Chapter 9

Conclusion

9.1 General

There are limitations of existing method for assessment of mechanical condition of transformer. Traditional electrical tests, Short-circuit impedance or leakage reactance, Magnetizing (exciting currents) currents, Winding capacitances and loss factor ($\tan\delta$) provide very little information about transformer insulation since they are limited to a single value results. These techniques depend on detecting the change in a global quantity, e.g. total leakage flux, that winding movement produces. Method should rely on detecting the effects of the resulting local change produced by a fault so that incipient fault in transformer can be detected.

Development of fast computers and digital signal processing technologies made a major break through in development of new measurement techniques for incipient fault detection in transformers. The Sweep Frequency response analysis (SFRA) is proved to be powerful diagnostic test technique and its measuring system is designed based on advanced DSP techniques. It consists of measuring the impedance of transformer windings over a wide range of frequencies and comparing the results of these measurements with a reference set. Differences may indicate damage to the transformer, which can be investigated further using other techniques or by an internal examination.

The main contribution of the thesis includes the development of,

- The degradation of the solid Insulation of transformer happening due to a combination of thermal, chemical, mechanical and electrical stresses. The mechanical mode of failure in transformer due electromagnetic forces and techniques for assessment

of mechanical condition of transformer.

- Various approachies has been developed to diagnosis the incipient fault in transformer using advanced DSP methods like : Detection of incipient turn to turn fault by wavelet analysis of impulse neutral current, Impedance measurement of winding in frequency range from 10 kHz. up to 10 MHz, Detection of incipient fault by Frequency Response Analysis (SFRA) using practical data from transformer in service.

- The basic of Sweep Frequency Response Analysis (SFRA) as a tool that can give an indication of core or winding movement in transformers. Changes in frequency response as measured by SFRA techniques indicate a physical change inside the transformer, the cause of which then needs to be identified and investigated.

- Interpretation of SFRA responses based on the Transformer circuit Modeling to accurately represent the behavior of a transformer across the wide range of frequency. Model circuit parameters for SFRA have been developed in several frequency regions and the dominant components in each frequency region is defined.

- Comparison of sfra plot for sister unit with full and partially filled oil, Variation due to residual moisture of winding, Variation due to residual magnetism of the core and Effect of electrical interference on the SFRA plot is discussed.

- Classification of faults based on the practical experience with SFRA analysis in the frequency range from $10Hz$ to $2MHz$ is sufficient for the analysis and divided into three frequency band. These frequency band are governed separately by the inductive effect of core , self and mutual inductance of the winding, series and shunt capacitance of the overall winding structures and the lead/tap connections.

- The expert system design based on ANN and Feed forward neural networks which can detect the multiple faults and incipient mechanical and electrical fault of transformer.

The objective of this chapter is to highlight the main findings of the work carried out in this thesis and provide suggestions for further research work in this area. Some of the main findings are given below.

9.2 Summary of Important Findings

The main primary fault-modes that can be detected from SFRA are:

- Axial displacement
- Displacement of the complete winding and core.
- Shorted turns
- Damage to the core insulation
- Radial deformation (Buckling)
- High impedance winding fault

In this thesis, a detailed study on application of SFRA for various fault detection in transformer is carried out and seems promising because it is able to detect mechanical deformation, electrical fault in core and in transformer windings. Hence, it can be used as part of a routine condition assessment program very well. Alternatively, SFRA may be used to make decision about the condition of transformer, if a transformer is suspected of being damaged.

However, the ability to interpret such differences when comparing the SFRA responses is of a great challenge and then expertise to further analysis of the plot for classification of fault is very limited today for the users who are not very familiar with SFRA and need experts for the conclusions and findings . Hence, the expert system based tools to assist in the analysis of SFRA results is developed in this project .

Hence, based on practical experience of years, in SFRA analysis of the field data, Artificial Neural Network (ANN) has been designed and applied to provide the means to comparatively analyze SFRA plots in the three frequency sub-bands for various type of Transformer fault and classify the fault.

The results show that the algorithm is capable of distinguishing between normal and failed state quite satisfactorily and thus successfully establish the efficacy of the proposed method. Therefore, for modern transformer windings with hidden deformation, the ANN aided SFRA method would be more effective. The method is simple and easy to implement as described for different fault.

9.3 Scope for Further Research

Consequent to investigations carried out in this thesis, the following aspects are being suggested as future research work to be carried out.

(i) Interpretation of SFRA responses is crucial in order to assess the integrity of transformer windings. In order to achieve the correct interpretation of SFRA response, the effect of various circuit parameter of transformer winding on SFRA plot is studied in detail and discussed in this project. However, The major factor that influenced the SFRA responses, the winding structure itself in low, medium and high frequency region can be studied in detail by the circuit modelling of the transformer winding.

(ii) By developing such model circuit, it will be possible to analyse the SFRA plot for predicting the location of deformation in a particular winding of transformer, if deformation is partial.

(iii) Aduptive resonance Theory based self learning Neural Network can be derived to predict the faults by pattern recognision technique.