Early Fire Detection System for Electric Vehicle Battery Using Machine Learning and IOT

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Abstract— The increasing prevalence of Electric Vehicles (EVs) presents a pressing need for advanced safety measures, particularly concerning the risk of battery fires. Early detection of fire hazards within EV batteries is critical for preventing catastrophic events and ensuring user safety. In this study, we propose a novel approach utilizing a Machine Learning (ML) framework integrated with Internet of Things (IOT) technology for the early detection of fire in EV batteries. The system continuously monitors various parameters such as temperature, voltage, and current levels within the battery pack using IOT sensors. These sensor data are then processed by ML algorithms trained on historical datasets to identify patterns indicative of fire initiation. The proposed system aims to provide real-time detection of potential fire hazards, enabling prompt intervention and mitigation strategies. Through comprehensive experimentation and validation, we demonstrate the effectiveness and reliability of our approach in detecting fire incidents in EV

batteries, thus contributing to enhancing overall safety in the electric vehicle.

Keywords — Electric Vehicles (EVs), EV batteries, Machine Learning (ML), Internet of Things (IOT), real-time detection, IOT sensors.

I. INTRODUCTION

The increasing adoption of Electric Vehicles (EVs) has brought about significant advancements in automotive technology, promoting cleaner and more sustainable transportation options. However, as with any technology, EVs present unique challenges, one of which is the risk of battery-related incidents such as fires. The safety of EV batteries is paramount, not only for vehicle occupants but also for the surrounding environment and infrastructure.

Early detection of potential fire hazards in EV batteries is crucial for preventing catastrophic events and ensuring the continued safety and reliability of electric vehicles. Traditional methods of fire detection in EV batteries often rely on basic sensors and monitoring systems, which may not always provide timely and accurate warnings.

In recent years, the integration of Internet of Things (IOT) devices and Machine Learning (ML) algorithms has emerged as a promising approach for enhancing the safety and efficiency of various systems, including EVs. By leveraging IOT sensors for real-time data collection and ML algorithms for predictive analysis, it becomes possible to detect and mitigate fire risks in EV batteries more effectively.

This paper explores the application of a Machine Learning approach combined with IOT technology for the early detection of fire hazards in EV batteries. We delve into the challenges associated with current fire detection methods, discuss the advantages of using IOT-enabled sensors for data acquisition, and highlight the potential of ML algorithms for analyzing complex datasets to identify precursors to battery fires.

Furthermore, we present a framework for implementing an integrated IOT-Machine Learning system for fire detection in EV batteries, outlining the key components, data processing pipelines, and predictive models involved. Additionally, we discuss the implications of early fire detection on EV safety, reliability, and overall adoption.

Overall, this paper aims to provide insights into the role of IOT and Machine Learning in improving the safety of Electric Vehicles, particularly in the context of early fire detection in battery systems. By leveraging advanced technologies and data-driven approaches, we can mitigate risks, enhance performance, and accelerate the transition towards a sustainable future of transportation.

II. LITERATURE SURVEY

Electric vehicle charging detection and early warning system based on internet of thing---Outlines a novel detection and early warning system for illegal electric vehicle charging, utilizing Internet of Things (IOT) technology. The hardware components feature an STM8S single-chip microcomputer and a 433 MHz radio frequency module for wireless data transmission. To address electronic tag conflicts, the software implements an improved ALOHA algorithm. Experimental results demonstrate the system's efficacy in monitoring and issuing early warnings for electric vehicle charging, particularly on campus. Real-time monitoring of charging status and temperature allows for proactive intervention, while sound and light alerts are triggered when temperatures surpass safe thresholds, mitigating the risk of fire accidents. Overall, this innovative solution promises to enhance safety and security in electric vehicle charging environments, potentially preventing hazardous incidents and promoting sustainable transportation practices.

A fault diagnosis method for lithium-ion battery packs using improved rbf neural network---Highlights the importance of addressing high voltage safety concerns in electric vehicles, particularly focusing on the fault diagnosis of lithium-ion battery packs, which contribute to over 30% of electric vehicle accidents. The proposed method introduces an improved radial basis function (RBF) neural network for fault diagnosis. By collecting fault information from battery test equipment and determining fault levels, the system utilizes experimental data to train the RBF neural networks. Results demonstrate that the improved RBF neural networks achieve a remarkable diagnosis accuracy of approximately 100%, effectively identifying fault information within the lithium-ion battery packs. This method offers a promising approach to streamline fault diagnosis processes, potentially reducing complexities and enhancing safety measures in electric vehicle systems. The findings contribute significantly to the advancement of electric vehicle technology, ensuring safer and more reliable operation in the face of growing demand.

A multimodel fire detection and alarm system for automobiles using internet of things and machine learning---Introduces a novel fire detection and alarm system for vehicles aimed at reducing false alarms and improving accuracy. By leveraging multiple Internet of Things (IOT) sensors including smoke/gas, flame, temperature, and a visualization camera, the system detects fires at the smoldering stage and triggers an alarm only when actual fire or smoke is detected. Continuous image capture by the visualization camera enables real-time monitoring of the vehicle's interior for fire presence. Machine learning algorithms are employed on sensor and image data to minimize false alarms and enhance accuracy, utilizing various performance metrics for evaluation. This comprehensive approach promises to enhance safety in vehicles by ensuring timely and reliable fire detection, thereby mitigating the risk of human casualties and property damage. The system represents a significant advancement in vehicle fire safety technology, addressing a critical concern in vehicular safety.

An intelligent fire warning application using iot and an adaptive neuro-fuzzy inference system---Outlines the development of an advanced fire alarm system addressing the limitations of existing models. Utilizing a combination of sensors including flame detection, humidity, heat, and smoke sensors, the system aims to accurately detect genuine fire incidents while minimizing false alarms. The novel approach employs an Adaptive Neuro-Fuzzy Inference System (ANFIS) to assess the likelihood of fire presence based on changes in smoke, temperature, and humidity levels. Sensor data is processed through fuzzy logic and trained in ANFIS to determine the probability of fire occurrence. Notably, the system is designed for user convenience, with alerts sent directly to smartphones. Using small, cost-effective sensors, the solution ensures reproducibility and feasibility. MATLAB-based simulations demonstrate satisfactory results, validating the effectiveness of the proposed methodology in achieving reliable fire detection and alarm generation. This innovation holds promise for enhancing life safety and reducing false alarms in fire detection systems.

Machine learning based data-driven fault detection/diagnosis of lithium-ion battery---The abstract underscores the critical role of fault detection and diagnosis within battery management systems (BMS) for the safe and reliable operation of lithium-ion batteries (LIBs) in advanced applications. It highlights the adoption of machine learning (ML) techniques in BMS to predict crucial states of LIBs, such as state of charge, state of health, and remaining useful life, efficiently and accurately. Emphasizing the advantages of ML-based approaches over conventional methods, the paper offers a comprehensive review focused on the latest ML-based data-driven fault detection and diagnosis techniques. By providing insights into current challenges and future prospects, it serves as a valuable resource for researchers aiming to develop adaptive, reliable, and easy-to-implement fault diagnosis strategies for LIB systems. This comprehensive analysis aims to guide the research community towards enhancing fault diagnosis in LIB systems, addressing current issues and anticipating future challenges.

III. EXISTING SYSTEM

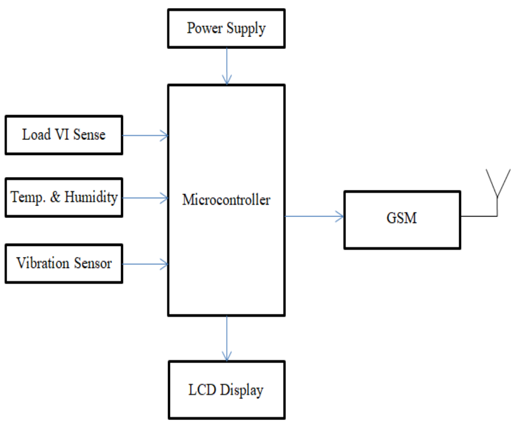
Traditionally, safety monitoring and automation systems were typically designed to meet the requirements of a single monitoring application. The EV application has already gone beyond the interconnection of a few large back-end systems, and more and more underground physical devices make the state of objects and their surroundings seamlessly accessible to software systems. As a matter of fact, most works are based on monolithic system architectures, which are brittle and difficult to adapt.

The existing systems for early fire detection in electric vehicle (EV) batteries typically rely on traditional methods such as thermal sensors or voltage monitoring systems. While these systems may provide some level of monitoring, they often lack the advanced capabilities necessary for early detection and proactive risk mitigation.

Traditional thermal sensors, for instance, are limited in their ability to detect subtle changes in temperature that may precede a fire incident. Similarly, voltage monitoring systems may only trigger alerts after a significant deviation from normal operating parameters, potentially leading to delayed responses.

Moreover, existing systems often operate in isolation, lacking the integration and real-time data analysis capabilities afforded by machine learning and Internet of Things (IoT) technology. This fragmentation can result in gaps in monitoring coverage and limited ability to detect complex patterns indicative of fire risks.

Overall, the existing systems for early fire detection in EV batteries fall short in terms of providing comprehensive and proactive safety measures.



BLOCK DIAGRAM

There is a clear need for more advanced solutions that leverage machine learning algorithms and IoT technology to enable early detection of fire risks and timely intervention to prevent catastrophic incidents.

DISADVANTAGE

• Environmental accidents

• High Maintenance

• Unpredictable Incidents

• Safety issues

• Possibly to adjust monitoring and control rules to ensure the safety

• The accuracy to a large extent owing to its low accuracy as a single parameter

IV. PROPOSED SYSTEM

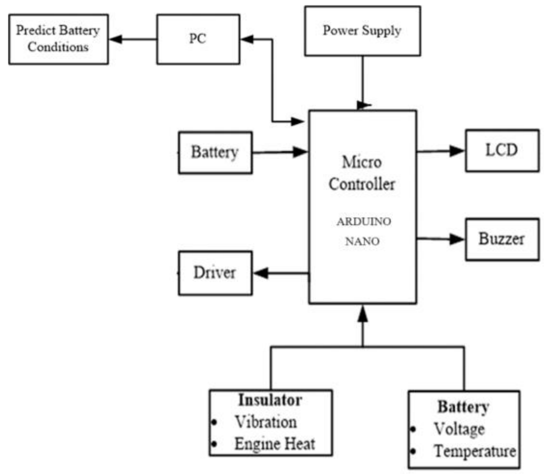
Reliable battery management is essential for safety in electric vehicles (EVs) due to the inherent risks associated with battery malfunction or failure. A comprehensive system for detecting and monitoring the conditions of EV batteries is crucial to ensure the safety of vehicle users and prevent potential accidents or hazards.

In this project, the primary objective is to develop a robust system capable of continuously monitoring the health and performance of EV batteries. This system will utilize various sensors and monitoring devices to track important parameters such as temperature, voltage, and state of charge. By constantly analyzing these parameters, the system can detect any abnormalities or potential issues with the battery.

Furthermore, the system will be designed to provide timely alerts to vehicle users via their mobile phones in case of any detected anomalies or critical battery conditions. This real-time notification mechanism ensures that users are promptly informed about the status of their vehicle's battery, allowing them to take appropriate action, such as seeking maintenance or adjusting their driving behavior to mitigate risks.

The proposed solution revolves around utilizing an embedded system based on a microcontroller, which is equipped with Internet of Things (IoT) connectivity. This approach enables seamless remote monitoring of devices involved in the project. By integrating IoT connectivity into the microcontroller, data from sensors and monitoring devices can be transmitted to a central server or cloud platform in real-time, facilitating remote monitoring and analysis.

This embedded system serves as the backbone of the comprehensive battery management solution, allowing for continuous monitoring of EV battery conditions. Through IoT connectivity, users can remotely access real-time data about their vehicle's battery health and receive timely alerts on their mobile phones in case of any detected anomalies or critical conditions.



BLOCK DIAGRAM

In proposed system the sensors will install in the battery pack of the EV. These sensors will constantly monitor things like temperature, voltage, and current. It will send this data to a central computer that has special software running on it.

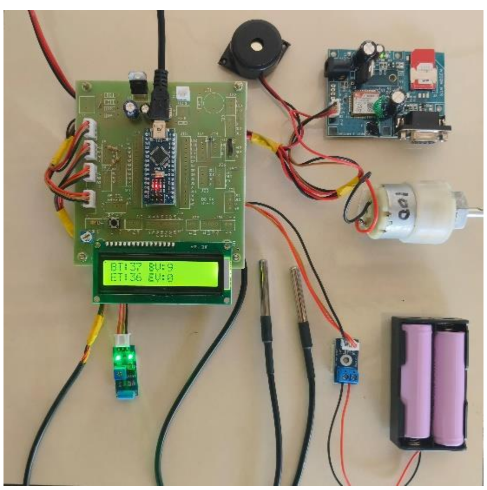
This software will use machine learning algorithms to analyse the data from the sensors. It will look for patterns that might indicate a fire risk, like sudden increases in temperature or unusual changes in voltage. If it detects anything concerning, it will send alerts to the EV driver.

By using machine learning and IoT, our system aims to catch fire risks early, keeping EV passengers and the surrounding areas safe. This project is important for improving the safety of electric vehicles and making them a more widely accepted form of transportation.

IV. RESULTS AND DISCUSSION

Discuss the process of data collection from various sensors monitoring battery temperature, battery voltage, engine vibration, and engine temperature. Present graphical representations of the collected data using Thingspeak software and MATLAB. Highlight any trends, patterns, or anomalies observed in the data.

Describe the process of training machine learning models using the collected sensor data. Specify the algorithms used for training, such as decision trees, random forests, support vector machines, or neural networks. Present the performance metrics achieved during the training phase, including accuracy, precision, recall, and F1-score.



HARDWARE IMPLEMENTATION

Evaluate the performance of the developed early fire detection system based on the trained machine learning models. Discuss the system's ability to accurately detect potential fire hazards in electric vehicle batteries. Present the detection time achieved by the system and compare it to traditional fire detection methods.

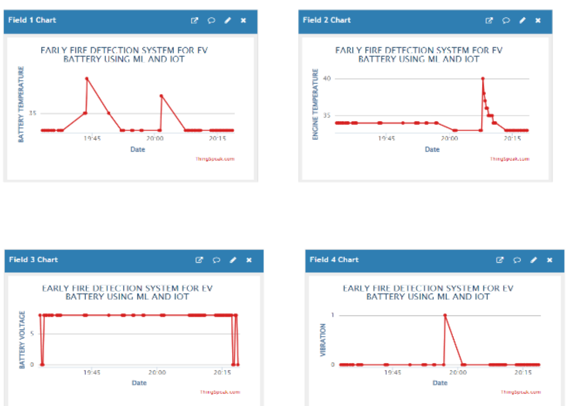
Discuss how integrating multiple sensors monitoring different parameters enhances the effectiveness of the fire detection system. Highlight the importance of considering various factors such as battery temperature, voltage, engine vibration, and temperature for early detection of fire hazards.

Discuss the contribution of machine learning algorithms in identifying patterns indicative of fire hazards in electric vehicle batteries. Highlight the advantages of using ML techniques, such as their ability to analyze complex datasets and adapt to changing conditions.

Discuss the role of IoT technology in real-time data acquisition from sensors and its integration with Thingspeak for visualization. Highlight the benefits of using Thingspeak and MATLAB for data visualization, such as facilitating easy interpretation of sensor data trends.

Explore potential real-world applications of the developed early fire detection system beyond electric vehicles. Discuss the implications of implementing such systems in enhancing safety and reducing the risk of fire-related accidents.

Address any limitations encountered during the project, such as sensor accuracy, data noise, or computational resources. Propose future research directions, such as improving sensor technology, refining machine learning models, or exploring additional parameters for monitoring fire hazards.



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Summarize the key findings of the project and their significance in advancing early fire detection systems for electric vehicle batteries. Emphasize the potential impact of the developed system in improving safety standards and mitigating risks associated with electric vehicles.

V. CONCLUSION

EV Control Systems have migrated from being dedicated, air-gapped, centralized infrastructures and have adopted the distributed, corporate systems accessible via the Internet. Although the efficiency, speed, precision quality is increased, this has exposed ICS to the unsecured Internet. Monitoring System for battery pack already designed and able to work well. Balancing cell is an action to prevent damage to the battery pack caused by voltage different between cells. Because the difference in cell voltage can make the lifetime of the battery decrease and break down quickly.

Although the efficiency, speed, precision quality is increased, this has exposed DL to the IoT. The proposed machine learning-based data analysis approach enables proactive and data-driven battery management strategies, leading to improved reliability, efficiency, and longevity of battery systems across various applications, including electric vehicles, renewable energy storage, and portable electronics.