

Simple and Robust Equivalent Circuit of Real Transformer for Harmonic Excitation

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Abstract In the case of harmonic excitation the ferromagnetic material can be described by a set of experimental waveforms from the small system of exciting voltages. If important harmonics of waveforms are used, the response for any excitation can be calculated with a high accuracy. The equivalent circuit can be derived from important harmonics of current spectrum. In the case of transformer arbitrary excitation more sophisticated equivalent circuit is necessary.

Keywords Ferromagnetic core, core loss, hysteresis loop, Fourier series, waveform frequency dependence.

I. INTRODUCTION

Irrespective of massive circuit integration, transformers become important parts of the electrical circuits. Modern core materials have low loss. Since the core exhibits nonlinearity and hysteresis, this economical effect, on the other hand, increase the number and amplitude of harmonics, which can lead to problems with electromagnetic compatibility. Therefore exact and robust analysis of designed transformer is necessary. Because of material non-linearity the task is difficult, in general both experimentally and theoretically. One possible solution based on simple equivalent circuit is the subject of the paper.

II. EQUIVALENT CIRCUIT

The harmonic voltage excitation of a transformer produces a current waveform, typical shape of which is shown in Fig. 1. According to Fourier series theory, the current waveform is a superposition of harmonic components. The most important harmonics can be used for waveform approximation [1]. If a systematic set of waveforms with increasing excitation is available, an arbitrary waveform can be predicted with a high accuracy [1], as it follows from Fig. 1. The curves are shifted in order to see details.

The equivalent circuit model in Fig. 2 is based on the same idea. The harmonics sources of frequencies $\omega_0, 2\omega_0, 3\omega_0, \dots, n\omega_0$ and of the same voltage U_0 and zero phase constant have inner impedance \hat{Z}_i derived for complex spectral amplitudes. The current in the load of impedance \hat{Z}_L is the sum of harmonic currents. Inner impedance \hat{Z}_i depends on both the exciting voltage and its frequency.

For the case of transformer harmonic excitation we can study the effect of amplitude of applied voltage for different loads. Unfortunately, it cannot be applied for the case of complicated excitation, since the superposition principle is not valid. As in this case the harmonic waveforms depend of bias current, more sophisticated equivalent circuit containing parametric impedances controlled by the applied voltage must be used.

III. CONCLUSION

General use of equivalent circuit needs measurement of current waveforms at different excitation and frequencies.

As soon as the complex measurements are made and saved in a data file, the computational transformer analysis at different conditions is possible. It can be applied approximately for excitation with low harmonics. All the losses, with an exception of winding ones, are included in the model

Often the hysteresis loop approach, based on Preisach model, is applied. Main problem, in this case, is to determine the model parameters in order the model can be used quite generally.

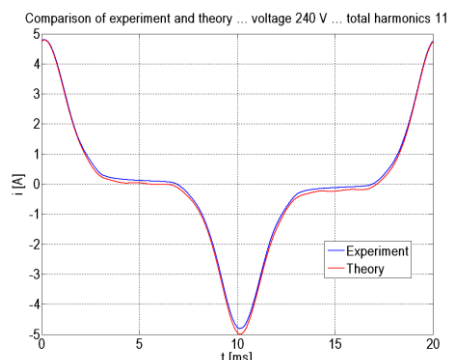


Fig. 1. Comparison of theory and experiment

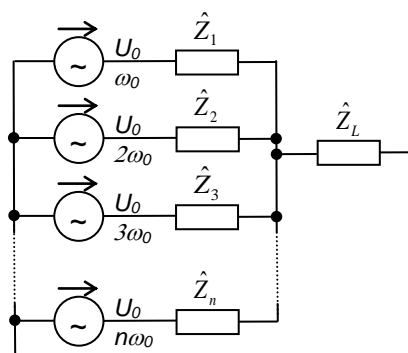


Fig. 2. Equivalent circuit based on harmonics.

IV. REFERENCES

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