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IoT based Monitoring and Control of Faults in Power Distribution Transformers

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Abstract - *Protection of the power system is an important aspect to protect electrical components against the faults to increase their lifetime, postpone unwanted replacement cost of damaged ones and assure continuity of supply to serve the growing demand. This work's prime objective is to develop an IoT (Internet of Things) based system that can be used to protect the transformer by monitoring and controlling the operating parameters, i.e., current value, oil level, etc., and reports that same. This system is so designed that it can sense the parameters beyond the standard preset level and alerts about the condition to isolate the transformer from the distribution line. This process ensures the safety of the transformer against any abnormal conditions. Therefore, this work presents the development of online monitoring and control of faults in a transformer and alerts the same. This IoT system is located at the transformer base, and considered parameters are monitored regularly, then transmitted to a centralized web server. Thus, the data are utilized to know the transformer condition on a real-time basis and are stored within a server database for future analysis purposes.*

Keywords - *Power System, Transformer Faults, Monitoring, Protection, Internet of Things.*

I. INTRODUCTION

In recent times, the power system network is spread worldwide to transfer large amounts of power from generating plants to the end-users through transmission and distribution lines. The power transformer forms an important element in a power transmission and distribution system [1, 2, 3, 6, 7, 8]. Monitoring of transformer is essential to assess the performance and to ensure its operational safety [8]. Therefore, it is essential to monitor regularly the operational status of the loaded distribution transformer. Monitoring is the observation of transformer conditions and is of two types: offline and online. The difference between the two is that in off-line, the transformer is in the off state, and online, the transformer is in on state to measure the data [6, 11 - 14]. The transformer is to be protected from both internal and external faults [8]. Among these temperature variations, oil level fall and load change require regular monitoring to safeguard the transformer [1, 7]. If transformers operate under healthy conditions, they have a long life; otherwise, their lives are significantly reduced. The main causes of failure in the transformer are overloading and ineffective cooling. Overloading of power transformers beyond the nameplate rating causes rise in temperature of both oil and windings. If the temperature rise of winding crosses the specified value, the insulation may get damaged [1, 3, 9]. Continuous heating weakens the insulation and causes an accelerated reduction in transformer life.

A. Literature Review

Literature review plays an important role in deciding the objectives of the study. It helps in the successful completion of the work to arrive at the desired results. Many improvements in communication and hardware technology have been developed - a promising one is the IoT technology, from home automation to industrial IoT. The IoT is an emerging technology, and it has been a great interesting topic for the past few years. Much literature is available on monitoring, controlling, and protecting the transformer, and enormous work has been done in this area.

A system based on the microcontroller to monitor and save the substation transformer from current rise due to overload is proposed [1]. A PLC-based automatic control system [2, 3] to monitor and detect the transformer's internal faults and external faults were proposed. In [4], a protective system using a temperature sensor, microcontroller, LCD, GSM, and Xbee was proposed to send the message to the electricity board. A conventional fault detecting method [5] have been employed for transformer protection. Nowadays, transformer fault monitoring based on vibration analysis drawing the attention of researchers because of added advantages. This method shows satisfactory results, but it can still be improved using computer algorithms to analyze the data and predict the fault.
This work presents, development of an IoT based system for real-time monitoring and control of transformer parameters. This system is placed close to the transformer, and considered parameters are diagnosed and are transmitted to a centralized web server. Thus, the data is utilized to know the transformer's condition on a real-time basis and are stored within a server database for future analysis.

II. METHODOLOGY

The main aim is to develop a methodology useful for power transformer protection and detect problems before exceeding the preset value. The data monitoring system is shown in Fig. 1, mainly composed of RTU and public data system (transmission). The RTU includes a microcontroller unit, peripheral circuits, and a wireless communication module. The hardware is made of various sensors - all connected to the transformer, and their outputs are fed to the microcontroller. The microcontroller also has a wireless module connected to it. This module will transmit the data to the server using the internet.

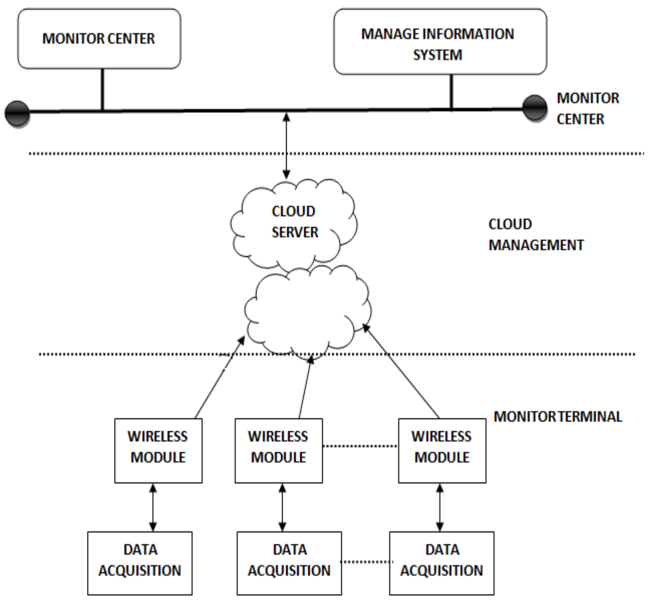


Fig. 1: Data monitoring system

The transmitted data is received and displayed in a cloud-based GUI monitoring unit, which contains an algorithm that processes the data. In the case of abnormalities in the processed data, an alert message is given to GUI and the peripheral devices connected to the web. Also, it is important to monitor transformer condition when the operator is not present at the site. Here is an embedded system to set up communication between the transformer and operator to send alert messages if the parameter values exceed the predefined one. This work also proposes a vibration analyzing algorithm to monitor transformer vibration during different faults based on learned data, and this system predicts the possible future faults.

A. Importance of power system protection

The occurrence of a fault is hazardous to both the electric power user and the electric power system itself. To the user, life is of most important concern. The prime duty of the electric system is to maintain power supply continuity without destroying the electrical components.

B. Transformer Faults

The various types of faults that occur in the transformer are classified into two types:

a) External Faults

Short circuit outside the transformer: This may occur externally between two or three phases. Due to this, the fault feeding transformer's copper loss is abruptly increased and causes internal heating in the transformer [10].

b) Internal Faults in Power Transformer

These faults within the transformer are classified as internal short circuit faults and incipient internal faults. Internal short circuit faults are usually between turns or turn to earth in transformer windings. Internal incipient transformer faults usually develop slowly, in the form of a gradual insulation deterioration due to moisture, overheating, vibration, voltage surges, and mechanical stress [6, 10], which finally leads to winding failure.

III. DEVELOPMENT OF METHODOLOGY

A. Hardware Development

The block diagram of Figure 2 shows the hardware architecture components of the proposed work. It consists of a transformer, sensors, power supply, microcontroller, and wireless module.

B. Components: The following are the components used.

a) phase voltage to a three single-phase voltage of rating of 230V/12V.
b) Power supply: 230V three-phase power supply is required to supply the three-phase transformer.

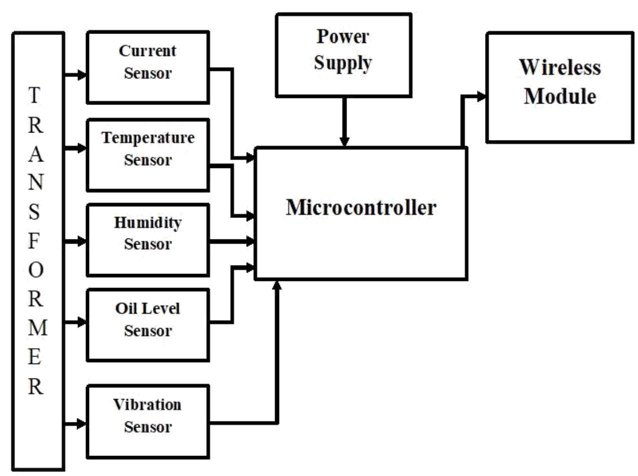


Fig. 2: The hardware architecture of the proposed system

***c) Sensors*:** Sensors are nothing but the condition monitoring devices installed at the transformer base, which senses the physical quantity and converts it into an analog to a digital signal.

Under/Over Voltage sensor: When the operating voltage decreases/increases to a lower/higher limit of the transformer's voltage rating, the under/over voltage fault will occur. The voltage sensor can detect this fault.

Overload sensor: When the current operating increases to the upper limit of the transformer's current rating, the overcurrent fault will occur. The current sensor can detect this fault.

Temperature sensor: Due to over current, oil temperature increases, which causes failure of insulation of transformer winding. When the transformer's temperature increases to the upper limit of temperature rating, the over-temperature fault will occur. This fault can be detected by a temperature sensor (LM35).

Humidity sensor: A humidity sensor (or hygrometer) senses, reports both moisture and air temperature.

Vibration Sensor: The spring-vibration switches are high sensitivity non-directional vibration induced trigger switches. When the switch is moved, the spring touches the center pole to make contact. So, when there's motion, the two pins will act like a closed switch. When everything is normal, the switch is in an open condition.

d) Rectifier Circuit

This circuit is used to energize the sensors. This circuit converts 12V AC to 12V DC.

C. Microcontroller Board

The Arduino Uno shown in Fig. 3 is a microcontroller board based on the ATmega328P. It contains everything needed to support the microcontroller; connect it to a computer (or appropriate wall power adapter) with a USB cable or power it with an AC-to-DC adapter or battery to get started. This auxiliary microcontroller has its USB boot loader, which allows users to reprogram it.

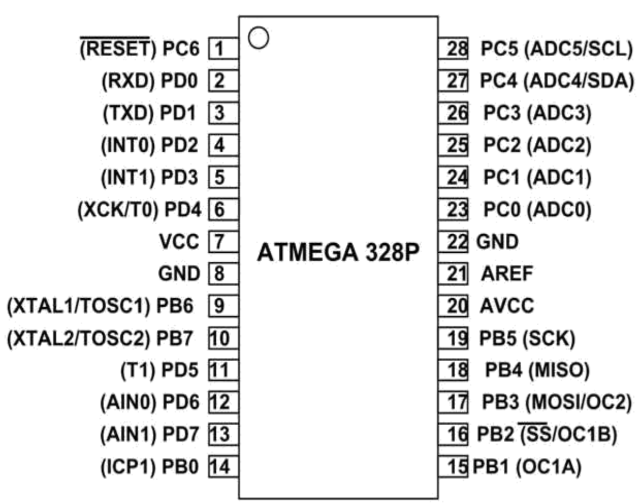


Fig. 3: Pin Diagram of Arduino Uno

D. The Wi-Fi Module: ESP8266

This module (Fig. 4) has a powerful enough on-board processing and storage capability that integrates the sensors and other application-specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. It contains a self-calibrated RF allowing it to work under all operating conditions and requires no external RF parts.

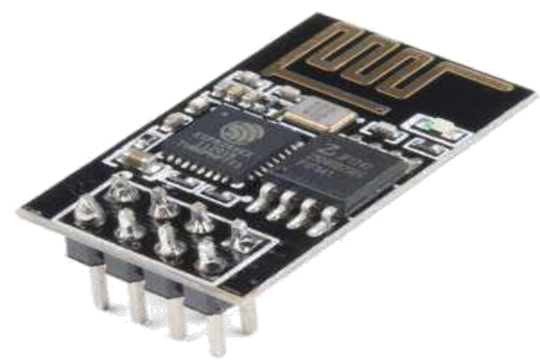
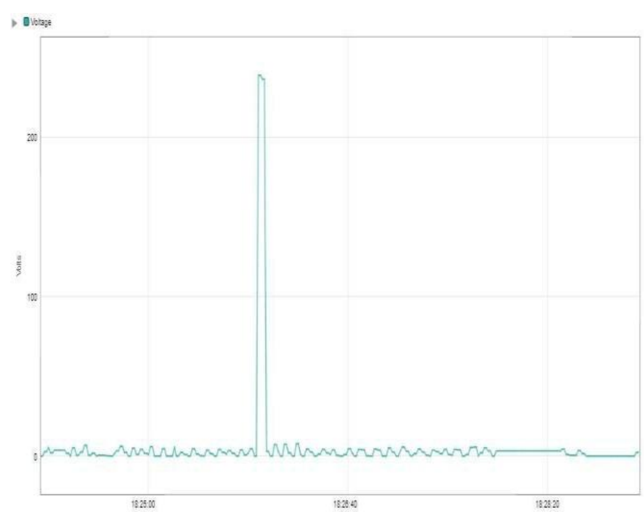


Fig. 4: ESP8266 Wi-Fi Module

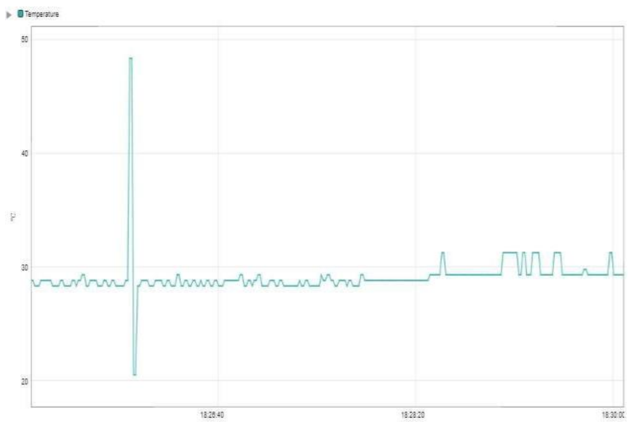
IV. RESULTS AND DISCUSSION

The following plots show the operating parameters, viz. voltage across transformer secondary, transformer temperature, humidity inside the transformer, and the oil level during normal/ healthy condition.

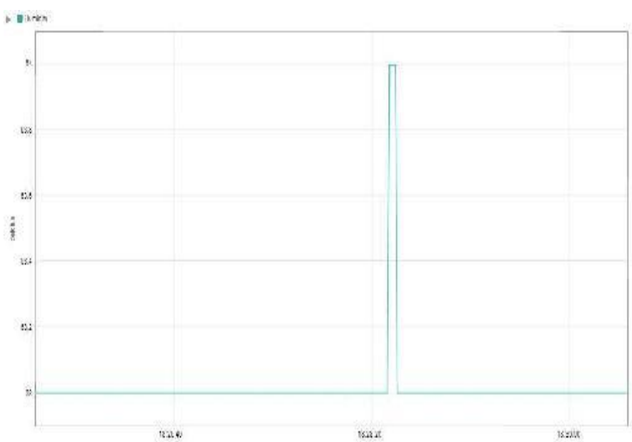
The voltage across the transformer secondary



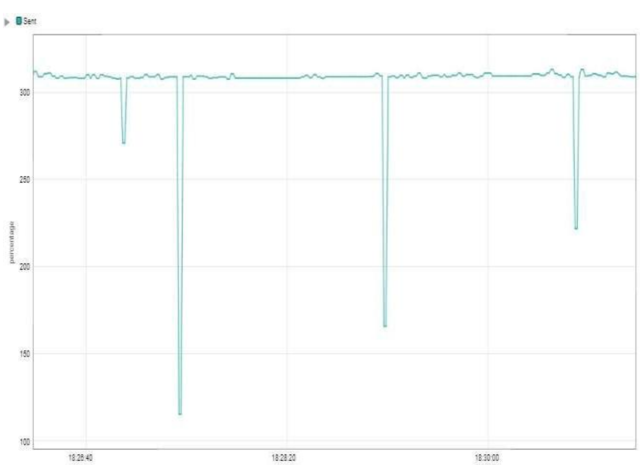
Transformer Temperature



Humidity inside transformer



Oil Level Measurement



This system is implemented on embedded microcontroller systems included with self-contained programs within the hardware. It is based upon online monitoring of the distribution transformer's operating parameters as defined in this work. Code is written for Arduino to monitor the considered operational parameters and the ESP8266 Wi-Fi module to maintain connectivity with a STOMP web socket. When any one of the operating parameters varies beyond the predefined/set value, this device can alert the condition of the transformer and help the utilities control operational parameters regularly. If there is any fault in the transformer, this system can identify the same and send a notification to the control room. Then the operator reads the message, and immediate remedial action is initiated to protect the transformer. For example, in this system, when transformer temperature increases beyond the set value, fans get started automatically. Similarly, when the voltage across the transformer increases or decreases from preset value, then the message is sent immediately to the operator. The operator reads the message, and immediate control action is being initiated to protect the transformer.

V. CONCLUSION

In this work, the development and implementation of real-time monitoring and control systems for transformer protection and recording have been presented. This system is designed to protect the distribution transformer from overloading, overheating, and other abnormalities. An IOT system is employed to monitor and control the operational parameters of the transformer. The IOT system is located close to the transformer base, and the above parameters are sensed and then transmitted to the centralized web server. Thus, the data is utilized to know the transformer condition on a real-time basis and are stored within a server-based database for future analysis and immediate protective precautions.

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List of Abbreviations

IOT - Internet of Things
ESP8266 - Wi-Fi Microchip
RTU - Remote Terminal Unit
GSM- Global System for Mobile Communications
PLC – Programmable Logic Controller
GUI- Graphic User Interface
PIC – Microcontroller
LV- Low Voltage
LCD – Liquid Crystal Display
LM35- Temperature Sensor
DHT11- Temperature and Humidity sensor
ADC- Analog to Digital Converter