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Effect of stack of transformer core lamination on losses and flux distribution in 3-phase distribution transformers 1000kVa

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ABSTRACT

This paper describes the results of an investigation on the effect of different amount of layers per stack of core lamination in the three of 3-phase distribution transformers 1000kVA. The investigation involves the variation of power loss, building factor, total harmonic distortion of flux and flux leakages. The power loss and flux distribution have been measured using no load test in three types of model of setting of core built from the same size and type of M5 (CRGO) laminations. The power loss of the transformer core assembled with 1 layer per stack of lamination is 6.58% better than the power loss of the transformer core assembled with 2 layers per stack of lamination and is also 8.31% better than the power loss of the transformer core assembled with 3 layers per stack of lamination, at 1.5T, 50 Hz. The flux leakage at the corner joint in the core assembled with 1 layer per stack of lamination is the lowest among the three of the transformer cores, over the whole flux density range. Total harmonic distortion flux is the largest in the transformer core with 3 layers per stack of lamination and the smallest in the transformer core with 2 layers per stack of lamination. Using 1 layer per stack of lamination in transformer core is more efficient than using the other two the three lamination of the transformer core.

Keywords: *Transformer core, flux distribution, harmonic flux, power loss, building factor (BF)*

INTRODUCTION

The rise in demand for electric power calls for optimum efficiency of power transformers, in particular, since demand for building generating stations and demand from consumers to obtain the power of transmission voltage might have risen five times or more. Each transmission may be 98% efficient, but the accumulated power loss in the interconnecting transformers might be10%. Transformer iron losses can be reduced either by improving the quality of the steel or by using better building and design techniques. The use of grain-oriented silicon-iron has been the main beneficial factor in increasing transformer efficiency, but it has major disadvantage because it has high stress sensitivity [1]. The efficiency of a transformer core is also largely dependent upon the design of number of core lamination.

The iron loss of a transformer core is usually greater than the nominal Epstein loss of the core material and the increased loss can be expressed in terms of the core Building Factor (B.F), the ratio of core loss to nominal loss. [2, 3]

Silicon steel continues to be the most useful magnetic core material of transformers, rotating machines and possessing the properties needed for such equipment. Grain oriented grades of silicon steel are usually used in distribution and power transformer. The user's requirements for transformer core are mainly: a lower core loss for the reduction of transformer loss, a lower magnetostriction for the production of a low noise transformer, and the possibility of operation at a higher induction for compact design and low cost. [4] Around the turn of the 19/20th century it was found that raising the resistivity of iron by alloying with silicon greatly helped to restrain the flow of eddy currents [5,]. That is possible to reduce power loss.

The objective of this investigation is to know the power loss of the transformer core of identical geometry built and grades of electrical steel (M5 grades material) with Cold Roll Grain Oriented (CRGO) 3% Silicon iron assembled with different number of layers per stack of transformer core laminations.

EXPERIMENTAL APPARATUS AND MEASURING TECHNIQUES

Three phases with 3 limb stacked cores are assembled with T-joint 90° mitred overlap corner joints is shown in Figure 1. The outer core dimensions are 970 mm x 780 mm with the limb of 150 mm wide. The transformer cores are assembled using 0.3 mm thick of laminations of M5 grain-oriented silicon iron (CRGO) with a nominal loss of 1.12 W/kg at 1.5 T. And each layer per stack of lamination has overlap length of 10 mm from adjacent layer per stack of lamination when setting the transformer core lamination as shown in Figure 2. The transformer cores assembled with 1 layer per stack comprises of 20 layers of lamination and the transformer core assembled with 2 layers per stack comprises of 20 layers of core lamination too. The other transformer core assembled with 3 layers per stack comprises of 21 layers of core lamination.

Each core could be energized 1 T to 1.8 T with less than 1.5% third harmonic distortion and the power loss is measured with repeatability better than ± 1% using a three phase power analyzer as indicated in Figure 4. Flux leakages at corner joint are measured by magnetic field meter.

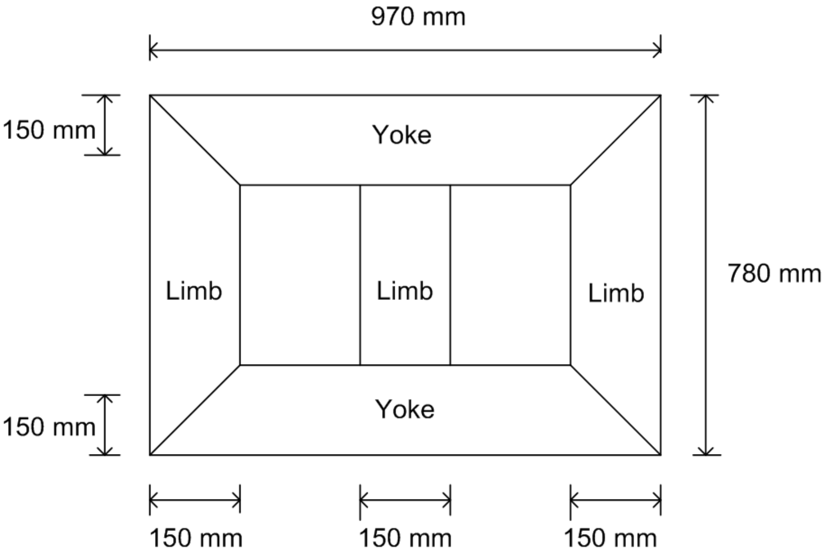


Figure 1. Dimension (mm) of 1000 kVA transformer core model.

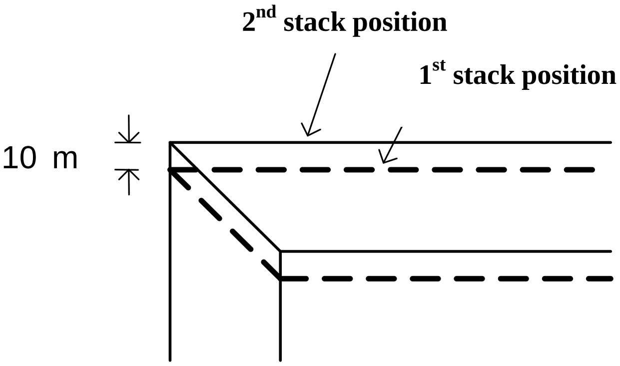
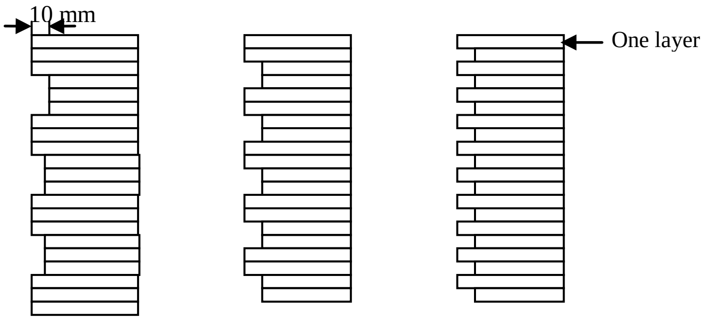


Figure 2. Layout of transformer core lamination at corner joint.



3 layers per stack of core lamination

2 layers per stack of core lamination

1 layer per stack of core lamination

Figure 3. Setting number of layer per stack for each transformer core see from the corner side.

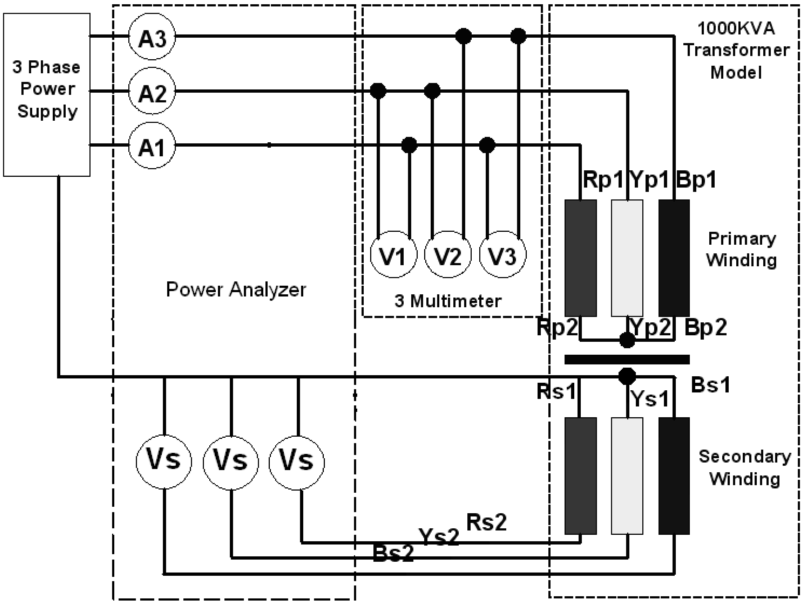


Figure 4. Test Circuit for Overall Power Loss measurement.

RESULT AND DISCUSSION

The total no-load core loss is a function of many factors which tend to make the localized internal loss distribution non-uniform. Rotational flux at joints, interlaminate (normal) flux, time varying harmonic components as well as flux non-uniformity due to the complex magnetic path in many stacked cores all cause additional losses. [6] Figure 5 shows the variation of overall power loss with flux density in the three phase cores. It can be seen that the power loss from 1 layer per stack increases up to 6.58% when number of layers per stack of core lamination is 2 layers. And the power loss from 1 layer per stack increases up to 8.31% when number of layers per stack is 3 layers at flux density 1.5T, 50Hz.

The B.F of each core reaches a peak at around 1.5 T as shown in Figure 6. The distortion of losses is the lowest in the core assembled with 1 layer per stack of lamination than the B.F of the core assembled with 2 layers per stack and 3 layers per stack of lamination over the whole flux density range. There are several differences in the power loss variation in the three cores. The transformer core assembled with 3 layers per stack of lamination has the largest rotational flux in the Corner joint.

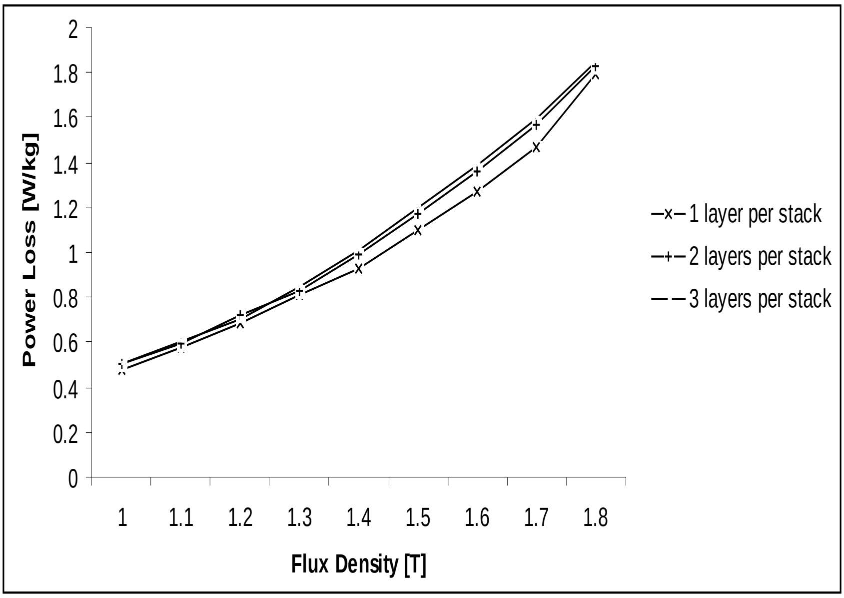


Figure 5. Graph Power Loss from measurement.

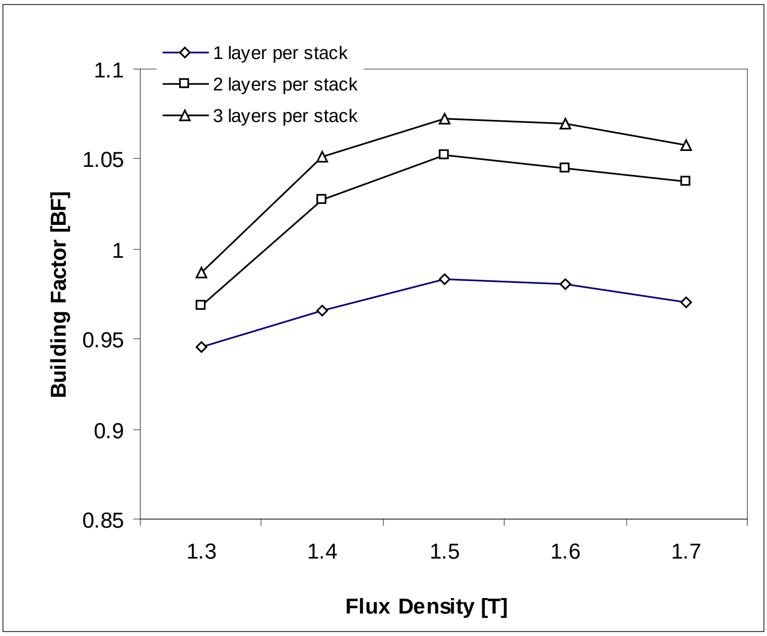


Figure 6. Building factor for different layer per stack of transformer core.

The flux comes from magnetic material in the transformer core can be divided into main flux and flux leakage. The main flux returns after passing through the core yoke and the core limb. This main flux is produced to convert electrical energy into a certain electrical energy. The flux leakage does not pass through the transformer core and it has no usefulness to the electrical energy conversion of the transformer core. [7] Figure 7 shows that the flux leakages measured at corner joint of the core assembled with 1 layer per stack of lamination is the lowest than the flux leakages at corner joint of the core assembled with 2 layers per stack and 3 layers per stack of lamination, over the whole flux density range.

Flux distortion increases the iron losses of the core so it is important to minimise the harmonic content.[8] The relative magnitudes and phase angles of the harmonic components in the flux-density waveform affect the core loss.[9] Figure 8 shows that the total harmonic distortion of the transformer core assembled with 2 layers per stack of lamination is 10.6% and 12% better than the core assembled with 1 layer per stack of lamination and the core assembled with 3 layers of lamination respectively, at 1.5T, 50 Hz.

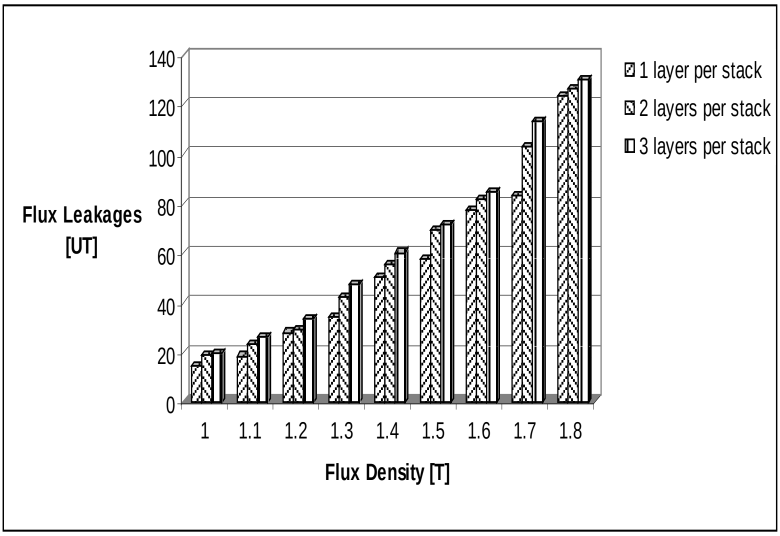


Figure 7. Flux leakages at Corner Joint.

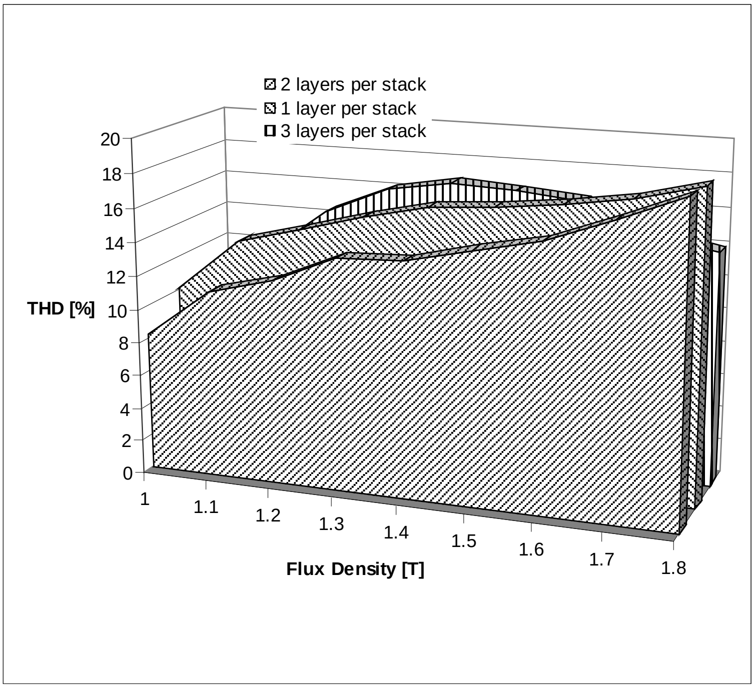


Figure 8. Total Harmonic Distortion of flux.

CONCLUSION

From the result of an investigation we can find that there are the smallest power losses, the smallest Building Factor and the smallest flux leakage at the core assembled with 1 layer per stack of core lamination. Although the smallest total harmonic distortion of flux is the transformer core assembled with 2 layers per stack of lamination. But the core assembled with 1 layer per stack of core lamination is more efficient than the core assembled with 2 layers per stack and 3 layers per stack of core lamination, respectively.

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