MOTOR DRIVE FOR INDUCTION MOTOR

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Date : ......7/5/09......................................

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In the name of Allah, The Most Gracious, The Most Merciful. Peace be upon the Messenger of Allah, Prophet Muhammad S.A.W, his companions (r.a) and followers until the end day.

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Abstract

The induction motor has been described as the workhorse for the power industry. This is due to its broad list of capabilities and its operating cost. However in order to efficiently run an induction motor, the output characteristics need to be controllable. This calls for some sort of device that enable the user to vary the input of the motor, so that ,it will operate at the desired speed and torque. These devices are known as motor drives. Basically, there are 3 stages to develop this project. First is a converter or rectifier. Its a process of converting an alternating (AC) voltage into one that is limited to one polarity. The output of rectifier circuit sometime produces an unacceptable ripple. This ripple can be taken care of with DC link circuit. The second stage in DC Link is to smooth the output of the rectifier. Finally, the inverter, the inverter circuit is used to produce a simulated AC circuit. This circuit is the main part to control the speed of a motor by using PWM method

Abstrak

Motor aruhan adalah sangat penting dalam industri pada masa kini.Wajarlah ia digelar sebagai pengerak dalam industri kuasa,ini kerana keupayaan dan kos operasinya.Walaubagaimanapun,untuk mengerakkan dan memacu motor aruahan ini, ciri-ciri keluarannya haruslah boleh dikawal. Sehubungan dengan ini, satu peranti telah dicipta untuk membolehkan pengguna mengawal masukan sesuatu motor aruhan, supaya motor dapat berkendali denagn kelajuan dan daya kilas yang diingini. Pada umumnya, terdapat 3 peringkat untuk membangunkan projek ini.Yang pertama ialah Penukar AC ke DC. Ia adalah proses dimana Voltan AC ditukar kepada Volta DC.Akan tetapi, keluaran dari Penukar ini terdapat riak yang tidak diperlukan.Peringkat kedua iaitu Penapis DC akan megurangkan riak ini dan sekaligus akan melicinkan keluaran.Peringkat yang terakhir ialah,Penukar DC ke AC.Peringkat ini adalah yang paling penting di dalam projek ini.Pada peringkat ini, kelajuan motor aruhan akan dikawal mengunakan kaedah PWM (Pulse Width Modulation).

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CHAPTER 1

INTRODUCTION

1.1 Introduction

An electric drive is an industrial system which performs the conversion of electrical energy to mechanical energy (in monitoring) or vise versa (in generator braking) for running various process such as, production plant, transportation of people or goods, home appliances, pump, air compressors, computer disk drives, robots, etc. Electric drives may run at constant speed or variable speed. For variable speed, AC motors require variable voltage amplitude and frequency. For this project an induction motor is used.

Ac motors exhibit highly coupled ,nonlinear, and multivariable structures as apposed to much simpler decoupled structures of separately excited DC motors. The control of AC drives generally requires complex control algorithms that can be performed by microprocessors or microcomputers along with fast –switching power converters.

The AC motors have a number of advantages ; they are lightweight (20 to 40% lighter than equivalent dc motors), are in expensive , and have low maintenance compared with dc motors. They require control of freqency, voltage,and current for variable speed applications. The power converters, inverters, and ac voltage controllers can control the frequency, voltage, or, current to meet the drive requirements. These power controllers, which are relatively complex and more expensive, require advanced feedback control techniques such as model reference, adaptive control, sliding mode control andfield oriented control. However, the advantages of ac drives outweigh the disadvantages.

There are two types of ac drives:

1. Induction motor drives
2. Synchronous motor drives

The AC induction motor is a rotating electric machine designed to operate from a three-phase source of alternating voltage. The stator is a classic three phase stator with the winding displaced by 120°. The most common type of induction motor has a squirrel cage rotor in which aluminum conductors or bars are shorted together at both ends of the rotor by cast aluminum end rings. When three currents flow through the three symmetrically placed windings, a sinusoidally distributed air gap flux generating the rotor current is produced. The interaction of the sinusoidally distributed air gap flux and induced rotor currents produces a torque on the rotor. The mechanical angular velocity of the rotor is lower then the angular velocity of the flux wave by so called slip velocity.

In adjustable speed applications, AC motors are powered by inverters. The inverter converts DC power to AC power at the required frequency and amplitude. The inverter consists of three half-bridge units where the upper and lower switch are controlled complimentarily. As the power device's turn-off time is longer than its turn-on time, some dead-time must be inserted between the turn-off of one transistor of the half-bridge and turn-on of it's complementary device. The output voltage is mostly created by a pulse width modulation (PWM) technique. The 3-phase voltage waves are shifted 120° to each other and thus a 3-phase motor can be supplied.

1.2 Problem statement

The invention of the three-phase induction motor really made automation possible. These machines may be used as generators or motors, just as DC machines and synchronous machines. However, due to poor performance, induction generators have not been very popular. Induction motors have been labeled the "workhorse of the power industry" due to its vast number of uses and popularity. Basically, there are various method to drive an induction motor.PWM (Pulse Width Modulation) method was knownly the simple and easy method to drive an induction motor compared to the other method which is more complicated drives. Using this method, an induction motor can be driven with various speed.

1.3 Project objectives

i) Design and develop a motor drive with power converter and inverter.

ii) Control the speed of induction motor by PWM's method.

1.4 Project Scopes

i) Able to simulate the driver with Matlab.

ii) Design power converter (from AC to DC)

iii) Design PWM power inverter

CHAPTER 2

LITERATURE REVIEW

In this chapter, it all about the paper review about induction motor drives including conclusion of these review. Then, the theories of induction motor drives are discussed.

2.1 Paper Review

This paper review is very important to this project because this motor drives project are based on the previous project that is correlated.

2.1.1 Vector Control of an Induction Motor Fed by a PWM Inverter with Output LC Filter by Janne Salomäki and Jorma Luomi

This paper explain about the voltage generated by a PWM frequency converter consists of sharp-edged voltage pulses. Sudden alteration of the voltage causes unwanted effects such as bearing currents and high voltage stresses in motor insulations. The oscillation at the switching frequency causes additional losses and acoustic noise. These phenomena can be eliminated by adding an LC filter to the output of the PWM inverter. In addition , the EMI shielding of the motor cable may be avoided if the output voltage of the inverter is nearly sinusoidal. The control of an induction motor becomes more difficult if an LC filter is used. Usually, a very simple scalar control method (volts-per-hertz control) is chosen.

Although better control performance is needed in many cases, only few publications deal with the vector control of an induction motor fed via an LC filter. A deadbeat controller has been used to control the inductor current and the capacitor voltage , the highpass filtered stator voltage has been used to correct the voltage reference , and a multi-loop feedback controller has been proposed . In these methods, extra current or voltage measurements are needed in addition to the phase current and dc voltage measurements usual in a frequency converter. A challenge for the motor drive control design is to keep the number of measurements low in order to obtain cost savings and reliability improvements. In this paper, a method is presented for the vector control of an induction motor fed by an inverter with an output LC filter. A cascade control method is used to control the inverter current, the stator voltage, the stator current and the rotor speed. The system states are estimated by a full-order observer.

2.1.2 PWM - CSI Inverter for Induction Motor Drives by Bin Wu, *Student Member, IEEE,* Shashi B. Dewan, *Fellow, IEEE,* and Gordon R. Slemon, *Fellow, IEEE*

A number of pulse-width modulated (PWM) current source inverters (CSI) using self-extinguishing switches. Usually, a relatively high switching frequency is employed to obtain a near-sinusoidal output voltage and current. With large induction motor drives using GTO switches, it is desirable to limit the switching frequency to a low value, e.g., < 200 Hz, to minimize switching losses. This requirement becomes increasingly important as the rated voltage of the motor is increased. This paper discusses a number of issues that arise in the design of a current-source Inverter system with a low switching frequency. Low harmonic content in both the motor voltage and current is desired for a number of reasons. Current harmonics cause additional heating of windings, particularly in large motors where skin effect is more significant. Voltage harmonics can increase core losses and rapid rates of change of voltage with time can increase insulation stress. In addition, these harmonics may cause torque harmonics and acoustic noise. These factors, together with the high-voltage commutation spikes, have limited the use of conventional CSI inverters for induction motor drives, particularly at low frequency.

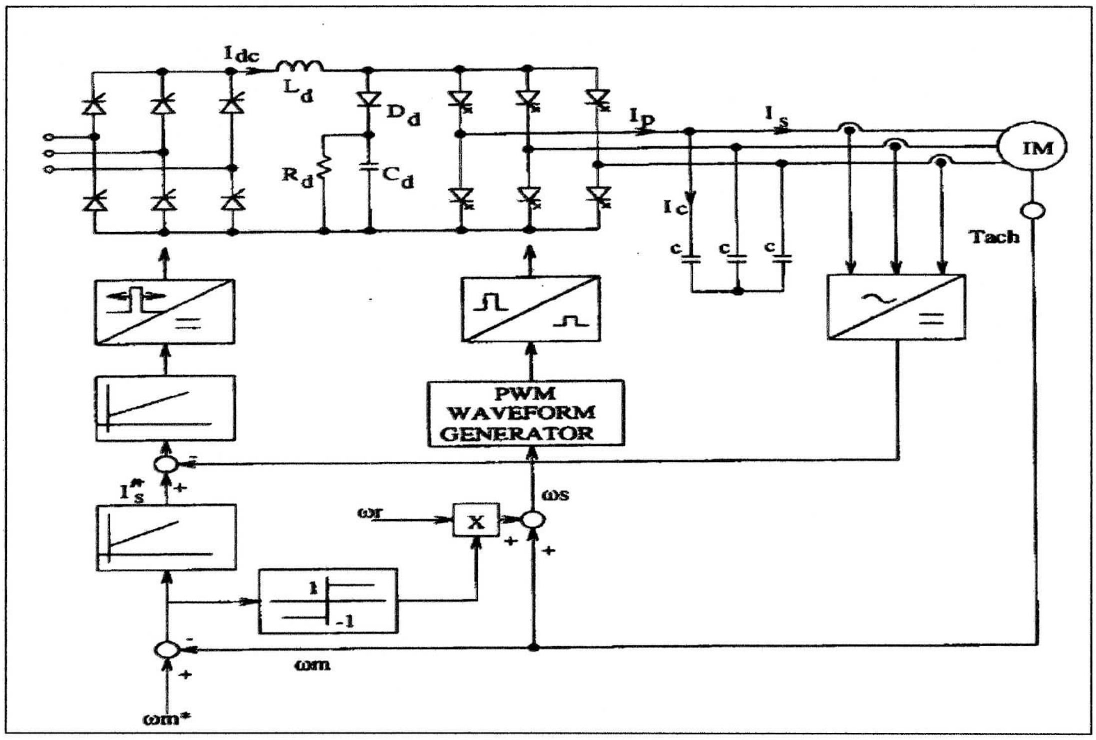

Figure 2.1: Block diagram of PWM-CSI-IM drive system from 2.1.2 Paper Review

A phase-controlled rectifier supplies dc link current Idc through an inductor L,. The inverter, consisting of six GTO switches, supplies the induction motor and a parallel capacitor. At any instant, two of the switches conduct the current from the dc link, leaving one of the inverter output terminals open circuited. The capacitors C absorb the rapid change in output current I,, which occurs on switching, and also provide a low impedance path for current harmonics. The dc link is provided with an absorber that clips high-voltage spikes that might otherwise occur during imperfectly synchronized switching operations. Control of motor current is provided by direct measurement of the motor stator currents and using this as a feedback to control the rectifier phase angle. Speed measurement is provided by a tachometer. Control of stator frequency *U,* is provided by adding a rotor (slip) frequency signal *U,* to the tachometer signal *U,*. The remaining part of the control system can be adapted for the specific application. The system of Fig. 1 provides for simple control of speed with constant rotor frequency. The CSI system is preferred for a number of large motor drives because of its simplicity, its inherent overcurrent protection capability, and its ability to regenerate. In most applications, the speed of response can be made adequate.

2.1.3 AC Drive For Induction Motor Application

This design project focuses on the power electronics involved in varying the speed of a motor through a Variable Frequency Drive (VFD). This process involves converting an AC signal into a smooth DC signal and then making that DC signal represents a simulated AC signal. By using this simulated AC signal we can vary its frequency thus changing the speed of an induction motor.

The motor drive designed here is a three-phase induction motor controller. It operates on an input of 220 volts at 60 Hertz. This is a NEMA (National Electrical Manufacturers Association) standard for three-phase motors. The drive consists of three main parts. The first is a converter. This takes the input AC voltage and converts it to a DC voltage. Next is the filter. This is to insure a clean DC signal to the motor. Last is the inverter, this is a series of transistors that switch on and off in a sequence such that the output signal is pulsing at a particular frequency. The inverter is the main operating part of the drive. Once the signal can be manipulated to a desired frequency, the motor can be run at any desired speed (without overloading the motor).

2.1.4 The Design and Implementation of a Three Phase Power Converter in the Power Electronics and Drives Subject by Omar M F Muhialdin, Ahmad Nahas and Takyin Chan

This paper describes the design and implementation of a Three Phase Power Converter (AC/DC/AC) as a fourth year group project for the Power Electronics and Drives B subject at Victoria University. The system implemented converts a three phase input voltage of 400 Vrms at a power rating of 500 W to DC by using a three phase diode bridge rectifier, and a Capacitive filter which assists in stabilising the output DC voltage produced. After that, the system provides the gate drive signal to a three phase pulse width modulated (PWM) inverter driving an induction motor. The pulse width modulation signal is generated by MATLAB using the Data Acquisition. The three phase MOSFET inverter uses the DC voltage supplied from the 3 phase bridge and the gate drive signals to produce a balanced three phase sinusoidal output which drives the induction motor. This project/paper can be useful for future power system students as more properties and specifications can be added to the designed product in order to investigate further issues and applications of Three Phase Power Converters.

2.1.5 VF Control of 3-Phase Induction Motors Using PIC16F7X7 Microcontrollers by Rakesh Parekh froMicrochip Technology Inc.

This paper represent a driving and controlling the induction motor efficiently are prime concerns in today's energy conscious world. With the advancement in the semiconductor fabrication technology, both the size and the price of semiconductors have gone down drastically. This means that the motor user can replace an energy inefficient mechanical motor drive and control system with a *Variable Frequency Drive* (VFD). The VFD not only controls the motor speed, but can improve the motor's dynamic and steady state characteristics as well. In addition, the VFD can reduce the system's average energy consumption.

Although various induction motor control techniques are in practice today, the most popular control technique is by generating variable frequency supply, which has constant voltage to frequency ratio. This technique is popularly known as *VF control*. Generally used for open-loop systems, VF control caters to a large number of applications where the basic need is to vary the motor speed and control the motor efficiently. It is also simple to implement and cost effective.

The PIC16F7X7 series of microcontrollers have three on-chip hardware PWM modules, making them suitable for 3-phase motor control applications. This application note explains how these microcontrollers can be used for 3-phase AC induction motor control.

2.1.6 3-Phase AC Induction Motor Vector Control Using a 56F80x, 56F8100 or 56F8300 Device from Freescale Technology.

This paper describes the design of a 3-phase AC Induction Motor (ACIM) vector control drive with position encoder coupled to the motor shaft. It is based on Freescale's 56F80x and 56F8300 dedicated motor control devices. The software design takes advantage of Processor ExpertTM (PE) software.

AC induction motors, which contain a cage, are very popular in variable-speed drives. They are simple, rugged, inexpensive and available at all power ratings. Progress in the field of power electronics and microelectronics enables the application of induction motors for high-performance drives, where traditionally only DC motors were applied. Thanks to sophisticated control methods, AC induction drives offer the same control capabilities as high performance four-quadrant DC drives.

This drive application allows vector control of the AC induction motor running in a closed-speed loop with the speed / position sensor coupled to the shaft. The application serves as an example of AC induction vector control drive design using a Freescale hybrid controller with PE support. It also illustrates the use of dedicated motor control libraries that are included in PE.

2.2 Paper Review Conclusion

For this project, Voltage Source Inverter have been choose Voltage Source Inverter (VSI) are more common compared to Current Source Inverter (CSI) since the use of Pulse Width Modulation (PWM) allows efficient and smooth operation, free from torque pulsations and cogging. Furthermore, the frequency range of VSI is higher and there are usually more inexpensive when compared to CSI drives of the same rating. Voltage Source Inverter employing a DC link capacitor and providing a switched voltage waveform compared to CSI which employing a DC link inductance and providing a switched current waveform at the motor terminals.

2.3 Induction motor theory

AC induction motors are the most common motors used in industrial motion control systems, as well as in main powered home appliances. Simple and rugged design, low-cost, low maintenance and direct connection to an AC power source are the main advantages of AC induction motors.

Various types of AC induction motors are available in the market. Different motors are suitable for different applications. Although AC induction motors are easier to design than DC motors, the speed and the torque control in various types of AC induction motors require a greater understanding of the design and the characteristics of these motors.

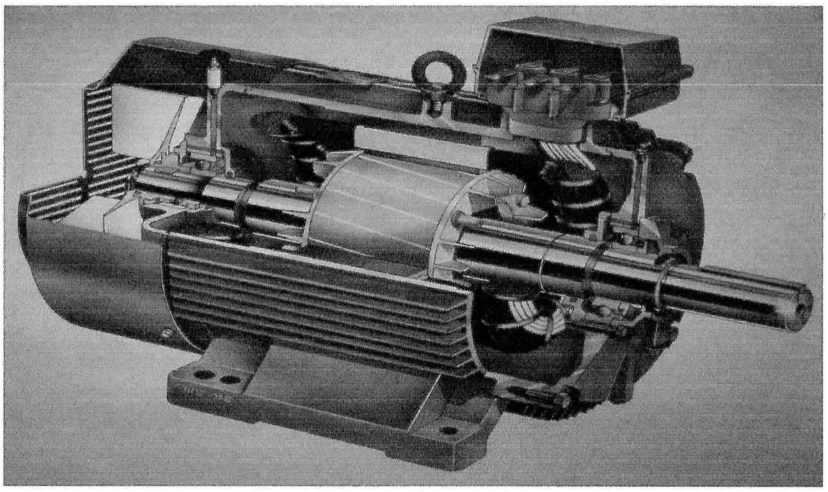

Figure 2.2: Induction motor

2.3.1 Basic construction of induction motor

Like most motors, an AC induction motor has a fixed outer portion, called the stator and a rotor that spins inside with a carefully engineered air gap between the two.

Virtually all electrical motors use magnetic field rotation to spin their rotors. A three-phase AC induction motor is the only type where the rotating magnetic field is created naturally in the stator because of the nature of the supply. DC motors depend either on mechanical or electronic commutation to create rotating magnetic fields. A single-phase AC induction motor depends on extra electrical components to produce this rotating magnetic field.

Two sets of electromagnets are formed inside any motor. In an AC induction motor, one set of electromagnets is formed in the stator because of the AC supply connected to the stator windings. The alternating nature of the supply voltage induces an Electromagnetic Force (EMF) in the rotor (just like the voltage is induced in the transformer secondary) as per Lenz's law, thus generating another set of electromagnets; hence the name – induction motor. Interaction between the magnetic field of these electromagnets generates twisting force, or torque. As a result, the motor rotates in the direction of the resultant torque [9].

2.3.2 Stator

The stator is made up of several thin laminations of aluminum or cast iron. They are punched and clamped together to form a hollow cylinder (stator core) with slots as shown in Figure 1. Coils of insulated wires are inserted into these slots. Each grouping of coils, together with the core it surrounds, forms an electromagnet (a pair of poles) on the application of AC supply. The number of poles of an AC induction motor depends on the internal connection of the stator windings. The stator windings are connected directly to the power source. Internally they are connected in such a way, that on applying AC supply, a rotating magnetic field is created.

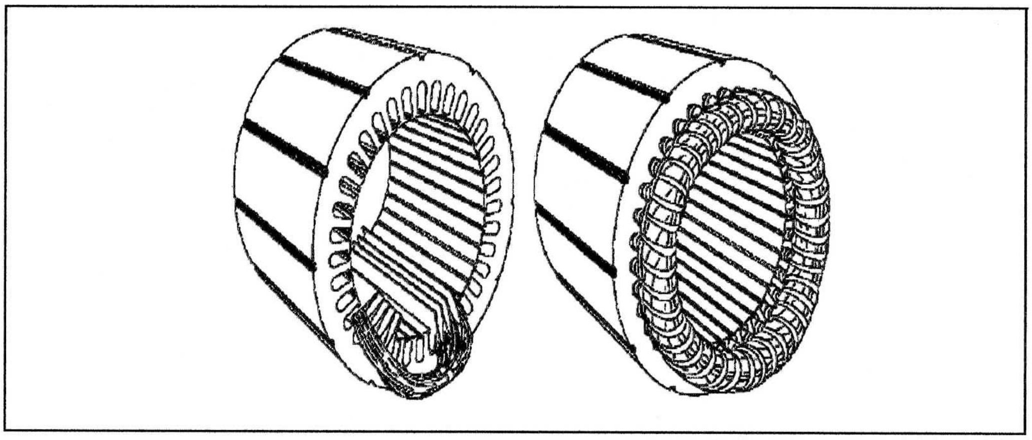

Figure 2.3: Stator of Induction motor

2.3.3 Rotor

The rotor is made up of several thin steel laminations with evenly spaced bars, which are made up of aluminum or copper, along the periphery. In the most popular type of rotor (squirrel cage rotor), these bars are connected at ends mechanically and electrically by the use of rings. Almost 90% of induction motors have squirrel cage rotors [9]. This is because the squirrel cage rotor has a simple and rugged construction. The rotor consists of a cylindrical laminated core with axially placed parallel slots for carrying the conductors.

Each slot carries a copper, aluminum, or alloy bar. These rotor bars are permanently short-circuited at both ends by means of the end rings, as shown in Figure 2. This total assembly resembles the look of a squirrel cage, which gives the rotor its name. The rotor slots are not exactly parallel to the shaft. Instead, they are given a skew for two main reasons.

The first reason is to make the motor run quietly by reducing magnetic hum and to decrease slot harmonics. The second reason is to help reduce the locking tendency of the rotor. The rotor teeth tend to remain locked under the stator teeth due to direct magnetic attraction between the two. This happens when the number of stator teeth are equal to the number of rotor teeth. The rotor is mounted on the shaft using bearings on each end; one end of the shaft is normally kept longer than the other for driving the load [9]. Some motors may have an accessory shaft on the non-driving end for mounting speed or position sensing devices. Between the stator and the rotor, there exists an air gap, through which due to induction, the energy is transferred from the stator to the rotor. The generated torque forces the rotor and then the load to rotate. Regardless of the type of rotor used, the principle employed for rotation remains the same.

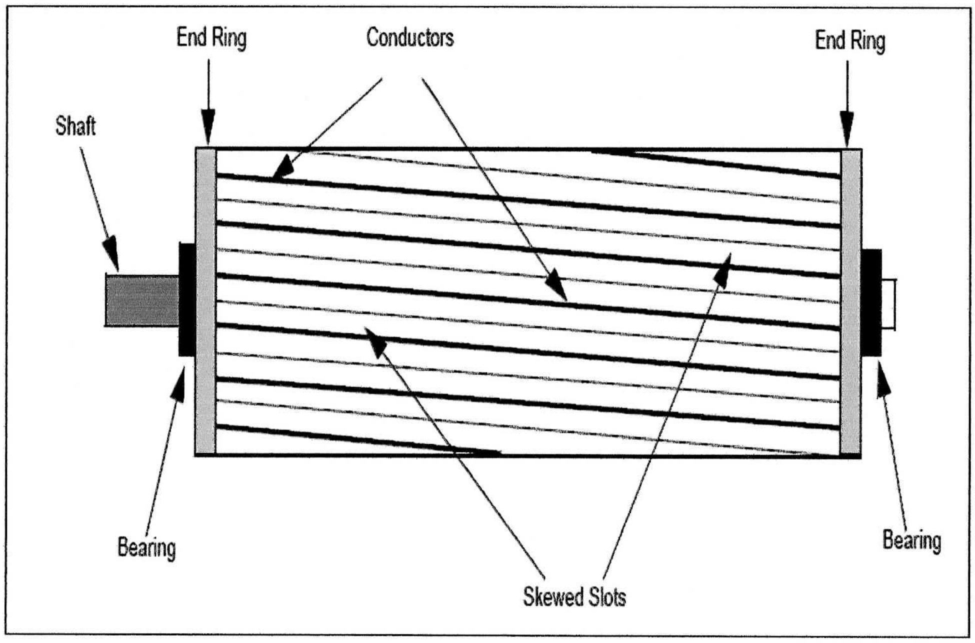

Figure 2.4: Rotor for Induction Motor

2.3.4 Speed of an Induction Motor

The magnetic field created in the stator rotates at a synchronous speed (*NS*).