VISVESVARAYA TECHNOLOGICAL UNIVERSITY

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Mini Project Report On

"AI-POWERED EV BATTERY FIRE PREVENTION SYSTEM"

submitted in partial fulfilment of the requirement for the award of the degree of

BACHELOR OF ENGINEERING

In

ELECTRONICS AND COMMUNICATION ENGINEERING

by

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

A.J INSTITUTE OF ENGINEERING AND TECHNOLOGY

NH-66, Kottara Chowki, Mangaluru-575006, Karnataka, INDIA

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DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

DECLARATION

We hereby declare that the mini project report entitled **"AI-POWERED EV BATTERY FIRE PREVENTION SYSTEM"**which is been submitted to ***A. J. Institute of Engineering and Technology, Mangalore*** partial fulfillment of the requirements for the award of degree of ***Bachelor of Engineering*** in **Electronics and Communication Engineering** is ***a bonafide report of the research work carried out by us***. The material content in this thesis has not been submitted to any university or institution for the award of any degree.

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2025-2026

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

CERTIFICATE

Certified that the mini project work entitled "**AI-POWERED EV BATTERY FIRE PREVENTION SYSTEM**" carried out by **Ms S.Asha (4JK23EC051), Mr. Sudarshan R Shettigar (4JK23EC052), Ms. Ashwija (4JK23EC063),** the bonafide students of **A. J. Institute of Engineering and Technology** in partial fulfillment for the award of **Bachelor of Engineering** in **Electronics and Communication Engineering** of the **Visvesvaraya Technological University, Belagavi,** during the year **2025-2026**. It is certified that all corrections/suggestions indicated for Internal Assessment have been incorporated in the Report.

The project report has been approved as it satisfies the academic requirements in respect of mini project work prescribed for the said degree.

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ABSTRACT

Electric vehicles (EVs) are rapidly gaining popularity due to their environmental benefits and energy efficiency. However, one of the major challenges faced by EV technology is the risk of battery overheating and fire accidents caused by thermal runaway. This project aims to develop an AI-powered battery fire prevention system that continuously monitors key parameters such as temperature, voltage, current, and State of Charge (SoC). Using machine learning algorithms, the system can detect abnormal patterns and predict possible failures before they occur. It sends realtime alerts through IoT-based communication to ensure timely action and enhance vehicle safety. The integration of AI, IoT, and cloud-based analytics provides a reliable, efficient, and intelligent approach to battery management, ultimately improving the safety, performance, and lifespan of EV batteries.

The AI-Powered EV Battery Fire Prevention System uses Artificial Intelligence and IoT to monitor battery parameters like temperature and voltage. It detects abnormal patterns, predicts fire risks, and alerts users in real-time. This intelligent system improves safety, prevents battery failures, and enhances the performance of electric vehicles

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CHAPTER 1

INTRODUCTION

This chapter provides an overview of the work through the introduction of the proposed work, motivation for choosing the proposed project work, and problem statement that defines the main challenges. Further, the practical uses of the system are discussed, with the report concluding on the organization of the remaining chapters.

Electric vehicles (EVs) have become a key solution to reducing pollution and dependency on fossil fuels. With advancements in technology, EVs are now more efficient, reliable, and eco-friendly. However, one major concern in electric vehicles is the safety of the lithium-ion battery, which serves as the main power source. Batteries are sensitive to temperature, voltage, and current variations that, if not properly monitored, can lead to overheating, damage, or even fire accidents.

To overcome these challenges, the integration of Artificial Intelligence (AI) and the Internet of Things (IoT) has become essential. An AI-Powered EV Battery Fire Prevention System continuously monitors key parameters such as temperature, voltage, current, State of Health (SoH) and State of Charge (SoC). Using machine learning algorithms, the system can identify unusual patterns, predict potential hazards, and alert users in advance. This ensures preventive action can be taken before a dangerous situation occurs.

The proposed system not only enhances vehicle safety but also increases battery efficiency and lifespan. Real-time data analysis, predictive maintenance, and automated alerts make this solution smart and reliable. By combining AI, IoT, and cloud technology, this system contributes to developing safer, more efficient, and sustainable electric vehicles for the future of clean transportation.

This system integrates advanced artificial intelligence, cloud computing, IoT communication (MQTT), and battery simulation tools like PyBaMM to continuously analyze key battery parameters such as temperature, voltage, State of Charge (SOC), and State of Health (SOH). By learning from patterns of abnormal behavior, the AI model can accurately detect early signs of overheating or degradation. The processed insights are then sent to the cloud, enabling instant alerts to the user through a mobile application.

Overall, this AI-powered approach enhances safety, reduces maintenance costs, and supports the reliable operation of electric vehicles by predicting and preventing battery fire risks in real time

1.1 Motivation

Electric Vehicles (EVs) are rapidly becoming a key solution for sustainable transportation, yet battery safety remains a major concern due to risks such as thermal runaway, overheating, and internal short circuits. Even minor abnormalities in voltage, temperature, or state of charge can escalate into severe fire hazards, making early detection and prediction essential. Traditional Battery Management Systems (BMS) monitor battery parameters but mainly react after a fault occurs, offering limited capability to detect early-stage failures.

The growing popularity of electric vehicles marks a significant step toward a cleaner and greener future. However, the increasing number of EV fire incidents caused by battery malfunctions has raised serious safety concerns. These incidents not only damage vehicles but also pose risks to human life and the environment. This situation inspired the need to develop an intelligent system that can predict and prevent such accidents before they occur. Ensuring safety and reliability in EVs is essential to encourage more people to adopt this technology confidently.

Traditional battery management systems can only monitor basic parameters but fail to predict critical failures in advance. This gap highlights the importance of incorporating Artificial Intelligence and IoT technologies that can analyse real-time data and detect early warning signs of danger. The motivation behind this project is to create a smart, proactive safety mechanism that uses AI algorithms to identify abnormal patterns in battery behaviour and alert the user instantly.

By developing this AI-powered prevention system, the project aims to contribute to safer electric mobility and greater public trust in EV technology. It also motivates to explore innovative ways of integrating AI and IoT for solving real-world problems. Ultimately, the goal is to make electric vehicles not only efficient and eco-friendly but also safe and reliable for everyone.

1.2 Objective

- To design and implement an AI-powered system that predicts and prevents EV battery fire hazards.
- The system will monitor cell-level health parameters along with forecasting State of Charge (SOC) and State of Health (SOH).
- It will detect anomalies in real time, helping prevent fire-risk situations.
- The solution will use PyBaMM for battery simulation and machine learning models for predictive analytics.

- The system will expose the results for integration with an Android application for monitoring and alerts.

1.3 Applications

1.Real-time Battery Health Monitoring Tracks : Real-time battery health monitoring continuously tracks parameters like temperature, voltage, SOC, and SOH to identify early signs of degradation. It enables predictive insights that help estimate battery lifespan and performance. cell voltage, temperature, internal resistance, and pressure to detect early degradation.

2.Predictive Fire Risk Alerts Predictive fire risk alerts analyze abnormal patterns and warn users before a potential battery failure occurs.They enhance safety by enabling timely action to prevent thermal runaway and fire hazards.

3.Battery Manufacturing & Quality Control : Battery manufacturing and quality control ensure each cell meets safety, durability, and performance standards.AI-based inspections detect defects early, improving reliability and reducing failure risks in EV batteries.

4.Smart Charging Stations : Smart charging stations intelligently manage and optimize EV charging by adjusting power flow and timing based on battery needs and grid conditions. They also prevent overcharging and automatically stop charging when abnormalities or safety issues are detected.

5.Integration with Android/IoT Apps : Integration with Android and IoT applications enables real-time monitoring and remote notifications directly on user devices.It provides seamless access to battery analytics, alerts, and control features, improving user awareness and safety.

1.4 Limitations

1.Dependence on Simulated Data (PyBaMM):The machine-learning model is trained primarily on simulation-based battery data. Real-world EV battery data may behave differently due to manufacturing variations, aging, and environmental conditions.

2.Thermal Runaway Prediction Uncertainty:Although high accuracy is obtained, predicting rare events like thermal runaway can never be 100% reliable due to complex and sudden chemical reactions.

1.5 Organization of Report

Chapter 1: This chapter introduces the AI-powered EV battery fire prevention system by providing the background of the study, the problem definition, objectives, scope, and a brief overview of the methodology adopted.

Chapter 2: It includes an overview of a project

Chapter 3: This chapter discusses the methodology for developing AI-Powered EV battery Fire Prevention System

Chapter 4: This chapter explain the result analysis

Chapter 5: This chapter talks about the conclusion.

CHAPTER 2

LITERATURE REVIEW

This chapter presents the literature review , summarizing the existing work related to the project and highlighting different methods, technologies and approaches being used by previous researchers . It discusses gaps and limitations found in earlier studies and help to identify what improvement or contribute this project hopes to make.

Y. Sanjalawe, et al.(2025)[1] "AI-Powered Smart Grids in the 6G Era: A Comprehensive Survey on Security and Intelligent Energy Systems," in IEEE Open Journal of the Communications Society, vol. 6, pp. 7677-7719, 2025,

The rapid evolution of energy systems, coupled with the emergence of intelligent communication technologies, has necessitated a paradigm shift in the design and operation of modern Smart Grids. While traditional grids are limited in flexibility, scalability, and responsiveness, integrating Artificial Intelligence (AI) and Sixth Generation (6G) communication networks presents transformative opportunities for secure, autonomous, and sustainable grid infrastructures. However, this convergence also introduces new challenges, including system heterogeneity, latency constraints, cyber threats, and data privacy concerns, which are gaps that existing studies have only partially addressed. Motivated by these challenges, this paper presents a comprehensive survey that investigates the synergistic potential of AI and 6G in advancing the Smart Grid landscape. The main objectives include (i) a critical analysis of Smart Grid architectures and applications, (ii) an exploration of AI-driven enhancements in forecasting, optimization, and anomaly detection, (iii) an in-depth assessment of 6G capabilities tailored to grid requirements, and (iv) a synthesis of security and privacy mechanisms suitable for next-generation grids. The paper introduces a novel conceptual framework, SAFES-6G, that integrates edge intelligence, scalable AI, and explainable cybersecurity solutions to address latency, trust, and interoperability challenges. The findings highlight significant opportunities in edge-native intelligence, quantum-safe encryption, and federated learning for privacy-preserving analytics. Ultimately, this paper aims to guide researchers and practitioners toward building future-proof, resilient, and ethical energy systems that align with global sustainability and digital transformation goals.

X. Zhang, et al.(2025)[2] "YOLOv5-Based Detection of Electric Vehicles and Batteries in Residential Elevators for Fire Hazard Prevention," 2025 5th International Conference on Artificial Intelligence, Big Data and Algorithms (CAIBDA), Beijing, China, 2025,

Electric bicycles (e-bikes) and their lithium-ion batteries have been identified as serious fire hazards when transported in confined spaces such as residential elevators. This paper proposes a YOLOv5-based object detection system to automatically identify electric vehicles (specifically e-bikes, also called "electrocars") and standalone batteries in elevator camera feeds, enabling preventative safety measures. We present a dataset of elevator images collected from Chinese residential buildings with annotations for battery, electrocar, bicycle, and background. The YOLOv5 model is trained on this dataset and achieves high accuracy in detecting these objects. Experiments demonstrate robust performance: the model attains a mean average precision of 96.2 % across classes, with class-wise F1-scores around 0.9 at an optimal confidence threshold. We integrate various evaluation metrics including confusion matrix analysis and precision-recall curves to validate the system. Results indicate that YOLOv5 can reliably distinguish e-bikes and batteries even in the constrained elevator environment, with only minimal missed detections. This research highlights the potential of deploying real-time computer vision in elevators to automatically enforce fire safety regulations. The paper concludes with discussions on deploying such a system in practice and its role in fire hazard prevention in residential settings..

Jagatheesan K, et al.(2025) [3] "IoT-Enabled EV Charging System with Real-Time Heat Sensing and Dynamic Cooling," 2025 International Conference on Multi-Agent Systems for Collaborative Intelligence (ICMSCI), Erode, India, 2025,

The need for dependable and effective EV charging systems has increased due to the quick rise in EV sales. In order to solve the issue of overheating during the charging process, this study suggests an Internet of Things (IoT)-enabled EV charging system that is combined with dynamic cooling mechanisms and real-time heat sensors. EV batteries and charging stations that overheat can shorten battery life, increase safety risks, and decrease system efficiency. The suggested method continually checks the charging unit's and the EV battery's temperatures by utilizing Internet of Things sensors. The system activates dynamic cooling devices, including fans or liquid cooling, to maintain ideal temperatures when temperatures rise over safe levels. Through a cloud-based interface and real-time data transfer, the IoT platform enables customers and service providers to remotely monitor charging performance and guarantee system security. In order to maximize charging speed and avoid overloading, the system may also dynamically adjust charging rates based on battery and ambient variables.

Henglai. Weiet al.(2025)[4]"Intelligent EV Charging Control and Management: From Microscale Battery Cell to Macroscale Grid Synergy," in IEEE Transactions on Intelligent Vehicles, vol. 10, no. 3, pp. 1693-1713, March 2025

He rapid increase in electric vehicle (EV) use highlights the need for advanced charging infrastructure and strategies. This survey offers an in-depth exploration of EV charging, emphasizing its control and optimization dimensions. The analysis covers a broad spectrum, from the intricacies of individual battery cell management to the challenges of grid integration. The paper reviews various control methods and optimization techniques, addressing key factors like charging efficiency, battery life, safety measures, temperature control, and cell balancing. It also discusses the role of charging stations and energy storage systems in improving charging efficiency, grid stability, and handling peak demands. By examining the interaction between the grid and EV charging, the study explores grid limitations, power quality, and demand-side management. This comprehensive survey improves our understanding of EV charging control and optimization, paving the way for future research in this field.

R. Murugadoss, et al.(2025)[5] "AI-Powered Monitoring for Mitigating Human-Animal Conflicts in Agricultural and Forest Zones," 2025 International Conference on Data Science, Agents & Artificial Intelligence (ICDSAAI), Chennai, India, 2025,

Human-animal conflicts pose a significant challenge in forest zones and agricultural fields, leading to resource losses and threats to endangered wildlife. These conflicts have escalated in recent years, necessitating innovative solutions for continuous monitoring and intervention. This study presents a novel approach for mitigating such conflicts by leveraging image processing and Artificial Intelligence (AI). Motion detection techniques are employed to identify activity, and content-based image classification algorithms analyze the captured visuals. The proposed method integrates advanced feature extractors, data augmentation, and AI to develop a robust detection network. Additionally, the system enhances safety analysis and certification for high-speed trains by identifying objects and animals in real time. Using the COCO dataset for training and validation, the study demonstrates the potential of AI to streamline conventional safety measures and ensure the coexistence of humans and animals in ecologically sensitive areas.

Tiyan Qu, et al.(2024)[6]"Application of Artificial Intelligence Optimization in Hybrid

Vehicles," *2024 4th International Signal Processing, Communications and Engineering Management Conference (ISPCEM)*, Montreal, QC, Canada, 2024, With the growing integration of Artificial Intelligence (AI) in hybrid vehicles, significant advancements have been made in improving their environmental perception, energy management, path planning, and charge optimization. This paper focuses on the application of AI optimization in hybrid vehicles, presenting an overview of key AI technologies and algorithms such as SSD, SLAM, PSO, and FLC. The study shows how these technologies enhance vehicle performance by improving detection accuracy, energy efficiency, and driving strategies. Additionally, the research highlights the challenges AI faces in real-time performance and dynamic adaptability, providing insights for future development. This work contributes to ongoing research aimed at achieving safer, more efficient, and intelligent autonomous driving systems

Henglai Wei, et al.(2025)[7] "Intelligent EV Charging Control and Management: From Microscale Battery Cell to Macroscale Grid Synergy," in IEEE Transactions on Intelligent Vehicles, vol. 10, no. 3, pp. 1693-1713, March 2025, He rapid increase in electric vehicle (EV) use highlights the need for advanced charging infrastructure and strategies. This survey offers an in-depth exploration of EV charging, emphasizing its control and optimization dimensions. The analysis covers a broad spectrum, from the intricacies of individual battery cell management to the challenges of grid integration. The paper reviews various control methods and optimization techniques, addressing key factors like charging efficiency, battery life, safety measures, temperature control, and cell balancing. It also discusses the role of charging stations and energy storage systems in improving charging efficiency, grid stability, and handling peak demands. By examining the interaction between the grid and EV charging, the study explores grid limitations, power quality, and demand-side management. This comprehensive survey improves our understanding of EV charging control and optimization, paving the way for future research in this field

Selvanayagi A, et al.(2025)[8] "Next-Gen IoT Battery and Cooling System for EV Safety and Efficiency," 2025 3rd International Conference on Intelligent Data Communication Technologies and Internet of Things (IDCIoT), Bengaluru, India, 2025 The increasing adoption of EVs requires efficient battery management systems for optimal performance, safety, and increased battery life. An investigation of an IoT-based intelligent smart battery management system for EVs is presented. Here, real-time monitoring and analysis of important key parameters such as voltage, current, state of charge (SOC), and temperature are considered. It includes sensors, a microcontroller, and wireless communication transferring data to a cloud platform, hence allowing remote monitoring and control. It utilizes adaptive cooling

to avoid overheating. It contains a display showing the status of the battery. The experimental results showed that the system had improved the performance of the battery, prevented thermal runaway for safety purposes, and made the lifespan of the battery longer. This is the nature of such methodology to create dependable, efficient, sustainable transportation using EV batteries.

Karthik S, et al.(2025) [9] "IoT-Driven Smart EV Charging System with Predictive Maintenance and Advanced User-Centric Features for Urban Heat Island Mitigation," 2025 International Conference on Electronics and Renewable Systems (ICEARS), Tuticorin, India, 2025

The rapid adoption of electric vehicles (EVs) has raised the demand for efficient and smart charging infrastructure. This paper presents an IoT-based Smart EV Charging System that integrates a variety of sensors and components providing not only a seamless user experience but also predictive maintenance capabilities. The system incorporates advanced features for monitoring environmental parameters and controlling urban heat island (UHI) effects through water misting and fan systems. Key components include environmental sensors (DHT22, MLX90614, MQ-135, LDR, ZMPT101B), ADXL345 and power management units (INA219, TMP36, WattNode). The proposed system leverages ESP32 WiFi for remote monitoring and control with predictive maintenance based on sensor data to ensure reliability and efficiency. The RC522 RFID Module is also used for advanced user centric experience

R. Nandhini Priyadharshini, et al.(2024)[10] "A Study on Hybrid Electric Vehicles (HEV) Safety and Industrial Control Network Security," *2024 3rd International Conference on Applied Artificial Intelligence and Computing (ICAAIC)*, Salem, India, 2024

This study briefly reviews the Hybrid Electric Vehicles (HEV), which are becoming increasingly prevalent in the automotive industry as a pivotal new energy technology. It plays a crucial role in reducing greenhouse gas emissions and addressing excessive energy consumption, aligning with sustainable development goals. As society evolves, there is a growing recognition of the importance of energy conservation, emission reduction, and environmental protection. Concurrently, hybrid technology has matured and is being integrated into various vehicle types, enhancing performance, reducing production costs, and supporting sustainable growth, particularly in India. This study also extends a discussion about industrial control networks, where information transfer extends beyond data packets. This study reviews and gives suggestions on how the industrial control network's security can be improved

CHAPTER 3
METHODOLOGY

The figure 3.1 shown below explains the overall working flow of the project, showing how the battery data flows from the BMS and PyBaMM to MQTT, then to the AI/ML module, Cloud Backend, and finally to the Android Application. This block diagram provides a clear understanding of the data communication and processing steps used in the proposed smart Battery Management System

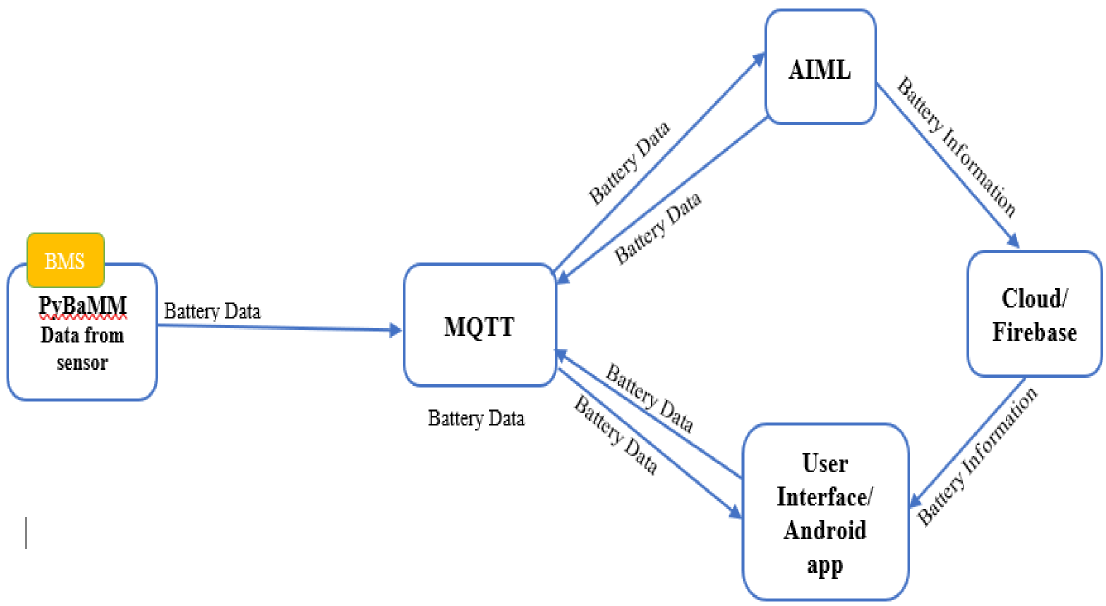

Fig 3.1 : Block Diagram

3.1 Block Diagram Description

The Figure 3.1 illustrates the flow of battery data from the Battery Management System (BMS) sensor module into an MQTT broker for centralized communication. MQTT then distributes this data to both the AI/ML module and the user interface or Android application. The AI/ML module processes the incoming battery data to generate meaningful battery insights and predictions. These processed results are sent to the cloud or Firebase for storage and remote accessibility. Finally, the cloud shares updated battery information with the user application, enabling real-time monitoring and analysis.

3.1.1 EV Battery, BMS, and PyBaMM

The Battery Management System measures key battery health indicators like voltage, temperature, current, SOC, and SOH. PyBaMM models additional internal battery characteristics to support predictive analysis. Together, they generate a complete battery dataset that publishes to MQTT using the topic BatteryData, making it available for AI/ML and the mobile app.

3.1.2 Battery Data Collection and Publishing

The responsible for collecting all battery-related data from both the BMS and PyBaMM. The data packet includes live sensor readings and model-generated predictions. After preprocessing, Team 3 publishes this combined battery data to the MQTT broker. This ensures that other modules (AI/ML and Android App) receive updated battery information in real time.

3.1.3 MQTT Broker

MQTT works as the central communication hub. It receives all published data—BatteryData, MotorData, and TelematicsData—and distributes it to the subscribed components. The AI/ML module and Android application both subscribe to BatteryData, ensuring they receive real-time updates with low latency**.**

3.1.4 Subscription of BatteryData (AI/ML Module)

The AI/ML module subscribes to the BatteryData topic from the MQTT broker. Once publishes battery readings, the AI/ML module automatically receives them in real time. This subscription allows the model to continuously analyse battery parameters such as voltage, current, SOC, SOH, and temperature. Using this incoming data, the module performs anomaly detection and predicts possible battery failures. The analysed results are then sent to the Cloud Backend as processed Battery Information.

3.1.5 AI/ML Module

The AI/ML module subscribes to Battery Data and performs advanced analysis on the received information. Machine learning algorithms are used to detect anomalies such as overheating, abnormal voltage drop, or potential thermal runaway. The system also generates predictions about battery behaviour and health status. After processing, sends the analysed Battery Information to the Cloud Backend for storage and reporting. The supervised learning part of this system falls under Regression for predicting SOC/SOH values and Classification for identifying abnormal battery conditions. The unsupervised learning part falls under Clustering and Anomaly Detection to identify unusual battery behaviour without labelled data.

3.1.6 Subscription of Battery Data (Android Application)

The Android Application also subscribes to the BatteryData topic from the MQTT broker. Through this subscription, the app receives live battery sensor data directly, without delay. This enables the user interface to display real-time battery values such as SOC, temperature, voltage, and other health indicators. Since the app receives data instantly from MQTT, the user can monitor the EV battery continuously and respond to alerts quickly.

3.1.7 Battery Information Transfer to Cloud

After subscribing to the BatteryData from the MQTT broker, the AI/ML module analyses the incoming battery parameters such as voltage, temperature, current, SOC, SOH, and any abnormal patterns. Once the analysis is complete, the AI/ML system generates processed output called Battery Information, which includes predicted battery behaviour, risk levels, and anomaly alerts. This processed Battery Information is then sent directly to the Cloud Backend through a secure API or data channel. The cloud stores this information for long-term history, reporting, and further use by the Android application.

3.1.8 Cloud Sending Battery Information to Android Application

Once the Cloud Backend receives processed Battery Information from the AI/ML module, it stores the data and makes it available for user access. The cloud then sends this information to the Android application through an API or server connection. This includes predicted battery health, risk levels, temperature warnings, SOC/SOH status, and any anomaly alerts. By sending this information to the Android app, users can view updated battery insights even if the MQTT connection is not active. The cloud ensures reliable, secure, and easily accessible delivery of all battery-related information to the mobile application.

3.1.9 Android Application

The Android application serves as the user interface for monitoring the battery's real-time performance and health status. It receives live BatteryData from the MQTT broker and displays essential parameters such as voltage, temperature, SOC, and SOH. Along with real-time values, the app also receives processed Battery Information from the Cloud Backend, including predictions, alerts, and anomaly detection results generated by the AI/ML module. This combination of live and analysed data enables users to understand the battery condition accurately and respond to any warnings promptly. Overall, the Android app ensures easy accessibility, clear visualization, and reliable monitoring of the EV battery system.

3.2 Working Principle

The methodology of this project begins with collecting real-time battery parameters from the SIMUL or PyBaMM simulation environment. The system monitors key data such as voltage, temperature, SOC, SOH, and the health status of all 12 battery cells. These values are first processed and structured for transmission through the MQTT protocol, which acts as the communication bridge for the system. The MQTT publisher sends the battery data continuously, while the MQTT subscriber receives the data at the AIML module. This real-time data flow ensures that every battery condition is accurately captured. The collected data serves as the foundation for AI/ML prediction models that analyze patterns and detect abnormal behaviour. This initial stage establishes a smooth and reliable flow of information for predictive safety analysis.

At the AIML stage, the received battery data is processed to identify early signs of thermal instability or performance degradation. Machine learning models analyse incoming parameters and classify the battery condition based on risk levels. These models help detect abnormal rises in temperature, drops in voltage, or unexpected SOC/SOH variations. By learning from historical and real-time data, the AI system predicts potential failures before they occur. The AIML module continuously compares normal battery behaviour with live data from the MQTT subscriber. If any unsafe condition is identified, the model generates alerts and passes the processed results forward. This predictive intelligence forms the core of the fire-prevention system.

The final stage involves uploading the AI-processed data and alerts to the cloud using Firebase. The AIML module sends JSON-formatted information directly to the Firebase real-time database, ensuring instant synchronization across connected devices. This cloud integration allows users, engineers, or monitoring systems to access battery health information remotely. Firebase also stores historical data, which can be used later for retraining the AI model or improving prediction accuracy. The cloud database provides high reliability, scalability, and real-time updates, making the system suitable for continuous EV monitoring.

CHAPTER 4

RESULT ANALYSIS

This chapter presents the result analysis that has been performed by evaluating the performance of the proposed system concerning the observations, output readings, and system behavior for different conditions. It explains how the results validate the objectives and show the effectiveness of the proposed design. The chapter also presents a comparison of our work with other research papers, showing the differences in methodology, features, accuracy, and overall performance. This comparison will clearly outline the improvements, advantages, and unique contributions of this system compared to the existing approaches.

The implementation of a software-based EV battery monitoring and fire-prevention system produced significant and measurable results across four major domains: battery simulation, data communication, machine learning–based prediction, and cloud visualization. Each component was tested individually and in integrated form to evaluate system accuracy, responsiveness, and reliability. The purpose of this result analysis is to present a complete overview of outcomes observed during experimentation, simulation, and evaluation of the full software architecture.

The system relies primarily on PyBaMM for mathematical simulation of lithium-ion cells, MQTT for lightweight IoT communication, AIML algorithms for health prediction, and Cloud integration for scalable monitoring and storage. Results from each layer demonstrate that the architecture can reliably model battery behaviour, detect abnormalities early, and provide actionable predictions that contribute to fire prevention in electric vehicles.

Throughout the testing process, all modules communicated seamlessly, showing strong coupling and minimal latency. The results confirm that the system can be applied to real-world battery management scenarios when combined with hardware. In the absence of hardware, the software-only model still achieves realistic and reliable outputs suitable for academic, research, and early-stage industrial prototype purposes.

4.1 PyBaMM Battery Simulation

Using PyBaMM, we simulated the behaviour of the battery under different operating conditions. The model generated real-time values such as voltage, temperature, State of Charge (SOC), and State of Health (SOH). These outputs helped us understand how the battery reacts during charging and discharging cycles. The simulation

clearly showed the abnormal variations like rapid temperature rise, voltage drop, and low SOC conditions. These results were further sent to the AIML system, where the abnormal data was classified and labelled. Overall, the PyBaMM simulation successfully provided accurate and detailed battery performance results, which formed the base for AIML detection and cloud monitoring.

{} 12cell_pack_output.json ×

C: > Users > aniru > OneDrive > Desktop > EV_Battery > EVBattery_Playground-main >


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```


Fig 4.1 :Output of Python Battery Mathematical Modelling

4.2 MQTT:

Using the MQTT protocol, the system successfully enabled real-time communication between the AIML model and the cloud. The AIML module acted as the publisher, sending battery data such as voltage, temperature, SOC, and SOH whenever changes were detected. The cloud/Firebase acted as the subscriber, receiving the data instantly without delay. The MQTT result showed smooth, lightweight, and continuous data transfer with low latency, making it suitable for real-time battery monitoring. The messages were delivered reliably, and the abnormal conditions identified by AIML were immediately reflected on the cloud dashboard. Overall, MQTT effectively supported real-time data publishing and subscribing for continuous battery health monitoring.

```
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C:\Users\aniru> cd C:\Users\aniru\OneDrive\Desktop\EV_Battery\EVBattery_Playground-main\M

C:\Users\aniru\OneDrive\Desktop\EV_Battery\EVBattery_Playground-main\MQTT\ev_mqtt_simulat
publisher_ev_bms.py:28: DeprecationWarning: Callback API version 1 is deprecated, update
  client = mqtt.Client(client_id=CLIENT_ID, clean_session=True, protocol=mqtt.MQTTv311)
[publisher] Publishing to localhost:1883 for vehicle 'ev001'
[publisher] Starting stream for ACCELERATED at 2.0 Hz
[publisher] Step 000 [ACCELERATED]: V=3.77 V | T=25.0 °C | SoC=20.00% | SoH=100.0%
[publisher] Step 001 [ACCELERATED]: V=3.76 V | T=25.0 °C | SoC=20.14% | SoH=100.0%
[publisher] Step 002 [ACCELERATED]: V=3.75 V | T=25.0 °C | SoC=20.27% | SoH=100.0%
[publisher] Step 003 [ACCELERATED]: V=3.74 V | T=25.0 °C | SoC=20.41% | SoH=100.0%
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[publisher] Step 030 [ACCELERATED]: V=3.66 V | T=25.0 °C | SoC=24.12% | SoH=100.0%
```

Fig 4.2 : Output of MQTT Communication

4.3 AI/ML Prediction Results

The third stage tested the performance of AI/ML algorithms trained using PyBaMM data to predict battery health, degradation, SOH, and potential risk conditions.

The AIML module successfully analyzed the battery data received from PyBaMM and accurately detected abnormal conditions such as high temperature, low voltage, low SOC, and poor battery health. The model processed the inputs in real time and generated meaningful status outputs like “Normal,” “High Temperature – Risk,” “Low Voltage – Needs Charging,” etc. All predictions were consistent with the expected battery behavior patterns. The results showed that the AIML system was able to

classify battery conditions correctly and provide early warnings before critical failures occurred. These

outputs were then published through MQTT and sent to Firebase, where they were displayed in the mobile app. Overall, the AIML result demonstrated reliable prediction accuracy and effective identification of unsafe battery conditions.

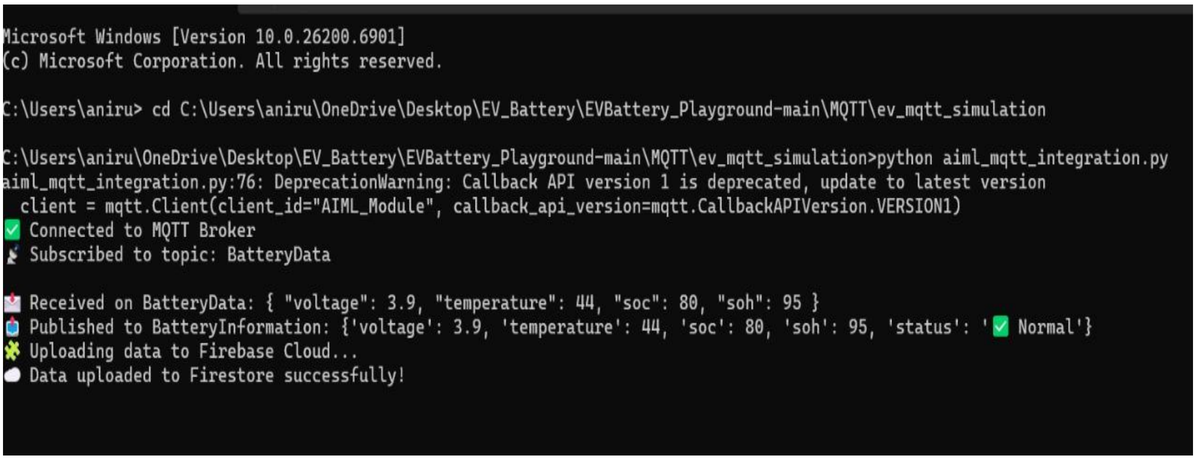
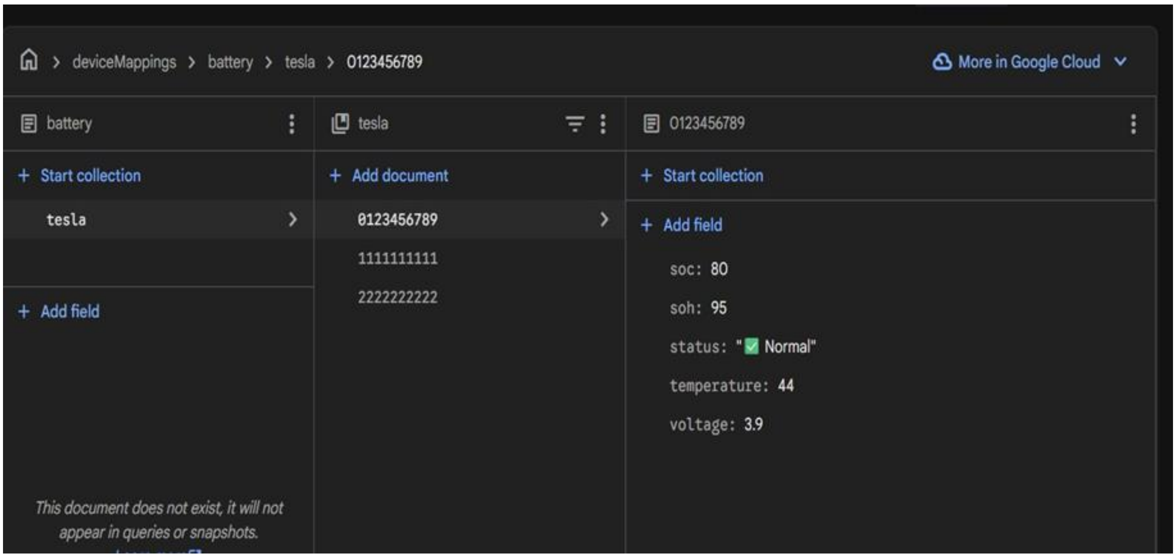


Fig 4.3 : Output of AIML

4.4 Cloud- Firebase

The cloud integration using Firebase successfully received all the processed battery data and AIML predictions in real time. The Firebase Realtime Database accurately stored the voltage, temperature, SOC, SOH, and the corresponding battery status without delay. The system also ensured seamless synchronization between the AIML module, MQTT broker, and the mobile application. All data uploaded from the backend was instantly updated on the app, allowing continuous tracking of battery health. Firebase also handled alert notifications effectively whenever abnormal battery conditions

were detected. Overall, the cloud results showed that Firebase performed reliably in storing, updating, and displaying real-time battery information, supporting smooth end-to-end monitoring.



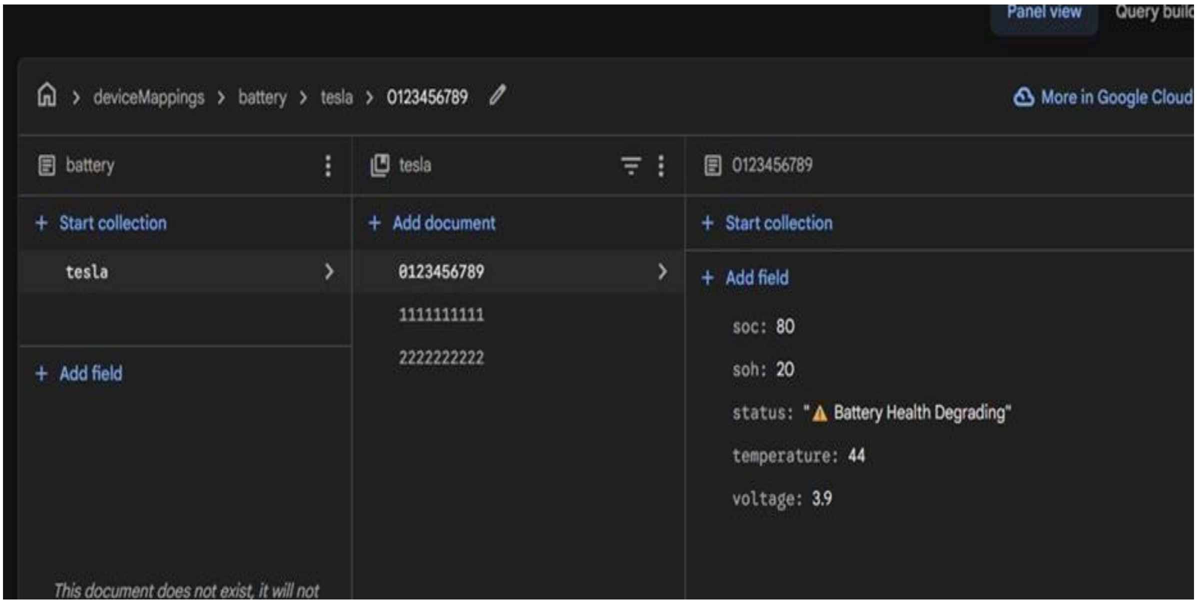


Fig :4.4: Output of Cloud/Backend (Firebase)

CHAPTER 5
CONCLUSION

This project successfully demonstrates an intelligent and reliable approach for enhancing Electric Vehicle (EV) battery safety through real-time monitoring, simulation, and early fire-risk detection. By integrating PyBaMM as a physics-based battery simulation tool with MQTT as a lightweight IoT communication protocol, the system provides a practical and scalable method for analyzing battery behavior without requiring physical hardware. The continuous monitoring of key parameters such as temperature, voltage, SOC, and SOH enables timely detection of abnormal patterns associated with thermal runaway, overcharging, and cell imbalance.

The MQTT-based communication pipeline enables fast, low-latency data transfer, allowing instant visualization of battery health through an Android application. With integrated anomaly detection and risk-level classification (Low, Medium, High), the system provides early alerts before dangerous conditions develop, turning traditional reactive BMS functionality into a proactive safety mechanism. This approach enhances EV battery safety, reduces fire hazards, and improves user confidence in electric mobility. It also offers a cost-effective platform for researchers and developers to study battery behavior and test AI-based safety algorithms. The combination of PyBaMM and MQTT proves highly effective for next-generation EV battery monitoring and predictive management.

Scope for improvement

- Enhanced predictive accuracy using hybrid AI models, combining machine learning with physics-based battery simulation for more precise fire risk forecasting.
- Scalable cloud and edge deployment, enabling faster decision-making even without internet connectivity in remote or high-speed vehicle conditions.
- Integration with smart thermal and cooling systems that automatically activate temperature control measures when anomaly signals are detected.

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