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Sweep Frequency Response Analysis for Assessment of Abnormalities in Power Transformer

Sayali G. Thakur, Dr. D. S. Bankar
Department of Electrical Engineering, Bharati Vidyapeeth Deemed University, College of Engineering, Pune, Maharashtra, India

ABSTRACT

For beneficial generation and transmission of electrical power trustworthy and continued performance of power transformer is necessary. Failure of large power transformer can cause serious damage as well as loss of very expensive equipment. If failure is not disastrous, their replacement can take a year and can results in formidable revenue losses and fires as they are most valuable asset in power system. Therefore, in order to reduce associated cost after its failure diagnosis of this equipment becomes more relevant. Regarding data acquisition, various aspects of measurement and analysis many technical advancement took place during last few years. Transformer is submitted to many short circuits during its life with high fault currents, which consequently, may cause deformations and displacements of windings as well as changes to winding inductance or capacitance in transformers. Through the traditional condition monitoring techniques, such as dissolved gas analysis, winding resistance measurements, capacitance and tan delta measurements etc. such small movements cannot be detected. Hence, for condition monitoring of power transformer sweep frequency response analysis is essential.

Keywords: Sweep Frequency Response Analysis (SFRA), Winding Deformation, Power Transformer

I. INTRODUCTION

To ensure the reliable power transmission in the power sector power transformers are important equipment. To safeguard the transformer from failure throughout its life it is necessary to provide timely monitoring and diagnostic programs, as it is most costly equipment in power network. No choice is left than replacing the transformer when mechanical failure which is considered to be most severe failure amongst all occurs as it leads to complete damage of winding. [1] Transportation and many in-service events such as short circuit faults and lighting may results into severe electromagnetic force leads to mechanical damage of transformer. The electromagnetic forces are mainly of two types axial and radial forces and hence deformation also may belong to axial deformation or radial deformation.

Like many electronic devices power transformers face many failures. To classify different faults that occur in transformer MIL-STD-1629A standard is used. [2] From the past 30 years it is the most frequently used standard throughout the world. Each fault is first categorised which is subdivided later. In the foremost category on the basis of severity of the fault the faults are classified. In this case bigger fault will be more severe. According to of the occurrence of the fault the second category faults are classified. In this case more frequent fault will be more severe. As per detection of the fault after it has occurred the third category faults are classified. This is an essential part after the fault is diagnosed it can be repaired.

Priority Number (PN) also called numerical value which depends on the fault value is assigned to each fault. After the occurrence of fault the action needed to be taken is decided by PN number. PN is given by Equation

$$PN = Occurrence * Severity * Detection$$

The minimum and maximum PN number for any fault is 1 and 120 respectively. The chance of occurrence of fault which can be occurred can be forecasted so that remedial action can be taken to restrict fault before its occurrence. Figure 1 shows the faults in transformers [3]. In the protection system more number of faults and failure happen. After protection system maximum number of faults occurs in tap changer and then in bushing with high PN number. The core of the transformer has less failure rate after tank having least PN number.

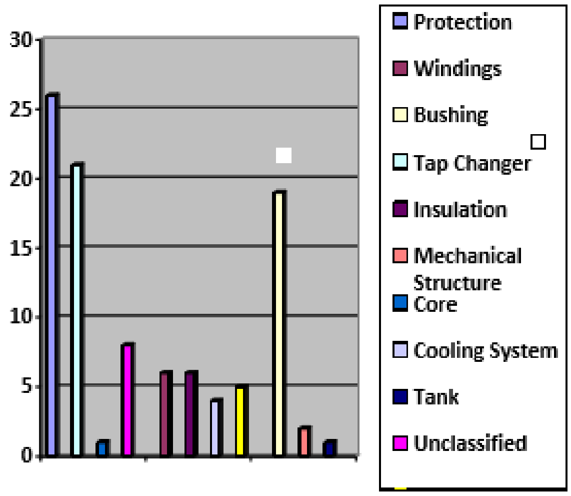

Figure 1: Failure in transformers

II. SFRA Basics

An The increasing number of mechanical type of faults in transformers due to distortion and movement of winding made it necessary for implementation of powerful technique for damage detection. Due to its high sensitivity in detecting such type of failure Sweep Frequency Response Analysis (FRA) is extensively used method. Frequency response is obtained by two methods namely SFRA and LVI.

Over LVI method SFRA has some benefits such as reproducibility, high signal to noise ratio, requirement of few measuring equipment and repeatability .The time required for measurement is more in case of SFRA is its important disadvantage. [4]

To determine integrity of core, windings and clamping structures of power transformers mechanically an effective and responsive method called Sweep Frequency Response Analysis is widely used now-a-days. It is based on the theory that over a wide frequency range their electrical transfer functions are measured.

Figure 2 shows the basic principle of SFRA in which magnitude and phase response of signal is measured with respect to frequency is shown. The aim of this test is to detect any physical change such as displacement which has occurred after events such as transportation, earthquakes, short circuit etc. It is a proven, non-intrusive and off-line method for frequency measurements. [5]

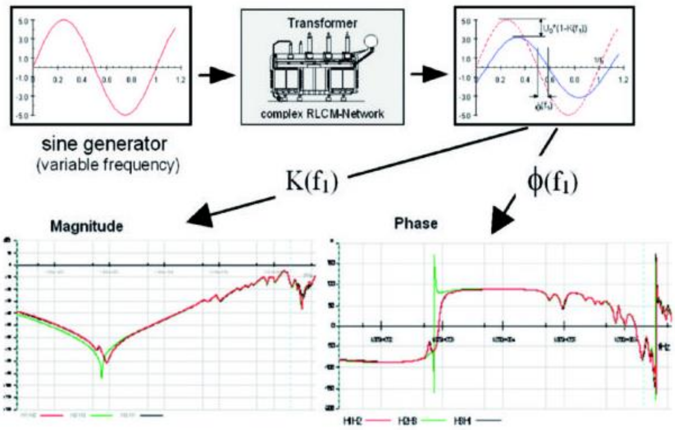

Figure 2: Basic principle of SFRA

The SFRA test evaluates condition of transformer by comparing obtained results with reference results. To assess the measured traces following three methods are commonly used: [6]

Comparison based on time –Previous results of same transformer unit are compared with current SFRA results. It is most effective and easy method to find out problem.

Type based comparison– SFRA signature of one transformer are compared with same type of transformer i.e. one with same manufacturer and same nameplate data.

Phase-based comparison – Obtained signatures of one phase are compared with the signatures of remaining phases of the similar transformer.

The various Dobel series SFRA analysers are shown in table I

TABLE I. Dobel SFRA analyser

	M5200
	M5300

	M5400

III. PROBLEM IDENTIFICATION

At 220/22 kV MSEB substation at Uran near New Mumbai India, 50 MVA power transformer got exploded. This transformer got burst caught fire along with bursting and fire of its 22 kV circuit breaker. This has resulted into complete failure of 22 kV and 220 kV bus which caused the total generation loss of about 458 MW and loss of about 34 MW at Uran substation. After this event it was needed to replace that transformer with new one.

After studying details of this event, developing system monitoring techniques for transformers condition is need of the hour. Analysis technique should be able to detect the abnormalities in transformer before occurrence of the fault so that remedial action can be taken immediately to avoid catastrophic failure.
Being expensive element in power system network diagnosis of this equipment is important to avoid its replacement and cost after its failure.

IV. RESULTS AND DISCUSSION

The results of SFRA test conducted at M.I.D.C Chakan on 167 MVA power transformer are given below:

The specification of 167 MVA power transformer are given in the table II.

TABLE II.167 MVA transformer specifications

Manufacturer	Alstom
Year of Manufacture	2015
Current	419
MVA Maximum	167
Phases	1
Windings	2
HV	400
LV1	220
LV2	33

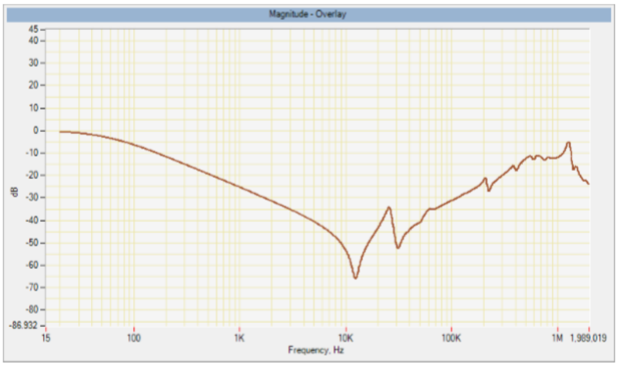

Figure 3:HV winding between 1U and 1N at tap no:1 , with LV short

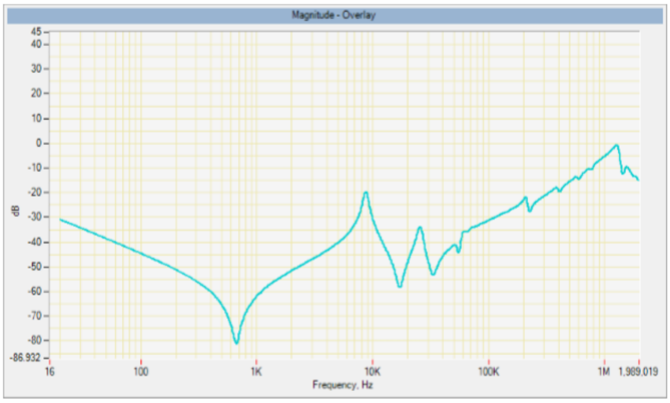

Figure 4 : HV winding between 1U and 1N at tap no:1 , with LV open

Some of the SFRA signatures obtained for different conditions such as short circuit and open circuit of LV winding are given in the figure 3 and figure 4.
The following conclusions are drawn after observing various SFRA responses for different conditions are given below:

- After observing SFRA results collected from different areas it can be concluded that for short circuit condition the graph starts from near about 0 dB and for open circuit condition graphs are starting negative side of y-axis i.e. at -25dB , -30dB and –45dB.
- It is observed from all graphs that for U and W phase the nature of the first dip in the graph is W-shaped and for V phase it is Y-shaped for open circuit condition.
- For short circuit condition nature of graph for U phase is Y-shaped and for V and W phase it is W-shaped.
- All these collected graphs are of healthy condition. After some years SFRA can be conducted on same transformers and collected graphs can be used as a reference and abnormalities within power

transformers can be detected by comparing these two graphs.

V. CONCLUSION

For the evaluation of mechanical integrity of core, winding and clamping structures within power transformers SFRA technique for their condition monitoring is helpful by measuring their electrical transfer functions over a wide frequency range. Various problems such as winding displacement and deformation, partial winding collapse, shorted or open turns, contamination of oil, faulty grounding of core , broken clamping structures, etc. can be detected by using this method. With highest precision than other methods SFRA delivers valuable information. In substations of rating 400kV/220kV/132kV/66kV faults can be easily found out as initial signatures of healthy transformers can be obtained for future comparison with the help of this method. Premature failures can be reduced considerably by employing such powerful technique for condition assessment of power transformer which can save power transformers from undergoing major damages. So the associated cost for maintenance and repair will also get reduced.

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