SPEED CONTROLLER FOR SINGLE PHASE AC INDUCTION MOTOR USING PWM

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"Saya akui bahawa saya telah membaca karya ini pada pandangan saya karya ini adalah memadai dari skop dan kualiti untuk tujuan penganugerahan Ijazah Sarjana Muda Kejuruteraan Elektrik (Kuasa Industri)"

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Tarikh : 10/03/05

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Fakulti Kejuruteraan Elektrik
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"Saya akui karya ini adalah hasil kerja saya sendiri kecuali nukilan dan ringkasan yang tiap-tiap satunya telah saya jelaskan sumbernya".

Tandatangan : ....

Nama Penulis : MOHAMAD RIZAL BIN MOHAMAD MASKUM

Tarikh : 10/3/2005

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ABSTRACT

This project revealed a new kind of method toward controlling the speed of single phase ac motor automatically; the new method is calling the Pulse Width Modulation (PWM). A single-phase ac induction motor controller is presented and the PWM frequency control part of the operation is verified experimentally. The application for this ac motor controller is existing single-phase ac induction motors less than ½ hp. The ac motor controller is a VFD (variable frequency drive). The IGBT (Insulated Gate Bipolar Transistor) are configured in a full H-bridge with unipolar voltage switching. A variable frequency output waveform is generated by the inverter to run a motor at variable speeds that is directly proportional to this range of frequencies. In this report, it will state the theoretical result that will be obtained. Despite of that, it will also give the theoretical result through a simulation analysis process through a software program. In fact, this will also explain the operation of the alternating current motor based on the theoretical method, which also include the component that was use to build the hardware.

ABSTRAK

Projek ini mendedahkan mengenai kaedah baru bagi mengawal kelajuan motor arus ulang-alik satu fasa secara automatic. Kaedah yang digunakan adalah dengan menggunakan kaedah *Pulse Width Modulation* (PWM). Sebuah motor arus ulang alik satu fasa dan PWM kawalan frekuensi adalah sebahagian daripada operasi yang menerangkan secara eksperimentasi. Applikasi ini mengunakan sebuah motor induksi arus ulang alik yang berkuasa kurang dari 1 kuasa kuda. Kawalan umtuk motor arus ulang alik ini adalah VFD (*Variable Frequency Drive*). Di mana IGBT (*Insulated Gate Bipolar Transistor*) telah dikongfigurasikan kepada sebuah *H-bridge* penuh dengan satu polar voltan pensuisan. Frekuensi pada gelombang keluaran yang dijanakan oleh inverter untuk mengerakkan motor pada kelajuan yang boleh dilaras dalam lingkungan jarak frekuensi yang ditetapkan. Di dalam laporan ini menyatakan secara teori keputusan yang diperolehi. Selain itu juga laporan ini menyatakan keputusan yang diperolehi melalui analisis semasa proses simulasi pada litar dan ujikaji pada *hardware* yang dibina. Selain itu juga ianya menerangkan secara teori berkaitan dengan operasi motor arus ulang-alik. Tidak cukup dengan itu komponen yang digunakan bagi menghasilkan *hardware* juga turut disertakan.

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INTRODUCTION

1.1 INTRODUCTION OF PROJECT

Numerous motor driven appliances operate in our homes and businesses today (refrigerators, air-conditioners, washers, dryers, basement water pumps and etc.). Most of these appliances run on single-phase ac induction motors less than ½ horsepower. And most of those motors lack a proper motor controller in order to run the motor more efficiently. Motors can run more efficiently by varying the speed of the motor to match the load. Motors are rated to operate best at full load. A motor controller that can vary the speed of the motor automatically as the load changes will save energy. Fifty percent of electrical energy is consumed by motors. An estimated 10% of this is wasted at idle and an additional 5% to 10% is wasted when the motor operates at less than full load.

Therefore, the purpose of this project is to describe an ac motor controller that can be applied to existing single-phase ac induction motor appliances, and to demonstrate sinusoidal PWM (Pulse Width Modulation) operation of the design. The prototype of this design experimentally verifies the key concept of pulse waveform generation to produce the switching action of an inverter in order to form a synthesized sine wave that runs an ac induction motor. The motor controller of this design is a PWM-inverter configuration. The dc voltage for circuit is taken from dc power supply.

The PWM drives the gates of the power transistors in the inverter. The inverter synthesizes an ac sine wave from the dc voltage by the switching intervals of its power transistors. The switching intervals are determined from the duration of the pulse from the PWM. The ac induction motor then synthesizes this chopped signal from the inverter into an ac sine wave, because the motor's inductance smoothes out the "notches" in the waveform. The motor will then run at a speed proportional to the frequency of this signal. This design is intended to be an interface between the ac source and the motor in order to regulate the motor speed of an appliance to match the load efficiently. The load requirements are determined by feedback from sensors to the PWM waveform generators.

The small-signal waveforms from the PWM shape the high voltage sinusoidal output waveform that runs the motor. The sine wave determines the frequency of the output waveform applied to the load. The triangle wave determines the switching frequency by the IGBT (Insulated Gate Bipolar Transistor) of the inverter. The resulting pulses from the comparison of the sine and triangle waves turn on the switches. The speed of the motor varies in direct relationship to the frequency.

1.2 OBJECTIVE

- To study about PWM and ac motor controller operation
- To construct an ac motor controller from scratch with as many base components as possible.
- To demonstrate the sinusoidal PWM operation of the inverter part of the design that runs an ac motor at variable speeds.
- To control speed for single-phase AC motor.

1.3 PROJECT METHODOLOGY

In the making of a certain project into a successful project, there is must be a plan to ease the working capabilities. For this project, there are two important steps taken to accomplish it. The first phase is the technical background and second phase is the hardware development, this phase will explain detail under here:

a. Technical Background

- First stage, research and collect data about this project from internet, book, journals, magazine and other source about ac motor, speed controller and PWM.
- From the data, create the subsections for project. Study and analyzed the system for each subsections.
- Base on theory, study the circuit and component for each subsection.

b. Hardware Development

- Every subsection has a circuit and their own component. So the circuit works accordingly when the simulation process going on. This process will ease the analysis during simulation test others than the real hardware test.
- After the simulation is through, here come for the real assembling process. Then follow by testing process, in doing so we could have the both information that consist of the real measurement and the simulation one.

- If the simulation process can not be done, then the assembling process of the project involving the real part and component should be continuing. After the testing and analysis toward it, the final result that we have should been compare and through this we will find whether that this project is a successful or not, this could be achieve through the theoretical method approach.
- Finally the final result is about the different between the theoretical ideas and data that we got from the simulation and the analysis that we done to the hardware through testing.

1.4 REVIEW OF EACH CHAPTER

This report consist several chapters, in chapter 2 it will represent the literature study about the theory of an AC motor controller operation, next on chapter 3 this brought you toward the design process for this project and also a bit of description on the proposed module, which explain the every components that been used in every inch of the modules. Meanwhile in chapter 4 there is an analysis toward this project, the analysis consist of a simulation, calculation and also testing on the hardware itself. Chapter 5 is the crucial of all. In this chapter where all the expected data and information will be represent after the analysis is done toward the modules. Finally, in chapter 6 where all the conclusion and decision is reveal.

CHAPTER 2

LITERATURE STUDY.

Faraday's Law sets the saturation flux for maximum energy conversion. The torque-speed characteristics of a motor are affected by the applied voltage and frequency. Inductive reactance can increase current and heat up the motor. The duty cycle is a measure of the ratio of the applied voltage and frequency to the motor. The volts-per-Hertz ratio is ratio exists between voltage and frequency. PWM is a switch-mode control method. The gate driver conditions the pulse that drives the IGBT gates. The speed of the motor is directly related to the applied frequency.

2.1 FARADAY'S LAW.

The ac induction motor requires a constant volt per Hertz ratio in the sinusoidal signal that it receives in order to operate at saturation flux. Saturation flux represents the highest value for a machine to maximize the energy conversion process, so the motor can supply its rated torque.

The constant volts per Hertz ratio is explained by Faraday's Law:

$$\oint_c \mathrm{E} \bullet dS = -\frac{d}{dt}\int_s B \bullet da \tag{2.1}$$

The line integral of the electric field intensity, *E*, around a closed contour is equal to the time rate of change of the magnetic flux, *B*, linking that contour.

In magnetic structures with windings, the *E* field in the wire is extremely small and can be neglected, so that the first term reduces to the negative of the induced voltage, *e*, at the winding terminals. The flux in the second term is dominated by the core flux ϕ. Since the winding links the core flux *N* times, Faraday's Law reduces to [1]:

$$e = N\frac{d\phi}{dt} \tag{2.2}$$

Since,

$$\lambda = N\phi \tag{2.3}$$

$$e = \frac{d\lambda}{dt} \tag{2.4}$$

And

$$e = V_0 \cos\omega t \tag{2.5}$$

So,

$$\frac{d\lambda}{dt} = V_0 \cos\omega t \tag{2.6}$$

Integrating:

$$\lambda = \frac{V_0}{\omega}\sin\omega t \tag{2.7}$$

Therefore, the saturation flux is :

$$\lambda_{\max} = \frac{V_0}{2\pi f} \tag{2.8}$$

Where ϕ is the magnetic flux in Webers, and λ is the flux linkage in Weber-turns.
So in order to achieve maximum flux linkage, a constant volts per Hertz ratio must be maintained.

2.2 TORQUE-SPEED CHARACTERISTICS.

The final speed of the motor is determined by the point in which the load torque equals the generated torque of the motor as shown in Figure.2.1 below.

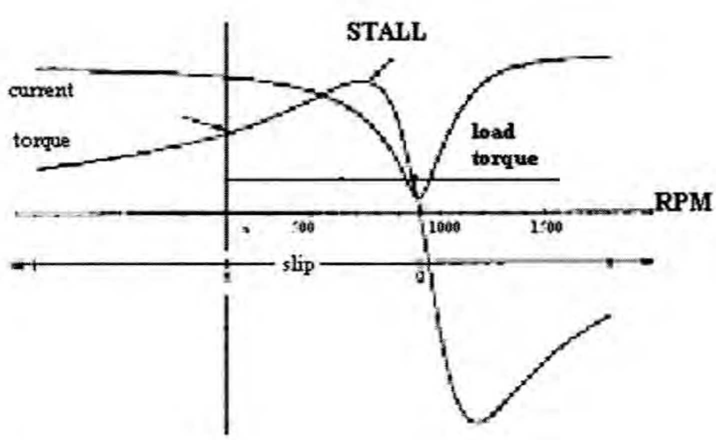

Figure 2.1: Torque-speed characteristics of a motor operating at saturation flux from stall to 0 slip for operation with no change in voltage, frequency, or speed. [2].

From the figure it can be seen that the final speed of the motor occurs at a low slip of around 0.1.

2.2.1 Effects of Constant Voltage.

If the motor does not maintain constant volts per Hertz ratio, the torque speed curve will not maintain that straight line characteristic around 0 slip shown in Figure 2.1 that is required for saturation flux. The following figure 2.2 illustrates maintaining constant voltage while varying the frequency.

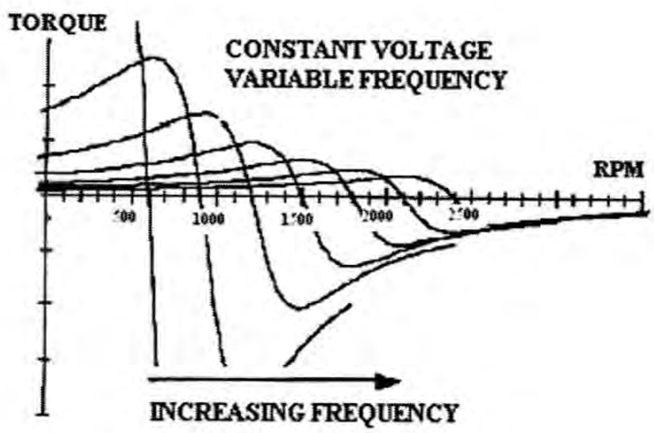

Figure 2.2: Torque-speed characteristics for constant voltage and variable frequency. The motor will increase speed but lose saturation flux at higher speeds. [2].

From figure 2.2 that the torque drops off at higher frequencies causing the motor to stall with an applied load.