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IoT-Based Fire Detection and Automatic Extinguishing System for EV Battery Safety

Prof. Shital Narayan Gavade¹, Mr. Darshan Shitalkumar Chougule², Ms. Pooja Sachin Neje³, Mr. Satej Sanjay Gaikwad⁴, Ms. Dhanashri Abhinandan Hatgine⁵

Electronics and Telecommunication Department, DKTE's Yashwantrao Chavan Polytechnic, Ichalkaranji

Abstract: In recent years, Electric Vehicles (EVs) have emerged as a sustainable and efficient alternative to conventional fuel-based vehicles. However, one of the major safety concerns associated with EVs is the risk of fire caused by battery overheating, short circuits, or overcurrent conditions. This paper presents an IoT-based Fire Detection and Automatic Extinguishing System designed to enhance battery safety in electric vehicles. The proposed system continuously monitors critical parameters such as battery temperature, smoke concentration, and current flow using dedicated sensors. A Node MCU (ESP8266) microcontroller processes the collected data and transmits real-time information to an IoT platform for continuous remote monitoring. When abnormal conditions are detected, the system automatically activates a solenoid valve to spray fire-extinguishing fluid and triggers a circuit breaker to isolate the power supply, thereby preventing further damage. Simultaneously, the user receives an instant alert through the IoT dashboard or mobile application. The developed system provides an intelligent, cost-effective, and reliable solution for early fire detection and prevention in EVs. Experimental results validate the system's efficiency in minimizing fire hazards and improving the overall safety and reliability of electric vehicle operations.

Keywords: IoT, Electric Vehicle (EV), Fire Detection, Battery Safety, NodeMCU (ESP8266), Solenoid Valve, Circuit Breaker, Lithium-Ion Battery, Smoke Sensor, Temperature Sensor, Overcurrent Protection, Fire Extinguishing System, Real-Time Monitoring, IoT Platform

I. INTRODUCTION

Electric Vehicles (EVs) are emerging as a sustainable alternative to conventional vehicles due to their zero emissions, low noise, and high efficiency. However, lithium-ion batteries used in EVs pose safety risks such as overheating, short circuits, and thermal runaway, which can lead to fires or explosions. Existing Battery Management Systems (BMS) mainly handle charging and discharging but lack fire prevention and suppression features.

To overcome this limitation, this paper proposes an **IoT-enabled Fire Detection and Automatic Extinguishing System** for EV batteries. The system uses sensors to monitor temperature, smoke, and current in real time through a **NodeMCU (ESP8266)** microcontroller, which sends data to an IoT cloud for remote monitoring. When abnormal conditions are detected, the system automatically activates a solenoid valve to release extinguishing material and disconnects the power supply to prevent escalation.

The IoT integration also provides instant alerts to users via a mobile or web dashboard. This low-cost and compact system ensures early fire detection, active suppression, and enhanced safety for various EV types, effectively bridging the gap between battery management and automated safety control.

II. WHY EVS CATCH FIRE?

- 1) Battery overheating (thermal runaway)
- 2) Overcharging or over-discharging
- 3) Internal short circuit in battery pack
- 4) Mechanical damage to battery cells
- 5) Poor or faulty Battery Management System (BMS)

III. BATTERY SPECIFICATIONS OF EV BIKE

- 1) Battery Type - Lithium-ion (Li-ion)
- 2) Nominal Voltage - 48 V to 72 V (commonly used in EV bikes)
- 3) Capacity - 20 Ah – 40 Ah (depending on vehicle range and motor power)

- 4) Energy Storage - 2 kWh – 3 kWh
- 5) Discharge Current - Continuous: 20 A – 40 A
- 6) Operating Temperature - -10 °C to 60 °C

IV. FIRE SUPPRESSION AGENTS FOR BATTERY FIRE

TABLE I

FIRE SUPPRESSION AGENTS FOR BATTERY FIRE

Agent	Battery Type	Release Moment	Suppression Effectiveness
Water Mist /Fine Spray	Li-ion, LiFePO ₄	During early flame or smoldering	High for small packs; cools and prevwnts spread
Class D Dry Powder (Lith-X/ Met-L-X)	Lithium metal (rare in bikes)	When lithium is exposed or fire starts	Very high; absorbs heat and isolates oxygen
CO ₂ Extinguisher	Li-ion, LiFePO ₄	When fire is surrounding the battery	Medium; displaces oxygen but doesn't cool cell
Fire Blanket / Thermal Blanket	All types	Immediately after fire ignition	Medium-High; contains heat, prevents fire spread
Gel-based Suppressants	Li-ion , LiFePO ₄	During or after ignition	High; coats battery, prevents reignition

V. METHODOLOGY

1) Data Collection:

Sensors continuously monitor the battery's temperature, current, and smoke levels.

2) Processing Unit:

The NodeMCU collects sensor signals, compares them with predefined thresholds, and determines whether a fire risk exists.

3) Decision and Action:

If values exceed safe limits, the controller triggers the solenoid valve to release the fire-extinguishing agent.

Simultaneously, it activates a circuit breaker to isolate the battery and stop current flow.

4) IoT Integration:

The NodeMCU connects to the IoT platform (Blynk or ThingSpeak) via Wi-Fi to upload live data. The user receives instant notifications or alarms on their smartphone or dashboard.

5) Feedback and Recovery:

Once normal conditions are restored, the system resets automatically and resumes monitoring.

VI. LITERATURE SURVEY

- 1) N. Kumar et al. (2022) – Proposed an IoT-based fire detection and control system using temperature and smoke sensors for real-time alerts.
 - Showed the importance of IoT for early fire warning.
- 2) Patil and P. Rane (2023) – Developed an automatic fire extinguisher for EV batteries using heat and gas sensors.
 - Helped in designing autonomous fire control in EVs.
- 3) M. Sharma et al. (2021) – Used NodeMCU (ESP8266) for IoT-based fire monitoring and alert system.
 - Proved NodeMCU's efficiency for IoT-based safety systems.
- 4) P. Sinha et al. (2022) – Studied thermal runaway in lithium-ion batteries and suggested continuous thermal monitoring.
 - Identified key reasons behind EV battery fires.
- 5) T. Mehta and K. Patel (2019) – Designed a solenoid valve-based automatic fire control system using IoT.
 - Supported the use of solenoid actuation for extinguisher control.

VII. PROPOSED SYSTEM

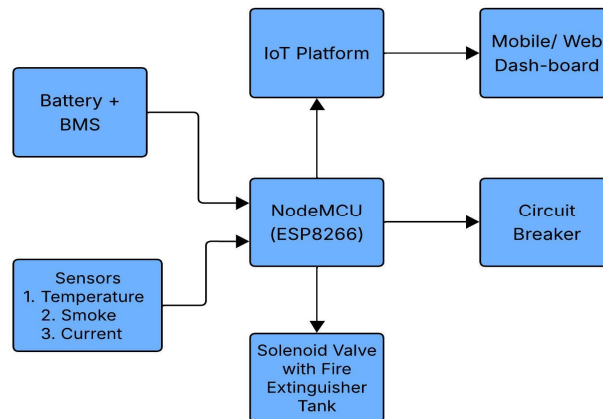


Fig. 1 Block Diagram

The IoT-Based Fire Detection and Automatic Extinguishing System for EV Battery Safety works on the principle of continuous monitoring, intelligent detection, and automatic action using sensors, a microcontroller, and IoT communication.

1) Monitoring Stage:

The system continuously measures important parameters like temperature, smoke, and current using dedicated sensors connected to the NodeMCU (ESP8266). The battery along with its Battery Management System (BMS) provides power and operational data to the controller.

2) Data Processing and Detection:

The NodeMCU processes the sensor data and compares it with preset threshold values.

If the temperature, current, or smoke level exceeds the safe limit, the system identifies it as a fire-risk condition.

The microcontroller then decides the required protective action.

3) Automatic Action:

The Solenoid Valve connected to a fire extinguisher tank is triggered to spray extinguishing fluid over the affected area.

At the same time, the Circuit Breaker disconnects the power supply from the battery to stop the current flow and prevent further damage.

4) IoT Communication and Alerts:

The NodeMCU transmits real-time data to the IoT platform (like Blynk or ThingSpeak) via Wi-Fi. The platform then sends alerts to the mobile or web dashboard, notifying the user about the detected fault or fire.

VIII. FUTURE SCOPE

- 1) **AI-Based Predictive Safety System** : Artificial Intelligence (AI) algorithms can be added to predict faults or fire risks before they occur by analyzing historical data and sensor trends.
- 2) **Advanced Fire Extinguishing Techniques** : Smart fire suppression systems with multiple extinguishing agents (CO₂, foam, or gel) suitable for lithium-ion battery fires.

IX. CONCLUSION

The proposed IoT-based Fire Detection and Automatic Extinguishing System ensures better safety for electric vehicles by monitoring temperature, smoke, and current in real time. When abnormal conditions occur, it automatically activates the fire extinguisher and cuts off power using a circuit breaker.



The system sends alerts to users through the IoT platform, providing quick response and preventing damage. It is low-cost, reliable, and easy to integrate with EVs, making it a smart solution for improving battery safety and vehicle performance.

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