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Design and Analysis of IoT-Based Battery Management and Monitoring System for Electric Vehicle

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***Abstract*— The growing popularity of electric vehicles (EVs) on a worldwide scale led to further research to monitor their performance. The use of internet of things (IoT) technology will make it easier to integrate the automated real-time monitoring system with the current EV technology. The great majority of EVs use rechargeable lithium-ion batteries. Use of lithium-ion batteries creates an overcharging situation in the battery, which significantly decreases battery life. It also increases the possibility of disastrous safety risks due to fire. This paper develops an IoT-based battery management system (BMS) to minimize hazardous situations. The proposed BMS notifies the user about the condition of the battery in real time.**

***Index Terms*— Internet of Things (IoT), Battery life, EV user interface**

I. Introduction

In today's world, using green energy is becoming more and more crucial. As a result, several manufacturers are searching for alternative energy sources to gasoline when it comes to both personal and public transportation. Less pollution may result from the utilization of electrical energy sources, thus enhancing the environment. In addition, EVs offer substantial benefits in terms of energy conservation and environmental protection. EVs are now the most environmentally friendly option.

EVs are being developed as a potential way to attain this ambitious objective of creating a cleaner environment and enabling better modes of transportation. Using a BMS and cell balancing in each lithium-ion battery cell can resolve this issue. When an EV's battery is depleted, it is nearly impossible to locate the closest charging station. To integrate a GPS system into our project to transmit the nearest location via a mobile device link [1]. Every battery cell is tracked and managed to avoid any overcharging or over-discharging of the batteries. Power BMSs, both hardware and software, have been developed. An appropriate BMS is essential for ensuring the safe and dependable operation of batteries in several high-power applications, such as electric cars (EVs) and hybrid electric vehicles (HEVs) [2]. A battery's cells may be unbalanced in several ways, including state of charge (SOC), self-discharge current, internal resistance, and capacity. Passive and active balancing topologies can be used to broadly classify balancing topologies [3]. Li-ion batteries are the most viable option for achieving equitable and efficient transportation for sustainable global development. Due to the varied battery charge-discharge behaviors at different temperatures and the fact that battery temperature will affect the cycle life of the battery, it is necessary to detect and control the temperature of the battery pack [4]. BMS has monitored and regulated the charging and discharging processes of the battery pack. In the charging process, the BMS sets the charging parameters and charging mode, and in the discharging process, the battery BMS controller receives the voltage and state of charge of the battery pack [5]. The battery pack of EVs often consists of hundreds of battery cells coupled in series or parallel to meet the high power and high voltage requirements of the vehicles [6]. Using wireless communication, researchers created a battery monitoring system for UPS to detect dead battery cells [7].

A BMS is essential for ensuring safety and extending the useful life of Li-ion battery packs [8]. The charging of EVs should be done in a balanced manner, taking into consideration prior experience, data-mined meteorological information, and simulation techniques. To connect electric vehicles and renewable energy sources to smart grids, this proposed smart electric vehicle charging system leverages

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vehicle-to-grid (V2G) technology [9]. Considering the most potential replacements for lowering CO2 emissions and the worldwide environmental challenges, EVs have already received widespread acceptance in the automotive industry. Lithium-ion batteries have attracted great interest for use in EVs due to their advantageous characteristics, which include their light weight, rapid charging, high energy density, low self-discharge, and extended lifespan [10]. Using IoT, a system can easily be monitored and controlled remotely [11-16]. IoT based intelligent battery management solution for electric vehicles Lithium-ion batteries have found widespread use in consumer electronics due to their superior energy density, power density, service life, and environmental friendliness in comparison to other regularly used batteries. However, lithium-ion batteries for vehicles have high capacities and large serial and parallel numbers, which, together with safety, durability, uniformity, and cost issues, restrict their widespread deployment in the vehicle industry [17–20].

The main objective of this paper is to design and monitor BMSs of EVs. It will be used to improve the vehicle's battery health. Monitoring systems will regularly monitor different health parameters, e.g., voltage, current, and temperature. The microcontroller will control systems, and a GSM module will help send data to the backend server. An LCD display is connected to the device to show the status of the sensors. A mobile application is developed to check the status remotely.

Section II describes the proposed model of BMS; Section III shows the hardware and software implementation models. The outcome and analysis are presented in Section IV. Section V concludes the paper.

II. Proposed Model

The proposed system architecture is presented in Fig. 1. It is composed of photovoltaic (PV) panel, charging system, proposed BMS system and IoT-interfaced app. The PV panel generates DC voltages in the presence of sunlight and transmits energy to the grid. The vehicle's Lithium-ion battery is charged by an EV charging station and controller as shown in Fig. 1. For the PV source, first energy must be stored in a battery. PV is not as efficient as natural fuels, so it must be stored when daylight produces electricity. So, it will be stored in the battery to be used during the demand [21]. In electric vehicles, the primary function of the BMS is to detect the battery type, voltage, temperature, capacity, state of charge, power consumption, remaining operational time, and charging cycles. Through a dedicated interface, the developed system can provide real-time information to EV users regarding the nearest charging station with the shortest waiting time and the lowest charging cost, as well as a secure online access mechanism for accessing the EV's State of Charge.

Fig. 1. Block Diagram of Proposed Battery Management System for Electric Vehicle.

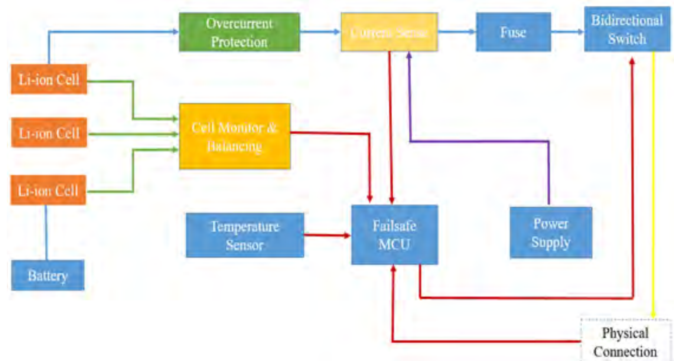


Fig. 2. Flowchart of BMS in EV

EVs are powered by high-voltage batteries. To ensure the safe operation of the battery, the BMS monitors factors such as temperature, input and output current, and voltage across the battery packs as shown in Fig. 2. Monitoring the current flowing towards the battery pack prevents overcharging. The BMS is also responsible for calculating the State of Health (SoH), which displays the battery's remaining capacity. BMS continuously monitors temperature and conducts thermal management duties. It measures characteristics such as average, intake, output, and individual cell temperatures. In BMS activates cooling system to the devices when the battery becomes overheated. BMS can connect with the vehicle's Electronic Control Units. The central controller of the BMS connects with the cell well's internal hardware or with external hardware. It transmits information about the battery parameters to the motor controller so that the vehicle can operate efficiently.

A flowchart of the battery charging unit is shown in Fig. 3. First, Initialize and set the voltage value on the Arduino. Then Configure the baud rate to enable communication between the Arduino and the computer. After establishing the Amp hour of the Li-ion battery that will be connected to the analog pin of the Arduino, the corresponding digital value (ADC Value) is recorded in the analog-to-digital converter (ADC). The remaining battery usage hours will be determined based on the updated battery status. The cost of charging will vary based on charging distance and duration.

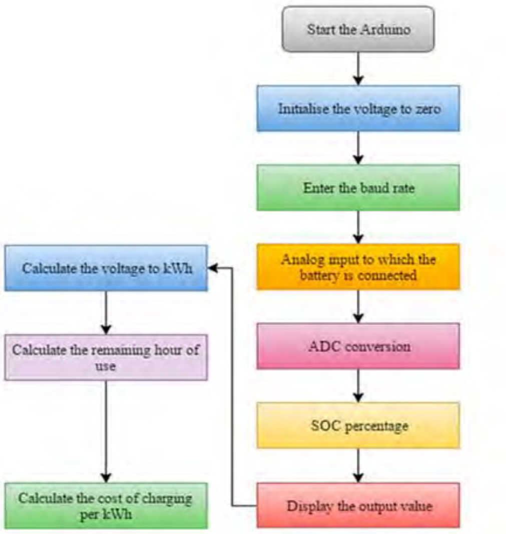


Fig. 3. Battery State of Charge estimation flowchart

III. SIMULATION AND HARDWARE PROTOTYPE ANALYSIS

A schematic simulation of the proposed model for battery management and monitoring systems for EVs is shown in Fig. 4. According to the model circuit, it is being implemented in Proteus software. The simulation model incorporates all the electronic components, including a voltage and current sensor, a temperature sensor, a gas sensor, and a relay protection, to detect the battery's health state. However, the IoT integration was implemented independently in this hardware. The solar system was manually programmed into the software, and the DC supply of the system was changed to an AC source. the Solar System followed. Voltage sensors are handcrafted, and three current sensors (ACS712 30A models) are utilized to indicate or display the voltage and current whenever a failure of any type occurs.

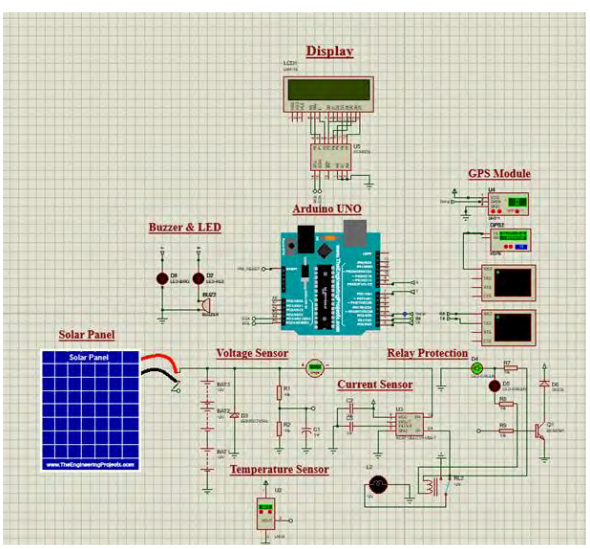


Fig. 4. Simulation Schematic for proposed design

In this study, cell balancing is used to utilise these sensors, a technique that extends the battery's life, creates an equal voltage and current level, and maximizes the battery pack's capacity. The temperature sensor fulfills the role of thermal management by continuously monitoring the temperature. It measures parameters such as the mean temperature. When a heating problem develops and the average temperature limit is exceeded, an alarm will sound to reduce the temperature. To reduce the temperature, connect the 5V colling fan to the battery and activate the relay to turn it on automatically. The fan will turn off automatically when the temperature is normal or average. Utilize the 16x2 LCD display that indicates the percentage of charge in the battery and the maximum range that can be achieved with this charge. And display the actual voltage and charging station location when charging is required. All of the Sensors collect data and transmit it to the Arduino Uno. This Arduino UNO transmits System Data to ESP3266 via the Wi-Fi module using serial connection. In this system, ESP8266 and Arduino IoT Cloud are utilized to create a Battery Status Monitoring System utilizing the Internet of Things, this project can directly notify people. The user can also remotely check the battery status of their smartphone or computer. And this Arduino Uno serves as the project's brain. With a pin that is explained in the coding section. In the simulation phase, the entire operation will run by uploading the hex file to the mega.

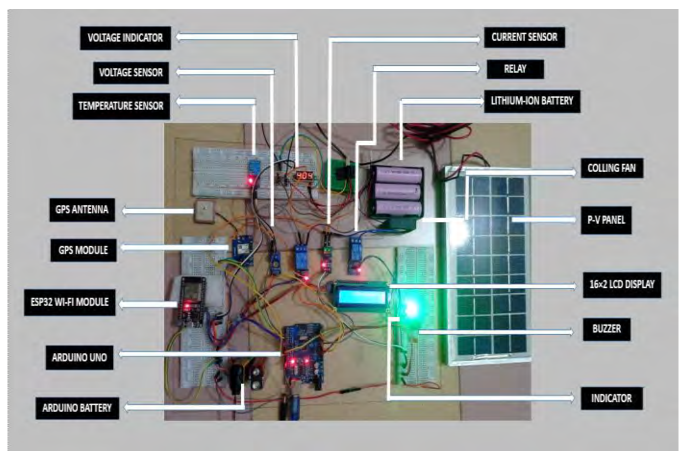


Fig. 5. Implemented Testing Hardware

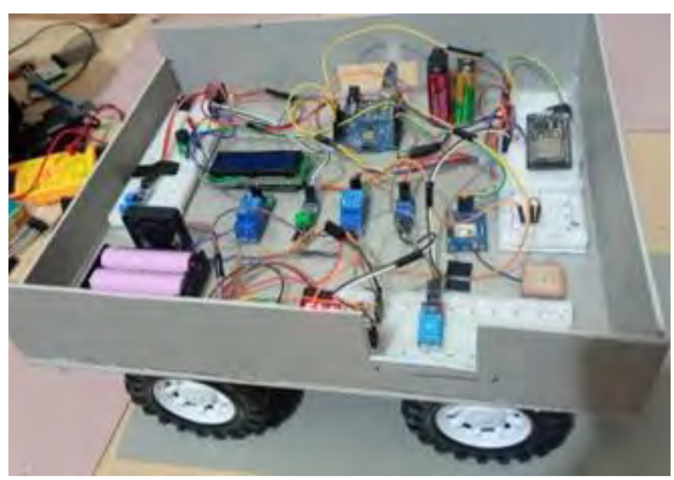


Fig. 6. Proposed hardware design (Exterior)

This equipment and instruments substantially on hardware components to function. Before final implementation, the microcontrollers and sensors were tested by constructing a test board, installing all sensors and modules based on the simulation model, and operating the system as shown in Fig. 5. A hardware model for implementation in Electric Vehicles is also shown in Fig. 6. A PV system is added as a backup system to the transmission grid.

IV. Result Analysis

Initialization of the EV is shown in Fig. 7. The process of starting the system when the EV State and other values are displayed on the display. There will be no warning on the notice site when the Arduino Uno is powered on, but it will be displayed on the LCD display.

Fig. 7. Reading from hardware at initial stage

An overview of the battery management system for electric vehicles where each data element has its own significance, such as battery information, PV information, and the exporting of solar energy to the grid as shown in Fig. 8. After the system has been installed and connected to the battery and solar panel, the battery's charge percentage will be displayed on the LCD display for the entire system. The actual voltage supply of the vehicle can be determined by connecting the voltage sensor to the battery. The voltage sensor synchronizes the voltage in each battery cell and measures the transmission voltage. The actual current of the battery can be measured. The current sensor measures the current flow and balances the current in each battery cell. when the temperature sensor was connected to the battery. This temperature sensor monitors the temperature continuously and performs the function of thermal management. This system will inform the user and display the nearby location on the LCD display.

TABLE I
BATTERY VOLTAGE MESUREMENT

SN	Voltage Sensor	Multimeter	Accuracy
1	3.79	3.70	94%
2	3.68	3.67	99%
3	3.68	3.62	93%

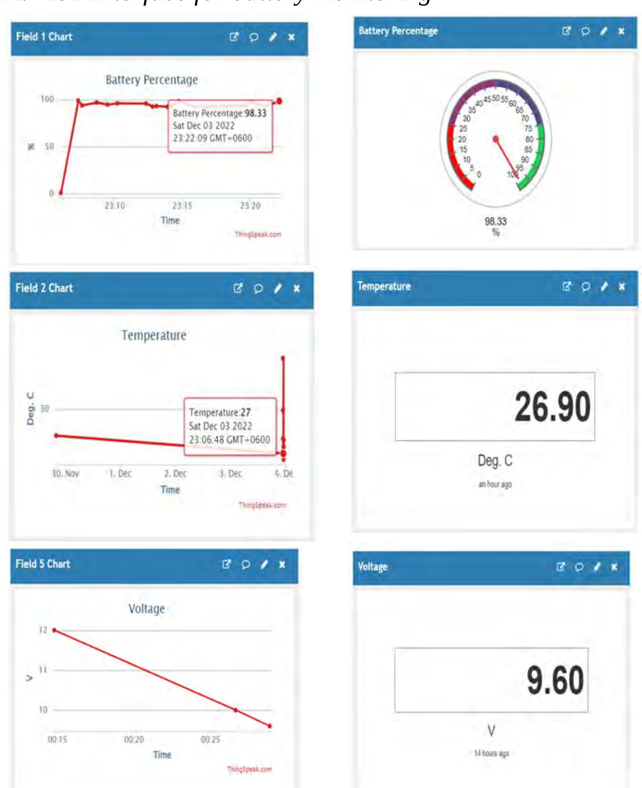
TABLE II
BATTERY CURRENT MESUREMENT

SN	Current Sensor	Multimeter	Accuracy
1	0.48	0.37	88%
2	0.42	0.34	91%
3	0.10	0.9	99%

The power consumption is lowest when the PV panels are the primary source of energy and it increases dramatically when the inverted ac supply is utilized. The measured voltage and accuracy of the system during the testing period is shown in Table I. Battery life requires special consideration in EV applications. Incorrect operations, such as current flow, excessively high or low temperatures, overcharging, or discharging, will dramatically accelerate the battery's degeneration. Table II represents the lithium-ion battery load current passing through the proposed circuit.

Fig.8. Data of battery charge, voltage, current temperature in LCD Display

A. IoT Interface for battery monitoring



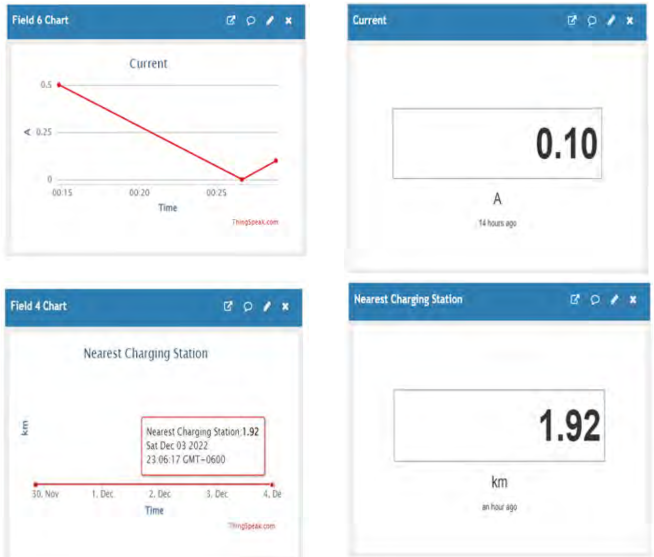


Fig. 9. Battery monitoring interface in Mobile Applications

The proposed system can monitor the battery condition stated in the proposed model using an Android smartphone shown in Fig. 9. User can monitor the charge, voltage, current, nearest charging station in a graphical user interface both in graph and numerical view.

B. Electric Vehicle User Interface

Additionally, the battery monitoring system includes a web-based user interface. The user interface can monitor the locations and conditions of multiple battery monitoring devices. connecting to batteries Therefore, the design of the user interface has considered the requirement to monitor the conditions of multiple batteries. The login page of the mobile applications allows users to access the applications by entering their username and password shown in Fig. 10. It can also be accessible by authenticating with a social login. In addition, the apps allow us to enter both authorized users and a login function that may be used to create content exclusivity.

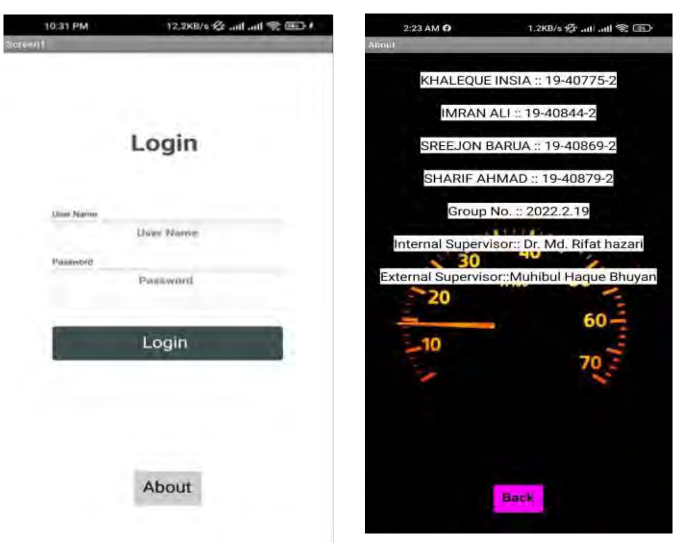


Fig. 10. Login interface and home page of the apps

Fig. 11 shows that when a charge is required and the battery charge is low, the smart electric vehicle will provide the approximate location of any charging stations. This system can be used to make payments in many ways for battery charging costs, including through the mobile banking system using their user ID on the gateway, and they also have the option to use debit or credit cards shown in Fig. 12. In the past few years, there has been a significant difference between conventional electric vehicles and newer models. The electric vehicle system has just been improved from conventional to modern. Digital systems allow users to see the results via smartphone applications.

Fig. 11. Low charge alert in mobile app

In this system, Android application shows the percentage of charge and battery status of electric vehicles, as well as a few alarms and a graph of consumed units. Since this intelligent electric car is directional, the meter can monitor both PV and grid voltage and consumed and exported units. Therefore, IoT features were applied to improve this project.

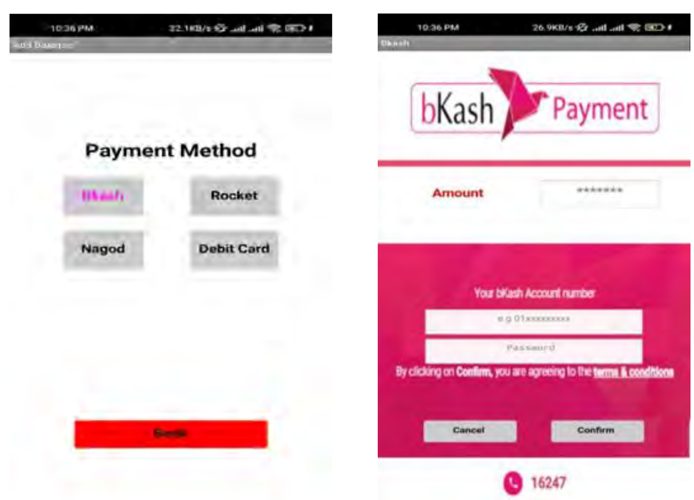


Fig. 12. Charging cost payment system via mobile app

C. Battery Charging and Discharging loss and Efficiency Analysis

The key function of a Lithium-ion battery is to provide power when other generating sources are unavailable; hence, batteries in systems will experience continual charging and discharging cycles. All battery parameters are affected by battery charging and recharging cycle. The well-known equation below is utilized to calculate the power.

$$Power\ (W) = Voltage\ (V) \times Current\ (A) \quad (1)$$

In this paper, Three lithium-ion batteries with 3.7V, 2000mAh or 2 Ah packs are in series connection and get 12V and operating current 6 Ah for this system. charging current should be 10% of the Ah rating of battery. So, 12V, 6Ah battery = 10% of 6Ah = 6 Ah x (10 ÷ 100) = 0.6 A. Considering 0.12A for charging loss. So total charging current= 0.72A Battery charging time (hour) = Battery capacity /Charging Current.

Battery discharging current = 10% of 6 Ah = 6 Ah x (10 ÷ 100) = 0.6 Ah. So total discharging current = 0.6 A. So, the battery charging and discharging losses are 0.12 or 20%.

The SOC of lithium-ion batteries is between 0 and 1. Under ideal conditions, when the charge runs out, the SOC = 0; for a fully charged new battery, the SOC = 1. If the initial charge in the battery is known, from then on "Coulomb Counting" can be used to calculate its SOC. For 6A current into a battery, for 2 hours, will add 2 * 2 = 4 Ah to the battery charge. The total battery capacity is 6 Ah, that will increase its SOC by 4/6 = 0.67.

Lithium-ion batteries are deep cycle batteries, so they have depth of discharge (DoD) around 95%. It indicates the percentage of the battery that has been discharged relative to the overall capacity of the battery. The charging efficiency is the ratio between the energy consumed by the charging process and the energy saved by the battery. A brand new fully charged battery has a DOD of 100%; an aging battery, even if fully charged, cannot reach 100% under different charge and discharge conditions.

The whole process takes some time and during this time there is an electric current through the connecting wires and the battery. Lithium batteries charge at nearly 100% efficiency, compared to the 85% efficiency of most lead acid batteries. This can be especially important when charging via solar, when you are trying to squeeze as much efficiency out of every amp as possible before the sun goes down or gets covered up by clouds.

V. Conclusion

The proposed method can reduce user discomfort and increase user awareness of inefficient energy usage and environmental degradation. Reduced pollution may result from the utilization of electrical energy sources, thus improving the environment. In addition, EVs offer substantial energy conservation and environmental protection benefits. The battery management system in an electric vehicle, which manages the electronics of a rechargeable battery, whether a cell or a battery pack, is thus a critical element in assuring the safety of electric vehicles. It protects the user as well as the battery by ensuring that the cell runs within its safe operating boundaries. Even though the system is operating as intended, it can be enhanced in the future by implementing an improved version of network communication to receive the data more precisely. A real-time data collection method can help in modeling a battery model as close to reality as possible for analysis, development, and performance enhancement.

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