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Thermal modeling of disc-type winding for ventilated dry-type transformers

Moonhee Lee [a,*], Hussein A. Abdullah [b], Jan C. Jofriet [b], Dhiru Patel [a]

[a] Hammond Power Solutions, Inc., 595 Southgate Drive, Guelph, ON, N1G 3W6 Canada
[b] School of Engineering, University of Guelph, Guelph, ON, N1G 2W1 Canada

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ABSTRACT

A thermal model for disc-type winding of ventilated dry-type power transformers is presented. The proposed model was based on fundamental heat transfer mechanisms, i.e. heat conduction, convection and radiation. All cooling surfaces were identified, and heat transfer coefficients for each identified surface were presented. The thermal model was applied to a ventilated dry-type power transformer rated at 2000 kV A under different load conditions. Temperature distributions were calculated, and the hottest-spots were located accordingly. The temperatures for the predicted hottest-spots were measured by an infrared thermometer, and they were compared with the temperatures calculated by the model. They are in good agreement.

1. Introduction

Thermal stress is one of the major causes of deterioration of insulation material for power transformers resulting in the failure of electrical distribution systems. The hottest-spot temperature due to overloading or local overheating is of particular interest to both manufacturers and customers for prolonging the life expectancy of the transformers. Nonetheless thermal modeling for identifying the locations and values of the hottest-spot temperatures in the ventilated dry-type transformer windings has not received much attention.

Stewart and Whitman [1] investigated the hottest-spot temperature by carrying out various temperature tests on dry-type transformer windings. They concluded that the hottest-spot temperature is different from winding to winding due to many variables affecting the hottest-spot. A mathematical thermal model for ventilated dry-type transformers was presented by Kömürgöz and Özkol [2]. Temperature distributions in the windings were achieved by computational fluid dynamics based on the velocity and momentum of the surrounding fluid, which was air. This method required much computational effort since three differential equations must be solved together. Their work did not consider time varying condition. The thermal and electromagnetic equations were not solved together. Since one of the major sources of heating is the magnetic field, the thermal problem for transformers should be solved coupled with the electromagnetic problem in order to provide better accuracy [3]. A coupled electromagnetic–thermal problem was well established by Nelson and Jessee [4]. However, most of the research on coupled electromagnetic–thermal models focused on how to solve the coupled model effectively. The thermal aspects of the transformer windings were often neglected.

Another mathematical approach to determining the hottest-spot temperature for ventilated dry-type transformers was attempted by Pierce [5]. His approach was based on the general heat conduction equation with convection and radiation heat transfer as the boundary conditions. The differential equation was solved by finite difference method. The calculation was conducted for layer-type windings and the test data showed reasonable accuracy. Dianchun et al. [6] also solved the heat conduction equation by the finite difference method in order to obtain the hottest-spot temperature for layer-type windings at steady state. However, the heat equations in both studies were not solved under time-dependent condition despite the fact that the operating temperature of the transformers changes with variations of load and ambient temperature. They were not solved as a coupled electromagnetic–thermal problem, and disc-type windings were not considered for calculating the hottest-spot temperature.

Although disc-type winding has been popularly used for power transformers, mathematical approach to determining the temperatures has received little attention. In particular, research on the mathematical thermal models for ventilated dry-type transformers is scarce while most of research published was for oil-filled transformers [7]. However, thermal modeling of disc winding for the oil-filled transformers is not appropriate for ventilated dry-type

* Corresponding author. Tel.: +1 519 822 2441; fax: +1 519 822 9701.
E-mail addresses: mlee@hammondpowersolutions.com (M. Lee), habdulla@uoguelph.ca (H.A. Abdullah), jjofriet@uoguelph.ca (J.C. Jofriet), dpatel@hammondpowersolutions.com (D. Patel).

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