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A NEW THERMAL MODELING OF DRY TYPE TRANSFORMERS AND ESTIMATING TEMPERATURE RISE

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Abstract— A power transformer is a static piece of apparatus with two or more windings, which by electromagnetic induction transforms a system of alternating voltage and current into another system of voltage and current, usually of different values and at the same frequency for transmitting electrical power. Temperature rise is one of the most crucial parameters that affect the transformer lifetime. Temperature rise in a transformer depends on variety of parameters such as ambient temperature, output current and type of the core. Considering these parameters, temperature rise estimation is still complicated procedure. In this paper, we present a new model based on temperature rise. This method avoids the complication associated to accurate estimation and is in very good agreement with practice.

1. INDRODUCTION

The purpose of this paper is to analyze the thermal model of dry type transformer. The usefulness of thermal model is to estimate the highest temperature transformer experiences during its functioning (the hot spot), so that relative ageing rate can be evaluated. The required transformer thermal model must be as simple as possible without losing represented mess of major phenomena involved; a compromise must then be achieved between accuracy and complexity. Given a few transformer specific parameters, the hot-spot temperature will be estimated as a function of the driving load and ambient temperature. Power transformer outages have a considerable economic impact on the operation of an electrical network. Temperature rise in a transformer depends on variety of parameters such as ambient temperature, output current and type of the core. The heating of a transformer arises from electric and magnetic losses. One can consider the existence of two main active heat sources: the winding losses and core functioning losses. Secondary heat losses, in the tank other metallic parts of the transformer, due to eddy currents will be neglected, due to their small proportions.

In this paper [1], is to introduce a general model of hot spot temperature rise calculation for the non-directed flow windings in order to explain the thermal overshoot phenomenon. In this paper [2], model the equivalent circuit simulating the thermal behavior of each element is extended to form the thermal model of transformer. In this paper [3], To analyze the temperature rise inside a transformer, the analogy between thermal and electrical process is employed. Thermal laws determine that once a thermal gradient is establish, thermal fluxes flow from higher temperature parts to lower once a thermal gradient is establish, thermal fluxes flow from higher temperature parts to lower ones, until the thermal equilibrium is reached. Considering these parameters, temperature rise estimation is still complicated procedure. In this project, estimation of temperature rise calculated by using conduction and radiation method. A new model for transformer thermal model analysis is done by using MATLAB and various method of analyzer is used to calculate the temperature distribution of transformer and compare with other method and give accurate estimation and very agreement with practice.

2. HEAT TRANSFER:

Heat transfer can be described as the process of energy transmission due to a gradient in temperature T, which is measurable quantity. Heat transfer in a transformer takes place through conduction and convection assisted by radiation. The heat generated inside various parts of the transformer is transferred to the surface by means of conduction. The conduction is nothing but the heat transferred from one material to other material.

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2.1 CONDUCTION:

The rate at which heat is conducted through a iron or any material of a particular to the area A of the material and to the temperature difference ΔT between its sides and inversely proportional to the material's thickness d. The amount of heat Q that flows through the material in the time t is given by

$$Q/t = (kA\,\Delta T)/d \qquad ----- \ (1)$$

Where k – Thermal conductivity of the material, is a measure of its ability to conduct heat (W/m°C)

2.2 ELEMENTARY HEAT CONDUCTION:

Conduction is a diffusion process that occurs via molecular mechanisms. The fundamental governing law is Fourier's law of heat conduction.

$$q'' = -k\,(dT/dx) \qquad ------- \ (2)$$

where, q'' - heat flux, k - Thermal conductivity

dT/dx – Temperature gradient along an independent coortinate x.

3. ESTIMATION OF TEMPERATURE RISE

The temperature rise in the transformer is calculated by using the transformer data. For example in this paper an 800 VA rating transformer is taken in account to calculate the temperature rise. It is dry type transformer. Based on the current and resistance value the copper loss is calculated. Based on weight of core and data given by the loss per 1 kg of core weight the core loss is calculated. By using the copper loss and core loss the winding (primary & secondary) temperature and temperature in core is calculated by using the final temperature formula. Once the winding temperature and core temperature are determined means it's used to calculate the rate of heat flow of from winding to core or core to nomex or windings into bobbin are calculated. These are done by using the convection method. Let, N_1 = Number of turns in primary N_2 = Number of turns in secondary, Φ_m = Maximum flux in the core in Weber, B_m = Flux density in Tesla, A= Net cross-sectional area of core in sq m, f = Frequency of ac input in Hz.

3.1 AMOUNT OF HEAT TRANSFER:

The amount of heat transfer is equal to ratio of multiplication of area of the bobbin, change in temperature and thermal conductivity of bobbin to thickness of the bobbin. Same way the rate of heat flow from secondary winding to primary winding is depend on their thermal conductivity of each material, thickness of each layer, area of heat transfer of each section and change in temperature difference between the primary and secondary winding.

4. THERMAL MODEL:

The heating of a transformer arises from electric and magnetic losses. One can consider the existence of two main active heat sources: the winding losses and core functioning losses. Secondary heat losses, in the tank other metallic parts of the transformer, due to eddy currents will be neglected, due to their small proportions. Thermal laws determine that once a thermal gradient is establish, thermal fluxes flow from higher temperature parts to lower once a thermal gradient is establish, thermal fluxes flow from higher temperature parts to lower ones, until the thermal equilibrium is reached. This heat transition between higher and lower temperature parts can be achieved either by conduction, convection and radiation. Each of these heat transfer mechanisms specific characteristic (thermal capacity, conductivity convection and radiation coefficients), materials anisotropy geometric parameters; some of these characteristic are itself, temperature dependent. The establishment of temperature distribution inside a transformer is very complex and thus, some simplifications must be admitted. Heat transfer from heat sources to cooling medium can be divided into three paths. 1. from inner parts of the active components (windings and core) to their external surface in contact with bobbin and insulation nomex. Here the heat transfer mechanism is mainly due to conductivity. 2. from inner parts of the active components (primary and secondary winding) to their inner surface in contact with insulation nomex and copper shield. 3. from outer parts of insulation nomex and bobbin to the air. Here the heat transfer mechanism is mainly due to convection and radiation. Based on the formulas the losses and temperature in a transformer is calculated. By using formula the model to be created in matlab, here, the program is inserted into the model. This model gives the outputs such as copper loss, core loss, temperature in each part and steady state temperature.

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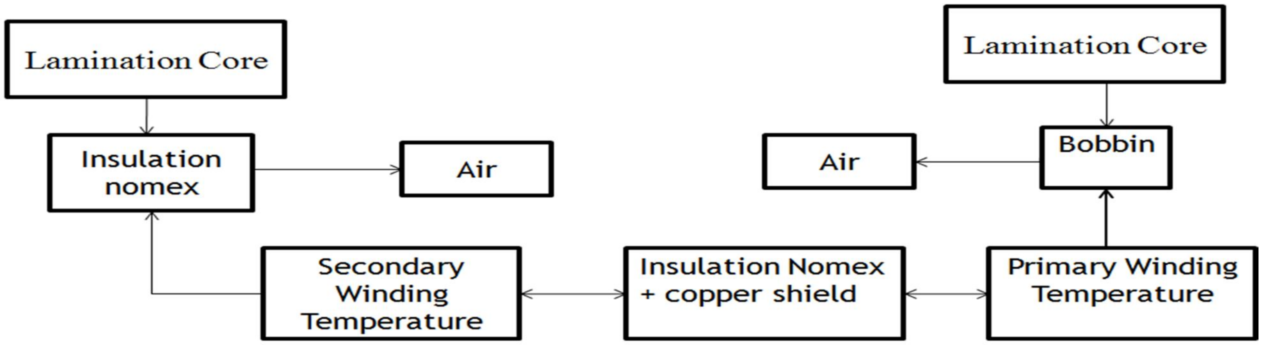

Fig 1. Block diagram of heat flow of dry type transformer.

The loss in core there was a btu/h in the core is consider c1 means after first hour the new btu/h is equal to sum of difference between rate of flow in of btu/h from winding to core, btu/h generated in core because loss and rate of flow out of btu/h from core to air. Because of new btu/h in the core there was a small amount temperature is increased. If temperature increases means amount of heat flow from core to air is also increased. By the way the temperature will reach the steady state after few hours. In that same way the secondary winding temperature and primary winding temperature will reach steady state temperature after few hours. Based on the temperature the thermal conductivity is changed and based on the thermal conductivity the rate heat flow from various parts is also changed. In the first hour because of loss there will be heat in various parts transformer.

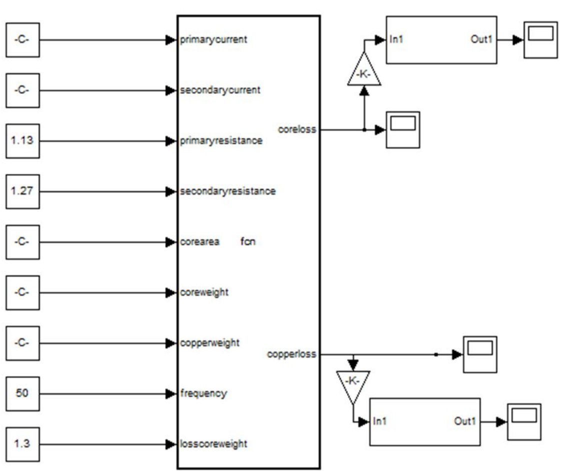

Fig 2. Simple model for calculate losses and temperature in transfomer

The above figure shows the simple model for temperature calculation of dry type transformer. In this model the amount temperature is developed in transformer is calculated and model to be done by using the basic formula. Below figure shows the output graph of various parts temperature in transformer.

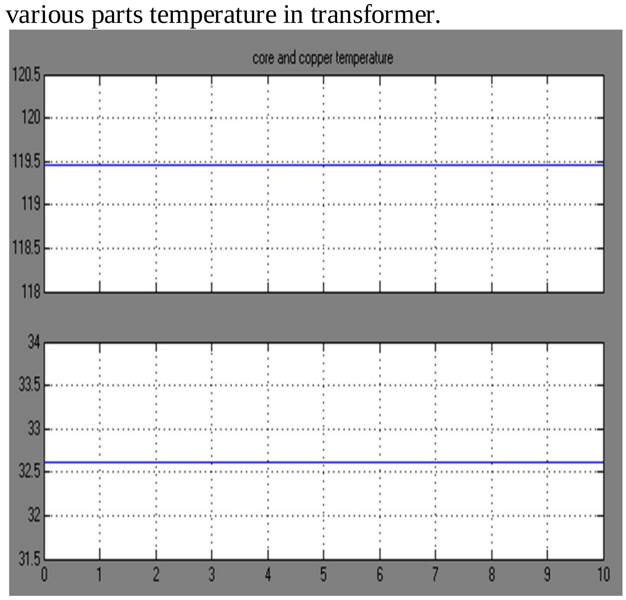

Fig 3. Output graph of core and copper loss

After the first hour the heat transfer operation is takes place. During that time the temperature in transformer increased slowly and it will reach steady state after few hour of time.

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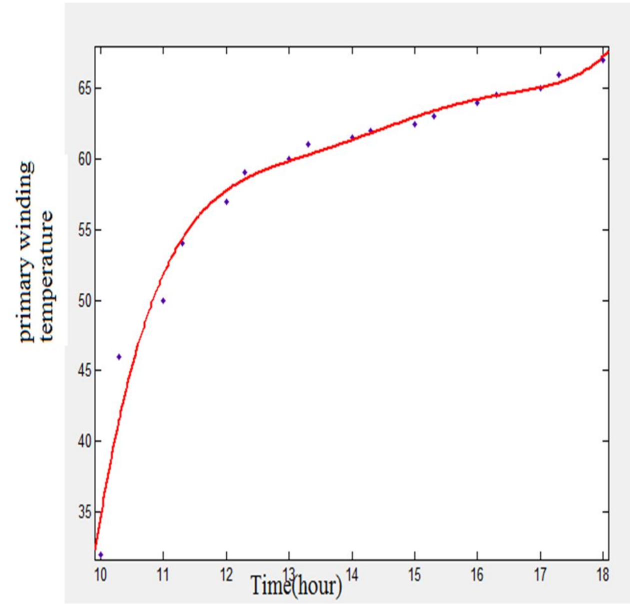


Fig 3. Output graph of primary winding temperature

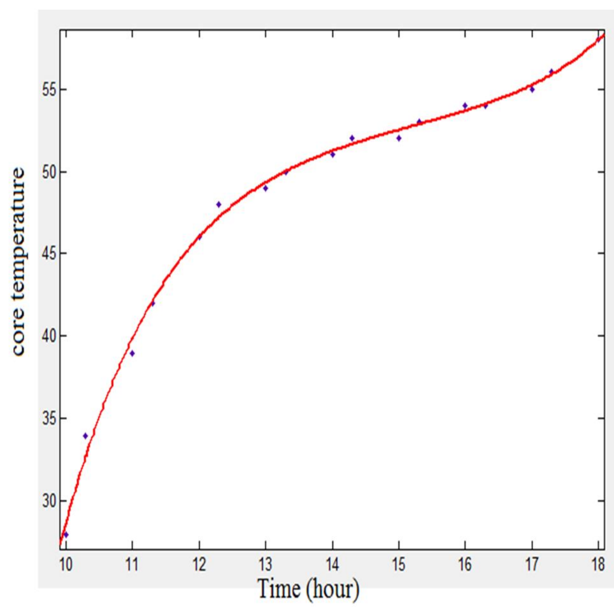
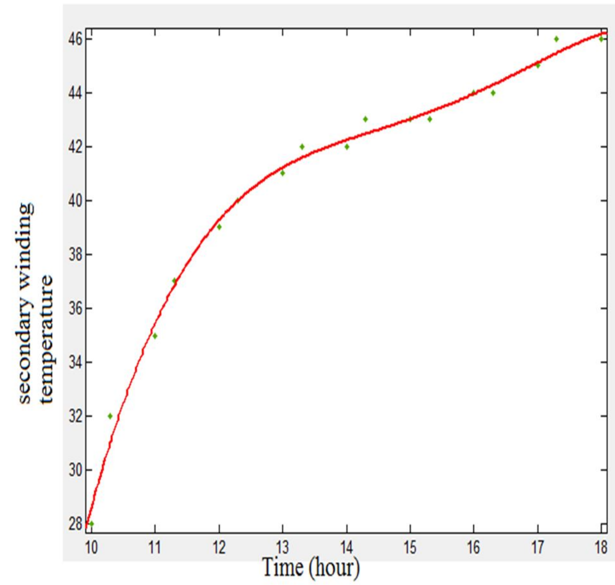


Fig 5. Output graph of core temperature

When the temperature is changed at the time thermal conductivity of the material is also changed. Because of changes in thermal conductivity the heat transfer from material to air is also increased. In that 800VA transformer



. Fig 6. Output graph of secondary winding temperature

has the core loss and copper are 6.9W and 38W respectively. The temperature developed in transformer of various as core, primary winding and secondary winding temperature are 119.4°C ,33°C and 32°C, respectively.

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