Electromagnetic Characterization of structural steel used in construction of large Power transformers

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This research improves the stray loss estimation in large power transformers by investigating the magnetic and electrical properties of structural steel used in the core clamping, pressure plates, and the tank wall. A set of sensitivity analysis is conducted to evaluate the sensitivity of stray loss on the steels' electric conductivity, and magnetic permeability. Next, the non-linear B-H behaviour of structural steel is measured using AC induction and DC permeameter measurement method. The equivalent linear permeability is extracted using the measured non-linear B-H curve and interpolating the simulation results.

Keywords: Large Power Transformers; Stray Loss; Mild Steel; Permeability.

1. Introduction

The stray losses in transformers are the component of total load loss and are produced by the leakage flux interacting with the windings, tank, core, core clamping plates, and magnetic shields, etc. They can account for 20-50% of power transformers load losses, and they significantly impacts the efficiency of transformers. Traditional methods of estimating these losses often rely on empirical formulas and simplified models that may not account for the complex interactions within the transformer's windings, core, and structural components. Alternatively, numerical models, such as 3D finite element analysis (FEA), can be used to improve the accuracy of estimations. However, these approaches result in extreme computational expenses. Significant research has been done to reduce the computational costs associated with this modelling technique, i.e. use of 3D reluctance network **[2]**, surface impedance boundary **[3]**, hybrid 2D/3D finite element (FE) **[4]**, and combined FE/analytical **[5]** methods. However, in addition to the accuracy of computations' technique, the assigned materials' magnetic and electrical properties has significant impact on the accuracy of loss estimations. Since the mild steel used in power transformers construction is predominantly manufactured for the purpose of being applied on the structural applications, their magnetic and electrical properties are merely determined based on informal approximations and could not be considered as precise. This research aims to improve the estimation of stray losses by focusing on the magnetic and electrical properties of lossy components, i.e. structural steel used in the construction of core clamping, pressure plates, and tank walls. By conducting a comprehensive sensitivity analysis, the study evaluates the impact of electric conductivity and magnetic permeability of these steels on stray losses. Furthermore, the non-linear B-H behavior of structural steel is measured using both AC induction and DC permeameter methods. The equivalent linear permeability is then derived from the measured non-linear B-H curves through interpolation of simulation results. This approach provides a more accurate and detailed understanding of the factors influencing stray losses, facilitating the development of more efficient transformer designs.

2. Results and discussion

To quantify the influence of the materials' electric conductivity and magnetic permeability on the estimated stray losses, a sensitivity analysis has been conducted on a 600 MVA large power transformer, designed, manufactured, and tested by **Royal SMIT Transformers**. The sensitivity of componential and total stray loss on these properties are determined. The results are presented in Figure 1.

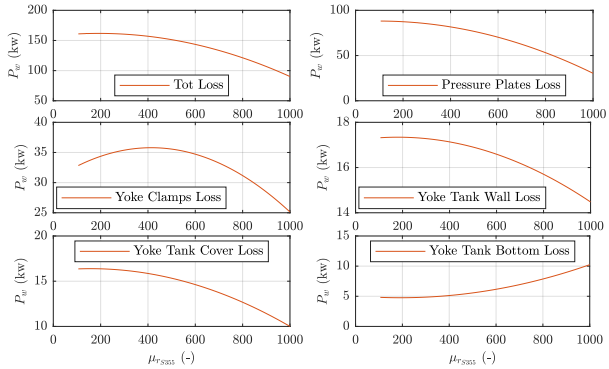

Figure 1: Sensitivity analysis results: influence of magnetic permeability of S355 steel used in the structural parts on the componential and total stray loss of the transformer under study.

The analysis results demonstrate a minimal influence of the materials electrical conductivity and a high influence of the magnetic permeability of mild steel on the stray loss component. Therefore, a set of DC permeameter and AC induction measurements are planned to be conducted in order to determine the magnetic behaviour of mild steel used in the structural parts of the transformer under study. The in-depth measurement results and the conclusive outcomes of this research will be presented during SMM 27.

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