THE COOLING SOLUTIONS INSIDE A POWER TRANSFORMER: EXPERIMENTAL RESULTS AND DISCUSSION

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Transformer is a device that converts AC voltage by means of electromagnetic induction and has no moving parts. It is used for a wide range of applications, and we are so much accustomed to employing this piece of apparatus in practice that sometimes forget about that fact that different mechanical, thermal and electrical processes are going on there, making it get hotter and hotter, in other words, causing thermal damage and decreasing the transformer's lifetime.

In this paper we will focus on studying the temperature distribution in power transformer components and the possible ways of improving the performance of oil-cooling methods.

During normal operation of an electric power transformer, a significant amount of heat is generated inside it on account of losses in various components, such as the primary and secondary windings, and the core, due to Joule effect and the Foucault currents. This requires adopting a suitable method of cooling to protect the transformer while maintaining its proper performance and lifetime. To remove this excessive heat, several cooling channels can be provided within the active parts of the transformer, and these are passed by a mineral oil, which is selected because of adequate electrical and thermal characteristics.

For complex experimental measurements in the design of new transformers, Computational Fluid Dynamics (CFD) techniques are usually used to predict the oil flow and temperature distribution in power transformers [1]. For example, numerical simulations have been used in [2] to study the aging effect on mineral oil cooling capacity and the oil aging effect on its viscosity and its physicochemical properties.

Analysis of heat transfer and oil flow in power transformers at natural convection of cooling oil was carried out by Yatsevsky V.A. [3], which resulted into the discovery of the effects of self-organization structure of oil flowing in the form of the unidirectional flow in the groups of horizontal channels between winding coils. It has been revealed that the flow features have an influence on the thermal state of winding coils of the transformer with the natural cooling system [4].

Yet another experimental study aimed at optimization of cooling modes was concerned with the assessment of radiator's cooling performance whenever they were used for oil-immersed power transformer applications with both non-direct flow and direct-oil-forced flow [5].

As stated in [4], the lifetime of a standard power transformer depends on cooling modes, and an optimal cooling design is essential to avoid materials degradation as a result of thermal damage. Since the heat generated inside the power transformers is often removed by circulating a mineral oil, it is important to assess the detailed description of its flow field and the heat removal efficiency.

For that reason, the numerical study must involve a parametric analysis in order to find the most appropriate efficient velocity and cost-effective technique to optimize the heat transfer, thus providing a better understanding of the thermal and dynamic effects of power transformer operation.

In their research Chereches et al. (2017) considered the 40 MVA transformer, having the primary and secondary voltages of 110 kV and 20.5 kV respectively, in which losses in the magnetic circuit and the two windings are dissipated as heat, causing overheating in all active parts. The cooling method adopted here is the one that combines a forced oil circulation by using a pump, and a forced air ventilation in the radiators. A CFD program based on the control volume method was used to solve the continuity, momentum and energy equations in the stationary state. They also used a Pressure-Implicit with Splitting of Operators (PISO) algorithm, which is based on the higher degree of the approximate relation between the corrections for pressure and velocity. To improve the calculation efficiency, the PISO algorithm performed two additional corrections, namely neighbour correction and skewness (coefficient of asymmetry, asymmetry in the frequency of distribution) correction.

A fully implicit numerical scheme was employed, in which upwind differences were used for the convective terms and central differences for the diffusion terms [4, p. 317]. Finally, the numerical modelling was applied to different oil velocity in order to identify the most efficient method of cooling the transformer under steady-state operation conditions.

A parametric analysis was performed to gain a better understanding of the structure of the flow and the temperature distribution in the transformer. In fact, the flow of oil inside the transformer was found to be very complex because of possible re-circulations, which made the fluid pass to certain cooling channels before it left the transformer. This different distribution of internal temperatures was further influenced by non-uniform heating of the active parts of the transformer. Moreover, it was shown that heat transfer is almost always accompanied by mixed convection as some channels do not allow the flow of a relatively viscous fluid whose thermophysical properties can vary with temperature. The experimenters suggested using an obstacle placed near the entrance in the transformer to direct the flow of oil and achieve a better efficiency of cooling the active parts.

This seems to be an acceptable solution as it requires low costs and does not affect the transformer performance [4].

To sum up, the enhancement of cooling technology for power transformers is an important engineering issue. It involves the assessment of fluid flow and heat transfer by convection, and we can apply a number of cooling channels and different inlet fluid velocities of oil to gain a better control over the temperature distribution inside the transformer. Further research in this area will bring more benefits in terms of better insulation performance and longer lifetime of power transformers.

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