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# Calculation of losses, heating in tank covers of powerful transformers

***Abstract.*** *The description of the main approaches to three-dimensional modeling according to the method of finite elements of electromagnetic and thermal processes in the areas of tank covers by means of ANSYS software is given. The results of researches of three-dimensional structures of tanks covers of single-phase and three phase transformers, taking into account not only magnetic field elbows, but also the field of windings scattering are performed.*

**Keywords:** powerful electrical transformer, losses, heating, three-dimensional modeling.

In the development of powerful transformers the problem of tanks protection from the intensive magnetic fields of windings and elbows stray remains urgent up to date. To reduce the losses in the sections of tanks of structural ferromagnetic steel, electromagnetic screens of copper and aluminum, magnetic screens of packages of electrical steel are traditionally used. Mathematical description of problems, calculation methods for simplified models, assuming analytical and numerically-analytical solutions (for the finite size screen height of tank) is performed, in particular, by Apanasewicz S., Turowski J. (1982). In this regard, it is indicated that in order to improve the computational accuracy it is necessary to take account of three-dimensionality of field and sources of current, overlapping of winding fields of different bars, variable geometry of tank, non-linear characteristic of magnetization and temperature of ferromagnetic steel dependence of conductivity, reactions of eddy currents. The complex indicated factors may be taken into account in numerical methods. To ensure the account of these factors Turowski J., Turowski M. and Kopec M. (1990) suggested using method that is similar to the method of finite differences, i.e. the calculation method of three-dimensional equivalent circuit with non-linear lumped parameters.

In recent years the developed methods of finite elements have been involved into analysis. Sufficiently detailed analysis of the works devoted to the problems of experimental researches and methods development for calculation of losses, heating of tanks and other parts of the transformers' structure presented in the book written by Kulkarni S.V., Khaparde S.A. (2004).

At that time the problem of developing an optimum structure of tank cover in the zone of elbows with currents around 20 kA remains one of the complex up to date. The problems and the experimental results of applying constructive measures to limit the losses are given, in particular, in the report of SIGRE in 1988 by Furman Ja.I. and others. It is shown that under existing overall restrictions a combination of measures is effective. This is the optimal performance of design of winding and elbows, the usage of electromagnetic screens, performance of covers and tanks' walls in the zone of influence of elbows' fields in the form of insertions of non-magnetic steel, the optimum elbows location relative to the holes in input boxes' covers. We also demonstrate the effectiveness of eddy currents reducing in nonmagnetic cover by arranging the package of electrical steel on it. Packages are perpendicular to the elbows, their length is less than the width of cover. This is the difference between them and traditional shunts near the ferromagnetic tank walls.

Simplified models assuming analytic solutions were analyzed in the reviewed paper to calculate the eddy currents in the areas of non-magnetic steel tank covers in order to highlight the main factors. Such models are the models of elbows over free plates made from nonmagnetic steel, over the nonmagnetic plates that contact with ferromagnetic, above plates with periodically distributed electrical steel package s on their surface, above plates with circular cutouts to output the elbows from the tank. Mathematical formulation and brief description of boundary problems solutions for the models mentioned are given.

The surface current density for non-magnetic plate is defined according to parameters of plate thickness, its conductivity, current component, touched with plate surface, and for ferromagnetic plate it is defined according to surface impedance. The Poisson's equation for potential function, which derivatives define surface current components, is formulated from Maxwell equations. Under the statement of boundary-value problems, the condition under which there is no component of eddy current that is normal to the boundary at the external boundary of conducting body. If there are notches on non-magnetic plate, the integral of component of electric field intensity touched with surface is connected with the flow of external field that enters into the contour area at right angle. On the contact line of non-magnetic plate with ferromagnetic one, the potential condition is defined according to the continuity of tangential current component. As a result, the averaged loss power density from eddy currents during the period of vibration is defined. The heat problem for determination of body temperature with given heat conductivity and heat-transfer coefficient on the surface is formed as Poisson's equation with inhomogeneous conditions on surfaces.

The description of the main approaches to three-dimensional modeling according to the method of finite elements of electromagnetic and thermal processes in the areas of tank covers by means of ANSYS software is also given. The results of researches of three-dimensional structures of tanks covers of single-phase and three phase transformers, taking into account not only magnetic field elbows, but also the field of windings scattering are performed.

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