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IOT based Transformer Health Monitoring System

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Abstract: Power transformers are one of the most critical and expensive components in power generation, transmission, and distribution systems. Any unexpected failure of a transformer can result in major power outages, economic losses, and damage to connected equipment. Therefore, continuous monitoring of transformer health parameters is essential to ensure reliability and long service life. This project presents the design and implementation of a Transformer Health Monitoring System using Internet of Things (IoT) technology. The system continuously monitors key parameters such as winding temperature, oil temperature, oil level, load current, supply voltage, and gas formation inside transformer oil. Sensors are interfaced with a microcontroller, which processes the data and transmits it to a cloud platform for real-time monitoring. Alerts are generated automatically when parameters exceed safe operating limits. The proposed system provides predictive maintenance, reduces manual inspection, improves transformer reliability, and enhances overall power system efficiency.

Index Terms – Internet of Things (IOT), power transformer, WI-FI Module

I. Introduction

The Electricity plays an important role in our life. Every moment of our life depends upon electricity; Electricity has several components and equipment helping human to transfer and regulate the distribution according to usage. The most crucial equipment of transmission and distribution of electric power is transformer. Operation of distribution transformer under rated condition (as per specification in their name plate) guarantees their long service life. However, their life is significantly reduced if they are subjected to overloading, heating low or high voltage current resulting in unexpected failure and loss of supply to a large number of customers thus is affecting system reliability. Overloading, oil temperature load current and ineffective cooling of transformer are the major cause of failure in distribution transformer. As a large number of transformers are distributed over a wide area in present electric systems, it's difficult to measure the condition manually of every single transformer. So, we need a distribution transformer system to monitor all essential parameters operation, and send to the monitoring system in time. It provides the necessary information about the health of the transformer. This will help and guide the utilities to optimally use the transformer and keep this equipment in operation for a longer period. The main aim of the project is to acquire real-time data of transformer remotely over the internet falling under the category of Internet of Things (IOT).

A recent huge interest in Machine-to-Machine communication is known as the Internet of Things (IOT), to allow the possibility for autonomous devices to use Internet for exchanging the data. This work presents design and execution of real time monitoring and fault detection of transformer and record key operation indictors of a dispersion transformer oil and encompassing temperatures. They have to look at it continuously by using this project it can minimize working efforts and improve accuracy, stability, efficiency in this project, sensors are used to sense the main parameters of equipment such as temperature and oil level this sensed data is sent to microcontroller and this controller checks parameter limits which further send to the IOT web server Adafruit software using Wi-Fi module of these data makes sure the right information is in hand to the operator and operator can make useful decisions before any catastrophic failure on basis of that data of parameters

Transformer is one of the important electrical equipment that is used in power system. Monitoring transformer for the problem before they occur can prevent faults that are costly to repair and result in a loss of electricity. Currently, failure of the transformer can be detected by colour changing of silica gel and decreasing the quality and viscosity of oil. The main aim of the project is to acquire real-time data of transformer remotely over the internet falling under the category of Internet of Things (IOT).

1. For this real-time aspect, we take one temperature sensor, one potential transformer and one current transformer for monitoring Temperature(T), Voltage(V), Current (I) data of the transformer and then send them to a remote location.
2. These three analog values are taken in multiplexing mode and connected to a programmable microcontroller of 8051 families through an ADC 0808.
3. They are then sent directly to a Wi-Fi module under TCP IP protocol to a dedicated IP that displays the data in real-time chart form in any web connected PC/Laptop for display in different charts. The real- time data is also seen at the sending end LCD display interfaced with the microcontroller.

II. PROPOSED SYSTEM

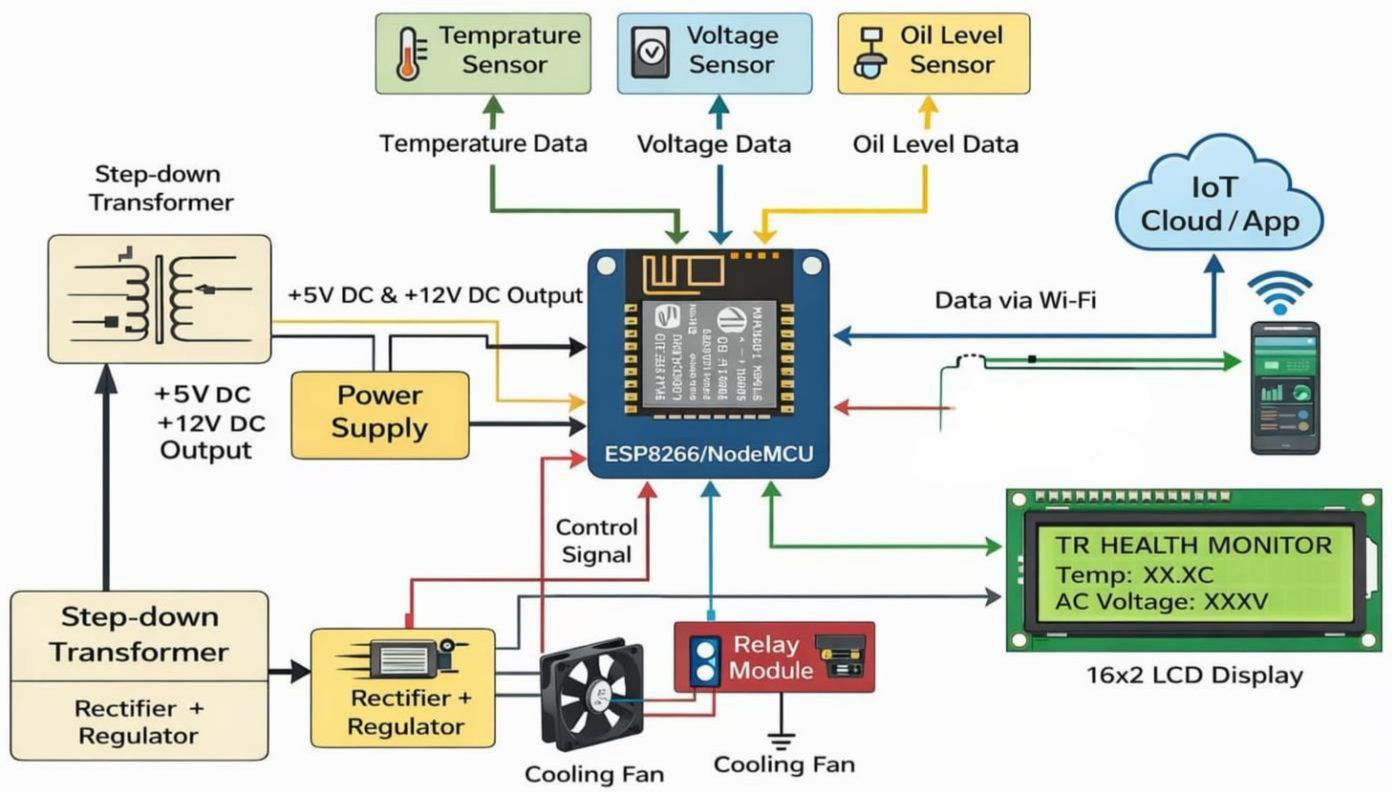

Fig 2.1 Block diagram

The provided block diagram illustrates an Internet of Things (IoT)-based transformer health monitoring system centered around an ESP8266/NodeMCU microcontroller. The system uses a temperature sensor, voltage sensor, and oil level sensor to acquire critical operational data from a step-down transformer. These sensors transmit temperature data, voltage data, and oil level data to the NodeMCU board. The NodeMCU processes this data and displays the current health status (e.g., Temp: XX.XC, AC Voltage: XXXV) on a local 16x2 LCD display.

For active management, the microcontroller sends a control signal to a relay module, which in turn activates cooling fans if necessary. The entire system is powered by a power supply unit that provides +5V DC and +12V DC outputs, derived from a step-down transformer and a rectifier/regulator circuit. Crucially, the NodeMCU leverages its Wi-Fi capabilities to send all collected data wirelessly to an IoT Cloud/App, allowing for remote monitoring and alerts via a smartphone.

III. HARDWARE DETAIL

3.1) Arduino nano

Fig 3.1 Arduino nano

The board pictured is an Arduino Nano, a small, complete, and breadboard-friendly microcontroller board based on the ATmega328P. It offers more or less the same functionality as the larger Arduino Uno board but in a much smaller form factor. The board can be powered via a mini-USB cable, a 9V battery, or through its Vin pin (recommended 7-12V input voltage). The Nano features 14 digital I/O pins (6 provide PWM output) and 8 analog input pins. It supports various communication protocols including UART TTL serial (RX/TX pins), I2C, and SPI. Due to its compact design and versatility, the Arduino Nano is suitable for a wide range of projects, from robotics to home automation.

3.2) WiFi Module(Wemos D1 mini)

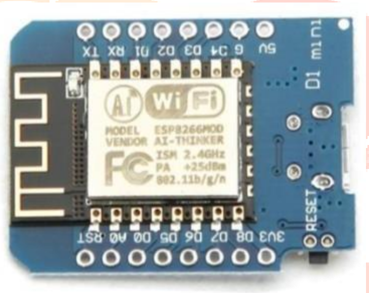

Fig 3.2 WiFi Module(Wemos D1 mini)

We are using WI-FI Module ESP8266 in this system, Which is shown in figure 3.4. This is a self contains SoC microchip which consists a TCP/IP protocols stack that permit access to any microcontroller to a Wi-Fi network.

It has enough storage capability and on-board processing that allows it to interact with the other sensors and gadgets. This module requires an external logic converter as it not capable of 5V– 3V logic shifting.

3.3) Relay

Fig 3.3 Relay

It is an electronic switching device used to control high-voltage AC or DC loads using low- voltage logic signals from microcontrollers like Arduino or Raspberry Pi. The main component is a blue JQC- 3F-15VDC-C power relay, which operates on a 15V DC coil voltage. This specific relay is rated to handle a maximum of 10A at 250V AC or 10A at 30V DC.

The module features screw terminals for connecting the load (Common, Normally Open, Normally Closed) and pin headers for control signals (VCC, GND, IN). Indicator LEDs for power and relay status are also visible on the blue printed circuit board (PCB). Relays like this are commonly used in various applications, including home appliances, industrial control systems, and automotive electronics, to safely interface between different voltage levels and switch higher power devices.

3.4) voltage sensor.

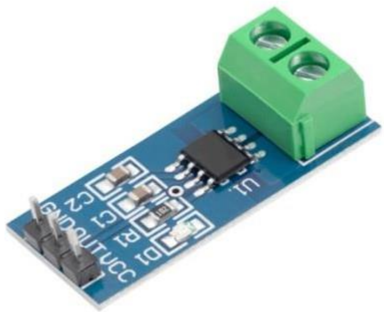

Fig 3.4 current sensor.

ACS712 current sensor module, which is an electronic component used for measuring both AC and DC currents. This module operates on the Hall effect principle, where current flowing through a copper path generates a magnetic field that is converted into a proportional analog voltage output. The sensor is available in different versions, such as \(\pm 5\text{A}\), \(\pm 20\text{A}\), and \(\pm 30\text{A}\) ranges, each providing a specific sensitivity in \(\text{mV/A}\). The output voltage at zero current is typically around \(2.5\text{V}\) (half of the \(5\text{V}\) operating voltage), with the voltage increasing or decreasing depending on the direction and magnitude of the current flow. These modules are widely used in applications like over-current protection circuits, battery chargers, and power supply monitoring due to their precision and non-contact current sensing method.

3.5) Voltage sensor

Fig 3.5 Voltage sensor

voltage sensor module, a simple electronic component designed to measure DC voltage. It operates based on the principle of a resistive voltage divider to scale down an input voltage by a factor of 5, allowing it to be safely read by microcontrollers like Arduino. The module can measure DC voltages in the range of 0V to 25V, providing an analog output signal typically in the 0V to 5V range. The output interface includes pins labeled "S" (signal), "+" (VCC, typically 5V or 3.3V), and "-" (GND). This sensor is commonly used in applications such as battery monitoring and power management due to its high accuracy and sensitivity.

3.6) LCD Display (16x2 LCD with I2C Module)

Fig 3.6 LCD Display (16x2 LCD with I2C Module)

JHD 162A 16x2 character LCD display module paired with an IIC/I2C serial interface adapter board. This combination is popular for microcontroller projects, such as those involving Arduino or NodeMCU, because the I2C interface significantly reduces the number of pins required to control the display, needing only two data wires (SDA and SCL) in addition to power (VCC and GND). The module typically operates at 5V, uses an HD44780 controller, and features a potentiometer on the adapter board for adjusting the display contrast. The specific I2C bus address is often 0x27 or 0x3F, depending on the chip used.

3.7) Temperature sensor

Fig 3.7 Temperature sensor

A burnt electronic temperature sensor, likely a DS18B20 model in a waterproof stainless steel casing, connected to other components via black wires.

The metallic tip of the sensor appears discolored and charred, suggesting it was exposed to extreme heat, significantly beyond its safe operating limits. This kind of damage usually indicates a severe overcurrent event, a short circuit, or exposure to a heat source that caused the internal components or the protective casing's heat- shrink tubing to melt or burn. The failure likely renders the sensor permanently inoperable.

3.8) Float sensor

Fig 3.8 Float sensor

The object pictured is a compact, vertically mounted water level float sensor switch. This device is easy to use and functions as a mechanical or dry contact switch with two wires. It can be mounted at either the top or bottom of a tank using the supplied O-ring and nut to sense the rise and fall of fluid levels. The sensor provides a digital signal (HIGH or LOW) depending on the water level and its orientation. These types of switches are commonly used as bilge pump or water level warning devices.

IV. RESULTS

The implementation of a Transformer Health Monitoring System (THMS) project, typically leveraging IoT technologies like Arduino, NodeMCU, or Raspberry Pi, yields a comprehensive, real-time, and predictive tool for managing electrical assets. The results demonstrate successful, continuous monitoring of critical parameters—such as oil temperature, oil level, load current, and voltage—reducing dependency on manual, periodic inspections. By interfacing sensors like DHT11 for temperature, ultrasonic sensors for oil levels, and CT sensors for current with a microcontroller (e.g., ATmega328P or ESP32), the system provides accurate, live data to both local LCD displays and remote cloud platforms (e.g., ThingSpeak).

Key results of the project include the successful implementation of automated fault detection, which significantly increases grid reliability and reduces the risk of catastrophic failures. The system is configured to detect abnormal conditions—such as overcurrent, high-temperature, or low-oil levels—and automatically triggers relays to disconnect the load, while simultaneously sending real-time alerts via Wi-Fi/GSM to operators. The data collected is transmitted, stored, and displayed on a user-friendly dashboard, allowing for historical trend analysis and optimized, condition-based maintenance.

Experimental findings from prototypes confirm that the system operates stably under various loading conditions, with high accuracy in fault prediction. For instance, systems utilizing machine learning models (e.g., Random Forest) have shown high, such as 99.2%, classification accuracy in identifying potential faults, allowing for timely intervention before they lead to outages. The integration of these components results in a scalable, low-cost solution that enhances the overall operational life of the transformer.

In summary, the project results highlight that the IoT-based THMS transforms maintenance from a reactive, time-based approach to a proactive, predictive one. It provides tangible improvements, including reduced operational costs, decreased downtime, improved safety, and increased efficiency. The successful deployment of this system supports the transition toward smarter power systems by providing continuous visibility into the transformer's health status, regardless of its location.

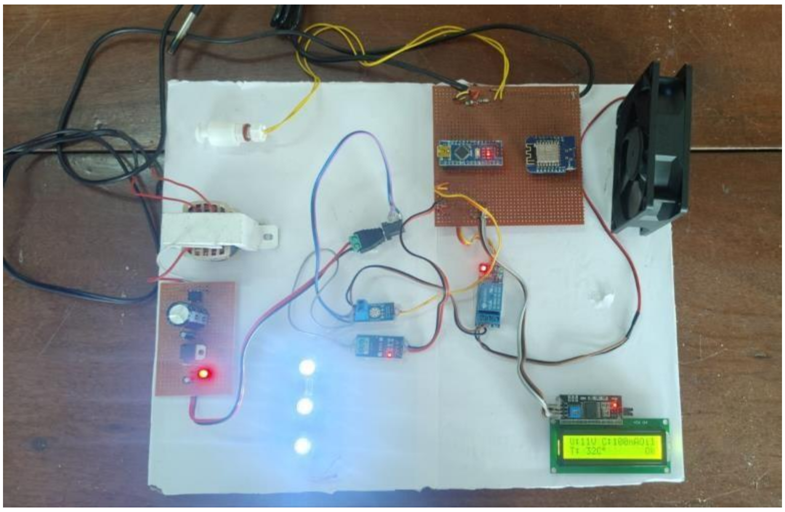

Fig 5.1 Hardware

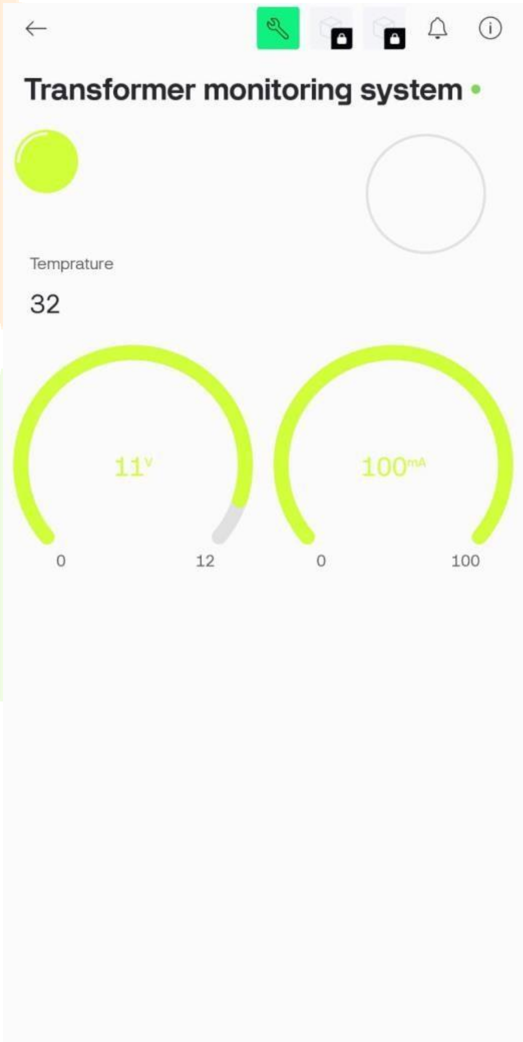

Fig 5.2 Software

V. CONCLUSION

In conclusion, our project on the loT-based transformer health monitoring system has been a success. We've built a system that uses technology to keep an eye on how well transformers are working. By constantly checking things like temperature, load, and oil condition, we can. spot problems early and fix them before they become big issues.

Our system doesn't just help avoid expensive repairs and downtime; it also makes power networks safer and more reliable. It does this by giving utilities important information about their equipment so they can plan maintenance better and keep the power flowing smoothly.

We've also made sure our system is easy to expand and improve in the future. This means we can keep making power distribution better and more efficient over time. Overall, our project is a big step forward in making sure we have reliable and sustainable power for everyone.

VI. REFERENCE

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