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REDUCTION of STRAY LOSS COMPONENT of POWER TRANSFORMER in ANSYS MAXWELL to OPTIMIZE the LOAD LOSS by USING DIFFERENT MAGNETIC MATERIALS

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Abstract: This Research paper contemplates the leakage flux and stray loss component, especially in the tank walls of the power transformer. For large power transformers, the location and concentration of stray parts had been developed by numerical calculations. A realistic and logical approach has been taken for the reduction of the stray loss in tank walls in Ansys Maxwell 3-D FEM. In this paper different ideologies of the minimization of stay loss of transformer especially in the tank walls have been taken into consideration This reduction technique includes different magnetic materials by considering the economic factors for the optimization of the load loss.

Keywords: Stray loss, tank walls, Shielding, Aluminium.

I. INTRODUCTION

The last couple of decades have seen variations of research orientation towards the implementation of advanced computational methods to estimate and control stray losses. The electromagnetic phenomena in the metal parts in power transformer is an important step in design process to control overheating. Designers should be aware of the difference between the actual (measured) and specified transformer short-circuit impedance values, as well as the limitations imposed by international standards [2]. In some cases, design modifications should be made in order to meet the specifications for a particular type of transformer. Stray load loss in large ratings of generator transformers and autotransformers can be appreciably high. The authors [3] treated this problem by $T - \Omega$ v method taking into account the loss in the yoke clamp plates. The surface impedance boundary condition (SIBC) is based on reduced scalar magnetic potential employed in [4] and [5]. There is an urgent need for a transformer manufacturing industry to improve efficiency and reduce cost, since high-quality low-cost products are the key to survival [6, 7]. To analyse the leakage magnetic flux and stray losses 3-D finite element-based package [8] is used. Numerical field analysis and algorithms for the design optimization of magnetostatic devices are widely encountered in the technical literature. In reference [9], for the sensitivity analysis of three-dimensional (3D) magnetostatic problems direct differentiation of finite element (FE) matrices is used. While in Ref. [10] the FE formulation is used for calculation of global quantities to obtain optimised methods. In Refs. [11, 12] the authors use the finite element method (FEM) for the shape optimization of a BLDC motor and a linear actuator. The boundary element method (BEM) is used in Refs. [13, 14], where the authors carry out the design optimization of magnetostatic devices through boundary integration formulas. A method based on a particular FEM-BEM hybrid formulation has been developed in [15]. This method is extended involving the shape optimization of power transformer magnetic shunts. It involves an algorithm that reduces the total time needed for the magnetic field calculation by more than 50%. In cases if difference between the actual (measured) and specified values do not satisfy the limitations [16], then design modifications should be implemented. The impact of magnetic shielding on the transformer electric shield will be examined by the three-dimensional finite element boundary element method (FEM-BEM) in Ref. [17]. An experimental study of this kind of shielding is also carried out in [18], while in [19, 20], the transformer tank shield geometry is optimized with the use of 2D FEM.

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II. COMPLETE MODEL OF TRANSFORMER ALONG WITH TANK

- For the analysis of stray loss in the tank, we have developed the full model of a 15MVA, 66/11 KV power transformer.

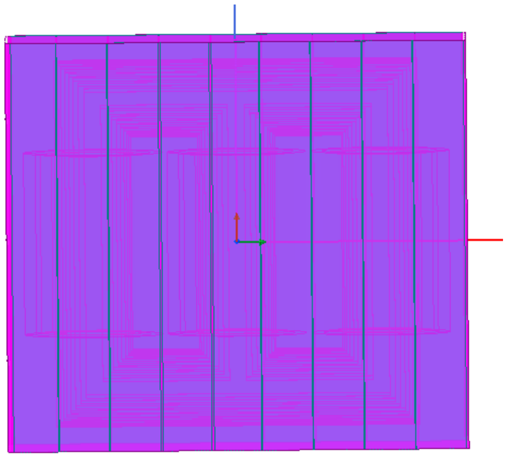

Figure 1: Construction of the Tank

Dimensions	Unit
Height	2769 mm
Width	2464mm
Length	1050mm

Table 1: Dimension of Tank

A. Analysis of Stray Loss & Leakage Flux

- Figure 1 shows the complete model of the tank. The tank is made up of mild steel material.
- Insulation between tank and winding is 170mm. Analysis of Flux Density in the Tank Wall & Flux Density in the Tank Wall of Power Transformer.

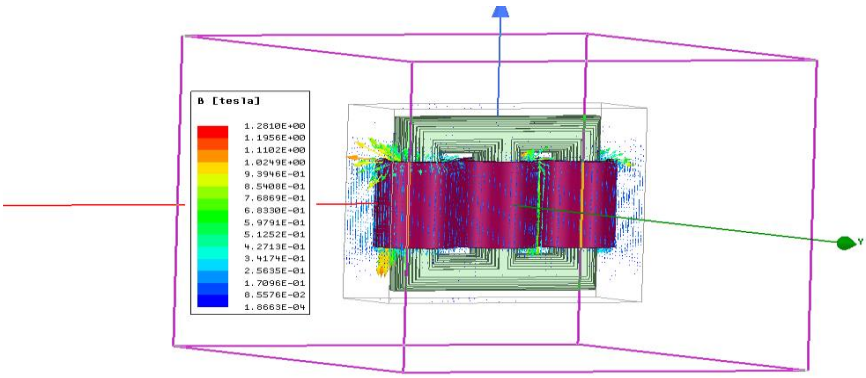

Figure 2: Flux Distribution of the Tank Walls of a Transformer

- Figure 2 shows the flux density distribution in the tank of the transformer. There is the leakage of fields which give rise to the losses in the tank wall. This loss is called stray loss.

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- It can be observed that side walls face more flux density compared to the top and bottom walls. Due to the high intensity of flux in some areas hot spots will be generated leading to the deterioration of the oil of the transformer.
- As a result we need to refine the oil more frequently and hence maintenance cost increases. Also, the life of the transformer decreases.
- Figure 2 also shows how the flux lines get linked to the transformer tank. This is the leakage flux and it gives rise to the losses called stray loss. It can be seen clearly that more lines get linked to the side walls. The flux density in the tank is observed to be nearly 1.28 T.
- The above Figure 2 shows the losses taking place in the tank. Due to the leakage flux as observed in the above figure losses takes place in the tank wall of the transformer. The stray loss in the tank of the transformer is 3409 W/m3 which comes out to be 8.522KW.

  Calculated value:

- Total Stray loss = 30% of ohmic loss = 17.325 KW Stray loss in tank walls is nearly 49 – 50% of total stray loss i.e. nearly 8.9 KW.

B. Total Loss of the Transformer

- The previous figure shows the total loss of the 15MVA, 66/11KV power transformer. The total loss comes out to be 1.7426*10^4 W/m3, therefore the total loss is 83.296KW.

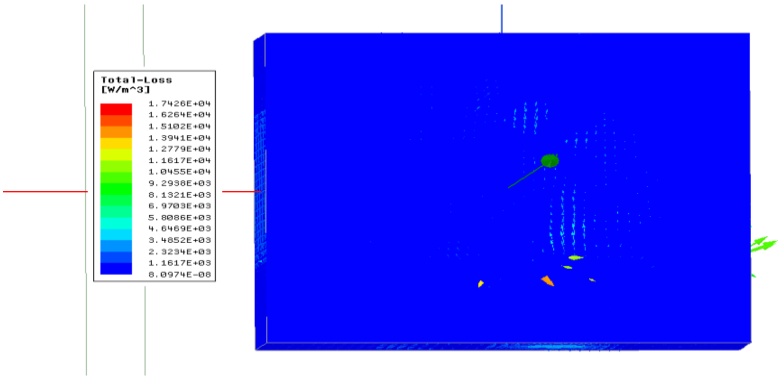

Figure 3: Total Loss Plot for the Transformer

C. Ideology behind the Reduction of Stray Loss Component

- Use of small dimensioned conductors for windings
- magnetic shielding of inner tank walls
- magnetic shielding of inner tank walls
- Use of non-magnetic materials in a strong magnetic field
- Optimal transposition of parallel plate strands.

III. IMPLEMENTATION OF STRAY LOSS REDUCTION TECHNIQUE

- Shielding of non-magnetic material and high conductivity is done in order to reduce the stray loss in the tank wall. Material such as aluminum, copper, and CRNGO can be used. The thickness of the material is an important parameter to be kept in mind while shielding. Different materials have different skin depths. Skin depth or depth of penetration of any material is given as,

$$\delta = \sqrt{2}/\sqrt{\omega\sigma\mu\mu r}$$

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Where, ω= angular frequency (rad/s)
σ = Conductivity (s/m)
μ= permeability of free space
μr= relative permeability

A. Skin Depth:

Materials	Unit
Aluminum	11.5mm
Copper	2.04mm
CRNGO	1.362mm

Table 2: Skin Depth of the Material Used for Shielding

B. Analysis of Tank Loss After Shielding

- Aluminum – 15 mm Thickness

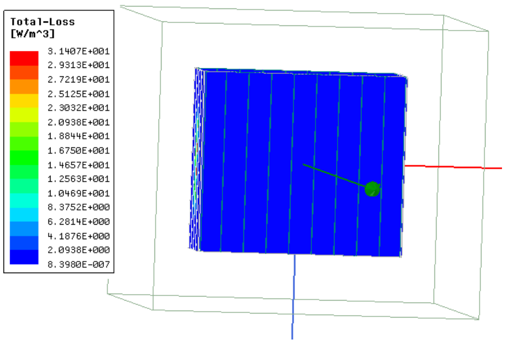

Figure 4: Using 15 mm of Lamination of Aluminium

- Copper – 10mm Thickness

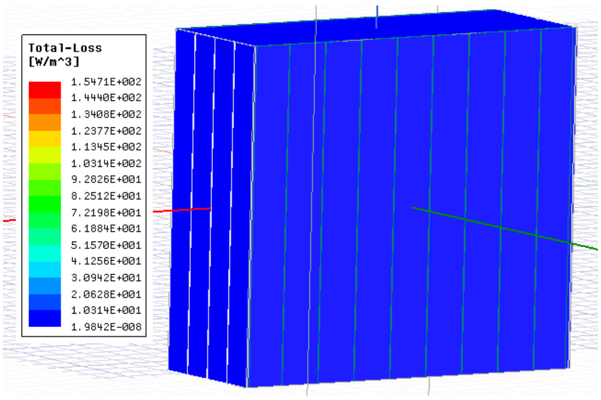

Figure 5: Using 10 mm of Lamination of Copper

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- CRNGO – 10mm Thickness

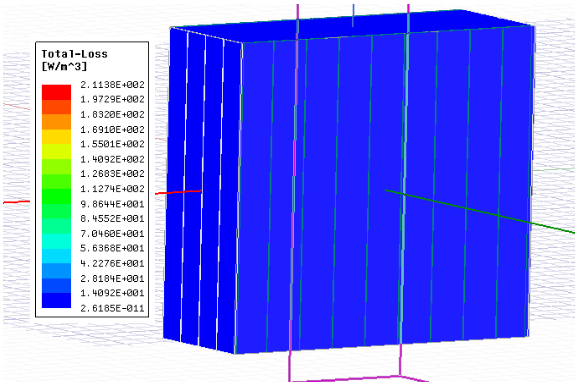

Figure 6: Using 10 mm of Lamination of CRNGO

C. Comparison of the Results Before and After Shielding:

Materials	Before	After	Reduction %
Aluminum	8900W	78W	99.1%
Copper	8900W	385 W	95.6%
CRNGO	8900W	528W	94.06%

III.CONCLUSION

The main aim of this paper is to give guidelines for loss reduction measures in the transformer tank. Design of 15 MVA, 66/11 KV power transformer is done using 3-D FEM and 2-D FEM. The transformer is simulated using Maxwell 19.0. Various losses such as core loss, ohmic loss, and stray losses are analyzed. Although 3-D design gives more accurate results its simulation time is very high and it requires high-speed computers for such analysis.

More flux lines link to the sidewall of the tank rather than the top and bottom walls so the shielding of only sidewalls can be done to reduce the loss. An electromagnetic shield prevents the penetration of leakage flux into the tank. By using the concept of shielding the required skin depth of material has been determined. After doing the aluminum shielding of 15mm the stray loss component is reduced by 99.1%. And also by using copper and CRNGO shielding of 10 mm thickness, the stray loss component has been reduced to 95.6% & 94.06% respectively. Results show that stray loss can be considerably reduced by shields of most of the material, but by considering the economic factor Aluminium is far the best material to reduce the stray loss in tank walls in the transformer.

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