REMOTE MONITORING AND CONTROL OF TRANSFORMERS USING IOT-BASED SYSTEMS

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ABSTRACT

Electrical transformer monitoring and maintenance are now more important than ever due to the rising need for dependable and effective power distribution. Conventional transformer management techniques often lack real-time capabilities and are reactive, which causes expensive downtime and delayed problem identification. In order to improve operational dependability, safety, and preventative maintenance, this study proposes an Internet of Things (IoT)-based system for remote power transformer monitoring and control.

To continually monitor important transformer characteristics including oil temperature, load current, voltage levels, and humidity, the suggested system makes use of a network of smart sensors that are integrated with microcontrollers. Wireless connection technologies like Wi-Fi and GSM are used to send these real-time measurements to a cloud-based platform. In order to identify irregularities and set off alarms, the gathered data is processed and examined, allowing for prompt actions. Additionally, transformer functions like load balancing and switching may be managed remotely using control instructions.

The system offers a scalable, economical, and intelligent solution for transformer health monitoring by using the Internet of Things (IoT). In addition to enhancing maintenance procedures, this strategy guarantees peak performance, minimises downtime, and facilitates the shift to smarter electrical grids.

I. INTRODUCTION

Transformers are essential to maintaining steady voltage levels and effective energy transmission in today's power distribution networks. The necessity for proactive transformer management and real-time monitoring has grown in importance as the need for reliable, high-quality electrical power keeps rising. Transformer failures, which are often brought on by overloading, insulation failure, overheating, or neglect, may lead to serious financial losses, power disruptions, and safety risks.

Traditional transformer monitoring techniques are mostly reactive and manual, meaning that problems are often discovered only after a breakdown has occurred. These conventional systems are less successful in preventing damage and downtime because they often lack remote accessibility, continuous observation, and fast problem identification. The shortcomings of these approaches emphasise the need for more intelligent and effective monitoring systems.

Modernising transformer monitoring and management is now possible because to the development of the Internet of Things (IoT). In order to gather, send, and analyse transformer performance data in real time, IoT makes it possible to integrate sensors, communication modules, and data analytics platforms. Key factors including oil temperature, voltage, current, load status, and humidity may be continually monitored and analysed with the use of Internet of Things-based solutions. This enables utility providers to promptly address anomalies and enhance system performance.

The design and implementation of an Internet of Things-based smart transformer monitoring and control system is the main goal of this project. By offering automated control mechanisms, remote diagnostics, and real-time data visualisation, the goal is to improve the safety, efficiency, and dependability of transformer operations. The suggested solution seeks to minimise service disruptions, assist predictive maintenance plans, and advance smart grid infrastructure by switching from manual inspection to intelligent, data-driven monitoring.

II. LITERATURE SURVEY

In order to guarantee effective and continuous energy distribution, power systems must regularly monitor and maintain the condition of their power transformers. Many research have been conducted over the years to increase transformer monitoring systems' intelligence, accuracy, and efficiency. Real-time data collection, remote control, and predictive maintenance have all been made possible by the development of IoT technology, which has significantly changed this field.

1. Transformer Monitoring Systems Based on Sensors

The use of embedded sensor systems for transformer parameter monitoring has been investigated by a number of researchers. Jain et al. (2015), for instance, created a microcontroller-based system that keeps track of the oil level and transformer temperature. Basic automation was provided by this system, but it lacked remote accessibility and real-time data sharing—two features that are critical to contemporary energy systems.

2. Notification Systems Based on SMS and GSM

A GSM-based transformer monitoring system with sensors that measure temperature, voltage, and current and deliver SMS warnings was suggested by Kumar and Rao (2016). Despite being a step in the direction of remote monitoring, this system's shortcomings were poor data transfer speeds and a lack of interface with centralised monitoring systems.

3. IoT-Powered Monitoring Techniques

IoT has become a revolutionary technology in electricity monitoring in recent years. Rathod et al. (2018) created an Internet of Things (IoT)-based transformer health monitoring system that shows data in real time using cloud platforms like ThingSpeak and NodeMCU. Their research showed how well Wi-Fi modules and cloud analytics work for ongoing control and monitoring.

4. Predictive analytics and cloud computing

Mehta and Shah (2020) used cloud computing, data analytics, and IoT to improve the conventional monitoring paradigm. In addition to gathering data in real time, their system used statistical patterns to forecast potential breakdowns. Predictive maintenance was made possible by this, greatly lowering maintenance expenses and downtime.

5. Industrial IoT (IIoT) and SCADA Integration

Transformer monitoring applications on an industrial scale have also been investigated. The integration of Supervisory Control and Data Acquisition (SCADA) platforms with Internet of Things (IoT)-based systems was covered by Chaudhary et al. (2021). Their research focused on enhancing transformer data handling security and dependability for big grid systems.

III. METHODOLOGY

A transistor's primary working principle is the mutual inductance of two circuits connected by a shared magnetic flux. Two coils that are inductive and electrically independent but are connected magnetically by a channel of reluctance make up a simple transformer.

To put it simply, a transformer performs the following functions: (1) The movement of electricity between circuits. (2) Electric power transfer without frequency modification. (3) Transfer via the electromagnetic induction technique. (4) Mutual induction connects the two electrical circuits.

Transformer defects and abnormalities. Internal issues include: (1) deteriorating insulation; (2) winding failure; (3) overheating; and (4) oil pollution.

Internal faults are often referred to as phase-to-phase faults. A short circuit inside the transformer might cause it to shut down if insulation begins to deteriorate. Overheating and winding issues may also result from a high current flow. When the cooling system malfunctions, mechanical issues may also arise. One of the main causes of faulting is insulation degradation, which may also be caused by high current levels. Testing and maintenance can stop the majority of these issues.

External issues include: (1) short circuits; (2) system overloads; and (3) lightning strikes.

Things that occur outside the transformer that are often not preventable by maintenance are known as external faults. Lightning strikes and other unavoidable external damage are among the risks that the transformers face. It is crucial to have a strategy in place to make repairs as quickly as possible since these things are unpredictable. Even though they may not seem like much, they may harm the insulation and eventually lead to issues with the transformer's internal components.

The bigger worry is when an external event causes the transformer to cut off instantly.

The protection that the transformer will provide

Variations in the power source via the power supply cause overvoltage and undervoltage. It happens when the mains input voltage rises or falls over a predetermined tolerable threshold, resulting in a high or low equivalent DC voltage. This results in excessive motor heating, increased stator and rotor losses, and a significant impact on machine insulation.

When a motor is subjected to an excessive amount of load, overloading occurs. Excessive current draw, inadequate torque, and overheating are the main signs of motor overload. In fact, early wear on mechanical and electrical components, which eventually results in motor failure, is mostly caused by high motor heat.

Unbalancing: Three-phase induction motors are made and constructed with the winding's three phases meticulously balanced in terms of winding resistance, winding position, and number of spins. Unbalanced currents will flow in the stator winding of a polyphase induction motor when the line voltages supplied to it are not quite equal; the amplitude of these currents will depend on the degree of imbalance. Even a little voltage imbalance might cause the current to rise too much. The engine may overheat to the point of burnout, and the impact might be severe. As precisely as possible, the voltages should be evenly balanced using the commonly used commercial voltmeter.

IoT (INTERNET OF THINGS)

The expansion of Internet connection into tangible gadgets and commonplace items is known as the Internet of Things (IoT). These gadgets, which are embedded with electronics, Internet connection, and other hardware (such sensors), may be remotely monitored and controlled as well as communicate and interact with others over the Internet.

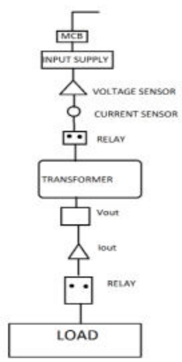
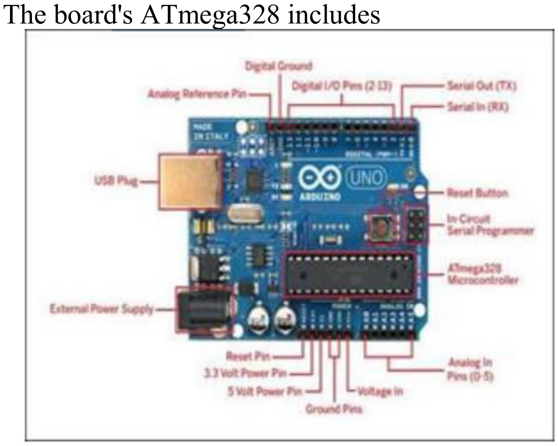


Fig -1: Block diagram of system

IV. COMPONENTS OF THE SYSTEM

4.1: ARDUINO UNO

The Arduino Uno is an open-source microcontroller board created by Arduino.cc that is based on the Microchip ATmega328P microprocessor. A variety of expansion boards (shields) and other circuits may be interfaced with the board's sets of digital and analogue input/output (I/O) pins. The Arduino IDE (Integrated Development Environment) may be used to program the board, which has six analogue and fourteen digital pins, using a type-B USB connector. Although it supports voltages ranging from 7 to 20 volts, it may be powered by an external 9-volt battery or by the USB connection. Additionally, it resembles the Leonardo and Arduino Nano. The Arduino website offers the hardware reference design for free under a Creative Commons Attribution Share-Alike 2.5 license. For some hardware versions, layout and production files are also accessible. "Uno" was selected to symbolise the first version of the Arduino software since it means "one" in Italian. Version 1.0 of the Arduino IDE and the Uno board, the first in a line of USB-based Arduino boards, served as the reference versions of Arduino until being upgraded to more recent iterations. The board's ATmega328 includes



built-in bootloader that enables fresh code to be uploaded without the need for an external hardware programmer.The FTDI USB-to-serial driver chip is not used by the Uno, which sets it apart from all previous boards even though it still uses the old STK500 protocol for communication. Rather, it makes use of the Atmega16U2 (or Atmega8U2 before version R2), which is configured as a serial-to-USB converter.

Specifications:

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

4.2: ESP8266 WIFI MODUL

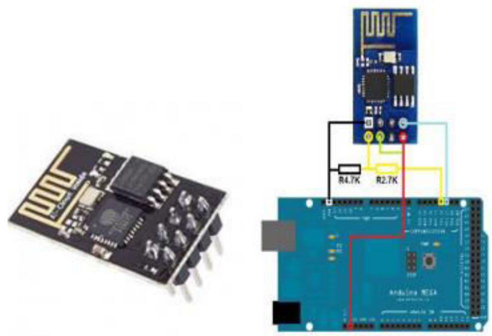


Fig 5 ESP8266 https:/ www.google.com

A self-contained SOC with an integrated TCP/IP protocol stack, the ESP-01 ESP8266 Serial WIFI Wireless Transceiver Module enables any microcontroller to connect to your WiFi network. Both hosting an application and outsourcing all Wi-Fi networking tasks to another application processor are options available to the ESP8266. Because each ESP8266 module is pre-programmed with an AT command set firmware, you can connect it to your Arduino device and get WiFi functionality comparable to that of a WiFi shield—and right out of the box! The ESP8266 module has a large and constantly expanding community and is a very affordable board.

4.3: VOLTAGE SENSOR

The voltage divider serves as the basis for measurement in voltage sensors. There are primarily two kinds of voltage sensors: resistive and capacitive versions.

Capacitive Voltage Sensor

As is well known, a capacitor is made up of two conductors, or simply two plates, with a nonconductor positioned between them. The word "dielectric" refers to the non-conductive substance. Current will begin to flow when an AC voltage is applied across these plates because of the attraction or repulsion of electrons by the voltage on the other plate. Without a hardware connection, the field between the plates will produce a full AC circuit. This is the operation of a capacitor.

he voltage division between two capacitors connected in series may then be discussed. High voltage will often build up across the component with the highest resistance in series circuits. Capacitance and impedance (capacitive reactance) are always inversely proportional when it comes to capacitors.

The relation between voltage and capacitance is

Q → Charge (Coulomb)

C → Capacitance (Farad)

XC → Capacitive reactance (Ω)

f → Frequency (Hertz)

It is evident from the two relationships above that the smallest capacitor will experience the biggest voltage buildup. This straightforward idea underlies the operation of the capacitor voltage sensors. Imagine that the sensor is in our palm and that we are putting its tip close to a live conductor. The high impedance sensing element is being inserted into a series capacitive coupling circuit in this instance. Right now, the smallest capacitor connected to the live voltage is the tip of the sensor. As a result, the whole voltage will build up across the sensor circuit, enabling it to detect voltage and the activation of indicators like lights or buzzers.

Resistive Voltage Sensor

The sensing element's resistance may be converted to voltage in two different methods. The simplest approach, shown below, involves applying a voltage to the resistor divider circuit, which is made up of a reference resistor and a sensor. sensor of resistive voltage.

The ADC receives the buffered voltage that develops across the reference resistor or sensor. The sensor's output voltage may be written as follows.

The amplifier in this circuit has the disadvantage of amplifying the whole voltage across the sensor. However, it is preferable to just increase the voltage change brought on by the sensor's altered resistance. The second approach, which uses the resistance bridge and is shown below, accomplishes this.

sensor for resistive voltage

The output voltage in this case is

The output voltage is roughly equal to A → Instrumentation Amplifier Gain when R1 = R.

δ → A change in the sensor's resistance that corresponds to a physical activity.

Since only the voltage change brought on by the sensor's resistance change is being amplified, the gain in this equation must be set high.

sensor for resistive voltage

Application of Voltage Sensor

- Power failure detection.
- Load sensing.
- Safety switching.
- Temperature control.
- Power demand control.
- Fault detection etc.

4.4: CURRENT SENSOR (ACS712)

Without compromising system performance, the ACS712 Current Sensor is a sensor that may be used to measure and compute the amount of current provided to the conductor.

A completely integrated linear sensor IC with a Hall-effect foundation is the ACS712 Current Sensor. This integrated circuit includes a low resistance current conductor and a 2.1kV RMS voltage isolation.

Working Principle

A current sensor measures the amount of current flowing through a wire or conductor and produces a signal proportional to the current, either as a digital output or an analogue voltage.

There are two methods for current sensing: direct sensing and indirect sensing. Ohm's law is used in direct sensing to measure the voltage drop that occurs in a wire as current passes through it in order to detect current.

A magnetic field is also created in the vicinity of a current-carrying conductor. In indirect sensing, the magnetic field is calculated using either Ampere's law or Faraday's law to determine the current. Here, the magnetic field is detected using either a transformer, a Hall effect sensor, or a fiberoptic current sensor.

The ACS712 Current Sensor determines the current using the indirect sensing approach. This IC uses a low-offset Hall sensor circuit to detect current. This sensor is situated on a copper conduction channel at the IC's surface. The Hall effect sensor detects the magnetic field created as current passes through this copper conduction route. The Hall sensor, which measures current, produces a voltage proportionate to the magnetic field it senses.

The device's accuracy is determined by how close the magnetic signal is to the Hall sensor. The accuracy increases with proximity to the magnetic signal. The ACS712 Current Sensor comes in a tiny, SOIC8 surface mount package. Current in this IC moves from Pins 1 and 2 to Pins 3 and 4. The conduction route where the current is detected is formed by this. This IC is fairly straightforward to implement.

Because the ACS712's conduction route terminals are electrically separated from the IC leads, it may be used in applications that require for electrical isolation. Therefore, no further isolation methods are needed for this IC. 5V is the supply voltage needed for this IC. The AC or DC current is proportional to its output voltage. ACS712 has almost little magnetic hysteresis.

4.5: Relay

An electrically powered switch is called a relay. A magnetic field produced by current passing through the relay's coil draws a lever and modifies the switch contacts. Relays have two switch positions since the coil current may be turned on or off, and as the figure illustrates, the majority have double throw (changeover) switch contacts.

A second circuit, which may be entirely distinct from the first, may be switched by a relay. For instance, a relay may be used to switch a 230V AC mains circuit in a low voltage battery circuit. The relay's internal link between the two circuits is mechanical and magnetic rather than electrical. A relay's coil conducts a comparatively high current; for a 12V relay, this is usually 30mA, but for relays designed to run at lower voltages, it may reach 100mA. A transistor is often employed to increase the little IC current to the higher amount needed for the relay coil since most ICs are unable to provide this current. The well-known 555 timer IC has a maximum output current of 200mA, which is sufficient to directly feed a relay coil.

Features:

- 12V DC SPDT Relay
- Rated up to 7A @240VAC
- Fully Sealed

4.6 THERMOCOUPLE

A sensor that measures temperature is called a thermocouple. Two wire legs composed of various metals make up thermocouples. A junction is formed when the legs of the wires are fused together at one end. The temperature is monitored at this intersection. A voltage is produced when the junction's temperature changes. The temperature may then be determined by interpreting the voltage using thermocouple reference tables.

Thermocouples come in a variety of forms, each with special qualities related to temperature range, longevity, vibration resistance, chemical resistance, and compatibility with various applications. The most prevalent kinds of thermocouples are "Base Metal" thermocouples, which include types J, K, T, and E."Noble Metal" thermocouples of types R, S, and B are used in high temperature applications; for further information, see to thermocouple temperature ranges.

Numerous OEM, scientific, and industrial applications call for thermocouples. They are present in almost every industrial industry, including cement, paper and pulp, biotechnology, pharmaceuticals, oil and gas, and power generation. Additionally, commonplace equipment like toasters, heaters, and stoves employ thermocouples.Usually, thermocouples are chosen because to their affordability, robustness, broad temperature ranges, and high temperature limitations.

4.7 BUZZER

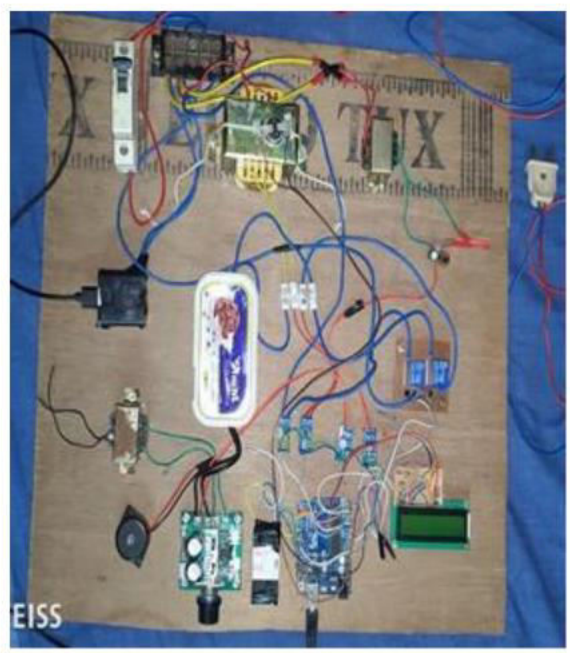
An audio signalling device, such as a buzzer or beeper, may be mechanical, electromechanical, or piezoelectric (abbreviated "piezo"). Buzzers and beepers are often used for timers, alarm devices, and verifying user input, such as a keyboard or mouse click.

3.8 MCB (Miniature Circuit Breaker)

A miniature circuit breaker (MCB) automatically cuts off an electrical circuit when the network is in an abnormal state, such as an overload or malfunction.In low voltage electrical networks nowadays, MCBs are used in place of fuses. The little circuit breaker detects it more reliably than the fuse, which may not. Compared to a fuse, an MCB is much more susceptible to overcurrent.An MCB is safer to handle electrically than a fuse. In the event of a fuse, the supply can be quickly restored since fuses need to be changed or rewired in order to restore power. Simply turning it on makes restoration simple. Let's see how the little circuit breaker works.

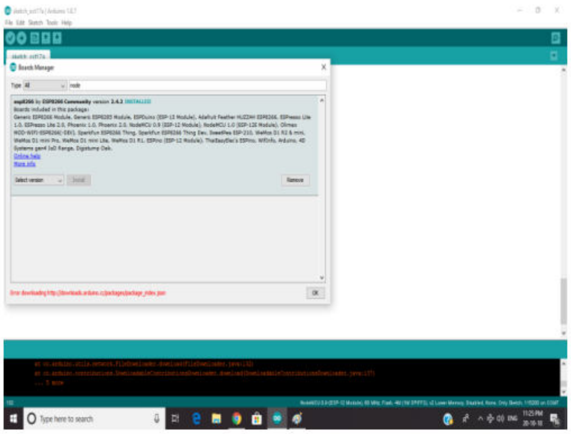
V. RESULTS AND DISUCSSIONS

5.1: HARDWARE:



5.2: Interfacing of ESP8266 With Arduino ide

STEP 1: First download the Ardiuno software application from the site ardiuno.cc which is freely available. It is an open source application. If the internet system is reliable then one can code online also.



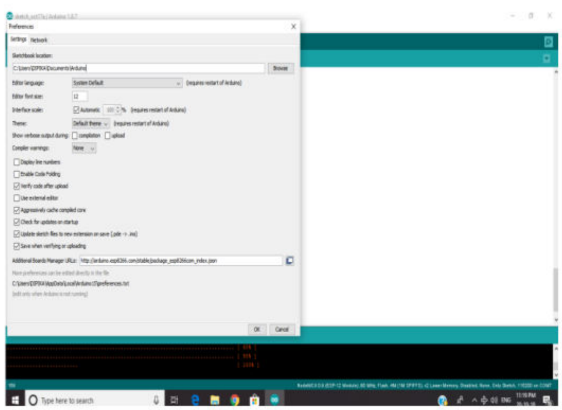
(Fig 14 ArduinoIDE Prefrence)

STEP 2: Once Arduino IDE is downloaded install the application.

STEP 3: The open arduino IDE go to Files>Preferences in the Arduino IDE and copy the below code for additional board manager: [http://arduno.esp866.com/stable /package_esp866com_index.json](http://arduno.esp866.com/stable/package_esp866com_index.json)

Interfacing ESP8266 and Arduino IDE

Step 4: Then go to tools>board>board Manager then navigate to esp866 by esp866 community and install the software for arduino



(Fig 15 Arduino Board Manager) Implementation of ESP8266

Interfacing ESP8266 and Arduino IDE

5.3 VOLTAGE AND CURENT MEASURING (PRIMARY AND SECONDSARY SIDE)

For measurement of primary side voltage : The supply given to the primary side of the main transformer is also given parallel to a 0-6V transformer. Thus the supply voltage is stepped down to 6V, it is then rectified through the bridge recitifier and given to the voltage sensor. The voltage sensor senses the voltage and sends the data to the arduino board. Any changes in the supply voltage will be directly senses by the voltage sensor. Thus the voltage of primary side is measured.

Note :

- to vary the primay side voltage auto transformer can be used.
- The limit for notification to the user is set to 250V and for tripping of the of circuit is 255V.
- The input voltage required by the voltage sensor is (5V DC) is given directly from the Arduino board.

For measurement of current :

The current sensors are connected in the series on both the sides (primary and secondary). The maximum limit of ACS712 is 30 Amp. The analog output of the current sensor is given to the Arduino board.

Note :

- The variation in current is obtained by the varying the load connected.
- Here, the current limit for notifying the user is 1.7 Amp and for the tripping of the circuit is 2.0Amp.
- The input voltage required by the current sensor is (5V DC) is given directly from the Arduino board.

Monitoring of voltage and current (primary and secondary)

Notification through buzzer at set threshold (1.70 Amp)

VI. PROJECT EVALUATIO

COST ANALYSIS

Future Scope

- To include additional defects, more sensors may be added.
- Machine learning techniques may be used to databases.

- The mqtt protocol and adafruit.io will be used for future project work (mobile application and cloud data storage).

(A) BUDGET FOR PERMANENT EQUIPMENT (IN RUPEES) (IN RUPEES)		
ITEM		BUDGET
1	Transformer	750
2	Current Sensors	250*2=500
3	Relay(10A)	35*2=70
4	Arduino Uno board	350
5	ESP8266	300
6	voltage sensors	250*2=500
7	Temparture Sensor	200
LOAD (SPEED CONTROLLER)		350
12V TRANSFORMER		50
LED DISPLAY		375
MCB		340
BUZZER		70
MISCELLANEOUS EXPENSES		1000
TOTAL		4850

VII. CONCLUSION

The stability and dependability of contemporary power distribution networks depend heavily on the effective and continuous functioning of power transformers. This study has shown how real-time data collection, problem detection, and remote control made possible by the integration of Internet of Things (IoT) technology may completely overhaul conventional transformer monitoring. Important characteristics like voltage, current, temperature, and humidity may be continually tracked and sent to a centralised platform for analysis and control by using smart sensors and communication modules.

The safety, effectiveness, and responsiveness of transformer maintenance are greatly improved by the suggested IoT-based solution. It lessens the need for human inspection, lowers the possibility of unplanned breakdowns, and encourages predictive maintenance techniques, all of which contribute to transformer longevity and reduced operating expenses. Additionally, remote control features enable quick reactions to anomalous situations, enhancing the electrical grid's overall resilience.

To sum up, the use of IoT in transformer monitoring is an important step in the creation of smart energy infrastructure. Future developments may include stronger cybersecurity standards to safeguard vital data, integration with SCADA systems for widespread deployment, and the utilisation of edge computing for quicker decision-making.

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