SPEED CONTROL OF INDUCTION MOTOR USING SCALAR CONTROL

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MAY 2006

"I hereby verify that I have read this report and I find it sufficient in terms of quality and scope to be awarded with the Bachelor's Degree in Electrical Engineering (Industrial Power)."

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I hereby certified that this report is of my own work except for the extracts and summaries, in which the sources have clearly noted.

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Date : MAY 2006

Dedicated to my beloved family…

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ABSTRACT

The ability to control speed of induction motor is desired in industry. Besides for control of the processing procedure, efficient speed control strategies can reduce the operation cost. There are several method can be used to control the speed of induction motor. It includes scalar control and vector control. This project will be focus on scalar control method. Scalar control is a very simple method for controlling speed motor. In scalar control, the speed of the induction motor can be change and control by just simply control the magnitude of voltage or frequency of the induction motor. It is different from vector control which is more complex. In this project the speed will be control by varying the induction motor frequency from 0 to 50 Hertz. The speed is first varied by increased the value of motor frequency, than the simulation will show the speed of induction motor will be increase proportionally and visa versa. The scalar controller is designed using Simulink/Matlab software. This program is used to calculate and plot the speed and torque response of the control system. When the program is run, it plots the desire speed response and torque response on the computer screen.

ABSTRAK

Kebolehupayaan untuk mengawal halaju motor adalah sangat penting diaplikasi dalam bidang industri. Selain memudahkan untuk mengawal perjalanan sesuatu proses, kawalan halaju yang cekap berupaya untuk mengurangkan kos operasi. Terdapat beberapa jenis kaedah mengawal halaju motor. Ia termasuk kawalan skalar dan kawalan vektor. Projek ini akan memfokuskan kepada kaedah kawalan halaju motor menggunakan kaedah kawalan skalar. Kawalan skalar merupakan suatu teknik kawalan halaju motor yang ringkas. Dalam kawalan skalar, pengguna hanya perlu mengawal magnitud kelajuan sesuatu motor sahaja berbanding dengan kaedah kawalan halaju vektor yang lebih kompleks. Berpandukan nisbah Volts/Hz, apabila voltan adalah tetap dan frekuensi dilaraskan kita boleh mengubah dan melaraskan halaju motor. Ketika frekuensi dinaikkan daripada 0 hingga 50Hz, halaju motor semakin bertambah dan begitu juga sebaliknya. Perisian Simulink/Matlab akan digunakan untuk mengaplikasi kaedah ini. Perisian ini digunakan untuk menjumlah dan memplotkan tindakbalas halaju dan tork motor. Ia akan memaparkan pada skrin komputer setiap tindakbalas halaju dan tork motor apabila nilai frekuensi berubah.

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CHAPTER 1

INTRODUCTION

1.0 Introduction

An important factor in industrial progress during the past five decades has been the increasing sophistication of factory automation which has improved productivity manyfold. Manufacturing lines typically involve a variety of variable speed motor drives which serve to power conveyor belts, robot arms, overhead cranes, steel process lines, paper mills, and plastic and fiber processing lines to name only a few.

Prior to the 1950s all such applications required the use of a DC motor drive since AC motors were not capable of smoothly varying speed since they inherently operated synchronously or nearly synchronously with the frequency of electrical input. To a large extent, these applications are now serviced by what can be called general-purpose AC drives.

In general, such AC drives often feature a cost advantage over their DC counterparts and, in addition, offer lower maintenance, smaller motor size, and improved reliability. However, the control flexibility available with these drives is limited and their application is, in the main, restricted to fan, pump, and compressor types of applications where the speed need be regulated only roughly and where transient response and low-speed performance are not critical.

Control systems are an integral part of modern society. It consists of subsystems and processes assembled for the purpose of controlling the outputs of the processes. With control systems we can move large equipment with precision that would otherwise be impossible. The advantages of a control system are the ability to compensate for disturbances.

The control of induction motors is more complicated than the control of dc motor, especially if we want to achieve the comparable accuracy. It is due to the complexity of the mathematical model of an induction machine and to more complicated power converters supplying these motor. The variable speed drives with induction motors use various control structure and algorithms. A choice of proper structure depends on a demand performance in an industrial application of the drive.

The speed of standard induction motors can be controlled by variation of the frequency of the voltage applied to the motor. Due to flux saturation problems with induction motors, the voltage applied to the motor must alter with the frequency. The induction motor is a pseudo synchronous machine and so behaves as a speed source. The running speed is set by the frequency applied to it and is independent of load torque provided the motor is not over loaded.

The principle of the scalar control is based on the regulation of only magnitudes of controlled variables, consequently control signals and feedback signals as well as dc signals. That is why control structure algorithms of scalar control are simple. In scalar control both the magnitude and the phase alignment of the vector variables are controlled. For example, the voltage of the machine can be controlled to control the flux, and the frequency of slip can be controlled to control torque. [8]

1.1 Project Objectives

The objectives of this project are:

1. The objective for this project is to develop a scalar control model in controlling the desire speed response of induction motor with the input voltage and frequency and those physical parameter.

2. To study how to control the speed of induction machine using scalar control.
3. Provide a package for learning purpose in controlling the speed control of induction motor using scalar control.

1.2 Project Scope

The scopes of this project are:

1. Build a scalar control model that can control the steady-state speed of induction motor.
2. Produce a learning package of scalar control for future reference purpose.

1.3 Organization of the Report

The thesis is divided into five chapters. Chapter 1 gives the overview of the entire project with the summary of the project background and the objectives of the project.

Chapter 2 introduces the Overview of Scalar Control of Induction Motor, which will discuss about the induction motor, the operating principles and etc.

Chapter 3 discuss about the Project Background and Methodology. The discussion including the formulation of the open loop Volts/Hertz speed control and the mathematical theory.

Chapter 4 discuss about the Modeling and Simulation Result of induction motor with Volts/Hz control. The modeling of the design is developed using the chosen software, MATLAB/SIMULINK.

Chapter 5 gives the conclusion of the thesis and highlights the suggestion for future development.

CHAPTER 2

OVERVIEW OF SCALAR CONTROL OF INDUCTION MOTOR

2.0 Induction Motor

Induction motor is a three phase AC motor and is the most widely used machine. Its characteristic features are:

- Simple and rugged construction
- Low cost and minimum maintenance
- High reliability and sufficiently high efficiency
- Needs no extra starting motor and need not be synchronized

An Induction motor has basically two parts which is Stator and Rotor. The Stator is made up of a number of stampings with slots to carry three phase windings. It is wound for a definite number of poles. The windings are geometrically spaced 120 degrees apart. Two types of rotors are used in Induction motors - Squirrel-cage rotor and Wound rotor. [9]

A squirrel-cage rotor consists of thick conducting bars embedded in parallel slots. These bars are short-circuited at both ends by means of short-circuiting rings. A wound rotor has three-phase, double-layer, distributed winding. It is wound for as many poles as the stator. The three phases are wyed internally and the other ends are connected to slip-rings mounted on shaft with brushes resting on them. The brushes are connected to an external resistance that does not rotate with the rotor. In fact an Induction motor can be compared with a transformer because of the fact that just like a transformer it is a singly energized device which involves changing flux linkages with respect to a primary (stator) winding and secondary (rotor) winding. [7]

An Induction motor operates on the principle of induction .The rotor receives power due to induction from stator rather than direct conduction of electrical power. It is important to understand the principle of rotating magnetic field in order to understand the operation of an Induction motor. When a three phase voltage is applied to the stator winding, a rotating magnetic field of constant magnitude is produced. This rotating field is produced by the contributions of space-displaced phase windings carrying appropriate time displaced currents. [7]

These currents which are time displaced by 120 electrical degrees are shown in Figure 2.1 below:

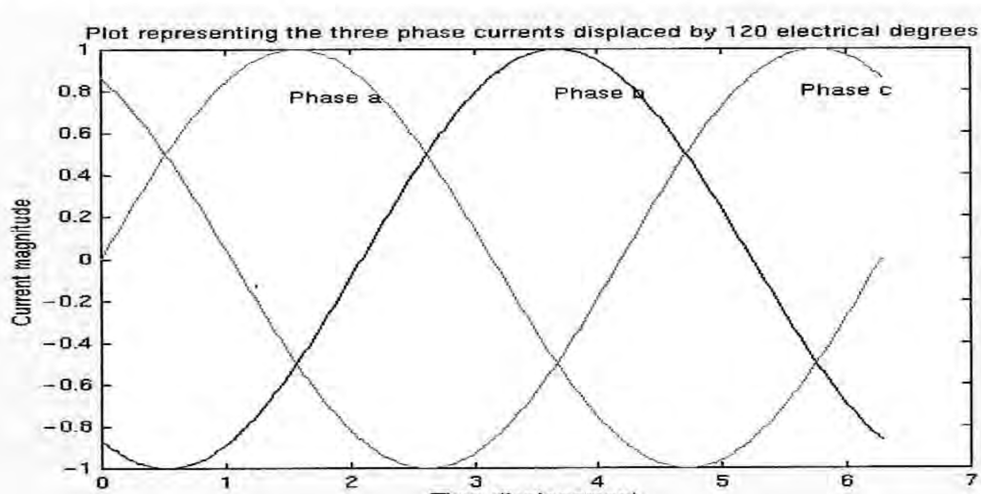

Figure 2.1: Three phase currents displaced by 120 electrical degrees

From Figure 2.1, we can determine the three phase currents displaced by 120 electrical degrees. It is obtain using the equations below.

$$C_a = C_m \times \sin(\omega t)$$

$$C_b = C_m \times \sin(\omega t - 120)$$

$$C_c = C_m \times \sin(\omega t + 120)$$

The above equations represent the relationship of current flow in each phase. It shows the phase shift which is equal to 120 degree for each phase.

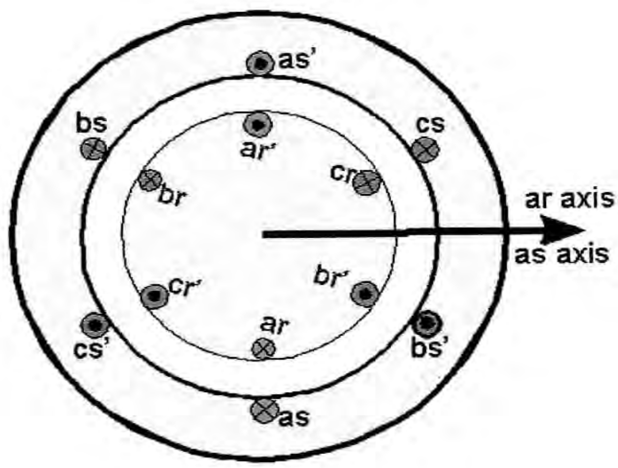

Figure 2.2: Cross section of a three-phase induction motor

Figure 2.2 shows a cross-section view of a three-phase induction motor, with the stator and rotor coils represented by concentrated windings. Voltage equations can be written for the stator and rotor phases in terms of self and mutual-inductances. As the rotor moves, the mutual inductances between the rotor and stator coils will change, because the angle between the axes of the rotor and stator changes. To eliminate the time-varying inductances, the equations are frequently transformed to q-d-0 variables in the arbitrary reference frame. For this simulation, we used a stationary reference frame, which has the advantage of eliminating some terms from the voltage equations. [14]

2.1 Adjustable Speed Drive

Adjustable speed drive is one of the most general terms applied to equipment used to control the speed of machinery. Adjustable speed drives are also known as variable speed drives. Industrial machinery is often driven by electric motors that have provisions for speed adjustment. Such motors are simply larger, more powerful versions of those driving familiar appliances such as food blenders or electric drills. In industrial terminology, these motors are called adjustable speed drives. [7]

Adjustable speed drives are used in a wide variety of industrial applications. They are used in the larger industrial versions of the food blenders and power tools mentioned. Adjustable speed drives are often used with fans to provide adjustable airflow in large heating and air conditioning systems. The flow of water and chemicals in industrial processes is often controlled by adjusting the speed of pumps.[7]

An adjustable speed drive might consist of an electric motor and controller that is used to adjust the motor's operating speed. The combination of a constant-speed motor and a steplessly adjustable mechanical speed-changing device might also be called an adjustable speed drive.

2.1.1 Adjusting Speed as a Means of Controlling a Process

Consider the process of driving to work. If you drove to work at the highest possible speed, you would probably cause an accident. If you drove at a single speed that would be safe for every part of the route, it would take too long to get to your destination. Adjusting your speed to suit the route minimizes the time to achieve the objective of the process within the limits of reliable operation.

The following are process control benefits that might be provided by an adjustable speed drive:

- Smoother operation
- Acceleration control
- Different operating speed for each process recipe
- Compensate for changing process variables
- Allow slow operation for setup purposes
- Adjust the rate of production
- Allow accurate positioning
- Control torque or tension

2.1.2 Electric Adjustable Speed Drives

There are three general categories of electric drives, DC motor drives, eddy current drives and AC motor drives. Each of these general types can be further divided into numerous variations. Electric drives generally include both an electric motor and a speed control unit or system. The term *drive* is often applied to the controller without the motor. In the early days of electric drive technology, electromechanical control systems were used. Later, electronic controllers were designed using various types of vacuum tubes. As suitable solid state electronic components became available, new controller designs incorporated the latest electronic technology.[7]