Industrial IoT Based Health Monitoring System of Motor or Transformer

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Abstract - This research introduces an Industrial IoT-based health monitoring system specifically designed for motor and transformer components within industrial environments. By integrating advanced sensors, microcontrollers, and the local web server for data visualization, the system enables real-time monitoring and predictive maintenance. The precise measurement of critical parameters, combined with effective anomaly detection algorithms, empowers operators to proactively address potential equipment failures. The system's reliability and effectiveness in enhancing equipment dependability and minimizing downtime present a promising solution for industrial maintenance challenges. The system comprises a network of sensors strategically positioned on motor and transformer components to collect essential operating data. Additionally, a relay-based feedback system is incorporated to execute protection actions when abnormal conditions are detected, ensuring improved equipment safety and reliability. These sensors interface with microcontrollers, which then use the web-based interface to transmit and display the processed and analyzed data to a central monitoring station. The efficiency and user-friendly nature of the web interface ensure the timely delivery of critical information, enabling operators to make quick decisions.

***Key Words*:** Industrial IoT, Health Monitoring System, Motor Components, Transformer Components, ESP32, ACS758, ADXL345, DHT11, Web-Based Interface, Predictive Maintenance, Relay based Feedback

1.INTRODUCTION *(Size 11, Times New roman)*

In the contemporary industrial environment, the adoption of advanced technologies is crucial for improving efficiency, reducing downtime, and ensuring the reliability of critical equipment. The Industrial Internet of Things (IIoT) has emerged as a transformative technology, enabling real-time monitoring and predictive maintenance of machinery and infrastructure. This research focuses on constructing an Industrial IoT-based health monitoring system tailored for motor and transformer components. These components are crucial in industrial operations, and their reliable performance is essential for maintaining productivity and safety. However, traditional maintenance methods often fail to provide timely insights into the condition of these components, leading to unforeseen failures and costly downtime. To address this challenge, our project harnesses IoT technologies to implement proactive and data-driven maintenance strategies. The system incorporates necessary components such as the ESP32 microcontroller, ACS758 current sensor, ADXL345 accelerometer, and DHT11 temperature and humidity sensor. These sensors are deliberately placed to monitor key parameters like temperature, humidity, current flow, and vibration levels in real-time. The information collected by these sensors is processed and examined using advanced algorithms to identify malfunctions and foretell potential failures before they occur. Additionally, a relay-based feedback system is integrated to initiate protective actions in response to detected anomalies, thereby enhancing equipment safety and reliability. Incorporation with the local web server ensures seamless and user-friendly interface for accessing real time sensor data, providing remote access and monitoring capabilities. By leveraging the power of IIoT and predictive analytics, our system aims to revolutionize maintenance practices by shifting from reactive to proactive approaches [1–5].

2. Methodology

The methodology involved a systematic approach to developing and implementing the Industrial IoT-based health monitoring system. Initially, requirements were identified through consultations with industry experts, which guided the design process. A comprehensive system architecture was created to integrate sensors, microcontrollers, and the Web Interface, focusing on real-time monitoring and predictive maintenance capabilities. Hardware components, including the ACS758 current sensor, ADXL345 accelerometer, DHT11 temperature sensor, relay module for feedback-based protection, and ESP32 microcontroller, were assembled and integrated into the system. Firmware development was carried out using the Arduino IDE, incorporating code for data acquisition, processing, relay control and MQTT communication. The Local Web Server was configured to facilitate seamless communication and data visualization between the monitoring system and the user interface. Rigorous testing and validation ensured functionality and reliability, with performance evaluation assessing sensor accuracy, real-time responsiveness, and predictive maintenance precision. The relay feedback mechanism was tested to ensure it responded effectively to abnormal conditions, activating protective actions as required. Feedback from the testing phases guided iterative optimization efforts, leading to firmware updates, hardware adjustments, and software refinements to enhance system performance.

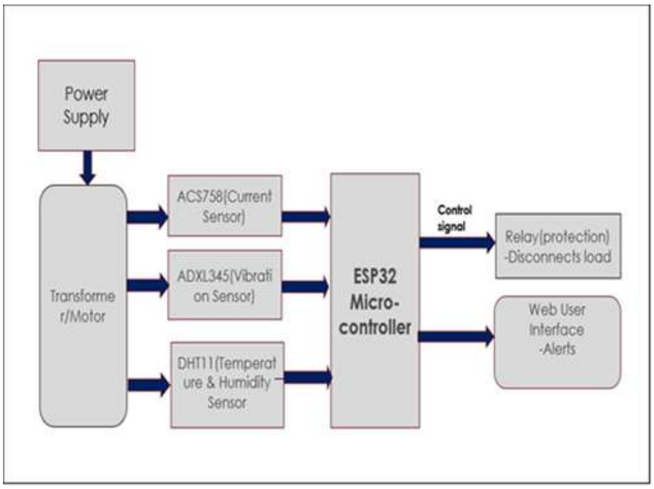

Fig -1: Block diagram

I. MODELING AND ANALYSIS

A. Hardware Components

1. ESP32

The ESP32 is a multipurpose microcontroller developed by Espressif Systems, known for its dual-core processing capabilities and built-in Wi-Fi connectivity. It plays a critical role in managing the system's functions, confirming secure and reliable communication with a cloud-based server. The ESP32's dual-core architecture allows for efficient multitasking, making it an ideal choice for real-time supervising and predictive maintenance in industrial settings. Additionally, its productive set of peripheral interfaces enables seamless integration with sensors such as the ACS758, ADXL345, and DHT11 (Figure 2).

Figure 2: ESP 32 Microcontroller

2. ACS758

The ACS758 is a Hall-effect-based current sensor from Allegro Microsystems. It provides precise, real-time electrical load measurements, outputting an analog voltage proportional to the measured current. This sensor is crucial for estimating power usage, ensuring effective energy management, and monitoring the overall condition of motors and transformers. In this system, the ACS758 interfaces with the ESP32 to provide instantaneous current data, enabling timely interference and predictive maintenance (Figure 3).

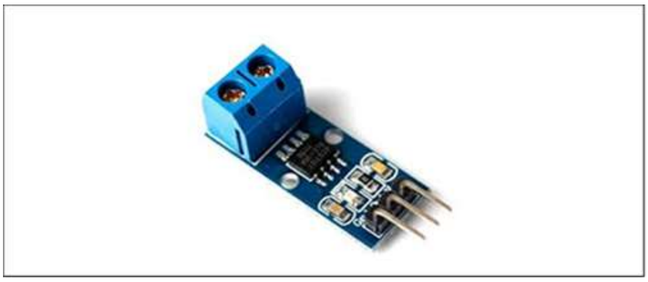

Fig. 3. ACS758 (current sensor)

3. ADXL345

The ADXL345, developed by Analog Devices, is a three-axis accelerometer used for sensing vibrations in motors and transformers. It measures both static and dynamic acceleration, providing necessary data for timely detection of mechanical problems. Incorporated with the ESP32, the ADXL345 boosts the system's ability to detect and respond to abnormalities (Figure 4).

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 04 | April - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

Fig.4. ADXL345 (Vibration Sensor).

4. DHT11

The DHT11 is a digital temperature and humidity sensor used in my Industrial IoT-based health monitoring system to measure the environmental conditions affecting electrical equipment. It provides a calibrated digital output and operates within a temperature range of 0°C to 50°C (±2°C accuracy) and humidity range of 20% to 90% RH (±5% accuracy). The sensor communicates via a single-wire protocol, enabling seamless integration with microcontrollers for real-time monitoring. In my project, the DHT11 plays a crucial role in assessing ambient conditions that may impact the performance and health of transformers and motors, with the data being processed and displayed on a local web server for easy access and analysis. (Figure 5).

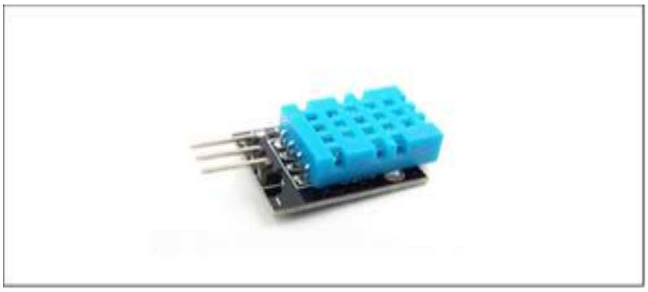

Fig.5. DHT11 (Temperature and Humidity Sensor).

5. Relay Module

The relay module is a crucial component in my Industrial IoT-based health monitoring system, serving as a protective mechanism to safeguard electrical equipment. It acts as a switch that can automatically disconnect or control power flow based on real-time sensor data. The relay operates by receiving signals from the ESP32 microcontroller, which processes data from temperature, current, and vibration sensors. If an anomaly is detected—such as overheating, excessive vibration, or abnormal current levels—the relay can trigger appropriate protective actions, such as shutting down the motor or transformer to prevent damage.

B. Software Components

1. Arduino IDE: The Arduino Integrated Development Environment (IDE) is utilized to program the ESP32 microcontroller. It offers an intuitive interface for writing, compiling, and uploading firmware code to the microcontroller.

2. Local Web Interface: Instead of relying on a cloud-based platform like Adafruit IO, our system implements a local web interface for real-time data visualization and monitoring. This approach ensures seamless interaction between the ESP32 microcontroller and the monitoring system without requiring an external cloud service, thereby reducing latency and dependency on an internet connection.

3. Data Communication via HTTP: The ESP32 microcontroller transmits sensor data to the local web server using HTTP requests. This method enables efficient and real-time monitoring of crucial parameters such as temperature, current, and vibration, directly accessible from a web browser on a connected device.

4. Data Analytics Algorithms: The firmware includes data analytics algorithms designed to analyze sensor data and identify patterns indicative of potential failures. These algorithms may include anomaly detection, trend analysis, and predictive maintenance models, enabling proactive maintenance strategies.

5. Local Web-Based Monitoring System: The local web interface receives sensor data and handles its storage, processing, and real-time visualization. It includes real-time dashboards, historical data analysis tools, and alerting mechanisms for remote monitoring and management of motor and transformer components within the local network.

3. CONCLUSIONS

In conclusion, our research has demonstrated the successful development and validation of an innovative Industrial IoT-based health monitoring system for motor and transformer components in industrial environments. By incorporating advanced sensors, microcontrollers, and real-time communication through the Local Web Server, the system provides real-time monitoring and predictive maintenance capabilities. Precise measurement of critical parameters, combined with effective anomaly detection algorithms, enables operators to proactively manage potential equipment failures, reducing downtime and enhancing operational efficiency. Looking ahead, deploying this system in real-world industrial environments is set to transform maintenance practices and significantly enhance equipment reliability.

RESULT AND DISCUSSION

Our project has successfully developed and validated a pioneering Industrial IoT-based health monitoring system for motor and transformer components. By integrating advanced sensors, microcontrollers, and real-time communication via Web Server, the system offers real-time monitoring and predictive maintenance capabilities. This approach ensures accurate measurement of critical parameters and effective detection of anomalies, allowing operators to address potential equipment failures proactively. The system's reliability and efficiency represent a significant advancement in industrial maintenance practices, promising improved equipment reliability and operational efficiency.

The relay module plays a crucial role in the system by providing automated feedback control, allowing the system to take immediate corrective actions when abnormal conditions are detected. For instance, if the current, temperature, or vibration levels exceed predefined safety thresholds, the relay can trigger necessary responses, such as disabling the faulty equipment or activating a cooling mechanism. This proactive intervention minimizes the risk of catastrophic failures and enhances equipment protection and operational safety.
However, the system has certain limitations, such as hardware constraints, network dependency, and security concerns, which could be addressed in future work. Potential future improvements include enhanced sensor integration, offline capabilities, power optimization, machine learning algorithms for advanced anomaly detection, and user interface enhancements.

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