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NO LOAD LOSS CALCULATION OF 90MVA 132/33kV POWER TRANSFORMER

This report is submitted in accordance with the requirement of
Universiti Teknikal Malaysia Melaka (UTeM) for
Bachelor‟s Degree of Electrical Engineering Technology (Industrial Power) with Honours

by

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as one of the requirements for the award of Bachelor‟s Degree of Electrical Engineering Technology (Industrial Power) with Honours. The following are the members of supervisory committee:

……………………………………………

(Halyani binti Mohd Yassim)

ABSTRACT

Transformer is an omnipresent device where core loss is one of the vital elements in it. High core loss can interrupt the system to perform its best. Thus, this project is carried to obtain data of losses as well as the magnetic plot of transformer by using finite element method and identify methods to minimize losses in the transformer. In order to achieve these purposes, it is necessary to translate the given parameter or dimension into finite element method, calculate no-load losses as well as obtain related data and graphs from finite element method. Meanwhile the obtained results were analysed and suggestions were provided in order to reduce the core losses. This is to ensure this project is fulfilling the objectives as well as a good conclusion can be deduced.

ABSTRAK

Pengubah adalah peranti yang boleh didapati di serata tempat di mana kehilangan merupakan salah satu elemen yang penting baginya. Kehilangan teras yang berlebihan akan menurunkan prestasi sistem. Demi mencapai objectif projek, projek ini dijalankan untuk mendapat data kehilangan serta plot magnet pengubah dengan menggunakan "finite element method" dan mengenal pasti kaedah untuk mengurangkan kehilangan dalam pengubah. Demi mencapai objektif tersebut, parameter dan dimensi yang diberi harus diterjemahkan ke dalam "finite element method", membuat kiraan kehilangan tanpa beban serta mendapatkan data dan graf berkaitan dari "finite element method". Sementara itu, keputusan yang diperoleh dianalisis dan cadangan dibentangkan bagi mengurangkan kehilangan teras. Ini adalah untuk memastikan agar projek ini mampu memenuhi teras objektif serta kesimpulan yang utuh dapat dirumuskan..

DEDICATIONS

To my beloved family

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LIST OF ABBREVATIONS, SYMBOLS AND NOMENCLATURES

FEM	=	Finite Element Method
FEA	=	Finite Element Analysis
CGRO	=	Cold Rolled Grained-Oriented
MVA	=	Mega Volt Ampere
kVA	=	Kilo Volt Ampere
B	=	Magnetic Flux Density
H	=	Magnetization Force
EMF	=	Electromotive Force
3D	=	3 Dimensional
2D	=	2 Dimensional

CHAPTER 1
INTRODUCTION

1.1 Introduction

Transformer is an omnipresent device which can be categorised into step-up as well as step-down transformer. Step-up transformer is where the transformer increases the voltage from the primary winding to secondary winding where the primary winding turns are lesser than secondary winding turns. Once the voltage being stepped up eventually the current will decreases and this results the amount of eddy current loss is lowered. As a result, the transformer can perform better in transferring the power in long distance due to its higher transmission efficiency. Conversely, the step-down transformer was designed oppositely from the step-up transformer.

According to Olivares-Galván *et al.* (2009), the preeminent losses of the transformer can be categorized into 3 types which are tank losses due to high-current bushings, losses in transformer core joints and stray losses in the transformer tank. Those aforementioned losses might cause degradation of the transformer and lower its efficiency. In this project, losses in transformer core were studied.

Core is normally made from a low loss material which is the mixture of iron with small amount of silicon as well as other elements. This combination can increase the magnetic properties as well as lowers the losses. The loss in the core can produce significant outcome to the transformer. Thus, many studies have been carried out in minimising the loss in the core such as study carried by Olivares-Galvan *et al.* (2010), emphasized on important transformer design in order to reduce eddy current losses and study carried by Chang *et al.* (2010), had proven that newly developed step-lap (NSL) core able to lower the core loss. Core losses caused by several factors and the size of cores are one of the main factors in contributing the losses. With an appropriate core size, the eddy current is lowered eventually the amount of heat dissipated from the core is reduced. As a result, the hysteresis losses are also reduced.

Generally, there are two types of core losses includes hysteresis and eddy current losses. Hysteresis can be defined as the time-based dependence of a system‟s output on the current and past input. Meanwhile eddy currents are circular electric currents that being induced within conductor by altering the magnetic field in conductor. Both types of these losses will be explained in chapter 2.

In this project, Finite Element Method (ANSYS MAXWELL) was used to collect and plot the data that are related to the core losses as well as to design and analyse a 2D and 3D transformer. The results obtained were studied in order to improve the efficiency of the transformer by minimizing the amount of losses.

1.2 Problem Statement

Core in power transformer is a crucial unit because it is responsible to generate magnetic flux and holds the windings on it. Unfortunately, tremendous loss occurred in core leads to certain drawbacks of the system. High temperature of the power transformer is mainly contributed by the heat energy generated during the core loss and it is one of the main constraints of the system. This high temperature in power transformer can accelerate the ageing rate of the insulation system. Apart from that, the electrical phenomena such as partial discharge and increment in electrical field intensity also are the factors lead to ageing of the insulation system. As a consequence, the high core loss in power transformer occurred due to the factors as described above can lead to inefficiency of the system. Essentially, core loss is important in designation level as it indirectly affects the manufacturing level whereby the capital cost can be minimised and in the meantime the efficiency of the system can be improved as discussed by Hajipour *et al*. (2011). Although the high temperature can be withstand due to the high quality materials used but the cost in manufacturing is relatively high. In addition, low efficient system requires high operation and maintenance cost. Minimize the core loss which tends to occurred as well as optimization of the operation is an important aspect to consider in order to produce an excellent outcome. As a result, the study of no load loss was carried out and method to minimize the core loss was identified from the study.

1.3 Objectives

i. To obtain data of losses and magnetic plot of transformer using FEM

ii. To identify method to minimize losses in the transformer core

1.4 Working Scope

In order to achieve the stated objectives, several work scopes had been identified. The work scopes are listed as below:

i. Translate the design parameter or dimension into FEM simulation model

ii. Calculate no-load losses

iii. Plot the magnetic field (B) of the core

iv. Compare the simulated result with actual result

v. Give suggestion to reduce the losses

CHAPTER 2
LITERATURE REVIEW

2.1 Introduction

This chapter focuses on power transformer, transformer core, core losses, and Finite Element Method. Power transformer is used to step up or step down voltage in transmission system and distribution system where the working principle of power transformer is similar to normal transformer. Transformer core which usually experience loss is an important element to be studied in order to ensure the efficiency of the power transformer is maintained. Besides, Finite Element Method was used throughout this project.

2.2 Power Transformer

Power transformer is defined as the transformer which rated 500kVA and above. Generally, power transformer is installed in a transmission system or in a distribution system. This type of transformer can be further categorised into 3 groups which are small, medium and large power transformer. Small power transformer has the range between 500kVA until 7500kVA meanwhile medium power transformer has the range between 7500kVA and 100MVA. As for the large power transformer, its rate is above 100MVA. In addition, the specification of the power transformer is selected according to its respective application. Generally, power transformer in a transmission system is responsible to step up the voltage whereas it is used to step down the voltage in a distribution system.

A power transformer is equipped with few basic components which are core, winding, transformer oil, tap changer, conservator, breather, cooling tubes, Buchholz relay and explosion vent. There are two windings wound over the core in a power transformer. The number of turns in each winding is based on the specification of the transformer. A step up transformer has more windings in the secondary coil compared to primary coil whereas for a step down transformer is vice versa.

Besides that, transformer oil has two vital functions in power transformer where it is responsible to provide insulation as well as to cool the core and windings in the same time. Generally, the oil used in the power transformer is in the form of hydrocarbon mineral oil. The purpose of tap changer in the transformer is to vary the output voltage according to the condition of the load. The tap changer will switch in order to provide a higher voltage during the peak load. However, in a sophisticated transformer, the tap changer is an automatic type.

The function of the conservator is to store the transformer oil and it is located above the transformer. The oil level is approximately in the middle of the tank which allows the expansion and contraction of oil. Transformer breather is a container which filled with silica gel. It absorbs the moisture from the air that enters into the tank. This is to prevent the moisture to cause fault towards the transformer. Cooling tubes is one of the important parts in the transformer because it functions to cool the transformer oil. Certain cooling tubes are installed with pump in order to circulate the oil.

Buchholz relay is a protection system in the power transformer. It is operated by emitting the gas formed due to the decomposition of oil during the internal fault. Meanwhile, the explosion vent is used to expel the boiling oil from the transformer during a heavy internal fault. Furthermore, function of the explosion vent is to avoid explosion of the transformer by release the oil out during the heavy fault.

Figure 2.1: Power transformer rating of 40MVA is under maintenance
Source: Purwadi *et al*. (2011)

2.3 Core

Core is used to hold the windings in the transformer besides than giving a low reluctance path to the flow of the magnetic flux. Materials used and geometry of the core are crucial properties in order to optimize the function of the power transformer. The transformer can be inefficient due to poor or inappropriate design even it is made from best materials. According to Marketos *et al*. (2012), factors such as type of steel used, core geometry and stacking configurations are important in no-load loss calculation in the transformer

There are many types of material are used in designing the core yet the material choice is done according to the size and user requirement. Meanwhile the geometry can be categorised into few types such as core construction, core method lamination and type of cores.

2.3.1 Core Construction

Core construction is the way of how the core is being build up. Generally, there are two types of construction which are the stacked core construction as well as the wound core construction. The main difference between both constructions is the number of gaps or joints of the core. Wound core has less or no joints in the core. As a result, the carried flux by the core almost uninterrupted by the gaps. In addition, wound core is very common being used in smaller distribution transformer. Besides that, the drawbacks of this wound core is more costly and required certain techniques to do windings. In contrast, the stacked core construction consists of many joints in it which can result a poor magnetic characteristic. Different T-joints configuration in core such 23 degrees, 45 degrees, 60 degrees and 90 degrees affect the efficiency of the transformer core loss as explained by Haidar and Al-Dabbagh (2013). However, this type of construction is predominating in larger transformer.

2.3.2 Core Lamination

Lamination is another vital factor for a transformer core. According to Collett and Buswell (2011), eddy current can be reduced by using lamination instead of solid core. A good lamination leads the transformer to be highly efficient. There are several factors such as thickness and shape of laminations can determine the quality of the transformer. According to Zhang *et al*. (2009), different thickness of laminations can alter the losses value in the transformer. Surface of lamination is covered with high resistivity mill finish. Olivares-Galvan *et al*. (2013) described that the thickness of laminations should be selected according to the size of the transformer as well as the material of the core. The most common lamination used is E-I shaped. The E-I shaped metal sheets are placed alternately to form a core with a small effective air gap. However, the E-I type is unable to take full advantage of low core losses and high permeability features. D-U shaped lamination is another type of lamination which able to overcome the disadvantages faced by the E-I type. The D-U type enlarges the area in the region where the flux path is perpendicular to the direction of rolling. The main drawback of this kind of lamination is its low versatility. As a result, the „I" shaped lamination is done in order to improve the versatility. The flux in the mentioned type is in the direction of the rolling in all legs of these cores.

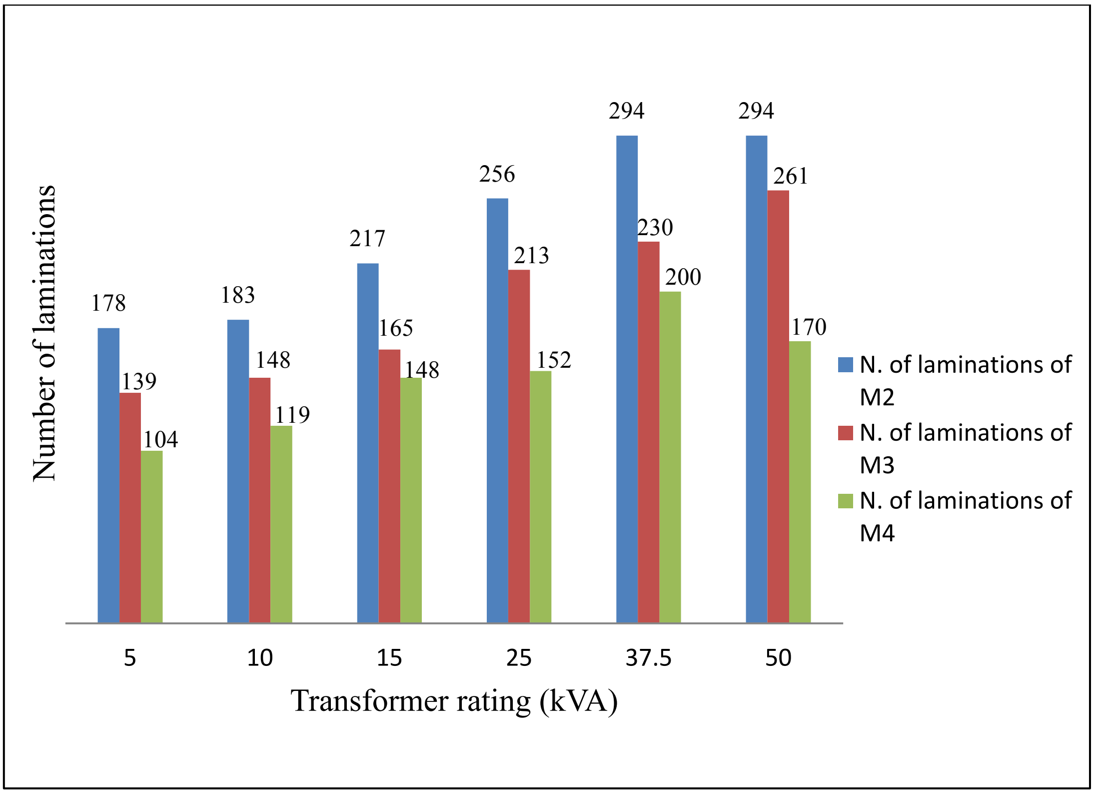


Figure 2.2: Number of core laminations against transformer rating
Source: Olivares-Galvan, Georgilakis *et al*.(2013)

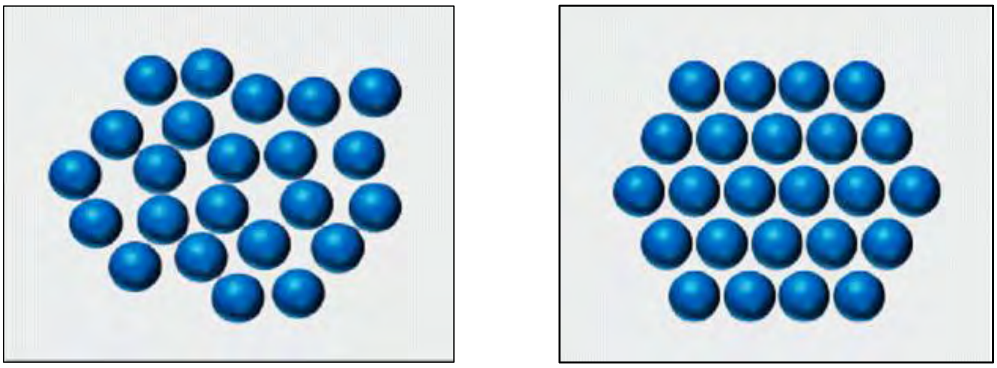
2.3.3 Core Material

Materials that are used to build power transformer core must in the form of magnetic material. Few examples of magnetic materials are soft iron, carbonyl iron, ferrite and others. However the mentioned materials are more suitable for small size transformer and electronic transformer but not power transformer. Normally, power transformer uses Cold Rolled Grain-oriented with steels or amorphous metal to build its core.

Iron is not suitable for power transformer because it has low saturation of flux density especially when in high temperature as described by Du *et al*. (2010). As a result, Cold Rolled Grain-oriented (CRGO) steel or amorphous is used to make the power transformer core. This is because steel is an alloy that comprises of iron and carbon. The CRGO steel is specially processed in order to develop a special grain orientation in the steel and this CRGO steel also produces certain magnetic properties such as low core loss and higher permeability.

Furthermore, silicon is also another element that can be added to this steel in order to improve its physical properties. Important parameters for the physical properties of silicon steels include resistivity, saturation induction, magneto-crystalline anisotropy, the magnetostriction and the Curie temperature. According to Ashbahani *et al*. (2011), an efficient and economical electrical transformer needs a high permeability and low core loss and this can be found in silicon alloys which normally consists of 3% of silicon level. Besides, addition of silicon can increase the resistivity and permeability, decrease the hysteresis loss, and virtually eliminated aging.

Besides that, an amorphous metal is also known as metallic glass or glassy metal. They are typical alloy of iron with Boron, Silicon and Phosphorus. Amorphous steel is hardened during its metallurgical process. As a result, the amorphous steel has a non-crystalline structure which gives higher resistivity compared to crystalline structure. Besides that, the mentioned metal is soft magnetic material which has low coercivity and core loss as well as high permeability. According to Yurekten *et al.* (2013), the core loss in amorphous oriented core is 25-30% lesser than the CRGO silicon steel type and this can improve the efficiency to the transformer. Thus, CRGO is built with amorphous oriented.



Disordered crystalline structure of amorphous steel

Ordered crystalline structure of amorphous steel

Figure 2.3: Different type crystalline structure
Source: Ramanan and Carlen (2012)