



(RESEARCH ARTICLE)



## EV BMS with charge monitoring and fire protection

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### Abstract

With the rapid rise in electric vehicles (EVs), intelligent Systems are being developed that will facilitate battery reliability, improve performance and optimize safety while operational.

This paper includes an advanced Battery Management System (BMS) that monitors battery charge in real-time and takes proactive measures in preventing fire. The BMS will be used for real-time monitoring of critical parameters of the battery, such as voltage, current drain, temperature, and state of charge (SOC). These will enable accurate control and extension of the life of battery packs. Each BMS will be connected to a monitoring unit that will process sensors for abnormal thermal and electrical states, which may cause hazardous situations.

To minimize safety risks associated with EV battery packs, the BMS will include a module for early detection and prevention of fire by monitoring thermal runaway and taking pre-emptive actions, i.e., isolating circuits and alerting. Intelligent algorithms will be included for effective energy management and efficient performance for various battery states of charge. These will be integrated into an enhanced safety system for overall safety and optimal charge/discharge cycles.

This model is intended to provide a robust, scalable and cost-effective solution to the next generation of electric mobility while promoting greater user safety and creating sustainable transport systems.

**Keywords:** Electric Vehicles (EVS); Battery Management System (BMS); State of Charge (SOC); Thermal Runaway; Internal Combustion Engine (ICE)

### 1. Introduction

Electric vehicles (EVs) are a modern class of automobiles that utilize one or more electric motors for propulsion, replacing the conventional internal combustion engine (ICE) that relies on fuel combustion.

In the case of EVs, the electrical energy is stored in the battery pack and is then supplied to the motor for the rotation of the wheels. In comparison to conventional vehicles, EVs have various advantages. These advantages include reduced emissions, reduced noise levels, energy efficiency, and reduced dependence on fossil fuels. In addition to the above advantages, the cost of operation is also reduced since the cost of electrical energy is less compared to the cost of gasoline.

As the world is moving toward sustainable and environmentally friendly technologies, the usage of EVs is increasing at a rapid pace due to government incentives and the advancements being made in automobile technology.

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However, despite these advantages, there are some challenges associated with EVs, especially in the context of battery safety and re-liability. These problems include internal short circuits, overheating, and thermal runaway, which can cause hazardous conditions such as fires. In overcoming these challenges, a Battery Management System (BMS) plays a vital role in the safe and efficient operation of the battery. [1,3]

The BMS is an electronic control device that constantly monitors parameters such as voltage, current, and temperature, and it is also responsible for estimating the SoC and health of the battery. The BMS regulates the charging and discharging of the battery to prevent overcharge, over-discharge, and overheat.

The general components found in a BMS include sensors, control circuits, and intelligent algorithms working together for the optimization of battery performance. Among the important functions performed by BMS is the ability to regulate the battery temperature within a predetermined safe temperature range through the regulation of charging rates or the disconnection of the battery when necessary. Additionally, BMS regulates the charging of individual cells, which is important for lithium-ion battery types used for EVs.[4]

In this project, an advanced monitoring and protection system is designed to increase the safety of the battery. In the system, the battery's voltage, current, humidity and temperature are monitored. In addition, the system is equipped with a fire detection system. When the temperature is higher than the predetermined limit, the system disconnects the battery using a relay.

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## **2. Literature Review**

### **2.1. Advancement of Electric Vehicles**

In recent years, electric vehicles (EVs) have received much attention as a green technology option instead of traditional internal combustion engine vehicles. This is mainly because of increasing environmental issues, stringent emission regulations, and fossil fuel depletion. In earlier models of EVs, energy storage and driving range were major drawbacks, but recent developments in EV technology have improved their performance and reliability considerably

### **2.2. Battery Technologies in Electric Vehicles**

The performance of an EV is largely dependent on its energy storage system. Considering various battery technologies, lithium-ion (Li-ion) batteries have become the most preferred choice for EVs owing to their high energy density, long cycle life, and relatively low weight. Research studies have shown that Li-ion batteries have better performance compared to conventional batteries such as lead-acid and nickel-metal hydride batteries. However, due to their response to voltage, current, and temperature, sophisticated control mechanisms have to be implemented.

### **2.3. Significance of Battery Management System (BMS)**

BMS is an essential system in electric vehicles that ensures the safe and efficient use of the battery pack. BMS constantly monitors the main factors affecting the battery, such as voltage, current, and temperature, while at the same time regulating the charging and discharging cycles of the battery. According to the literature, an efficient BMS not only increases the performance of the battery but also protects the battery from potential risks such as overcharging, over-discharging, and short circuits, thus increasing the lifespan of the battery system. [5-8]

### **2.4. State of Charge (SoC) Estimation Techniques**

The precise estimation of the State of Charge (SoC) is necessary for the effective utilization of the battery and prediction of the range. In the literature, various methods for SoC estimation have been proposed. These methods include Coulomb counting methods, OCV-based methods, and model-based methods for SoC estimation. Although simple methods provide the benefits of ease of implementation, they accumulate errors over time. In contrast, model-based methods provide high accuracy at the cost of increased complexity.

### **2.5. Thermal Management and Safety Considerations**

Thermal management is another significant factor considered for EV battery systems. Excessive heat generation is a major problem, and thermal runaway is one of the possible issues, which is considered a safety threat, as it may lead to fire and explosion. The importance of including temperature monitoring and control mechanisms within the BMS is highlighted by research. Advanced battery management systems include temperature sensors and shutdown mechanisms to ensure that the battery is within a safe temperature range.

## 2.6. Cell Balancing Mechanisms

In the case of the multi-cell battery configuration, cell balancing is a common problem. It may cause a reduction in the performance of the system. Therefore, balancing techniques like passive balancing and active balancing are commonly used. In passive balancing, the extra energy is dissipated in the form of heat. It is evident from the literature that cell balancing improves the efficiency of the battery.

## 2.7. Fire Detection and Protection Strategies

In our research, there is a significant emphasis on integrating fire detection and protection means into battery systems. The application of sensors for abnormal temperature increases, gas, and flame detection is useful for early detection of possible battery faults. Once a fault is identified, protective actions such as battery disconnection and load reduction can be implemented. These methods have played a vital role in reducing possible risks due to battery faults.

## 2.8. Integration of Smart Monitoring Systems

With the growth of modern communication technologies, BMS systems are now becoming smarter by integrating IoT and communicating it with other systems like Advanced Driver Assistance Systems (ADAS). This allows real-time monitoring of battery parameters, early fault detection, and enhanced vehicle protection. Such smart features improve system reliability and make the overall EV system more efficient and user-friendly.

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## 3. Methodology

In this work, we have focused on developing a compact and efficient Battery Management System (BMS) with enhanced monitoring and safety features. The approach we followed involves integrating sensing, control, and protection mechanisms into a single system to ensure reliable battery operation. To begin with, we have selected a lithium-ion battery (3.7V each) as the energy source and identified the key parameters that need continuous monitoring, such as voltage, current, humidity and temperature. For this purpose, we have used dedicated voltage and current sensors to measure the electrical behavior of the battery during charging and discharging conditions. A temperature sensor is also incorporated to track thermal variations, as temperature plays a critical role in battery safety and the humidity sensor as well.

All the sensor outputs are connected to a microcontroller, which we have used as the central processing unit of the system. The microcontroller reads real-time sensor data and processes it to estimate the State of Charge (SoC) of the battery. For SoC estimation, we implemented a current-based approach, where the flow of current is continuously tracked to determine the remaining charge.

To improve safety, we introduced a protection mechanism based on predefined threshold limits. If the battery voltage or temperature exceeds safe operating conditions, which is set to 13V for the input voltage, the system automatically responds by activating a relay to disconnect the battery. In addition to this, we have also integrated a fire detection sensor to identify abnormal conditions such as flame or excessive heat. This provides an extra layer of protection against potential hazards. The system also detects the active charger compatibility which ensures that the vehicle take charging current from original charger only.

For user interaction, we have included a Liquid Crystal Display (LCD) to show important parameters like voltage, temperature, humidity, current (charging and load current) and SoC in real time.

Overall, the methodology we have adopted focuses on combining monitoring, control, and safety features into a single integrated system. The aim is to enhance battery reliability, prevent failure conditions, and improve user awareness through real-time data visualization and warning.

### 3.1. Circuit Diagram

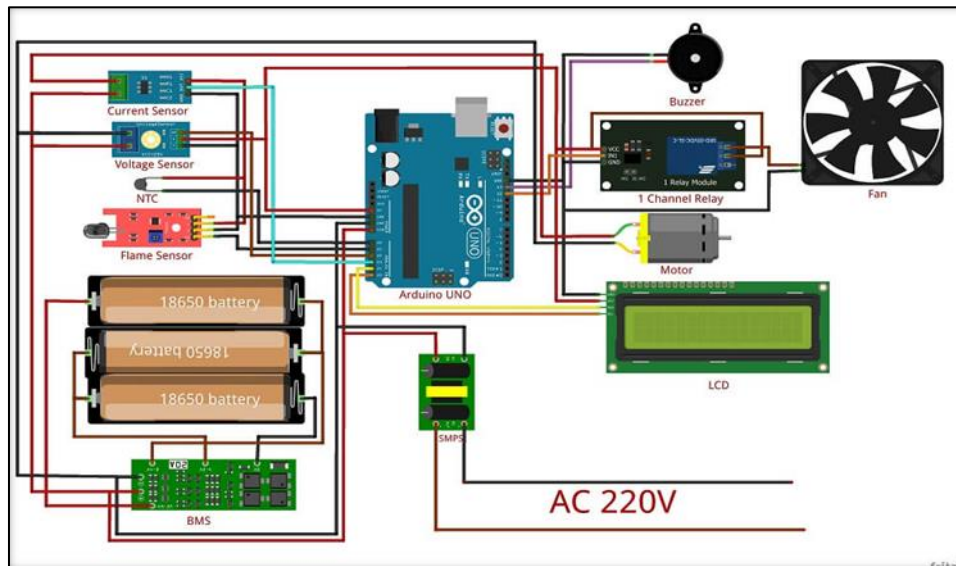


Figure 1 Circuit Diagram

### 3.2. Existing Systems

In conventional Battery Management Systems (BMS), the primary focus is on monitoring electrical parameters such as voltage, current, and temperature to ensure safe battery operation. While these systems are effective in preventing overcharging, deep discharging, and basic thermal issues, most existing designs do not incorporate direct fire detection mechanisms.

Additionally, many systems rely only on passive thermal monitoring without implementing active cooling solutions such as cooling fans. As a result, in situations involving rapid temperature rise or internal faults, the response may be limited to system shutdown without addressing the root cause of overheating.

### 3.3. Disadvantages

- Does not provide an active cooling technique.
- Does not have sensors to detect the flame, humidity or an active overheat protection system.

### 3.4. Proposed Systems

In contrast, the proposed system enhances the safety and reliability of conventional BMS by integrating a flame sensor for real-time fire detection and cooling fans for active thermal management. The inclusion of a flame sensor enables early identification of fire hazards, allowing immediate preventive action. Similarly, the use of cooling fans helps in regulating battery temperature proactively, reducing the chances of thermal runaway. These additional features make the proposed system more robust, responsive, and suitable for high-safety applications, thereby providing a significant improvement over existing solution.

### 3.5. Advantages

- **Enhanced Safety through Fire Detection:** Unlike existing systems that rely only on temperature monitoring, the proposed system incorporates a flame sensor, enabling direct and early detection of fire hazards. This significantly reduces the risk of accidents.
- **Active Thermal Management:** The inclusion of cooling fans provides an active method to regulate battery temperature. This is more effective than passive thermal monitoring used in traditional systems, helping to prevent overheating and thermal runaway.
- **Real-Time Multi-Parameter Monitoring:** The system continuously monitors voltage, current, temperature, humidity and fire conditions simultaneously, ensuring a more comprehensive assessment of battery health compared to conventional BMS.
- **Automatic Protection Mechanism:** The use of a relay-based cut-off system allows immediate disconnection of the battery under unsafe conditions, improving response time and preventing damage.

- **Improved Battery Lifespan:** By maintaining optimal operating conditions through proper monitoring and cooling, the system helps in reducing battery stress and extending its service life.
- **Higher Reliability and Fault Detection:** The integration of multiple sensors improves the accuracy of fault detection and reduces the chances of system failure.
- **User-Friendly Monitoring Interface:** Real-time display of battery parameters on an LCD enhances user awareness and enables better decision-making during operation.
- **Compact and Integrated Design:** The proposed system combines monitoring, protection, fire detection, and cooling into a single unit, making it more efficient and practical for real-world applications.

### 3.6. Applications

- **Electric Vehicles (EVs):** Improves battery safety, performance, and lifespan through advanced monitoring, fire detection, and thermal management.
- **Autonomous and Advanced Driver Assistance Systems (ADAS) Enabled Vehicles:** Ensures stable and reliable power supply for critical systems such as ADAS and autonomous driving functions.
- **Fire Safety in EV Systems:** Provides early fire detection using a flame sensor, reducing the risk of thermal runaway and improving passenger safety.
- **Smart and Connected EV Systems:** Supports real-time monitoring, remote diagnostics, and predictive maintenance in IoT-enabled electric vehicles.
- **Energy Storage and Backup Systems:** Enhances safety and efficiency in battery-based energy storage applications by preventing overheating and fire hazards.

Equations

$$SOC(t) = SOC(t-1) + \int_0^t I / C_{bat} \cdot dt \quad (1)$$

where

- SOC(t): Battery state-of-charge t [%]
- SOC(t-1): Battery initial state-of-charge [%]
- I: Charge/discharge current [A]
- t: Time [h]
- C bat: Battery Capacity [Ah]

$$SOH (\%) = (C_{current} / C_{rated}) * 100\% \quad (2)$$

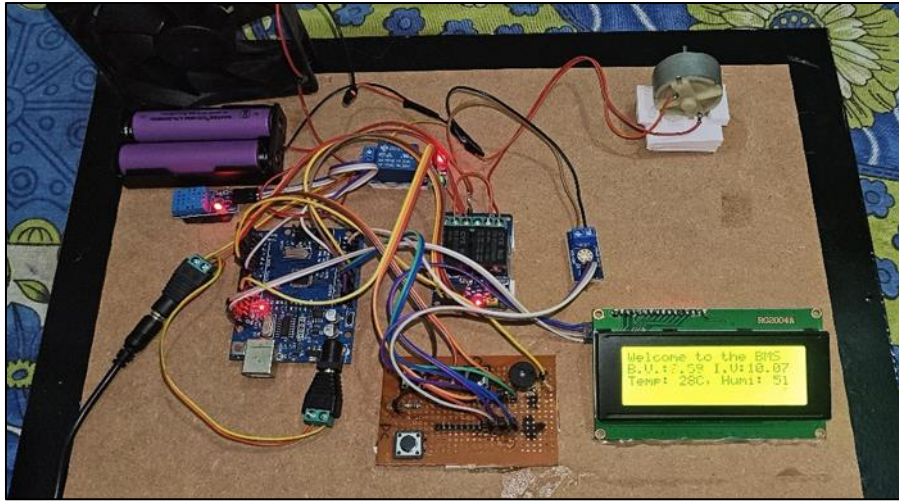
Where

- C<sub>CURRENT</sub>: Maximum available charge capacity now.
- C<sub>RATED</sub>: Initial, rated, or nominal capacity.

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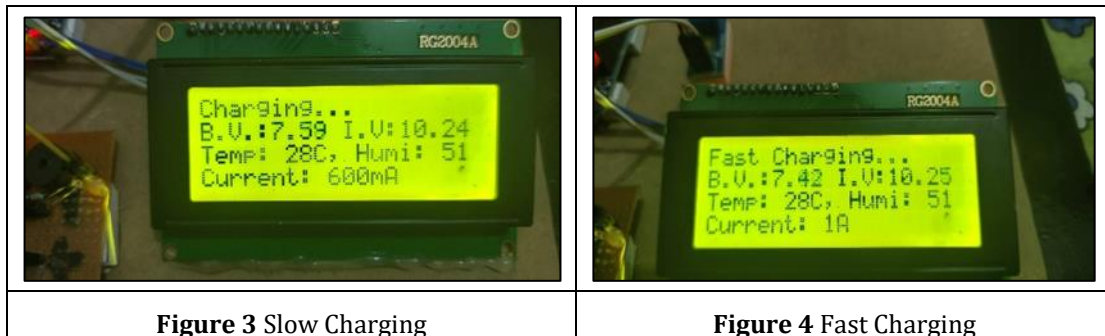
## 4. Results and Discussions

Fig. 2 shown below shows the complete component of the project which have Arduino, Motor, Cooling fan, LCD Display, Relays, Buzzer, lithium-ion battery, cooling fan, push buttons, flame, humidity, voltage and current sensor.



**Figure 2** Complete System

- **Step: 1** The LCD will show a welcome message when a 12V adapter is connected for the supply.
- **Step: 2** Two batteries of 3.7V each are connected in series which provide a total of 7.4V. When the battery voltage goes beyond threshold (8.2V) it turns OFF the charging automatically.
- **Step: 3** After that it shows every detail by measuring all the parameters which are necessary for a car before we drive.
- **Step: 4** We can choose for the fast charging (1A) as well as slow charging (600mA) as per our requirement which is displayed in the figure 3 and 4 below.



**Figure 3** Slow Charging

**Figure 4** Fast Charging

- **Step: 5** The motor acts as a load which is turned ON to discharge the battery up to a certain level, the motor used takes up to 800mA running at full speed.
- **Step: 6** The battery takes the charging time as shown in the table below: -

**Table 1** Charging time estimation

Battery (3.7V*2, 1200mAh)	4.44Wh,	Charging time (With slow charging 600mA)	Charging time (with fast charging 1A)
-		1-1.2 hours	2-2.5 hours

**Step: 7** Battery temperature, humidity, active flame detection is measured and shown continuously on the display. When the battery temperature reaches threshold mark (30 degree) the system (BMS) gives a warning by turning ON the Buzzer and the point it reaches above 30 degree it will cutout the battery supply from system and turning OFF the safe operation.

**Step: 8** After that when the battery cools down (below 30 degree) with the help of cooling fan it will resume its operation again.

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## 5. Conclusion

This study discusses an advanced Battery Management System (BMS) aimed at ensuring the safety and efficiency of lithium-ion battery operations through real-time monitoring of voltage, current, humidity, temperature, and State of Charge (SoC). The proposed system is differentiated from existing ones by its fire detection, humidity sensing and active cooling capabilities. By using real-time monitoring and protective mechanisms, this system will enhance battery safety, lifespan, and minimize hazardous failure risks.

Additionally, its capacity for power delivery will make it suitable for integration into future electric vehicles, particularly those using smart and automated technologies. Overall, this proposed system is a comprehensive and effective solution for improving safety, efficiency, and technological advancements in electric vehicles.

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## Compliance with ethical standards

### *Disclosure of conflict of interest*

No known financial interests or personal relationships that have affected the presented work.

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