

SMART AI FRAMEWORK FOR EV BATTERY HEALTH & PARAMETER MONITORING

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ABSTRACT

The rapid adoption of electric vehicles (EVs) has increased the demand for efficient battery management systems to ensure safety, performance, and longevity. This paper presents an AI-assisted framework for real-time monitoring and analysis of critical EV battery parameters such as voltage, current, temperature, and state of charge (SoC). The proposed system integrates Internet of Things (IoT) sensors with advanced machine learning algorithms to collect, process, and predict battery behavior under varying operating conditions. The framework leverages data-driven models to detect anomalies, estimate battery health, and provide predictive maintenance insights. By using artificial intelligence techniques, the system enhances accuracy in parameter estimation and enables early fault detection, reducing the risk of battery failure and improving overall efficiency. Experimental results demonstrate that the proposed approach significantly improves monitoring precision and reliability compared to conventional battery management systems. This framework contributes to the development of smarter and safer EV ecosystems.

INTRODUCTION

The global shift towards sustainable transportation has accelerated the adoption of electric vehicles, making battery technology a critical component in modern mobility solutions. The performance, safety, and lifespan of EV batteries depend heavily on effective monitoring and management of key parameters, including voltage, current, temperature, state of charge (SoC), and state of health (SoH). Traditional battery management systems (BMS) rely on rule-based methods and limited sensing capabilities, which often fall short in handling complex and dynamic operating conditions.

With advancements in Artificial Intelligence and Internet of Things, there is a growing opportunity to enhance battery monitoring systems through intelligent, data-driven approaches. AI techniques, particularly machine learning and deep learning models, can analyze large volumes of sensor data to identify patterns, predict battery degradation, and detect anomalies in real time.

This paper proposes an AI-assisted framework that integrates IoT-enabled data acquisition with intelligent analytics to improve the monitoring and management of EV battery systems. The framework is designed to provide accurate estimation of battery parameters, early detection of faults, and predictive maintenance capabilities. By combining real-time data collection with advanced analytical models, the proposed system aims to overcome the limitations of conventional BMS and support the development of reliable and efficient electric vehicles.

Furthermore, the implementation of such intelligent frameworks can reduce maintenance costs, enhance safety, and extend battery life, which are critical factors for the widespread adoption of EV technology. The remainder of this work discusses the system

architecture, methodology, and performance evaluation of the proposed framework.

PROBLEM STATEMENT

Electric Vehicles (EVs) are becoming widely adopted due to their eco-friendly nature and reduced dependence on fossil fuels. However, the performance and safety of an EV mainly depend on the condition of its battery. EV batteries are sensitive to parameters such as **voltage, current, temperature, state of charge (SOC), and state of health (SOH)**. Improper monitoring of these parameters may lead to issues like **overcharging, overheating, deep discharging, reduced battery life, sudden breakdowns, and even fire hazards**.

In many existing EV systems, battery monitoring is either limited to basic dashboard indicators or is not accessible remotely. This lack of real-time monitoring and predictive analysis creates difficulties for vehicle owners and service providers in detecting faults early, managing battery efficiency, and ensuring safe operation. Therefore, there is a need for an **IoT-based EV battery parameter monitoring system** that continuously tracks battery conditions, provides real-time updates, and alerts users in case of abnormal behavior.

OBJECTIVE

The main objective of the **Electric Vehicle Battery Parameters Monitoring System using IoT** is to design and implement a smart system that monitors key battery parameters in real time and transmits the data to a cloud platform for remote access and analysis.

Specific Objectives

- To monitor EV battery parameters such as:
 - **Voltage**
 - **Current**
 - **Temperature**
 - **Battery charge level (SOC)**
 - **Batter health condition**
- To develop an embedded system using sensors and microcontroller for continuous data acquisition.
- To transmit battery data to the cloud using IoT modules such as **ESP32 / GSM / Wi-Fi**.
- To provide a real-time monitoring dashboard through mobile or web application.
- To generate alerts and notifications for unsafe conditions such as:

- Overheating
- Overcharging
- Deep discharge
- Sudden voltage drop
- To improve battery lifespan by maintaining safe operating limits.
- To ensure safe and reliable EV operation through predictive maintenance support.

LITERATURE REVIEW

- Wahab et al. (2018) designed an IoT-based electric vehicle battery monitoring system with a focus on real-time data acquisition for improving battery performance and lifespan [1]. Prasath et al. (2023) also proposed an IoT-driven UPS battery monitoring system to provide high availability and reliability for mission-critical systems, highlighting the need for continuous monitoring in power management [9]
- Sasirekha et al. (2023) also suggested an IoT-based battery monitoring system for electric vehicles, strengthening the application of IoT in predictive maintenance and effective energy management [10].
- The application of machine learning in battery health estimation has received major attention. Sundararaju et al. (2023) utilized machine learning algorithms to estimate the state of charge (SoC) of lithium-ion batteries in electric vehicles, enhancing accuracy in battery performance prediction [8]. Leninpugalhanthi et al. (2022) also investigated machine learning-based battery lifespan estimation, where predictive models were found to optimize battery life effectively [12]. Umapathi et al. (2023) applied a model predictive controller for estimating battery health, presenting a control-oriented method for battery management [13]. Maheshwari et al. (2024) concentrated on electric vehicle battery health monitoring, combining advanced data analytics for more comprehensive diagnostics [11]. Traditional battery monitoring solutions have used multiple control and communication means. Suresh et al. (2012) presented a PLC-based battery monitoring system to effectively use the batteries in industrial use [3]. Sardar et al. (2015) proposed a GSM-based wide-area monitoring of UPS batteries to confirm the effectiveness of remote management of batteries [4]. Rauniyar et al. (2017) presented an IoT-based real-time monitoring system for a group of lead-acid batteries, enhancing efficiency in multibattery systems [5]. Rahman et al. (2017) presented a wireless battery management

system for electric transportation, improving the application of wireless technology in battery monitoring [6]. Mobile-based battery monitoring developments have also been investigated. Menghua and Bing (2017) designed an Android-based realtime monitoring system for electric vehicle lithium-ion batteries, demonstrating the applicability of mobile applications in battery diagnostics [7]. Karthika et al. (2024) suggested an IoT-based smart battery management system that is aided by cloud-based analytics for intelligent decision-making in electric vehicle battery systems [14].

EXISTING SYSTEM

In the existing system, Electric Vehicle (EV) battery monitoring is mostly handled through **basic Battery Management Systems (BMS)** which monitor essential battery parameters such as voltage, current, and temperature. These systems are generally limited to internal vehicle dashboards and service centers.

Technologies Used in Existing System

1. **Traditional Battery Management System (BMS)**
 - Monitors battery voltage and current.
 - Protects battery from overcharging and deep discharging.
 - Provides limited display on vehicle screen.
2. **Manual Battery Health Checking**
 - Battery inspection performed during servicing.
 - Requires professional tools and technicians.
3. **Onboard Diagnostic Systems**
 - Displays basic alerts such as low battery, overheating, and charging status.
 - Data is not stored or analyzed deeply.
4. **Limited Communication Monitoring**
 - Some advanced EVs use CAN bus monitoring.
 - Mostly accessible only by manufacturers.

Limitations of Existing System

- Monitoring is limited to **vehicle display only**.
- No real-time remote monitoring facility.
- Battery data is not available to users through mobile apps in low-cost EVs.
- Difficult to predict battery failures early.

- No cloud storage for long-term analysis.
- Maintenance is reactive rather than predictive.
- Lack of GPS integration and remote diagnostics.

PROPOSED SYSTEM

The proposed system introduces an **Electric Vehicle Battery Parameters Monitoring System using IoT** that continuously monitors EV battery conditions and sends data to a cloud platform for real-time tracking, analytics, and alerts.

This system helps EV owners and service providers monitor battery health remotely using a mobile or web dashboard.

PARAMETERS MONITORED IN PROPOSED SYSTEM

- **Battery Voltage**
- **Battery Current**
- **Battery Temperature**
- **State of Charge (SOC)**
- **State of Health (SOH)**
- **Charging/Discharging Status**
- **Battery Power Consumption**
- **Battery Fault Detection (overcharge, short circuit, overheating)**

WORKING OF PROPOSED SYSTEM

1. Sensors measure battery voltage, current, and temperature continuously.
2. Microcontroller collects and processes sensor readings.
3. SOC and SOH are calculated using algorithms.
4. Data is transmitted to cloud through IoT connectivity.
5. Cloud platform stores data and generates visual graphs.
6. If abnormal conditions are detected (overheating, overcurrent, low voltage):
 - Alert notification is sent to user/service center.
7. Users can monitor battery parameters remotely using app/dashboard.

FEATURES OF PROPOSED SYSTEM

- Real-time EV battery monitoring.

- Cloud-based data storage and analysis.
- Remote access through mobile/web dashboard.
- Battery fault prediction and preventive maintenance.
- Alerts for overcharging, overheating, and deep discharge.
- Improves battery safety and lifespan.

ADVANTAGES OF PROPOSED SYSTEM

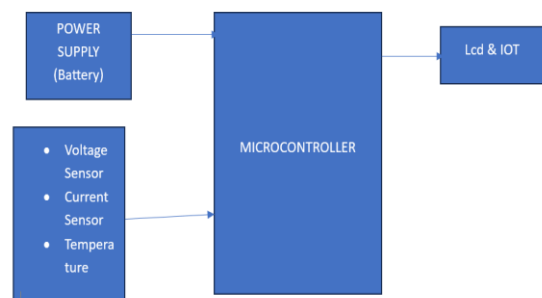
- Enhances battery safety by detecting faults early.
- Helps reduce maintenance cost.
- Improves driving reliability.
- Supports predictive analytics for battery health.
- Useful for EV fleet management systems.
- Increases battery efficiency and lifespan.

COMPARISON TABLE

Feature	Existing System	Proposed System
Monitoring	Dashboard limited	Cloud-based remote monitoring
Parameters	Basic voltage/temp	Voltage, current, temp, SOC, SOH
Alerts	Local alerts only	Mobile/SMS/email alerts
Data Storage	Not available	Cloud data logging
Predictive Analysis	Not possible	Possible using analytics/ML
User Accessibility	Limited	Mobile/Web access anytime

IMPLEMENTATION

BLOCK DIAGRAM



BLOCK DIAGRAM EXPLANATION

- The system begins with a power supply (battery) that provides energy to all components.
- This battery represents the EV battery whose parameters are to be monitored.
- Multiple sensors are connected to measure key battery parameters.
- The voltage sensor continuously measures the battery voltage level.
- The current sensor tracks charging and discharging current in real time.
- The temperature sensor monitors thermal conditions to prevent overheating.
- These sensors convert physical parameters into electrical signals.
- The sensor outputs are fed into the microcontroller for processing.
- The microcontroller acts as the central control unit of the system.
- It collects real-time data from all connected sensors.
- Analog signals are converted into digital values using ADC inside the controller.
- The processed data is used for parameter estimation like SoC and SoH.
- AI algorithms can be integrated within or alongside the controller.
- These algorithms analyze patterns and predict battery behavior.
- The system can detect abnormalities such as overvoltage or overheating.
- Processed information is displayed on the LCD for local monitoring.
- Simultaneously, data is transmitted to cloud platforms using IoT modules.
- Remote users can monitor battery status through web or mobile applications.
- The framework enables predictive maintenance and fault diagnosis.
- Overall, the system improves safety, efficiency, and lifespan of EV batteries.

WORKING

Step	Process	Description
1	Power Supply	The EV battery provides power to the microcontroller, sensors, LCD, and IoT module.
2	Sensing	Sensors measure key parameters: Voltage, Current, Temperature.
3	Data Acquisition	Sensor data is continuously collected and sent to the microcontroller.
4	Data Processing	Microcontroller processes raw data and prepares it for analysis.

Step	Process	Description
5	AI Analysis	AI algorithms analyze data to estimate State of Charge (SoC) and State of Health (SoH) and detect anomalies.
6	Communication	Processed data is sent to LCD display and IoT cloud platform.
7	Output	Real-time monitoring, alerts, and predictive maintenance insights are generated.

ADVANTAGES

Category	Details
Real-Time Monitoring	Continuous tracking of battery parameters
Predictive Maintenance	Detects faults before failure
Improved Safety	Prevents overheating, overcharging
Accuracy	AI improves SoC & SoH estimation
Cost Saving	Reduces maintenance and replacement costs
Remote Access	Data available via IoT/cloud
Performance Optimization	Enhances battery efficiency and lifespan

DISADVANTAGES

Category	Details
High Cost	AI + IoT implementation is expensive
System Complexity	Requires integration of hardware and software
Data Dependency	Needs large datasets for accurate AI models
Connectivity Requirement	IoT depends on internet availability
Security Risks	Data privacy and cyber threats possible

Category	Details
Maintenance	Sensors and modules need periodic calibration

APPLICATIONS

Area	Use Case
Electric Vehicles (EVs)	Real-time battery monitoring and safety
Fleet Management	Monitor multiple EVs remotely
Battery Manufacturing	Testing and quality analysis
Energy Storage Systems	Monitoring lithium-ion battery banks
Smart Grid Systems	Battery usage optimization
Research & Development	AI model training and battery analysis

CONCLUSION The study develops an IoT-based monitoring system to evaluate key parameters of lithium-ion batteries in electric vehicles, including temperature, current, voltage, and State of Charge (SOC). The system reliably collected and analyzed real-time data, ensuring all monitored parameters stayed within the expected operational ranges during both charging and discharging cycles. The integration of multiple sensors enabled comprehensive monitoring, allowing for the timely detection of issues such as overheating or excessive discharge. A cloud-based platform for data visualization further improved usability by providing stakeholders with valuable insights into battery health and performance. This study underscores the significant role of IoT technologies in enhancing battery management systems for electric vehicles. By facilitating real-time monitoring and analysis, the system supports improved battery efficiency, longevity, and safety. Future developments, including the integration of predictive analytics and monitoring of multiple batteries, could expand the system's capabilities, advancing smarter and more reliable electric vehicle technologies.

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