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ANALYSIS OF SHORT CIRCUIT AXIAL FORCES IN DISTRIBUTION TRANSFORMER WITH TAPPING ARRANGEMENT

ANUPAM SINHA
Post Graduate Student,
UIET, Punjab University,
Chandigarh, India,
E-Mail: sinha.90@gmail.com

SARPREET KAUR
Assistant Professor,
UIET, Punjab University,
Chandigarh, India,
E-Mail: sarpreetdua@yahoo.co.in

ABSTRACT

Short circuit axial forces in transformer can cause very severe damage to the transformer. Short circuit axial forces are calculated for a 630kVA, 11000/433V distribution transformer. Finite Element Method (FEM) has been used for calculating the electromagnetic forces in the windings of transformer. Short circuit force under tapping arrangements has also been considered separately.

Keywords: *Finite Element Method, Short Circuit, Electromagnetic Forces, Distribution Transformer, Tapping*

I. INTRODUCTION

Design of transformer is very important before manufacturing it and in order to manufacture it the effect of short circuit forces must be carefully studied. Short Circuit forces have two components in it. One is Axial force which acts in Y axis direction and other is radial force which acts in X axis direction. There is not much variation in the values of radial force under no tapping condition and tapping condition so if the transformer is designed to withstand radial force without tapping arrangement then it can withstand the effect of radial force under tapped condition also. On the other hand axial force has a large variation if we compare its values under the condition when no tapping is applied with the condition when tapping is applied so axial forces are very important to study as its effect causes severe damage to the winding structure

Several mathematical tools are available to calculate short circuit forces in transformer. In this research two dimensional Finite Element Method has been used to calculate short circuit axial forces. Actual transformer is three dimensional in nature but two dimensional studies is sufficient in order to study axial forces in the windings of transformer [3].

In this paper short circuit axial forces are calculated in a distribution transformer. Short Circuit axial force under tapping arrangement has also been calculated.

II. SHORT CIRCUIT CURRENT

Three phase short circuit current is taken as it considered as the most severe one cause maximum damage to the transformer. The short circuit current is given by

$$I = \frac{\sqrt{2}\; X\; k\; X\; MVA\; X\; 10^6}{\sqrt{3} \times V\; X\; e} A \qquad (1)$$

Where V is rated primary voltage of the winding, e is the fractional per unit voltage and $\sqrt{2}\,X\,k$ is calculated as per IEC 60076-5 standard [8].

III. FORCES IN WINDINGS

Short circuit current causes forces in the winding of transformer. Two types of forces are there one radial force and other is axial force. Axial Force is calculated in this research paper. Lorentz Force, F is computed by the vector product of current density, J, and leakage flux density, B, is given by

$$\vec{F} = \vec{J} \; X \; \vec{B} \qquad (2)$$

IV. MODELLING AND SIMULATION

A. Modelling

Transformer modelled is a three phase 630kVA distribution transformer with three limbs. The voltage ratio is 11000/433 volts and winding orientation is delta star. The material used in core is M4 steel with stacking factor of 0.97, window height is 440mm and yoke height is 195mm. The specifications of transformer used in the modelling is shown in Fig.2

Parameters	HV	LV
Type of Coil	Cross-Over	Helical
Number of coils per phase	2	1
Number of turns per phase	1062	23
Conductor size	2.85	6.70X4.25X10
Conductor placement	-	2WX5D
Number of turns per coil	531	23
Number of layers	9	1
Number of turns per layer	59	23
Voltage (V)	11000	433
Yoke Clearance	21	11
Inter phase connections	Delta	Star

Fig. 2 Specifications of Transformer used in modelling

The winding are modelled in rectangular bocks and with LV winding has dimension of 398x23.75mm and HV winding has dimension of 392x32mm. LV and HV windings are modelled into cells and each cell contains turns of coil. Axial compressive force in the winding is the sum of axial forces in all the cells of the winding.

B. *Simulation*

Software used for simulation is Finite Element Method Magnetics 4.2 by D.Meeker [4]. Boundary condition applied to the problem is Dirichlet boundary condition. The simulation has been done in axisymmetric mode with problem type as magnetics problem. The magnetic density plot for the winding without tap and with tap is shown in Fig. 3 and Fig. 4 respectively.

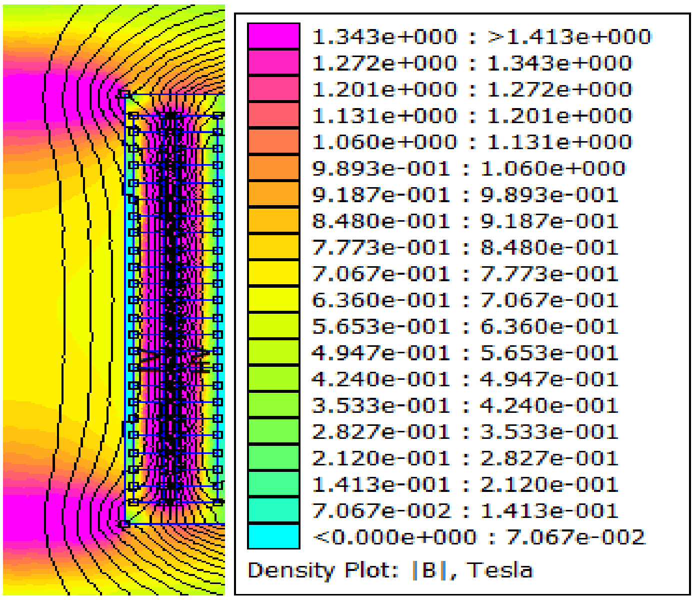

Fig.3 Magnetic Density Plot for untapping winding

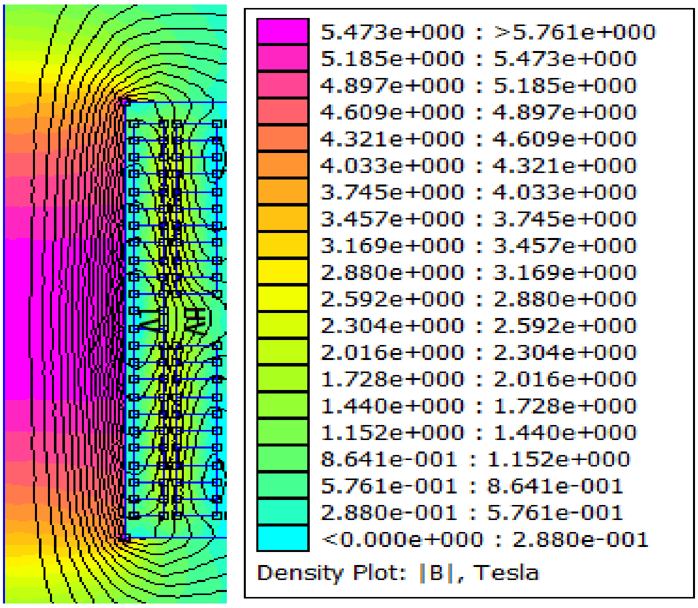

Fig 4 Magnetic Density Plot for tapped winding

V. SHORT CIRCUIT AXIAL FORCE IN WINDINGS

A. *Without Tapping Arrangement*

Axial Compression Short Circuit Force in the winding is shown in Fig.5. In order to find axial compression force in the winding the force in each cell is added with the next cell. The integral of axial force of each cell will give the plot of axial compression force in the winding. The maximum axial compression force occurs in the central region of the winding and its magnitude is coming around 34.598kN for LV winding. For HV winding this force is around 18.733kN.

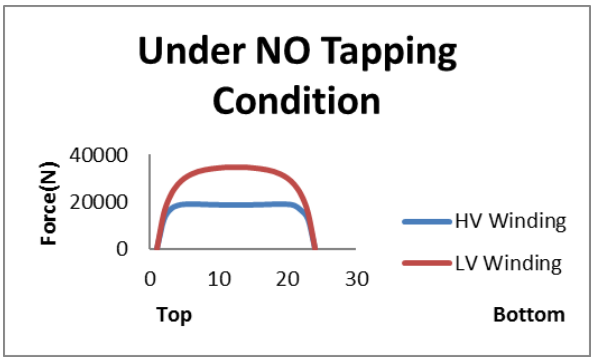

Fig.5 Axial Compression Force under normal condition (untapped winding)

B. With Tapping Arrangement

Axial compressive force for the winding under tapped condition is shown in Fig. 6.The axial compressive force is calculated by following the steps as mentioned in part A. The value of maximum axial compression force under tapped condition is almost of same value for both LV and HV winding but its position is not same. For LV winding maximum axial compression occurs at the point exactly opposite where tapping is applied on the HV winding. For LV winding maximum axial compression occurs at the turs which are near to the end of winding. The value of maximum axial force for both the winding is around 105.765kN for LV winding and 95.286kN for HV winding.

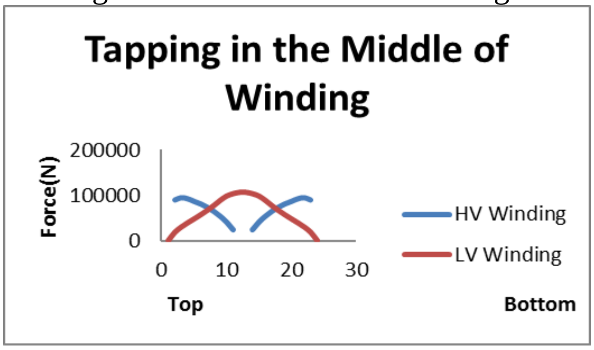

Fig.6 Axial Compression force for tapped winding

VI. Conclusions And Future Scope

In this paper finite element method of analysis was used and the modelling of transformer was done in axisymmetric mode to compute the maximum compression force in the windings of transformer. The position where maximum force occurs was also located. To find the axial compression force the winding was modelled in cells. The results obtained are matching with the results obtained by analytical method. The winding must be tightly braced to avoid damage. The result obtained from the research work can also be beneficial to designers while designing the transformer. For future scope radial forces can also be calculated, effect of axial asymmetry can also be considered. Analysis can also be done for double layer helical HV winding.

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