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Transformer Shunt Fault Detection using Two Techniques

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ABSTRACT: Throughout the decades transformer has become a vital part of our power system. Thus any failure or disturbance in its operation may lead to further disruption of power. They have become far complex to model these days in terms of accuracy. These days due to varied reasons, mainly short circuit faults, the transformer failures have increased excessively. For this reason and so as to predict the faults before their occurrence the modeling of transformers becomes imperative. This paper discusses the numerous reasons for transformer deterioration. Also it discusses the techniques used for condition monitoring of the transformer. In addition to this two methods for detection of fault in the transformer are implemented.

KEYWORDS: Comparison, Condition monitoring, Frequency response, Stresses, Transformer failures.

I. INTRODUCTION

The growing times have seen a tremendous development in the power systems. The transformer has now become a vital part of the power system. The basic requirement of any electrical system is operation without any interruption. For the adequate as well as trustworthy operation of the transformer some consideration needs to be given to the causes leading to the failure of transformer. The varied reasons which may lead to the failure in a transformer may be the effect of the tensions acting on the transformer. These tensions can be categorized as electric, electromagnetic, insulating, thermal and chemical. These tensions on the transformer affect the various parts of the transformer and either one or a combination of more than one of these tensions may lead to the failure of transformer. The failures may sometimes be disastrous and altogether lead to severe damage. A power system being reliable is a crucial necessity for the performance of the power system. The utility as well as the consumers can be widely affected in terms of monetary expenditures due to the prolonged loss of power. Approximately 2% [1] of the total transformers that have been in service fail every year. The transformer failure is sometimes for the long haul as the means for maintenance is limited on some sites [1], [2]. Also the replacing in such cases becomes difficult due to its size, accessibility of auxiliary transformer as well as additional cost of a new transformer. Therefore the utilities have an obligation of adapting new methods to establish a proficient maintenance approach with minimum mishandling of the equipment.

This paper studies the numerous reasons for transformer failures as well as the diagnostic techniques that have been adapted to detect certain types of failures. It discusses the advantages of some techniques over the other. A healthy transformer is also modeled and compared to faulty condition in the transformer. The results of these are discussed briefly. The frequency response in a healthy as well as faulty situation is compared and its nature is observed.

II. TRANSFORMER FAILURE

Transformers are affected due to the various tensions acting on them. These tensions can cause severe damage in the transformer and decrease their lifetime. Hence, the proper assessment of transformer condition leads to:

- Increasing of transformer life
- Improvement in the loading of transformer

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- Enhancing the reliability
- Preventing harm on transformer and loss in power
- Introduction of condition based approach

On occurrence of fault in a transformer it becomes necessary to detect the type of fault and reduce the repair time predominantly where continuous supply is essential. To limit the damage caused due to the failure of transformer on the system swift recognition of fault and monitoring the transformer condition becomes obligatory.

The main reasons for failure of transformers are considered to be the faults that are occurring within the transformer or most commonly they are called as incipient faults. This can be proved by the various surveys that have been conducted throughout the decades [1], [3], [4], [5].

The percentage failure rate along with the component where the failure occurs is given in Fig.1. From the bar graph it is clear that the percentage of failures due to winding and core is maximum. So the possibility that the failure that has occurred is due to winding and core increases. So we can say that the failure of transformer due to internal faults is most common. In order to avoid such type of failures that can further lead to catastrophic effects on the transformers we must undertake some preventive techniques. Amongst the various techniques adopted two of them are discussed in this context.

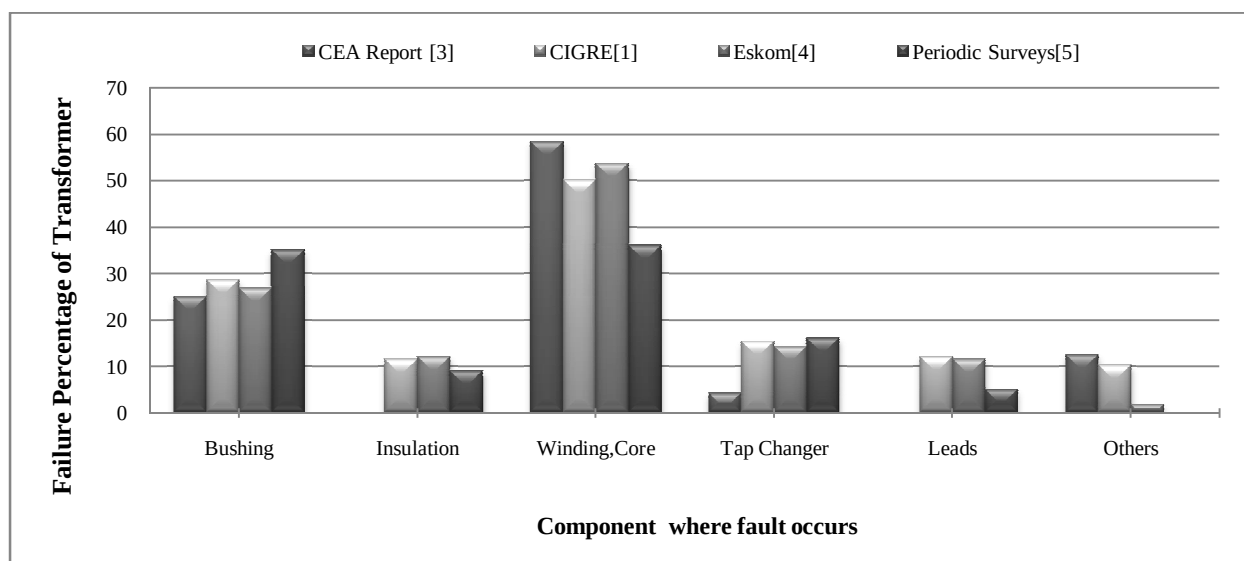


Fig. 1: Comparing various failures in transformers

III. VARIOUS TECHNIQUES TO DIAGNOSE FAULTS

The approach towards monitoring of the transformers has changed considerably [6]. Earlier an approach based on the time was considered whereas due to the increase in the usage, a condition based approach is more favorable these days. Generally there are two approaches to monitor the transformer one is online and the other is offline. The methods in which the transformers need to be taken out of service are the offline methods whereas the methods where uninterrupted operation is possible along with the testing are online methods. The online methods are advantageous than the offline ones due to their predictive nature which helps in identification of failure before it has occurred.

Transformer fault diagnosis techniques can also be categorized into electrical, chemical, dielectric and visually distinguishable. Every one of these comprises of different performances which need their individual accessories and precise test methods. The electrical diagnostic technique consists of the methods enlisted in TABLE I. Amongst the methods [7], [8] mentioned in the table only Partial Discharge Method can be conducted online.

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TABLE I
ELECTRICAL METHODS OF DIAGNOSING TRANSFORMER FAILURES

Method	Purpose	Affected part
<i>Measuring Resistance</i>	Recognize turn to turn faults, loose connections, increase in tap changer and bushing resistance	Winding
<i>Measuring Ratio</i>	Sense the failings in tap changer and winding short circuits	Winding
<i>Measuring Leakage Inductance</i>	Detect degradation in winding and mechanical displacement	Winding
<i>Measuring Excitation Current</i>	Expose short circuit in windings ,damage to the core and failing of taps	Winding and core
<i>Frequency Sweep Method</i>	Mechanical deformation detection	Winding and core
<i>Partial Discharge</i>	Detect fragile spots within the insulation[12]	Active part and oil

The chemical techniques used to detect failures are as shown in TABLE II. The major benefit of this type of technique [9],[10] is that it can be performed online. The first two methods mentioned in the table are most commonly used for condition monitoring of transformer whereas the other two methods are mainly used as additional tests.

TABLE II
CHEMICAL METHODS OF DIAGNOSING TRANSFORMER FAILURES

Method	Purpose	Affected part
<i>Dissolved Gas Analysis</i>	Senses thermal as well as electrical failures viz. partial discharge, corona, arc etc.	Oil
<i>Detection of Oil Parameter</i>	Determine the oil quality and aging of oil and the decisions about treating and repairing the oil	Oil
<i>Furan Analysis</i>	Estimate age of paper	Paper
<i>Degree of Polymerization</i>	Determine aging of cellulose	Paper

The dielectric techniques are shown in TABLE III. All the methods under these are generally conducted online.

TABLE III
DIELECTRIC METHODS OF DIAGNOSING TRANSFORMER FAILURES

Method	Purpose	Affected part
<i>Measuring Insulation Resistance</i>	Determine the dielectric strength and evaluate the dryness in insulation	Active Part and Oil
<i>Dissipation Factor</i>	Determine degradation of insulation	Active Part and Oil
<i>RVM</i>	Determine humidity in insulation and analyze effects of aging	Paper
<i>DFR</i>	Determine moisture in paper	Paper and Oil
<i>PDC</i>	Determine moisture in paper	Paper and Oil

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The visually distinguishable techniques can be categorized as shown in TABLE IV.

TABLE IV
VISUAL METHODS OF DIAGNOSING TRANSFORMER FAILURES

Method	Purpose
<i>Inspecting Visually</i>	Detect leakage, contamination etc.
<i>Thermography</i>	Detect sources of heat
<i>Thermal Monitoring</i>	Detect hot spots
<i>Ultra-Violet Camera</i>	Detect Corona Discharge

The precision and effectiveness of these diagnostic techniques differs from one another. Some are improved as compared to others. Frequency Sweep Method [7] has a relatively better sensitivity in detection of mechanical deformations. DGA [10], Oil Quality Parameters [10], Furan Analysis[11] are the effective techniques in detecting thermal faults. In order to detect dielectric damages and aging of insulation Partial Discharge and DFR can be recommended.

IV. SIMULATION AND RESULTS

The transformer nature can be studied by considering it in healthy as well as faulty conditions [14]. A 1MVA, 33/11kV transformer winding was simulated in order to study its nature on the occurrence of certain fault as well in case of no fault condition. The healthy graph comes out to be as shown in Fig.2.

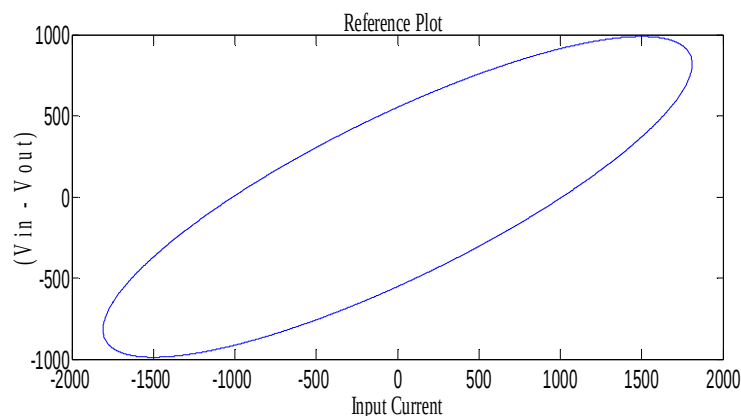


Fig. 2: Reference Plot

The transformer healthy condition plot in Fig.2 shows that its nature is elliptical. IEC [15] recommends the measurement of the leakage inductance while testing of transformers.

Now if a fault condition is taken into consideration, the fault condition being a shunt fault or most commonly known as leakage fault then the above graph turns out to be something as shown in Fig.3.

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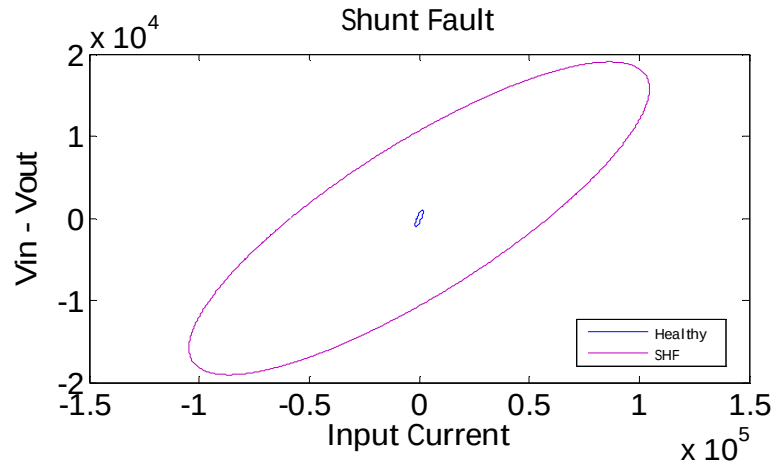


Fig.3: Shunt Fault

As can be seen in Fig.3 that the shunt fault leads to an increase in size of the plot and as compared to the healthy plot the shunt fault condition is extremely large as well as rotated.

Another method of comparing all the faults is by determining its frequency response. In order to observe the frequency response of the implemented model in fault as well as in healthy conditions the model is simulated again in MATLAB/SIMULINK. The obtained frequency response is shown in Fig.4.

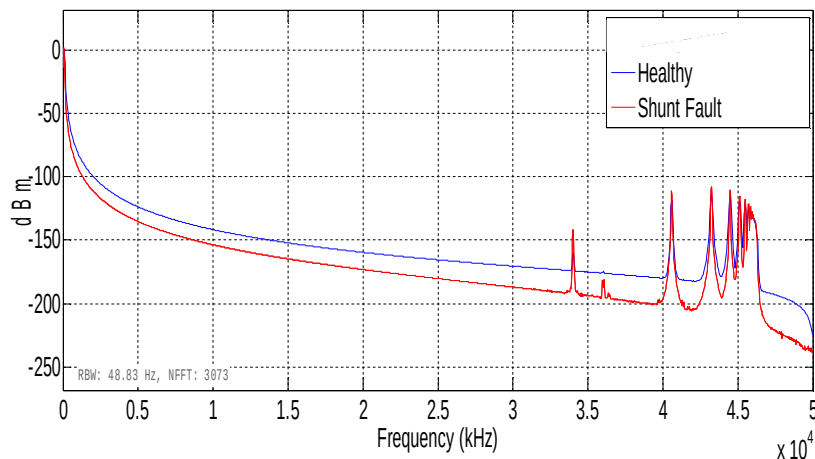


Fig. 4: Frequency Response Comparison of Shunt Fault and Healthy Condition

As can be seen in the Fig.4 the leakage fault does have a significant effect on the response in the range of lesser frequency where the plot is shifted in the downward direction for the lower frequencies whereas for the higher frequencies i.e. for frequencies above 30 kHz an observable rise in the magnitude is witnessed. At the frequency above 45 kHz the voltage magnitude suddenly decreases in comparison to the healthy condition.

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V. CONCLUSION

A brief study has been carried out on the various tensions acting on the transformer and the effects of these tensions on the transformer condition. Also the various diagnostic techniques have been discussed briefly out of which the Frequency Sweep Method is considered to be most sensitive in case of mechanical deterioration while the Dissolved Gas Analysis as well as Furan Analysis prove to be beneficial in detecting the thermal faults.

The transformer has been modeled using two methods. The first method compares the healthy plot with the faulty plot with the help of the transformer winding model. In the second method the frequency response in case of the healthy as well as faulty transformer is shown. Considerable changes have been observed in both the cases. Thus both the methods have proven to be effective in terms of identification of fault in the transformer. Therefore we can conclude that in a way these methods demonstrate to be a preventive technique where the transformer fault is considered.

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