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2[nd] IEEE International Conference on Power and Energy (PECon 08), December 1-3, 2008, Johor Baharu, Malaysia

Measurement of Flux Density Distribution on 100kVA 3-Phase Distribution Transformer Assembled With 90° T-Joint and Mitred Lap Corner Joint with Stagger Yoke by Using Search Coil

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***Abstract*— This paper describes the result of measurement of flux distribution on 100kVA 3phase distribution transformer assembled with 90° T-joint and mitred lap corner joint with stagger yoke. The measurement involves the variation of flux. The flux density distributions have been measured using no load test by arrays of search coil in M5 (CGO) grades material of transformer core laminations. The localised flux density at the outer 90° T-joint is 90 mT and rises to be 198 mT at the inner 90° T-joint and the localised flux density at the outer corner-joint is 81 mT and rises to be 149 mT at the inner corner-joint when the transformer core energized 1.5 T 50Hz. A small amount of flux deviation from the rolling direction occurs at the overlap.**

***Keywords*—Transformer core; flux distribution; power loss; searchcoil.**

I. INTRODUCTION

The efficient operation of power transformer cores depends to a large extent on the design of the joints between their limbs and yokes. In the three-phase, three limb core the most complex joints are the T-joints at the intersection of the centre limb and yokes. The joint should be constructed to give mechanical stability to the core and to be magnetically efficient.

Under ideal conditions the total flux in the limbs of a transformer core has a sinusoidal waveform, but in the corners of the core the flux is far from sinusoidal. The additional loss caused by the flux distortion can lead to localized heating within the joints.

Another possible cause of increased power loss in the T-joint is rotational hysteresis which might occur. This caused when the magnitude of the flux remains constant and its direction varies in a cyclic manner. Some flux might rotate and oscillate producing local hot spot.[1].

Transformer iron loss can be reduced either by improving the quality of the steel or by using better building and design techniques. The efficiency of a transformer core is also largely dependent upon the design of the joints at the junctions of the yoke and limbs. In these regions the flux may deviate from the rolling direction of the steel or become distorted so that local areas of the high loss are produced. [2]

The objective of this investigation is to know the flux distribution of the transformer core built from electrical steel (M5) with 3% silicon iron assembled with 90° T-joint and mitred lap corner joint with stagger yoke by using search coil

II. EXPERIMENT APPARATUS AND MEASURING TECHNIQUES

A 3-phase,3 limb stacked cores are assembled with 90° T- joint and mitred lap corner joints as indicated in Fig. 1.The core is 550 mm x 580 mm with the limbs and yokes 100 mm wide. The core is assembled from 0.3 mm thick laminations of M5 grain-oriented silicon iron (CGO) as indicated in Fig. 2 and the core comprises of 15 layers has staggered yoke of core with overlap length of 5 mm from other adjacent lamination. Staggering alternate layers of laminations in the yoke direction as indicated in Fig. 2 is

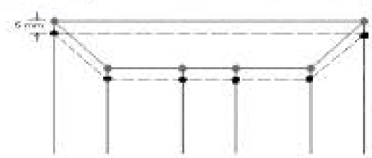

Figure 1 Transformer core type with T-joint

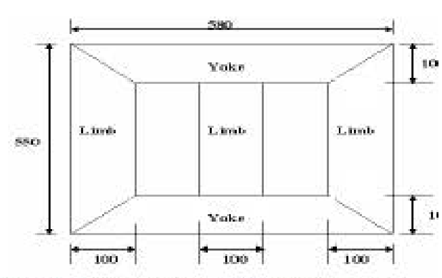

Figure 2 Dimension (mm) of 100kVA transformer model

known to reduce the losses of core assembled from silicon iron [3]

Flux distribution in the Cold Rolled Grain Oriented (CRGO) is measured by using an array of search coils to get the satisfactory result. In this investigation an array of single turn search coil is employed to measure in-plane (longitudinal and transverse) of flux density in the lamination within the transformer core.

The locations chosen must cover the areas where the flux is more likely to vary direction so as to find distribution of the flux behavior as shown in Fig. 3 and 4. The testing process is done by using the No-Load Test

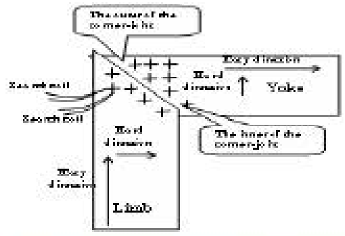

Figure 3. The position of easy and hard direction in the corner joint of transformer core

Frame. The No-Load Test Frame consisting of three windings for each three phase core are designed in order not only to avoid introducing stress to the laminations but also to keep the magnetism exactly constant in all limbs of

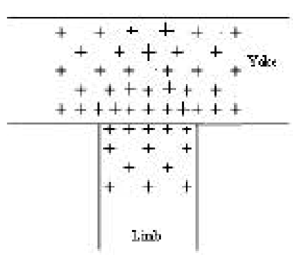

Figure 4. The search coil position in the T-joint of transformer

the cores as indicated in fig. 5. The core could be energized to 1.5 T (50Hz)

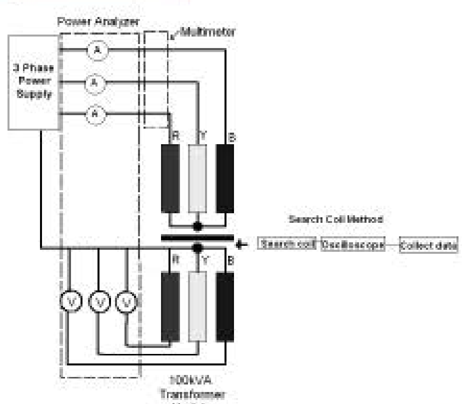

Figure 5. The diagram of the methods that is used to measure the localised flux density

The magnitude and direction with reference to the x axis of the in-plane instantaneous flux density can be written in the form [3]:

$$|b| = \frac{1}{4fNAn}\left[\dot{e}_x^{\,2} + \dot{e}_y^{\,2}\right]^{1/2} \tag{1}$$

And

$$\alpha = \tan^{-1}\left(\frac{e_y}{e_x}\right) \tag{2}$$

Where

f = frequency supply

N = Number of transformer winding

A = Cross section area of transformer core lamination that measured

n = number of layer of transformer core lamination

e_x = maximum value of the component of induced emf in the easy direction

e_y = maximum value of the component of induced emf in the hard direction

Sample calculation as follow:

From transformer frame are obtain number of turn is 254 turns, area of lamination is 0.000003m^2 with number of layer is 15 layers and frequency supply is 50 Hz. When the supply adjusted to transformer at 1.5T so at the search coil will find the induced emf by oscilloscope measurements at easy direction is 190mV and hard direction is 180mV. By using the equation (1) will find the flux density at this point is 103mT.

III. EXPERIMENT RESULT AND DISCUSSION

Fig. 6 shows the mesh graph of the localised flux density measured by using the search coil at the 90° T-

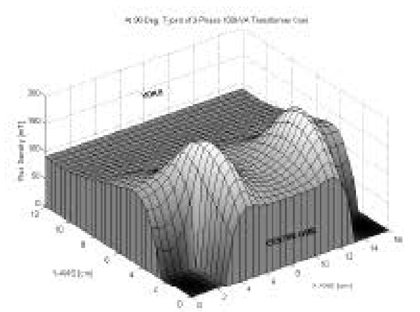

Figure 6. The mesh graph of the localised flux density measured by the search coil at the 90° T-joint.

joint of transformer core lamination. This mesh graph is drawn by using the Matlab software based on the result of this investigation. The flux density at 90° T-joint causes the flux density in lamination yoke drop in the 90° T-joint and flux transfers into the laminations above and below it.

The flux density in the limb then drops rapidly as the flux distributes itself equally between the laminations. The flux density reaches a peak at the inner of 90° T-joint; this is caused by the saturated material. The minimum flux density occurs at the outer of 90° T-joint of transformer core lamination. The localised flux density will increase from the outer to the inner of the 90° T-joint. The localised flux density at the outer 90° T-joint is 90 mT and rises to be 198 mT at the inner 90° T-joint when the transformer core energized 1.5 T 50Hz.

Fig. 7 shows the measuring point of location and

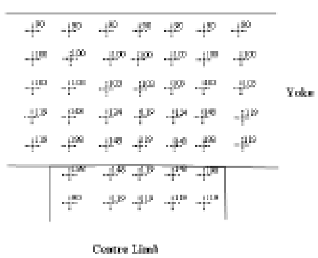

Figure 7. The average flux density at 90° T-joint (the values are expressed in mT) is measured by using search coil.

localized flux densities at 90° T-joint that are measured by using the search coil on transformer core. This result is produced by calculating localized flux density after the search coil measures the vector of the voltage in the easy and hard direction at the lamination.

Fig. 8 shows the variation in magnitude and direction of flux density at 90° T-joint. A small amount of flux

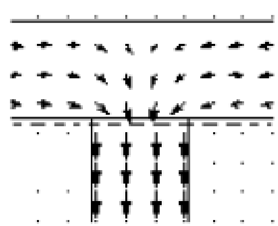

Figure 8. Distribution of localized flux density at 90° T-joint.

deviation from the rolling direction occurs at the overlap.

Fig. 9 shows the mesh graph of the localised flux density measured by using the search coil at the Corner-joint of transformer core lamination. This mesh graph is drawn by using the Matlab software based on the result of the investigation. The flux density at corner joint causes the flux density in lamination yoke drop in the corner joint and flux transfers in to the laminations above and below it.

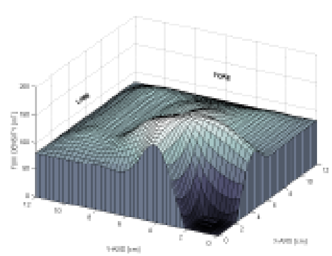

Figure 9. The mesh graph of the localised flux density measured by the search coil at the corner-joint.

The flux density in the limb then drops rapidly as the flux distributes itself equally between the laminations. The flux density reaches a peak at the inner of corner joint; this is caused by the saturated material. The minimum flux density occurs at the outer of corner-joint of transformer core lamination. The localised flux density will increase from the outer to the inner of the corner-joint. The localised flux density at the outer corner-joint is 81 mT and rises to be 149 mT at the inner corner-joint when the transformer core energized 1.5 T 50Hz.

Fig. 10 shows the measuring point of location and localized flux densities at corner-joint that are measured by using the search coil on transformer core. This result is produced by calculating localized flux density after the

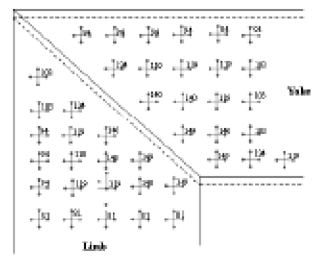

Figure 10. The average flux density at corner joint (the values are expressed in mT) is measured by using search coil.

search coil measures the vector of the voltage in the easy and hard direction at the lamination

Fig. 11 shows the variation in magnitude and direction of flux density at corner joint. A small amount of flux deviation from the rolling direction occurs at the overlap,

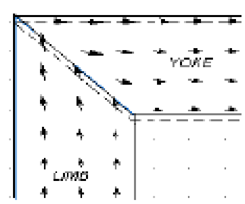

Figure 11. Distribution of localized flux density at corner joint.

but no rotational flux is present in the joint. The major regions where the flux deviates from the rolling direction are the corners where the flux passes from the yoke to the limbs.

IV. Conclusion

The flux distribution in cores assembled with M5 materials varies with the stagger length. The localised flux density will increase from the outer to the inner of the 90° T-joint. The localised flux density at the outer 90° T-joint is 90 mT and rises to be 198 mT at the inner 90° T-joint when the transformer core energized 1.5 T 50Hz.

The localised flux density will increase from the outer to the inner of the corner-joint. The localised flux density at the outer corner-joint is 81 mT and rises to be 149 mT at the inner corner-joint when the transformer core energized 1.5 T 50Hz.

The localised changes can be related to the changes in in-plane flux distribution particularly in overlap regions of the joints. [3]

A small amount of flux deviation from the rolling direction occurs at the overlap, but no rotational flux is present in the joint.

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