Chapter - 9

GENERAL CONCLUSION & SUGGESTION
FOR FUTURE WORK
9.1 General Conclusion:

The modelling of magnetisation characteristic of transformer has been extensively studied in the present thesis. In addition, the method of modelling a single phase transformer by magnetising branch has been extended for determination of third harmonic flux linkage on the secondary side of a \( \gamma/\Delta \) transformer bank.

The magnetisation characteristic of a transformer with negligible core loss is modelled. A generalised technique has been developed to derive true saturation characteristic in piece wise linearised segments. The suggested method to derive the I.C. is accurate over any extended range, including every high voltage in the saturated air region.

The accuracy of the method has been improved by optimising the number of segments representing the I.C. over desired range, thus the computer added method for deriving I.C. with optimal number of segments from the r.m.s. saturation data yields an optimal true saturation characteristic with prescribed degree of accuracy. A new concept of r.m.s. error has been introduced in this thesis for deriving magnetisation and hysteresis loss characteristic of transformers. Moreover the method of computation of I.C. does not involve any trial and error procedure where as earlier method (1) involves cut and try.

The true saturation characteristic has also been represented by a two term fifth degree polynomial and it is shown that it can be predetermined using r.m.s. data available from the manufacturer. The method suggested are (i) two point
method (ii) unweighted method of least squares (iii) weighted method of least squares. The two points method is suitable and the computation for modelling would be simple and quick. Methods suggested for predetermination of I.C. using a polynomial has also been applied to evaluate the resultant true saturation characteristic of two reactors connected in series or parallel. It has also been found that the true saturation characteristic of individual reactors need only be available in one form, namely \( i = f(\lambda) \) and \( \lambda = f(i) \).

A procedure is developed for quantitative determination of third harmonic flux linkage and consequent over voltage magnitude on secondary side of \( \gamma/\Delta \) transformer bank under certain internal fault conditions. The computed results validated by experiment establish the existence of over voltage phenomenon so that the over voltage problem hither to unknown can be considered by distribution engineers in future to make necessary provision for proper co-ordination of protective device. Finally it is adequate to model the transformer saturation characteristic by a single valued non-linear inductance, neglecting the hysteresis phenomenon. However for improved accuracy it is desirable to include hysteresis phenomenon. In this thesis, the magnetisation characteristic of transformer including hysteresis have been presented in analytical form containing two polynomial expressions, one polynomial expressing representing the true saturation part and other representing the loss part of magnetisation characteristic.

Each of the polynomial expressions has been found with two terms only. The data of r.m.s. voltage versus magnetising component of no load current are useful to evaluate the coefficients of polynomial expressing representing the true
saturation part of the magnetising characteristic. Modelling of transformer including hysteresis is desirable in transient stimulation studies such as in rush current drawn by transformer possessing a residual flux when it is energised, the determining of residual flux remaining in transformer when it is deenergized and examination of ferro-resonance phenomena. For the purpose, the modelling of hysteresis loop has been presented in the existing literature [3,4,10,44,46,55,67] either by a differential equation or some mathematical expressing on fourier series or rational function approximation. All the suggested method requires experimental hysteresis loops to determine the analytic form of magnetisation characteristic.

The expressions suggested in this thesis for describing hysteresis loop also exhibit the hysteric property of increasing loop area with increase of frequency of operation and vice-versa.

The expression describing the hysteresis loop under various approximations of loss part have been used to derive the corresponding expressions for hysteresis energy loss.

All the expressing for hysteresis loop and energy loss derived with different approximations are found to yield accurate result when compared to the experimental observations. The method suggested in this thesis are found to be quite accurate and it is believed that the technique will be much useful in modelling magnetisation characteristic of transformers for study of behaviour in power system networks.

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q.2 Suggestions for future work:

Any future extension of the work embodied in the present thesis may include various features.

a. Multivalued modelling having major and minor loops of magnetisation extending the methods suggested for modelling transformer including hysteresis with the help of fourier/polynomial expression.

b. Extension of the modelling equation for the magnetisation curve including the hysteresis for analysis of transient over voltage generated due to presence of transformer.

c. A sensitivity analysis for coefficients of the polynomial and their effect on transient phenomena.

d. Inclusion of three terms polynomial expression for modelling the given transformer.

e. Explanation of inrush current phenomenon with the help of modelling approach suggested.

f. The effect of residual flux on time response behaviour of transformer can be modelled properly by modelling the hysteresis loop.

g. Modelling of transformer core for three phase ferro - resonance circuits is necessary for practical application is owner system electrical network.

h. An analytical computer based, method is needed for modelling of various transformer core losses.