COMPARISON ON LOSSES AND FLUX DISTRIBUTION BETWEEN TWO 3-PHASE DISTRIBUTION TRANSFORMERS 1000KVA ASSEMBLED WITH AIR GAP AND WITHOUT AIR GAP OF TRANSFORMER CORE LAMINATION

I.Daut, Dina M.M. Ahmad, S. Zakaria and S. Taib

School of Electrical System Engineering, Universiti Malaysia Perlis (UniMAP),
P.O Box 77, d/a Pejabat Pos Besar
01007 Kangar Perlis, Malaysia
Email: ismail.daut@kukum.edu.my, dina@kukum.edu.my

Abstract.- This paper describes the result of an investigation on the effect of air gap of core lamination in two 3-phase distribution transformers 1000kVA. The investigation involves the variation of power loss, building factor, the third harmonic distortion and flux leakages. The power loss and flux distribution have been measured using no load test in two types of model of setting of core built from the same size and type of M5 (CGO) grades material of laminations. And the loss of the transformer core without air gap of layer joint of core lamination is 2.75% better than the loss of the transformer core with air gap of layer joint of core lamination at 1.7T, 50 Hz. The flux leakage at the corner joint in the core without air gap of layer joint of lamination is lower than that in the transformer core with air gap of layer joint of lamination, over the whole flux density range. The third harmonic distortion of flux is smaller in the transformer core without air gap of layer joint of lamination and larger in the transformer core with air gap of layer joint of core lamination. Using the type without air gap of layer joint of lamination in transformer core is more efficient than the other types of transformer core lamination.

Key words: Transformer core, flux distribution, power loss.

1. Introduction

Transformer represents the largest capital investment in the distribution section of a power system and provides the best opportunity to make the system more efficient whenever possible. The efficiency of transformer can be as high as 99% but because transformer is employed to a large extent throughout an electrical system distribution, the accumulative losses are significant. Reducing the waste of electrical energy is still the highest priority especially since losses in transforming electrical power can amount 4.5% of all energy generated and about one third of this is dissipated in distribution transformer. Efficiency and cost reduction have become so important for the production of power transformer core. [1] 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) that is the ratio of core loss to nominal loss. [2,3,4]

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. [5]

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) with 3% silicon iron assembled with and without air gap of transformer core laminations.

2. Experimental apparatus and measuring techniques

Two 3-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 two cores are assembled using 0.3 mm thick of laminations of M5 grain-oriented silicon iron (CGO) with a nominal loss of 1.12 W/kg at 1.5 T. And each layer has overlap length of 10 mm from adjacent layer when setting the transformer core lamination as shown in Figure 2. Each core comprises of 20 layers in the arrangement. The type with air gap of core lamination shows that the 1st to 4th layers and 17th to end of layers of core lamination have not air gap but for 5th to 16th layers of core

1-4244-1435-0/07/$25.00©2007 IEEE

lamination have 1 mm air gap between joint of layer of core lamination as shown in Figure 3.

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 shown in Figure 4. Flux leakages at corner joint and T-Joint are measured with magnetic field meter.

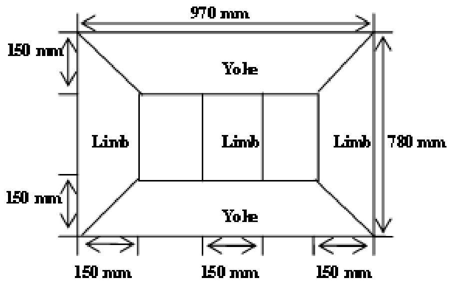

Figure 1: Dimension (mm) of 1000 kVA transformer core model

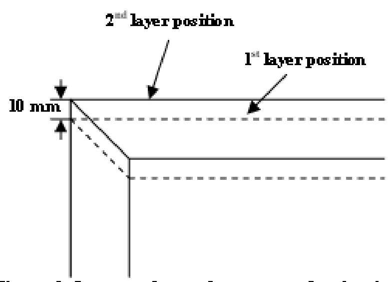

Figure 2: Layout of transformer core lamination at corner joint

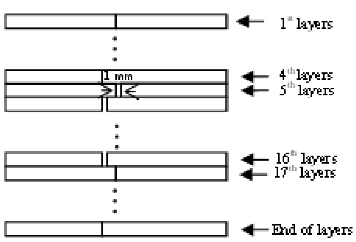

Figure 3: Shows setting of transformer core from side.

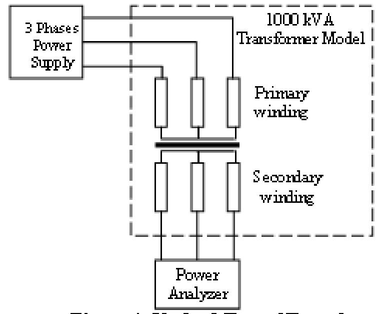

Figure 4: No-load Test of Transformer

3. Experimental 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. The power loss of the transformer core assembled without air gap of layer joint of core lamination is 2.75% better than the loss of the transformer core assembled with air gap of layer joint of core lamination at 1.7T, 50 Hz.

The B.F of each core reaches a peak at around 1.5 T as shown in Figure 6. The distortion of losses is lower in the core assembled without air gap of layer joint of core lamination, and at 1.5 T the B.F is 2.25% lower than the B.F of core assembled with air gap of layer joint of core lamination. The B.F of the core assembled without air gap of layer joint of core lamination is lower over the whole flux density range. There are several differences in the power loss variation in the two cores. The layer joint with air gap of transformer core lamination has the larger rotational flux in the Corner joint.

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. Figure 7 shows that the flux leakages measured at corner joint of the core assembled without air gap of layer joint of core lamination is lower than that at corner joint of the core assembled with air gap of layer joint, over the whole flux density range.

Figure 8 shows that the flux leakages measured at T-joint of the core assembled without air gap of layer joint of core lamination is lower than that at T-joint of the core assembled with air gap of layer joint, over the whole flux density range.

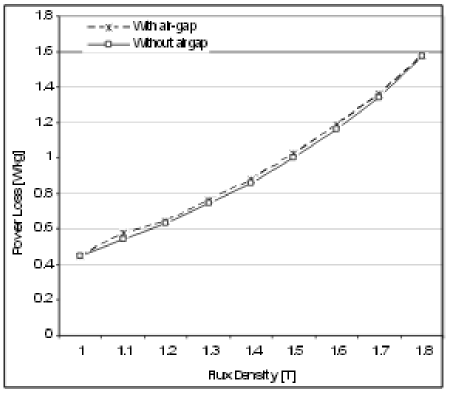

Figure 5: Graph Power Loss from measurement.

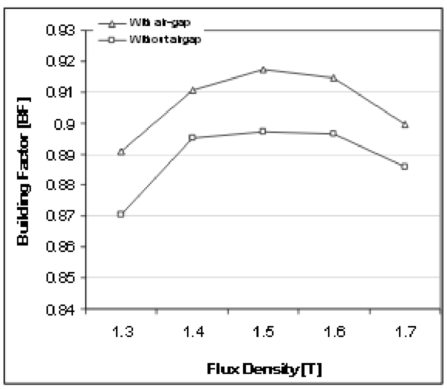

Figure 6: Building factor for type with and without air gap of layer joint of transformer core lamination

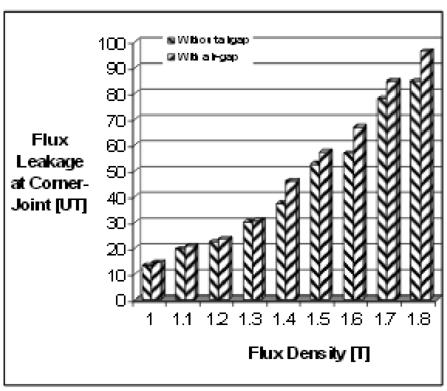

Figure 7: Flux leakage at Corner Joint

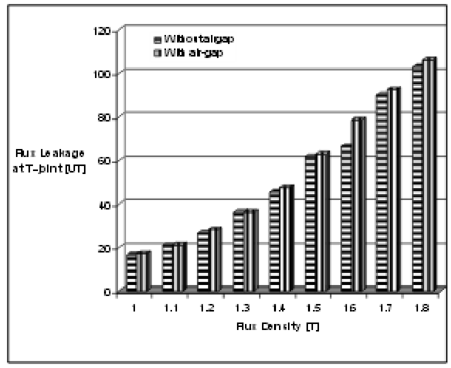

Figure 8: Flux leakage at T-Joint

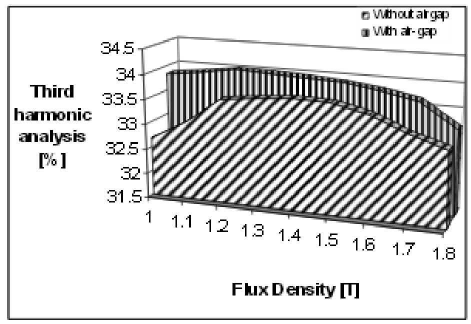

Figure 9: Third harmonic distortion of flux

Flux distortion increases the iron losses of the core so it is important to minimise the harmonic content.[7] The relative magnitudes and phase angles of the harmonic components in the flux-density waveform affect the core loss.[8] Figure 9 shows that the third harmonic flux is larger in the core assembled with air gap of layer joint and smaller in the core assembled without air gap of corner-joint, over the whole flux density range.

4. Conclusion

From the result of this investigation it is obvious that if the core is assembled without air gap of layer joint of lamination we can find smaller power loss, smaller Building Factor, smaller flux leakage and smaller total harmonic of flux. In other words, the core assembled without air gap of layer joint is more efficient than the core assembled with air gap of layer joint of transformer core lamination.

References

[1]. Günther F. Mechler, Ramsis S. Girgis, Calculation of Spatial Loss Distribution in Stacked Power and Distribution Transformers Cores, *IEEE Trans. on Power Del., Vol 13, No. 2*, April 1998.

[2]. Daut, I, PhD Thesis University of Wales, London, pp:65-80, (1992)

[3]. Ahmed M.A. Haidar, I. Daut, S. Taib, S. Uthman, Building factor and clamping effect on 1000 kVA Transformer with 90° T-Joint and 45°Mitred corners Joint, *Proc. of the Int. Confer. On Mod. and Simulation., pp. no. 212*, 2006.

[4]. A.A. Abdul Qader and A. Basak, Building Factor of a 100 kVA 3 Phase Distribution Transformer Core, *IEEE Trans. On Mag., Vol, MAG-18, No.6*, June 1982

[5]. Taguchi S., Yamamoto T., Sakakura A, New Grain-Oriented Silicon Steel with High Permeability 'Orientcore HI-B', *IEEE Trans. On Mag., Vol, MAG-10, No.2*, June 1974

[6]. Daut, I. and Moses, A.J., Some Effects of Clamping Pressure on Localised Losses and Flux Distribution in A Transformer Core Assembled from Powercore Strip, *IEEE Trans. On Mag., Vol, MAG-27, No.6*, November 1991.

[7]. Basak, A. and Moses, A.J., Harmonic losses in a Three Phase Transformer Core, *IEEE Trans. On Mag., Vol, MAG-14, No.5*, September 1978.

[8]. Paresh Rupanagunta, John S. Hsu, Determination of Iron Core losses Under Influence of Third-Harmonic Flux Component, *IEEE Trans. On Mag., Vol, MAG-27, No.2*, March 1991.

[9]. Beckley P., *Electrical Steels for rotating machines*, The Institution of Electrical Engineers, 2002.

url: https://ieeexplore.ieee.org/document/4603874

IEEE

IEEE Catalog Number: 07EX1860C
ISBN: 1-4244-1435-0
Library of Congress: 2007929337

APACE2007

2007 ASIA-PACIFIC CONFERENCE ON APPLIED ELECTROMAGNETICS

4 – 6 DECEMBER 2007

RENAISSANCE HOTEL MELAKA

ORGANIZING COMMITTEE

GENERAL CHAIR
Prof.Dr. Mohamad Kadim Suaidi, *UTeM*

GENERAL CO-CHAIR
Assoc. Prof. Dr. Mazlina Esa, *UTM*

SECRETARY
Imran Mohd Ibrahim, *UTeM*
Mohamad Zoinol Abidin Abd. Aziz, *UTeM*

TECHNICAL PROGRAM CHAIR
Prof. Dr. Mohd Zarar Mohd Jenu, *UTHM*

TECHNICAL CO-CHAIR
Assoc. Prof. Dr. Mohamad Kamal A. Rahim, *UTM*

FINANCE
Suhaila Subahir, *UNISEL*
Mazran Esro, *UTeM*

REGISTRATION
Noor Hasimah Baba, *UiTM*
Maisarah Abu, *UteM*
Abdul Majid Darsono, *UteM*

EXHIBITION & SPONSORSHIP
Assoc. Prof. Abdul Rani Othman, *UTeM*
Imran Hindustan, *UTeM*
Fadeli Hizam Shamsudin, *Winpower Corporation*

INTERNATIONAL ADVISORY COMMITTEE

Prof. Todd Hubing, *USA*
Prof. Michael John Lancaster, *UK*
Prof. Peter Hall, *UK*
Prof. Christos Christopoulus, *UK*
Prof. John Senior, *UK*
Dr. Anthony Centeno, *UK*
Prof. Le-Wei Joshua Li, *Singapore*
Dr. Li Er Ping, *Singapore*
Prof. Ke Wu, *Canada*

CHIEF EDITOR

Prof. Dr. Mohd Zarar Mohd Jenu

EDITORS

Prof. Dr. Mohamad Kadim Suaidi
Assoc. Prof. Abdul Rani Othman
Imran Mohd Ibrahim
Muhammad Syahrir Johal

PUBLICATION
Mohd Shahril Izuan Mohd Zin, *UTeM*
Muhammad Syahrir Johal, *UTeM*
Aziati Husna Awang, *UiTM*

LOCAL ARRANGEMENT & PUBLICITY
Nor Zaidi Haron, *UTeM*
Azmi Awang Md. Isa, *UTeM*
Ahmad Asari Sulaiman, *UiTM*

OPEN CEREMONY
Norhashimah Mohd Saad, *UTeM*
Abd Shukur bin Ja'afar, *UTeM*

TUTORIAL
Assoc. Prof. Dr. Zaiki Awang, *UiTM*

SUB - COMMITTEE

Tan Kim See
Redzuan Abdul Manap
Md Saiful Azri Sahingan @ Samingan
Mohd Faieszal Mohd Selamat
Asreen Anuar Abdul Aziz
Mohd Syaiful Redzwan Mohd Shah
Mohd Hafizan Che' Halim
Mohd Sharim Zakaria
Muhammad Rafie' Che Rose
Dalila Misman

KEYNOTES

KEYNOTE SPEECH 1
KEYNOTE SPEECH 2
KEYNOTE SPEECH 3
KEYNOTE SPEECH 4

DISTINGUISHED MICROWAVE LECTURE (DML)

DML 1
DML 2
DML 3

INVITED PAPERS

INVITED PAPER 1
INVITED PAPER 2
INVITED PAPER 3
INVITED PAPER 4
INVITED PAPER 5
INVITED PAPER 9
INVITED PAPER 10

CONFERENCE PAPERS

APACE 01
APACE 02
APACE 03
APACE 05
APACE 06
APACE 07
APACE 08

APACE 70
APACE 71
APACE 72
APACE 73
APACE 74
APACE 75
APACE 76

APACE 134
APACE 135
APACE 137
APACE 139
APACE 140
APACE 142
APACE 144

Organized By

IEEE AP/MTT/EMC CHAPTER
Malaysia

The IEEE Antennas and Propagation,
Microwave Theory and Techniques and
Electromagnetic Compatibility Chapter, Malaysia

In Collaboration With

Centre for Telecommunication Research and Innovation, CeTRI
Faculty of Electronics and Computer Engineering
Universiti Teknikal Malaysia Melaka, Malaysia

The Department of Radio Communication Engineering
Faculty of Electrical Engineering
Universiti Teknologi Malaysia, Malaysia

Microwave Technology Centre
Universiti Teknologi MARA, Shah Alam, Malaysia

Centre for Electromagnetic Compatibility
Universiti Tun Hussein Onn Malaysia, Malaysia, and

Faculty of Engineering
Universiti Industri Selangor, Malaysia

UTeM UTM UiTM UTHM UNISEL