

Developing a Battery Management System for Electric Vehicles to Rectify Battery Charging, Discharging and Fire Protection Issues

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ABSTRACT

The increasing adoption of electric vehicles (EVs) has created a need for reliable Battery Management Systems (BMS) capable of monitoring battery operating conditions and protecting the battery from unsafe charging, discharging, overheating, and fault conditions. This paper presents the development of a microcontroller-based BMS intended to monitor and manage important battery parameters while providing protection against hazardous operating conditions. The proposed system uses an Arduino Nano based on the ATmega328P microcontroller, together with voltage, current, and temperature sensors, an LCD display, relay, buzzer, and power supply. Battery parameters are continuously monitored and processed by the controller to identify abnormal conditions. The system provides real-time information through the LCD and activates protective actions when unsafe conditions are detected. The proposed system also incorporates accident detection using a MEMS accelerometer and provides location-related alert functionality through a communication module. During abnormal conditions, the system can stop the power supply and disconnect the battery through the relay mechanism. The developed prototype demonstrates the integration of battery monitoring, charging/discharging control, temperature-based protection, and accident-related safety functions in a compact and cost-effective platform.

Keywords— Battery Management System, Electric Vehicle, Lithium-Ion Battery, State of Charge, Temperature Monitoring, Fire Protection, Arduino Nano, Battery Safety.

INTRODUCTION

Electric vehicles are increasingly being adopted as an alternative to conventional internal-combustion-engine vehicles because of their potential to reduce emissions, fuel consumption, and environmental impact. The project report identifies EVs as an important technology for addressing pollution, global warming, and depletion of conventional energy resources. The development of modern EVs has also increased the importance of reliable battery systems because the battery is one of the major components determining vehicle performance, operating range, and safety.

An Electric Vehicle Battery Management System acts as the monitoring and protection unit of the battery pack. It monitors parameters such as voltage, current, temperature, charging and discharging conditions, and State of Charge (SOC). Proper monitoring is necessary to prevent overcharging, deep discharge, excessive current, and overheating. Such conditions can reduce battery life and, in severe cases, result in thermal runaway or fire. The project report therefore emphasizes the need for integrated charging, discharging, and fire-protection functions within the BMS.

The proposed system combines sensing, processing, display, protection, and alert functions using an Arduino Nano. Voltage and current sensors provide electrical measurements, while a temperature sensor monitors the thermal condition of the battery. The controller processes these sensor signals and provides information through an LCD. A

relay is employed to disconnect the power path during abnormal conditions, while a buzzer provides an audible warning. The implementation therefore provides a low-cost prototype for demonstrating essential BMS functions.

In addition to battery monitoring, the project incorporates an accident-detection feature based on a MEMS accelerometer. Abnormal acceleration or tilt is interpreted as a possible accident condition. The system can obtain location information, communicate the accident condition, display the detected status, and stop the power supply to improve safety. The integration of battery protection and accident detection makes the proposed system suitable as a prototype for safety-oriented EV applications.

LITERATURE SURVEY

Battery Management Systems (BMS) have become an essential part of electric vehicles (EVs) for monitoring battery voltage, current, temperature, State of Charge (SOC), and overall battery condition. BMS technologies are intended to improve battery efficiency, extend battery life, and protect the battery from unsafe operating conditions. Babu *et al.* [1] investigated the design, modelling, and fabrication of a four-wheeler electric short commuter, highlighting the importance of battery-based propulsion systems in EV development. Guarnieri [2] presented the historical development of electric vehicles and discussed the evolution of electric propulsion technologies. Rajashekara [3] reviewed the present status and future trends of EV propulsion systems, emphasizing the importance of efficient power and energy management. Denton [4] discussed electric and hybrid vehicle technologies, including their electrical and battery systems. Zhang [5] investigated the modelling and control of modular BMSs for lithium-ion battery packs, demonstrating the importance of coordinated battery monitoring and control.

Recent studies have also focused on battery health monitoring, charging/discharging management, and safety. Hemmati *et al.* [6] investigated the scheduling of battery swapping stations in smart microgrids, demonstrating the interaction between EV batteries and modern energy systems. Shah *et al.* [7] studied battery health monitoring for commercialized lithium-ion EV batteries, emphasizing the importance of monitoring battery condition for reliable operation. Devkar *et al.* [8] discussed BMS-based safety and accident prevention using electronic sensing and embedded control. Kuttukkaran *et al.* [10] proposed an intelligent accident detection and alert system using sensors such as accelerometers and gyroscopes to identify abnormal vehicle movement and provide emergency information. These studies indicate that combining battery monitoring, protection, and accident detection can improve the overall safety and reliability of EVs. Based on these developments, the proposed work integrates voltage, current, and temperature monitoring with relay-based protection, buzzer indication, LCD display, and MEMS-based accident detection using an Arduino Nano platform. The literature and references used here are derived from the uploaded project report.

PROBLEM STATEMENT

The increasing use of EVs requires battery systems that can operate safely and efficiently under varying charging, discharging, and thermal conditions. Conventional monitoring without integrated protection may not provide adequate response to overvoltage, over current, deep discharge, overheating, and accident-related conditions.

OBJECTIVES

The main objectives of the proposed system are:

1. To develop a microcontroller-based BMS for monitoring battery voltage, current, temperature, and SOC-related conditions.
2. To provide protection against unsafe charging, discharging, overheating, and electrical fault conditions.
3. To provide real-time battery information through an LCD display.
4. To incorporate audible and relay-based protection mechanisms during abnormal conditions.
5. To integrate accident detection and location-related alert functionality for improved EV safety.

PROPOSED SYSTEM

The proposed BMS consists of an Arduino Nano, battery, voltage sensor, current sensor, temperature sensor, LCD display, relay, buzzer, potentiometer, and regulated power supply. The Arduino Nano functions as the central controller. It receives sensor signals, processes the measurements, evaluates battery conditions, and controls the display and protection devices. The hardware components identified in the project report are the Arduino Nano, battery, voltage sensor, current sensor, LCD display, temperature sensor, power supply, buzzer, potentiometer, and relay.

The Arduino Nano uses the ATmega328P microcontroller and operates at 5 V with a 16 MHz clock. It provides 14 digital I/O pins, eight analog inputs, and communication interfaces including UART, SPI, and I²C. These features make it suitable for interfacing the different sensing and indication elements required by the prototype.

The voltage sensor measures the battery voltage and provides a scaled signal suitable for the microcontroller. The current sensor measures the charging or discharging current, while the temperature sensor monitors the thermal condition of the battery. The LCD displays measured values and system status. The relay provides electrical isolation and switching for disconnecting the battery or load during hazardous conditions, while the buzzer provides an audible warning.

Block Diagram

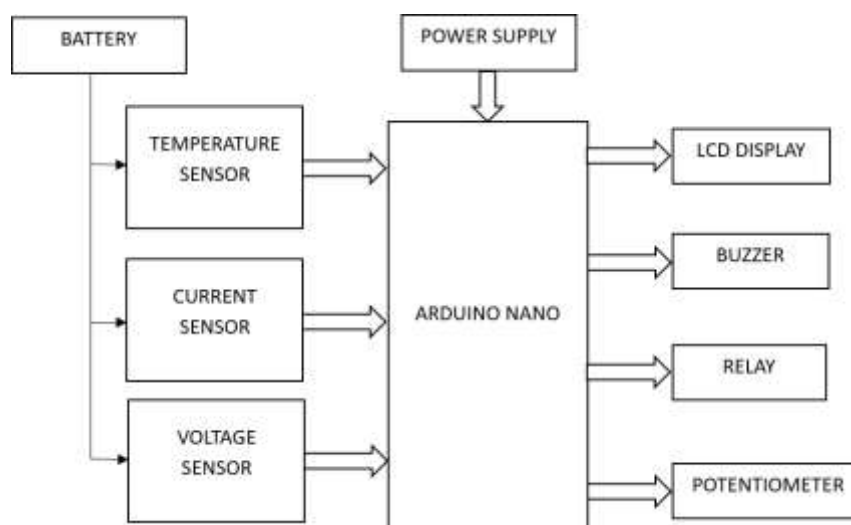


Fig 1Block diagram of battery Management System

Circuit Diagram

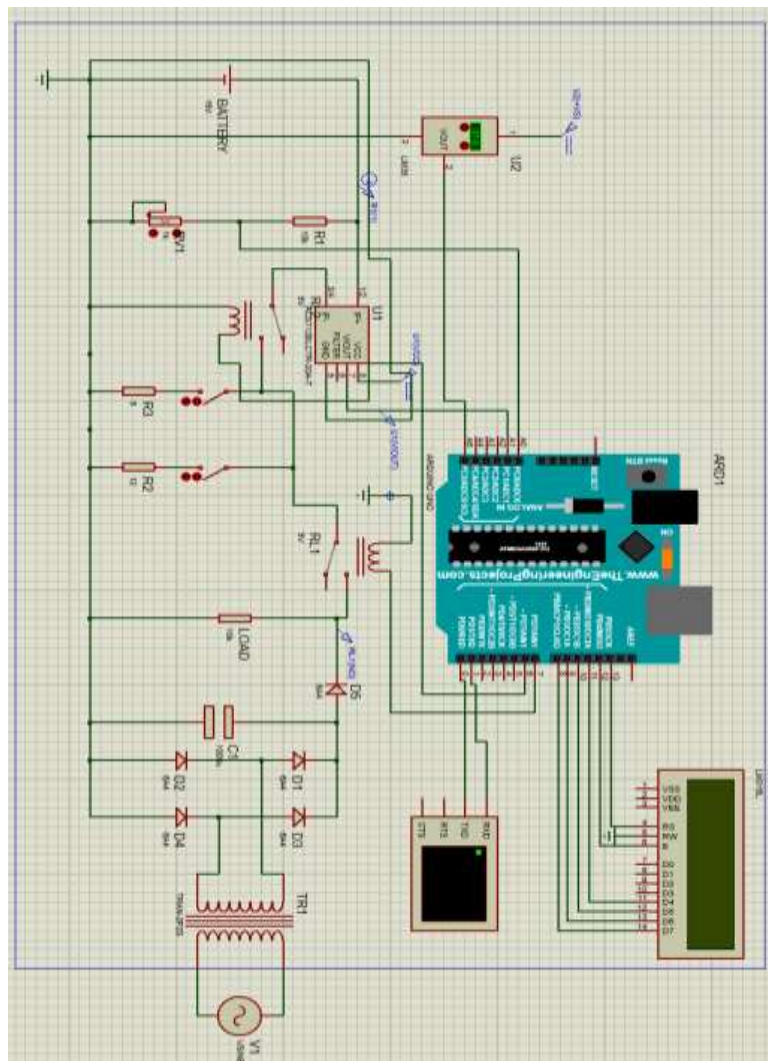


Fig 2 Circuit diagram of Battery management system

METHODOLOGY

The proposed Battery Management System (BMS) integrates battery monitoring, charging and discharging control, thermal protection, and accident detection using an Arduino Nano as the central controller. The voltage, current, and temperature sensors continuously monitor the battery parameters, while the controller processes the sensor outputs and compares them with predefined operating limits. During charging and discharging, the system monitors voltage and current to prevent overcharging, excessive current, and deep discharge.

Temperature is continuously monitored to identify abnormal heating and potential thermal-runaway conditions. When an unsafe condition is detected, the controller initiates the required protective action. The methodology also incorporates a MEMS accelerometer for monitoring X- and Y-axis acceleration and detecting abnormal vehicle movement.

The hardware implementation consists of an Arduino Nano, battery, voltage sensor, current sensor, temperature sensor, LCD display, relay, buzzer, potentiometer, and power supply. The Arduino Nano processes the sensor signals and displays the battery status on the LCD. The relay is used to disconnect the power supply during hazardous conditions, while the buzzer provides an audible warning. The software is developed using the Arduino IDE, where the controller continuously reads battery voltage, current, temperature, and accelerometer values. When the measured

parameters remain within the permissible range, normal operation continues; otherwise, the appropriate protection mechanism is activated. In the case of an accident, the accelerometer detects abnormal acceleration or tilt, after which the system identifies the accident condition, obtains location information, displays the status, activates the alert, and stops the power supply.



Fig 3 Hardware Setup

RESULTS AND DISCUSSION

The developed Battery Management System was successfully implemented using the Arduino Nano, voltage sensor, current sensor, temperature sensor, LCD, relay, and buzzer. The prototype provided continuous monitoring of battery operating parameters and displayed the corresponding information on the LCD. The temperature-monitoring function provided real-time indication of the battery thermal condition, while the buzzer was activated during abnormal conditions. The relay-based protection mechanism enabled the power supply to be disconnected when an unsafe condition was detected. The project report identifies the normal LCD display, temperature display, and buzzer operation as the principal prototype outputs.

The accident-detection function was also demonstrated using the MEMS accelerometer. Abnormal acceleration along the X- and Y-axes was detected and interpreted as an accident condition. For the simulated right-direction, negative-direction, and frontal-impact conditions, the system identified the abnormal movement, obtained location information, displayed the accident status, activated the alert, and stopped the power supply. These results demonstrate that the proposed system can integrate battery monitoring, fault protection, and accident detection within a single embedded platform, thereby improving the safety and reliability of the EV battery system.

CONCLUSION

This paper presented the development of a microcontroller-based Battery Management System for electric vehicles with integrated battery monitoring, charging/discharging protection, thermal monitoring, and accident-related safety functions. The proposed prototype uses an Arduino Nano as the central controller and integrates voltage, current, temperature, and acceleration sensing with an LCD, buzzer, and relay.

The implemented system continuously monitors battery operating conditions and provides real-time information to the user. When abnormal conditions are detected, the protection mechanism can disconnect the power supply and generate an alert. The accident-detection functionality further enhances the safety capability by identifying abnormal acceleration or tilt and initiating a protective response. The reported prototype outputs demonstrate the practical operation of the monitoring and alert functions.

The project demonstrates that integrating battery monitoring and protection functions into an embedded BMS can improve the safety, reliability, and operational management of EV battery systems. Future improvements involving AI-based prediction, advanced thermal management, solid-state batteries, and wireless BMS technology can further enhance the performance and safety of the proposed system.

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