UNIVERSITI TEKNIKAL MALAYSIA MELAKA

FACULTY OF ELECTRICAL ENGINEERING

FUZZY LOGIC SPEED CONTROL FOR INDUCTION MOTOR DRIVES

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Faculty of Electrical Engineering

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APPROVAL

I hereby declare that I have read through this report entitled "Fuzzy Logic Speed control of induction Motor drives" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering

.

Signature: ....

Supervisor's Name: Prof Dr Zulkifilie Bin Ibrahim

Date : 6/6/2018

DECLARATION

I declare that this report entitles "Fuzzy Logic Speed control of induction Motor drives" 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: OSAMA ABDUL QADIR

Date : 6/6/2018:

DEDICATION

To my beloved father and mother

Acknowledgment

In preparing this report, I was in contact with many people, researchers, academicians and practitioners. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my main project supervisor, Prof Dr Zulkifilie Bin Ibrahim, for encouragement, guidance critics and friendship. I am also very thankful to my friends for their guidance, advices and motivation. Without their continued support and interest, this project would not have been same as presented here.

ABSTRACT

In recent years, the application of high performance Induction Motor Drives has become a great attention of motor drive player. The demand of robustness controller is necessary to meet satisfactory performance cover various speed demand and other variation such as parameters and load. The conventional controllers of motor drive such PI controller can't handle non-linearity of the drive as well as sensitive to parameters change. In this project fuzzy logic controller FLC is utilized to drive the induction motor to enhance the speed performance of the motor. The FLC is robust controller that can handle non-linearity of the motor parameters unlike the conventional controllers. The principle of fuzzy logic is to drive the IM system based on the speed error produced in which the fuzzy membership function is designed to effectively reduce the error as much as possible in order to produce optimum performance. The IM model was designed using Matlab/Simulink environment. Three different rules selection of fuzzy logic controller were considered which are 9,25 and 49 rules. The drive performance was investigated without load disturbance and under load disturbance. The settling time rise rime and percent overshoot of the speed response in forward and reverse operation was analyzed a compared in order to validate the performance of the fuzzy logic controller. Therefore, the objective of this project was successfully achieved by designing Fuzzy logic speed controller based induction motor drive system.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, penerapan pemacu Motor Induksi prestasi tinggi telah menjadi perhatian utama pemacu motor. Permintaan pengawalan keteguhan diperlukan untuk memenuhi prestasi yang memuaskan meliputi pelbagai permintaan laju dan variasi lain seperti parameter dan beban. Pengawal konvensional pemacu motor pengawal PI tersebut tidak dapat mengendalikan linieriti pemacu serta sensitif terhadap perubahan parameter. Dalam projek ini fuzzy logic controller FLC digunakan untuk memacu motor induksi untuk meningkatkan prestasi kelajuan motor. FLC adalah pengawal teguh yang dapat menangani non-linearity parameter motor tidak seperti pengendali konvensional. Prinsip logik fuzzy adalah untuk memacu sistem IM berdasarkan ralat kelajuan yang dihasilkan di mana fungsi keahlian fuzzy direka untuk mengurangkan kesilapan secara berkesan sebanyak mungkin untuk menghasilkan prestasi yang optimum. Model IM direka menggunakan persekitaran Matlab / Simulink. Tiga pilihan pemilihan pengawal logik fuzzy telah dipertimbangkan iaitu 9,25 dan 49 peraturan. Prestasi pemacu disiasat tanpa gangguan beban dan di bawah gangguan beban. Masa penyelesaian, kenaikan harga dan peratus overshoot terhadap tindak balas kelajuan operasi ke hadapan dan terbalik dianalisis berbanding untuk mengesahkan prestasi pengawal logik kabur. Selain itu, matlamat projek ini berjaya dicapai dengan merancang pengawal kelajuan logik Fuzzy sistem pemacu motor induksi berasaskan.

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CHAPTER 1

1. INTRODUCTION

1.1 Background

The usage AC motors increases largely because of their features and application in industrial field and house equipment (single phase). The induction motor considered as one of the well-known used type of ac motor due to their robust and less maintenance characteristics. (IMs) have been widely known as key element in the industry for long time because of its less cost, simple and robust construction. However, the drive of IM is complex because of its non-linear attributes in nature and the parameters changes with several operating conditions. Normally, the conventional fixed-gain (PI) and (PID) and their controlled classes have been widely used for IM drive. However, the fixed-gain and controlled drives mostly encounter smatter in the steady-state, parameters variations and output disturbance. Lately, researchers and industry are concerning in utilizing intelligent methods for IM drive due to their characteristics compared to the conventional PI, PID and their controlled classes. The crucial characteristics are that the construction of these drive does not depends on efficient designing mathematic model and their performance.

The recent drives area has contributed widely to provide various sets of drivers that have made it simple to alter the speed with a huge operating range. However, the big non-linear method of the IM control mechanical methods needs efficient drive method for driving speed. The conventional driver’s types that are used for the aims of motor control are may be numeric or neural or fuzzy. The driver's types that are normally used are: PI, PD, PID, FLC or a combination of two of them. In this project fuzzy logic controller FLC is utilized to drive the induction motor to enhance the speed performance of the motor. The FLC is robust controller that can handle non-linearity of the motor parameters unlike the conventional controllers.

1.2 Problem statement

In the past decades, proportional integral (PI, PID) have been utilized as speed controllers in IM drive system. These controllers drive the speed of induction motor in accordance to the speed error. The issues with such controllers can be visualized by their incapacities on handling parameters changes. These controllers are considered non-linear controllers with fixed gains vales in which they must be retuned if any changes occurred to the system [1].

However, with the rapid advancement in technology and industrial application, the fuzzy logic controllers have been proposed as an alternative effective approach to drive the IM system. Fuzzy logic controllers in IM drives have received a great attention by numerous researchers in the past few decades due to the robustness and enhanced performance compared to the conventional PI controller. The principle of fuzzy logic is to drive the IM system based on the speed error produced in which the fuzzy membership function is designed to effectively reduce the error as much as possible in order to produce optimum performance.

1.3 Objectives

The main aim of this project is to design an induction motor drive system based on fuzzy logic controller, hence these objectives to be achieved:

i. To build and design vector control of induction motor drive.
ii. To design hysteresis current control of induction motor drive.
iii. To design Fuzzy Logic Speed Controller FLC of induction motor drive to overcome the shortcomings of conventional controllers.

1.4 Scopes

The scope of this project includes designing and simulating induction motor drive system-based speed control fuzzy logic control. The scope of the project covers the following:

i. Mathematical modelling of 3 phase induction motor drive.
ii. Hysteresis current controller of induction motor drive.
iii. Fuzzy logic controller speed control of induction motor drive.
iv. Implementation of fuzzy logic speed controller of induction motor using Matlab/Simulink.

1.5 Expected Outcomes

The expected outcomes of this project are as follow:

i. Study the behavior of variable induction motor drive.
ii. Improved overall performance with fuzzy logic controller.
iii. Variable speed operations with better speed characteristics under load disturbance.
iv. Different rules design of Fuzzy Logic Controller (FLC).

1.6 Report Organization

This report consists of five chapters which are presented as below:

Chapter 1: Introduction-This chapter provide introduction and illustration of the project background, problem statement, scope and objectives

Chapter 2: Literature Review – presents the theoretical background of the ac motor drive including the conventional drives. Previously published work is also analyzed and investigated.

Chapter 3: Methodology- The project flow and steps are presented in thus chapter including the project flow chart and design procedures of the fuzzy rules and membership function.

Chapter 4: Result and discussion- the simulation results of the IM drive system obtained from Matlab/Simulink are presented. No load operation and with load operation were analyzed considering different speed range.

Chapter 5: Conclusion and recommendation- summary of the project finding and outcomes and future work suggestion are presented in this chapter.

CHAPTER 2

2. LITERATURE REVIEW

2.1 Introduction

AC motors are getting into the industrial field of motor control, in which DC motors were always used. Sophisticated inverter methods have led the AC power source very adjustable. Varied frequency power source enabled the ac motor to get rid of from the constant synchronizing speed and tend to be controllable speed motors [2]. It is proving that the determination of IM is of huge essentiality in various industry implementations. From all the sets of ac motors, the cage type IM is largely utilized in industrial field. The IM is also referred as the asynchronous motor [3][4]. The induction motor has numerous advantages such as simple construction and robustness. The induction motor is very popular in industry due to its advantages and robustness and less maintenance [5][6]. The squirrel cage induction motor is mostly used in most application [7].

2.2 Conventional AC Motor Drive

For long time, the Ac motor has been controlled by conventional methods. One of the ancient methods used to control the Ac motor is the V/F or scalar control.

2.2.1 Scalar control (V/F)

In the scalar control, the speed of AC motor is driven by the controlled value of stator voltages and frequency in a method which the air gap flux is usually kept at the required amount at the steady-state. This control method is named the scalar control due to its concern on the steady state conditions. It might be illustrated the way this control method operates by considering the basic equivalent model motor at steady state operations, the stator resistor (Rs) is expected to be zero and the stator leakage inductor (Lls) is incorporated into the rotor leakage inductor (Llr) and the magnetic inductor (Lm), which represents the value of air gap flux, is placed in front of the overall leakage inductor (Ll = Lls + Llr). Based on this the magnetic current that produces the air gap flux might roughly the stator voltage to frequency ratio. Thus, the phasor equivalent circuit can be analyzed as follow [9]:

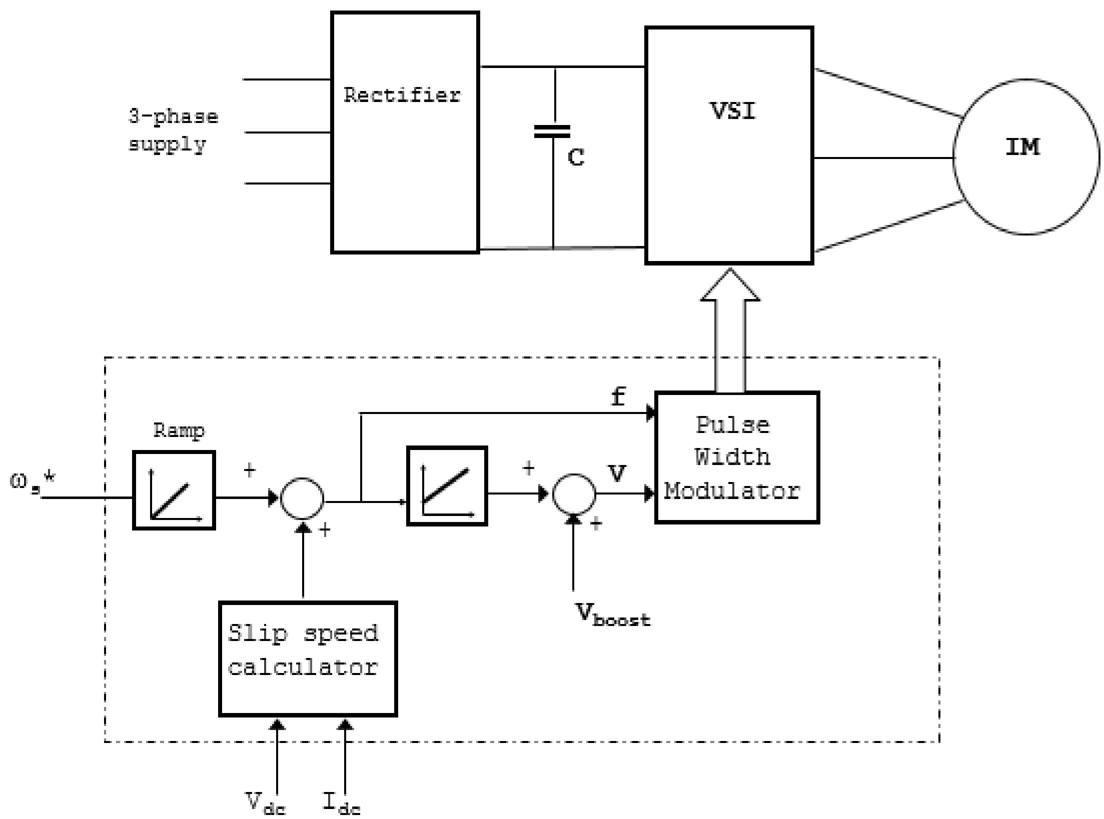

Figure 2.1: Constant V/f – open-loop with slip compensation and voltage boost

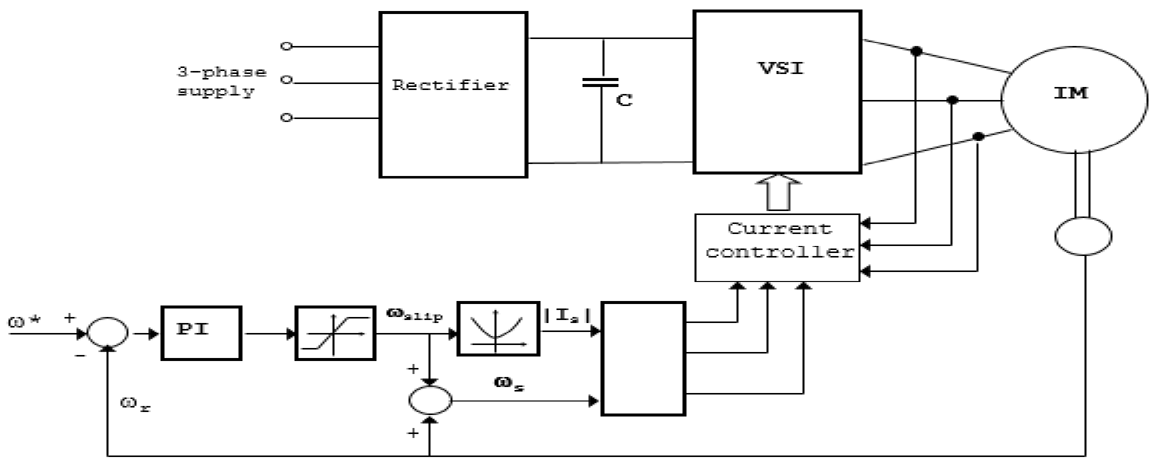

Figure 2.2: V/F scalar control

$$I_m = \frac{V_s}{j\omega L_m} \qquad 2.1$$

If the motor is working in the linear magnetized area, the Lm is fixed. So, equation 2.1 could be presented as follow:

$$I_m = \frac{\Lambda M}{Lm}\frac{V_s}{2\pi f L_m} \qquad 2.2$$

V and Λ are their values of stator voltage and stator flux, and Ṽ is the phasor value.

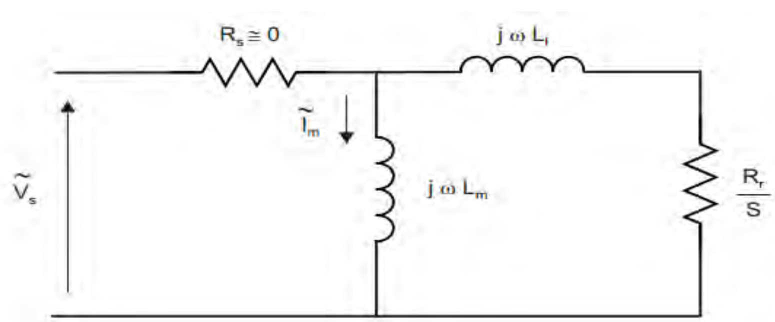

Figure 2.3 Equivalent circuit of motor in steady state condition

Based on equation 2.2, it shows that if the V/f kept fixed for any changes in frequency, so flux kept fixed and the torque doesn't rely on the frequency of the supply. For maintain ΛM fixed, the ratio of frequency / voltage would as well be fixed at the various speed. As the speed rises, the voltages should, hence, be increasing in proportional way so that the voltage/ frequency ratio of Vs/f maintain fixed. But, the frequency is not the actual speed due to the slip as a part of the load. With no- load, a small value of the slip is obtained, and the speed is almost the synchronizing speed. Therefore, the basic open-loop scalar control system will not effectively drive the speed with the existence of load torque. The slip compensating could be easily attached in the drive. The closed-loop scalar control (V/f) with a speed encoder can be presented in Figure 2.3.

In reality, the v/f ratio is normally in accordance to the rated magnitudes of such parameters. The basic V/Hz profile can be presented in Figure 2.4. Simply, three speed ranges in the v/f profile is presented

Range 1: From 0- cutoff frequency (Hz), a voltage is needed, so any decrease in the voltage along the stator resistor will not be ignored and should have compensation by the increment of voltage. Hence, the V/Hz profile is non-linear.

Range 2: from cutoff frequency (Hz), -F rated (Hz); it acts similarly to the fixed V/Hz relation. The curve normally shows the air gap flux magnitude as presented in equation 2.2.

Range3: At high rated frequency (Hz), the fixed Vs/f relationship cannot be followed due to the voltages will have limitation up to the rated amount, to prevent insulating breaking down at stator windings. Hence, the produced air gap flux will be minimized, and then consequently make the developed torque decrease. This range is normally referred as "field-weakening range". To prevent such this from occurrence, fixed V/Hz principle is not followed at such range [10].

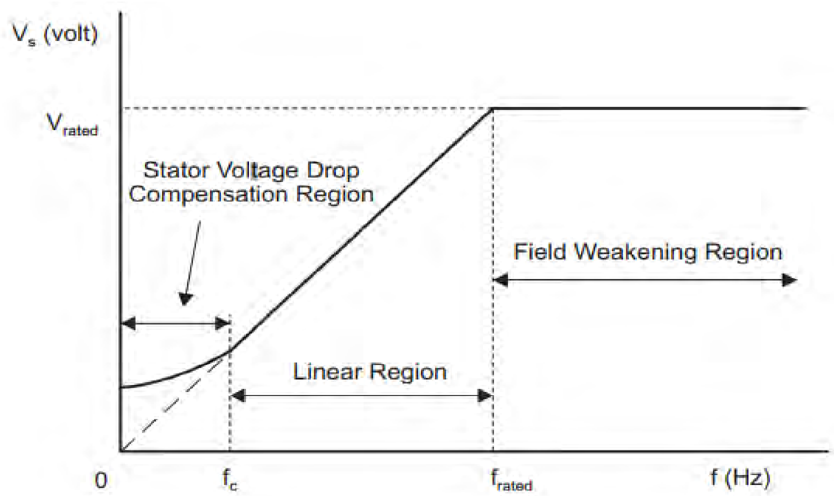

Figure 2.4 Voltage Vs frequency under V/F control

Because of the value of the flux is continuously kept constant, the developed torque relies on the slip speed. It is presented in Figure 2.4. By controlling the slip, the torque and speed of the motor can be driven by the fixed V/Hz control method. Open and closed-loop drive of the speed of an AC motor can be utilized in accordance to the fixed V/Hz method. Open-loop speed drive is utilized if efficiency in speed performance is not a required like HVAC (Heating, Ventilation and air conditions), fan or blower implementations. In such situation, the frequency of the supply is identified in accordance to the required speed and the expectation which assumes the motor would approximately acts with its synchronizing speed. This method however only provides satisfactory performance during steady-state condition but not in transient. The scalar control method does not achieve a good accuracy in speed and torque responses because the stator flux and torque are not directly controlled. Thus, this method only suitable for applications which does not required high accuracy and crucial transient behaviors [11] [12].

2.2.2 Vector control of AC Drives

The demands of high performance motor drive which have good transient and steady state performances introduce the vector control methods. FOC and DTC method is the most well-known vector control methods. It is become the standard control method for high performance motor drive system. This vector control methods directly control the instantaneous position of the voltage, current and flux vectors. The invention of the FOC and DTC solved the problem of scalar control method. This method independently controls the flux and torque component in a similar fashion of separately excited Direct Current (DC) machine [13].

In the past decades, the area of control electrical drives has experienced fast extension because of primarily, the features of power electronics. This rapid technology enhancement had allowed the construction of actual efficient AC drive system with ever less power losses porotype and ever much precise drive configuration. The electric drive controls tend to be much precise in the concept that not just are the DC current and voltage driven but also the 3- ∅ currents and voltages are controlled by as referred vector control.

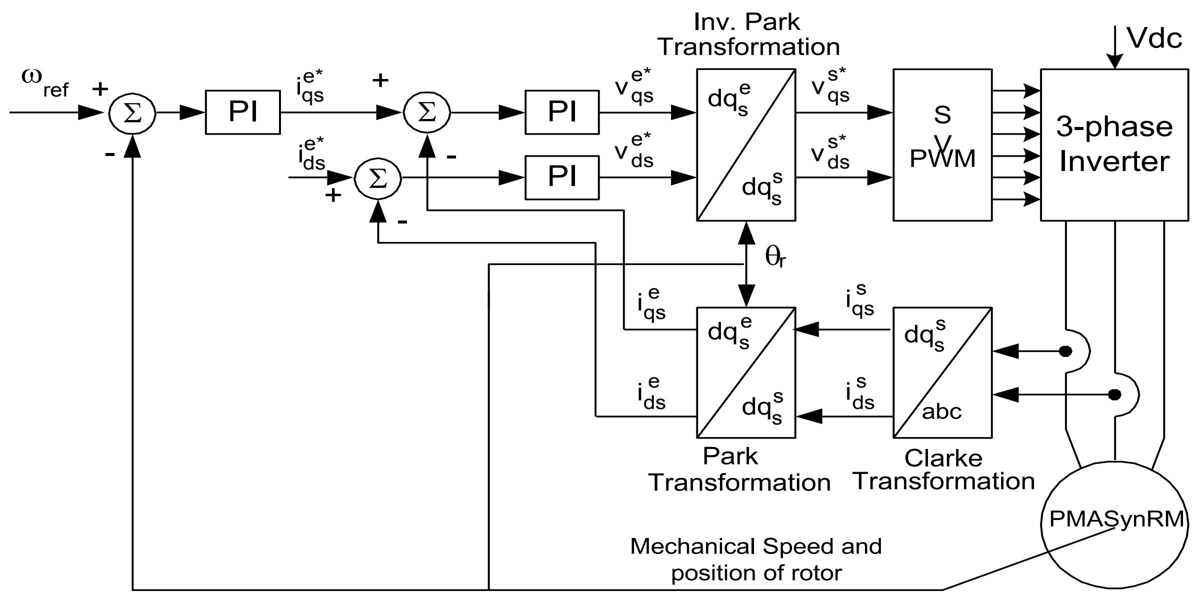

Figure 2.5: Vector control of induction motor

The Field Orientated Control (FOC) is one of the most well-known type of vector control of AC drive. It worked in accordance to three essential points: the motor current and voltage space vectors, the transforming of a 3-phase speeds and times reliable model to a 2-phase. The FOC is in accordance to projections by transforming a 3-phase quantities system into 2-phase quantities system (d-q system). . These transformations produce a structure same like that of a DC motor control. FOC requires two parameters as input references: the torque parameter (q quantity) and the flux parameter (d- quantity) [14].

FOC is closed loop control system of ac motor, which compares the actual speed of the motor with standard reference speed utilizing a speed controller to produce the reference torque quantity (q-component). Then, it transforms the q-component and referenced d-component (d-q) into the three-phase system. The result of the phase transformation is then applied to a current controller (hysteresis controller) to generate the switching pulses for voltage source inverter (VSI) which will control the AC motor. The block diagram showed in Figure 2.6 present the basic construction of Field Oriented Control (FOC) including its main components.

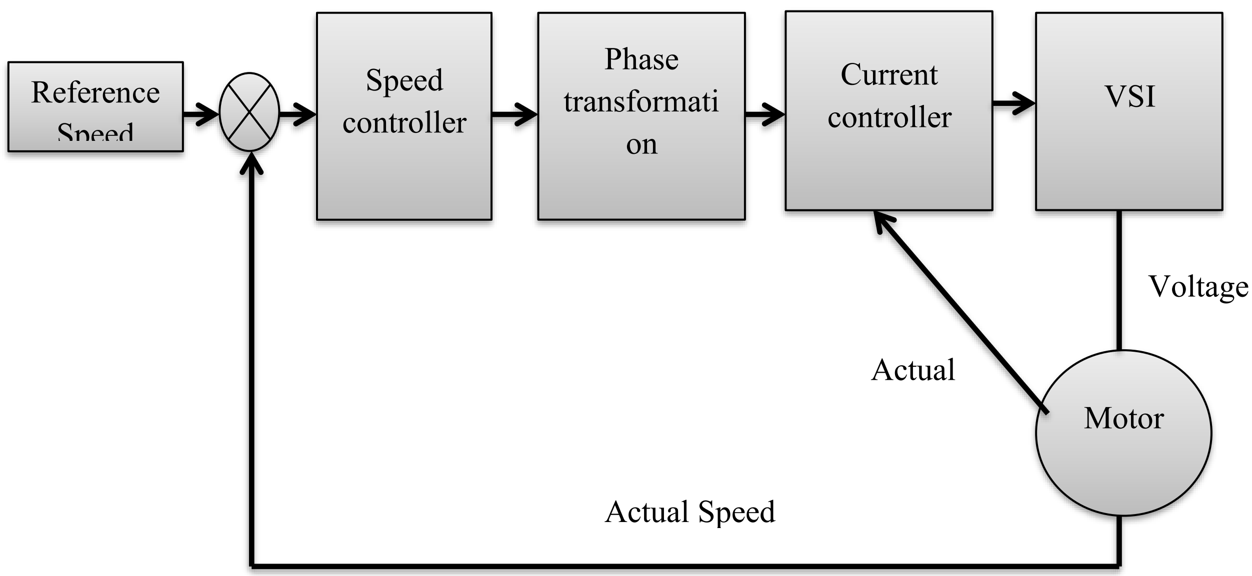

Figure 2.6 Basic block diagram of FOC

2.2.2.1 Speed control

The speed control is the one of the main components of Field Oriented Control of induction motor drive. The working principle of speed control in the motor drive is illustrated such that, the actual speed of the motor is measured and compared with standard reference speed. The resultant error of the speed comparison is fed into the speed control system which produce the reference current (iq) . Different method can be used to construct the speed control system such as the conventional PI controller, or intelligent control method such as Fuzzy logic controller [15].

Conventional PI speed Controller

Since the development of vector control method as a reliable alternative for the traditional scalar control, conventional PI controller has aged for long as speed controller in the vector control. Various studies as well as industries have developed AC motor drive system utilizing PI controller as the speed controller. The simplicity and easy construction of the PI controller made it as dominant speed controller for considerable period of time.

The construction of PI controller is quite simple and straightforward; it combines the proportional and integral part to result in analytic expression which can drive a control process. The working concept of PI is to control a resultant error utilizing the derivative and integral part to produce a controlled variable. Figure 2.7 shows the block diagram of PI controller visualizing its proportional and integral components [16].

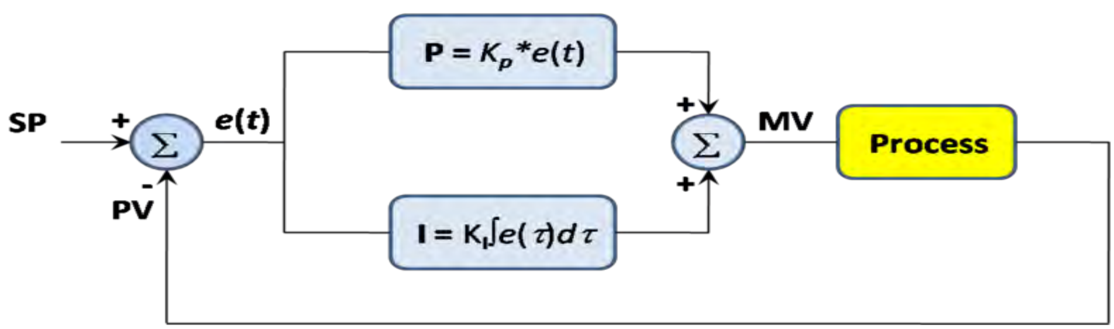

Figure 2.7 PI controller structure

In AC motor drive, PI controller is utilized as speed controller. The resultant error of speed comparison is fed into the PI controller to produce the controlled variable (iq). Proportional and integral gain of the PI controller is tuned to produce the best performance of the drive system. The features of the PI are that it can be changed practically by varying the gain amounts and noticing the alterations in system performance. It is expected that the PI controller is performing frequently sufficient; hence, the drive can be effectively driven. The resultant error is obtained by comparing the standard speed of motor to the practical obtained speed of the motor. The value of the error shows the direction of changes to be implemented by the control