Distribution Transformer Health Monitoring System

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Abstract: This research explores the issue of the health of distribution transformers and provides valuable insights into the importance of continuous monitoring and the use of thermal imaging in the maintenance of distribution networks. Distribution transformers are an essential element of any power system, fulfilling the vital function of supplying electricity for residential, commercial, and industrial purposes. However, it is important to acknowledge certain weaknesses associated with these transformers, such as excessive load, reduced efficiency, and shorter lifespan. The primary objective of this study is to employ thermal imaging as a means to assess the performance of distribution transformers, thus enabling the early detection of faults and facilitating enhanced maintenance procedures.

Keywords: Distribution Transformer, Health Monitoring, Thermal Imaging, Early Fault Detection, FLIR Thermal Camera, FLIR Thermal Studio.

1. Introduction

Electricity has emerged as an essential prerequisite for existence in the contemporary world, with both residential and commercial sectors relying heavily on it. The indispensability of electricity is particularly significant for a nation's progress and economic advancement [1]. Distribution transformers play a critical role as part of electric power system, they ensure supply of reliable safe electric energy to household, businesses, and institutions. These transformers find themselves faced with various problems as the demand for electricity goes high such as decreased efficiency and shorter operating lives [2]. The demand for electricity on a global scale is on the rise due to factors such as population growth, urbanization, and the extensive development of industrial areas. According to the annual energy outlook report, it is projected that the demand for electricity in the year 2040 will reach 4.93 trillion kWh, which represents a 28% increase compared to the demand in 2011.

However, power companies are currently facing significant challenges in terms of generating and delivering electrical power [3]. The primary issue arises from the increasing load demand, which has prompted consumers to turn towards distributed generation as a means of meeting their energy needs [4]. Nonetheless, this shift towards distributed generation has various effects, including changes in load losses, heightened short circuit levels, voltage transients, congestions in system branches, concerns regarding power quality and reliability, as well as network protection issues such as false tripping, nuisance tripping, unintentional islanding, and neutral shifting [5]. Renewable energy is generally considered as a means to achieve an untainted and less contaminated environment. The intermittent nature of renewable energy sources has the potential to cause fluctuations in power supply, potentially resulting in changes in voltage and frequency levels. These variations in voltage and frequency have the potential to impact the efficiency and durability of transformers, as they are designed to operate within specific voltage and frequency limits [6]. This paper aims at addressing the current concern on Distribution Transformer Health by emphasizing the need for routine check-ups and advanced techniques, such as thermal imaging. Fig. 1 clearly shows the life of transformer with or without health monitoring techniques.

There are some common techniques for maintenance of transformer: Routine inspection, Oil analysis and Electrical tests.

In Routine inspection an engineer or an expert visits every transformer of plant and check its external components such as insulators, bushing and cooling fans but it is time consuming and internal faults such as winding deformation or insulation degradation can’t be detected with routine inspection [7].

Oil analysis which is highly used in detecting internal faults such as insulation breakdown or gas formation but oil analysis has its limitations, as it cannot detect certain types of faults, such as mechanical deformation or conductor damage.

Electrical tests include various tests, such as insulation resistance and winding resistance tests which can provide information on the transformer's electrical performance and condition. But electrical tests are time-consuming and require the transformer to be taken off the load, which can be costly and cause damage to the power system and these tests cannot detect thermal faults or partial discharges which can indicate potential faults.

Overall, the traditional methods of transformer health monitoring has its limitation to cope up to the faults that can occur in a transformer so a new technique should be introduced that can help in maintenance of transformer and prevent future failures.

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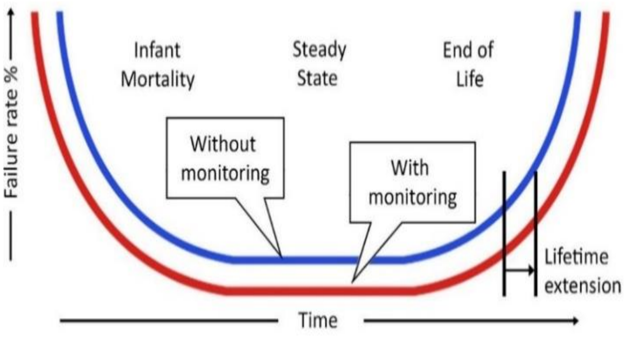

Fig. 1 Graph showing life of transformer with or without monitoring [8]

1 THERMAL IMAGING

That is why this research will use thermal imaging technology with the view of revolutionizing the monitoring and maintenance of distribution transformers in responding to such challenges. However, these traditional monitoring methods such as routine inspections, oil analysis or electrical tests, can be limited in monitoring the real-time problems in machinery equipment. There are significant benefits associated with the use of thermal imaging, a noninvasive and real-time method of monitoring. It reveals hotspots, temperature anomalies and possible defects in distribution transformers. This allows monitoring of transformers in loading position which is helpful for safety of engineering staff as well as increase effectiveness in fault detection.

Thermal imaging is important as it allows the problems associated with transformers to be detected and rectified at an early stage or stage of infancy resulting increasing the reliability of distribution transformers and extending their operational lives. The paper's purpose is to investigate the use of thermal imaging in monitoring the distribution transformer. Focus lies on early fault detection [9], good maintenance practice, and reliable electricity supply. Ultimately this study will make a contribution towards the stability and efficiency of electricity supply chain in the electrical power distribution networks [10].

2 CONDITION MONITORING TECHNIQUES

2.1 Sweep Frequency Response Analysis (SFRA):

The author's uses sweep frequency response analysis for detecting faults in power transformers. One of the most impressive attributes of SFRA is that it measures the frequency response of components in the transformer such as winding motion, partial discharge and transient faults. It provides high bandwidth, good phase resolution, and low noise. Thus, it is a useful instrument for detecting faults in the transformers. This paper also explores the application of the Low Voltage Impulse (LVI) method for finding short-circuits, as well as peculiarities of suppressing transient overvoltage's and noise emanating from devices of protection in transformer windings [11].

2.2 Dissolved Gas Analysis (DGA):

The author gives review on Discharge Ground Assisted Corona for Power Transformers. The article examines several ways of interpreting transformer conditioning and primarily based on one of the gas measurement methods, known as the Key Gas Method that assesses separate gases released from insulating oil after a fault it is fault detection by monitoring unique gases instead of gas ratios. In addition, the paper provides discussion on other techniques like Dornenburg Ratio, Rogers Ratioa and Nomograph. Dissolved Gas Analysis is presented as an important tool which helps to identify precursor's faults that lead to predictive maintenance [12].

2.3 Cooling Optimization:

Large power transformer expected lifetime effects resulting from cooling optimization are explored by author. The paper categorizes cooling systems into three types: oil natural convection, oil forced convection, oil directed convection. The chart displays diversities of cooling devices including oil forced using forced convection with oil pumps, oil directed exploiting forced convection with pumps and directed oil flow, and oil natural relying on natural convection. Transformer oil viscosity, designing of the cooling channels between windings and the presence of impurities which affects cooling power are some of other elements in this context [13].

2.4 Ultrasonic Testing

The ultrasonic method of testing power transformers, as explained by author. The method involves detecting ultrasonic acoustic waves, which travel to the tank wall in a transformer. The device is able to identify several shortcomings that occur within transformers such as loosened contact and hotspots on a particular part of the transformer oil. Three case applications are presented in this paper using the ultrasonic method.

The monitoring technique picked out Dissolve Gas Analysis indicating a thermal problem with the oil, to begin with. In the latter case, the ultrasonic technique revealed areas of the returning limb electrostatic screen that were not grounded after detection of a sharp rise of partial discharge. However, the method did not contribute to identification of mechanical cracking. Failure was detected only due to the presence of strong ionization sources. The one–off diagnostic character of the ultrasound methodology is underscored because it diagnoses defects with transformers that are outside full discharge [14].

2.5 Low-Cost Health Assessment System for Transformers

An affordable health assessment system of oil immersed service transformers based on real-time grid energy monitoring. Transformer health is assessed using measurements of top oil temperature, vibration, and transformer load by the system. It is therefore worth noting that through this work, the authors suggest application of a fuzzy logic in assessing transformer's state of health without the need for expensive sensors. This paper tests the feasibility of the system, its high efficiency and quick respond for monitoring the health of an oil-immersed service transformer, 50 kVA, through different test cases [15].

3 METHODOLGY

The methodology opted in this research can be explained with the help of Fig. 2.

Fig. 1 Block Diagram of Methodology

3.1 Thermal Camera

For taking thermal images of transformer Flir One Pro camera is used as shown in Fig. 3. The FLIR ONE Pro is a professional level, high resolution thermal imaging device capable of measuring up to 400˚C (752˚F). It comes with image processing for increased detail, adjustable connector used together with phone cases, and strong measurement tools at hand. FLIR ONE app enables multi-temperature measurement, remote view on Smart Watch, as well as several applications in the area of electrical panel's inspection and HVAC troubleshoot. It is also endowed with numerous other features such as the 40 min charging and it supports video and image captures, numerous thermal imaging ways and secure connection to mobile devices among others thus it's a competent equipment for professionals. [16]

Fig. 2 Figure of FLIR One Pro Thermal Camera

3.2 Flir Thermal Studio

Thermal images taken are now uploaded in FLIR Thermal studio. FLIR Thermal Studio is a software program designed at FLIR Systems for producing thermographic report templates and automated editing functions in thermal images. We can use it comfortably to create thermal inspection reports and automate any editing tasks in thermal images. We can also use this program to create and save several Rapid Report shortcuts on their desktop for accessing reports fast. In FLIR Thermal Studio we can use palettes, they create their own overlays, palettes are imported by them from other thermographs and the colors are applied to the images. It provides a user-interface made up of different pages such as Home, Library, Reporting, and Batch processing. We can choose an image from the folder and insert several objects such as image, table, plot, field, thermal field, and formula into the workspace of the report. Options are available in FLIR Thermal Studio to set the position, image size, and the type of an overlay for each image in a report which helps in analyzing the images [17].

4 Case Study

Two case study transformer A and B are taken to understand the methodology of this research as shown in Fig. 4.

Fig. 3 Figure of Case Study Distribution Transformers A and B

4.1 Case study A

Thermal image taken of Transformer can be shown in fig. 5 and Fig. 6 shows the result got from FLIR thermal, the spot temperature is 42.8 C. The highest temperature of the above image is 48.2 C, whereas the lowest temperature is 12.9 C. In this image, red color does not appear. It infers the state of the transformer is healthy. The transformer technical specification is shown in Table I.

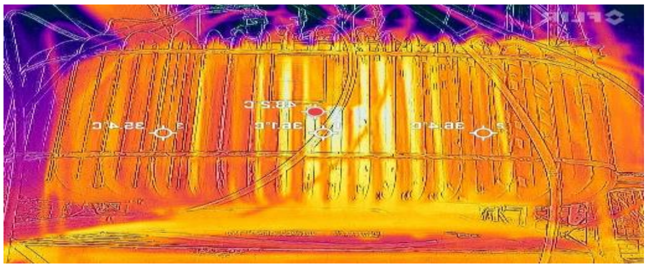

Fig. 4 Figure of Thermal Image of Case Study Transformer A

TABLE I. CASE STUDY TRANSFOREMER TECHNICAL SPECIFICATION

KVA	200	Type of cooling	ONAN
Volts at HV	1100	Frequency Hz	50
No load LV	415	Impedance voltage%	4.9%
Amperes HV	13.15	Vector symbols	DY11
LV	3.09	Weight of oil kg	330
Phases LV	3	Liftable weight kg	780
HV	3	Total weight kg	1300

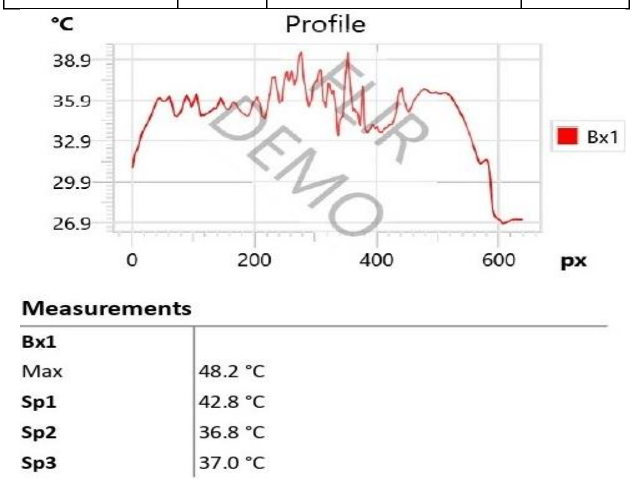

Fig. 5 Figure of Results of Case study Transformer A

4.2 Case study B

Thermal image taken of Transformer can be shown in fig. 7 and Fig. 8 shows the result got from FLIR thermal, the spot temperature is 36.5 C. The highest temperature of the above image is 39.1 C, whereas the lowest temperature is 12 C. In this image, red color does not appear. It infers the state of the transformer is healthy. The transformer technical specification is shown in Table II.

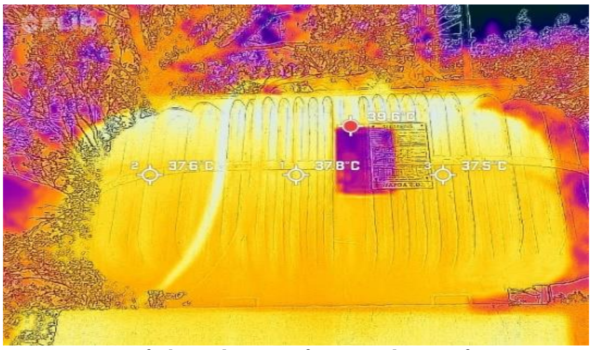

Fig. 6 Figure of Thermal Image of Case study Transformer B

TABLE II. CASE STUDY TRANSFOREMER TECHNICAL SPECIFICATION

KVA	200	Type of cooling	ONAN
Volts at HV	11000	Frequency Hz	50
No load LV	415	Impedance voltage%	4
Amperes HV	10.5	Vector symbols	DYn11
LV	278.2	Weight of oil kg	203
Phases LV	3	Liftable weight kg	485
HV	3	Total weight kg	968

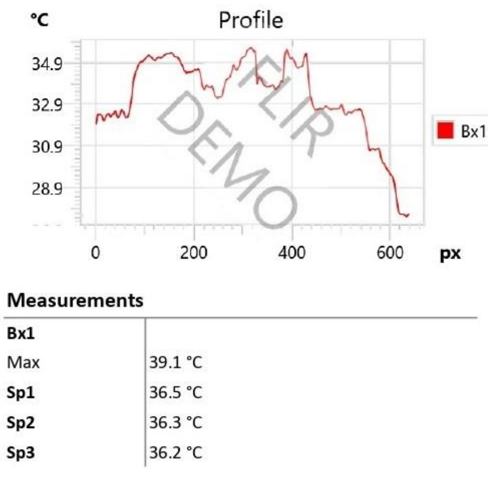

Fig. 7 Figure of Results of Case study Transformer B

5 Conclusion

A critical review about the Health Monitoring of Distribution Transformer has been made. The main conclusions are summarized as follows:

a) The distribution transformer is at the heart of any power system serving the residential, commercial, and industries. Nevertheless, when the need for electricity increases, distribution transformers come across problems of reduced efficiency, low duty cycle durations and heavy loads.

b) The traditional maintenance techniques like routine inspection, oil analysis, and electrical test, are important but limited in detecting many transformer faults. However, in order to address these weaknesses, a study was conducted on using thermal imaging technology.

c) Thermal imaging helps improve the reliability and prolongs operations for distribution transformers by identifying problems before they escalate. Therefore, this study has revealed the importance of applying sophisticated methods on transformer maintenance so as to avert any recurrence of failure with respect to stable power generation.

d) Furthermore, this paper explored various techniques for monitoring the condition of transformers, including Sweep Frequency Response Analysis (SFRA), Dissolved Gas Analysis (DGA), optimization of cooling, ultrasonic testing, and a cost-effective system for assessing the health of transformers. Each of these techniques has its own unique strengths and applications in identifying faults in transformers and ensuring predictive maintenance.

e) The methodology uses thermographic vision via FLIR ONE Pro cameras and thermal analysis in FLIR Thermal Studio. This approach was confirmed by two case studies. According to Findings, thermal imaging was successful in capturing abnormal temperature readings in Case Study A and Case Study B, signifying that it is effective in monitoring transformer health. Importantly, this research enhances the reliability of the electricity supply network. This points out the need for incorporating thermal imaging and advanced monitoring techniques into distribution transformer health monitoring. Through this transformative way, there is a reliable electricity supply that lowers operational risks, and it prolongs the lifespan of distribution transformers which benefits the entire society. This study is another positive stride towards distribution transformer health monitoring and its future.

In essence, this research work provides valuable insights into the utilization of thermal imaging and other techniques for monitoring the health of distribution transformers. By embracing these advanced tools and methodologies, power utilities and maintenance professionals can proactively address issues with transformers, prolong their operational lives, and optimize the reliability of the supply of electricity in distribution networks. The findings of this study emphasize the significance of continuous observation and early detection of faults, thereby highlighting the path towards a more resilient and efficient system for monitoring the health of distribution transformers.

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