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IoT Based Distribution Transformer Condition Monitoring System with Load Sharing

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Abstract: The transformer serves as a stationary apparatus, it transfers the electrical power between circuits, adjusting voltage and current to desired levels while maintaining a consistent frequency. A transformer can operate most efficiently from no load condition to full load capacity, but it will face issues when it is overloaded, which will lead to a serious problem for the health of the transformer. Therefore, it is essential to monitor their health and efficiently distribute the load among multiple transformers. To prevent a transformer from overloading, a backup transformer is employed to power the load when the main transformer is overloaded. The backup transformer is activated automatically by a microcontroller. This setup ensures optimal loading for both transformers. Additionally, both transformers can be turned on to provide the load alternately when the load is normal.

I. INTRODUCTION

Electricity is a vital component of our everyday lives and affects many aspects of them. Electricity is a necessary component of innumerable events and activities. The most critical apparatus for the transmission and distribution of electric power is the transformer. The transformer is a crucial component of any electrical system installation, helping to ensure that power flows smoothly from the source to the final consumer. It is essential to voltage control and transformation because it makes sure that consumers receive electricity at the right voltage levels for their individual requirements. The user at the end of the line receives electricity through this

An automated monitoring system made exclusively for electrical gadgets is desperately needed to solve this problem. This kind of system would continuously check these devices vital properties and functions, sending real-time data to a central monitoring system. The Internet of Things-based Thing Speak server program can be used to carry out this monitoring process at a voltage that is secure and suitable for their gear and gadgets.[1]

Operating electrical devices within their rated conditions, as specified on their nameplates, is crucial for ensuring their extended service life. When devices are used within these specified parameters, they are more likely to have a longer operational lifespan. Conversely, overloading, exposure to excessive heat and operating at low or high voltage levels can significantly shorten their lifespan. Excessive loading, elevated temperatures, high currents, and inadequate cooling are primary contributors to the failure of electrical devices within distribution systems. Transformers, in particular are distributed widely across extensive areas within modern electrical systems. Manually monitoring the condition of each transformer in such a vast network is often a difficult task. Modern times have seen an increase in the need for electrical power generation systems due to the rise in industrial development and fast population growth. This escalating consumer need has strained existing distribution networks, resulting in an overload on transformers. This overload results in a decrease in efficiency, an increase in voltage regulation, and winding overheating. One way to address these issues is to connect transformers in parallel. The load on a single transformer is reduced when it is divided over several transformers, which improves efficiency and lowers the chance of a winding breakdown. However, one significant drawback of parallel operation is the requirement for identically rated transformers.

An automated monitoring system made exclusively for electrical gadgets is desperately needed to solve this problem. This kind of system would continuously check these devices vital properties and functions, sending real-time data to a central monitoring system. The Internet of Things-based Thing Speak server program can be used to carry out this monitoring system.

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[2] The use of IOT in transformer health monitoring systems is a proactive maintenance and management strategy. It makes use of sensors, data analytics, and remote moni- toring to increase the dependability of electrical distribution systems, minimize downtime, and identify problems early. [3] Significant cost reductions, improved operational efficiency, and increased system reliability are all provided by this technology.[4]

II. TRANSFORMER

Transformers are essential electrical components that use electromagnetic induction to move electrical energy between circuits. Coils are coiled around a ferromagnetic core to form their structure. Alternating current (AC) causes a fluctuating magnetic field in the core of the main coil, which in turn causes a voltage to be induced in the secondary coil. This allows voltage to be changed based on the ratio of turns between the coils. This equilibrium in the electrical power system is mostly maintained by the extensive use of transformers.[5]

Simply put, a transformer is a device that steps up or down in voltage. The output voltage is increased in a step-up transformer and decreased in a step-down transformer. In order to maintain the balance between the system's input and output power, a step-up transformer lowers the output current while a step-down transformer increases it. Fundamental ideas like electromagnetic induction, mutual induction, and Faraday's law underpin how the transformer operates.

A. Types of Transformer

Transformers are used in a wide range of industries, such as electric energy consumption, transmission networks, distribution sectors, and power generation grids. They are divided into several kinds according to various criteria, and they are as follows:

1) Based on Voltage level:
- Step up: It's an electrical device that increases the voltage between the primary and secondary windings. The input voltage is sent to the primary coil, and the increased output voltage is delivered to the secondary coil.
- Step-down: It's an electrical device that decreases the voltage between the primary and secondary windings. The input voltage is sent to the primary coil, and the decreased output voltage is delivered to the secondary coil.

2) Based on Medium of Core:
- Air Core Transformer: The primary and secondary windings are linked by flux through the air.
- Iron Core Transformer: Multiple iron plates are stacked together to wind the coils.

3) Based on Install location:
- Power Transformer: Used at power generation stations.
- Distribution Transformer: It is mostly used at distribution lanes for domestic purposes.
- Measurement Transformers: They are mainly used for measuring voltage, current and power.

- Protection Transformers: They are used for component protection purposes.

In transformer systems, step-down transformers are essen- tial, especially for auto-load sharing and health monitoring. By reducing the voltage from the primary side to the secondary side, they provide easy installation of monitoring equipment for the real-time observation of parameters such as insulation conditions, voltage, current, and temperature, hence enabling effective health assessment. This makes it easier to continu- ously assess the performance and health of the transformer. Furthermore, in situations where several transformers are functioning in tandem, step-down transformers are essential for automatic load sharing. They accomplish this by varying voltage levels prior to applying power to various loads or sections. This guarantees effective transformer distribution, which helps to maintain balanced loads and improves system reliability.

B. Health Monitoring

By identifying unanticipated events before a severe failure occurs, the Transformer Health Monitoring System improves reliability and saves a significant amount of money. Tempera- ture and humidity are the two main variables for transformer health monitoring in this project. In this research, temperature and humidity are two crucial variables for transformer health monitoring.

1) Humidity: The importance of humidity monitoring for transformer health is in its potential to prevent moisture-related issues, preserve the integrity of insulating systems, and extend the overall lifespan and dependability of the transformer. By incorporating humidity data into the Transformer Health Monitoring System, possible moisture-related problems can be proactively identified and addressed. By reducing the possi- bility of unanticipated malfunctions, this method eventually improves the transformer's performance.

2) Temperature: Given that high temperatures play a major role in reducing the lifespan of transformers, temperature stands out as a key element affecting transformer longevity. The temperature rises, causing hotspots to emerge inside the transformer that are noticeably hotter than the surrounding regions.

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The transformer's overall lifespan may decrease as a result of these hotspots and insulation failure. Temperature monitoring is crucial in this system because frequent temperature variations that result in thermal cycling can also cause mechanical strains and premature aging.

C. Auto Load Sharing

The transformer auto-load-sharing system is an advanced solution engineered to intelligently allocate electrical loads across numerous transformers within a network. This innovative technology plays a pivotal role in maintaining equilibrium, significantly amplifying the reliability and efficiency of power distribution systems. Its automated functionality ensures that each transformer handles a fair share of the load, preventing any single unit from bearing excessive strain. As a result, this system reinforces the network's robustness, minimizing the system.[2] The use of IOT in transformer health monitoring systems is a proactive maintenance and management strategy. It makes use of sensors, data analytics, and remote monitoring to increase the dependability of electrical distribution systems, minimize downtime, and identify problems early. [3] Significant cost reductions, improved operational efficiency, and increased system reliability are all provided by this technology.[4]

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ESP32 board, activates and seamlessly integrates additional transformers to share the load. This design ensures automatic load sharing among multiple transformers, preventing overload and ensuring uninterrupted power supply. Additionally, the system is equipped to detect abnormal conditions. The project has been successfully designed and tested, and a demonstrative unit has been built to showcase the seamless operation of parallel transformers for health monitoring and load sharing. All systems were controlled by the ESP32 board, but in Proteus software, they are controlled by an Arduino UNO microcontroller. The implementation of IOT is carried out through the Thing Speak platform, where the humidity and temperature of the transformer surrounding it are shown. It will replace manual monitoring and testing. An automated monitoring system made exclusively for electrical gadgets is desperately needed to solve this problem. This kind of system would continuously check these devices vital properties and functions, sending real-time data to a central monitoring system. The Internet of Things-based Thing Speak server program can be used to carry out this monitoringThe design of the system encompasses the arrangement of its diverse components, the fundamental operational principles governing the employed devices, and the specific functions assigned to each. The design carefully considers the accessibil- ity of the components essential for implementing the system. Comprising distinct modules, as depicted in Fig. 1, the system is structured to optimize its overall functionality.[7]

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B. Power Monitoring

The hardware setup of the system necessitates several key components, like a microcontroller (ESP32), an LCD display (20x4), a current sensor (ACS712), a temperature and humidity sensor (DHT11), and a 230V transformer AC load.

A. Proteus Simulation

In order to achieve our objectives, we have used the Proteus simulation software tool, Arduino IDE software, to write an embedded C program that acts as an interface between a microcontroller and a circuit system. Here we have built a circuit in Proteus software, which includes a transformer rating (230V/12V) and a microcontroller. For Proteus simulation, we use an Arduino UNO and sensors like the ACS712 and DHT11. Here we have used a relay, which acts as a switch, to disconnect the second transformer when not necessary.

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Initially, monitor the health of the first transformer by checking the humidity and temperature. Based on the requirement, apply the load to the first transformer. Loading to the circuit is provided using bulbs connected in parallel. Each bulb provides a current of 0.25 A. When 5 bulbs are in ON state (0.25x5= 1.25A) and this load is greater than 1A, it is considered an overload condition, which leads to turning on the second transformer to share the load. We have used an LCD, which displays the necessary conditions on the screen as shown in Fig. 9. The ESP32 microcontroller is attached to a liquid crystal display (LCD). The 16x2 and 20x4 LCD models are usually the most widely utilized ones. (System on a Chip) modules, Expressif Systems developed the ESP32 as shown in the above Fig. 8. By collecting information from multiple sensors, the ESP32 micro-controller is utilized likelihood of disruptions caused by equipment overload and fortifying its resilience against potential downtime.[6]

III. DESIGN FOR HEALTH MONITORING AND LOAD SHARING OF A TRANSFORMER

A. block diagram

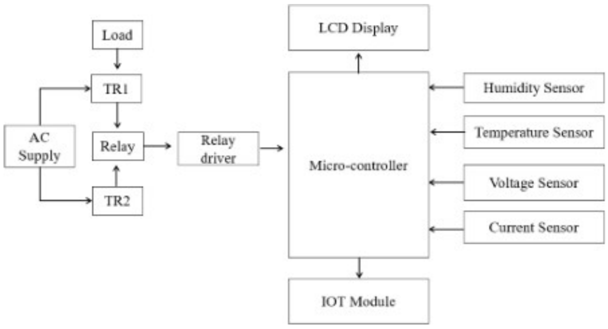

Fig. 1: Block Diagram

The design of the system encompasses the arrangement of its diverse components, the fundamental operational principles governing the employed devices, and the specific functions assigned to each. The design carefully considers the accessibility of the components essential for implementing the system. Comprising distinct modules, as depicted in Fig. 1, the system is structured to optimize its overall functionality.[7]

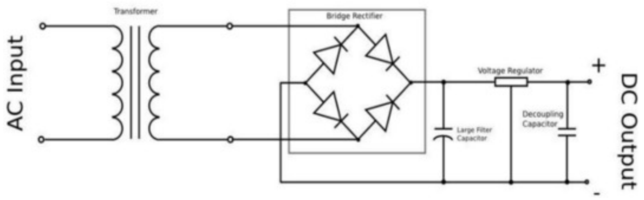

Fig. 2: Power Supply Unit

The initial module depicted in Fig. 2 functions as the power supply unit, responsible for delivering a regulated +5V DC voltage to the entire circuit from a 230V AC supply. This is achieved through the utilization of various components, including a transformer, rectifier, large filter capacitor, decoupling capacitor, and voltage regulator (IC7805), ensuring a consistent +5V DC supply for the rest of the circuitry. The sensors receive a DC input from the rectifier and assess the transformer condition, relaying this information to the microcontroller. Comprising current, voltage, humidity, and temperature, the sensors provide comprehensive data for further processing.[8] The microcontroller system operates in two primary steps. Firstly, the current sensors continuously feed data to the microcontroller. For hardware implementation, we are using an ESP32 board, which acts as the central processing unit. If the signal conditioner within the ESP32 detects that the load current value exceeds a predefined limit, it triggers the connection of a second transformer to manage the increased load, ensuring the system remains within safe operational parameters. The relay serves as a switch to control the AC load.[9] The final stage encompasses the display unit, which showcases the operational results of the project when an overload occurs. Utilizing a liquid crystal display (LCD), this will visually represent the transformer's condition for easy monitoring, such as humidity, temperature, and load current.

B. Hardware components

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TABLE I: Comparison of current values

Load	Theoretical Values	Current Sensor Values
No Bulb	0.00A	0.01A
1 Bulb	0.25A	0.25A
2 Bulb	0.50A	0.46A
3 Bulb	0.75A	0.70A
4 Bulb	1.00A	0.91A
5 Bulb	1.25A	1.15A

C. IOT implementation

It is an open-source application enabled by IOT, including an HTTP API, and it captures data from things through the internet. With the help of this, we can create a network of various things that can be further used for the logging of data, tracking, etc. The primary thing we have to do is open and make an account on the Thing Speak website.

Fig. 11: Humidity

Fig. 11 shows the humidity of vibrations in the transformer. It varies from 40% to 80%, and it is constant between these two levels. Here, it is equal to 65%.

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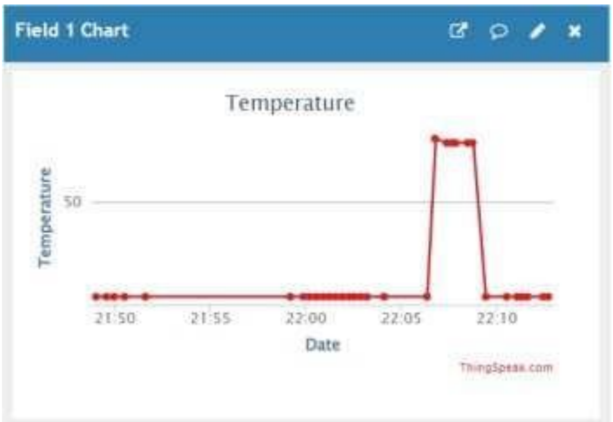

Fig. 12: Temperature

Fig. 12 shows the temperature of the vibrations in the trans- former. It varies from 24°C to 30°C and it is constant between these two levels. Here it is equal to 27°C.

IV. CONCLUSION

In this project, we initially monitored the health of a transformer by observing the temperature and humidity of the surrounding area, which are suitable for the proper working of a transformer. A proper climate allows for efficient working of the transformer. We have also observed that an increase in load on one transformer triggers the relay to detect the current change. The micro-controller, specifically programmed for the ESP32 board, activates and seamlessly integrates additional transformers to share the load. This design ensures automatic load sharing among multiple transformers, preventing overload and ensuring uninterrupted power supply. Additionally, the system is equipped to detect abnormal conditions. The project has been successfully designed and tested, and a demonstrative unit has been built to showcase the seamless operation of parallel transformers for health monitoring and load sharing. All systems were controlled by the ESP32 board, but in Proteus software, they are controlled by an Arduino UNO microcontroller. The implementation of IOT is carried out through the Thing Speak platform, where the humidity and temperature of the transformer surrounding it are shown. It will replace manual monitoring and testing.

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