Power Transformer No Load Loss Optimization considering Manufacturing Process Effects

Th. D. Kefalas[1], M. A. Tsili[1], A. G. Kladas[1], P. S. Georgilakis[2], A. T. Souflaris[3] and D. G. Paparigas[3]

[1] School of Electrical & Computer Engineering, National Technical University of Athens, kladasel@central.ntua.gr

[2] Department of Production Engineering & Management, Technical University of Crete

[3] Schneider Electric AE, Elvim Plant, GR-32011, Inofyta, Viotia, Greece

Abstract— Transformer no load loss optimization is crucial for transformer manufacturers as well as for electric utilities, since it results to significant economic benefits. In this article, the three-dimensional finite element analysis is applied to power transformers in order to predict and minimize the iron loss. The proposed model is based on a particular reduced scalar potential formulation, necessitating no prior source field calculation, and employs detailed modeling of the core geometry and material, considering for manufacturing core formation process effects by convenient hysteresis phenomenological models. Comparisons between this method and test values for a number of commercial transformers, prove its validity and accuracy, rendering it a reliable tool for customized design of an industrial plant.

I. Proposed Transformer Finite Element Model

The proposed finite element method is based on a particular scalar potential formulation, enabling the 3D magnetostatic field analysis, necessitating no prior source field calculation by using Biot-Savart's law [1].

The considered transformer is a three-phase, wound core, shell type distribution transformer as shown in Fig. 1.

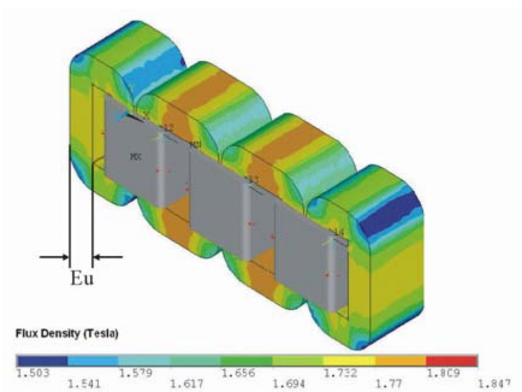

Fig. 1. Magnetic induction distribution under open-circuit test, for the considered wound core power transformer.

For the calculation of no load loss, the transformer's magnetic field during open-circuit test must be evaluated. In the case of open-circuit test, the magnetic flux mainly traverses the cores area, therefore, the detailed representation of this area in the finite element model is crucial for the accuracy of the results. Moreover, the microscopical characteristics of iron laminations are represented by phenomenological models including grain orientation effects [2] as well as specific manufacturing procedures impact on hysteresis macroscopical characteristics. The three-phase representation was chosen instead of an equivalent one-phase model, in order to take into account the asymmetry caused by manufacturing processes in the two external core parts.

II. Results And Discussion

Fig. 1 illustrates the magnetic induction magnitude distribution along open-circuit test, as it was calculated with the use of a dense mesh and the adoption of a tensor magnetization. Fig. 1 confirms local flux distribution changes due to manufacturing process effects. The core loss value computed with the use of the finite element model of a 400 kVA, 20-15/0.4 kV transformer was compared to the value measured after the transformer construction, during the quality control procedure. However, the variation of the error with the number of nodes is not significant, and the deviation becomes practically stable at an intermediate mesh density. Fig. 2 illustrates the variation of the composite objective function of the transformer manufacturing and operating cost with respect the core width Eu (shown in Fig. 1) and the transformer short circuit impedance Uk. In order to perform a sensitivity analysis of the impact of the mesh density in the accuracy of the no load loss evaluation, various mesh densities were employed, consisting up to 30,000 nodes, approximately, involving an underestimation which reaches the value of 1%.

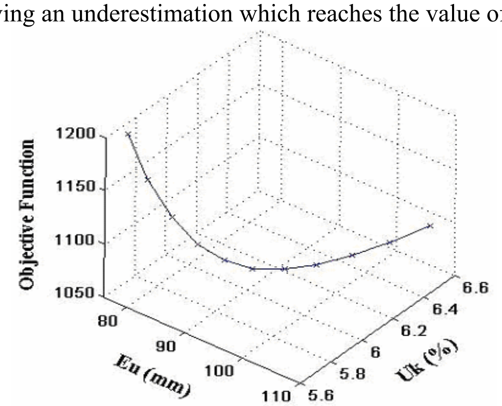

Fig. 2. Objective function variation with respect the core width Eu and the transformer short circuit impedance Uk.

III. References

[1] A. Kladas, J. Tegopoulos, "A new scalar potential formulation for 3D magnetostatics necessitating no source field calculation", IEEE Transactions on Magnetics, vol. 28, pp. 1103-1106, 1992.

[2] M. Enokizono, N. Soda, "Finite element analysis of transformer model core with measured reluctivity tensor," IEEE Transactions on Magnetics, vol. 33, No 5, pp. 4110-4112, 1997.

[3] F. Ossart, E. Hug, O. Hubert, C. Buvat, R. Bilardon "Effect of Punching on Electrical Steels: Experimental and Numerical Coupled Analysis", IEEE Trans. on Magnetics, vol. MAG-36, No.5, pp.31347-3140, 2000.