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Low-Cost IoT-Based Fault Detection & AI Prediction for Electric Vehicle

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Abstract: The increasing adoption of electric vehicles (EVs) requires reliable and cost-effective solutions for fault detection to ensure safe operation. This paper presents a low-cost IoT-based prototype system for fault detection and basic AI-based condition analysis of electric vehicle motors. The proposed system continuously monitors key parameters such as current and temperature using sensors, and the collected data is transmitted to the ThingSpeak platform for real-time visualization and storage. A simple machine learning approach is implemented to analyze the data and classify the motor condition as normal or abnormal based on predefined patterns. Unlike complex predictive models, the proposed system focuses on practical implementation using limited data, making it suitable for low-cost applications. The integration of IoT enables remote monitoring, while the AI-based classification helps in early identification of potential faults. Experimental results from the prototype demonstrate effective detection of abnormal conditions, improving system safety and reducing the risk of unexpected failures. This work highlights a simple, scalable, and affordable approach for smart monitoring of electric vehicle motors.

Keywords: Electric Vehicles (EV), Internet of Things (IoT), Motor Fault Detection, ThingSpeak Cloud, Machine Learning, Real-Time Monitoring, Low-Cost Prototype.

I. INTRODUCTION

The rapid advancement of electric vehicles (EVs) has significantly transformed the transportation sector, driven by the growing demand for sustainable and environmentally friendly mobility solutions. Conventional vehicles powered by internal combustion engines contribute heavily to air pollution and the depletion of fossil fuels. In contrast, electric vehicles offer reduced greenhouse gas emissions, improved energy efficiency, and lower operational costs, making them a promising alternative for future transportation systems*[1]*

Electric vehicles are widely used in various applications, including personal transportation, public transit, and commercial fleet operations. As the adoption of EVs increases, the reliability and performance of their electrical systems become critically important. Among these systems, the electric motor plays a key role in converting electrical energy into mechanical motion. However, motor systems are prone to faults such as overheating, winding failures, bearing defects, and electrical imbalances, which can negatively affect vehicle performance and safety *[2]*

Traditional fault detection methods are generally reactive and limited, as they detect faults only after they occur and lack real-time monitoring and predictive capabilities. With the increasing complexity of EV systems, there is a need for advanced technologies to monitor motor conditions continuously. The integration of Internet of Things (IoT) technology enables real-time data collection using sensors such as temperature, current, and voltage sensors mounted on the motor. This data can be transmitted to cloud platforms for remote monitoring and analysis *[3]*

Furthermore, Artificial Intelligence (AI) and Machine Learning (ML) techniques can be applied to analyse the collected data and identify abnormal patterns that indicate potential faults. These techniques enable predictive maintenance by detecting faults before they occur, thereby reducing downtime and improving system reliability. In this context, the proposed project focuses on developing a **low-cost IoT-based fault detection and AI prediction system for electric vehicle motors**, which ensures enhanced safety, reduced maintenance costs, and improved performance of electric vehicles

II. LITERATURE REVIEW

A comprehensive review of existing research has been carried out to understand the current advancements in fault detection and prediction systems for electric vehicles (EVs). Various approaches using Artificial Intelligence (AI),

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Internet of Things (IoT), and sensor-based systems have been proposed to improve the reliability and safety of EV components, particularly motors and batteries.

Several studies have focused on the application of machine learning techniques for fault detection and prediction. An AI-based framework for battery health monitoring demonstrates the use of real-time data such as voltage, current, and temperature to detect anomalies and predict remaining useful life (RUL). The study highlights that machine learning algorithms can effectively identify abnormal patterns and provide early warnings of potential failures, thereby improving system reliability and reducing maintenance costs*[4]*

Research on fault detection techniques in EV electrical systems shows that faults can occur in motors, batteries, and power electronic components, significantly affecting performance and safety. Various techniques such as model-based methods, signal processing approaches, and data-driven algorithms have been analysed. Among these, data-driven and hybrid techniques provide better accuracy in complex systems, especially when combined with computational tools like MATLAB and Simulink for simulation and analysis*[5]*

Another study presents a sensor-based fault detection and prediction system for electric vehicle converters. The method utilizes voltage and current signals to identify faults in power electronic components, including single and multiple fault conditions. The research emphasizes the importance of using intelligent algorithms and sensor data for accurate fault diagnosis, highlighting that real-time monitoring improves the efficiency and reliability of EV systems [*6]*

In addition, IoT-based battery management systems have been developed to enhance real-time monitoring and safety. These systems integrate sensors with microcontrollers and cloud platforms to continuously track parameters such as temperature, voltage, and abnormal conditions. The use of IoT enables remote monitoring, automated alerts, and data storage for predictive maintenance. Such systems provide a cost-effective solution for improving battery safety and overall system performance [*7]*

From the literature, it is observed that although significant advancements have been made in fault detection and prediction systems, most existing approaches focus either on battery systems or complex high-cost solutions. There is a need for a low-cost, integrated system that focuses on motor fault detection with real-time monitoring and predictive capabilities. The proposed project aims to address this gap by developing an IoT-based and AI-driven fault detection system for electric vehicle.

III. PROPOSED SYSTEM AND SYSTEM DESIGN

A. Proposed System
B.

1)System Overview:

The proposed system is a **low-cost IoT-based fault detection and AI prediction system for an electric vehicle motor**, designed to monitor, control, and ensure safe operation in real time. The system uses an Arduino Mega 2560 as the central controller, interfaced with sensors such as temperature, current, voltage, and an IR-based fire sensor to continuously track motor conditions. A potentiometer is used for speed control, while an LCD display provides real-time visualization of parameters. In case of abnormal conditions such as low voltage, over-temperature, or fire detection, the system generates alerts through a buzzer and automatically stops the motor using a relay mechanism. Additionally, sensor data is transmitted to cloud platforms like ThingSpeak and ThingView via an IoT module for remote monitoring and storage, where it is further analysed using AI techniques to predict potential faults and enhance system reliability.

2)Functionalities:

- **Real-Time Monitoring**
  Continuously monitors motor parameters such as voltage, current, and temperature using sensors.
- **Motor Speed Control**
  Controls the speed of the motor using a potentiometer by varying the input voltage.
- **Fault Detection & Protection**
  Detects faults like low voltage and over-temperature, and automatically stops the motor using a relay.
- **Alert and Display System**
  Displays all parameters on LCD and activates a buzzer during fault conditions.
- **IoT & AI-Based Prediction**
  Sends data to cloud platforms for remote monitoring and uses AI to predict possible faults.

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3)Components used:
The system consists of the following main components:

- **Temperature Sensor** – Measures motor temperature to detect overheating conditions
- **INA219 Sensor** – Monitors motor current to identify overload and Measures voltage variations affecting motor performance
- **Microcontroller Arduino Mega 2560** – Processes sensor data and controls system operations
- **IoT Module(ESP8266)** – Enables wireless data transmission to the cloud
- **Cloud Platform (ThingSpeak) -** Stores and visualizes real-time data
- **Buzzer** – Provides immediate warning during abnormal conditions
- **IR Based Fire Sensor** – Fast Detection of the Fire in EV.
- **LCD Display** – offering Local alert for the real Monitoring.
- **GSM Module –** Getting the alert to the mobile phone
- **Motor Driver and DC Motor**- Controlling the Motor
- **GPS Module –** For the location of the Vehicle for emergency case
- **Potentiometer –** Controlling and adjusting the speed of the Motor

The selection of these components is based on cost-effectiveness, ease of integration, and reliability in real-time monitoring systems *[8]*

B. System Design
1)Hardware Design:
The hardware design of the proposed system is based on the integration of sensors, control units, and communication modules to achieve real-time motor monitoring and fault detection. The **Arduino Mega 2560** acts as the central controller, interfaced with sensors such as temperature, current, voltage, and an IR-based fire sensor, which are mounted on the motor to continuously measure operating conditions. A potentiometer is used to control the motor speed by adjusting the input voltage. The system includes an LCD display for real-time visualization of parameters and a buzzer for alert generation during fault conditions. A relay module is incorporated to automatically stop the motor when abnormal conditions such as overheating or low voltage are detected. Additionally, an IoT module (ESP8266/NodeMCU) is used to transmit sensor data to cloud platforms for remote monitoring and analysis. This hardware setup ensures efficient data acquisition, system control, and safety in the motor operation.

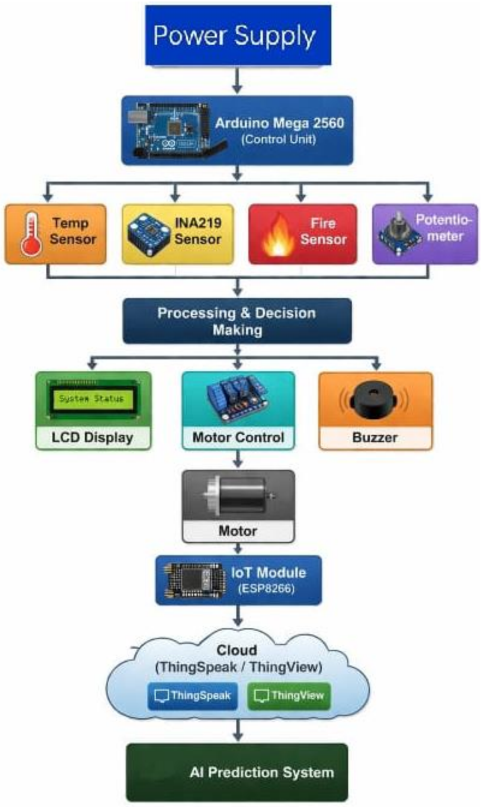

Fig 1. Block Diagram

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2)Software Design:

The proposed system is a **low-cost IoT-based fault detection and AI prediction system for an electric vehicle motor**, designed to monitor, control, and ensure safe operation in real time. The system uses an Arduino Mega 2560 as the central controller, interfaced with sensors such as temperature, current, voltage, and an IR-based fire sensor to continuously track motor conditions. A potentiometer is used for speed control, while an LCD display provides real-time visualization of parameters. In case of abnormal conditions such as low voltage, over-temperature, or fire detection, the system generates alerts through a buzzer and automatically stops the motor using a relay mechanism. Additionally, sensor data is transmitted to cloud platforms like ThingSpeak and ThingView via an IoT module for remote monitoring and storage, where it is further analysed using AI techniques to predict potential faults and enhance system reliability.

3)Working Principle:

The proposed system operates using an **Arduino Mega 2560** as the central control unit, which manages data acquisition, processing, and control operations. When the system is powered using a battery supply, the LCD display initializes and shows the starting parameters, and the motor begins to rotate under normal conditions. A potentiometer is used to control the motor speed by varying the input voltage. Sensors such as temperature, current, voltage, and an IR-based fire sensor are continuously used to monitor the motor's operating conditions in real time. The Arduino processes the sensor data and compares it with predefined threshold values to detect abnormal conditions. If a fault such as low voltage or over-temperature is detected (temperature exceeding 36°C), the system displays a warning message on the LCD and automatically stops. In case of fire detection, the system immediately activates a buzzer alert and displays the warning, and get the SMS Alert to mobile through GSM Module ensuring safety and quick response. In addition to local monitoring, the system uses an IoT module to transmit real-time data to cloud platforms such as ThingSpeak and ThingView. The data is stored and visualized for remote monitoring and further analysed using an AI model to predict potential faults. This enables early fault detection, improves system reliability, and supports predictive maintenance of electric vehicle.

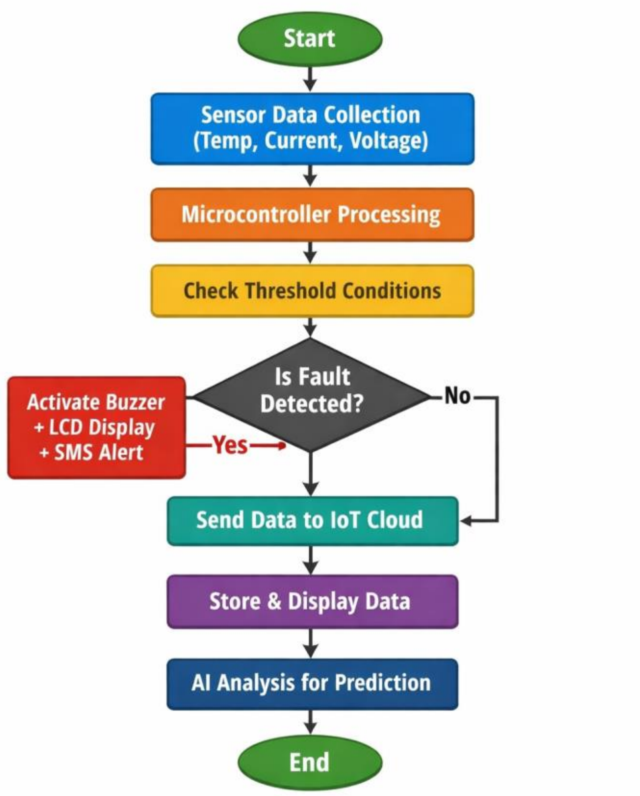

Fig 4. Workflow

IV. RESULTS

The proposed system was experimentally tested under various operating conditions, and the obtained results demonstrate its effectiveness in detecting and indicating fault scenarios in real time.

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A. Local Alert

1) Low Voltage Condition: The system successfully detects the low voltage condition and displays the message **"LOW VOLTAGE"** on the LCD. The voltage level drops to approximately **2V**, indicating an under-voltage fault. This confirms the reliable performance of the voltage monitoring unit.

Fig 1. Low Voltage

Fig 2. Over Current

2)Over Current Condition: The system detects overcurrent when the load increases beyond the safe limit of **550 mA**. The LCD displays **"OVER CURRENT"**, indicating an abnormal current condition. This confirms the system's capability to prevent damage due to excessive load.

3) Fire Detection: The fire sensor accurately identifies the presence of fire and triggers an alert message **"FIRE DETECTED"** on the display. The response is immediate, ensuring safety in the EV system. This validates the effectiveness of the fire detection mechanism.

Fig 3.Fire Monitoring

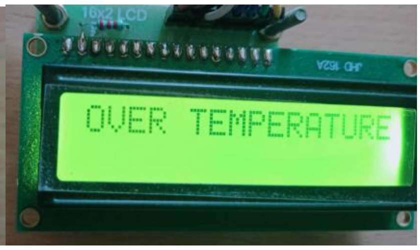

Fig 4. Temperature Monitoring

4) Over Temperature Condition: The system continuously monitors temperature and detects when it exceeds **35°C**. Upon reaching this threshold, the LCD displays **"OVER TEMPERATURE"**, indicating a critical condition. This ensures proper thermal protection of the system.

B. Graphs

1. Voltage:

- The voltage initially remains **stable around 11–12 V**, indicating proper power supply regulation under normal conditions.
- A **sudden drop to ~2 V** is observed, which may be due to **load disconnection, power interruption, or sensor fluctuation**.
- The voltage quickly **recovers back to the nominal range**, showing **system stability and reliable restoration capability**.

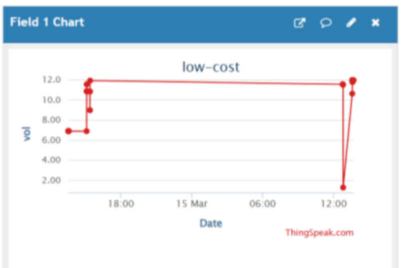

Fig 1. Voltage

Fig 2. Current

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2) Current:

- The current shows an initial high value (~350–400 mA), indicating active load operation.
- A gradual decrease to near zero suggests load reduction or switching OFF condition.
- Sudden spikes after zero current indicate intermittent load switching or transient behavior in the system.

3)Temperature:

- The temperature initially stays stable around 32–33°C, representing normal operating conditions.
- A gradual decrease to ~29°C may be due to reduced system activity or environmental cooling.
- A sudden rise to ~36°C indicates increased load operation or heat generation in components.

Fig 3. Temperature

4) Power:

- The power initially increases to ~4–4.5 W, corresponding to active load consumption.
- A steady decrease to near zero indicates reduction or disconnection of the load.
- Sudden power spikes after zero confirm intermittent switching and variation in load demand.

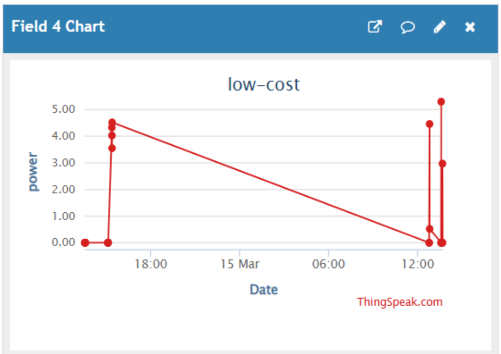

Fig 4. Power

5)Latitude:

- The latitude shows an initial change from 0 to ~16, indicating GPS signal acquisition or device initialization.
- The value then remains constant, confirming stable device location.
- No fluctuations indicate accurate and consistent positioning performance.

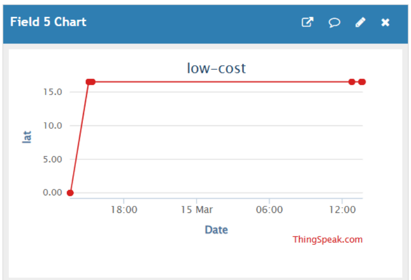

Fig 5. Latitude

Fig6.Longitude

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6)Longitude:

- The longitude increases from 0 to ~80, representing initial GPS synchronization.
- It remains constant over time, indicating no movement of the system.
- This stability confirms reliable GPS data tracking.

C. AI Prediction

The implemented model combines IoT-based monitoring with machine learning to evaluate system behavior, where the Random Forest classifier effectively determines the system status based on real-time sensor data.

1)Abnormal Conditon:

- The system records a voltage of 8.29 V with zero current and power, indicating that the load is in an OFF state or no energy consumption is occurring, despite the presence of supply voltage.
- The temperature is observed at 38.9°C, which is relatively high and may be due to ambient environmental conditions or prior system operation heat retention.
- The system status is classified as “Normal” by the Random Forest model, showing that the measured parameters fall within acceptable operating thresholds, even with zero load conditions.

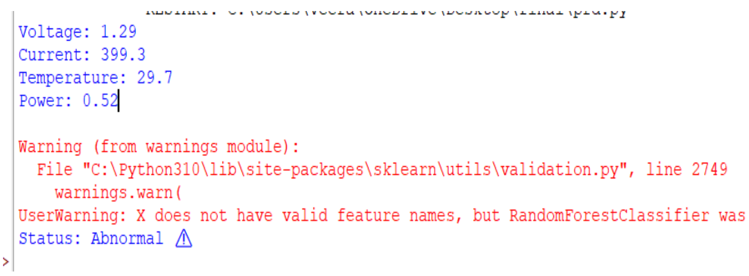

Fig 1. Abnormal

2)Normal Condition:

- The system records a very low voltage of 1.29 V with a high current of 399.3 mA, which indicates an abnormal operating condition such as short circuit or severe voltage drop under heavy load.
- The power value is low (0.52 W) despite high current, suggesting inefficient operation caused by voltage collapse or fault condition in the circuit.
- The temperature is relatively moderate (29.79°C), indicating that the abnormality is likely electrical in nature rather than due to thermal overload.

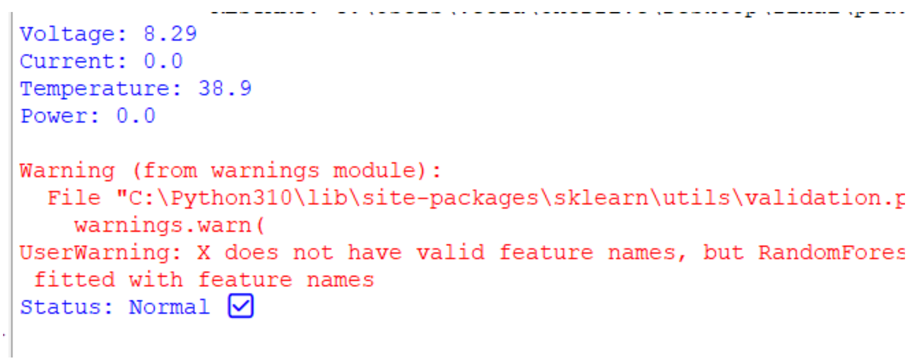

Fig 2. Normal

V. CONCLUSION

The proposed project successfully demonstrates a low-cost IoT-based fault detection and AI prediction system for electric vehicle motors, focusing on improving safety, reliability, and performance. The system effectively monitors key motor parameters such as voltage, current, temperature, and fire conditions in real time using sensors and an Arduino-based control unit. It is capable of detecting abnormal conditions like low voltage, overheating, and fire hazards, and responds immediately by generating alerts and automatically stopping the motor to prevent damage.

The integration of IoT technology enables remote monitoring and data storage through cloud platforms such as ThingSpeak and ThingView, allowing users to access system data from anywhere. Furthermore, the use of AI techniques

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for analysing collected data helps in predicting potential faults before they occur, enabling predictive maintenance and reducing system downtime. Overall, the proposed system provides a simple, cost-effective, and efficient solution for motor fault detection in electric vehicles, making it suitable for practical implementation and future enhancements.

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