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Procedia Technology 24 (2016) 428 – 435

Procedia Technology

International Conference on Emerging Trends in Engineering, Science and Technology (ICETEST - 2015)

Performance Analysis and Optimisation of an Oil Natural Air Natural Power Transformer Radiator

S Anishek*, Sony R[#], Jayadeep Kumar J[$], Pradeep M Kamath*[@]

**Department of Mechanical Engineering, Govt. Engineering College Thrissur, Kerala, India*
#Department of Mechanical Engineering, College of Engineering Perumon, Kollam
[$]Department of Mechanical Engineering, College of Engineering Chengannur

Abstract

In Power transformers are inevitable components in alternating current generation, transmission, distribution and utilization systems. Lifespan and performance of power transformer are dependent on cooling system employed for dissipation of heat generated during its operation. In this paper numerical simulation of an oil natural air natural power transformer radiator was performed to determine its cooling capacity. In addition, optimum spacing between sections and optimum length of sections of radiator were also determined. An optimised radiator design was proposed and was simulated to determine its cooling capacity. The proposed radiator design was found to 14% more efficient than existing design in terms of cooling capacity for same material cost. The control volume method has been used to resolve the continuity, the momentum and the energy equations in steady state.

Peer-review under responsibility of the organizing committee of ICETEST – 2015

Keywords: Power transformer; radiator; oil natural air natural; cooling capacity.

1. Introduction

Power transformer is a stationary electric device that employs Faraday's laws of induction to transform electrical energy from one circuit to another without changing the frequency of AC.

[@] Corresponding author. Tel.: +91 9562430075;
E-mail address: pradeepmkamath@gmail.com

Peer-review under responsibility of the organizing committee of ICETEST – 2015
doi:10.1016/j.protcy.2016.05.059

AC is generated at low voltage level and transmission of large amount of power to load centres incurs huge power loss (I^2R loss) in transmission lines. Also cross sectional area of transmission lines should be large to accommodate high current and this increases cost involved many folds to transmit a given amount of power. High voltage power transmission is the solution to avoid power loss and to reduce cost involved in transmission. Power transformers are used at power generating stations to step up AC voltage before transmission and at load centres to step down its voltage to safe and suitable value.

Transformers are associated with primary copper loss, secondary copper loss, iron loss, dielectric loss and stray loss. These losses are proportional to size and weight of transformer and therefore are large for power transformers. Losses are transformed into heat which rise winding temperature and hot spot temperature within transformer. The hot spot temperature and winding temperature should be within prescribed limits so as to ensure life and reliability of transformer. In power transformers, the cooling is provided by circulation of oil between heated parts and radiators outside transformer tank. The simplest power transformer cooling system is oil natural air natural. In this method, heat generated within transformer core and winding is transformed to oil. The oil flows from transformer to radiator and back to transformer due to thermo-syphon effect. The heat from the oil will be dissipated in atmosphere due to natural convection of air around the radiator.

In literature, limited works related to transformer radiator cooling performance are available. In preceding works the focus was on thermal modelling of transformer and prediction of hot spot and top oil temperature.
Amoiralis et al. [1] numerically studied optimum design of ONAN transformer cooling system. They applied MNLP and BB technique to overall design optimization. Cha et al. [2] numerically simulated improvements in heat transfer in power transformer by varying difference in elevation between the center of the coils and center of radiators. Stefan et al. [3] performed dimensional optimization of frontal radiators of 630 kVA 20/0.4kV power transformer. Fdhila et al. [4] developed a model to study the effect of radiator design parameters like fan position, fan size and oil flow rate on the cooling capacity of radiators. They choose porous medium approach to model the radiators on a fine numerical grid, coupled with a turbulent heat transfer model on a much coarser grid for the heat and mass transport in the air surrounding the radiators. Sefidgaran et al. [5] developed a reliability model of power transformer with ONAF cooling. Kim et al. [6] predicted and evaluated the cooling performance of radiators used in oil-filled power transformer applications with non-direct and direct-oil-forced flow. They found the temperature difference between the top and bottom oil of radiator decreased according to increase in flow rate, cooling capacity increased at high flow rates due to its high volume flow rate. Paramane et al. [7] studied thermal performance of radiators in a power transformer in two parts: effect of blowing direction and offset of fans. Their studies showed that horizontal blowing to be more efficient than vertical blowing configuration, as the sideways leakage of air was less for horizontal. Also a small offset of 50 mm at top and bottom fan increased heat transfer by 3%.

The objective of the paper is to numerically determine cooling capacity of an ONAN power transfer radiator and to optimise it.

Nomenclature

u, v, w	Velocity components in x, y, and z directions
ν	Kinematic viscosity (m^2/s)
ρ	Density (kg/m^3)
K	Thermal conductivity (W/mK)

2. Problem Description

Power transformers are equipped with detachable radiators, in order to provide the necessary cooling surface. Radiators are steel plate heat exchangers that are installed vertically next to transformers. As shown in Fig. 1, a typical radiator consists of top header pipe, bottom header pipe and sections. Two identical steel plates are pressed and welded to each other to form a radiator section. And each section consists of seven channels for oil passage. Each channel is equipped with two internal throughout wings to increase the heat transfer rate from section. At the upper and lower parts of radiator section, semi-circular channels are provided for oil flow entry and exit. Oil from transformer flows to the top header and it directs the oil to semi-circular channels. These channels direct the oil into the provided ways inside the section. Finally, oil is collected in lower semi-circular channel and flows back to