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**LAPORAN PROJEK
SARJANA MUDA**

ANALYSIS OF FIVE PHASE TRANSFORMER

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Bachelor of Electrical Engineering (Power Electronic and Drive)

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ANALYSIS OF FIVE-PHASE TRANSFORMER

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**A report submitted in partial fulfilment of the requirements for degree of Bachelor of
Electrical Engineering (Power Electronic and Drive)**

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

YEAR 2014

I declare that this report entitle “Analysis of Five-Phase Transformer” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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ABSTRACT

Beginning in the late 1970s, the first five-phase induction motor drive system was proposed. Since then, there is large number of research has been in placed to develop the multiphase drive systems. Due to that, there is a need to develop a static phase transformation system in order to provide a multiphase output from the available three-phase supply. Three-phase supply are readily available in most area such as industrial premises, power generation and distribution station or from the grid. The study of five-phase transformer is not yet matured and the development of five-phase transformer is still in progress. In this study, the focus is to design and develop a transformer that able to convert a fixed voltage three-phase supply to a five-phase while maintaining its frequency. There are three single laminated cores are used to develop the five-phase transformer by manipulating the winding arrangement to produce five-phase output from three-phase source. Enamelled wires are used in this research due to its thin layer of insulation for efficiency and ability to operate at high temperature. Besides, in this study, the performance of the transformer has been analyzed in term of efficiency and voltage regulation. There are two other parameters that has been analyze are the phase shifts of the output waveform and the voltage ratio from primary to secondary windings. To achieve the objectives, the output voltage should close to sinusoidal in shape and the phase shift for five-phase system is approximately 72° . In addition, total harmonic distortion of five-phase transformer also has been analysed and presented in this report. Thus, this proposed five phase transformer connections, is able to run the five-phase induction motor in the laboratory.

ABSTRAK

Bermula pada lewat tahun 1970-an, sistem pemacu motor aruhan lima fasa yang pertama telah dicadangkan. Sejak itu, terdapat banyak penyelidikan telah dilaksanakan dalam membangunkan sistem pemacu berbilang fasa. Lanjutan dari itu, terdapat keperluan untuk membangunkan system penukar fasa statik bagi mendapatkan bekalan berbilang fasa dari bekalan tiga fasa yang sedia. Bekalan tiga fasa boleh didapati di kebanyakan tempat seperti di premis industri, stesen penjanaan dan pengagihan atau *grid*. Kajian tentang pengubah lima fasa masih belum matang dan pembangunan berkaitan dengannya masih dijalankan. Dalam kajian ini, tumpuan adalah dalam merekabentuk dan seterusnya membangunkan sebuah pengubah yang boleh menukar bekalan kuasa tiga fasa kepada bekalan kuasa lima fasa dengan mengekalkan frekuensi yang sama. Tiga teras pengubah berlapis digunakan untuk membangunkan pengubah lima fasa dengan memanipulasi susunan belitan bagi menghasilkan keluaran lima fasa dari sumber kuasa tiga fasa. Wayar enamel dipilih untuk digunakan dalam kajian ini kerana mempunyai lapisan penebat yang nipis bagi meningkatkan kecekapan dan juga mampu beroperasi pada suhu yang tinggi. Selain itu, tumpuan kajian ini adalah juga untuk menganalisis prestasi pengubah yang dibina dari segi kecekapan dan regulasi voltan. Terdapat dua parameter lain yang perlu dianalisis iaitu anjakan fasa pada keluaran dan nisbah voltan antara belitan utama dan belitan sekunder. Untuk mencapai objektif kajian, voltan keluaran perlu hampir kepada bentuk sinus dan anjakan fasa bagi keluaran lima fasa adalah hampir 72° . Di samping itu, jumlah herotan yang disebabkan oleh harmonik bagi pengubah lima fasa juga akan dianalisis dan diterangkan dalam laporan ini. Dengan itu, pengubah lima fasa yang dihasilkan ini berjaya memacu motor aruhan lima fasa yang terdapat di makmal.

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LIST OF ABBREVIATIONS

A_{core}	-	Cross-sectional Area of the core material
AC	-	Alternating Current
B_{max}	-	Maximum Flux Density in the Core
DC	-	Direct Current
E	-	Rated Coil Voltage
E.M.F	-	Electro-Motive Force
F	-	Operating Frequency
HVAC	-	Heating, Ventilation and Air-conditioning
N	-	Number of turn in winding
N_p	-	Number of turn in Primary winding
N_s	-	Number of turn in Secondary winding
V_p	-	Primary Voltage
V_s	-	Secondary Voltage
P	-	Power
S	-	Rated power
TH	-	Total Harmonic
THD	-	Total Harmonic Distortion
TR	-	Turn Ratio

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

In the early 19th century, there is rapid development in the power system application in many areas such as transmission, distribution and power system appliances. In the year 1970s, there is rapidly growth in the sector of machines [2]. Therefore, there is an interest on five-phase motor drive system increased over years. Recently, multiphase systems are the focus of research due to their inherent advantages compared to the three-phase counterparts [1].

Multiphase transformer that provide precisely controlled multiphase output resulting in low harmonic currents over a wide range of load currents without requiring resistive and inductive tuning when applied to a rectifier system and provide specified output voltage for a given input voltage [3]. Therefore, multiphase transformer system can improve the phasor balance and reduce total harmonic distortion. There are many electrical system require direct current power. Those direct current (DC) is typically produced by rectifying three-phase alternating current (AC) voltage. The rectifiers, yet, induce harmonic distortion in the input line [4].

In the ac-dc rectifier system, multiphase such as 6-phase and 12-phase system is found to be fewer ripples with a high frequency of ripple. The purpose of choosing a 6-, 12-, or 24-phase system is because these numbers are multiple of three. Besides, the design for this kind of system is simple and straightforward. The increase number of phases

definitely enhances the complexity of the system. However, there are none of these designs are available for odd number of phases like 5, 7, 11 etc [1].

1.2 PROBLEM STATEMENT

In the past decade, the sector of machines has growth rapidly. The interest of study five-phase motor drive system has increased over years. The advantages of five-phase transformer over three-phase transformer are low harmonic distortion and the rated current per phase is small. However, the study of five-phase transformer is not yet matured and it is not widely available in industry.

1.3 OBJECTIVE(S) OF THE PROJECT

The objectives of this project are:

- To design and develop a five-phase transformer by converting the three-phase grid supply to a five-phase fixed voltage by maintaining the constant frequency supply
- To analyze the performance of the transformer base on the efficiency and voltage regulation, the phase shift of the output waveform and the voltage ratio (primary winding to secondary winding)
- To analyse total harmonic distortion for five-phase transformer

1.4 PROJECT SCOPE

This project is focus on design and develops a transformer that able to produce five-phase output from three-phase input. Besides, this project is also focus on analyze the performance of a five-phase transformer based on the efficiency and voltage regulation, the

phase shift of the output waveform and the voltage ratio (primary winding to secondary winding). This project is only focus on five-phase transformer and other phases like four-phase, six-phase, seven-phase etc. are not covered. The frequency is fixed to 50Hz. The stability of five-phase transformer is not considered in this project because it is only focused on the phase shift of the waveform and more sinusoidal waveform. Base on the available core; a step-down and 1-to-1 transformers will be designed and developed to test the consistency. The supply voltage per phase on primary side for this transformer is 86.97V due to number of turns on the primary side, estimated rated current is 2.2A and the estimated rated power per phase is 191VA.

1.5 CONTRIBUTION OF RESEARCH

- To gain new knowledge on five-phase transformer since there is not widely used in industries
- To extend the knowledge of five-phase transformer based on the performance analysis of the five-phase transformer

1.6 REPORT OUTLINES

This report consists of five chapters. Chapter one is the 'Introduction'. This chapter will explain about the conceptual and theoretical information regarding the five-phase transformer. It includes the project background, problem statement, objectives of the project, scope of the project, contribution of this research and report outlines.

Chapter two is the 'Literature Review'. This chapter describe about background theory of the transformer and three-phase transformer. Besides, related previous work for this project also included in this chapter.

In this chapter three, it is described about the methodology of the project. It is included the basic design of the project, hardware development, testing and measurement.

Chapter four is the 'Result and Analysis'. The performance of hardware are important to validate the findings accordingly to the objectives of the project and analysis of the hardware and theoretical estimation.

Chapter five is the 'Conclusion and Recommendation'. This chapter is important to conclude the major result of the research. Besides, the recommendations are to improve the project in future.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter introduces and explains the source of idea for design, concept, specification and other information that related to the project. It is found base on the product that have been developed or research by institutions before this project. From this study is to analyze the performance of the transformer which converts the three-phase grid supply to a five-phase fixed voltage by maintaining the constant frequency supply as proposed in [1] as well as achieving the desired objectives.

A literature review is to summarize all the information which is related to the selected area of study. From the literature review, we can reuse or develop the design and also reduce the troubleshooting on hardware by referring to the previous journals.

2.2 THEORY

2.2.1 TRANSFORMER

Since 1830s, transformers have been an essential component in electrical and electronic circuits. Although there are new technologies in some electronic circuits have reduced the need for transformer, but they are still important in many applications [6]. A transformer is a static device to convert the electric power in one circuit to electric power in another circuit with same frequency. A transformer consists of two or more coils of wire wrapped around a common ferromagnetic core. These coils are not directly connected. The only connection between the coils is the common magnetic flux present within the core [5]. One of the transformer windings is connected to a source of ac electric power, and the second (and perhaps third) transformer winding supplies electric power to the load. The transformer winding connected to the power source is called the primary winding or input winding, and the winding connected to the load is called the secondary winding or output winding. If there is a third winding on the transformer, it is called the tertiary winding [5]. The working principle of the transformer is shown in Figure 2.1.

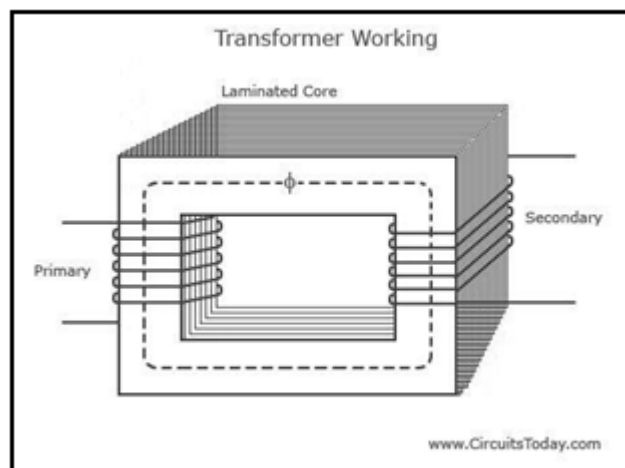


Figure 2.1: Transformer working [7]

In Figure 2.1, it is shown that transformer has primary and secondary windings. The core laminations are joined in the form of strips in between the strips that there are

some narrow gaps right through the cross-section of the core. These staggered joints are said to be ‘imbricated’. There have high mutual inductance in both coils. A mutual electromotive force is induced in the transformer from the alternating flux that is set up in the laminated core, due to the coil that is connected to a source of alternating voltage [7].

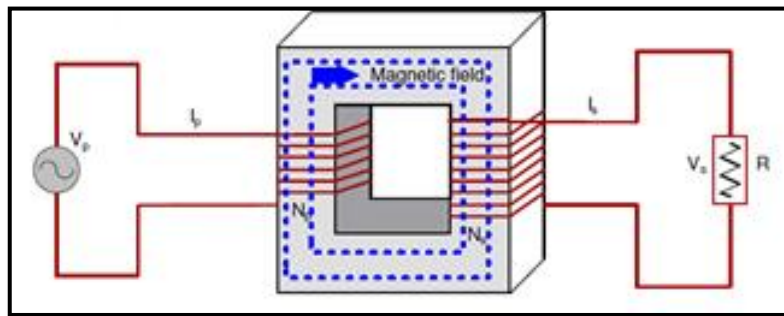


Figure 2.2: Transformer schematic [8]

When an alternating voltage is applied to the primary winding, the back electromotive force (E.M.F) generated by primary is given by Faraday’s law:

$$EMF = V_p = -N_p A \frac{\Delta B}{\Delta t} \quad (2.1)$$

A current in the primary winding produces a magnetic field in the core. The magnetic field is almost totally confined in the iron core and couples around through the secondary coil. The induced voltage in the secondary winding is also given by Faraday’s law:

$$V_s = -N_s A \frac{\Delta B}{\Delta t} \quad (2.2)$$

The rate of change of flux is same as in primary winding. Therefore, dividing the equation (2.1) by (2.2) gives:

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad (2.3)$$

Figure 2.2 show the magnetic circuit has the primary and secondary coils on separate legs. In fact, half of the primary and secondary coils are wound on the two legs, with sufficient insulation between the two coils and the core to properly insulate from each winding and the core. A transformer wound will greatly reduce the effectiveness of the