Faculty of Electrical and Electronic Engineering Technology

INVESTIGATION OF NO-LOAD LOSS CALCULATION FOR POWER TRANSFORMER WITH DIFFERENT CORE JOINT USING FINITE ELEMENT SOFTWARE

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Bachelor of Electronics Engineering Technology with Honours

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INVESTIGATION OF NO-LOAD LOSS CALCULATION FOR POWER TRANSFORMER WITH DIFFERENT CORE JOINT USING FINITE ELEMENT SOFTWARE

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I declare that this project report entitled "Investigation of no-load loss calculation for power transformer with different core joint using finite element method" is the result of my own research except as cited in the references. The project report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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I hereby declare that I have checked this project report and in my opinion, this project report is adequate in terms of scope and quality for the award of the degree of Bachelor of Electronics Engineering Technology with Honours.

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DEDICATION

My dissertation is dedicated to my family and many friends. I am very grateful to my loving parents, En. Baddrul Sham and Pn. Salinda, whose words of support and push for persistence continue to ring in my ears. My precious brothers and sisters who have never left my side.

I also dedicate this dissertation to my numerous friends and family members who have been there for me throughout the process. I will be eternally grateful for everything they have done for me, especially my fellow friends who have assisted me in developing my technological abilities, as well as the many hours of proofreading and technical competence.

ABSTRACT

The core losses account for about 70% of the total transformer losses, which makes it a fundamental consideration when designing transformers. Transformer no load loss contributes less than 10% of the total losses of transformer. Even though, the no load loss is small, but it affects the transformer prolong capital investment. Due to this scenario, in this work, investigations on the core joint type are vital to see if there any possibility to reduce stray flux (due to air gap) that could reduce the transformer no load (core losses). Ansys Maxwell finite element base software will be the calculation tool.

ABSTRAK

Kerugian teras menyumbang kira-kira 70% daripada keseluruhan kerugian pengubah, yang menjadikannya pertimbangan asas semasa merancang transformer. Transformer tiada kehilangan beban menyumbang kurang dari 10% daripada jumlah kerugian pengubah. Walaupun, kehilangan beban tidak kecil, tetapi mempengaruhi transformer memanjangkan pelaburan modal. Oleh kerana senario ini, dalam karya ini, penyelidikan mengenai jenis sambungan inti sangat penting untuk melihat apakah ada kemungkinan untuk mengurangkan aliran sesat (kerana jurang udara) yang dapat mengurangkan pengubah tanpa beban (kehilangan teras). Perisian asas elemen teratas Ansys Maxwell akan menjadi alat pengiraan.

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TABLE OF CONTENTS

CHAPTER 1

1.1. Introduction

This chapter will discuss about the context of the project regarding the Investigation of No-load loss calculation for power transformer with different core joint using finite element software including the software that used for calculation purposes, description, objectives and conclusion. This chapter also sets out the outline for this project and the paper material.

1.2. Problem statement

The transformers have two types of losses. There were load losses and no-load losses. The former is mainly affected by the windings and coils, while the latter are affected by various factors such as the angle at which the joints are aligned. No-load losses are typically less than 1% of the power rating of transformers. Since they do not vary with the load, they are very costly to operate and can be reduced by proper measurements.

Hence, the developed system presented by this project focused on:

1. Losses on different stages of step core joints.

2. The design of the core due to different type of core joints.

3. Transformers different core losses from time to time.

1.3. Objective

In order for this project to be success, the objectives which need to be achieve are:

- To identify calculation on no load losses in different type of core.
- To identify on the core joint whether to see if there any possibility to reduce stray flux due to air gap.
- To identify on the core joint that can reduce the transformer no load core losses.

1.4. Scope

The project only has one section only. this project only used software. The circuit for the transformers and the core were designed using software implementation. This practice-oriented project is to make sure the designed project can operate while using the different type of core joint for the power transformers weather the no load loss percentage increase or decrease. Using the Ansys Maxwell software, this project needs to calculate the no load losses in using the different type of core joint, such as step lap joints by overlap joints.

1.5. Organization of report

In general, the final report is divided into five chapters: Introduction, Literature Review, Methodology, Results, Discussion, and Conclusion. The background of the research, the project's issue statement, the project's objective, the project's scope, and the report's organization were all discussed in Chapter 1. This chapter would clarify much of the philosophy that is relevant to Chapter 2. Each research has been compared in terms of hardware and the benefits and disadvantages of each research. The processes, strategies, and project preparatio

n used in this project will be addressed in Chapter 3. It would be created a structural model. This chapter will cover the general scope of our project as well as the accomplishment of the target.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will provide previous accomplishments that have been made from other researchers that are relevant to the project. The sources that have been taken have been analysed in detail in order to extract their knowledge regarding their thesis. This chapter will review the details of the no load loss contributes less than 10% of the total losses of transformer, investigation of different type of core joints, and to investigate whether to see if there any possibility to reduce stray flux due to air gap.

2.2 TRANSFORMER LOSSES

Transformers are designed to deliver the required power to the connected loads with minimum losses. Transformer losses are a result of the electrical current flowing in the coils and the magnetic field alternating in the core. The losses associated with the coils are called "load losses", while the losses produced in the core are called "no-load" losses. The losses are illustrated in equation below

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Power Input}} = \frac{P_S}{P_P} \times 100$$

$$\text{Efficiency} = \frac{\text{Power Output}}{\text{Power Output} + \text{Copper Loss} + \text{Core Loss}} \times 100$$

$$\text{Efficiency} = \frac{V_S\, I_S \times PF}{(V_S\, I_S \times PF) + \text{Copper Loss} + \text{Core Loss}} \times 100$$

NO LOAD-LOSSES

No-load losses are caused by the magnetizing current needed to energise the core of the transformer, and don't vary in line with the loading on the transformer [5]. They're constant and occur 24 hours daily, one year a year, irrespective of the load, hence the term no-load losses. They will be categorized into five components: hysteresis losses within the core laminations, eddy current losses within the core laminations, I^2R losses thanks to no-load current, stray eddy current losses in core clamps, bolts and other core components, and dielectric losses. But in this section, we take the Hysteresis losses and eddy current losses that contribute over 99% of the no-load losses, while stray eddy current, dielectric losses, and that I^2R losses thanks to no-load current are small and consequently often neglected. Thinner lamination of the core steel reduces eddy current losses

2.2.1 EDDY CURRENT LOSSES

Eddy current misfortunes are the consequence of Faradys law [1]. When a motor core is rotated in a magnetic field, a voltage, or EMF, is induced in the coils. This instigated EMF makes coursing flows stream, alluded to as whirlpool ebbs and flows. The force misfortune brought about by these flows is known as whirlpool current misfortune. Engines armature centers utilize many, flimsy bits of iron (alluded to as "overlays"), instead of a solitary piece, in light of the fact that the opposition of individual pieces is higher than the obstruction of one, strong piece. This higher opposition (because of more modest region per piece) decreases swirl flows, and thus, vortex current misfortunes. The overlays are protected from one another with a polish covering to keep the swirl flows from "hopping" starting with one overlay then onto the next.

Figure 2.1 show how the eddy current works.

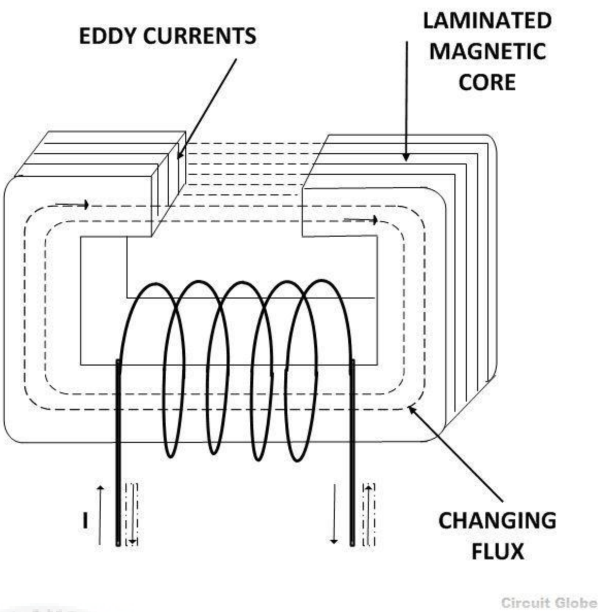

Figure 2.1: A sectional view of the magnetic core is shown in the figure above. When the changing flux links with the core itself, it induces emf in the core which in turns sets up the circulating current called **Eddy Current**.

The core limb clamp plates are in the high leakage flux area and subjected to intense radial field at the end of windings. This will lead to eddy losses in clamp plates ends and local hotspots. The reduction in losses & temperature rise can be achieved by using clamp plates of non-magnetic materials like stainless steel. Slots are provided in clamp plates to reduces these losses. Thus stray & eddy current losses are essentially produced in transformer but can be reduced considerably by adopting suitable available means.

2.2.2 HYSTERESIS LOSSES

Hysteresis losses are caused by magnetization and demagnetization of the core as current flows forward and reverse [10]. As the magnetic force (current) increases, the magnetic flux increases. But when the magnetic force (current) is reduced, the magnetic flux does not decrease at the same rate, but little by little. Therefore, when the magnetic force reaches zero, the flux density still has a positive value. In order for the flux density to reach zero, a magnetic force must be applied in the negative direction. The relationship between the magnetic force, H, and the flux density, B, is shown on the hysteresis curve, or loop. The hysteresis loop area represents the energy required to complete the full magnetization and demagnetization cycle, and the loop area represents the energy lost during this process. Figure 2.2 show the hysteresis cycle of the ferromagnetic.

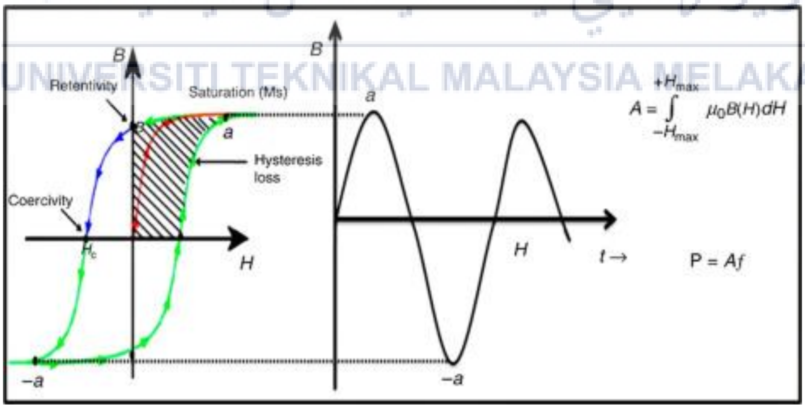

Figure 2.2: Hysteresis cycle of a ferromagnetic multi-domain magnetic material with application of time varying magnetic field.

The biggest contributor to no-load losses is hysteresis losses. Hysteresis losses come from the molecules in the core laminations resisting being magnetized and demagnetized by the alternating magnetic field. This resistance by the molecules causes friction that results in heat. The Greek word, hysteresis, means "to lag" and refers to the fact that the magnetic flux lags behind the magnetic force. Choice of size and type of core material reduces hysteresis losses.

2.3 REDUCING DISTRIBUTION TRANSFORMER LOSSES

Although distribution transformers have relatively high efficiencies, about 99%, the total amount of loss can be considerably high due to the large quantity of distribution transformers used in the electrical grid [7, 8]. As costs of energy and system investment rise, it becomes increasingly important to consider the costs associated with distribution transformer losses. In many cases the cost of distribution transformer losses exceeds the purchase price of the transformer when the two are evaluated on the same basis. If the cost of losses is properly evaluated and added to the purchase price of the transformer, various transformers with different prices and different loss levels can be compared to find the design with the minimum total cost [9]. Transformer efficiency is a function of its loss. Decreasing the no-load losses would result in increased transformer efficiency. Increased efficiency brings long term value, but it can also have a significant impact on its initial cost. The higher the cost of raw materials, such as copper, steel, insulation materials and dielectric fluid, the greater the cost of more efficient transformers. As the efficiency of a transformer improves, the transformer cost increases; this increase is due to the price of the laminated steel core grade. Hence it is vital to maintain the appropriate balance between transformer efficiency and its increased cost. The relationship between transformer cost and efficiency is illustrated in Figure 2.3 below.

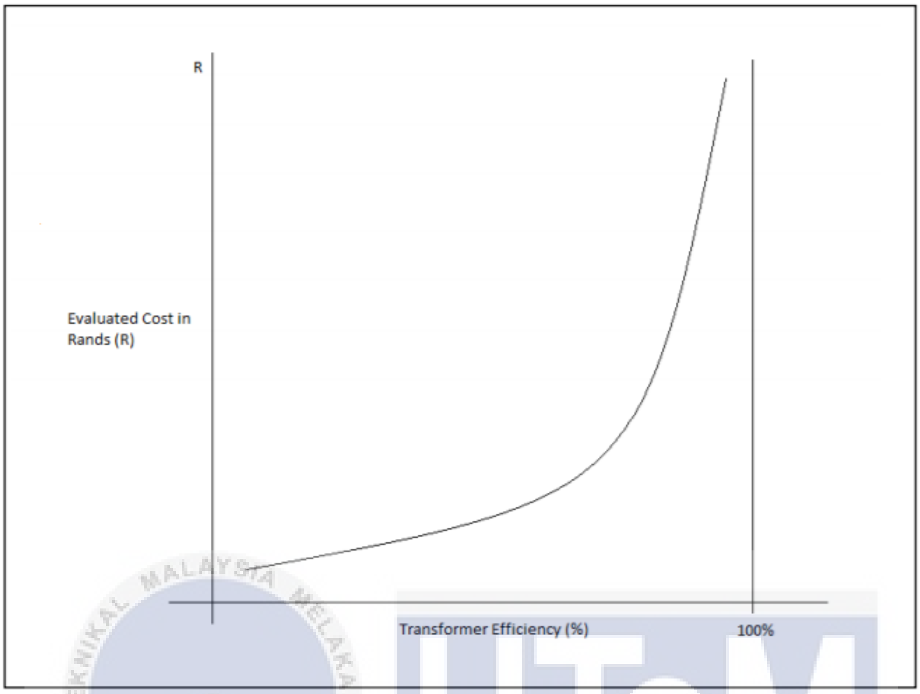

Figure 2.3: Transformer cost and efficiency relationship, an increase in efficiency results in an increase in the capital cost of the transformer

2.4 METHODS TO REDUCE THE LOSSES

There have been numerous studies on transformer efficiencies, the topic of transformer loss reduction. The objective of this research is to find ways to reduce the distribution transformer losses. These are the methods that can reduce the no load-losses in the transformers:

2.4.1 USE OF ELECTRIC SHIELDS

Transformer losses can be reduced by using electromagnetic shields to prevent stray losses [11]. Electromagnetic shields are placed in the transformer tank walls for the reduction of losses. An experiment has been conducted in 2003 where the transformer tank was lined with aluminium foil. In the transformer, the leakage flux is high in the tank walls which causes high-power losses [12].

2.4.2 SMART GRID MONITORING

Distribution losses can be reduced by the use of smart grid monitoring. A study was performed in 2009 on how to utilize a Smart Grid monitoring system in conjunction with loss of life calculations in order to identify overloaded transformers [14]. The study concluded that a Smart Grid has the capability of actively monitoring distribution transformers, which if applied to Smart Grid software or a multi-agent, has the ability to identify overloaded transformers without human interaction. By utilizing actual demand data, unlike many existing programs, the accuracy of calculating transformer loss of life is improved.

2.4.3 AMORPHOUS METAL CORE TRANSFORMERS

Amorphous metals were first produced in the early 1960s. The magnetic properties of these metals were only discovered in the 1970s. The extreme low magnetising losses of these materials made it ideal for use as core steel for transformers. Experimental transformers hat were produced with amorphous metal ores resulted in a 70% core loss reduction when compared to conventional transformers [15, 16]. 17 Amorphous metal alloys differ from metals as there is no crystallization of the atoms. Its atoms are bonded in an instructed way similar to that of metal and glass. Amorphous metals are easier to magnetise and demagnetise, hence they have lower losses. Research has found that transformers made by amorphous metals can reduce no-load losses by anywhere between 60 – 70% [17]. Figure 2.4 below show the different between amorphous core and CRGO core.

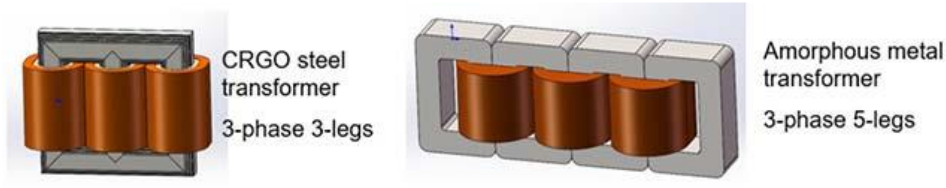

Figure 2.4: The different of Amorphous metal transformer and CRGO steel transformer

2.4.4 INFLUENCE OF TRANSFORMER CORE DESIGN

The magnetic properties of a transformer core are influenced by three basic factors: quality (grade) of material, processing of steel sheet during core manufacture, and core design [20]. Symmetric core design applies to three phase transformers. In a symmetric core, each transformers leg is identically connected to the other two. This results in a 120° radical symmetry which results in a triangular shaped core. The advantage of this type of transformer is that the core is completely symmetrical, thus resulting in a reduction in no-load losses. In wound core transformers, minimum losses occur when the rolling direction of the electrical steel coincides with flux magnetic lines. This condition is not satisfied in the core joints of transformers that are produced from stacks of electrical laminations, because there are air gaps within the joints that cause local disturbances of magnetic flux. The main advantages of wound cores include reduction of joints and the use of the grain direction of the steel for the flux path [21].

2.5 CORE

This section will conclude everything about core in transformers. Three-phase distribution transformers feature planar core types as seen in figure 2.5, i.e. the core limbs and the yoke are in the same plane. These cores are manufactured using either stacked or wound core standard technologies. However these core topologies introduce an asymmetric component in the three-phase AC system, as the outer phases have different electromagnetic properties than the enter phase [18].

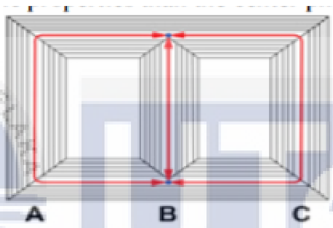

Figure 2.5: Core configuration

A. STACKED CORE

For constructing stacked planar cores, the core limbs and yokes are manufactured by stacking large number offlat sheets of electrical steel on top of one another.

B. WOUND CORE

The wound planar cores usually consist of many individual bodies of different shapes. These wound bodies are manufactured by winding thin electrical steel foils on a mandrel. Usually, the core bodies are cut and opened during the manufacturing process to position the windings on the limbs. The air gap that creeps up from the cutting and opening of the core bodies increases the reluctance of the core and correspondingly the no-load losses of the transformer units [18].

C. TRIANGULAR WOUND CORE

The triangular wound core configuration as presented here consists of three identical wound core rings as seen in figure 2.6. The formation of these core rings is done by continuously winding a lamination of electrical steel on a mandrel. The transformer core is then assembled by arranging these core rings in an equilateral triangle as shown in figure 2.6. All the core limbs, which are formed by two adjacent rings each, are positioned at the corners of the equilateral triangle. As a result, a magnetically symmetric transformer topology is obtained [18].

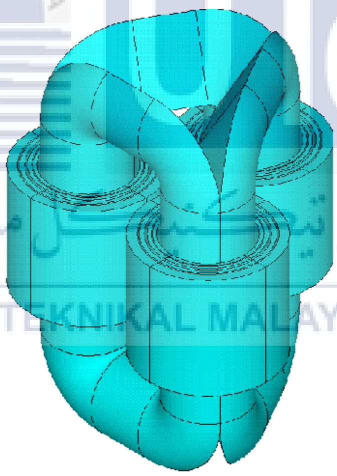

Figure 2.6: triangular wound core design

This section has the advantages of a better core construction involving negligible amount of air gaps and thereby low stray magnetic loss. The filling or the stacking factor is as high as 98% as each core ring limb resembles a semi-circle and two rings combine to form a core limb. The magnetic circuit is balanced in all the 3 phases and hence the exciting currents are also reduced. This reduces the core losses by up to 15-20%. The stray field emissions are less and noise generated is lower by 5-10 decibels [19]. The harmonic content is also lower. Additionally, the material consumption and costs also reduced by about 20% due to its compact footprint as compared to a conventional planar transformer.

2.6 CORE JOINT

Core joint is the place where limbs and yokes meet each other. Joints play an important role in the performance of transformer cores. Due to the importance of improved electrical core performance, transformer manufacturers and some universities are very active in the development of better steel cores. Experimental work is done to arrive at the optimum core joint configuration for a family of distribution transformers [22]. Figure 2.7 shows cross sections of overlap and step lap joints. The quality of joints can affect the performance of the core. Overlap joint and Step lap joint with three steps

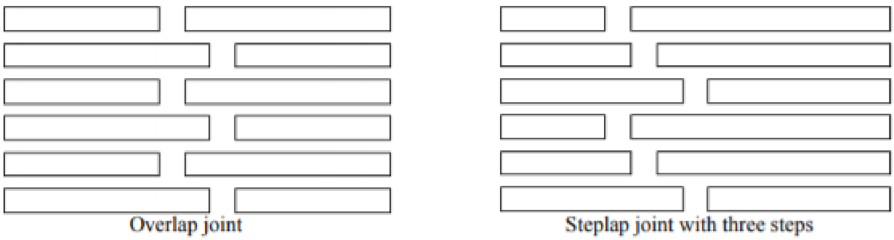

Figure 2.7: Overlap and steplap joints