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DISTRIBUTION TRANSFORMER MONITORING USING GSM TECHNOLOGY

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A B S T R A C T :

Reliable operation of distribution transformers is essential for maintaining stability in electrical power networks, yet their performance is often affected by overheating, overloading, and insulation degradation. Conventional monitoring practices rely heavily on periodic manual inspection, which is insufficient for detecting early-stage faults and often results in unexpected outages. This paper presents a GSM-enabled transformer health monitoring system capable of real-time acquisition, analysis, and communication of critical electrical parameters. The proposed design employs an ESP32 microcontroller interfaced with voltage, current, and temperature sensors to obtain continuous measurements, which are displayed locally and evaluated against predefined safety thresholds. Upon detection of abnormal conditions, the SIM800C GSM module automatically transmits alert messages to the operator, ensuring rapid and effective corrective action. The system further integrates cloud-based data logging, enabling long-term storage, trend analysis, and remote visualization through an IoT platform. Experimental validation demonstrates reliable sensor accuracy, stable wireless communication, and prompt fault notification across multiple test scenarios. The results indicate that the proposed solution provides a cost-effective, scalable, and efficient platform for predictive maintenance, ultimately enhancing the overall reliability, safety, and operational lifespan of distribution transformers in modern power grids.

Keywords:

- Distribution transformer
- SMS Alert System
- GSM Technology
- Fault Detection
- Real-time monitoring
- Predictive Maintanence

Introduction

Distribution transformers are essential components of the electrical power system, responsible for reducing medium voltage to usable low-voltage levels for end-users. Transformer failures commonly occur due to overloading, insulation breakdown, temperature rise, and poor maintenance practices. Traditional monitoring of transformers involves manual inspection, which is time-consuming, inaccurate, and inefficient for real-time fault detection.With advancements in communication and embedded systems, **remote monitoring** has become both affordable and highly effective. A GSM-based monitoring system allows operators to receive live updates and immediate SMS alerts whenever critical parameters exceed safe limits. Such systems prevent breakdowns, improve maintenance response, and increase the overall lifespan of transformers.The proposed project integrates sensors, an Arduino microcontroller, and a GSM module to continuously monitor temperature, voltage, load current, and oil level. The system sends SMS alerts to maintenance personnel, ensuring quick detection of abnormal operating conditions.

Problem Statement

Distribution transformers often face faults like overheating, overload, and voltage/current fluctuations that go undetected through manual monitoring.Traditional inspection methods are slow and cannot provide real-time fault detection.This leads to unexpected transformer failures, power outages, and high maintenance costs.A system is needed to continuously monitor transformer parameters and provide instant alerts during abnormalities.GSM-based monitoring offers a reliable, low-cost solution for real-time remote fault detection and improved safety.

Literature review

Previous studies show that real-time monitoring of distribution transformers is essential to prevent failures caused by overload, overheating, and voltage fluctuations. Researchers like Msane et al. (2023) proposed IoT-based monitoring systems using sensors and cloud platforms for continuous data tracking. Sharma and Singh (2022) introduced GSM-based monitoring, where abnormal conditions trigger SMS alerts, making it useful in remote areas without internet access. Patel (2023) highlighted the efficiency of ESP32 for real-time electrical parameter measurement due to its fast processing and sensor compatibility. Kumar (2021) demonstrated the accuracy of ZMPT101B and ACS712 sensors for voltage and current measurement in transformer applications. Overall, existing research confirms that combining sensors, microcontrollers, and GSM technology can provide a reliable, low-cost solution for transformer health monitoring.

Existing System

In the current distribution network, transformer monitoring is mostly done through manual inspection, where technicians periodically check temperature, oil levels, load conditions, and physical faults. This method is slow, infrequent, and unreliable, often failing to detect abnormalities in their early stages. Existing systems use basic instruments such as thermometers, ammeters, and voltmeters, which do not provide continuous monitoring or automatic alerts. As a result, faults like overheating, overload, insulation failure, or low oil levels are identified only after major damage occurs. Some advanced systems exist, but they are costly and not suitable for rural or remote installations. Therefore, the existing system lacks real-time data, automated alerts, and remote monitoring capability, leading to unexpected transformer failures and increased maintenance cost.

Methodology

The methodology of the proposed system involves a step-by-step process to monitor transformer parameters in real time using sensors, a microcontroller, and GSM communication. First, the 230V AC supply is stepped down to a safe level and regulated to power the ESP32 microcontroller and sensors. The ZMPT101B voltage sensor, ACS712 current sensor, and DHT11 temperature sensor continuously measure the transformer's electrical and environmental parameters. These sensor outputs are fed into the ESP32, which processes the data, converts the analog values, and compares them with predefined threshold limits.The processed values are displayed on a 16×2 LCD for local monitoring. When the system detects an abnormal condition such as over-voltage, over-current, or high temperature, it activates alert indicators like a buzzer and LEDs for immediate on-site warning. Simultaneously, the ESP32 communicates with the SIM800C GSM module to send SMS alerts to the user or maintenance team. Additionally, real-time data can be uploaded to the ThingSpeak cloud platform for remote visualization and logging. Through this integrated flow of sensing, processing, displaying, and alerting, the system ensures continuous monitoring and timely detection of transformer faults.

System Architecture

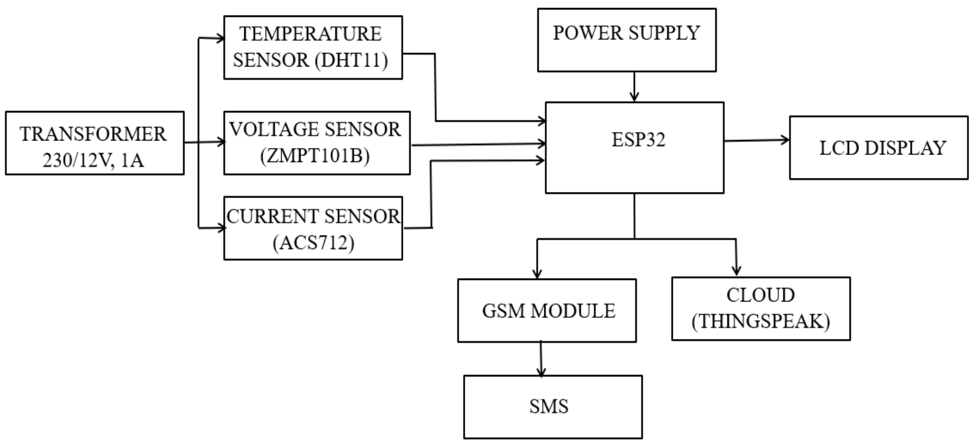

Fig: Block Diagram of Distribution Transformer Monitoring System

The system is designed to monitor key electrical parameters—voltage, current, and temperature using an ESP32-based IoT architecture. The process begins with a 230V/12V transformer, which steps down the mains voltage to a safer level used for sensing and powering the system. A temperature sensor (DHT11) records the ambient temperature and sends the data directly to the ESP32 in digital form. The voltage sensor (ZMPT101B) measures AC mains voltage and provides a scaled, isolated analog signal that the ESP32 can safely interpret through its ADC input. Similarly, the ACS712 current sensor measures the load current using Hall-effect sensing and outputs an analog voltage proportional to the current, allowing real-time monitoring of load behavior. A regulated power supply converts the transformer output into stable DC voltage required by the ESP32, sensors, LCD, and GSM module. Acting as the central controller, the ESP32 collects data from all sensors, processes the readings, and controls the communication modules. The measured voltage, current, and temperature values are displayed on an LCD for local monitoring. The ESP32 transmits the processed data to the cloud platform

ThingSpeak via Wi-Fi, enabling remote monitoring, data logging, and visualization from anywhere. Additionally, a GSM module is integrated to enhance safety and reliability by sending SMS alerts to the user during abnormal conditions such as over-voltage, over-current, or high temperature. Through this combination of local display, cloud connectivity, and SMS-based alerts, the overall system provides a complete and intelligent solution for real-time electrical parameter monitoring.

Distribution Transformer Monitoring using GSM Technology hardware and Software components Implementation

Hardware Implementation:

1. ESP32 Microcontroller

The ESP32 is a powerful dual-core microcontroller with built-in Wi-Fi and Bluetooth capabilities. It serves as the central controller of the system, responsible for collecting data from sensors such as voltage, current, and temperature. The ESP32 processes sensor outputs, compares them with threshold values, displays real-time results on the LCD, and communicates with the GSM module to send SMS alerts during abnormal conditions. Its high-speed ADC, multiple GPIO pins, and UART/I2C connectivity make it ideal for real-time monitoring applications.

2. ZMPT101B Voltage Sensor

The ZMPT101B is a highly accurate AC voltage sensor used to measure the transformer's output voltage. It is designed with an onboard voltage transformer, providing electrical isolation and safe measurement. The sensor produces a proportional analog signal that is fed into the ESP32 ADC pin. This allows the system to continuously monitor voltage fluctuations, detect over-voltage conditions, and ensure stable transformer performance.

3. ACS712 Current Sensor

The ACS712 is a Hall-effect-based AC/DC current sensor that accurately measures load current without direct electrical contact. It senses the magnetic field produced by current flow and outputs a corresponding analog voltage. This ensures complete isolation and safety. In this project, the ACS712 helps detect overload conditions and irregular current consumption, which are early signs of transformer stress or failure.

4. 16*2 LCD Display with I2C Module

The 16×2 character LCD shows real-time transformer parameters such as voltage, current, and temperature. The I2C interface reduces the number of wires required, using only two communication lines (SDA and SCL). This simplifies the wiring and ensures clear visual output for technicians. The display helps users easily read live data during testing and field operation.

5. DHT11 Temperature Sensor

The DHT11 is a digital temperature and humidity sensor used to monitor the environmental temperature surrounding the transformer. Although ambient temperature differs from oil temperature, it still serves as an indicator of overheating risks. The sensor sends a calibrated digital output to the ESP32, enabling precise temperature monitoring. High temperature readings trigger the system’s alert mechanisms to prevent thermal damage.

6. SIM800C GSM Module

The SIM800C is a compact, quad-band GSM module used for wireless communication. It operates using a standard SIM card and communicates with the ESP32 through UART serial communication. When the ESP32 detects over-voltage, overload, or high temperature, it sends AT commands to the GSM module, which then transmits SMS alerts to the user. This ensures remote monitoring even in locations with no internet access.

7. 230V/12V Step-Down Transformer

A step-down transformer converts the high-voltage 230V AC mains supply into a safer 12V AC output. This low-voltage AC is used for powering the circuit after rectification. It plays a critical role in isolating the system from dangerous high voltages and preventing electrical hazards.

Software Implementation:

1. Introduction of Arduino IDE

The ESP32 consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

2. Programming language used

First, the ESP32 compiler/IDE accepts C and C++ as-is. In fact, many of the libraries are written in C++. Much of the underlying system is not object oriented, but it could be. Thus, "The ESP32 language" is C++ or C.

3. Getting started with Arduino IDE

This is the Arduino IDE once it’s been opened. It opens into a blank sketch where you can start programming immediately. First, we should configure the board and port settings to allow us to upload code. Connect your Arduino board to the PC via the USB cable.

4. Arduino IDE: Board setup

To set up the ESP32 module in Arduino IDE, install the ESP32 board package via Boards Manager, select the correct board and COM port, install necessary USB drivers if required, and verify the setup by uploading a basic Blink LED program.

5. Arduino IDE com port setup

To set up the COM port for ESP32 in Arduino IDE, first connect the ESP32 board to the computer using a USB cable. Open Arduino IDE, go to Tools → Board, and select ESP32 Dev Module. Then, navigate to Tools → Port and choose the correct COM port where the ESP32 is connected. If the board is not detected, install the necessary CP2102 or CH340 drivers. After selecting the correct port, the board type and COM number will appear in the bottom-right corner of the IDE. This confirms that the ESP32 is successfully recognized and ready for programming.

6. Introduction of processing IDE

Processing (programming language) Processing is an open-source computer programming language and integrated development environment (IDE) built for the electronic arts, new media art, and visual design communities with the purpose of teaching non-programmers the fundamentals of computer programming in a visual context.

7. Processing software

Word processing software is used to manipulate a text document, such as a resume or a report. You typically enter text by typing, and the software provides tools for copying, deleting and various types of formatting.

1. Getting started

- Open processing IDE.
- Go to the file menu and create a new page.
- Write the code.
- Run.

2. How processing IDE Communicate with Arduino IDE

The Arduino IDE and the Processing IDE will communicate with each other through serial communication. The Processing IDE has a serial library which makes it easy to communicate with the ESP32.

3. Circuit Diagram

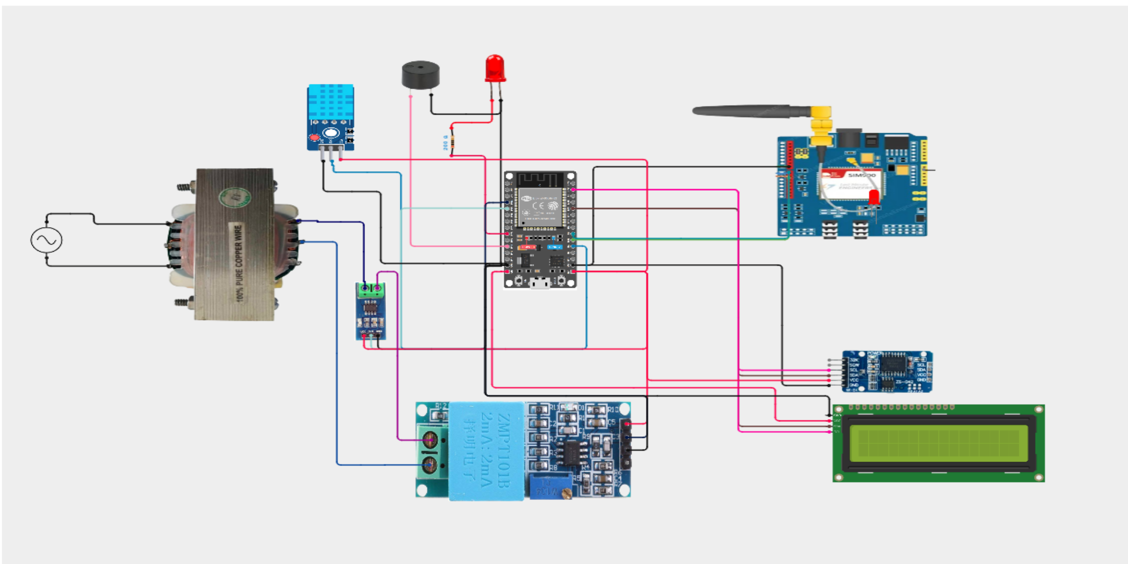

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Fig: Circuit Diagram of Distribution Transformer Monitoring System

Main Components in the Connection Diagram

ESP32 / Microcontroller: Central controller of the entire monitoring system.

Power Supply (230V AC → 12V/5V DC):

GSM Module (SIM800C):
Sends SMS alerts during abnormal transformer conditions.

Voltage Sensor (ZMPT101B):
Measures AC output voltage of the transformer.

Current Sensor (ACS712):
Detects load current drawn from the transformer

Temperature Sensor (DHT11):
Monitors transformer temperature in real time.

LCD Display (16×2 with I2C):
Displays live voltage, current, and temperature values.

Indicator LED & Buzzer:
LED shows device status.
Buzzer activates during critical fault conditions.

Cloud Platform (ThingSpeak):
Displays graphical trends of voltage, current, and temperature.

Results of Photographs

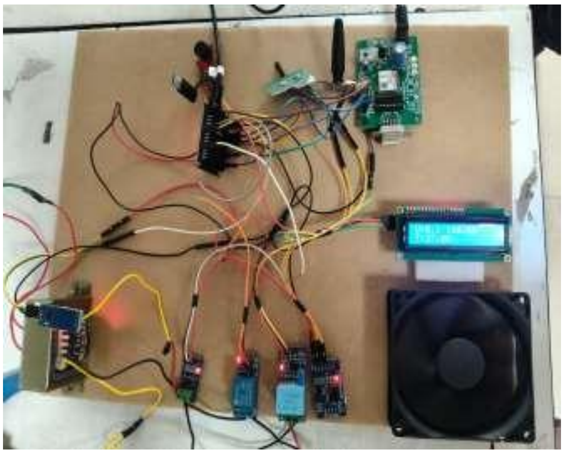
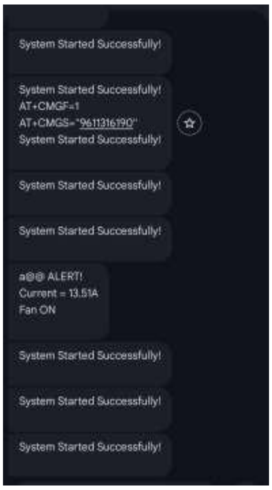


Fig:1 System model

Fig:2 Output in LCD



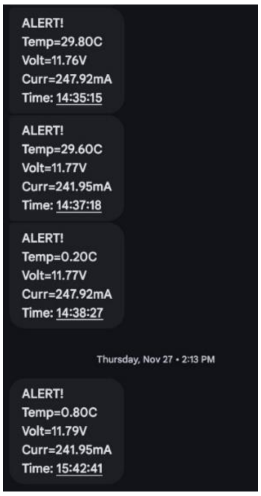


Fig:3 System started SMS **Fig:4 Alert SMS**

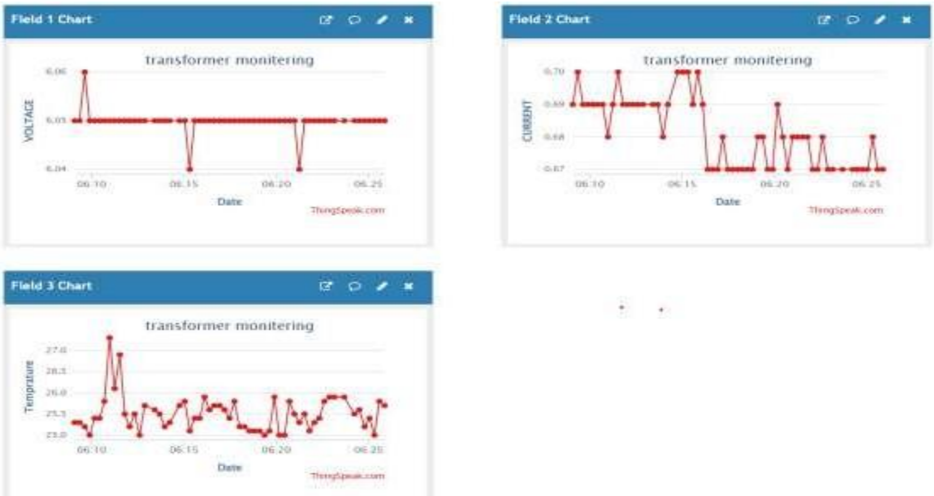


Fig:5 Real Time graph in Thingspeak

Discussion

The proposed system provides real-time monitoring of transformer parameters such as voltage, current, temperature, and oil level. By using GSM technology, it sends instant alerts to maintenance personnel when abnormal conditions occur, reducing the risk of transformer failure and minimizing downtime. Compared to manual inspection, this system is faster, more reliable, and cost-effective. It also allows preventive maintenance, extending the transformer's lifespan. The integration of sensors and GSM communication ensures timely intervention and improves the overall efficiency of the power distribution network.

Conclusion

The Distribution Transformer Monitoring System using GSM technology effectively monitors critical transformer parameters in real time. It provides instant alerts for abnormal conditions, reducing maintenance delays and preventing failures. This system enhances the reliability and efficiency of power distribution, ensures timely preventive maintenance, and is a cost-effective solution compared to traditional methods

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