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An IoT-Enabled Smart System for Real-Time Motor Health Monitoring

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Abstract: *In modern industrial environments, electric motors play a critical role in ensuring uninterrupted production processes. However, unforeseen motor failures often result in costly downtime, reduced productivity, and higher costs for upkeep. This project offers an IoT-enabled Motor Health Condition Monitoring System to deal with these problems. The system will be able to keep track on motor operating conditions all the time and find possible problems early on. The system uses several sensors to keep an eye on important factors like electrical current, voltage, vibration levels, temperature, and rotational speed. Together, they give a full picture of the motor's health. The main processing unit is an ESP32 microcontroller, which makes it possible to collect and analyse data in real time. Lightweight TinyML models add edge intelligence, which lets devices find anomalies on their own and cuts down on the need for constant cloud connectivity. Collected data is transmitted wirelessly to IoT platforms such as Blynk or ThingsBoard, where it is visualized through interactive dashboards for remote monitoring and decision-making. To enhance system reliability, an LCD display provides immediate on-site feedback, while an SD card module ensures secure data logging during communication failures or network interruptions.*

Keywords: IoT, Motor Health Condition Monitoring, ESP32, TinyML, Predictive Maintenance, Vibration Analysis, Edge Computing, Industrial Automation, Real- Time Monitoring, Fault Detection

I. INTRODUCTION

Electric motors are fundamental components in modern industrial systems, serving as the primary drivers of mechanical operations across sectors such as manufacturing, automation, power generation, oil and gas, and process industries. It is estimated that electric motors consume a significant portion of industrial electrical energy, making their reliable and efficient operation critical for both productivity and energy management [1]. Any unexpected motor failure can interrupt production lines, cause equipment damage, and lead to substantial financial losses due to unplanned downtime and maintenance costs.

During prolonged operation, electric motors are subjected to varying mechanical loads, electrical stresses, and harsh environmental conditions such as excessive heat, dust, moisture, and vibration. These factors gradually degrade motor components including bearings, windings, insulation, and shafts. Common motor faults such as bearing wear, rotor imbalance, misalignment, overcurrent, and overheating often develop slowly and remain undetected until they result in sudden and catastrophic failure [2]. Traditional fault detection techniques largely depend on manual inspections or periodic testing, which aren't good enough to find early signs of degradation in real time.

To address these limitations, industrial maintenance strategies have evolved over time. Reactive maintenance, which involves repairing equipment only after failure, leads to high downtime and repair costs. Preventive maintenance, although more systematic, relies on fixed service intervals and often results in unnecessary maintenance or overlooked faults [3]. As a result, industries are increasingly adopting predictive maintenance, a data-driven approach that continuously monitors equipment condition and predicts failures before they occur. Predictive maintenance improves asset availability, reduces maintenance expenses, and enhances overall system reliability [4].

Recent progress in the Internet of Things (IoT) has made it possible to make smart monitoring systems that can gather, process, and send real-time data from industrial equipment.IoT-based condition monitoring systems use interconnected sensors, embedded controllers, and cloud or edge computing platforms to provide continuous visibility into machine health [5]. When it comes to electric motors, things like vibration, temperature, current, voltage, and rotational speed are well-known signs of how well they are working and when they are broken [6].

The IoT-Enabled Motor Health Condition Monitoring System proposed in this project aims to support predictive maintenance by offering a compact, low-cost, and intelligent monitoring solution. The system is being developed as a working prototype using an ESP32 microcontroller that was chosen because it has built-in Wi-Fi, a lot of processing power, and is good for edge-based apps. To get complete real-time data on the motor, a number of sensors are built in, such as an ADXL345 vibration sensor, a DS18B20 temperature sensor, a ZMPT101B voltage sensor, an ACS712 current sensor, and a speed sensor.

To enhance responsiveness and reduce dependence on cloud connectivity, the system incorporates edge intelligence using TinyML models, allowing abnormal operating conditions to be detected directly on the device. This approach enables faster fault detection, reduced latency, and improved system robustness, particularly in environments with unreliable network connectivity [7]. Detected anomalies such as excessive vibration, abnormal temperature rise, overcurrent conditions, or speed deviations can indicate developing faults like bearing damage, insulation failure, or mechanical misalignment.

The system architecture supports remote monitoring through IoT platforms such as Blynk or ThingsBoard, where motor performance data is visualized using web or mobile dashboards. For reliability and data integrity, local data logging is implemented using an SD card, ensuring continuous data storage even during network failures. Furthermore, a relay-based protection mechanism allows the system to automatically disconnect the motor under critical fault conditions, preventing further damage and improving operational safety.

At its current stage of development, the project focuses on hardware integration, firmware development, and sensor calibration to achieve accurate data acquisition and stable communication under varying load conditions. Once fully implemented and validated, the proposed system will demonstrate how IoT and edge computing technologies can be effectively applied to industrial motor health monitoring. The solution has the potential to enhance equipment reliability, reduce maintenance costs, improve energy efficiency, and contribute to the broader adoption of smart maintenance practices in industrial environments [8].

II. PROBLEM STATEMENT

Electric motors are essential components in industrial systems, but their continuous operation under varying load and environmental conditions leads to gradual performance degradation. Common faults such as overheating, excessive vibration, overcurrent, and mechanical misalignment often develop unnoticed and result in sudden motor failures. These unexpected breakdowns cause production downtime, equipment damage, and increased maintenance costs.

Most industries still rely on reactive or time-based preventive maintenance methods, which are inefficient for detecting early-stage faults. Traditional monitoring techniques lack real-time data collection, intelligent analysis, and remote accessibility. Additionally, existing advanced monitoring solutions are often expensive, complex, and unsuitable for small- and medium-scale industrial applications.

An affordable, smart motor monitoring system that can keep an eye on important things like current, voltage, temperature, vibration, and speed all the time is needed. The system should analyze data in real time, provide early fault detection, support remote monitoring, and ensure safe motor operation through automatic protective actions. Addressing these challenges is essential for enabling predictive maintenance, improving motor reliability, and enhancing overall industrial efficiency.

III. OBJECTIVE

• To monitor motor parameters in real-time such as temperature, vibration, voltage, current, and speed using sensors.

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- To detect faults early by analyzing sensor data on the ESP32 microcontroller.
- To store sensor data safely using an SD card, even when the internet connection is lost.
- To send motor health data to the so that it can be viewed remotely through mobile or web apps.
- To reduce unexpected motor failures by using data to plan maintenance before problems occur.

IV. LITERATURE SURVEY

Paper 1: Overview of IoT Security Challenges and Sensors Specifications in PMSM for Elevator Applications
Authors: Eftychios I. Vlachou, Vasileios I. Vlachou, Dimitrios E. Efstathiou, and Theoklitos S. Karakatsanis Year: 2024
Publication/Journal: Machines, MDPI
Summary: This thorough research article examines the amalgamation of Internet of Things (IoT) technology with Permanent Magnet Synchronous Motors (PMSMs) in lift applications, emphasising condition monitoring, fault detection, and security problems. The authors conduct a comprehensive examination of diverse fault categories in Permanent Magnet Synchronous Motors (PMSMs), encompassing electrical faults (including inter-turn short circuits, phase-to-phase short circuits, and insulation failures), mechanical faults (such as bearing failures, eccentricity, and unbalance), and magnetic faults (notably demagnetisation). The research thoroughly analyses condition monitoring methods, such as vibration analysis, current signature analysis (MCSA), heat analysis, and torque measurements.The study emphasizes the importance of sensor specifications according to international standards like ISO 10816 for vibration measurements and proper sensor placement strategies.
Paper 2: Digital Twin-Based Monitoring System of Induction Motors Using IoT Sensors and Thermo- Magnetic Finite Element Analysis
Authors: Jhennifer F. dos Santos, Bendict K. Tshoombe, Lucas H. B. Santos, Ramon C. F. Araújo, Allan R. A. Manito, Wellington S. Fonseca, and Marcelo O. Silva
Year: 2023
Publication/Journal: IEEE Access
Summary:This research presents an innovative approach to industrial motor monitoring by integrating Internet of Things (IoT) technology with Digital Twin (DT) concepts through high-fidelity Finite Element Method (FEM) simulations. The The authors created a complete monitoring system for a 1.1 kW three-phase induction motor utilising inexpensive sensors such the SCT-013 current sensor and the NTC thermistor for measuring temperature. They connected these sensors to an ESP32 microcontroller. One important new thing about this work is that it uses FEMM (Finite Element Method Magnetics) software to run strongly-coupled thermo-magnetic simulations. This lets the system guess what the internal conditions of the motor are, even when sensors can't directly measure them. The monitoring system sends real-time data to cloud storage using Wi-Fi and the Heroku Postgres platform. This makes it possible to retrieve the data using web interfaces for remote monitoring. The authors effectively illustrated the system's ability to monitor motor current and temperature, achieving relative errors under 4% for conductivity assessment and 10% for temperature evaluation when benchmarked against reference instruments (Hioki power quality analyser and FLIR thermal camera). The Digital Twin implementation enables comprehensive investigation of internal motor characteristics, encompassing resistive losses in the stator and rotor, temperature distribution, magnetic flux intensity, and fluctuations in electrical conductivity.
Paper 3: IoT-Based Prognostics and Systems Health Management for Industrial Applications
Authors: Daeil Kwon, Melinda R. Hodkiewicz, Jiajie Fan, Tadahiro Shibutani, and Michael G. Pecht
Year: 2016
Publication/Journal: IEEE Access
Summary: This important study gives a full picture of how Prognostics and Health Management (PHM) works with Internet of Things (IoT) technologies in different industries. The authors characterise PHM as a field comprising four essential dimensions: sensing, diagnosis, prognosis, and management, intended to identify anomalies, diagnose failures, forecast remaining usable life (RUL), and facilitate risk-based decision-making. The report thoroughly examines three principal prognostic methodologies: Physics-of-Failure (PoF) based methods that utilize mathematical models and

physical laws to predict degradation, data-driven approaches employing machine learning and statistical methods to identify patterns in operational data, and fusion approaches that combine the strengths of both methodologies. The study presents numerous industrial applications across sectors including manufacturing (with examples from Siemens, GE's Predix platform, and Germany's Industrie 4.0 initiative), heavy industry mobile assets (aircraft, ships, construction equipment), energy generation (nuclear, thermal, renewable), transportation and logistics, infrastructure assets, automobiles, medical consumer products, and robotics.

Paper 4: IoT-Based Health Monitoring and Fault Detection of Industrial AC Induction Motor for Efficient Predictive Maintenance

Authors: Muhammad Yousuf, Turki Alsuwian, Arslan Ahmed Amin, Sanwal Fareed, and Muhammad Hamza Year: 2024

Publication/Journal: Measurement and Control Summary: This research study introduces a comprehensive IoT-based health monitoring and defect detection system tailored for industrial AC induction motors, aimed at facilitating efficient predictive maintenance. The authors performed a comprehensive literature study, examining fault statistics from many reliable sources, including IEEE and EPRI studies, revealing that bearing faults constitute 41- 44.5% of motor failures, stator faults 28-29.9%, rotor faults 9-11%, with the remaining attributed to other causes. The proposed system integrates multiple sensor types including LM35 temperature sensors, vibration sensors, current sensors (SCT-013), voltage sensors, and speed sensors, all interfaced through Arduino and NodeMCU microcontrollers. The mathematical modeling section provides detailed equations for three-phase induction motor operation, including d-q axis transformations and electromagnetic torque calculations. The system architecture employs GSM communication for emergency alerts and Wi-Fi (IEEE 802.11) for continuous data transmission to the Blynk IoT cloud platform, enabling remote monitoring through mobile applications. A crucial aspect is the use of relay modules to control and protect motors. These modules automatically disconnect the motor when they find electrical problems and send GSM alerts right away when they find mechanical problems. The system was tested with both Proteus circuit simulation and real hardware, and it was shown to be 99% accurate at finding problems with vibration, temperature, speed, three-phase currents, and voltages.

Paper 5: IoT-Based Healthcare-Monitoring System towards Improving Quality of Life: A Review

Authors: Suliman Abdulmalek, Abdul Nasir, Waheb A. Jabbar, Mukarram A. M. Almuhaya, Anupam Kumar Bairagi, Md. Al-Masrur Khan, and Seong-Hoon Kee

Year: 2022

Publication/Journal: Healthcare, MDPI

Summary:This comprehensive review paper systematically examines the current state and future prospects of IoT-based healthcare monitoring systems with a focus on improving quality of life through continuous patient monitoring and early disease detection. The authors provide an extensive analysis of recent studies, categorizing healthcare monitoring systems based on their methodology, hardware/software technology, features, evaluation metrics, and communication protocols. The paper extensively discusses the Internet of Wearable Things (IoWT) architecture consisting of three key elements: Wireless Body Area Networks (WBAN) for data collection, Internet-connected gateways for data transmission, and cloud infrastructure for storage and analysis. A significant contribution is the classification of health monitoring sensors into contact sensors (on-body wearables) for physiological, chemical, and optical measurements, and therapeutic purposes, as well as non- contact sensors (peripherals) for fitness, behavioral monitoring, and rehabilitation.

V. PROPOSED SYSTEM

The proposed system is an intelligent motor health monitoring and predictive maintenance framework that integrates Internet of Things (IoT) technology with machine learning techniques. The system is built to keep an eye on how the motor is working all the time, look at real-time data, and find problems before they cause the system to fail.

A. System Overview

The proposed system is an IoT-based motor health condition monitoring solution designed to continuously observe and analyze the operational status of electric motors. It integrates multiple sensors with an ESP32 microcontroller to collect

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real-time motor data, perform local analytics, and transmit information to remote monitoring platforms. The system enables early fault detection, predictive maintenance, and automatic motor protection.

B. Sensor Data Acquisition

The system employs a set of sensors to measure key motor parameters, including vibration, temperature, voltage, current, and rotational speed (RPM). These parameters are critical indicators of motor health and help in identifying mechanical and electrical abnormalities such as imbalance, bearing degradation, and overload conditions.

C. Edge Processing and Analytics

Collected sensor data is processed locally on the ESP32 using Fast Fourier Transform (FFT) techniques and lightweight TinyML models. This edge-based analysis enables real-time anomaly detection by identifying abnormal vibration patterns, temperature rise, or electrical irregularities without relying solely on cloud processing.

D. Microcontroller and Control Unit

The ESP32 serves as the central control unit, managing sensor sampling, data preprocessing, fault evaluation, relay control, and wireless communication. Its built-in Wi-Fi capability allows seamless integration with IoT platforms, while its processing power supports edge intelligence.

E. Safety and Motor Protection Mechanism

A relay module is incorporated as a fail-safe mechanism to protect the motor from severe operating conditions. When critical faults are detected, the relay can initiate an emergency shutdown or perform controlled soft-stop operations, thereby preventing further motor damage and improving system safety.

F. Local Data Logging and Display

An SD card module is used for local storage of raw sensor data, ensuring data integrity during network outages or communication failures. Additionally, an LCD display mounted near the motor provides real-time parameter values and system status to on-site maintenance personnel.

G. Cloud Connectivity and Remote Monitoring

The system transmits processed data to IoT platforms such as Blynk or ThingsBoard, enabling remote monitoring, visualization, and historical trend analysis through web or mobile dashboards. This feature allows maintenance teams to access motor health information from anywhere in real time.

H. System Adaptability and OTA Updates

Over-the-air (OTA) update capability is implemented to allow remote firmware upgrades and TinyML model updates. This ensures the system remains adaptable to new fault conditions, evolving algorithms, and future industrial requirements without physical intervention.

Input Parameters

Sr. No.	Parameter	Description
1	Voltage	Measures the voltage supplied to the motor.
2	Current	Measures the current drawn by the motor.
3	Vibration	Detects mechanical vibrations, used for fault diagnosis.
4	Temperature	Monitors motor casing or internal heat level.
5	Speed (RPM)	Tracks the rotational speed of the motor shaft.
6	Wi-Fi Signal	Indicates availability of internet for communication.

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8	Power Supply	Provides 3.3V/5V to the microcontroller and connected modules.
9	User Input (Optional)	Manual button press or app interaction for testing or reset.

Table 1: Input parameter Output Parameters

Output parameters are the actions or signals generated by the system in response to inputs.

Sr. No.	Parameter	Description
1	Real-Time Display	Shows live motor health data (e.g., RPM, temp, vibration) on LCD.
3	Local Storage (SD Card)	Stores data locally when Wi- Fi is unavailable.
4	Relay Control	Activates shutdown or control sequences in response to faults.

Table 2: Output parameter

VI. SYSTEM DESIGN

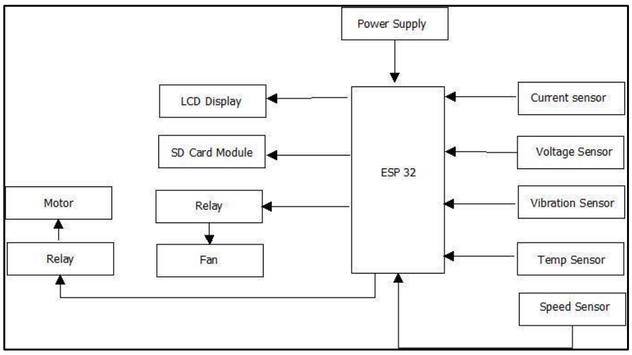

Fig 1: System Architecture

The illustrated system is a microcontroller-based monitoring and control unit centered around the ESP32 development board. The system integrates multiple sensors, input/output devices, and communication interfaces to collect physical parameters such as acceleration, temperature, voltage, and current, and then processes and displays the data while also enabling Using a relay to operate an induction motor. The ESP32 is the main processing unit that handles sensing, calculation, decision-making, user display, and communication with a laptop outside of the system.

This architecture is suitable for applications such as industrial equipment monitoring, motor health analysis, predictive maintenance, IoT-based control systems, and embedded automation solutions, where real-time data acquisition, remote monitoring, and reliable actuation are essential.

1. Power Supply Unit

The power supply unit provides the necessary electrical energy to all components of the system in a regulated and stable form. It converts the available AC or higher DC input voltage into low-voltage DC outputs such as 5V and 3.3V, which are suitable for the ESP32 microcontroller and connected sensors. Proper voltage regulation ensures that the system operates reliably without voltage drops, electrical noise, or component damage. Protection elements such as capacitors, regulators, and filtering circuits improve power quality and prevent malfunction due to fluctuations or surges. In addition to voltage conversion and regulation, the power supply unit plays a critical role in overall system efficiency and safety. It ensures adequate current delivery to meet the dynamic power demands of the ESP32, especially during peak operations such as Wi-Fi communication, sensor data acquisition, and actuator control. A well-designed power supply minimizes power losses and heat generation, thereby improving the longevity of components and reducing energy consumption. Features such as over-current, over-voltage, and short-circuit protection further safeguard the system against fault conditions, ensuring continuous and stable operation even under varying load and environmental conditions.

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Fig 2: Power Supply Unit

2. ESP32 Microcontroller (Central Processing Unit)

The ESP32 is the main part of the system that processes and controls everything. It gets data from all the sensors that are linked to it, processes that data using programmed algorithms, and then makes decisions based on rules that have already been set.The ESP32 also manages communication between system components, controls output devices such as the relay and LCD display, and sends data to an external laptop for monitoring or storage. Its built-in Wi-Fi and Bluetooth capabilities further allow wireless connectivity, making the system suitable for IoT-based applications and remote access.

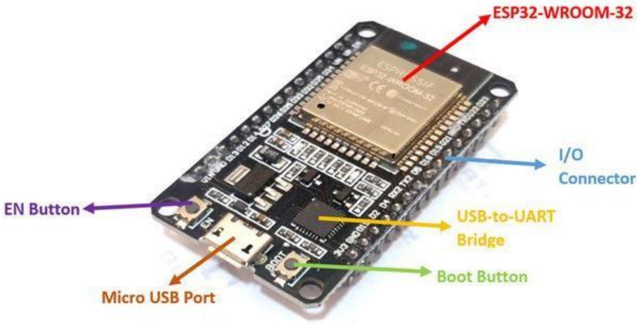

Fig 3: ESP32 Microcontroller

3. Vibration Sensor

A vibration sensor, or vibration detector, measures vibration levels in machinery for screening and analysis. Maintenance teams use industrial vibration sensors for condition monitoring, giving them insight into the magnitude and frequency of vibration signals. Vibration sensors often provide overall vibration levels, indicating whether your asset is under stress, but they can also give more sophisticated readings. Best-in-class industrial sensors like the Fluke 3563 Analysis Vibration Sensor go deeper. The Fluke 3563 distinguishes vibration signals from individual components and identifies what common faults are associated with their vibration levels: bearing faults, looseness, imbalance, and misalignment.

By capturing high-resolution time-waveform and frequency-domain data, the sensor supports advanced diagnostics and root-cause analysis. Wireless connectivity allows continuous, real-time monitoring without complex wiring, reducing installation and maintenance effort.

Integrated analytics and alert thresholds help maintenance teams prioritize actions and shift from reactive to predictive maintenance strategies. Overall, such intelligent vibration sensors improve equipment reliability, reduce unplanned downtime, and extend the service life of critical assets.

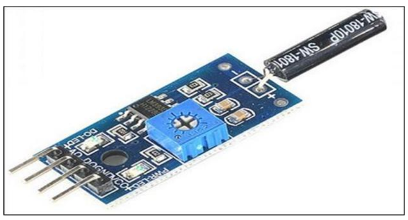

Fig 4: Vibration Sensor

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4. Voltage Sensor

The voltage sensor measures the electrical voltage supplied to the motor or system circuitry. Since the ESP32 operates at low voltage levels, the sensor uses voltage division or signal conditioning circuits to reduce high voltages to safe ranges for analog-to-digital conversion. Continuous voltage monitoring helps identify conditions such as under-voltage, over-voltage, or supply instability, which can negatively impact motor performance and system safety. The ESP32 processes this data to ensure reliable operation and initiate protective measures when necessary.

Fig 5: Voltage Sensor

5. Current Sensor

The current sensor detects the amount of current flowing through the motor or connected electrical load. It plays an essential role in determining system load conditions, power consumption, and efficiency. Abnormal current levels can indicate overloads, electrical faults, or mechanical issues within the motor. By continuously analyzing current data, the ESP32 can generate alerts, log operational trends, and activate protection mechanisms such as disconnecting the motor through the relay.

6. Temperature Sensor

The temperature sensor measures temperature digitally and communicates with the ESP32 using a single-wire protocol, making it simple and reliable to integrate. It monitors ambient or motor surface temperature to detect overheating conditions that could damage components or reduce system lifespan. Accurate temperature data enables thermal protection strategies such as alarm generation, cooling system activation, or automatic shutdown of the motor when unsafe temperature levels are reached.

Fig 6: Temperature Sensor

7. LCD Display Module

The LCD screen shows real-time values of voltage, current, temperature, and vibration data, which lets the user see what's going on with the system. It also displays system status messages such as motor ON/OFF state, fault alerts, and warning indications. This local display eliminates the need for external monitoring equipment and allows operators or technicians to quickly assess system performance and respond to abnormal conditions.

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Fig 7: LCD Display Module

8. Relay Module

The relay module is an electrically controlled switch that lets the low-power ESP32 output signals securely regulate the high-power induction motor. It gives power to isolation between the control circuitry and the high-voltage motor circuit, ensuring user and device safety. The relay enables automatic or manual switching of the motor based on sensor readings, threshold conditions, or external commands, making it an essential component for system actuation and protection.

Fig 8: Relay Module

9. Speed Sensor

Fig 9: Speed Sensor

A speed sensor module is an electronic device that tells you how fast something is moving, like a wheel, motor shaft, or other mechanical part. It converts the physical motion into an electrical signal that can be interpreted by microcontrollers, PLCs, or other monitoring and control systems. Speed sensor modules are widely used in automotive, industrial, and robotics applications to monitor rotational speed, control motors, and enhance system safety.

10. SD Card

Fig 10: SD Card

An SD (Secure Digital) card is a compact, portable, non-volatile memory storage device used to store and transfer digital data. It is widely used in consumer electronics, including cameras, smartphones, tablets, drones, and embedded systems, due to its small size, high storage capacity, and compatibility across devices. SD cards allow users to store files such as images, videos, documents, and software programs in a reliable and convenient manner.

11. Fan

A fan controller is an electronic device used to regulate the speed and operation of a fan based on specific conditions such as temperature, voltage, or manual input. Fan controllers are widely used in applications ranging from computer systems and HVACsystems to industrial machinery and automotive cooling systems. By controlling fan speed, these devices help optimize airflow, reduce energy consumption, and maintain optimal operating temperatures for equipment and environments.

Fig 11: Fan

VII. RESULT

Fig 12: ESP32-Based Motor Monitoring System

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Fig 13: Experimental Setup

The developed IoT-Enabled Motor Health Condition Monitoring System was successfully implemented and tested in different operating settings to see how well it works, how reliable it is, and how well it can find faults. The prototype effectively monitored critical motor parameters including current, voltage, temperature, vibration, and speed in real time. All sensors operated as expected and provided stable, continuous data to the ESP32 microcontroller.

During normal operating conditions, the system recorded steady values for temperature, current, vibration, and RPM, which were displayed on the LCD screen and simultaneously transmitted to the IoT dashboard. The collected data was also logged onto the SD card, confirming reliable local storage even when network connectivity was temporarily unavailable. This showed that the technology could keep data safe in the actual world.

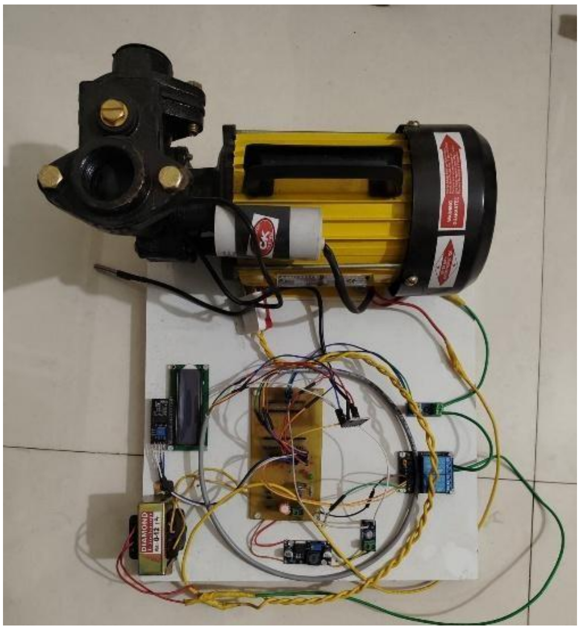

Fig 14: Side View of the Hardware Prototype

When abnormal conditions were introduced, such as increased mechanical vibration, overload current, or elevated temperature, the system successfully detected deviations from predefined thresholds. Vibration analysis using FFT helped identify abnormal frequency patterns associated with mechanical imbalance and bearing-related issues. Similarly, excessive current and temperature rise were detected promptly, indicating overload and thermal stress conditions. These

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results confirm the effectiveness of edge-level analytics and TinyML-based decision logic in identifying early fault symptoms.

Upon detection of critical fault conditions, the relay module was triggered automatically to disconnect the motor supply or activate protective actions, preventing further damage to the motor. This automatic response validated the system's safety mechanism and its suitability for real-time motor protection. Alerts and parameter changes were also reflected instantly on the IoT dashboard, enabling remote monitoring and quick maintenance decisions.

VIII. CONCLUSION

The development of the IoT Enabled Motor Health Condition Monitoring System successfully demonstrates how modern sensor technology and Internet of Things (IoT) integration can transform traditional motor maintenance into a smart, data-driven process. The suggested system uses calibrated sensors connected to the ESP32 microcontroller to keep an eye on important things like voltage, current, temperature, vibration, and speed all the time. These real-time measurements are processed, shown on a screen nearby, and sent to an IoT platform so that people can access them from anywhere. This makes it possible to find problems early and do maintenance before they happen.

The performance analysis confirms that the system operates with high reliability, accuracy, and efficiency under various test conditions. The combination of low-cost sensors, efficient data transmission, and edge-level processing ensures minimal latency and effective fault identification. With the help of relay-based control, the system can take immediate corrective actions, such as disconnecting the load during abnormal conditions, thus preventing potential equipment damage and ensuring operational safety. Additionally, the integration of SD card data logging provides redundancy, maintaining complete data integrity even in the absence of network connectivity.

IX. FUTURE SCOPE

The IoT-Enabled Motor Health Condition Monitoring System presents significant opportunities for further enhancement and real-world deployment. Future work can focus on integrating advanced Using machine learning and deep learning models to make fault categorisation more accurate and to forecast how long motor parts will last (RUL). This would let businesses go from finding faults to accurately predicting failures. The system can be extended to support multiple motors through a centralized cloud dashboard, making it suitable for large- scale industrial environments. Integration with industrial communication protocols such as MQTT, Modbus, or OPC- UA can further enhance compatibility with existing industrial automation systems and SCADA platforms.

Additional sensors, including acoustic emission, humidity, and insulation resistance sensors, can be incorporated to provide a more comprehensive assessment of motor health. The use of higher-resolution vibration sensors and advanced signal processing techniques can further improve detection of early-stage mechanical faults. Future enhancements may also include mobile application development for real-time alerts, maintenance scheduling, and historical performance analysis. Energy efficiency monitoring and optimization features can be added to support sustainable industrial operations. Moreover, the system can be upgraded with enhanced cybersecurity mechanisms to ensure secure data transmission and device authentication.

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