"I hereby declare that I have read through this report entitle "Analysis of Three to Five-Phase Transformer" and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Power Electronic and Drive)"

Signature : ……

Supervisor's Name : Dr. Kasrul Bin Abdul Karim

Date : ……

ANALYSIS OF THREE TO FIVE-PHASE TRANSFORMER

MOHAMMAD NUR HAKIMI BIN SULAIMAN

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 2015

I declare that this report entitle “Analysis of Three to 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.

Signature : ……..

Name : Mohammad Nur Hakimi Bin Sulaiman

Date : ……..

DEDICATION

This report is specially dedicated to my beloved family

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First of all, I am grateful to ALLAH because can complete my final year project successfully on time.

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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. Enameled 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 frekuesi 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 pasa 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 dianalisiskan 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 di hasilkan 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	-	TurnRatio

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

In the early 18th century, Michael Faraday has done the research about the transformer. End of the research, Michael Faraday had found the electromagnetic induction to contain at all basic elements of transformers for two independent coils and close iron core [1]. After 54 years passed, they find that transformer can be used to transfer energy as we use today for transferring electric energy to power system [1].

In the early 19th century, there are many developments in the power system application in many areas such as transmission, distribution and power system application. In the late 1970s, the first five phase induction motor was being proposed for adjusting speed drive application [2]. Based on that proposed, many researchers had done in developing a multiphase drive system for use in the future [2]. Normally, the system use in the world is a three-phase system that we can get from the grid and for multiphase system

need to have the static transformer for obtain a motives supply by using three-phase system [2]. Lately, since the focus of research of multiphase system about the inherent advantages compared to three-phase counterpart [2].

Method for designing a multiphase transformer that provides 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 that provides a specified output voltage for a given input voltage [3].

Usually, multiphase system found in 6-phase and 12-phase produces less ripple with a higher frequency of ripple in an AC-DC rectifier system. The reason of choice for a 6-, 12-, or 24-phase system is that these numbers are multiples of three and designing this type system is simple and straightforward. However, increasing the number of phases certainly enhances the complexity of the system. None of these designs are available for an odd number of phases, such as 5, 7, 11, etc.. [2].

1.2 PROBLEM STATEMENT

Nowadays, sector of machinery is growing rapidly by following the technology. The study of five phase motor drive system was increasing past, years ago, but still not matured yet. The advantages of five phase transformer are allowed to reduce torque pulsation and higher torque density. Otherwise, Noise characteristics of multi-phase drives are better when compared three-phase drive as demonstrated by Hodge et al. (2002) and Golubev and Ignatenko (2000). Other than that, in five-phase system has rated current per

phase is lower with the same power delivery capacity besides has low Total Harmonic Distortion (THD). The reason is multiphase transformer is produces low voltage ripple due to pure sinusoidal of output signal generating compared power electrical converter by inverter. Hence, by introduce the new five-phase transformer it can solve the voltage and current ripple despite for certain application require in single-speed application. Recently, five phase transformer is still new and not widely used in industry.

1.3 OBJECTIVE(S) OF THE PROJECT

The objectives of this project are:

- To develop static three-to-five-phase transformer by converting the three-phase grid supply to a five-phase fixed voltage by maintaining the constant frequency supply
- To clarify 72^{o} in phase shift between the entire of output phase 'A', 'B', 'C', 'D' and 'E'.
- To analyze the performance of the transformer based on voltage regulation, power factor of five-phase output, Total Harmonic Distortion (THD) during no-load, static load and dynamic load.

1.4 PROJECT SCOPE

These projects focus on develop a static five–phase transformer by using supply from the standard three–phase system. This project only focusses to developed three-to-

five-phase transformer. The voltage supply for this project is 240V and frequency is fixed to 50 Hz. The performance of three-to-five phase transformer is being studies through several experiments: static load of R and RL series impedance and finally with dynamic load (coupled of output transformer with five-phase induction motor with rated speed 3000 rpm and 3HP).

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 is explain about the conceptual and theoretical information regarding the five-phase transformer. It includes the project background, problem statement, objectives of the project, the scope of the project, contribution of this research and report outlines.

Chapter two is the Literature Review. This chapter describes about the background theory of the transformer, three-phase and five-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 and hardware development. Chapter four is the Expected Result. The performance of hardware is 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. 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 ideas for design, concept, specification and other information that related to the project. It is found based on the product that have been developed or research by institutions previously. From this study, the main objectives is study the performance of the transformer which converts the three-phase grid supply to a five-phase fixed voltage by maintaining the constant frequency supply well as achieving the desired objectives.

First part of this literature review is about theory of transformers. Second part is cover about theory of three-phase system and wye-wye connection of transformers. Last part is explain about theory of the five-phase system for five-phase inverter and five-phase static transformer.