of Charge (SOC) and State of Health (SOH) using predefined algorithms. Based on this analysis, the system ensures proper functioning and includes protection mechanisms such as over-voltage, under-voltage, over-current, and over-temperature protection, and whenever any parameter exceeds the safe limits, switching devices like MOSFETs or relays are activated to disconnect the battery from the load or charging source. The system also incorporates a cell balancing technique to maintain equal voltage across all cells, thereby improving battery efficiency and extending its lifespan, along with a communication interface for real-time monitoring and data transmission.

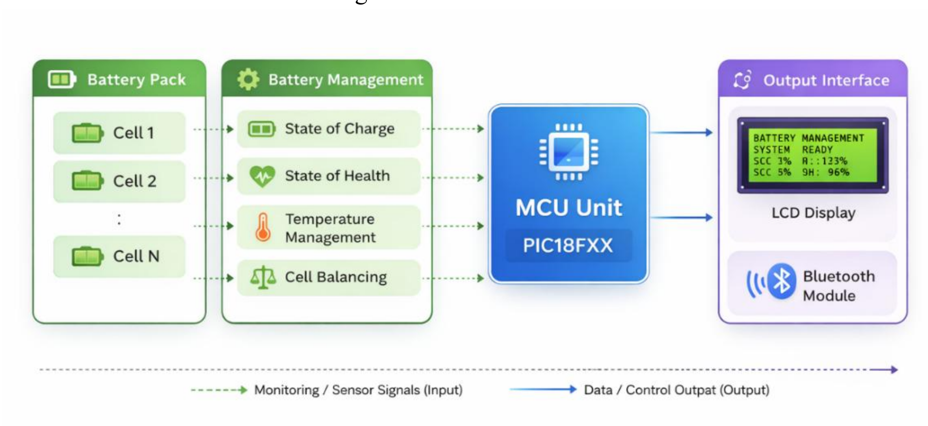


Fig. 1. Block diagram of the IoT-based Industrial Safety Monitoring System

The block diagram of the Battery Management System in Fig. 1. represents the functional arrangement of different components working together to manage the battery effectively. It begins with the battery pack, which serves as the main energy storage unit consisting of multiple interconnected cells. Sensors are connected to the battery pack to continuously measure parameters such as voltage, current, and temperature, and these analog signals are provided to the data acquisition system where they are converted into digital form using an analog-to-digital converter. The converted data is then sent to the microcontroller, which acts as the brain of the system and processes the information to determine the operating condition of the battery. Based on this processing, the microcontroller controls the protection circuit, which includes switching devices like MOSFETs or relays to protect the battery from unsafe conditions. The system also includes a cell balancing circuit to ensure uniform charge distribution among all cells, thereby improving performance and battery life. Additionally, a communication interface is used to transmit data to external monitoring systems or displays, allowing real-time observation of battery parameters, and all these blocks work together in a coordinated manner to ensure safe, reliable, and efficient operation of the battery system.

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**B. Circuit Diagram and Design Considerations**

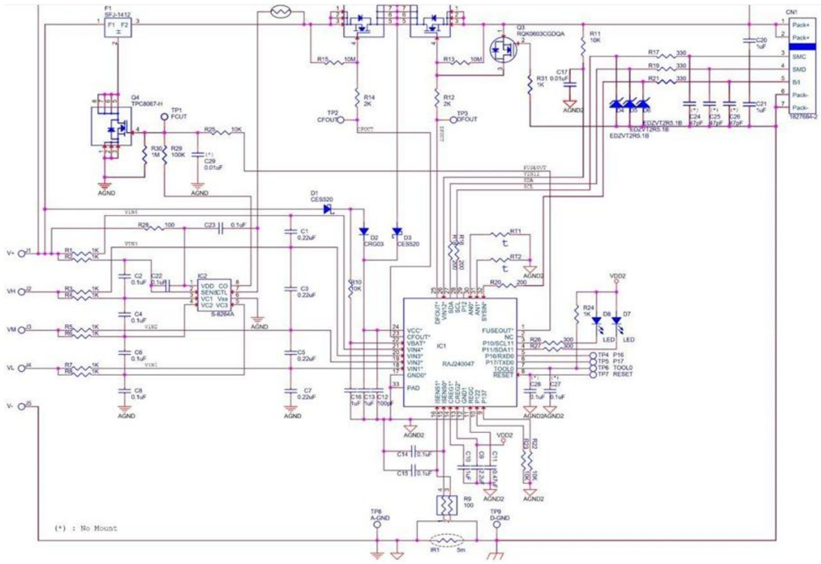

Fig. 2. Circuit Diagram and Design Considerations

The schematic in Fig 2 appears to be a multi-cell battery operation and protection circuit erected around a devoted regulator IC( probably an energy-hand/ BMS chip). It monitors individual cell voltages through sense inputs(labelled V1 – V5), uses filtering factors( resistors and capacitors) to stabilize measures, and includes balancing or protection rudiments similar as MOSFETs and zener/ TVS diodes, to control charging/ discharging and cover against overvoltage or faults. Current sensing is enforced via a low- value shunt resistor, allowing the IC to track charge and discharge currents. The design also features communication lines( SMBus/ I ² C) for data reporting, status LEDs for suggestion, test points for debugging, and a connector interface for pack outstations( Pack, Pack −) and signals, making it a complete battery pack monitoring and safety system.

**C. Cell and Requirement Specifications**

The design objectives and the individual cell specifications are defined as:

i. Required Terminal Voltage (Vreq): 12V

ii. Required Capacity (Creq): 8Ah

iii. Nominal Cell Voltage (Vcell)=3.7V

iv. Nominal Cell Capacity (Ccell)=2.7Ah

Number of Cells in Series

$$N_S = \frac{V_{req}}{V_{cell}} = \frac{12}{3.7} \approx 3.24 \approx 3$$

Number of Cells in Parallel

$$N_P = \frac{C_{req}}{C_{cell}} = \frac{8}{2.7} \approx 2.96 \approx 3$$

Battery Configuration

$$Configuration = 3s3p$$

Total Number of Cells

$$N = N_s \times N_P = 3 \times 3 = 9\, cells$$


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Pack Voltage

$$V_{pack} = N_s \times V_{cell} = 3 \times 3.7 = 11.1\text{V}$$

Pack Capacity

$$C_{pack} = N_p \times C_{cell} = 3 \times 2.7 = 8.1Ah$$

Pack Energy

$$E_{pack} = V_{pack} \times C_{pack} = 11.1 \times 8.1 \approx 89.91 \approx 90$$

Maximum Voltage (Fully Charged Condition)

$$V_{max} = N_g \times 4.2 = 3 \times 4.2 = 12.6$$

## IV. RESULTS AND DISCUSSION

The developed Battery Management System (BMS) was successfully implemented and tested. The system continuously monitors voltage, current, and temperature in real time. Sensor data is processed by the PIC18FXXX microcontroller and displayed on the 16×2 LCD. Using the HC-05 Bluetooth module, the data is also transmitted to a mobile application for remote monitoring. The system effectively detects abnormal conditions and provides warnings, ensuring safe and reliable operation.

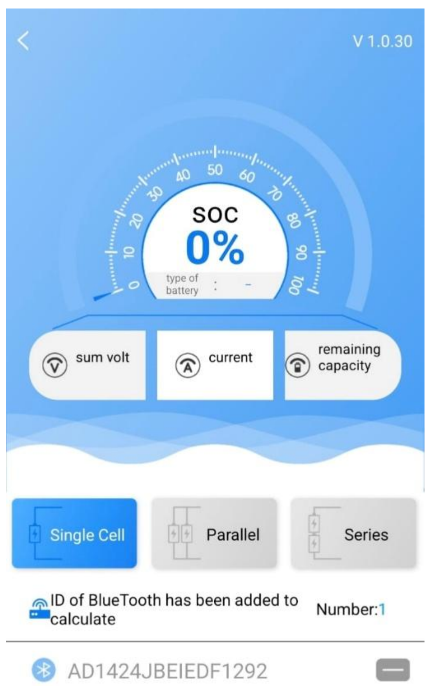


Fig. 3. Login Interface for the Battery Management System

Fig. 3 illustrates the user interface of a Battery Management System (BMS) dashboard designed to monitor and manage battery parameters in real time. The interface prominently displays the State of Charge (SOC) at the center using a circular gauge, currently indicating 0%, which represents the battery's remaining capacity. Below the SOC indicator, three key monitoring parameters are shown:

i. Sum Voltage – Displays the total voltage of the battery pack

ii. Current – Indicates the real-time current flow

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iii. Remaining Capacity – Shows the available battery capacity

The interface also provides configuration options for different battery setups such as Single Cell, Parallel Configuration and Series Configuration.

The "Single Cell" option is currently selected, indicating the system is configured for monitoring an individual battery cell. At the bottom, the interface includes Bluetooth connectivity details, showing that a device ID has been successfully added for communication. The displayed Bluetooth identifier ensures wireless data transmission between the battery system and the monitoring application. Overall, this dashboard provides a user-friendly and intuitive platform for monitoring critical battery parameters, enabling efficient battery analysis, configuration, and control in real time.


Fig. 4. Real-Time Monitoring Dashboard of the for the Battery Management System

Fig. 4. shows the real-time monitoring interface of the Battery Management System (BMS) implemented using a mobile application connected via a Bluetooth module (HC-05). This dashboard displays live sensor data transmitted from the battery system to the user interface.

The application presents multiple parameters in a sequential format, including:

i. V2 = 607.2 – Represents the voltage reading of a specific battery cell or module

ii. X, Y, Z = 0.018 – Indicates sensor data, possibly related to orientation or acceleration (from an accelerometer sensor) V4 = 014.4V – Shows another voltage measurement within the battery system

iii. V1 = 003.6V – Displays the voltage of an individual battery cell

Each data entry is timestamped (e.g., 02:05 pm), confirming that the readings are updated and logged in real time. The use of the HC-05 Bluetooth module enables wireless communication between the hardware system and the mobile device, ensuring convenient and continuous monitoring without physical connections.

Overall, this real-time dashboard allows users to track battery parameters and sensor outputs efficiently, aiding in performance analysis, fault detection, and system safety monitoring.

## V. CONCLUSION

The development of the electric vehicle is core to battery operation systems, which are directly related to safety, performance, and sustainability. The review of the state-of-the-art in BMS technologies handed in the paper demonstrated that there are still gaps in SOC/ SOH estimation and thermal operation, integration of AI and IoT, and sustainability. The literature review was grounded on a large literature review, empirical data like EVBattery, PulseBat, CALCE, and VED, and patent analysis, which illuminated invention hotspots and the trends that could be anticipated in the future.

The analysis has shown that, though the current designs of BMS have bettered significantly, they are not over to the conditions of the coming- generation electric mobility. To fill these gaps, a new frame was suggested, which would combine AI- grounded SOC/ SOH estimation, prophetic thermal operation, IoT- driven pall analytics, and a sustainability module. The frame provides lesser delicacy, safety and environmental responsibility through methodical invention principles and TRIZ- grounded resolution of contradiction. This will provide clear guidelines for developing smarter, safer, and greener BMS results. The discussion showed the implicit advantages of the frame, similar as better perfection of prognostications, active safety control, better decision-making, and facilitation of an indirect frugality practice. Nonetheless, the issues of cybersecurity pitfalls, data demands, and the necessity of artificial cooperation should be overcome to grease the perpetration. The frame proposed is not only harmonious with the focus of the International Journal of Methodical Innovation on innovative problem working but is also virtually helpful to the experimenters, masterminds, and policymakers who are presently engaged in the process of designing the future of battery operation in electric vehicles .Future BMS will use Artificial Intelligence and Machine Learning for predictive conservation and accurate SoH estimation. Real- time data analysis will help predict battery failures before they do, perfecting responsibility and safety.

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