Expert system for Sweep Frequency Response Analysis of Power Transformer

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Abstract
In recent years there have been widespread interests in sweep frequency response analysis of transformer. SFRA is being popular because without, opening of transformer we can detect the different faults. In classical method the interpretation of the result to diagnosis the fault in power transformer depends upon the experience of human experts. Sometime a high degree of inconsistency and ambiguity have absorbed regarding interpretation of result by different human experts, so there is a need of development Expert system for SFRA Data analysis. This paper explains in detail expert system developed by authors. The working Principle has been applied to the power transformer
Keywords: SFRA, DGA, Expert system, Data analysis

1. Introduction:

Sweep Frequency Response Analysis (SFRA) is a tool that can give an indication of core or winding movement & dislocations in transformers. This is done by performing a measurement, a simple one, looking at how well a transformer winding transmits a low voltage signal that varies in frequency. Just how well a transformer does this is related to its impedance, the capacitive and inductive elements of which are intimately related to the physical construction of the transformer. Changes in frequency response as measured by SFRA techniques may indicate a physical change inside the transformer, the cause of which then needs to be identified and investigated.
Sweep Frequency Response Analysis (SFRA) testing by swept frequency method makes a qualitative assessment of the mechanical condition of the transformer core and winding. The loss of mechanical integrity might occur due to:

- Large electromechanical forces due to fault currents
- Winding shrinkage causing release of clamping pressure
- Transformer transportation and relocation.
- Also from some external causes like earth quake, lighting stroke etc.

It is expected that a transformer will experience and survive a number of short circuits during its service life, but sooner or later one such event will cause some slight winding movement, and the ability of the transformer to survive further short circuits will then be severely reduced. Another important factor is that significant winding shrinkage can occurs with age, leading to a reduction in clamping pressure and short circuits withstand strength. It is therefore desirable to be able to check the mechanical condition of transformer periodically during their service life.
Conventional condition monitoring techniques such as DGA are unlikely to detect mechanical damage until it develops into a dielectric or thermal fault, so a specialist technique is clearly required for the monitoring and assessment of mechanical condition. The improvement in SFRA is something that is worth developing as it can give a non-destructive indication of winding movement, and as early indication of a developing problem.
Roads and rail transport offer far more difficult conditions and internal inspection after receipt of transformer at site or after incidence are often inconclusive. Due to short circuit forces, there could be winding movement as well as changes to a winding inductance or capacitance in transformers. Such changes cannot be detected through conventional conditions techniques. Sweep Frequency response measurements (SFRA) has proved to be a very effective tool to detect these changes.
SFRA has been recognized as the most sensitive technique to detect the winding movement of power transformer. It consists of measuring the impedance of transformer winding over a wide range of frequencies. Faults, which can change either the winding capacitance or the winding inductance, are detectable. It allows detection of most possible modes of winding distortion such as radial, axial, twisting and as well as changes in the clamping pressure
Sweep Frequency Response Analysis essentially consists of measuring the impedance of transformer over a wide range of frequencies and comparing the results .There are two ways of injecting the wide range of frequency either by injecting an impulse into the winding or by making a frequency sweep using sinusoidal signal. Sweep

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2. Proposed Expert system for SFRA

A knowledge based expert system for SFRA was greatly in need as SFRA tool is becoming popular day by day for the good health for power transformer. There is no such smart tool for analysis of SFRA results. Knowledge based Expert and effective system can predict more précised analysis of SFRA data with the help of appropriate computer programming .The block diagram of proposed Expert system is shown in figure 4. A suitable matlab code has been developed for knowledge based expert system analysis.

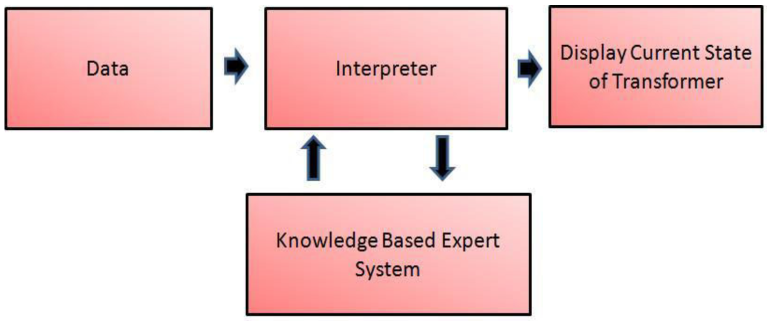

Figure 4 Block diagram of expert system proposed

3. Analysis and interpretation with knowledge based expert system

The knowledge based expert system give indication of probable fault in transformer. The use of knowledge based expert system can improve reliability and repeatability of analysis of SFRA data. A great deal of research has been done to develop expert system for the interpretation of different faults in transformer. Expert system has been developed to give indication of fault directly to user.

There is a hierarchy of analysis using SFRA the best method is to compare results to those obtained previously as a baseline. But some time baseline results are not available then we can rely on three further types of comparison over baseline comparisons

- Comparison with sister unit of identical parameter
- Phase to phase comparison of short circuit test results
- Phase to phase comparison of open circuit test results

Features of knowledge based expert system tool for SFRA

- Interface for normal user
- Interface for advanced user
- Interface for advanced user with user defined limits for analysis
- Interface for phase to phase comparison analysis
- Interface for baseline comparison analysis

4. Application of knowledge based expert system for SFRA

Stage 1: SFRA data is imported

Stage 2: A matlab code has been developed which loads data in workspace as input for the knowledge Based expert system

Stage 3: Classification of data is done based on the table 1

Stage 4: Checks the probable fault level in each frequency band as mentioned in table 2

Stage 5: Calculate the probable fault in percentage

Stage 6: Displays the results of analysis done if fault is present then display the corresponding fault with the help of table 2

Table 1 Probable fault with range of difference in magnitude at same frequency

Difference in db	Probable fault level
< 2db	Very low
2 db - 3.5 db	Low
3.5 db – 5 db	High
5db<	Very high

Table 2 Probable faults with range of frequency [5]

Frequency Band	Probable fault
< 2kHz	Core deformation, open circuits, shorted turns & Residual magnetism
2kHz to 20kHz	Bulk winding movement relative to each other , clamping structure
20kHz to 400kHz	Deformation within the main and tap windings
400kHz to 2MHz	Movement of main and tap winding leads, axial shift

Analysis through knowledge based expert system and obtained results

Analysis has been done with the help of matlab programming and based on our programming we found appropriate results which are given below.

In our analysis we have used Knowledge based Expert system with phase to phase comparison method in this was carried out on power transformer described in table 3 transformer (A) and (B) respectively.

Table 3

Transformer Details	Transformer (A)	Transformer (B)
Manufacturer	ZWAR	Apex electric Ltd
Location	Anu substation H.P(India)	Kangra substation H.P(India)
Year of Manufacturer	1994	1994
Winding	3	3
HV	132kV	132kV
LV	33kV	33 kV
Transformer Rating	5.33 MVA	16 MVA

These are substation Power transformer and we have obtained appropriate results with the help of knowledge based expert system. And results obtained by analysis of transformer (A) & (B) respectively are given below.

For transformer (I)

Open circuit test

Open circuit test has been done on A, B, C phase respectively. In figure 6 analysis has done for phase A & B and obtained results in figure 7 which indicates overall percentage probable fault level obtained from each zonal analysis according to table 2. Similarly for phase B & C and phase C & A in figure 8 & figure 10 respectively and Its overall probable fault level in figure 9 & figure 11

For phase A & B

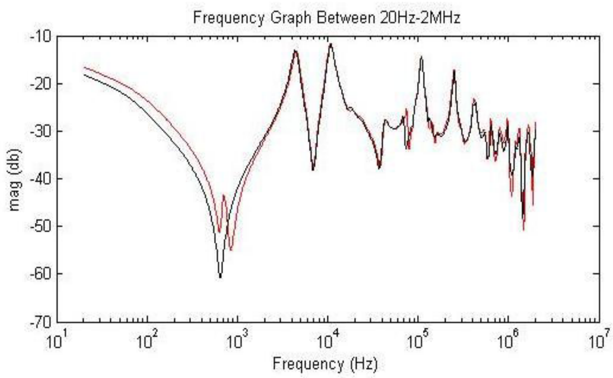

Figure 6

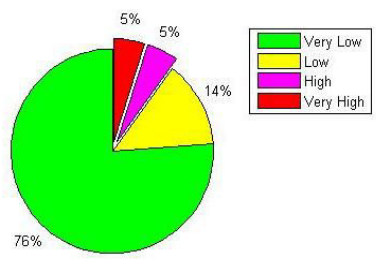

Figure 7

For phase B & C

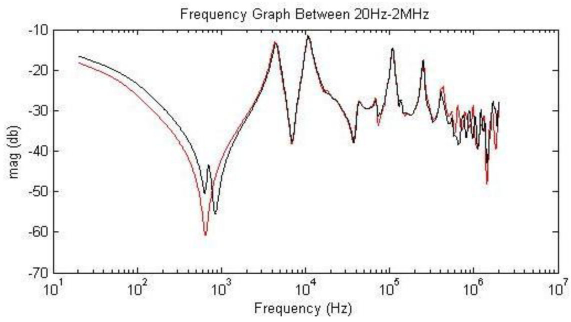

Figure 8

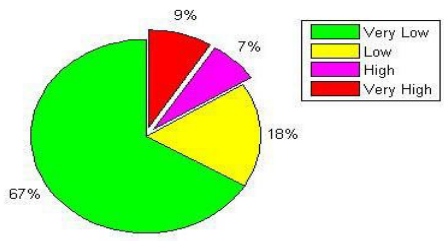

Figure 9

For phase C & A

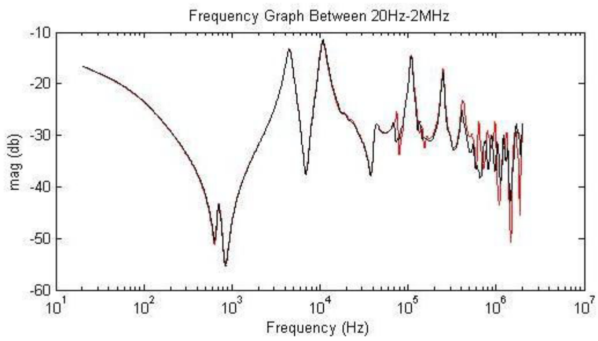

Figure10

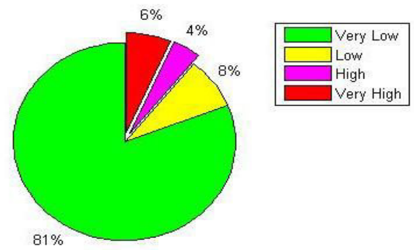

Figure 11

For transformer (II)

Open circuit test

Open circuit test has been done on A, B, C phase respectively. In figure 12 analysis has done for phase A & B and obtained results in figure 13 which indicates overall percentage probable fault level obtained from each zonal analysis according to table 2. Similarly for phase B & C and phase C & A in figure 14 & figure 16 respectively. Its probable fault level in figure 15 & figure 17.In figure 16 Frequency Graph between 400 kHz-2MHz show high degree of fault of Movement Of Main Winding Leads and Axial Shift. While in figure 17 shows fault level very high 52 % in this corresponding zone.

For phase A & B

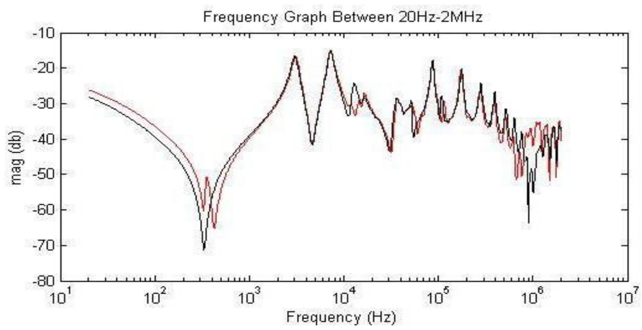

Figure 12

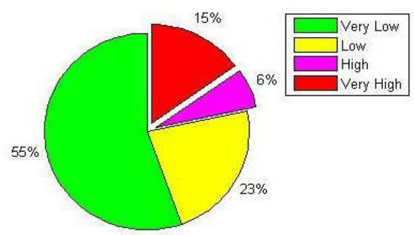

Figure 13

For phase B & C

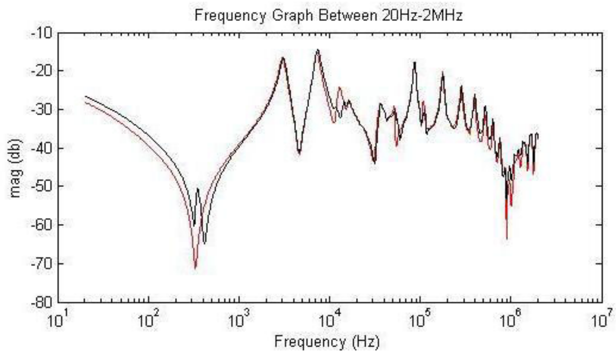

Figure 14

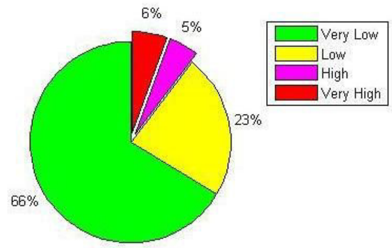

Figure 15

For phase C & A

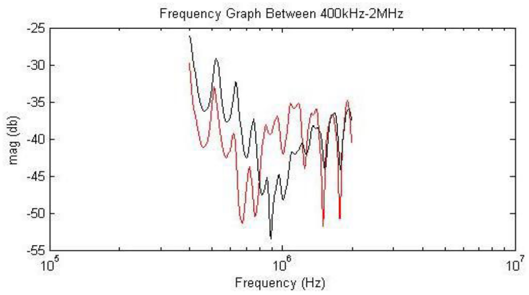

Figure 16

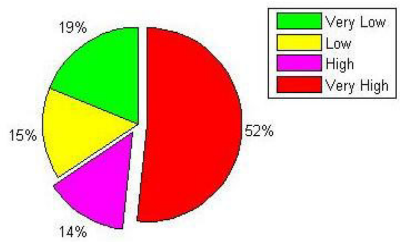

Figure 17

Conclusion

This paper has explained in detail the various steps involved in area of application of expert system. The Knowledge based expert system so developed has been successfully applied for the SFRA of two different power transformers. Data analyses were done with the help of Knowledge Based Expert System and it was concluded that the structural health of core and winding is good and there is no indication of any deformation or displacement of winding in transformer (I) while transformer (II) is effected from Movement Of Main Winding Leads and Axial Shift between phase C & A and figure 16,17 explains degree of fault .Our experience supports the development of expert system, further development is being carried out to enhance more features in our knowledge based Expert system.

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