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EFFECT DIFFERENT LIMB OF TRANSFORMER CORE ASSEMBLE ON PERFORMANCE

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Abstract. This paper described the performance of transformer affected by different limb assembling. The experiment that used to investigate core is no-load, short circuit and load test to find the core loss, copper loss, flux leakage at corner joint and limb and total harmonic distortion of the flux at flux density range from 0.2 T to 1.6 T, 50 Hz. From the result of this investigation shows the core loss of transformer assembled with 2 limbs is 18.45% and 32.21% better than the transformer assembled with 3 and 5 limbs respectively at a flux density of 1.6T, 50 Hz. To increase the numbers of core limb assemble will reduce the efficiency of transformer.

Introduction

The transformer operate when the primary winding are given the supply. From there, the coil produces the magnetic field to the transformer core and generates the flux. Every core design has different flux distribution. Flux distribute not only in the core yoke but also in the limb. [1] For the ideal condition, the flux in the limb show the sinusoidal waveform but when at the corner side of limb the waveform show that flux are far from sinusoidal.[2] In every design of core, the 2 limb and 3 limb design shows that the flux distribution is sinusoidal and has a little distortion. For the 5 limb, the flux is non-uniform and flux waves are much distorted. [3]

To build the transformer core, suitable material has built to manage the magnetic flux transfer on the core. These are continuous development and introduction of better grades of core material. There are several materials that use of transformer core such as cold rolled grain oriented (CRGO). The material of cold rolled grain oriented is widely used as magnetic material in distribution and power transformer because strongly oriented with respect to the direction of rolling. This material is high induction and low loss at magnetizing force. Saturation of the flux density of the cold rolled grain oriented is remaining constant around 2.0 Tesla also has an improvement on the watt/kg and volt-ampere/kg. [4]

The properties of this material are flux that the transfer will loss at the end of core because don't have a backup from another layer. To reduce the loss of flux on the material, the lamination can be arranged by mitered the core at 45° angle. Flux changes the direction by 90° when the layers are mitered 45°. [5] Grain oriented along the length of the laminations in the horizontal and vertical directions. The magnetic flux density of material is influenced by the BH curve material itself to see the three conditions of the domain. [6]

There are two factors that affected the amount of flux flow in the core such as magnetic property of material and distance between primary winding and secondary winding position in the core. One of them is the magnetic property of 3% Si-Fe is based on the BH curve as indicated in figure 1. In magnetic property of core material has three conditions excitation such as under excited, operation and saturation. Under excited condition is flux domain material has random direction in the core. When primary winding adjust at the under excited condition so the secondary winding of transformer will produce low losses.

The objective of this investigation is to evaluate the performance of transformer core based on number of limbs assembled with 3% Si-Fe, Cold Roll Gain Oriented material.

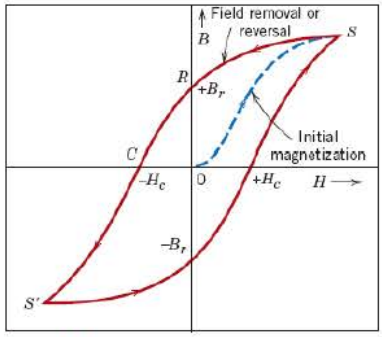


Figure 1 The B vs. H behavior for ferromagnetic material [6]

Methodology

The three of single phase with 2, 3, and 5 limbs stacked core are assembled with mitred overlap corner joints are shown in Figure 2. The outer core dimensions of two limbs are 220 mm x 270 mm with the limb of 50 mm wide. The outer core dimensions of three limbs are 270 mm x 270 mm with the limb of 50 mm wide. The outer core dimensions of five limbs are 400 mm x 270 mm with the limb of 50 mm wide. The material that used is 3% silicon ferrite (M5) with the thickness of 0.3mm on the three cores with nominal loss of 1.12 W/kg at 1.5T and has stagger yoke of core with overlap length of 5mm from other adjacent laminations as shown in Figure 3. Each transformer core comprises of 133 layers.

Each core could be energized 0.2 T to 1.6 T and the power loss is measured using single phase power analyzer.

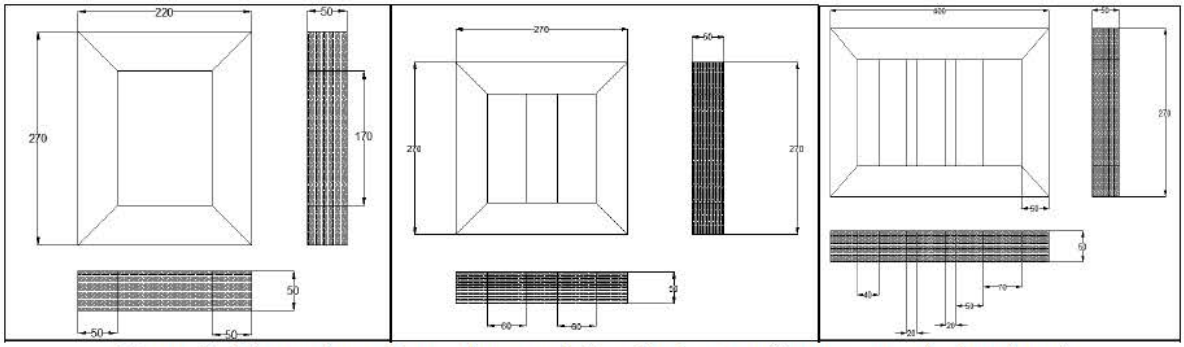


Figure 2 Dimension of two, three and five limbs transformer core design (mm)

There have 3 tests for testing every transformer design. The first test is an open circuit test, a second test is a short circuit test and last test is a load test where the load is fixed. The circuit connection is shown in Figure 4

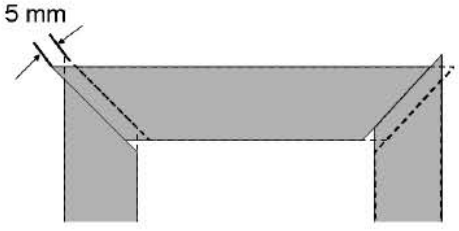


Figure 3 Transformer core type with stagger yoke

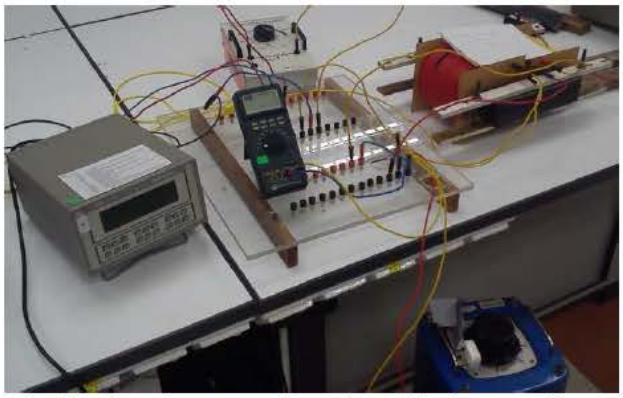
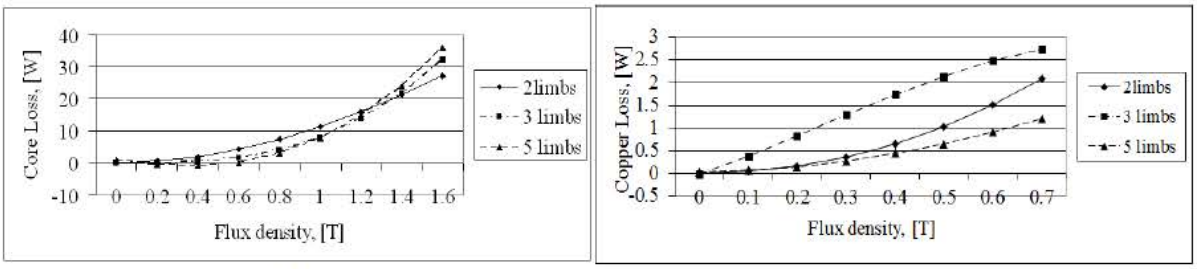


Figure 4 The circuit connection of two limbs transformer core

Result

From the measurement is found some data like power, flux leakage and total harmonic distortion of flux for each different flux density. The core loss transformer data is found from the no-load test, which is the variation of the overall core loss graph with flux density in the single phase core are shown in figure 5 (a). The core loss of transformer assembled with 2 limbs is 18.45% and 32.21% better than the transformer assembled with 3 limbs and 5 limbs respectively at a flux density of 1.6T, 50 Hz.

From figure 5 (b) shows the lowest copper loss is shown at transformer assembled with 5 limbs and the highest copper loss is shown at transformer assembled with 3 limbs over the whole flux density range. Which is the copper loss data find from the short circuit test.



(a) (b)

Figure 5 (a) Core loss and (b) Copper loss of transformer under different limb

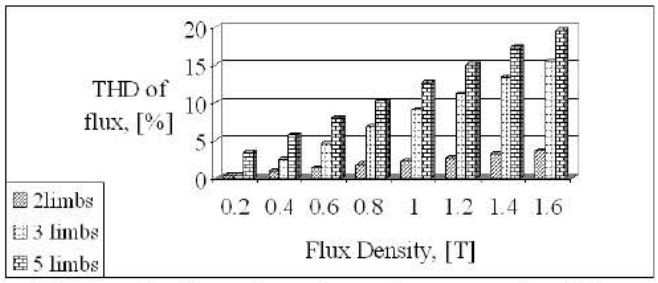


Figure 6 Total harmonic distortion of transformer under different limb

The overall total harmonic distortions of the transformer under different limb are shown in figure 6. The total harmonic distortion of transformer core assembled with 2 limbs is lower than the core assembled with 3 limbs and 5 limbs respectively, over the whole flux density range.

Figure 7 (a) shows that the flux leakage measured at corner joint in the transformer core assembled with 2 limbs is the lowest than the core assembled with 3 and 5 limbs respectively, over the whole flux

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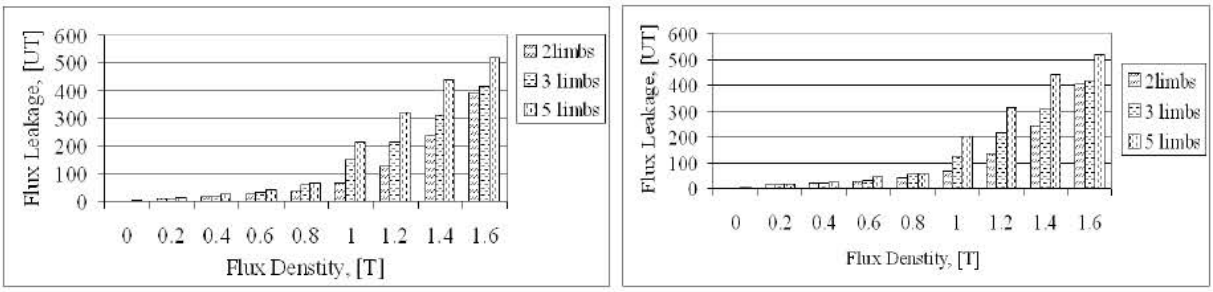

Figure 7 (a) Flux leakages at Corner joint and (b) flux leakages at Limb of transformer under different limb

Table 5 shows the performance of transformer core, which is the efficiency of transformer assembled with 2 limbs is higher than other type transformer core. The voltage regulator of transformer assembled with 5 limbs is lower than other type of the transformer core.

Table 1 Comparison of the transformer performance.

B = 1.2T	2 limbs	3 limbs	5 limbs
P_{load}, [W]	50.2	0.00243	0.00372
Core Loss, [W]	15.908	13.721	14.82
Copper Loss, [W]	7.012	1.851	3.17
Pin, [W]	73.12	15.57443	17.9937
Eff (%)	68.6543	0.015602497	0.02067
$V_{no\text{-}Load}$, [V]	308.9	128.81	32.56
V_{load}, [V]	46.6431	5.44	5.44
VR [%]	5.62263	22.67830882	4.98529

Discussion

For the transformer assembled with 5 limbs show the fewest losses than the other 2 and 3 limbs core because the distance between primary to secondary winding is more distant and the reluctance of the core will increase, hence the fluxes produce is less as indicated in figure 8 and 5 (a) at 0 to 0.6T flux density range and similarly with the harmonic distortion and flux leakage at corner and T-joint.

If the flux density increase from 0.6T to 1.2T, the transformer core under operation. In this condition, the flux flow in near one direction and the total flux flow in the core is more than the core under excited.

Next, the flux density adjusted more than 1.2T in core so the flux density directions have already change because the total flux flow in the core is more. The flux flow not only in the yoke but also flows in the centre limb and it's because the core loss will decrease if the core has more limbs. It is shown in the different limb will cause different losses that produced in the core in similar adjusted.

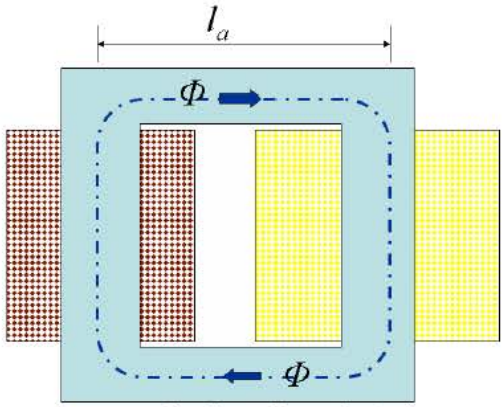

Figure 8 The flux flows in the core

Conclusion

In this paper the performance of transformer affected by the number of limbs are presented. Increase the number of core limb assembling will reduce the efficiency of transformer. It is because the long yoke between primary and secondary winding position is more distant and the reluctance of the core is higher so the flux flow not full toward the secondary winding of the transformer. And flux leakage will increase at corner joint and limb causing the total harmonic distortion of the flux will go up.

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