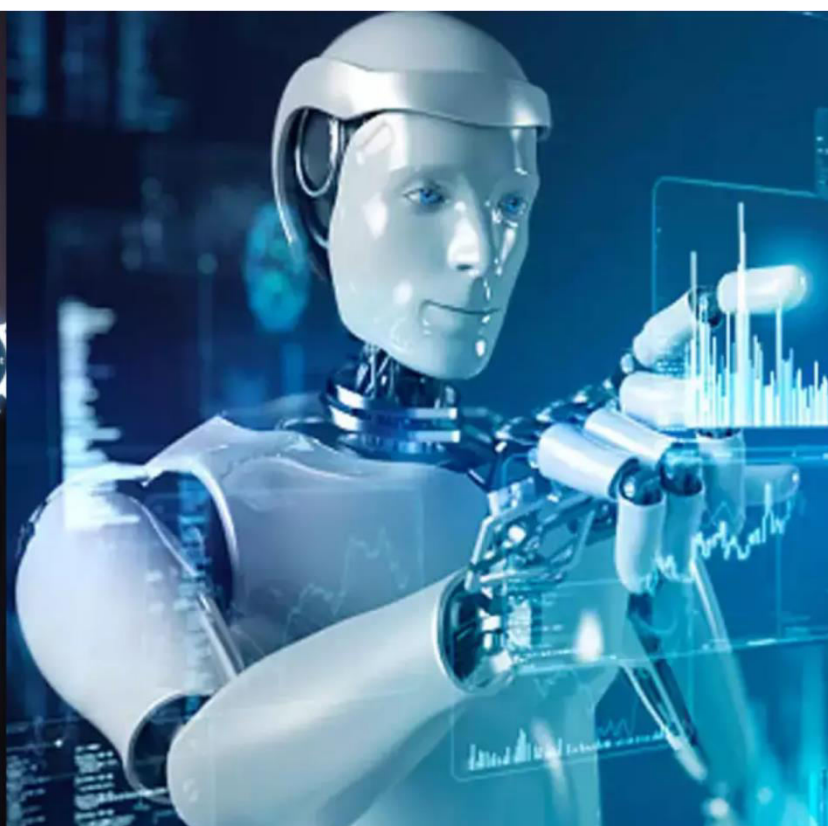




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Smart HEV Energy Management, Fire & Gas Detection and Protection System

Lokesh Kiran Kapure¹, Omkar Nivruti Kangane¹, Durgesh Nandakishor Gaware¹,

Ruturaj Yuraj Challare¹, Prof.Yashwant Sangita Dhanraj Mahajan²

Student , K K Wagh Education Society's K K Polytechnic, Nashik, India¹

Project Guide & Assistant Professor, K K Wagh Education Society's K K Polytechnic, Nashik, India²

ABSTRACT: The rapid growth of Hybrid Electric Vehicle (HEV) technology has increased the need for intelligent energy management, continuous battery monitoring, and advanced safety systems. This project proposes a **Smart HEV Energy Management, Fire & Gas Detection and Protection System** for real-time monitoring, control, and protection of hybrid vehicle electrical systems. The proposed system utilizes voltage, current, temperature, gas, and flame sensors to continuously monitor battery condition, electrical energy flow, and safety-related parameters.

The system employs an ESP32-based controller to collect sensor data, process operating conditions, and communicate information through an Internet of Things (IoT) platform. Important parameters such as battery voltage, current, temperature, State of Charge (SOC), gas leakage level, and fire status are displayed on a local display as well as a mobile monitoring application. The system enables real-time identification of abnormal conditions including battery overheating, over-current, over-voltage, short circuits, gas leakage, and fire hazards.

When a fault condition is detected, the protection system automatically activates safety mechanisms such as battery disconnection, fuel supply cut-off, alarm generation, and mobile notifications. The integration of energy management with fire and gas protection improves vehicle safety, reliability, and operational efficiency. The proposed approach provides a low-cost, scalable, and intelligent solution suitable for modern HEV and EV applications.

Furthermore, the collected operational data can be used for future predictive maintenance, battery health analysis, energy optimization, and AI-based fault prediction. The proposed methodology demonstrates the potential of IoT-enabled smart monitoring systems to improve energy utilization, vehicle safety, and intelligent decision-making in next-generation transportation systems.

KEYWORDS: Hybrid Electric Vehicle (HEV), Energy Management System (EMS), IoT, ESP32, Battery Monitoring, Fire Detection, Gas Detection, Protection System, Smart Vehicle, Predictive Maintenance.

I. INTRODUCTION

Hybrid Electric Vehicles combine an electric propulsion system with a conventional fuel-based engine to improve fuel efficiency and reduce environmental pollution. Efficient management of electrical energy and continuous monitoring of vehicle operating conditions are essential for improving battery performance, safety, and vehicle reliability.

Traditional HEV systems generally focus on energy management, while safety systems such as fire detection and gas leakage monitoring are implemented separately. This project integrates battery monitoring, energy management, fire detection, gas leakage detection, fault monitoring, and IoT-based remote monitoring into a single smart platform. Similar to integrated monitoring concepts used in smart industrial systems, this project combines sensing, data acquisition, communication, monitoring, and protection functions in a unified architecture.

II. OBJECTIVES

1. Monitor battery voltage, current, temperature, and SOC in real time.
2. Detect gas leakage and fire conditions inside the vehicle.
3. Provide automatic protection against abnormal operating conditions.

4. Generate local alarms and mobile notifications.
5. Improve vehicle safety and energy efficiency.
6. Enable remote monitoring through IoT technology.
7. Support future predictive maintenance and battery health analysis.

III. METHODOLOGY

Sensing Layer

The system continuously measures:

- Battery Voltage
- Battery Current
- Battery Temperature
- Gas Leakage Level (MQ-5 Sensor)
- Fire Detection Status (Flame Sensor)

Data Acquisition Layer

ESP32 collects sensor signals and converts them into digital data for processing.

Processing Layer

The controller evaluates operating conditions and compares measured values with predefined safety limits.

IoT Communication Layer

Sensor data is transmitted through Wi-Fi to a cloud/mobile monitoring platform.

Monitoring Layer

The LCD display and mobile dashboard provide:

- Voltage
- Current
- Temperature
- Battery SOC
- Gas Status
- Fire Status
- System Health Status

Protection Layer

When unsafe conditions are detected:

- Relay disconnects battery supply.
- Fuel/CNG solenoid valve is closed.
- Alarm and warning indicators are activated.
- Mobile alert is sent.

System Flow:

Battery/CNG System → Sensors → ESP32 Controller → IoT Monitoring → Protection Relay → Alarm & Mobile Alert

ADVANTAGES

- Real-time monitoring
- Improved battery safety
- Fire detection capability
- Gas leakage detection
- Remote monitoring using mobile app
- Automatic fault protection
- Low-cost implementation
- Easy scalability for future upgrade

IV. FUTURE SCOPE

- AI-Based Battery Health Prediction
- Predictive Maintenance
- Cloud Data Analytics
- Regenerative Braking Monitoring
- GPS Vehicle Tracking
- Smart EV Charging Integration
- Vehicle-to-Grid (V2G) Technology
- Machine Learning-Based Fault Prediction
- Solar-Assisted Charging System

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We sincerely acknowledge the contribution of everyone who directly or indirectly helped us in successfully completing the Smart HEV Energy Management, Fire & Gas Detection and Protection System project.

VI. CONCLUSION

The proposed **Smart HEV Energy Management, Fire & Gas Detection and Protection System** provides an intelligent and integrated solution for monitoring and protecting hybrid electric vehicles. By combining energy management, battery monitoring, fire detection, gas leakage monitoring, IoT communication, and automatic protection mechanisms, the system improves vehicle safety, operational reliability, and energy efficiency. Similar to modern smart monitoring architectures, the integration of sensing, communication, visualization, and fault protection enables real-time decision-making and supports the development of safer and smarter transportation systems.

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