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LAPORAN PROJEK SARJANA MUDA

TO CONSTRUCT AND ANALYSIS OF FIVE-PHASE INDUCTION MOTOR

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Bachelor of Electrical Engineering (Power Electronic and Drive)

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

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“ I hereby declare that I have read through this report entitle “ To Construct and Analysis of Five-Phase Induction Motor” and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Power Electronic and Drive with Honors.”

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Supervisor’s Name : DR. KASRUL B. ABDUL KARIM

Date : 18 JUNE 2014

I declare that this report entitle “To Construct and Analysis of Five-Phase Induction Motor” 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

One of the most common electrical motor used in most applications is known as Induction Motor. Three-phase and single phase induction motor is common widely used in industry because only three-phase supply is available. But in five-phase induction motor, it is still not be used in general because the information about this motor is not matured yet and the development of five-phase induction motor still not widely available in industry today. Advantage of 5-phase induction motor compare with the previous type which is three-phase and single-phase induction motor is, this motor capable to start and run even on one or two its many stator phase open or short circuited, lower current per phase without an increase voltage per phase, higher reliability and increased power in the same frame. In this project, the focus is to design and develop a motor by using stator frame available in FKE laboratory. There are 24 slot of stator core used to develop five-phase motor, difference with the previous five-phase motor that has been design, the number of stator slot used multiples of five example 20-slot, 30-slot, 45-slot and so on. But in this project will implement in multiple of four (24-slot). The SWG copper wire used to develop motor winding. Besides that, this project focuses on analysis performance of three-phase and five-phase induction motor in term of current, voltage and speed. However the phase shifts between phase-to-phase at the motor also observe. Thus, with this proposed of five-phase induction motor, which can be used in application because nowadays the five-phase motor drive is widely used and easy available in the market.

ABSTRAK

Satu daripada motor elektrik yang biasa digunakan didalam aplikasi hari ini ialah motor aruhan. Motor aruhan tiga-fasa dan satu-fasa biasanya digunakan secara meluas didalam industri kerana bekalan tiga-fasa mudah didapati. Tetapi didalam motor lima-fasa masih tidak digunakan secara umum sebab maklumat berkenaan motor ini masih belum matang dan pembinaan motor aruhan lima-fasa masih belum boleh didapti secara meluas di pasaran sekarang. Kelebihan motor aruhan lima-fasa berbanding dengan motor yang jenis sebelum ini iaitu motor tiga-fasa dan satu-fasa, motor lima-fasa ini berupaya mula dan bergerak walaupun satu atau dua fasa stator terbuka atau litar pintas, rendah arus elektrik setiap fasa tanpa menaikkan voltan setiap fasa, tinggi kebolehpercayaan, menaikkan kuasa didalam frame yang sama. Didalam projek ini, hanya tumpu kepada rekabentuk dan pembinaan motor menggunakan frame stator yang sedia ada di dalam makmal FKE. Terdapat 24 slot teras stator yang dugunakan untuk membina motor lima-fasa, berbeza yang pernah di reka bentuk, bilangan slot yang digunakan ialah gandaan lima contohnya 20-slot, 30-slot, 45-slot dan sebagainya. Tetapi didalam projek ini akan dilaksanakan mengunkan gandaan empat (24-slot). Dawai kuprum SWG digunakan untuk membuat gegelung motor. Selain itu, didalam projek ini fokus kepada prestasi analisis tiga-fasa dan lima-fasa motor aruhan dari segi arus elektrik, voltan dan kelajuan. Walaubagaimanapun perbezaan fasa diantara fasa-kepada-fasa pada motor juga diperhatikan. Oleh itu, dengan ini mencadangkan motor aruhan lima-fasa, yang mana boleh diaplikasikan didalam penggunaan sebab pada masa kini pemacu motor lima-fasa sudah digunakan secara meluas dan mudah didapati dipasaran.

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CHAPTER 1

INTRODUCTION

1.1 Background

An induction or asynchronous motor is an AC electric motor in which the electric current in the rotor is needed to produce torque is induced by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal motor, DC machine and large synchronous motors. The rotor for induction motor can be either wound type or squirrel-cage type.

Induction motor with squirrel-cage rotor is the workhorses of industry because of their low cost and rugged construction. When operate directly from line voltages (50 – 60 – Hz utility input at essentially a constant voltage), the induction motor will operate at a nearly constant speed. Induction motor employs a simple but clever scheme of electromechanical energy conversion.

Three phase induction motor are the motors most frequently using in industry. They are simple, rugged, low price, and easy to maintain. They run at essentially constant speed from zero to full load. The speed is frequency-dependent and consequently, these motor are not easily adapted to speed control. In three phase system, there are three single phase line with 120° phase difference. So the rotating magnetic field is having the same phase difference which will make the rotor to move. Beside that the single phase motor also dominant for domestic and low power level, this is because it is used in home appliances and portable machine tool. In general, they are employed when three-phase power is not available. The construction of single phase induction motor is almost similar to the squirrel cage three-phase induction motor except that in case of single phase induction motor, the stator has two windings instead of one-phase as compare to the single stator winding per-phase in three-phase induction motor.

Now this project, the five-phase induction motor is introduced, The construction of five-phase induction motor is almost similar to the squirrel cage three-phase and single-phase induction motor except, they need a five-phase incoming ac voltage and the stator consist of five-phase winding. In five-phase system, there are five phase line with 72° phase difference. Advantages of the five-phase machine over three-phase machine are superior torque density, better efficiency, low torque pulsations, better fault tolerance, and reduced rating per inverter leg. Furthermore, the noise levels of the drive improve as well. The limitation of five-phase machine is that it needs a five-phase power supply or power electronic drive for phase conversion because only three-phase supply is easily available.

1.2 Motivation

In a balance 5-phase induction motor, the five stator phase groups are distribute with a spacing of 72°. Advantage of 5-phase induction motor is, that motor capable to start and run even on one or two its many stator phase open or short circuited, lower current per phase without an increase voltage per phase, higher reliability and increased power in the same frame. The limitation of 5-phase machine is that it needs a power electronic circuitry or special transformer for phase conversion because three-phase supply is only easily available.

1.3 Problem Statement

The purpose of designing and constructing of five-phase induction motor is to observe the characteristic of five-phase induction motor, because nowadays knowledge on five-phase induction motor are not matured yet. The three-phase and single-phase motors, there are widely used and many people have knowledge about it and can be found in almost every production machine today. Besides that, five phase induction motor also are not widely available in the market, because majority of the application is design for three phase and single phase motor only.

1.4 Objective

i. To design and develop three-phase and five-phase induction motor using available single phase motor frame

ii. To analyse the performance of three-phase and five-phase induction motor in term of current, voltage and speed.

1.5 Scope

The scope of this project is to design and analyse of five-phase induction motor by using stator and rotor same as single-phase induction motor that available in the lab. The equipment for the hardware is cooper wire, stator frame, and squirrel cage rotor. The enamelled copper size for winding is 0.7mm and this size ability to carry current capacity as much as 1.2A, while for the stator frame included stator core which is contents 24 number of slot. Maximum supply voltage is 300V. Five-phase voltage supply is not develop in this project but experiment is perform by using available five-phase transformer in the laboratory.

1.6 Report Outline

This report consists of five chapters. The first chapter covers about introduction including background, problem statement and objective of this project. The scope of research and report outline is also included in this chapter.

Then for the second chapter emphasize on theory and principle operation of induction motor. Study about both type of induction motor which are three phase induction motor and five phase induction motor will be carried out. It also mention about the characteristic of the component used in this project.

The following chapter is the methodology which explains in detail the procedures and steps that have been done to complete this project to get result. Design and development of the three phases and five phase motor also explained briefly in this chapter. Besides that, this chapter also discusses the experiment set-up that has been made in order to test the performance of the induction motor.

In chapter four, the result of this project will be shown. The experiment result is used for comparison between three-phase and five-phase induction motor. Several test were implement to observe the performance of induction motor during no-load and with load test. The experiment result analysed to measure the performance of induction motor are voltage, current and speed.

Lastly, chapter five concludes the outcome this project. It also present about how to improve the design of five-phase induction motor and other recommendation in order to provide benefit for future studies.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

An electric motor is a device that converts an electrical energy to mechanical energy. One of the most common electrical motor used in most applications which is known as Induction Motor. This motor is also called as asynchronous motor because it runs at a speed less than synchronous speed. In this project, we need to define what actually synchronous speed. Synchronous speed is the speed of rotation of the magnetic field in a rotary machine and it depends upon the frequency and number poles of the machine. An induction motor always runs at a speed less than synchronous speed because the rotating magnetic field which is produced in the stator will generate flux in the rotor which will make the rotor to rotate, but due to the lagging of flux current in the rotor with flux current in the stator, the rotor will never reach to its rotating magnetic field speed i.e. the synchronous speed.

2.1.1 Faraday's Law of Electromagnetic Induction

In 1831, while pursuing his experiment, Michael Faraday made one of most important discoveries in electromagnetism. Now known as Faraday's Law of electromagnetic induction, it reveals a fundamental relationship between the voltage and flux in a circuit [1]. Faraday's low state:

a) If the flux linking a loop (or turn) varies as a function of time, a voltage is induce between it terminals [1].
b) The value of the induce voltage is proportional to the rate of change of flux [1].

By definition and according to the SI system of units, when the flux inside a loop varies at the rate of 1 Weber per-second, a voltage of 1V is induce between its terminals [1]. Consequently, if the flux varies inside a coil of N turns, the voltage induced is given by

$$E = N\frac{\Delta\phi}{\Delta t} \tag{2.1}$$

Where :

E = induce voltage [V]

N = number of turns in the coil

$\Delta\phi$ = change of flux inside the coil [Wb]

Δt = time interval during which the flux changes [s]

Faraday's law of electromagnetic induction opened the door to a host of practical applications and established the basis of operation of transformers, generator and alternating current motor.

2.1.2 Voltage Induced in a Conductor

In many motor and generator, the coil move with respect to a flux that is fixed in space. The relative motion produces a change in the flux linking the coil and consequently, a voltage is induced according to faraday law. However, in this special (although common) case, it is easier to calculate the induced voltage with reference to the conductors, rather than with reference to the coil itself [1]. In effect, whenever a conductor cuts a magnetic field, a voltage is induced across its terminals. The value of the induced voltage is given by

$$E = Blv \tag{2.2}$$

Where

E = induced voltage [V]

B = flux density [T]

l = active length of the conductor in the magnetic field [m]

v = relative speed of the conductor [m/s]

2.1.3 Lorentz Force on a Conductor

When a current-carrying conductor is placed in a magnetic field, it is subjected to force which we call *electromagnetic* force, or Lorentz force [1]. This force is of fundamental importance because it constitutes the basis of operation of motors, of generators, and of many electrical instruments. The magnitude of the force depends upon the orientation of the conductor with respect to the direction of the field. The force is greatest when the conductor is perpendicular to the field and zero when it is parallel to it. Between these two extremes, the force has intermediate values[1].

The maximum force acting on a straight conductor is given by

$$F = BlI \tag{2.3}$$

Where

F = force acting on the conductor [N]

B = flux density of the field [T]

l = active length of the conductor [m]

I = current in the conductor [A]

2.1.4 Slip, S

Slip of an induction motor is the difference between the synchronous speed and the rotor speed, expressed as a percent (or per-unit) of synchronous speed [1]. The per-unit slip is given by the equation

$$s = \frac{ns - nr}{ns} \tag{2.4}$$