CHAPTER 6

SUMMARY AND CONCLUSIONS

The Thesis deals mainly with identification and location of faults within a transformer winding. The study begins with experimental investigations of the response of a uniform layer winding to a standard lightning impulse. General high frequency modeling is performed for the two winding transformer. Self inductances and mutual inductances between different sections are computed from the first principles laid down for the modeling. An appropriate ten section model is developed. The resonant frequencies are found by conducting experiments by frequency sweep on the transformer. SPICE simulated lightning impulse is applied to the simulated two winding transformer and the resonant frequencies are obtained. Resonant frequencies were also found by actually conducting lighting impulse test on the two winding transformer with the impulse generator. Lightning impulse test are conducted on the above transformer for four different types of connections on the secondary. The waveforms of winding current and their Fourier transforms are found.

The chopped lightning impulse was applied to various sections of primary winding such as full, 50%, 25% and 10%. The waveforms obtained at the secondary as transferred surge were shown.

Objective definitions of seven possible types of faults were presented.
While conventional fault identification involved time domain analysis methods, frequency domain analysis throws better insight into the phenomenon. Fault location problems are shown to be more amenable to analysis in the frequency domain.

It was shown that frequency response analysis in conjunction with time domain responses could help to locate faults. Simulated experiments were conducted on transformer by introducing faults across the sections by connecting different values of resistances and nonlinear elements.

A new procedure based on a model reference approach is proposed in order to evaluate the frequency response with intermittent type of faults. This method also helps to improve the recognition of complex faults. In establishing fault identification location, the distinction between a discharge and a breakdown was clarified. Smallest deviation in response will indicate the resolution. The procedure suggested here also provides a measure of the smallest recognizable fault.

It was seen from simulation that the frequency changes resulting from faults are dependent on the magnitude of resistances across faults. A method based on clustering of resonant frequencies is proposed for fault identification. A centroid of the changes in each resonant frequency is obtained and the method involves the comparison of the fault vector with that of cluster location. An improved clustering method is proposed in which faulted vector includes the current components along with centroids of resonant frequencies.
Another method for location of PD in time domain is also proposed. In this method the PD signal is injected across different sections of the primary of two winding transformer and the following responses are obtained:

1. Current through secondary
2. Voltage at secondary
3. Voltage across measuring impedance

To locate the fault in the winding, matched filter approach was proposed. The input signal and previous impulse responses are correlated. The outputs obtained are compared. The maximum value of the outputs indicates the location of faults.

Based on the study conducted the following conclusions are drawn:

- Lumped parameter networks can be used to estimate the response of a winding to a standard lightning impulse. The response could be the winding current, the transferred surge to the secondary winding or a capacitively transferred current.

- Experimental studies on a two winding transformer were conducted to validate the utility of lumped parameter networks.

- Experimental investigations were performed on a two winding transformer to study the responses to a chopped lightning impulse. In addition to the response of the winding as a whole, energisation was also done across sections of the primary. This paved the way for identification of faults involving ground.
It is observed that the shapes of output voltage waveform obtained through chopped lightning impulse test were different for different sections. The results served to validate the use of lumped parameter models for the study of responses to lightning impulses and chopped lightning impulse tests.

Validation of the model was performed in time domain as well as frequency domain. Frequency domain validation was done on the basis of a comparison of the simulated resonant frequencies of the winding with experimentally observed values.

Objective criteria were developed for the distinction of a non self restoring type of break down as compared with a partial discharge or the presence of a non linear element within the winding.

The classification of faults led to methods of fault location.

The fault model considered was very general in nature with faults having unknown resistances. The fault could also be initiated after arbitrary time delay from the time of application of the impulse.

The model reference approach was proposed for the identification of changes in resonant frequencies for the above cases.

The model of the winding used in the model reference approach could be determined from the external measurement with no apriori information about the winding.
• The model could also be based on the lumped parameter network of the winding determined from the geometry of the winding.

• A frequency domain method was proposed to locate faults within the winding. The method catered to the inclusion of any resistance in the fault.

• By clustering the resonant frequencies for different fault resistances, the centroids were obtained. From the vector of centroids of resonant frequencies the fault is located by applying nearest neighborhood rule.

• The fault location method could be validated with test data without the need to the use of neural network based training data.

• In addition to frequency domain methods, a time domain solution for PD location within windings is proposed. It used a matched filter or correlation technique for PD location. The method was validated on a two winding transformer.