

Review on Power Transformer Monitoring and Notification System Using IOT Technique

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Abstract -

Power transformers are critical components of modern power systems, and their reliable operation is essential for ensuring uninterrupted power supply. Transformer failures can lead to significant economic losses, equipment damage, and power outages. To address these challenges, Internet of Things (IoT)-based monitoring systems have emerged as an effective solution for real-time condition assessment and predictive maintenance of power transformers. This review paper presents a comprehensive analysis of IoT-enabled power transformer monitoring techniques and their applications in smart grid environments.

The proposed monitoring framework is designed to continuously assess the health and operating conditions of power transformers through the integration of multiple sensors, cloud computing, and wireless communication technologies. Key parameters such as transformer temperature, oil level, voltage, current, ambient humidity, gas leakage, load condition, fire detection status, and real-time geographical location are monitored continuously. The review discusses various sensing technologies, communication protocols, cloud-based monitoring platforms, and fault detection methodologies employed in recent transformer monitoring systems. The integration of IoT, cloud computing, GPS-based location tracking, and GSM alert mechanisms enhances transformer reliability, reduces maintenance costs, enables predictive diagnostics, and improves overall power system stability. This study highlights current advancements, challenges, and future research directions in the development of intelligent transformer monitoring systems for smart power networks.

Key Words: Power Transformer Monitoring, Internet of Things (IoT), Smart Grid, GSM Alert System, Cloud Computing, Gas Leakage Detection, Fire Detection, GPS Tracking, Predictive Maintenance, Industrial Automation.

1. INTRODUCTION

Power transformers are among the most critical and expensive assets in electrical power generation, transmission, and distribution systems. They play a vital role in maintaining a reliable and continuous supply of electricity to industrial, commercial, and residential consumers. Any unexpected transformer failure can lead to significant economic losses, power interruptions, equipment damage, and safety hazards. Therefore, continuous monitoring of transformer operating conditions is essential to ensure system reliability, improve operational efficiency, and extend transformer lifespan.

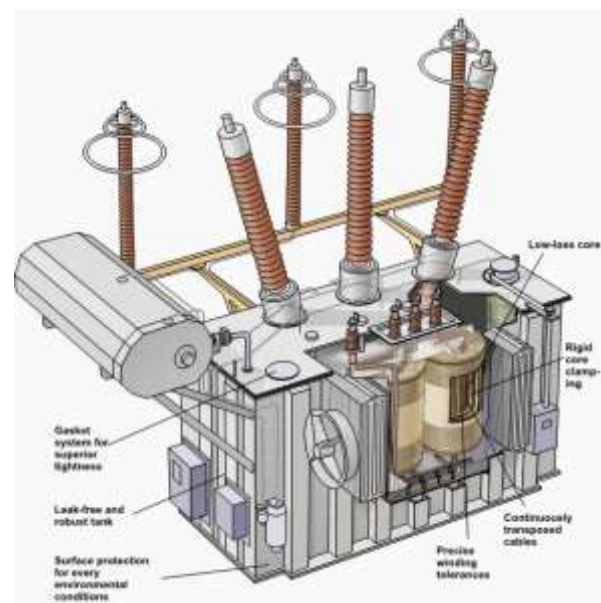


Fig1:- Introduction To Power Transformer

Traditionally, transformer maintenance has been performed through periodic inspections and manual measurements. However, conventional monitoring techniques are often time-consuming, labor-intensive, and incapable of providing real-time information regarding transformer health. As modern power systems become increasingly complex, there is a growing demand for intelligent monitoring solutions that can continuously assess transformer conditions and provide early warning of potential faults.

The rapid advancement of the Internet of Things (IoT) has enabled the development of smart monitoring systems capable of collecting, processing, and transmitting real-time data from remote electrical equipment. IoT-based transformer monitoring systems integrate multiple sensors, communication technologies, and cloud platforms to provide continuous supervision of critical transformer parameters. These systems facilitate predictive maintenance by detecting abnormal operating conditions before catastrophic failures occur.

This review focuses on IoT-based power transformer monitoring systems designed to continuously monitor transformer health and operating conditions using cloud integration and GSM communication. The proposed monitoring framework acquires real-time data from various sensors measuring transformer temperature, oil level, voltage, current, humidity, gas leakage, load conditions, and fire detection status. In addition, Global Positioning System (GPS) technology is incorporated to provide real-time location tracking of transformers, particularly useful for mobile substations and transformers deployed in remote areas.

The collected sensor data are processed using microcontroller-based embedded systems such as ESP32, Arduino, or other IoT-enabled controllers. The information is then transmitted to cloud servers through wireless communication networks, allowing authorized personnel to access transformer status remotely through web dashboards or mobile applications. Furthermore, a GSM module is integrated to generate instant SMS alerts whenever abnormal conditions such as overheating, excessive loading, oil leakage, fire incidents, gas accumulation, or voltage fluctuations are detected. This

immediate notification capability significantly enhances fault response time and improves operational safety.

Recent research has demonstrated that IoT-enabled transformer monitoring systems offer several advantages, including real-time data acquisition, remote accessibility, predictive maintenance capabilities, reduced maintenance costs, improved reliability, and enhanced asset management. The integration of cloud computing, wireless sensor networks, GSM communication, and GPS tracking further strengthens the effectiveness of transformer condition monitoring in modern smart grid environments.

This review paper presents a comprehensive analysis of existing transformer monitoring techniques, IoT architectures, communication technologies, sensor integration methods, cloud-based monitoring platforms, and GSM alert mechanisms. The study also discusses current challenges, emerging trends, and future research opportunities in the development of intelligent transformer monitoring systems for smart power networks.

2. Literature Survey

Introduction

Power transformers are critical assets in electrical power transmission and distribution systems. Transformer failures can lead to significant economic losses, power outages, and safety hazards. Traditional maintenance methods rely on periodic inspections, which may fail to detect developing faults in real time. The integration of Internet of Things (IoT), cloud computing, GSM communication, and intelligent sensing technologies has enabled continuous monitoring of transformer health parameters such as temperature, oil level, voltage, current, humidity, gas leakage, load conditions, fire detection, and geographical location. Recent research focuses on predictive maintenance, remote monitoring, and real-time fault diagnosis to improve transformer reliability and lifespan.

1. Kalpana Hazarika, Gauri Katiyar, Noorul Islam (2021)**"IoT Based Transformer Health Monitoring System: A Survey"**

The authors presented a comprehensive survey of transformer monitoring systems based on IoT technologies. The study reviewed various sensor-based monitoring architectures capable of measuring transformer temperature, oil level, voltage, and current. GSM-GPRS communication was highlighted as one of the most widely adopted technologies for remote fault notification. The survey concluded that continuous online monitoring significantly reduces catastrophic transformer failures and improves maintenance planning. The paper also emphasized the role of cloud platforms in storing and analyzing transformer data remotely.

2. Mzamo R. Msane, Bonginkosi A. Thango, Kingsley A. Ogudo (2024)**"Condition Monitoring of Electrical Transformers Using the Internet of Things: A Systematic Literature Review"**

This systematic review analyzed global research trends in IoT-based transformer monitoring systems. The authors found that most IoT systems utilize sensors integrated with microcontrollers such as Arduino, ESP32, and Raspberry Pi. Real-time monitoring of oil temperature, voltage, current, and oil levels was identified as the most common approach. The study highlighted the advantages of cloud-based visualization, predictive maintenance, and automated fault detection. The review also emphasized the importance of integrating protection relays and intelligent fault isolation mechanisms with IoT monitoring systems.

3. Pankaj Kumar Dubey et al. (2025)**"Review of Transformer Health Monitoring System and Fault Detection"**

The authors proposed a Transformer Health Monitoring System (THMS) capable of continuously monitoring voltage, temperature, and load conditions. The system uses IoT technology to gather sensor data and perform remote analysis.

The study highlighted the economic benefits of early fault detection and predictive maintenance. The proposed framework improves operational reliability and reduces transformer downtime through real-time diagnostics.

4. Priti Pal et al. (2023)**"A Review Paper on Transformer Health Monitoring System"**

The researchers developed a transformer monitoring system based on ESP32 and multiple sensors. The system continuously measures voltage, current, oil level, and temperature. Data is transmitted wirelessly and displayed in real time on both mobile devices and LCD displays. The paper demonstrated how low-cost IoT hardware can significantly improve transformer monitoring capabilities while maintaining affordability.

5. Shelke Aishwarya Abasaheb et al. (2025)**"Transformer Health Monitoring System"**

This work proposed an IoT-based transformer monitoring platform using ESP8266 and cloud communication. The system performs continuous monitoring of transformer parameters and supports predictive maintenance through remote data logging. The study emphasized the importance of cloud-based analytics and wireless communication in modern smart grid environments.

6. Dr. Sachin Gee Paul et al. (2022)**"Transformer Health Monitoring and Protection Using IoT"**

The researchers implemented a practical transformer monitoring system that continuously monitors oil level, voltage, current, and temperature using sensor networks. Data is transmitted to an IoT platform via ESP8266. The system improves monitoring accuracy and reduces manual inspection efforts. The authors demonstrated the effectiveness of IoT technologies in preventing transformer failures through continuous observation of critical operating parameters.

7. Jehan Parvez, Salman Khan, Imran Khan (2021)

"Real-Time Monitoring System of Power Transformer Using IoT and GSM"

This study specifically focused on combining IoT and GSM technologies for transformer health monitoring. The system monitors abnormal conditions such as overheating, overload, over-voltage, abnormal frequency, and breaker failures. GSM modules are used to send instant SMS alerts to maintenance personnel whenever abnormal conditions occur. The authors concluded that GSM-based notifications significantly improve response times and prevent major transformer failures.

8. Deepak Kulkarni and N. Kumar Swamy (2023)

"Machine Learning-Based Real-Time Fault Prediction"

This research introduced machine learning into transformer health monitoring systems. Voltage, current, temperature, and load capacity data are collected through IoT sensors and analyzed using predictive algorithms. The system can forecast potential transformer failures before they occur, enabling proactive maintenance strategies.

Research Gap Analysis:-

Based on the literature review, most existing transformer monitoring systems focus on:

- Temperature monitoring
- Voltage monitoring
- Current monitoring
- Oil level monitoring

However, only a limited number of studies integrate all critical parameters into a single system, including:

- Transformer temperature
- Oil level
- Voltage
- Current
- Humidity
- Gas leakage detection

- Load monitoring
- Fire detection
- GPS-based transformer location tracking
- GSM notification
- Cloud-based IoT dashboard

Most current systems also lack:

- Real-time GPS location tracking
- Combined fire and gas leakage monitoring
- Multi-channel notification systems
- AI-based fault prediction
- Comprehensive cloud analytic

3. METHODOLOGY

A. System Overview

The proposed IoT-based Power Transformer Monitoring System is designed to continuously monitor the operational health and safety conditions of distribution and power transformers in real time. The system utilizes various sensors connected to an ESP32 microcontroller to collect critical transformer parameters. The acquired data is transmitted to a cloud server through Wi-Fi and simultaneously monitored using a GSM communication module for emergency notifications. In addition, a GPS module is incorporated to provide the real-time geographical location of the transformer.

The primary objective of the system is to detect abnormal operating conditions at an early stage, thereby reducing transformer failures, maintenance costs, and power interruptions.

B. System Architecture

The monitoring system consists of five major layers:

1. Data Acquisition Layer

This layer includes sensors installed on the transformer to measure various operating parameters:

- Temperature Sensor (DS18B20/LM35)

- Oil Level Sensor
- Voltage Sensor Module (ZMPT101B)
- Current Sensor (ACS712)
- Humidity Sensor (DHT22)
- Gas Leakage Sensor (MQ-2/MQ-135)
- Flame/Fire Detection Sensor
- GPS Module (NEO-6M)

These sensors continuously monitor transformer conditions and provide real-time analog or digital signals to the controller.

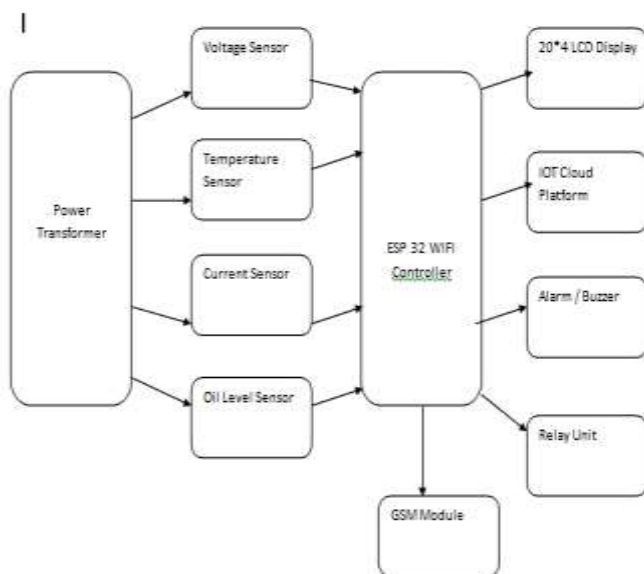


Fig2:- Block Diagram Of Proposed System

2. Processing Layer

The ESP32 microcontroller serves as the central processing unit. It performs:

- Sensor data acquisition
- Signal conditioning
- Data filtering
- Threshold comparison
- Fault detection
- Communication management

The controller converts analog sensor outputs into digital values using its built-in ADC and processes the data according to predefined operating limits.

3. Communication Layer

The communication layer consists of:

- Wi-Fi module (integrated with ESP32)
- GSM Module (SIM800L/SIM900)
- GPS Module

The Wi-Fi network is used for cloud communication, while the GSM module provides backup communication and emergency notifications via SMS.

4. Cloud Monitoring Layer

The collected sensor data is transmitted to an IoT cloud platform such as:

- Blynk IoT
- ThingSpeak
- Firebase
- AWS IoT

The cloud platform stores historical data and provides real-time visualization through dashboards, graphs, and status indicators.

5. User Interface Layer

Users can monitor transformer conditions remotely using:

- Mobile Application
- Web Dashboard
- SMS Alerts

Maintenance personnel receive immediate notifications when abnormal conditions are detected.

C. Monitoring Parameters

1. Temperature Monitoring

Transformer winding and oil temperatures significantly affect insulation life. A temperature sensor continuously measures the transformer temperature.

If:

Temperature > Preset Threshold

the system generates an alert and sends notifications to maintenance personnel.

2. Oil Level Monitoring

Transformer oil provides insulation and cooling.

The oil level sensor continuously measures the oil quantity.

Abnormal conditions include:

- Low oil level
- Sudden oil leakage
- Critical oil depletion

Such events trigger warning messages and cloud alerts.

3. Voltage Monitoring

Voltage sensors measure transformer input and output voltages.

The system detects:

- Over-voltage
- Under-voltage
- Voltage fluctuations

These conditions are recorded and analyzed for preventive maintenance.

4. Current Monitoring

Current sensors monitor transformer load current.

The system detects:

- Overload conditions
- Short-circuit indications
- Excessive current draw

Current values are continuously uploaded to the cloud platform.

5. Humidity Monitoring

Humidity inside transformer enclosures may cause insulation degradation and corrosion.

The DHT22 sensor continuously monitors ambient humidity levels.

When humidity exceeds permissible limits, warning notifications are generated.

6. Gas Leakage Detection

Faults inside transformers often produce combustible gases.

MQ-series gas sensors detect:

- Smoke
- Methane
- LPG
- Other combustible gases

Gas concentration values are continuously monitored and uploaded to the cloud.

7. Fire Detection

A flame sensor provides immediate fire detection capability.

Upon detecting fire:

- Alarm is activated
- SMS alert is transmitted
- Emergency cloud notification is generated

This enables rapid response and damage prevention.

8. Load Condition Monitoring

Load condition is determined using measured voltage and current values.

The controller calculates:

$$\text{Power (P)} = \text{Voltage} \times \text{Current}$$

Load status categories include:

- Normal Load
- Medium Load
- High Load
- Overloaded Condition

These values assist in transformer capacity management.

9. Real-Time Location Tracking

The GPS module continuously acquires latitude and longitude coordinates.

Location information enables:

- Asset tracking
- Maintenance scheduling
- Fault localization
- Theft prevention

GPS coordinates are displayed on the cloud dashboard and can be linked to Google Maps.

D. Fault Detection Algorithm

The system employs a threshold-based fault detection mechanism.

The algorithm follows these steps:

Step 1:

Acquire sensor data from all monitoring sensors.

Step 2:

Convert raw sensor values into engineering units.

Step 3:

Compare measured values with predefined safety thresholds.

Step 4:

Identify abnormal operating conditions.

Step 5:

Generate local alarm.

Step 6:

Upload fault information to the cloud server.

Step 7:

Transmit SMS alerts through GSM module.

Step 8:

Store event records in cloud database.

This methodology enables real-time fault diagnosis and preventive maintenance.

E. Cloud Data Management

Sensor data is periodically transmitted to the IoT cloud.

The cloud platform performs:

- Data storage
- Historical analysis
- Trend visualization
- Fault logging
- Predictive maintenance support

The dashboard provides graphical representations of:

- Temperature
- Oil level
- Voltage
- Current
- Humidity
- Gas concentration
- Load condition
- GPS location

F. GSM Alert Mechanism

The GSM module acts as an emergency notification system.

When any monitored parameter exceeds its threshold:

- SMS alert is generated automatically.
- Transformer identification is included.
- Fault type is specified.
- GPS location is attached.

Example Alert:

"Transformer T-101 Alert: Temperature = 95°C, Oil Level Low. Location: 19.8765, 75.3432"

This feature ensures immediate fault reporting even when internet connectivity is unavailable.

G. Performance Evaluation

The effectiveness of the proposed monitoring system is evaluated using:

- Sensor Accuracy
- Data Transmission Reliability
- Alert Response Time
- Cloud Update Delay
- GSM Notification Time
- Power Consumption
- Fault Detection Accuracy

The collected data is analyzed to assess system reliability and operational efficiency under various transformer loading conditions.

H. Overall Workflow

1. Sensors continuously monitor transformer parameters.
2. ESP32 processes acquired data.
3. Sensor values are compared with threshold limits.
4. Data is uploaded to the IoT cloud.
5. Dashboard displays real-time transformer status.
6. Fault conditions trigger GSM notifications.
7. GPS module provides real-time location.
8. Historical data is stored for predictive maintenance and future analysis.

4. CONCLUSIONS

The review of IoT-based power transformer monitoring systems demonstrates that continuous and intelligent monitoring is essential for improving transformer reliability, operational efficiency, and service life. Traditional inspection methods are often insufficient for detecting developing faults in real time, which can lead to unexpected failures, costly repairs, and power interruptions. The integration of IoT technology, cloud computing, and GSM communication provides an effective solution for real-time condition monitoring and predictive maintenance of power transformers.

The proposed monitoring system continuously acquires critical transformer parameters such as temperature, oil level, voltage, current, humidity, gas leakage, load condition, fire detection status, and geographical location. These parameters are transmitted to a cloud platform for remote monitoring, data storage, and analysis. Furthermore, the GSM module enables instant notifications and alerts to maintenance personnel whenever abnormal operating conditions are detected, ensuring rapid response and fault mitigation.

The incorporation of real-time location tracking further enhances asset management and security, especially for transformers installed in remote or inaccessible areas. By enabling continuous monitoring, early fault detection, and remote accessibility, the system contributes significantly to reducing maintenance costs, minimizing downtime, and enhancing power system reliability.

Future developments may include the integration of artificial intelligence, machine learning algorithms, and predictive analytics for advanced fault diagnosis and transformer health assessment. Overall, IoT-enabled transformer monitoring systems represent a promising advancement toward the realization of smart grids, intelligent power networks, and efficient energy management systems.

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