7.1 CONCLUDING REMARKS

One of the prime motivations for improved methods of failure identification is the need for eliminating subjectively associated visual comparison and speculation by test engineers. The analysis techniques discussed in the thesis use a synthesis of time, frequency and time-frequency technique for identification of the non-restoring faults and the partial discharge for the case of layer-windings. Efficiency of the three new signal processing performances namely the short time Fourier transform, wavelet transform and Wigner Ville distribution in detecting and analysing the winding failure is compared. These signal processing theories are initially described from the basic comparison principle used in the Fourier transform. The techniques lead to comparable time-frequency representation of analysed signals. Then representative examples of the insulation failure like a non-restoring short-circuit fault, internal discharge within windings, are computed by specific examples of each tool. Comparison of the results focuses on the application of the inherent specific properties of each technique in terms of winding failure analysis.

The discussions are reported based on observations from

- an experimental layer winding model.
- an analytical Abetti coil, RLC Lumped parameter model
The need for a noise-free data acquisition with high resolution during impulse testing is a major issue in test centers seeking improved instrumentation techniques. A virtual instrumentation is configured for data acquisition and post signal analysis using a 12-bit digitiser HP 1429B, with VEE soft codes as discussed in Appendix 3. The 12-bit digitiser offers improved signal to noise ratio than the 10-bit scope.

The results have been confirmed by analysis of test reports of many transformers reported in IEC-76 (1980) standards.

The following are the major contributions of the thesis:

- A new structure for data acquisition, using filters makes the recognition of discharge events explicit.
- The utility of the transfer function method has been extended to identify the conductance of a non-linear arrester within the winding.
- A virtual instrumentation is developed for computerised data acquisition and post signal analysis by configuring it to conduct impulse testing and frequency response analysis, applied to winding failure analysis.
- The application of Wavelet Transforms has been shown for time-frequency localisation of discharge signals.
- The optimal choice of the mother wavelet adopted for analysis is also discussed with results after a thorough perusal on various signals with suitable wavelet types.
- The magnitude and location of winding faults can be estimated using the new parameter estimation techniques namely the PVR, AVR, UCRP methods.
- The utility of the Wigner Ville Distributions is extended as a new and improved method for a simultaneous time-frequency identification and energy density estimation of faults and discharges.
- The frequency response analysis method using the sweep signals is proposed newly for confirming the location of winding fault.
- The entire analysis is summarised in the form of a flow chart that utilises time, frequency and time-frequency methods in conjunction.
The thesis presents improved methods for the following:

- Recognition of failure and distinction of the type of winding failure like the winding short-circuit and partial discharge,
- Locating the site of fault and its magnitude,
- Recognition of an surge arrester conduction in response to impulse signal, and
- Detecting the time instance of failure with a simultaneous time-frequency representation.

It is important to mention here that, there are failures that are better visible in the time-domain where others are better visible in the frequency domain. So, a reliable testing procedure would need both to make a final conclusion. The utilities of the time-frequency analysis techniques precisely cater to this requirement.

The time – frequency localisation of the failure could be useful for studies related to the analysis on breakdown strength of the winding insulation. The ability to perceive events in time domain, frequency domain, and time-frequency domains ensures a significant improvement over subjective assessment methods that are largely followed even to this day.

As far as the manufacturers are concerned, the techniques proposed in the thesis would provide improved and reliable methods of detection and location of transformer winding faults during impulse testing.
7.2 FUTURE SCOPES

The time, frequency and time-frequency analyses of signals have been elaborated in this thesis based on the analyses of impulse test reports of many transformers.

The identification of location and magnitude of failure for layer-winding transformers could be extended to other types of transformers with interleaved -winding and other non-uniform winding.

There is scope for increasing the range of validity in the frequency domain of the transfer function method by considering the evaluations with the capacitive current, or from division of the neutral current by the capacitive current of the testing winding.

The recognition of multiple defects that commonly occur with partial discharges leading to intricate discharge patterns is difficult to analyse. This could be because of the difficulty in distinguishing between two or more sources of the same type of discharges or because of two or more sources of different types of discharges. Further work can be extended to quantify the sources of pd and their distribution.

The digital instrumentation proposed in the thesis can be made for complete utility if the computerised measurement and analysis are made online and interactive to the user.