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IOT-BASED DISTRIBUTION TRANSFORMER CONDITION MONITORING SYSTEM

Sandhya Deepthi A., Mahammed Jubair N.S., Greeshma R., Divya P., Rama Narayana K., Sumanth Goud K.

Sandhya Deepthi A., Mahammed Jubair N.S., Greeshma R., Divya P., Rama Narayana K., Sumanth Goud K.
Department of ECE, Chaitanya Bharathi Institute of Technology, Proddatur, India
E-mail: deepthisreekanth90@gmail.com,
mahammadjubair786@gmail.com

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Abstract

Distribution transformers are critical components in electrical networks, and their performance directly influences the reliability of power supply systems. This paper presents an IoT-based transformer condition monitoring and alerting system that continuously evaluates parameters such as temperature, oil level, current, and voltage. By integrating sensors with a microcontroller and wireless communication modules, the system collects real-time data and transfers it to a cloud platform for analysis. Abnormal readings trigger instant alerts to maintenance personnel through mobile or web applications. The proposed model significantly enhances transformer reliability by enabling early fault detection, reducing manual inspections, and supporting predictive maintenance strategies. The results demonstrate that continuous monitoring and automated notifications can minimize downtime and extend the operational life of power transformers.

1. Introduction

Electric power distribution systems rely heavily on the efficient functioning of transformers. These devices operate under fluctuating load and environmental conditions, making them vulnerable to failures such as overheating, insulation breakdown, oil leakage, and overloading. Traditional maintenance methods based on manual observation and scheduled inspections—often fail to detect issues before they escalate.

With the evolution of IoT and embedded systems, it is now possible to monitor transformer conditions in real time. Sensors integrated with a microcontroller can continuously collect data, analyse operational states, and send alerts when abnormalities occur. This approach not only enhances fault detection capabilities but also reduces maintenance costs and downtime.

The present study develops and evaluates an IoT-enabled Transformer Condition Monitoring System that observes crucial parameters, transmits information to a remote platform, and generates immediate alerts under fault conditions

2. Related Work

Earlier methods for transformer maintenance focused on manual checks of temperature, oil quality, and load conditions. However, such techniques lacked real-time accuracy and delayed fault detection. Recent studies have proposed automated condition monitoring using microcontrollers and sensors.

Advancements in IoT technologies have introduced networked systems that gather, process, and transmit transformer data to remote servers or dashboards. These systems employ modules such as GSM, Wi-Fi, or LoRa to facilitate instant alerts and graphical visualization. As a result, IoT-enabled condition monitoring has become an effective approach to ensuring uninterrupted and efficient transformer operation.

3. Methodology

The proposed approach combines sensing, data processing, and communication technologies to ensure real-time status evaluation.

3.1 Data Acquisition

Temperature, oil level, current, and voltage sensors are connected to the transformer to measure critical operational parameters. The data are continuously collected and converted into digital signals for analysis.

3.2 Processing and Fault Analysis

A microcontroller such as Arduino or Raspberry Pi acts as the processing hub. It compares the sensed data with predefined thresholds representing safe operational limits. If deviations are detected, the system identifies the potential fault and logs the data for analysis.

3.3 Communication and Alert Generation

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Data are transmitted via GSM or Wi-Fi modules to a cloud platform. The system triggers automatic alerts through SMS, email, or a web dashboard when abnormal readings occur. These notifications enable timely maintenance intervention and minimize transformer downtime.

3.4 Data Storage and Predictive Analysis

Historical data are archived for trend analysis, helping predict component deterioration or emerging faults. This supports predictive maintenance planning and reduces unexpected equipment failures.

4. System Architecture

The overall structure of the monitoring system includes four layers—sensor, processing, communication, and monitoring (Figure 1).

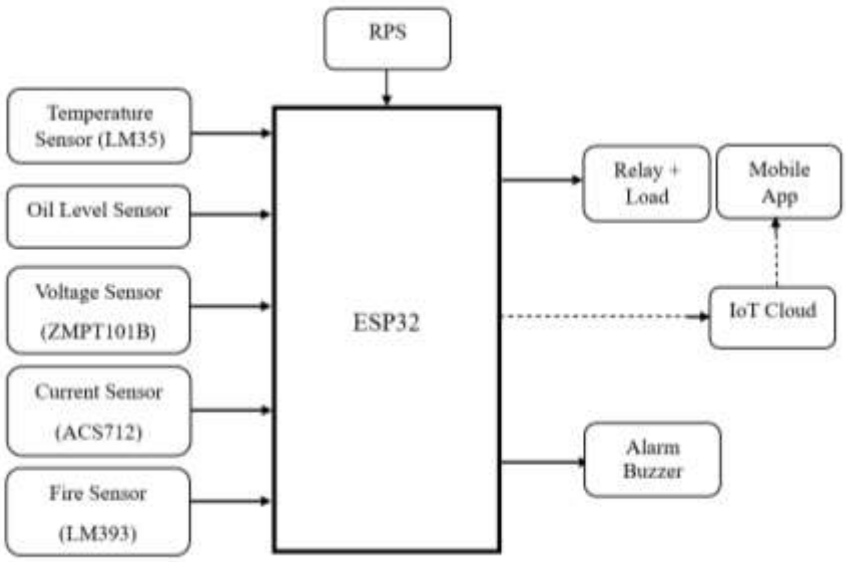

Figure 1. Block diagram of the IoT-based transformer condition monitoring system.

The sensor layer monitors the physical parameters of the transformer. The processing layer analyses this data and determines abnormal conditions. The communication layer transmits information to a centralized server, and the monitoring platform displays it in real time. Automated alerts are issued when unsafe conditions are detected.

5. Results and Discussion

Experimental evaluation confirmed that the monitoring system effectively gathered and processed transformer data. The readings from temperature, current, and oil level sensors accurately reflected real transformer conditions.

When tested under varying load conditions, the system quickly identified instances of overheating and overloading. Abnormality detection triggered notification messages, demonstrating fast response and high reliability. The cloud dashboard also stored historical readings, allowing trend visualization and predictive fault analysis.

Compared to manual inspection, the IoT-based system improved detection accuracy, reduced operator workload, and provided continuous visibility into transformer performance.

6. Comparative and Predictive Evaluation

Traditional monitoring methods only provide periodic status checks, whereas the proposed IoT system ensures continuous real-time monitoring. This reduces the interval between fault occurrence and detection, resulting in rapid response.

Graphical analysis revealed clear parameter trends, aiding in early identification of deteriorating conditions. Predictive algorithms analysed parameter variance to forecast potential issues such as thermal degradation or load imbalance. The system achieved high accuracy in predicting faults while minimizing false alarms, as verified using a confusion matrix model (Figure 2).

Figure 2. Comparison between predicted and actual transformer states.

7. Conclusion

An IoT-based transformer condition monitoring and alerting system has been successfully developed and tested. The design integrates sensors, microcontrollers, and wireless modules to continuously track transformer performance metrics. Real-time analysis and alert notifications improve fault response and reduce maintenance costs.

Experimental evaluations confirmed that the system provides accurate monitoring, rapid alerting, and reliable operation in real-world conditions. Its capability for predictive analysis further enhances preventive maintenance and operational efficiency. This system represents a practical, low-cost solution for smart energy management and the modernization of power distribution infrastructure.

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Data Availability Statement

All experimental and analytical data supporting this study are available upon reasonable request from the corresponding author.

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