Novel Way of Computation of Magnetic Field in Transformer Window

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Abstract **The paper deals with a proposal of a novel computational method of magnetic field distribution in a transformer window. The method reduces demands on computational time and computer memory whereas it increases accuracy of the results. The principle of the method is described and discussed on a simple case of planar 2D arrangement.**

Keywords **transformer window, electromagnetic field computation.**

I. Introduction

The paper deals with a novel method of computing of magnetic field distribution in a transformer window.

When computing short-circuit parameters of a transformer, knowledge of the magnetic field distribution in the transformer window is an essential prerequisite. When a FEM-based method was employed without any geometrical simplification, each single wire would have to be included into its geometry and into the corresponding mesh. It would lead to a great number of degrees of freedom and, subsequently, to time costs and memory demanding code. Therefore, major geometry simplifications are usually done in the magnetic field computation. This leads to errors which are still acceptable when an integral value is computed. However, when local values are needed, for example, for calculation of forces in the windings, the reliability of such results is much lower. Inclusion of details into the computational geometry can also improve integral value computations. Therefore. a novel, low demanding method was suggested for computation of the magnetic field in a transformer window.

The novel method is based on basic characteristic properties of computation of magnetic fields in transformer windows. The first one is linearity of such a computation and the second is the fact that the geometry consists of a great number of identical and periodically repeated patterns.

II. Description of the Method

The method will be explained on a very simple example. Let's assume a transformer with two identical windings, each with the same number of coils. Assume further that the coils carry the same, but opposite currents I_W, so that the total number of amperturns through the transformer window is zero. This is almost completely satisfied for a transformer in the short-circuit state.

We will utilize geometrical symmetry and compute magnetic field only in the left half of the transformer window. For simplification, we will use Cartesian coordinate system and compute planar 2D problem for the purpose of explanation of the method. Later we will discuss another situation, when an axisymmetric problem is solved.

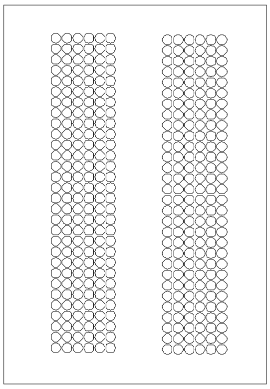

Fig. 1. Original geometry (transformer window with two coils)

The complete geometry of one half of the transformer window is depicted in Fig. 1. Only half of the window is computed because of the geometrical symmetry. The equation that describes the corresponding magnetic field distribution reads

$$\mathrm{curl}\left(\frac{1}{\mu}\mathrm{curl}\,\boldsymbol{A}\right)=\boldsymbol{J}_{\mathrm{W}}\,, \qquad (1)$$

where $\boldsymbol{A}$ is the magnetic vector potential and $\boldsymbol{J}_{\mathrm{W}}$ is the current density in windings. The skin-effect in the wires is neglected.

The Neumann boundary conditions are used on the boundaries representing the magnetic core surface and Dirichlet boundary condition is used along the axis of symmetry.

As the first step of the novel method we must describe the periodicity of geometry by enclosing each winding into regions uniformly divided to blocks with identical geometries.

Than a coarse field calculation is carried out on geometry which consists only of the artificial regions without any division (Fig. 2). All the repeated blocks are removed from this geometry. The current density $\boldsymbol{J}_{\mathrm{r}}$ in each region is set so, that the total current in the region is equal to the total current $\sum I_{\mathrm{W}}$ through the winding, so that

$$J_{\mathrm{r}} = \frac{\sum I_{\mathrm{W}}}{A_{\mathrm{r}}}, \tag{2}$$

where A_{r} is the cross-section area of the region.

Such geometry with appropriate boundary conditions can be solved on a substantially rougher mesh.

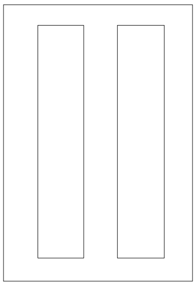

Fig. 2. Geometry for the computation on rougher mesh

Next a corrective field will be computed. This field is computed on geometry comprising the shape of the block repeated in region and of the shape of the winding held by the block (Fig. 3). The computational area should appropriately overreach the block geometry. The current density in the area of the block (but not in the winding) should be set to the value $-J_{\mathrm{r}}$ and in the area with the winding to the value $\frac{I_{\mathrm{W}}}{A_{\mathrm{W}}} - J_{\mathrm{r}}$ *r*, where A_{W} is the cross-section area of the winding.

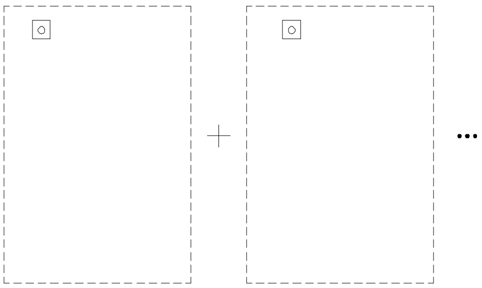

Fig. 3. Geometries for calculation of corrective fields

The resultant field is computed as a superposition of the coarse field computation and the corrective computations. The corrective geometries for corresponding blocks differ only in space shift and, therefore, it can be computed only for one case and the other can corrective fields can be obtained by a simple linear transformation.

When an axi-symmetrical calculation is carried out, only the geometrical repetition in the z - direction can be used for transformation of one result of corrective field into another. The method is then somewhat less effective, but the computational savings can be significant as well.

III. Conclusion

A novel method for computing of magnetic field distribution in a transformer window was suggested. The method should save computational time and memory demands and increase the accuracy of the computation at the same time.

IV. Acknowledgements

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V. References

[1] Sratton, J. A.: Theory of electromagnetic field (in Czech) SNTL,1961

[2] Sadiku, M.N.O.: Numerical Techniques in Electromagnetics. CRC Press, Florida, 2000, ISBN 0-8493-1395-3