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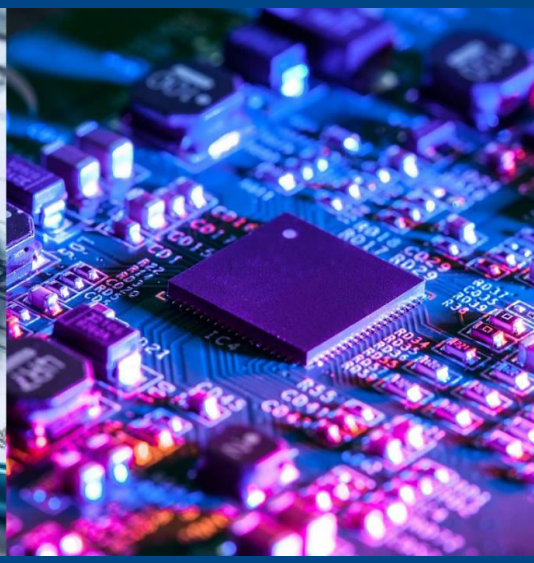

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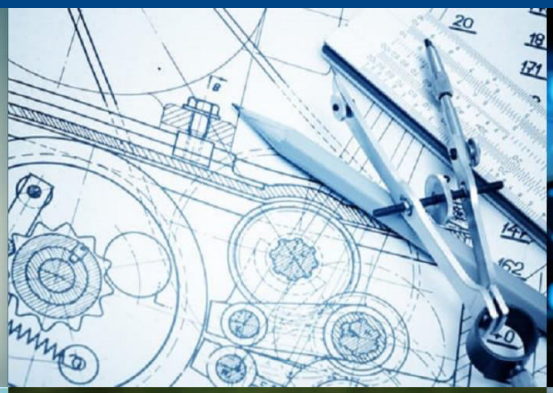

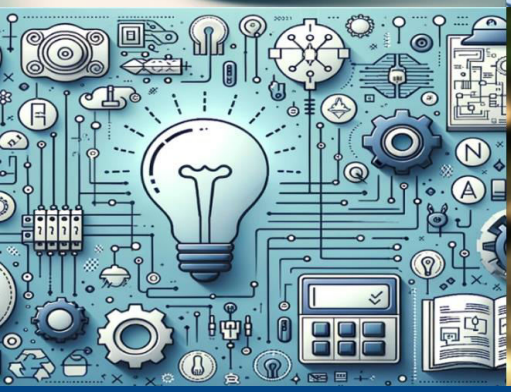

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Battery Power Management System for Electric vehicles

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ABSTRACT: This research focuses on the development of an intelligent Battery Management System (BMS) designed specifically for electric vehicles (EVs), incorporating both Arduino and STM32 microcontrollers for enhanced processing and reliability. The system integrates GPS and SIM800L GSM modules to offer real-time monitoring and remote alert capabilities. It continuously tracks battery parameters, including voltage and temperature, to ensure safe operating conditions and to protect the battery from critical issues such as overcharging, deep discharge, and overheating. In the event of any abnormal readings, the system automatically sends SMS alerts with accurate GPS coordinates to pre-defined recipients, allowing for prompt response and maintenance. The prototype emphasizes low-cost implementation, modularity, and ease of scalability, making it suitable for a wide range of EV platforms. Through rigorous testing, the system has proven to be effective in enhancing battery safety, extending battery life, and reducing the risk of failure during vehicle operation.

I. INTRODUCTION

The rapid shift towards electric mobility has brought electric vehicles (EVs) to the forefront of sustainable transportation. As EV adoption increases, the performance, safety, and reliability of the battery system become critical factors influencing overall vehicle efficiency. The battery pack is not only the most expensive component in an EV but also the most vulnerable to environmental and operational stresses such as overcharging, deep discharge, and thermal overload.

To address these challenges, Battery Management Systems (BMS) play a crucial role by continuously monitoring and controlling battery parameters. Traditional BMS designs, however, often lack advanced communication capabilities or are too costly for wide deployment in low-cost or modular EV platforms. There is a growing need for an affordable, flexible, and reliable BMS that provides real-time monitoring and remote alerting features.

This project introduces a smart BMS architecture implemented using Arduino and STM32 microcontrollers, integrated with GPS and SIM800L GSM modules. The system monitors essential battery metrics—voltage and temperature—in real time. If any irregularities such as over-voltage, under-voltage, or overheating are detected, the system automatically sends an SMS alert containing the vehicle's exact GPS location to a designated mobile number. This enables swift preventive actions, minimizing the risk of battery failure or fire.

The proposed system emphasizes low-cost design, modular hardware, and open-source compatibility, making it suitable for both academic research and real-world applications in two-wheelers, three-wheelers, and small electric fleets. The combination of GPS tracking and GSM-based alerting ensures robust safety monitoring even in remote areas, where traditional BMS solutions may fall short.

This paper discusses the design methodology, hardware integration, software development, testing, and validation of the system. The results demonstrate that the proposed BMS not only enhances battery safety and lifespan but also provides a scalable foundation for future advancements in EV battery monitoring.

II. PROBLEM STATEMENT

Electric vehicles (EVs) rely heavily on battery packs as their primary power source, making battery health and performance critical to vehicle reliability, safety, and longevity. However, batteries are vulnerable to issues such as

overcharging, deep discharge, and overheating, which can lead to reduced battery life, thermal runaway, and in severe cases, fire or explosion. Despite the availability of commercial Battery Management Systems, many existing solutions are either too expensive, lack real-time tracking and communication features, or are not scalable for use in small or low-cost EV platforms.

In most budget or custom EVs, battery safety mechanisms are basic and reactive, offering limited preventive functionality. Moreover, they often lack remote monitoring capabilities, which are essential for fleet management, safety assurance, and timely maintenance. This limitation becomes more significant in rural or remote areas where vehicle breakdowns or battery failures can lead to delays, increased maintenance costs, or safety hazards without immediate assistance.

III. OBJECTIVES

- To design a BMS capable of monitoring voltage (1V to 24V) and temperature using Arduino.
- To implement GPS tracking and send real-time SMS alerts using STM32 and SIM800L GSM module.
- To provide remote monitoring capabilities by transmitting battery health status along with location.
- To ensure timely fault detection and notification for preventive maintenance.
- To develop a scalable system adaptable to various battery configurations.

IV. SCOPE

To design a cost-effective and scalable Battery Management System (BMS) for electric vehicles.
To monitor battery voltage and temperature in real-time using Arduino and STM32 microcontrollers.
To detect and prevent battery faults such as overcharging, deep discharge, and overheating.
To integrate GPS and GSM modules for real-time location tracking and alert notifications.
To send SMS alerts with GPS coordinates when abnormal battery conditions are detected.
To improve battery safety, extend battery life, and enable preventive maintenance in EVs.

V. LITERATURE SURVEY

Battery Management Systems (BMS) are critical components in electric vehicles to ensure battery safety, optimize performance, and prolong battery life. Various studies and implementations have explored different approaches to BMS design and communication integration.

Monitoring Battery Parameters: Most existing research focuses on real-time monitoring of battery voltage, current, and temperature to prevent hazards like overcharging, deep discharge, and thermal runaway. For example, [1] implemented a BMS using Arduino to monitor battery voltage and temperature, providing basic fault detection.

Microcontroller-Based BMS: STM32 microcontrollers have gained popularity in advanced BMS designs due to their high processing speed and low power consumption. Research in [2] demonstrated an STM32-based BMS capable of precise data acquisition and control for lithium-ion batteries in EVs.

Communication and Remote Monitoring: Integrating GSM modules such as SIM800L enables remote alert systems via SMS, crucial for early fault detection. Studies like [3] have shown that combining GSM with GPS modules provides real-time location tracking alongside battery alerts, enhancing safety in electric vehicle fleets.

Challenges and Limitations: Despite advances, many BMS prototypes lack scalability or are cost-prohibitive for mass adoption. Additionally, GPS and GSM integration often faces challenges in areas with poor network coverage, as discussed in [4].

Gap in Research: Current literature lacks comprehensive, low-cost BMS solutions combining robust real-time monitoring with GPS-based location alerts suitable for a wide range of EV applications, especially in emerging markets.

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This project aims to fill this gap by developing a modular BMS integrating Arduino, STM32, GPS, and SIM800L GSM modules to provide an affordable, scalable, and reliable battery safety system with real-time alerts and location tracking.

VI. METHODOLOGY

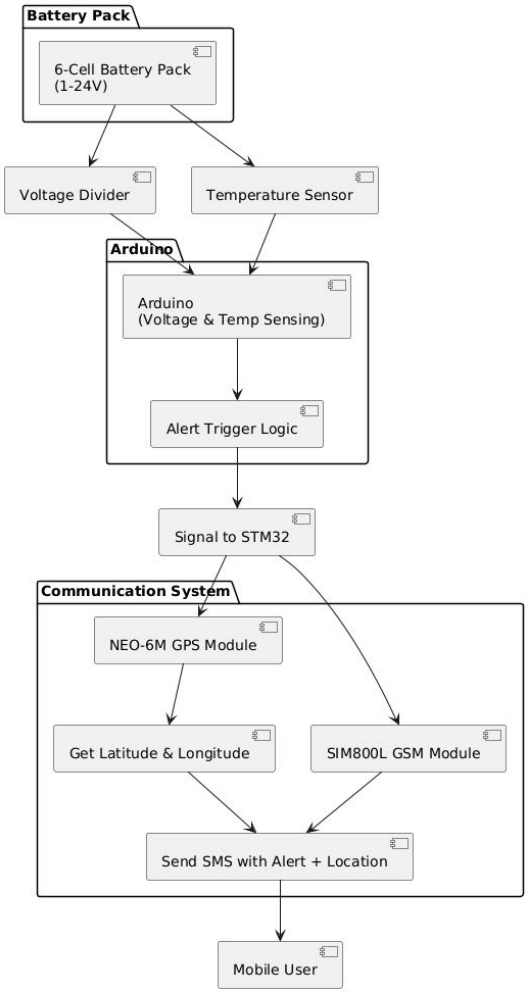
Hardware Design

- Arduino Uno measures voltage
- Voltage sensed using a voltage divider, scaled for 12V max input.
- Data sent via UART to STM32F103C8T6 microcontroller.
- STM32 reads GPS data from NEO-6M module via UART.
- SIM800L module connected to STM32 to send SMS alerts.
- Power supplied and regulated to ensure stable operation.

Software Design

- Arduino runs sensor reading code, sends processed data to STM32.
- STM32 processes sensor data, compares against thresholds.
- Upon fault detection, STM32 reads GPS coordinates.
- STM32 sends SMS via SIM800L with battery status and location.

6.1 Block Diagram



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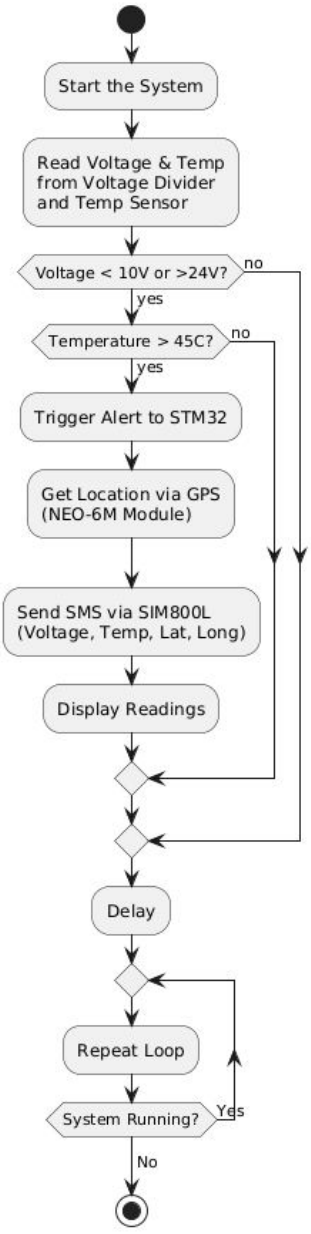
VII. HARDWARE COMPONENTS

- Arduino Uno R3
- STM32F103C8T6 (“Blue Pill”)
- SIM800L GSM Module
- NEO-6M GPS Module
- LM35 Temperature Sensor
- Voltage Divider Resistors
- 6-Cell Battery Pack (1V to 24V range)
- Power Supply Modules

Flowchart



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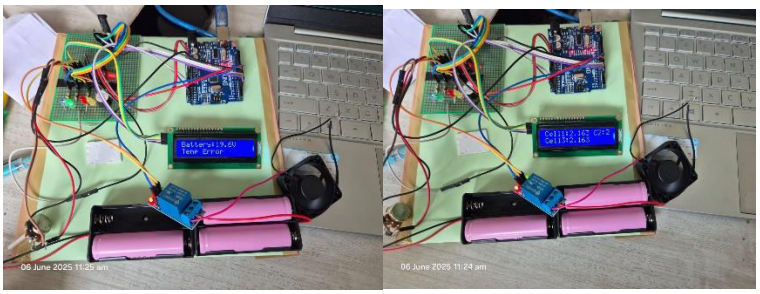
VIII. SOFTWARE REQUIREMENTS

- Arduino IDE for Arduino programming
- STM32CubeIDE for STM32 firmware development
- AT command set for SIM800L control
- Serial communication protocols (UART)
- GPS NMEA sentence parsing

X. TESTING & RESULTS

Testing verified the system's ability to detect voltage and temperature anomalies and send SMS alerts with GPS location. Tests included varying battery voltages, simulating temperature changes, and verifying GPS accuracy. The system successfully sent timely alerts, confirming reliability and accuracy.



X. CONCLUSION

The project demonstrates a functional and practical battery management system for electric vehicles, leveraging Arduino and STM32 microcontrollers with GPS and GSM modules. It successfully monitors key battery parameters and alerts users remotely, improving safety and maintenance effectiveness.

XI. FUTURE SCOPE

- Incorporate current sensing and SOC/SOH estimation.
- Add IoT connectivity for cloud monitoring and analytics.
- Implement predictive maintenance using machine learning.
- Develop dashboard interfaces for local display and control.
- Enhance GPS reliability via A-GPS or other positioning methods.

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