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DESIGN AND DEVELOPMENT OF SOPHISTICATED BATTERY MANAGEMENT SYSTEM OF EV

[1]Sangharsh Bapu Thakare, [2]Thombare Amit Rajendra, [3]Thakare Akshay Arun, [4]Nagesh Laxman Saundane, [5]Prof .P.S.Gosavi

[1]UG Scholar, Electrical Dept., SND College of Engineering and research center,Yeola
[2]UG Scholar, Electrical Dept., SND College of Engineering and research center, Yeola
[3]UG Scholar, Electrical Dept., SND College of Engineering and research center, Yeola
[4]UG Scholar, Electrical Dept., SND College of Engineering and research center, Yeola
[5]Asst. Prof. Electrical Dept. ., SND College of Engineering and research center, Yeola
sangharshthakare67@gmail.com

ABSTRACT- The development of electric vehicles (EVs), which mainly rely on safe and effective battery systems, has accelerated due to the growing demand for environmentally friendly transportation on a worldwide scale. In order to guarantee performance, dependability, and safety, battery activities must be monitored and controlled by a Battery Management System (BMS). In this project, a hybrid STM32 and Arduino-based architecture is used to design and create an advanced BMS for a 48 V (13S) lithium-ion battery pack. The suggested system uses Kalman filter techniques to estimate the State of Charge (SOC) and State of Health (SOH) while keeping an eye on important battery metrics including cell voltage, current, and temperature. Furthermore, heat, overvoltage, and passive cell balancing protection, and Controller Area Network (CAN) communication are integrated to enhance system efficiency and safety. MATLAB/Simulink simulations validate the accuracy of SOC estimation (±2%) and demonstrate effective cell balancing (>95% efficiency). The developed BMS ensures improved battery lifespan, operational safety, and compatibility with EV standards, making it a cost-effective and scalable solution for modern electric mobility applications.

***Keywords*:** Battery Management System (BMS); Electric Vehicle (EV); State of Charge (SOC); State of Health (SOH); STM32 Microcontroller; Arduino; Cell Balancing; Lithium-ion Battery; CAN Communication; MATLAB/Simulink; Fault Detection; Thermal Management; Energy Efficiency; Embedded System Design.

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I. INTRODUCTION

In the worldwide automobile industry, the switch from traditional internal combustion engine cars to electric vehicles (EVs) is a significant technical advancement. The battery pack, a sophisticated collection of lithium-ion cells that store and supply energy to the car's motor, is the central component of any electric vehicle. The Battery Management System (BMS), an advanced electronic system, is necessary to guarantee the longevity, performance, and safety of this battery pack. The design and development of an advanced BMS that can monitor, regulate, and optimize the performance of a 48 V lithium-ion battery pack used in electric vehicles is the main topic of this study. The hybrid STM32 and Arduino microcontroller architecture used in the construction of the suggested system combines the STM32's fast data processing speed with the Arduino's adaptability for auxiliary control.

The developed BMS performs key functions such as:

1. Continuous monitoring of cell voltage, current, and temperature
2. State of Charge (SOC) and State of Health (SOH) estimation using Kalman filter algorithms
3. Passive cell balancing to equalize cell voltages and improve battery life
4. Thermal and fault management to prevent unsafe operating conditions
5. CAN bus communication for real-time data exchange with other vehicle control units

1.1 Problem Definition

With the rapid adoption of Electric Vehicles (EVs), ensuring the safety, reliability, and efficiency of battery systems has become one of the most critical challenges in modern automotive engineering. The performance and longevity of an EV depend largely on the proper management of its lithium-ion battery pack, which is highly sensitive to voltage, temperature, and current variations. Improper handling can lead to serious issues such as overcharging, over-discharging, overheating, or even thermal runaway, posing significant safety risks. Existing Battery Management Systems (BMS) often suffer from limitations such as inaccurate estimation of State of Charge (SOC) and State of Health (SOH), lack of effective cell balancing mechanisms, and inadequate thermal monitoring.

II. LITERATURE SURVEY

Sr.no	Title	Author name	Year
1.	Review of Battery Management Systems (BMS) development and industrial standards	Gabbar, H.A.	2021
2.	Battery Management System for Electric Vehicles.	A. Kurkin, D. Droz and N. Prokofiev	2025
3.	Enhanced State of Charge Estimation of Lithium-ion Batteries Using Machine Learning Regression Algorithms.	Babu, M., Singh, A Kumar, R.	2024
4.	Review of Battery State Estimation Methods for Electric Vehicles – Part I: SOC Estimation	Demirci, U. B., Ozturk, S., & Gunes, M.	2024
5.	Battery Technologies and Functionality of Battery Management Systems for Electric Vehicles	M. Waseem, H. Arshad, and N. Khan	2023
6.	A Novel Electric Vehicle Battery Management System with Improved Fault Detection and SOC Estimation	L. Zhang, K. Yao, T. Wang	2023

Table 1 : Literature Surve

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III. EXISTING SYSTEM

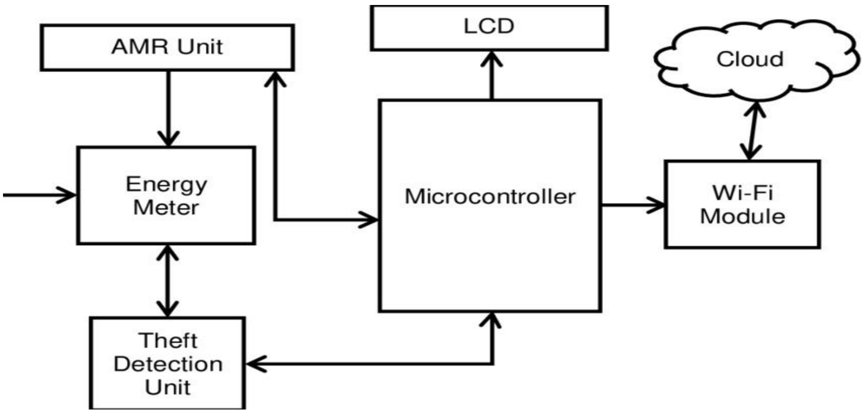

Fig.1- Existing system

The system consists of several interconnected modules that work together to monitor energy consumption, detect abnormalities, and transmit data to the cloud:

- **Energy Meter:**
  Measures electrical parameters such as voltage, current, and energy consumption. It serves as the primary sensing unit that provides real-time energy usage data to the microcontroller.
- **AMR Unit (Automatic Meter Reading):**
  Automatically collects meter readings without manual intervention and forwards the data to the microcontroller for processing. This unit enhances accuracy and reduces manual reading errors.
- **Theft Detection Unit:**
  Monitors abnormal activity such as bypassing or tampering with the meter. If suspicious patterns are detected, it sends alerts to the microcontroller for further action.
- **Microcontroller:**
  Acts as the central processing unit of the system. It receives data from the energy meter, AMR unit, and theft detection unit, processes the readings, and prepares the information for display and transmission.

- **LCD Display:**
  Provides real-time feedback to users by displaying current consumption, meter readings, and alert messages generated by the microcontroller.
- **Wi-Fi Module:**
  Enables wireless communication between the system and the cloud. It transmits processed energy data and alerts from the microcontroller to the online database or dashboard.
- **Cloud Server:**
  Stores incoming data and makes it accessible through web/mobile applications. It supports real-time monitoring, billing calculations, historical analysis, and remote access for both consumers and utility providers.
- **Microcontroller:**
  Acts as the central processing unit of the system. It receives data from the energy meter, AMR unit, and theft detection unit, processes the readings, and prepares the information for display and transmission.

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IV. PROPOSED SYSTEM

System Architecture

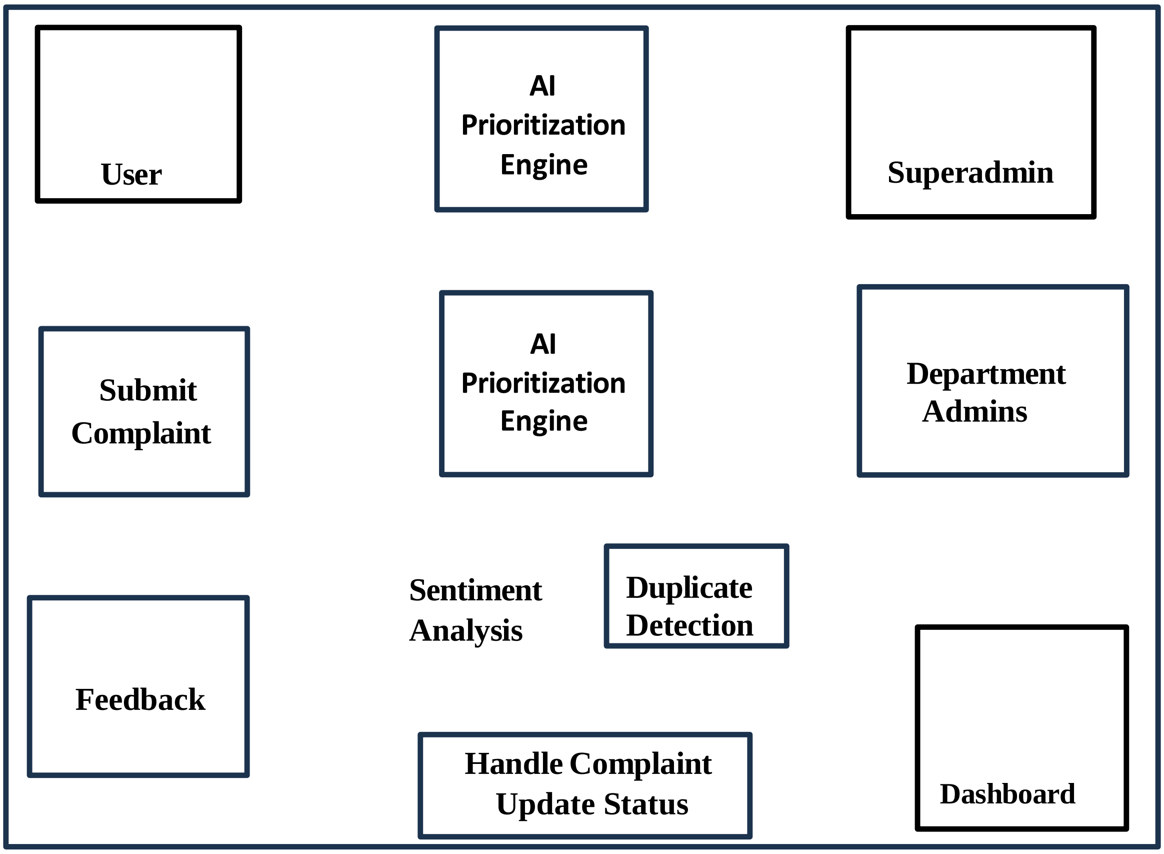

Figure 2- System Architecture

User Interaction

- **User:** The process begins with a user (such as a customer, employee, or citizen) submitting a complaint through the web application
- **Login or Register:** Before submission, users are required to create an account or log in to ensure authentication, data security, and personalized complaint tracking

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Complaint Submission

- The structured input ensures that the AI engine can effectively **analyze, classify, and prioritize** each complaint. The system automatically logs the timestamp and assigns a unique complaint ID for future tracking

Data Collection and Preprocessing

- **Dataset Creation:** Each new complaint is stored in a centralized database that maintains historical records This dataset serves as the input for AI model training and continuous learning, allowing the system to improve its predictions over time.
- **Data Cleaning and Text Preprocessing:** Using NLP libraries such as spaCy and NLTK, the system performs tokenization, stop-word removal, and sentiment extraction to prepare the data for analysis.

AI Model Training for Categorization and Prioritization

- **Priority and Escalation Prediction Model:** Another AI model analyzes complaint text and metadata (e.g., sentiment score, complaint frequency, keywords) to predict urgency and escalation level.

Dashboard and Analytics

- **Admin/Support Dashboard:** Administrators and staff can view complaint trends, resolution rates, and escalation statistics in real time dashboard .
- **AI Insights:** The system provides insights such as the most common complaint types, average response time, and customer sentiment trends, helping organizations identify systemic issues

V. CONCLUSION

The Design and Development of a Sophisticated Battery Management System (BMS) for Electric Vehicles has effectively shown how to monitor and manage lithium-ion battery packs in a dependable, effective, and economical manner. By continually monitoring important factors like voltage, current, and temperature across individual cells, the system guarantees safe operation, optimal performance, and longer battery life. The BMS achieves better accuracy than traditional methods by integrating sophisticated algorithms for State of Charge (SOC) and State of Health (SOH) estimates using the Kalman Filter approach using a hybrid STM32 and Arduino-based design. Strong safety and performance control are provided by the integration of passive cell balancing, fault detection, and thermal protection methods. Additionally, smooth data interchange with the vehicle control unit (VCU) is made possible by CAN bus connectivity, providing real-time monitoring and diagnostics.

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