

# **Faculty of Electrical and Electronic Engineering Technology**



# MUHAMMAD FAISAL BIN BADDRUL SHAM

**Bachelor of Electronics Engineering Technology with Honours** 

2021

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

# MUHAMMAD FAISAL BIN BADDRUL SHAM



Faculty of Electrical and Electronic Engineering Technology

# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2021

# DECLARATION

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.

Signature Student Name MUHAMMAD FAISAL BIN BADDRUL SHAM : Date 11/1/2022 TEKNIKAL MALAYSIA MELAKA UNIVERSITI

# APPROVAL

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.

ШΚ

# 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.

#### ACKNOWLEDGEMENTS

First and foremost, I'd want to offer my heartfelt thanks to the many people and organizations that helped me throughout my graduate studies. First and foremost, I would like to express my heartfelt gratitude to my supervisor, TS. DR. Zulkifli Ibrahim, for his enthusiasm, patience, insightful comments, helpful information, practical advice, and neverending ideas, which have greatly aided me throughout my research and writing of this thesis. His vast knowledge, extensive experience, and professional skills in Electrical Engineering helped me to effectively accomplish my research. This would not have been feasible without his help and supervision. I could not have asked for a better supervisor during my studies.

My heartfelt gratitude goes to my parents and family members for their love and prayers during my studies.

I'd also want to thank you to Universiti Teknikal Malaysia Melaka (UTeM) for allowing me to complete my bachelor's degree program. I am also grateful to the following FTKEE university personnel, co-workers, and classmates, as well as those persons who are not included, for their assistance.

Finally, but not least, thank you to everyone in my course for a wonderful four years of sharing premises with you.

رسيتي تيكنيكل مليسيا ملاك

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

# **TABLE OF CONTENTS**

			I
DEC	LARATION		
APP	ROVAL		
DED	ICATION		
ABS	ГКАСТ		i
ABS	ГКАК		ii
ACK	NOWLEDGEMENTS		iii
TAB	LE OF CONTENTS		iv
<b>CHA</b> 1.1 1.2	PTER 1 INTRODUCTION Introduction Problem Statement	1Error! Bookmark not 1Error! Bookmark not 1Error! Bookmark not	defined. defined. defined.
1.5 1.4 1.5	Scope of Project Organization of Project	3Error! Bookmark not	2 defined.
CHA	PTER 2 LITERATURE REVIEW		4
2.1	Introduction		4
2.2	Transformers Lossses	-	4
	2.2.1 Eddy Current Losses	اوية مستر ت	с 7
2.3	Reducing Distrubution on Transformers Los	sses	, 8
2.4	Method to Reduce the Losses KNIICAL	AL AVSIA MELAKA	9
	2.4.1 Use of Electice shields	INCAT ON THE EARCH	10
	2.4.2 Smart Grid Monitoring		10
	2.4.3 Amorphous Core Metal Transformer		11
25	Core		12
2.6	Core Joints		12
2.7	Impact of Core Joints In No-load Losses		15
2.8	Manufaceture Of Core Joints		18
2.9	Summary		20
СНА	PTER 3 METHODOLOGY		21
3.1	Introduction		21
3.2	Project development		21
	3.2.1 Project Design Development		22
	3.2.2 Specify Excitation		25
2.2	3.2.3 Assign Material		26
5.5 21	Finite Element Method		31 21
5.4	3 4 1 Ansys Maxwell Software		31
3.5	Conclusion		32

#### page

СНАР	TER 4	RESULTS AND DISCUSSION	33
4.1	Introduction		33
4.2	Results and Ana	ılysis	33
	4.2.1 Test results	on the different steps of core joints	34
	4.2.1.1 Sim	ulation results for 5 steps of core joints	34
	4.2.1.2 Sim	ulation results for 7 steps of core joints	36
	4.2.1.3 Sim	ulation results for 9 steps of core joints	38
	4.2.1.4 Sim	ulation results for 11 steps of core joints	40
4.3	Comparison of t	he collected data with all the result	41
4.4	Summary		42
СНАР	TER 5	CONCLUSION AND RECOMENDATIONS	43
5.1	Conclusion		43
5.2	Future Works		44

# REFERENCES

45



#### **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. Noload 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.

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

#### **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**

AALAYS/A

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

Efficiency = 
$$\frac{Power Output}{Power Input}$$
 =  $\frac{P_s}{P_p} \times 100$   
Efficiency =  $\frac{Power Output}{Power Output + Copper Loss + Core Loss} \times 100$   
Efficiency =  $\frac{V_s I_s \times PF}{(V_s I_s \times PF) + Copper Loss + Core Loss} \times 100$ 

#### 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 <sup>2</sup>R 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 <sup>2</sup>R 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 multiagent, 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 **UNERSTITEKNIKAL MALANSIA** 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].



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

# UNIVERSITI TEKNIKAL MALAYSIA MELAKA





Figure 2.7: Overlap and steplap joints

#### 2.7 IMPACT OF CORE JOINTS IN NO LOAD LOSSES

The design of the joints of wound cores has a profound impact on core losses and transformer efficiency. In order to determine the optimum joint design, transformer manufacturers must evaluate accurately the flux density distribution at the joint. This research analyze wound-core misfortune conduct in circulation transformers, as an element of plan boundaries of the joint setup. This examination, completed tentatively on the arrangement of step-lap joint, is validated by limited component technique reproductions [23-24]. In this examination, the impact of the accompanying elements is thought of:

- (1) Overlap length
- (2) Number of laminations per step or group.

Various of materials required to build a transformer, electrical steel is generally the largest component of the total material cost. Table 2.1 shows a comparative analysis of transformer costs by components. Table 2.1 was made taking into account six wound-type transformers, with a range from 15 to 1000 kVA, and the voltage considered was 13200 V-220Y/127 V. The dash (-) is used to separate voltages of different windings [27].

Material	Percentage
Electrical steel	$32.5\pm5.5$
Copper and aluminum	$22 \pm 6$
Insulation	$14.1\pm5.5$
Carbon steel	$16.4\pm8.5$
Fabricated parts	$15\pm9$

#### Table 2.1: Composition of Transformer Material Costs

Optimization of the core has significant impact on the total cost of the transformer. When the performance characteristics of the steel improve, the size of the core can be reduced. Use of better material with improved core 151 joints will permit a higher operating flux density. With this, for a given flux in core, one can reduce core area with higher flux density. If flux density is kept constant, reduction in core size will reduce the mean turn length of copper, which in turn may compensate the increase in copper content on account of extra turns required. As a consequence, less copper and insulation in the coil will be required. With a smaller core and coil, a smaller tank is required, and as a result less insulating oil is required.



Figure 2.8: Relation between a smaller core and the transformer price, when the performance characteristics of the steel improve

The heaviness of conductors and weight of core have inverse conduct; if the heaviness of conductors is decreased the heaviness of core is expanded (see table 2.2). The two plans utilize a similar electrical steel grade (m3). Then again, it very well may be seen that the conductor weight is diminished from 356.94 kg to 329.37 kg also, that core weight is diminished from 600.46 to 562.16 kg in the plans of line 1 and 3. The line 1 plan utilizes m3 steel and the column 3 plan utilizes m4 steel.

Type of	Size of	Weight of	Weight of	Total	No-load	% Z	Magnetic	Electrical
Winding	High-Voltage	Aluminum	Core	Losses	Losses	at	Density	Steel
	Conductor (AWG)	and Copper (kg)	(kg)	(w)	(w)	85° C	(T)	Grade
LHL	2*12	329.37	562.16	5388.9	821.60	1.63	1.676	M3
LH	1*10	195.78	647.38	5561.9	977.9	2.61	1.6939	M3
LHL	2*11	356.94	600.46	5491.1	995.74	1.64	1.677	M4

Table 2.2: Numeric Experiments with a Transformer-Design Program



Figure 2.9: a model of step lap

- Step or book (n). Set of laminations, which can vary between 4 and 20, and this set of laminations forms a cycle.
- Air gap (g). The air gap is the separation between laminations in the direction of rolling.
   This value is less than 3.00 mm in practice.
- Overlap (L). The overlap is the length between the half points of the air gaps of two contiguous laminations in the rolling direction. The typical range of this parameter is 1–2 cm.
- Lamination thickness (T). Grain-oriented silicon steel is graded according to the American Iron and Steel Institute (AISI). Typical designations are [26]: M3-0.009" (0.23 mm) and M4-0.011" (0.27 mm). Considering M3 steel, the number of laminations per core varies from 100 to 400 laminations for the distribution transformer family analyzed in this research.
- Insulation thickness (Ti). Grain-oriented electrical steels are coated with C-2 coating or C-5 over C-2 coating. Typical C-2 coating thickness is 0.0001 cm per surface [28].



Figure 2.10: Core joint (shown 10 lamination per step)

The laminations are put in a staggered fashion to obtain a higher mechanical stability. If the joints are rigid and strong, laminations will not come apart under severe operation conditions, and also the noise which emanates from their vibration during transformer operation will be reduced. This research is to investigate experimentally and to explain theoretically the effects of core parameters on wound-core losses in a distribution transformer [27].

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

#### **2.9 SUMMARY**

For this part discussed about the summary in this chapter. Transformers consists of two different type of losses, Load losses and no-load losses. Eddy current losses and hysteresis losses are the family from the no-load losses. This chapter also conclude with how to reduce the distribution on the no-load losses in transformers. Besides that, core is the heart of the power transformer. It creates a closed magnetic circuit with minimum air gap and minimum magnetic reluctance in order to carry the linkage flux among the windings. In core, there were core joints. The quality of joints can affect the performance of the core. There were two types of core joints such as overlap joints and step lap joints. In this research but the most effective for the no load losses in transformers was the step lap joints that was consist in the wound core. The core joints manufacturing decides to take the wound core to the next level as they reduce the air gap and change material of the core. Lastly for this chapter, this will conclude for the research on the different type of core and the no-load losses consist 10% of the total losses in transformers.

#### CHAPTER 3

#### METHODOLOGY

#### **3.1 INTRODUCTION**

Methodology is an important part which represents a set of guidelines and helps a researcher solve problems with specific methods, techniques, tools, tasks and calculation with software. It provides detailed and accurate information on procedure. Chapter 3 describes the project methodology used to reflect visually all the operations phase of the process to achieve project goals as described at the beginning of chapter 1.

#### **3.2 PROJECT DEVELOPMENT**

In this chapter, the objectives are to do the planning and designing the No load loss for power transformers with different core joints. The design is consisting of one module of different platform which are using the Ansoft Maxwell software. In this project development part will be shown the how to create the design, specify excitation, assign material and the system flowchart.

#### 3.2.1 PROJECT DESIGN DEVELOPMENT

The project design for the no-load loss for power transformers. First of all, launch the Ansoft Maxwell. Then, set the solution type for the project design that use is transient. Then go to draw above to prepare the geometry for the transformers design. The figure below shows how to prepare the geometry for the project.

Magnetic:	
C	Magnetostatic
0	Eddy Current
(•	Transient
Electric:	
0	Electrostatic
С	DC Conduction
	Include Insulator Field
C	Electric Transient
	OK Cancel

Figure 3.1 set the solution type for the design is transient



Figure 3.2 prepare the core for the project design

Name	Value	Unit	Evaluated Value	Description	1
Command	CreateUserDefinedPart				
Coordinate Sys	Global				
DLL Name	RMxprt/TransCore				
DLL Location	syslib				
DLL Version	6.0				
DiaLeg	40	mm	40mm	Outer diameter of leg cr	
DistLeg	100	mm	100mm	Leg center to center di	
DistYoke	150	mm	150mm	Yoke center to center	
Stages	9		9	Number of stages of le	

Figure 3.3 set the parameters for the design project







Figure 3.5 prepare the coil for the geometry

Name	Value	Unit	Evaluated Value	Description
CoilType	2		2	Coil type: 1 for solenoid
WidthIn	42	mm	42mm	Coil width between two
DepthIn	42	mm	42mm	Coil depth between two
RadiusIn	21	mm	21mm	Coil inner fillet radius
ThickCoil	10	mm	10mm	Coil thickness of one side
HighCoil	96	mm	96mm	Coil height
Layers	1		1	Number of layers
GapLayer	4	mm	4mm	Gap between two layers
InfoCore	0		0	0: all coils; 1: one coil o

Figure 3.6 set the parameters for the coil transformers



Figure 3.7 Transformers design for the first data

#### 3.2.2 SPECIFY EXCITATION

This part is to create the excitation for the transformers design. To specify the excitation is to create the coil terminal first for the coil. Then, assign the excitation for the 3 coils terminal that has been made. The conductors for the 3 coils terminal was 76 respectively. The excitation for the coil must have 3 terms. Next, create the windings. The windings voltage was 11268V.



Figure 3.8 create the separate windings for the coil

Winding				×
General Defaults				
Name:	WindingA			
Parameters				
Type:	Voltage 💌	⊖ Solid ⊙	Stranded	
Initial Current	0	A	•	
Resistance:	1	mOhm	•	
Inductance:	0	mH	•	
Voltage:	Vpeak*(1-exp(-50*time))*cos		•	
Number of par	allel branches: 1			
	Use Defaults			_
		ОК		Cancel



## Figure 3.9 Windings data

#### Figure 3.10 assign windings to terminal

# 3.2.3 ASSIGN MATERIAL

The transformers for the design must have to assign the material to get the actual results for the simulation later. The material for the coil is copper as usual. For the core, the material needs to assign on this simulation is M125\_027. The relative permeability for the material was a Nonlinear. The core loss type was electrical steel. Then, that set the whole material for the project design. Finally set the assign mesh operation for the core and coil with the same parameters, set the core loss calculation and set the eddy effect for the design.



Figure 3.11 data set for the B-H curve



Figure 3.12 data set for the coreloss

t Eddy Effe	ect				×
llse checkh	oves to turn on i	off eddu effect	eattings:		ested values
DSE CHECKD	oxes to taillion?	on eddy enec	i settings.	Use sugg	ested values
	Object	Eddy Effect			
TransC	oil1				
TransC	oil1_Separate1				
TransC	oil1_Separate2				
Select	By Name			D	eselect All
		OK	Cancel		1
TERUP	Figure 3.	13 set eddy	y effect fo	or the de	sign
General Use of Settin UN definit	Advanced Advanced checkboxes to tr g will only take e tion in the mater	um on/off core effect if the obj	loss settings ect has a co	ی شع s. Pleasen rresponding	نبو مر سد ote the core loss A MELAM
	Object	Core	Loss Setting	Defined	in Material
	TransCore1		<b>~</b>	[	~
	TransCoil 1			ſ	
	TransCoil1_Sepa	arate1		1	
	TransCoil1_Sepa	arate2		ſ	
۲					>
	Select By Name			Dese	elect All
				ОК	Cancel

Figure 3.14 set core loss for the design

	Element Length Based Refinement $\qquad  imes$
	Name: Length_core 🔽 Enable
	Length of Elements
	Restrict Length of Elements
	Maximum Length of Elements:
	47.596 mm 💌
	Number of Elements
	Restrict the Number of Elements
	Maximum Number of Elements:
	10000
	OK Cancel
A MA	LAYSIA
TER	Figure 3.15 mesh operation for the core
FIRE	
SAIN	Element Length Based Refinement
all	اونية است تتكنيكا مليسيا
	Name: Length_coil → I Enable
UNIVE	RSLENDTHOEDEMENT
	Restrict Length of Elements
	Maximum Length of Elements:
	47.596 mm 💌
	Number of Elements
	Restrict the Number of Elements
	Maximum Number of Elements:
	10000
	OK Cancel

Figure 3.16 mesh operation for the coil



#### 3.3 The Finite Element Method (FEM)

The Finite Element Method (FEM) is a broadly utilized technique for mathematically addressing differential conditions emerging in designing and numerical demonstrating. Common pain points of interest incorporate the conventional fields of primary investigation, heat move, liquid stream, mass vehicle, and electromagnetic potential. The FEM is an overall mathematical technique for settling halfway differential conditions in a few space factors (i.e., some limit esteem issues).



#### **3.4 SOFTWARE**

For this part, the software is used to analyse the calculation for the no load losses based on the literature review data by using the Finite Element Method in Ansys Maxwell software.

# 3.4.1 ANSYS MAXWELL SOFTWARE

ANSYS Maxwell is an exhaustive electromagnetic field re-enactment programming for engineers entrusted with planning and breaking down 3D/2D designs, like engines, actuators, transformers and other electric and electro-mechanical gadgets. ANSYS Maxwell can address static, recurrence space and time-shifting electromagnetic and electric fields.



3.5 CONCLUSION/VERSITI TEKNIKAL MALAYSIA MELAKA

This section generally discusses about the project development, designing the project, specify the excitation for the design, assigning the material and the method of no-load loss calculation for power transformers with using different type of core joints. The performance of the core joints is based on the core design that have applied with different type of core in transformers.

#### **CHAPTER 4**

#### **RESULTS AND DISCUSSIONS**

#### 4.1 Introduction

Result is the most important thing that need to be consider whenever some work or process is being done. As for this chapter, the result can be got from the design and simulation of the transformer from the software and the calculation that will be done later. The detail of the Ansoft Maxwell software has been stated early at the chapter 3. The transient type of solver will be used for this chapter.

#### 4.2 **Results and Analysis**

The step to make the model is being done during the process to record the reading needed for the simulation is being done. To get the reading for the core loss on the power transformer, the first thing is to start with the core loss on the 5 step core joints on the transformers design. As for this project the reading will be have 4 results for the no load losses. Then the simulation will be run to get the reading and the condition of the magnetic flux of the transformers that affecting the model of transformer core. After that, the reading for coreloss (W) also being taken at the same position as the current winding (I) and the reading will be recorded.

# 4.2.1 Test results on the different step of core joints

The test result on step core joints will be taken when there will be only one part of the magnetic flux, current winding, input voltage and average of core loss



# 421.1 Simulation results for 5 step of core joints

Figure 4.2 current windings on the 5 step core joints



Figure 4.3 input voltage on the 5 step core joints



# B[testal] 2.2569e+002 2.1166e+002 1.6379e+002 1.6385e+002 1.977e+002 1.907e+002 2.9039e+001 2.9039e+001 2.9039e+001 2.9039e+001 2.9039e+001 2.9039e+001 2.9039e+001 2.9039e+001 2.9039e+001 2.904e+001 1.907e+002 1.907e+002 2.904e+001 2.904e+001

# 421.2 Simulation results for 7 step of core joints



Figure 4.6 current windings on the 7 step core joints



Figure 4.7 input voltage on the 7 step core joints



Figure 4.8 Core loss on the 7 step core joints

# B[tes1a] 2.3801e+002 2.2329e+002 2.0858e+002 1.9386e+002 1.7915e+002 1.6444e+002 1.4972e+002 1.3501e+002 1.2030e+002 1.0558e+002 9.0868e+001 7.6154e+001 6.1441e+001 4.6727e+001 3.2013e+001 1.7299e+001 2.5856e+000 Time =0.0805s Figure 4.9 magnetic flux on the 9 step core joint ه دره XY Plot 3 Maxwell3DDesign1 🔬 12.50 Curve Info InputVoltage(Wind Setup1 : Transient KNIK UNIVERSIT InputVoltage(WindingB Setup1 : Transient InputVoltage(Win Setup1 : Transient 6.25 0.00 X1 [K] -6.25 -12.50 0.00 80.00 20.00 40.00 60.00 100.00

# 4213 Simulation results for 9 step of core joints

Figure 4.10 current windings on the 9 step core joints



Figure 4.11 input voltage on the 9 step core joints



Figure 4.12 Core loss on the 9 step core joints



# 4.1.2.4 Simulation results for 11 step of core joints

Figure 4.13 magnetic flux on the 11 step core joint



Figure 4.14 current windings on the 11 step core joints



Figure 4.15 input voltage on the 11 step core joints



Figure 4.16 Core loss on the 11 step core joints

#### 4.3 Comparison of the collected data with all the result

Core loss density (PL) is a function of half of the AC flux swing ( $\frac{1}{2}$  B=Bpk) and frequency (f). It can be approximated from core loss charts or the loss equation:

# $PL = aB_{pk}{}^{b}f^{c}$

As for the data that being taken through simulation is done. Then it will be compared to the data that being taken from this simulation about the core loss, magnetic flux and the current winding. There is a big difference in the data collection between the different of the step core joints. As shown that the simulation get the data different from each of the following transformers core joints. This is because on the different of the table about the data will be put below.

5 m				
STEP	CURRENT	MAGNETIC	INPUT	AVERAGE
CORE	WINDING	FIELD (B)	VOLTAGE	CORE LOSS
JOINTS	(A)		(V)	<b>(W</b> )
5 1	ىل مايتى يا ما	2725e	ويبونر 11268يتي	67.4944
	VERSITI TEK	NIKAL MALA'	<u>YSIA MELAK</u>	
7	2.69	2563e	11268	70.1914
9	2.68	3801e	11268	71.1908
11	2.67	2560e	11268	73.1855

 Table 4.1 Calculation result

# 4.4 Summary

From this chapter the result that need to be find for this project have been discussed. Several tests have been done to get the result needed. Then when the result needed have been found it will be compared with all the result that have be done to prove that the no load loss on transformers with different type of core joints that happen during the simulation.



#### **CHAPTER 5**

# CONCLUSION AND RECOMMENDATIONS

## 5.1 Conclusion

Knowing that the losses in electrical devices is important in terms of the exploitation of the device but also in terms of its design. Therefore, accurate simulation models for anticipating the losses are helping the designers in their task to design energy efficient devices. Simulation model of transformer based on FEM is presented. Models are powered with 60 Hz power supply. Flux density distribution in transformer cross-section is calculated as well. Obtained results in all models have proved that transformer at no-load is operating well. Further research will be focused on calculating the core losses for all operating modes and obtaining the efficiency core losses of the transformer, based on simulation models and analysis.

Next, this study proves the transformers consists of two different type of losses, Load losses and no-load losses. Eddy current losses and hysteresis losses are the family from the noload losses. This also conclude how to reduce the distribution on the no-load losses in transformers

As conclusion, this project enables to prove that the no load losses can decrease based on the study and simulation that been made before. Finally, this project has been designed, simulated and proven to be working successfully.

# 5.2 Future Works

For future improvements, of no-load loss on power transformer with different core joints the estimation results could be enhanced as follows:

i) Decrease the step joints for the core.

ii) Include study to find a better and accurate material or different type of transformers design.

iii) Made a real power transformers model so can get the accurate results.



#### REFERENCE

 [1] S.K. Shrivastava
 Retd. GM -BHEL, Founder & Chief Transformer Consultant (Power & Distribution) at TransElectrics Consultancy Pvt. Ltd.
 Published Feb 4, 2019

[2] Sharifian, M.B.B., Faiz, J., Fakheri, S.A. and Zraatparvar, A, "Derating of Distribution Transformers for Non-Sinusoidal Load Currents Using Finite Element Method," ICECS 2003. Proceedings of the 2003 10th IEEE International Conference on Electronics, Circuits and Systems. 14-17 December. Iran: IEEE, 754 – 757.

[3] Jayasinghe, N.R., Lucas, J.R. and Perera, K.B.I.M, "Power System Harmonic Effects on Distribution Transformers and New Design Considerations for K Factor Transformers," IEEE Sri Langka Annual Sessions. September 2003. Sri Lanka: IEEE,

[4] Radmehr, M.; Farhangi, S.; Nasiri, A.; , "Effects of Power Quality Distortions on Electrical Drives and Transformer Life in Paper Industries: Simulations and Real Time Measurements," Pulp and Paper Industry Technical Conference, 2006. Conference Record of Annual , vol., no., pp.1-9, 18-23 June 2006 doi: 10.1109/PAPCON.2006.1673766

[5] Said, D.M.; Nor, K.M.; Majid, M.S.; , "Analysis of distribution transformer losses and life expectancy using measured harmonic data," Harmonics and Quality of Power (ICHQP), 2010 14th International Conference on , vol., no., pp.1-6, 26-29 Sept. 2010 doi: 10.1109/ICHQP.2010.562

[6] Oliveira, Hermes; Montani, Pedro; Picanco, Alessandra; Dias, Jussara; Martinez, Manuel; , "Efficient transformers for medium voltage networks - Analyses and 51 proposal," Electricity Distribution - Part 1, 2009. CIRED 2009. 20th International Conference and Exhibition on , vol., no., pp.1-4, 8-11 June 2009

[17] de Oliveira, H.R.P.M.; Batista, E.L.; Coriolano, D.L.; Martinez, M.L.B.; Neto, E.T.W.; Nunes, A.A.; Diniz, A.M.M.; , "Economical analysis for efficient transformers projects," Modern Electric Power Systems (MEPS), 2010 Proceedings of the International Symposium , vol., no., pp.1-5, 20-22 Sept. 2010

[8] Carlen, Martin; David Xu; Clausen, Johannes; Nunn, Tommy; Ramanan, V. R.; Getson, Douglas M; , "Ultra high efficiency distribution transformers," Transmission and Distribution Conference and Exposition, 2010 IEEE PES , vol., no., pp.1-7, 19-22 April 2010 doi: 10.1109/TDC.2010.5484301

[9] Scofield, J.B.; , "Selection of Distribution Transformer Efficiency Characteristics Based on Total Levelized Annual Costs," Power Apparatus and Systems, IEEE Transactions on , vol.PAS-101, no.7, pp.2236-2242, July 1982 doi: 10.1109/TPAS.1982.317497

[10] Magnetic nanoparticles mediated cancer hyperthermia; Shorif Ahmed, ... Haladhar Dev Sarma, in Smart Healthcare for Disease Diagnosis and Prevention, 2020

[11] Olivares, J.C.; Yilu Liu; Canedo, J.M.; Escarela-Perez, R.; Driesen, J.; Moreno, P.; , "Reducing losses in distribution transformers," Power Delivery, IEEE Transactions on , vol.18, no.3, pp. 821- 826, July 2003 doi: 10.1109/TPWRD.2003.813851 [12] F. J. Vogel and E. J. Adolphson, "A stray loss problem in transformer tanks," in Amer. Inst. Elect. Eng. Trans., Aug. 1954, pp. 760–764.

[14] McBee, Kerry D; Simoes, Marcelo G.; , "Reducing distribution transformer losses through the use of Smart Grid monitoring," North American Power Symposium (NAPS), 2009 , vol., no., pp.1-6, 4-6 Oct. 2009 doi: 10.1109/NAPS.2009.5483980

[15] Ng, H.W.; , "EPRI report-amorphous core transformers show promise," Electrical Insulation Magazine, IEEE , vol.5, no.3, pp.36-38, May-June 1989 doi: 10.1109/57.32448

[16] DeCristofaro N. Amorphous Metals in Electric-Power Distribution Applications.http://www.amorphousmetals.com/downloads/lit/amor\_elec\_pow\_di st\_appl.pdf, last accessed 2 July 2011.

[17] W.J Ross, T.M Taylor, Amorphous metal transformer save energy and capacity investment, GE Industrial and Power system, USA, Electrical Power Research Institute, USA.

[18] T. Steinmetz, J. Smajic, S. Outten, T. Hartmann and M. Carlen, "Benefits of transformers based on triangular wound core configurations," CIGRE paper A2.306, Paris, 2012.

[19] R. Findlay, R. Beimans, D. Mayo, "Intluence of The Stacking Method On The Iran Losses In Power Transformer Cores", IEEE Transactions On Magnetics, Vol. 26, No. 5, September 1990.

[20] Valkovic, Z.; , "Influence of transformer core design on power losses," Magnetics, IEEE Transactions on , vol.18, no.2, pp. 801- 804, Mar 1982 doi: 10.1109/TMAG.1982.1061824

# UNIVERSITI TEKNIKAL MALAYSIA MELAKA

[21] Olivares, J.C.; Yilu Liu; Canedo, J.M.; Escarela-Perez, R.; Driesen, J.; Moreno, P.; , "Reducing losses in distribution transformers," Power Delivery, IEEE Transactions on , vol.18, no.3, pp. 821- 826, July 2003 doi: 10.1109/TPWRD.2003.813851

[22] M.A. Jones, A.J. Moses, & J.E. Thompson, Flux distribution and power loss in the mitered overlap joint in power transformer cores, IEEE Trans. on Magnetics, MAG-9 (2), 1973, 114–122

[23] M. Elleuch and M. Poloujadoff, "New transformer model including joint air gaps and lamination anisotropy," IEEE Trans. Magn., vol. 34, no. 5, pp. 3701–3711, Sep. 1998.

[24] C. Nussbaum, H. Pfutzner, T. Booth, N. Baumgartinger, A. Ilo, and M. Clabian, "Neural networks for the prediction of magnetic transformer core characteristics," IEEE Trans. Magn., vol. 36, no. 1, pp. 313–329, Jan. 2000.

[25] A. Mae, K. Harada, Y. Ishihara, and T. Todaka, "A study of characteristic analysis of the three-phase transformer with step-lap wound-core," IEEE Trans. Magn., vol. 38, no. 2, pp. 829–832,

[26] M. Pietruszka & E.N. Juszczak, Laminations of T-Joints in the transformer core, IEEE Trans. on Magnetics, 32 (3), 1996, 1180–1183.

[27] J.C. Olivares, Distribution transformer design course (in Spanish), EMSA, 1998, Guadalajara, Jalisco, Mexico.

[28] Correspondence with Frank Gaudino, Armco, 6 July 1999.

[29] A.J. Pansini, Electrical transformer and power equipment (Prentice-Hall, USA, 1988).

