Condition Monitoring of Power Transformer by using SFRA Test

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Abstract— Transformers are the most critical part of electrical transmission and distribution network, also when it is come to quality and continuity requirements on delivery of electrical energy. Power outages cause loss of income for power consumers and the power industry itself, as well as loss of consumer confidence in the power provider. Transfer function measurements have been used as a diagnostic tool to detect mechanical failures in power transformers. Geometrical changes in the transformer windings and core due to mechanical stress can be reflected as a change in the RLC parameters of the equivalent circuit of the power transformer. Such changes can be detected through the change in the transfer function. [1] This paper discusses the measurement principle of sweep frequency response analysis (SFRA) on power transformer and result interpretation, which is complimented with case studies. Frequency Response Analysis (FRA) is the only reliable technique often called as tool for determining mechanical faults in transformer winding. There are main techniques available for the electrical fault detection. [2].

Key words: Power Transformer, Internal Faults, Frequency Response Analysis, Maintenance and Condition Monitoring, Sweep Frequency Response Analyser Winding Deformation, Case Studies Component

I. INTRODUCTION

Transformer is an electrical device which is used for energy transfer between two or more circuits. So, all electrical devices faults cause a failure in transformer. One failure can cause many problems. A simple fault can cause black-out of power to the whole area. So it is necessary to detect the faults as soon as possible to save the transformer life. To find faults in high ratings of transformer is not easy, and if we try to find fault in it by dismantling which is very time consuming process. It impact on the transformer reliability, lifecycle cost and efficiency. So the best solution is to use different condition monitoring techniques for particular different problems.

Sweep Frequency Response Analysis gives an indication for core or winding movement in transformer. This is done by looking at how well a transformer winding transmits a low voltage signal that varies in frequency. This is related to its impedance, capacitive &inductive elements of which are directly related to the physical construction of the transformer. Changes in frequency response are measured by SFRA a technique which is indicating physical changes in transformer. The deregulation of electric power raises the economic pressure. To control this pressure requires decrease in servicing and decrease in maintenance cost. When the load of transformer is raise thus diagnosis of transformer becomes more important. Sweep Frequency Response Analysis SFRA has been a strong and non-destructive way to find the mechanical strength in components of power transformer by finding electrical transfer function through wide range of frequency.

This is done by entering a less frequency voltage signal into one terminal of transformer winding & determining response on other terminal this is performed on every existing winding with guidelines. The comparison of input and output signal generates frequency responses which are compared with standard data.

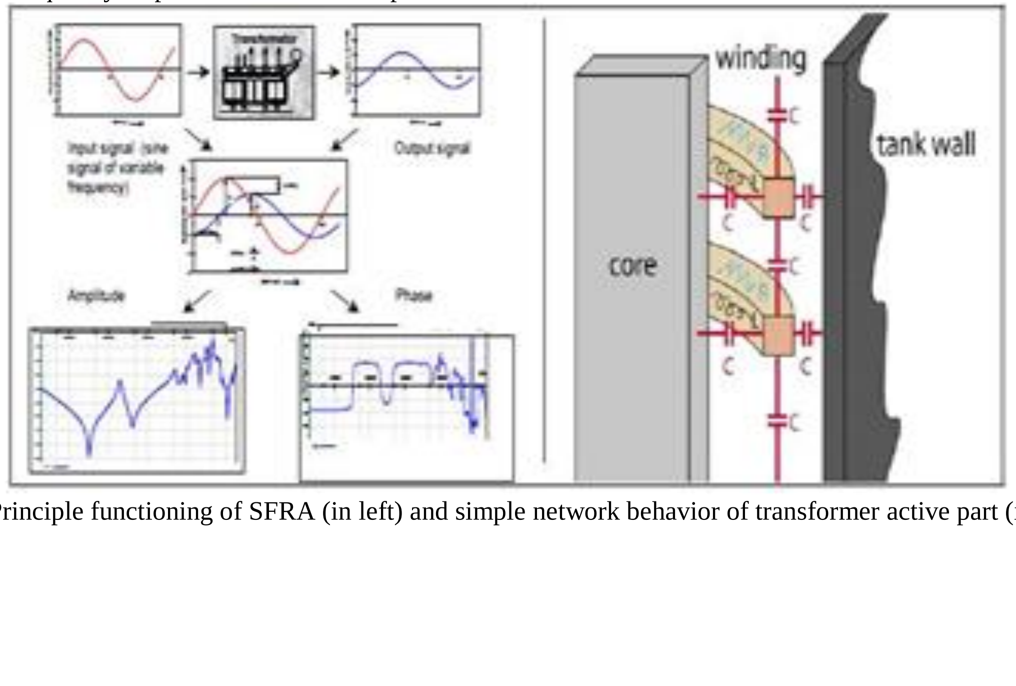

Fig. 1: Principle functioning of SFRA (in left) and simple network behavior of transformer active part (in right)

II. PROPOSED MODEL OF SFRA

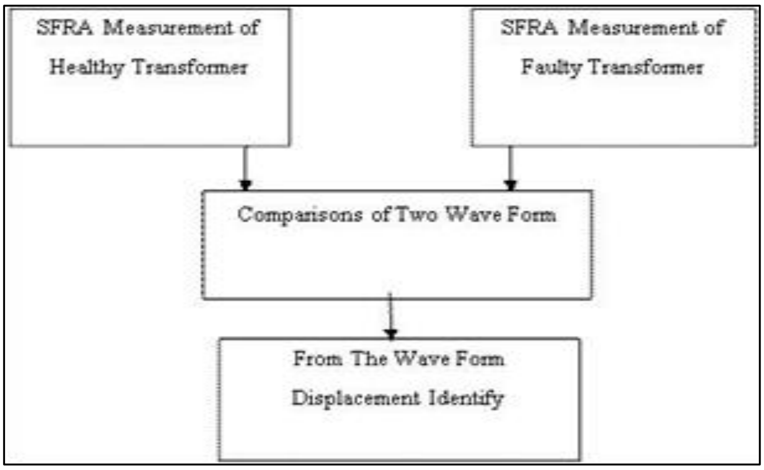

Fig. 2: Proposed Model

The four steps of diagnosis method are listed:

1) A measurement in the healthy state of the transformer is made.
2) Another measurement is carried out in the supposed fault state.
3) Two responses are compared.
4) Any difference between them means fault has occurred. [3]

III. SWEEP FREQUENCY RESPONSE ANALYZER

The SFRA consist of measuring the impedance of a transformer winding over a wide range of frequencies & comparing the results with a reference set. SFRA is non-destructive test, Off-Line testing and it can be carried out for any voltage rating of Power Transformer. The measurement of SFRA can be a part of regular transformer maintenance. The SFRA Analyzer detects the following fault in the power transformer before break down occur.

1) Displacement of Core
2) Deformation and displacement of winding
3) Faulty core ground
4) Partial winding collapse
5) Hoop Buckling
6) Broken or loosened clamping structures.
7) Shorted turns and open winding.

The technique of SFRA is a major advance in transformer condition analysis. This is a tested technique for obtain precise and repeatable measurements. The test can be carried out,

1) First to obtain initial signature of the transformer sweep frequency response as a record for the future reference comparison.
2) Periodical measurement as a maintenance check, once in two years.
3) Immediately after a major external shortcuts, especially for faults electrically closer to transformer.
4) Transportation or re-location of transformer.
5) Earthquakes.
6) Pre-commissioning check. [4]

IV. SWEEP FREQUENCY RESPONSE TEST

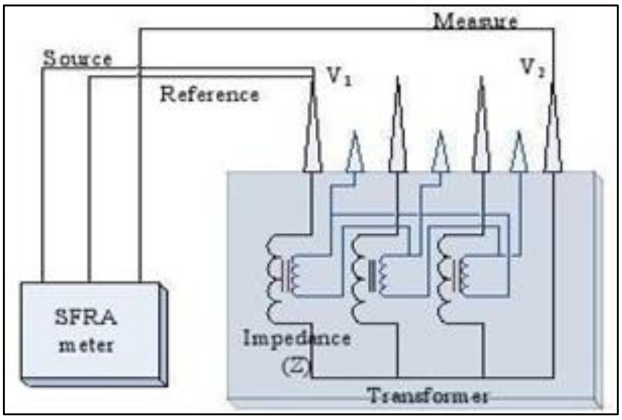

Fig. 3: A typical SFRA test connection

SFRA proceeds by applying a sinusoidal signal of constant amplitude and variable frequency to one end of the winding under test (V1 (f)) shown in fig. The response is measured on the other end of the winding (V2 (f)). The response will vary in amplitude and phase. The transfer function (H (f)) is a comparison of the applied signal and the response. Figure show the typical SFRA test connection. The main task of test is to measuring the transfer function. The mostly to plot a graph of the amplitude, as measured by the network analyzer, over frequency. Both linear and logarithmic scales are used the amplitude is defined by:

$$K(f) = 20 * \log10 (V2(f) / V1(f))$$

The phase, as measured by the network analyzer, is defined by:

$$\varphi(f) = \tan^{-1}(\angle U1(f) / \angle U2(f)) \quad (3)$$

This work will focus on the SFRA method only, since the SFRA method is superior to the IFRA method. The IFRA method lacks of reproducibility for in-site test.

Generally SFRA instruments have three leads source, reference and measure which are shown in figure 3. According to standard IEC 60076-18, the source and reference terminals are connected to the input end while the measure terminal is connected to the output end. [5],[6]

V. TERMINOLOGY OF TRANSFORMER MEASUREMENTS

According to terminology these measurements can be subdivided into four groups,

1) End to end open circuit test
2) End to end short circuit test
3) Capacitive inter winding test
4) Inductive inter winding test

The most common type is the end to end open circuit test. This type of test provides information about both the winding and the core. The end to end short circuit test is normally performed for on-site measurements in which only problems in the winding structure have to be identified. Inter winding test have recently been introduce. Capacitive inter winding measurement seem to be a potential type of FRA measurements due to its higher sensitivity in the detection of radial deformations.

Figure 4 shows the typical response of an end to end open circuit test on a YN connected power transformer. The source (yellow) and the reference input (red) are connected to one phase. The response (blue) is measured on the neutral as per the IEC 60076-18 standard.

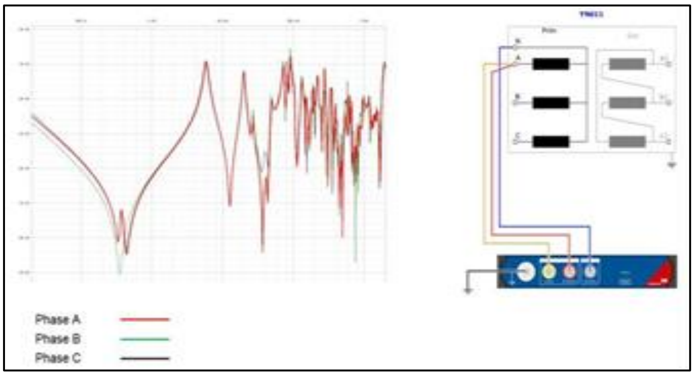

Fig. 4: Typical response of an end to end open circuit test (left) and connection diagram (right)

Figure 5 shows the typical response of an end to end short circuit test on a YN connected power transformer. A comparison between the response of a end to end open circuit test and an end to end short circuit test is shown on the left hand side. At low frequencies the differences between the two measurement methods is caused by the short circuit of the magnetic core. At higher frequencies the response of both methods line up as the actual winding structure is dominating the response at high frequencies. The end to end short circuit test is very sensitive to any change in the leakage channels. Therefore, it is the preferred method for detecting any axial or radial movements of the windings.

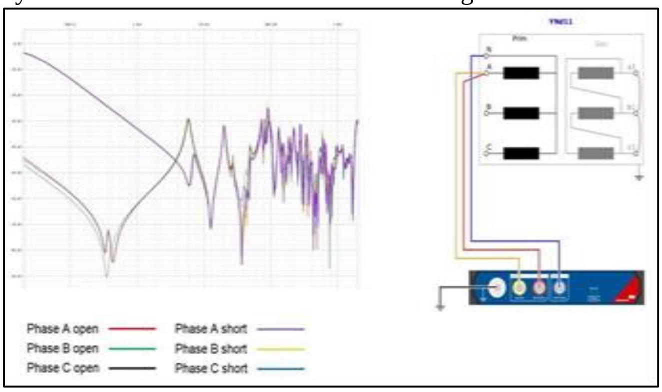

Fig. 5: Typical response of an end to end short circuit test (left) and connection diagram (right)

VI. PRACTICAL ASPECTS OF SFRA TESTING

SFRA is a comparative measurement method. This implies that any sort of reference data has to be available in order to analyze the test results. This means results of an actual test, which is usually a certain set of curves, are compared to reference baseline data. Three methods are commonly used to assess the measured traces,

1) Time-based comparison-Current SFRA results are compared to previous results on the same power transformer under test.
2) Type-based comparison-Current SFRA results are compared to another power transformer of the same design (sister unit).
3) Phase-based comparison-Current SFRA results of one phase are compared to the results of the other phases of the same power transformer under test

VII. RULES TO ACHIEVE REPEATABILITY

Finally a summary of guidelines derived from a large number of successful measurements is given to put the reader in a position to achieve a good degree of repeatability, too. This is of need because all types of assessments explained in chapter 3 are based on the ability to exactly reproduce the measurement results under same conditions. Without this it is often very critical or even impossible to distinguish between measurement mistakes and real damage inside the tested transformer.[7]

- All connections from the transformer except the tank ground and auxiliary connections shall be removed.
- The contacts of the bushings shall be cleaned and the connection clamps have to be tightened firmly to assure reliable electrical contact.
- Three shielded high frequency cables (usually coaxial cables) of exactly same length should be used.
- It must be assured that the ground extensions of the measuring cable shields do not have electrical contact with the terminal contacts.
- Ground extension of the test leads must be of low inductance (broad braids with large surface, made of a large number of small wires to reduce the skin effect at higher frequencies).
- Ground extension to the base of the bushing (reference potential is the transformer tank) shall be as short as possible and with the smallest achievable loop.
- It is very important to ensure reliable contact between ground extension and tank. A lot of measurement mistakes are

VIII. CONCLUSION

The SFRA measurement is a powerful method for detecting and diagnosing defects in the active part of a power transformer.

Reliable information about the mechanical and electrical condition of the core, windings, internal leads and contacts can be gathered using the described diagnostic method.

No other single test method for the condition assessment of power transformers can deliver such a diversity of information.

On the other hand, the engineer relying on this method has to be aware of its limitations as well. The key for a successful application is the reproducibility.

Therefore particular attention would be required on the test setup.

REFERENCES

[1] Florian Predl “Interpretation of Sweep Frequency Response Analysis (SFRA) Measurement Results” OMICRON Australia.
[2] Rohini D. Jiwane. “Detection of mechanical faults on transformer winding using frequency response analysis (FRA)
[3] T.Mariprasath1, Dr.V.Kirubakaran2 Research scholar 1, Assistant Professor, Power Transformer Faults Identification using SFRA,International Journal of Scientific & Engineering Research, Volume 5,ISSN 2229-5518 IJSER © 2014,
[4] Power Linker Group, Sweep Frequency Response Analysis (SFRA) A Major Advance in Transformer Condition Analysis.
[5] C. Sweetser and T. McGrail, “Sweep frequency response analysis transformer applications,” presented at the Relatoriotrcnico, Doble Engineering Company, 2003.
[6] SFRA, Detect Of Winding Deformation in Power Transformer Shivangi Rai1, (Prof.) N.P. Gupta2, IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 9, Issue 6 Ver. IV (Nov – Dec. 2014), PP 53-57 www.iosrjournals.org
[7] Aspects of the Practical Application of Sweep Frequency Response Analysis (SFRA) on Power Transformer A. KRAETGE1*, M. KRÜGER1, J. L. VELÁSQUEZ1 OMICRON electronics GmbH Austria. CIGRE 2009, 6th Southern Africa Regional Conference.