Air Core Reactor Analysis Based on RNM Method

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Abstract—**This paper aims to present a 3D Reluctance Network Method (RNM) to compute the leakage field in air core reactors, which has an important function on large power transformers operation. The well known RNM basis are presented with the goal of making easier the understanding of the 3D geometry discretization into reluctances. Thus the power reactor is presented as well as its 3D RNM model. The results obtained through this methodology are compared with those obtained with a 3D FEM commercial package.**

Index Terms — Reluctance Network Method, Finite Element Method, Power Reactors, Power Transformers

I. INTRODUCTION

Considering the electromagnetic analysis on power transformer and reactors, it is possible to apply symmetries and perform 2D (two dimensional) simulation in some cases. One well established analysis is to model the leakage flux pattern along the core window, through a 2D magnetostatic simulation [1]. However, the air core reactor studied here does not have 2D symmetry, so a three dimensional (3D) modeling is mandatory. In order to evaluate its electrical and mechanical design, it is important to compute the magnetic induction along the whole reactor domain. Such analysis has a crucial importance, once this reactor is connected to the tertiary transformer windings, in order to limit the short circuit currents. So, this reactor is submitted to short circuit duty and must withstand it, because the reactor failure implies the transformer failure. Commonly, the Finite Element Method (FEM) is applied for this purpose, but it is well known that this method may require some large amount of computation time, what makes this method very difficult to apply daily, during the transformer design lead time. Thus, a 3D RNM is proposed here to model the reactor. The RNM has been used successfully for many years for core type power transformer [1]-[2]-[3], shell type power transformer [4]-[5]-[6] and electrical machines [7]-[8] analysis. Nevertheless few papers deal with the air core reactor.

II. RNM BASIS

The RNM is based on Ohm`s laws for magnetics circuits, through a geometric discretization of the electromagnetic device into lumped parameters circuit [2][3].

The reluctances are obtained from the classical magnetic flux tubes theory and those used principally for this work are depicted in Fig. 1 a) and b). Their respective reluctance are presented in equations (1) and (2)[9].
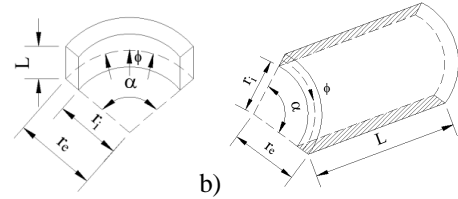

Fig. 1. a)Tube sector with radial flux b) Tube sector with circular flux

$$\Re = \frac{\ln\left(r_e / r_i\right)}{\mu \, L\alpha} \tag{1}$$

$$\Re = \frac{\alpha}{\mu \, L\ln\left(r_e / r_i\right)} \tag{2}$$

The Magneto motive forces are obtained considering the Ampère-Turns of the windings, according to their flux direction.

Solving the linear system, the scalar magnetic potential is obtained for each node. So, it is possible to compute the fields applying (3).

$$\mathbf{H} = -\nabla\theta \tag{3}$$

Where $\mathbf{H}$ is the magnetic field vector and θ is scalar magnetic potential.

III. 3D REACTOR ANALYSIS

Moving toward to the before mentioned realistic problem, the 1420kVAr/15kV air core reactor presented in Fig.3 is modeled.

Fig. 2. Studied Air reactor

From the magnetic field vector streamlines presented in Fig.3, it is possible to verify the air core reactor is a true 3D electromagnetic structure, hence it is not possible to have a good approach through 2D modeling. Due to the large amount of leakage fluxes compared to electromagnetic

devices having magnetic core, the discretization is not easy to implement.
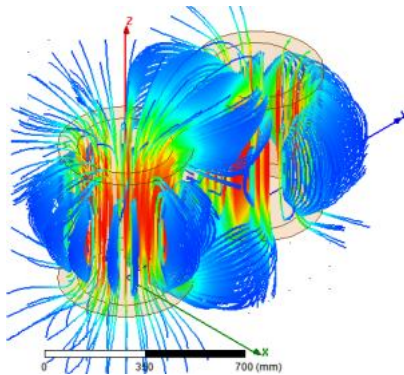

Fig. 3. Magnetic field streamlines

Analysing the above streamlines arrangement, it is possible to deduce the magnetic reluctances in some configuration that represent those flux paths, i.e. the flux tubes. Due to its complexity, the construction of the equivalent magnetic circuit is perfomed in two steps: 1) generation of the 2D circuit for one layer and 2) connection of each layer to its subsequent, with the vertical reluctances. The reluctances inside the domain are obtained considering the air magnetic permeabilty. However, those located externally, are calculated considering the low carbon iron magnetic characteristics. As the result, the magnetic circuit consists of about 9100 reluctances and 3100 nodes. Fig. 4 illustrates half of the implemented circuit.
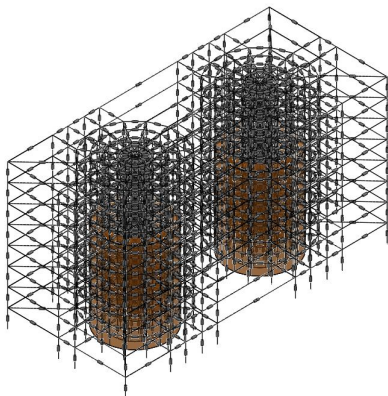

Fig. 4. RNM lumped circuit

Then using the magnetostatic formulation, the magnetic induction normal to a plane, symmetrically placed between the two windings is calculated. The results are presented in Fig. 5, where a) shows the RNM results, which means the magnetic induction into those reluctances placed between the windings and b) presents the results obtained using a FEM commercial package 0. As above mentioned, the main application of this work is to analyze the electrical and mechanical designs of the air core reactor. For this purpose, the attractive force between the windings calculated with RNM is 23.7kN and with FEM is 29.7kN. Methodology used to determine this force and that between the windings and tank wall will be more deeply examined on the extended version of this paper.
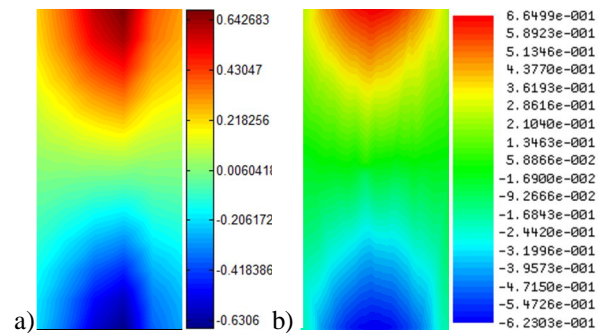

Fig. 5. Magnetic Induction (T) - a) RNM results b) FEM results

IV. CONCLUSION

The 3D RNM reactor model results are in accordance with those computed with 3D FEM commercial package. However, this modeling suggests the need for a 3D mesh generator, in order to make easier the geometry discretization.

The computed results are consistent and, considering the low computation time in comparison with 3D FEM, the RNM method is considered a good first approach for fast electromagnetic simulations on air core power reactor which is very useful for its optimization process for example.

V. ACKNOWLEDGMENT

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