

Design of Distribution Transformer Health Management System using IoT Sensors

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Abstract

Transformers are one of the primary device required for an AC (Alternating Current) distribution system which works on the principle of mutual induction without any rotating parts. There are two types of transformers are utilized in the distribution systems namely step up transformer and step down transformer. The step up transformers are need to be placed at some regular distances for reducing the line losses happening over the electrical transmission systems. Similarly the step down transformers are placed near to the destinations for regulating the electricity power for the commercial usage. Certain regular check-ups are must for a distribution transformer for increasing its operational life time. The proposed work is designed to regularize such health check-ups using IoT sensors for making a centralized remote monitoring system.

Keywords: Transformer maintenance, IoT in distribution systems, transformer health analysis

1. Introduction

The distribution transformers are also called as service transformers, as they are working for 24 hours continuously [1, 2]. Basically, the transformer requires a set of coils and core for their primary construction. The coils utilized in the work are insulated separately from each other and the core. The core is constructed on laminated steel metals for regulating the flow of magnetic flux over the air gap available in it. The steel material employed for the core

lamination process are having high silicon content for generation high permeability and reduced hysteresis loss. The lamination process of the steel core reduces the eddy current loss presence in the power transforming process [3].

The coils rotated over the magnetic cores are physically separated to each other and magnetically connected between each other. The two coils are also called as primary winding and secondary winding of a transformer. An alternating magnetic flux is generated from the primary winding when it is connected with a regulated AC supply [4]. The generated alternating flux moves over the secondary winding by the magnetic path created by the laminated cores. The flux which are connected over the secondary winding are termed as main flux or the useful flux. The flux which are missing to reach the secondary winding are termed as leakage flux. Therefore due to Faraday's law of mutual induction an EMF (Electro Motive Force) will be generated in the secondary winding and it is termed as mutually induced EMF [5, 6]. A mutually induced current will flow over the closed circuit connected on the secondary side of the transformer. Therefore the electricity supply given at the primary side is moved over the secondary side circuit. The amount of voltage transmitted from the primary and secondary side are changed with respect to the number of primary winding and secondary winding rotations made over the transformer cores [7].

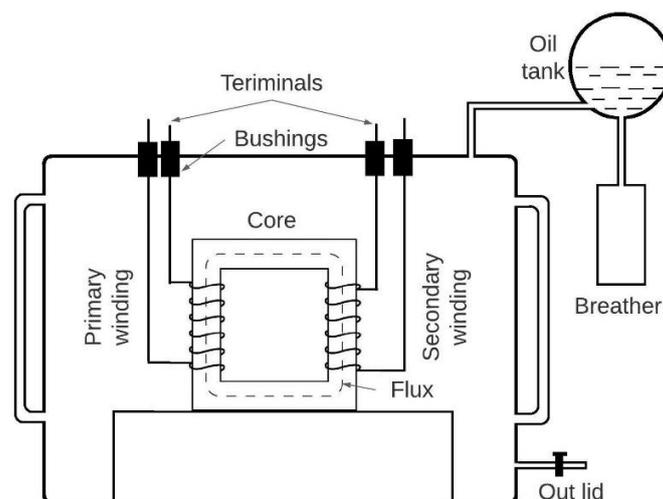


Figure 1. Construction of a distribution transformer

The core and the steel windings are kept over a container by taking out the primary and secondary winding connections outside. The taken out connections are connected with a bushing material for an electrical safety on the container material. Similarly an oil conservator is connected with the container for providing oil circulation over the container for cooling purposes [8]. A basic construction of a distribution transformer is shown in figure 1.

The breather is a module connected with the oil tank for proving the air circulation over the oil tank on different temperature conditions. The breather is filled with silica jelly for observing the water moistures from the atmospheric air. The oil tank is also filled only with half of its capacity for maintaining the space availability due to change in viscosity of the oil at different operation stages. The out lid is a place where a maintenance person can open the transformer container for taking away the old oil [9, 10].

2. Related Work

To ensure the working efficiency of a transformer, certain periodic check-ups are required for a transformer. The three phase transformers are need to be inspected on hourly basis on their voltage and load capacity which is prescribed by the manufacture. Similarly the temperatures of windings and oil are need to be ensured their changes within the limit. The ambient temperature of the transformers are also need to be verified on hourly basis to ensure its efficient operation. A single degree change of ambient temperature will be resulting in 0.4% reduction of the transformer VA ratings [11, 12].

In the same way, an inspection on daily basis is also required for a three phase transformers. The check list includes verification of transformer oil level through a gauge fixed over the oil conservator tank. If there is a reduction in oil quantity, additional amount of oil is need to be added to be conservator tank for maintaining the level. At the same time, leakage of oil from the tanks are need to be inspected. Then the colour of an active agent or silica gel kept over the breather tank are need to be verified. If the colour founds pink, then the silica gels are need to be replaced with the new one. The air passages in the breather are all also need to be

inspected for identifying any abnormal blocks. A relief diaphragms are also a device placed over the main container of the transformers for maintaining the high pressure production of oils during the faulty conditions. Therefore leaks in relief diaphragms are need to be visually verified. Similarly the operation of cooling fan and bearing motors are verified on daily basis by providing lubrication over the bearings. The operating mechanisms like the main connector and other contacts are verified for their interlock and manual control operation. The broken and burnt contacts are need to inspected and changed immediately when it is found with errors [13, 14].

The quarterly maintenance schedule of a single and three phase transformer requires an inspection on the dielectric strength and water contents presence in the transformers. The oil contents are need to be replace if it is found with any change than the normal condition. The dirt deposits over the bushings of the transformers are need to be cleaned without damaging it. The bushings found with minor cracks and damage are need to be replaced at their quarterly maintenance. In the same way, the oil level in the OLTC (On Load Tap Changer) are need to be inspected for their dielectric strength on every six months. The oil taken from the OLTC are filtered and performed with a breakdown down voltage test for ensuring its continuous operation. Similarly a Karl fisher method is employed over the oil for measuring its water content. If there is any deviation found over the prescribed limits, then the oil will be replaced with a new one [15, 16].

The yearly inspection of a transformer includes verification of acidity resistivity and sludge presence in the oil transformers. Similarly the oil impregnated paper bushings are verified as per the recommendations suggested by a manufacturer. The uneven pressure in the gasket joints are verified and corrected by tightening the bolts. The sealing arrangement of the cables boxes are also verified on yearly maintenance and the work replaces the gaskets if found with leakages. The relay and alarm contacts are also examined for their accuracy in operation and replaces if found necessary. A painting work is done to the transformer tank for preventing it from the rust and colour change. The earth resistance level of a transformer is also verified

and corrected on yearly basis when it is found higher than the specified value. An overall inspection is required for coil and transformer core for every five years on 1000 to 2000 kVA transformers and same will be done to the transformers with range of 3000 kVA on seven year basis. The core and coil of the transformers are washed during the inspection with fresh and clean oil for smoother operation [17, 18].

The motive of the proposed work is to implement an IoT system for verifying certain maintenance check-ups on transformers [19]. The primary source of IoT systems are sensors, all the required sensor modules of an IoT operations are fixed with a microcontroller and wifi module for data transmission to the destinations [20, 21]. The IoT based applications are widely implemented on agriculture, health care and several automation systems like home automation [22], power circuit operations etc. The collected informations from the sources are plotted in the destination place for monitoring and decision making process. In most of the cases the systems are automated by giving some desired operation on change in readings observed from the source point [23]. The general automated process are intimation of the changes to the authorities, enabling the control circuits and modifying the operations [24, 25]. The reason for developing an IoT system for transformer maintenance operation is to regulate the hourly maintenance process for huge number of transformers from a primary station which is located far away from the transformer. The system can also be extended for transferring the information to the manufacturers for enabling the scheduled and preventive maintenance tasks.

3. Proposed methodology

The proposed work is designed to monitor all the hourly inspections and oil level inspections on a transformer from a remote place. The architecture of the proposed IoT based monitoring system is shown in figure 2. The proposed work is employed with a microcontroller unit connected with a Wi-Fi module for data collection and transmission. The number of sensors employed in the proposed work are seven. In these, three sensors are utilized for measuring temperatures of the transformer's ambience, winding temperature and oil

temperature. The current sensor measurement of the transformer indicates the load of the transformer in amps. At the same time a voltage sensor is also employed in the work for transmitting the transformed voltage levels. There are two oil level sensors employed in the work for measuring the transformer oil level and the conservator tank oil level.

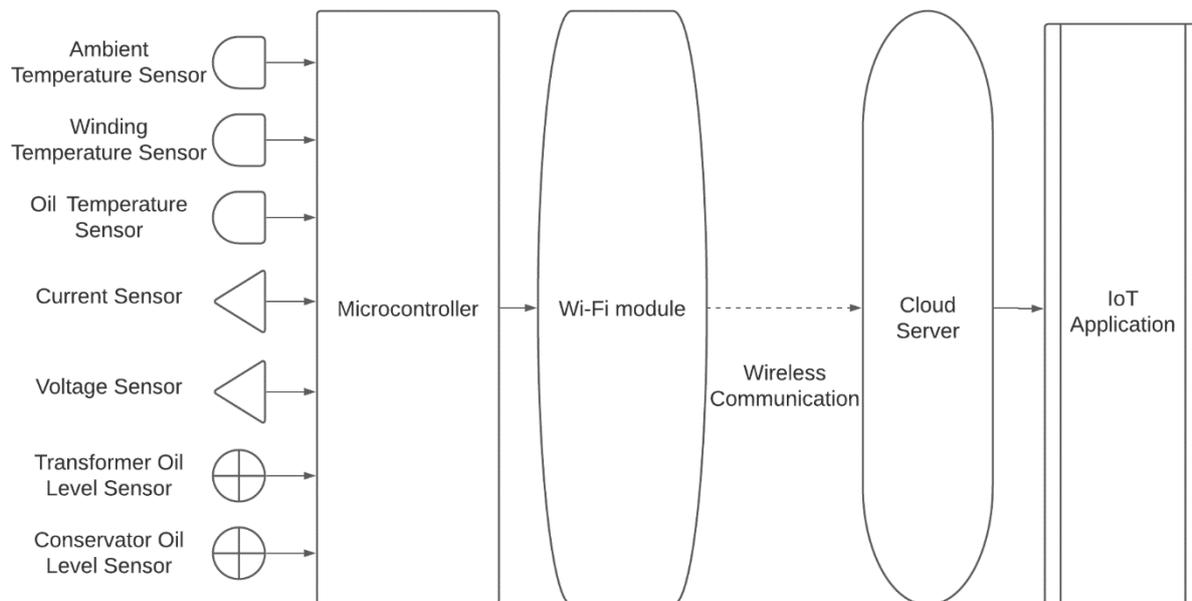


Figure 2. Architecture of the proposed model

Table 1. Details of the sensors employed in the prototype

S.No.	Application	Sensor Model
1.	Ambient Temperature Measurement	DHT22
2.	Winding Temperature Measurement	DS18B20 (Insulated)
3.	Oil Temperature Measurement	DS18B20 (Insulated)
4.	Current Measurement	AC712
5.	Voltage Measurement	ZMPT101B
6.	Transformer Oil Level Measurement	LLC200D3SH-LLPK1
7.	Conservator Oil Level Measurement	Ultrasonic Sensor

All the connected sensors will generate an analog output with respect to change in their respective observations. However, the sensors are connected with a summing amplifier circuit for enhancing the output information. The generated output from the amplification circuit is forwarded to the microcontroller unit for a mathematical processing. After that the collected informations are transferred to an IoT platform with the help of a Wi-Fi module. The communication between the microcontroller and an IoT application will be generated through a respective cloud server connected with the employed IoT platform. The proposed work utilizes the thingspeak IoT application for its operation and monitoring process [26, 27]. The details of the sensors utilized in the work for verification process are listed out in the table 1.

The proposed work is verified with a prototype setup of a single phase transformer with the help of an adjustable autotransformer. The winding temperature of the autotransformer is measured with the DS18B20 sensor. Similarly the current output and voltage regulation of the autotransformer is verified in the process. Two set of oil tanks are employed in this work for considering it as transformer main tank and the conservator. The oil level of the both the tanks are verified with their reputed sensors and the temperature change in main tank sensor is also observed. The measured readings are connected to the microcontroller circuit for IoT communication.

4. Experimental Analysis

The developed prototype is connected to the thingspeak server for enabling the remote monitoring process. The thingspeak application is utilized in the work for data collection process only. There is no analysis work made in the proposed work from the collected data. Similarly the work is also not designed taking any predetermined actions automatically based on the values received from the sensor. The developed module is designed only to make ease of moving between the transformer to transformer for their routine verifications. Figure 3 explores the observations on temperature from a transformer winding, oil and its ambience.



Figure 3. Observation of temperatures from a transformer ambience, winding and oil

A window from thispeak application is explored in Figure 3 for mentioning the change in temperature on various places of a transformer. The application window is designed to specify the changes for every fifteen minutes and that can be changed in the microcontroller program or even in the application chart. The observation on temperature indicates that there is no change temperature of transformer winding is affected with its ambience. The change of transformer winding is directly proportional to its load current and oil temperature. The oil temperature changes in proportional to the winding temperature by observing the heat generated from the windings.



Figure 4. Observation of current and voltage of a transformer along with oil level

The voltage fluctuation of the utilized autotransformer is observed only when there is change in load. The voltage regulation of the transformer found satisfied at the time no change to the connected load. The oil level of the conservator tank and transformer main tank are directly proportional to the temperature of the oil during its operation. The oil level of the conservator tank gets increase with respect to the ambient temperature rise and the load variations. The increase in transformer conservator tank oil level is not good for the health of a transformer.

5. Conclusion and future work

The possibility of measuring certain regular metrics needed for transformer maintenance are verified by with an IoT application and the real-time changes in observations are explored in the result analysis. The work will be extended in future with a single phase distribution transformer for its maintenance. The challenges in implementation of the proposed work with a single phase distribution transformer are its design. The work requires to modify certain changes in conservator tank and main tank of the transformer for sensor placement. Similarly the right range of sensors with appropriate tuning circuits are need to be designed for observing readings from a single phase distribution transformer. The work assures about the possibility of data transmission from a source place at any distance to the destination for regular observations. In future the work will also be extended to generate certain alarm signals on critical stage.

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