AC MOTOR SPEED PERFORMANCE IMPROVEMENT USING FUZZY LOGIC CONTROL

MOHD AZKAR BIN SIDIK

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A special dedication to:

"My mother, My wife AND My daughter"

RUGAYAH BINTI IDRIS, NOREEN BINTI SUKIMIN and NURUL AISYA BINTI MOHD AZKAR

And

All my families and friends,

Who encouraged and inspired me throughout my journey of education.
Finally, this thesis is dedicated to all those who believe in the richness of learning.

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ABSTRACT

This project focuses on the fuzzy logic controller design to control single phase induction motor. The controller strategy is done through phase angle control method. The phase angle is controlled by controlling the firing angle delay of the triac. This controller system is implemented and simulated using MATLAB Simulink software. The performance of the single phase induction motor are investigated and compared with the PID controller. Based on the simulation, fuzzy logic controller is suitable to control single phase induction motor because it can reduce the rise time, settling time, peak time and overshoot to 0.10s, 0.17s, 0.29s and 0.09 % OS respectively. The comparison between fuzzy logic controller and PID controller shows that the fuzzy logic controller gives better performance response with the rise time (*Tr*), the settling time (*Ts*), peak time (*Tp*) and overshoot (% OS) are 0.08s, 0.08s, 0.05s and 0.004% smaller than PID controller.

ABSTRAK

Fokus projek ini adalah membina pengawal logik fuzzy untuk mengawal motor induksi satu fasa. Strategi pengawalan adalah menggunakan kaedah kawalan sudut fasa. Sudut fasa dikawal dengan mengawal masa tunda bagi triac. Sistem pengawal ini dilaksanakan dan disimulasi menggunakan perisian MATLAB Simulink. Prestasi motor induksi satu fasa dikaji dan dibandingkan dengan sistem pengawal PID. Berdasarkan kepada keputusan simulasi, pengawal logic fuzzy adalah sesuai digunakan untuk mengawal motor induksi satu fasa apabila ia dapat mengurangkan masa naik (Tr), masa puncak (Tp), masa menetap (Ts) dan peratus lonjakan (% OS) adalah 0.10s, 0.29s, 0.17s dan 0.09 %. Perbandingan antara pengawal logic fuzzy ini dengan pengawal PID menunjukkan bahawa pengawal logic fuzzy memberikan prestasi yang lebih baik dengan masa naik (*Tr*), masa puncak (*Tp*), masa menetap (*Ts*) dan peratus lonjakan (% OS) adalah 0.08s, 0.08s, 0.0.05s dan 0.09 % lebih kecil dari pengawal PID.

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LIST OF ABBREVIATIONS

AC	Alternating Current
AI	Artificial Intelligent
DC	Direct Current
FLC	Fuzzy Logic Controller
FPGA	Field Programmable Gate Array
MATLAB	MATrix LABoratory
PIC	Programmable Interface Controller
PID	Proportional Integral Derivative
SPIM	Single Phase Induction Motor
TRIAC	TRIode for Alternating Current

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Single phase A.C supply plays important roles in electrical usage because it is commonly used for general purpose electrical purpose in domestic or commercial applications where three phase power supply is not available. Based on this supply, single phase induction motors become one of the most widely used for numerous domestic and industrial applications like home appliances, industrial control system, and automation because of their it offer lower maintenance, reliable and smaller motor size. Single phase induction motor has been covered most servo application in robotics, machine tools and positioning devices.

Normally, it has two winding, main and auxiliary while auxiliary winding has more turns than winding has [1]. Traditional single phase induction motor run directly from AC voltage at one speed only. The improvement in ac motor control enable the speed of single phase induction motor to be run on variable speed, which can reduce power consumption, acoustic noise and mechanical vibration. The critical aspect in AC motor industry is the role of the researcher/ engineer to control the speed of an AC motor that being used. Traditionally, the AC motor is controlled by two classical strategies, vector control and torque control. Vector control and direct torque control are the two classical strategies to control synchronization and asynchronous of induction motor [2].

Basically, single phase induction motor is widely use in our daily application because of their ability to operate from a single phase power supply. Since it is impossible to reliably operate at unstable range, simple voltage control (open loop control) is limited to controlling in a narrow range. The speed of the single phase AC induction motor can be adjusted either by applying the proper supply voltage amplitude and frequency (called volts per hertz) or by the changing of supply voltage amplitude with constant frequency (slip control) [3]. To make it is possible to operate reliably even in the unstable range, it is necessary to detect the rotational speed of the motor and use a voltage control mechanism (closed loop control) that reduces the speed error when compared to a set value [4].

The speed of induction motor can be control by controlling the voltage applied to the stator voltage. With the enhanced technology in power electronics, a number of semiconductor devices have been introduced in voltage control application. The use of solid state components like the triac for the control of ac drives have been widely used in recent years for several industrial and home applications [5]. The voltage applied to the stator winding of the single phase induction motor can be control to achieve the desired speed by controlling the firing angle of the triac that are used this project.

For efficient control strategies, the speed of the single phase induction motors need to be controlled properly. The control of the stator voltage is needed in order to control the speed. It is because the voltage is directly proportional to the motor speed. For this reason, the phase control technique can be applied for single phase induction motor control. In this technique, a power device known as triac can be used. Triac is a power electronics device which conduct based on the gate pulses it receive rather than the supply voltage [6]. Triac is connected in series with the motor, and hence by controlling the gate pulse of the Triac, speed of the induction motor is controlled smoothly and effectively with less power consumption [7].

Mostly, for closed loop system, conventional or intelligent control techniques were used to provide signal to the firing angle circuit [5]. As the advancement of the technology, the use of intelligent system to control the induction motor is required because of the traditional controllers does not give the satisfactory results when loading variation condition. In recent years, the artificial intelligent (AI) technique, such as fuzzy logic controller has shown high potential for induction motor application [8].

1.2 Problem Statement

Most of the application of control systems nowadays used the Proportional Integrated Derivative (PID) controller. Although the PID controller is simple and easy to practice, the linear PID control method is not working well in ac induction motor drive because of the nonlinearity properties of induction motor. The traditional controller such as PID controller does not give a satisfactory response when loading various conditions and different control parameters. In recent years, the artificial intelligent (AI) techniques such as fuzzy logic controller have shown high potential for induction motor application. The needs for an intelligent system controller that has the capability to control nonlinear, uncertain systems is important to improve the performance of induction motor speed controller. In fact, a new controller is need to be develop using intelligent system to guarantee the stable operation even there is a change in the parameter of the induction motor and sudden load variation.

1.3 Aim and Objectives

The aim of this project is to improve the performances of a speed control of AC motor. It will be done by developing a fuzzy logic controller (FLC) .The controller has the ability to control the TRIAC phase angle delay using pulse fuzzy logic controller (FLC). The output of the controller is used to control the speed of a single phase induction motor (SPIM). In order to achieve this aim, the objectives of this project are describes as follows:

(i) To study the characteristic of single phase induction motor and the effect of triac firing angle delay on the single phase induction motor speed.

(ii) To design and develop closed loop simulation model of fuzzy logic controller using MATLAB-Simulink platform

(iii) To observe the performances of fuzzy logic controller by simulation

(iv) To analyze the results from the fuzzy logic controller and compare with the PID controller

1.4 Project Scopes

The scopes and limitation of this project are given below:

(i) The simulation model is based on the single phase induction motor running 240 V 50 Hz ac voltage supply.

(ii) The control system used in this project was fuzzy logic controller (intelligent control)

(iii) The control strategy is done through phase angle control method

(iv) Triac is used to control the voltage supplied to the single phase induction motor.

(v) The simulation model of the fuzzy logic controller is developed using Matlab-Simulink software.

(vi) The reference speed of motor is 1500 rpm

(vii) The range of time delay generation of the triac firing pulse is between 0 to 9 ms.

1.5 Report Outline

This report is divided to four chapters and the first chapter briefly describes the introduction of this project. This chapter represents the overview of the project includes the problem statement, the objectives of the project.

In chapter 2, the literature review of the previous projects that is related to this project is discussed. All these projects then are compared about the advantages and disadvantages.

The methodology of the proposed project explained in chapter 3. The methodology is divided into three parts. The first part is to study the single phase induction motor characteristics. The second part is to develop design and simulation model for the fuzzy logic controller using Matlab-Simulink.

Chapter 4 discusses the result and analysis of the fuzzy logic controller that included the dynamic response of the motor speed. This chapter highlights the overall of the project outcomes with the simulation result that is obtained using MATLAB Simulink.

Chapter 5 is the final chapter that entails the conclusion of the project design and the recommendations for the future project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The design and development of fuzzy logic controller (FLC) to improve the single phase induction motor performance need an extensive study and research of the previous papers and projects. In this chapter, the previous works that have been accomplished by other researchers will be discussed.

2.2 Related Work

Zeyad Assi Obayed, Nasri Sulaiman and M.N Hamidon [9] have developed a fuzzy logic controller using VHDL for implementation of field programmable logic array (FPGA) to control position in AC motor. The controller accepts two types of digital outputs, the first one is the plant (Yp) and the second one is the desired output (Yd) and deliver control action signal as a digital output. It also accept 8 bit digital signal that represent the gain parameter needed by the controller and the other two bits signal to select the type of the controller. Figure 2.1 shows the general layout of the controller in a unity feedback control system.

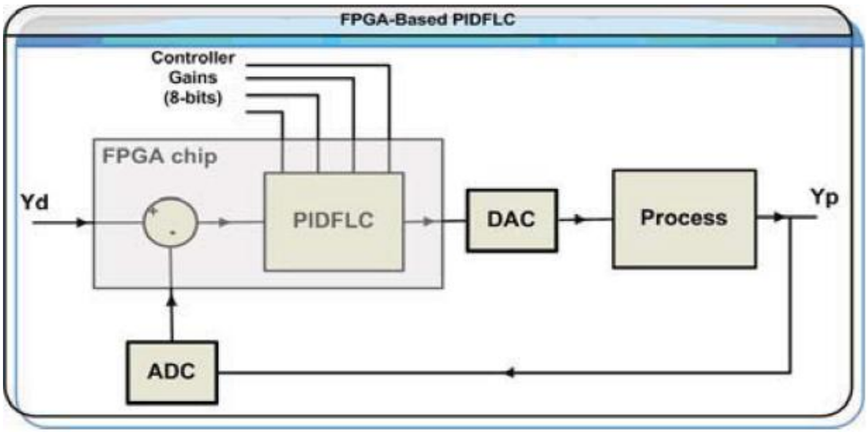

Figure 2.1: Layout of the proposed controller in unity feedback control system

In this paper, Altera Quartus 2 version 9.0 software has been used to get the simulation and timing result as well as synthesized design. Besides that, ModelSim simulation program is used for the purpose of the simulation for all tests for the proposed design. The same design has been done in Matlab environment. For comparison purposes, ModelSim store the simulation data in text files, these file have been used in Matlab to convert it to decimal vectors, and the use vectors to plot the analog response. Figure 2.2 describes the coding and simulation environment for the design.

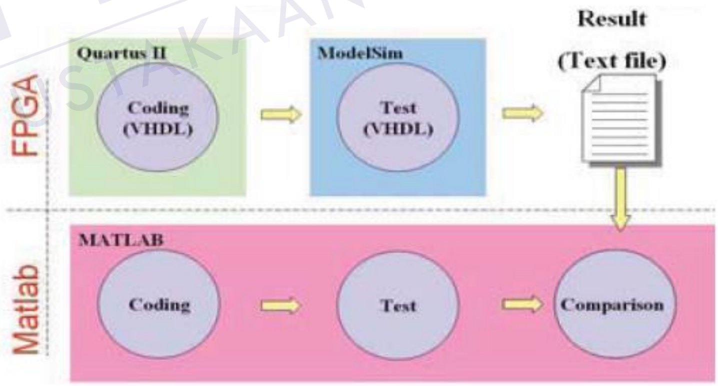

Figure 2.2: Coding and simulation environment

The result of the second order linear plant of the developed PIDFLC is shown in Figure 2.3.

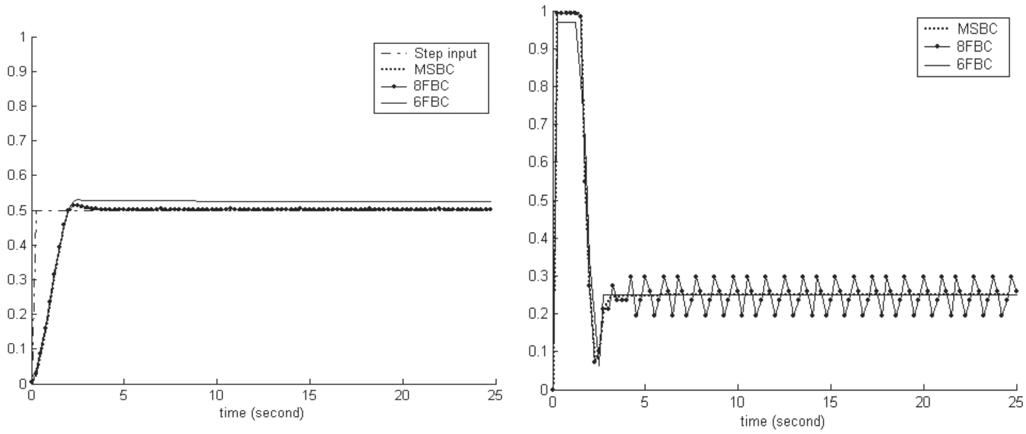

Figure 2.3: Second order linear plant controlled by the PIDFLC

(a) Step Response (b) Control action

T.D Dongale, S.R Jadhav, S.V Kulkarni, T.G Kulkarni, R.R Mudholkar and M.D Uplane [10], have describe the implementation of the controller based on PID and Fuzzy Logic strategies. They have made the comparative performances analysis exploring of Fuzzy Logic control strategies and PID control strategies. In this project, a system to control speed of three phase motor have been developed using PIC16F877A microcontroller which includes with inverter design, gate drive circuit and isolation. Figure 2.4 shows the system block diagram for the system that have been developed.

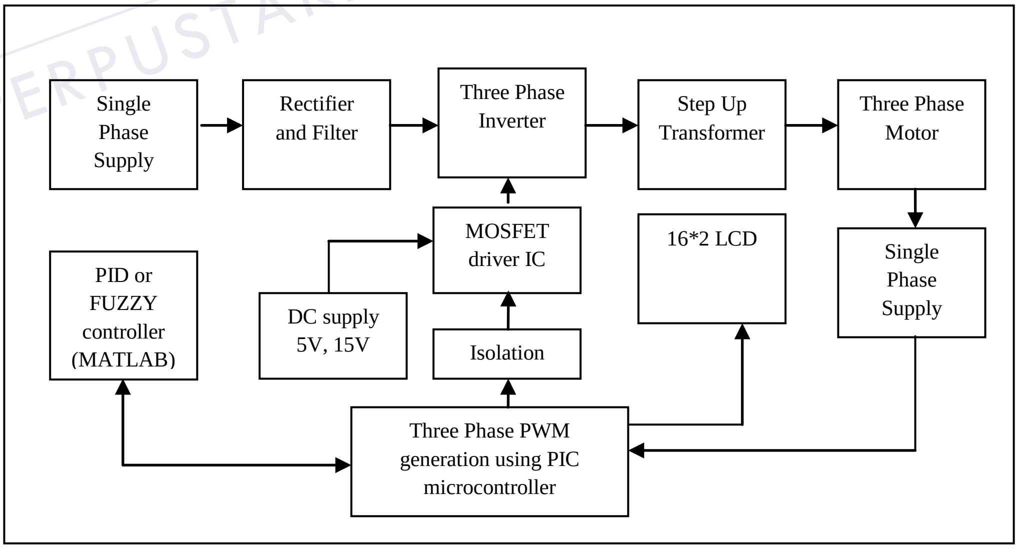

Figure 2.4: A system block diagram using PIC16F877A

The model of for PID and Fuzzy Logic controller have been developed using MATLAB-SIMULINK for real time motor speed control. For the PID model, the actual speed of the motor is sensed by the speed sensor using PIC controller and it sent serially to Simulink. The transfer function of the system is the second order type the exhibit overshoot and large settling time which form the metrics of performance in the previous study. The real time PID response is illustrated in Figure 2.5.

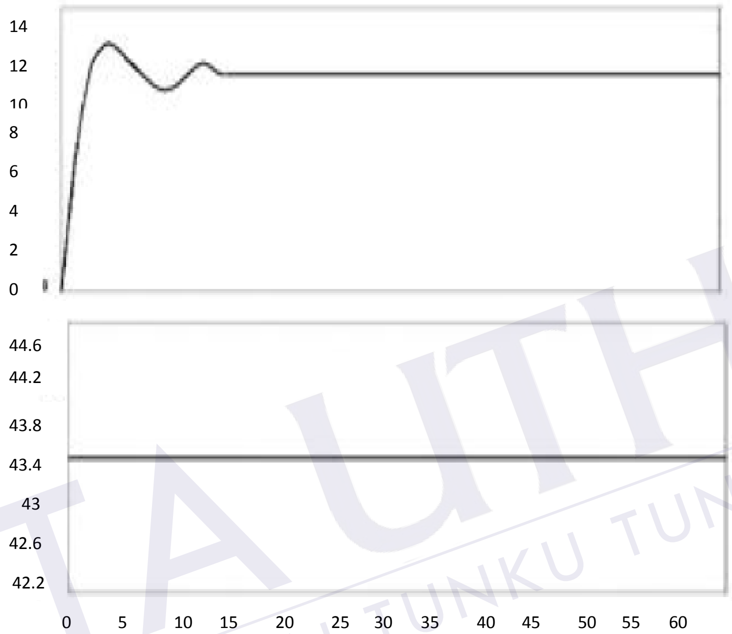

Figure 2.5 Real time PID response

For the fuzzy logic controller, the reference speed is set as a constant. Error block generate the output which is the error between actual speed and the set speed that is applied to one input of fuzzy controller and other to store the error in the memory to compute the change in error. Multiplexer combine both inputs and give it to Fuzzy logic controller. Real time scope is used observe the actual behavioral of the system. The instrument block is used to send the output of Fuzzy Logic Controller to PIC. The Fuzzy controller in this project is design using Mamdani method as a Fuzzy Inference Scheme (FIS). The real time Fuzzy logic controller response is shown in Figure 2.6.

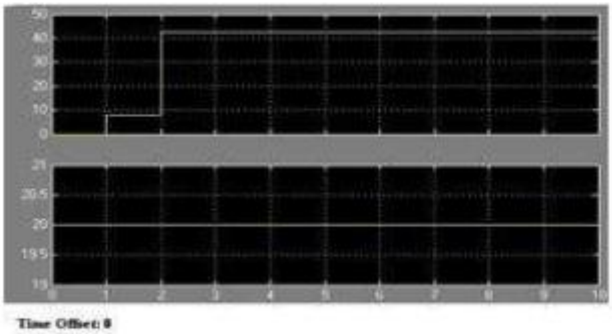

Figure 2.6: Real time fuzzy controller response

Ebrahim Abd El Hamid Mohamed Ramaden *et al* [11], have proposed a fuzzy system that has been supplied to a permanent magnet DC motor via a configuration of H-Bridge. In this paper, a fuzzy logic control (FLC) system and a conventional proportional-integral (PI) controller for speed control of DC motor have been implemented using Field Programmable Gate Array (FPGA) circuit. The architecture of the fuzzy logic controller that has been developed is shown in Figure 2.7.

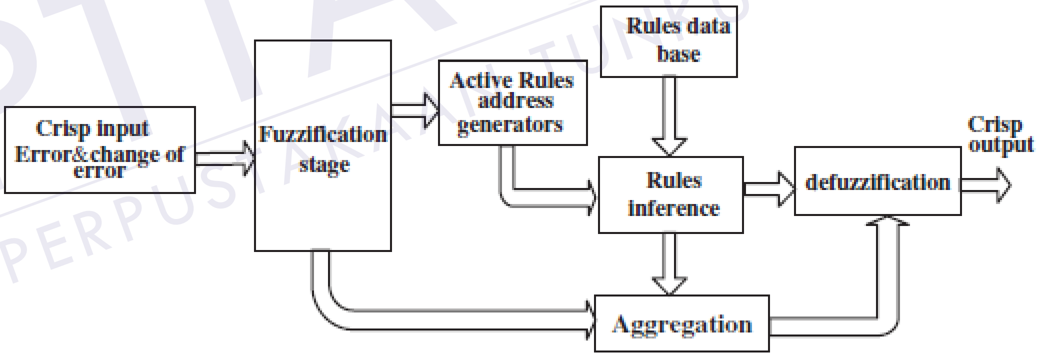

Figure 2.7: FLC architecture

In the proposed fuzzy system as in Figure 2.7, the fuzzification process is performed by reading out from the system's memory the value of membership function of activated sets and also codes of these sets. The characteristic parameters of the fuzzy logic system are elaborated in Table 2.1.

Table 2.1: The proposed fuzzy characteristics

Fuzzy inference system	Mamdani FIS
Inputs	2
Input Resolution	8 bit
Output	1
Output resolution	8 bit
Antecedent MF's	7 triangular per fuzzy se
Antecedent MF degree of truth resolution	8 bit
Consequent MF's	7 triangular per fuzzy se
Antecedent MF degree of truth resolution	8 bit
Aggregation method	MAX
Implication method	MIN
Defuzzification method	Center of Gravity (COG)

The DC motor response of the PI and FLC controller are described in Figure 2.8. From the results, the PI controller performances result in the lack of smooth transition between the required speed and the present of overshoot and higher rise time. For the FLC controller, less oscillation, zeros overshoot and less rise time. This project describes that the performances of FLC is better than PI controller. The detail information about the comparison is elaborated in Table 2.2.

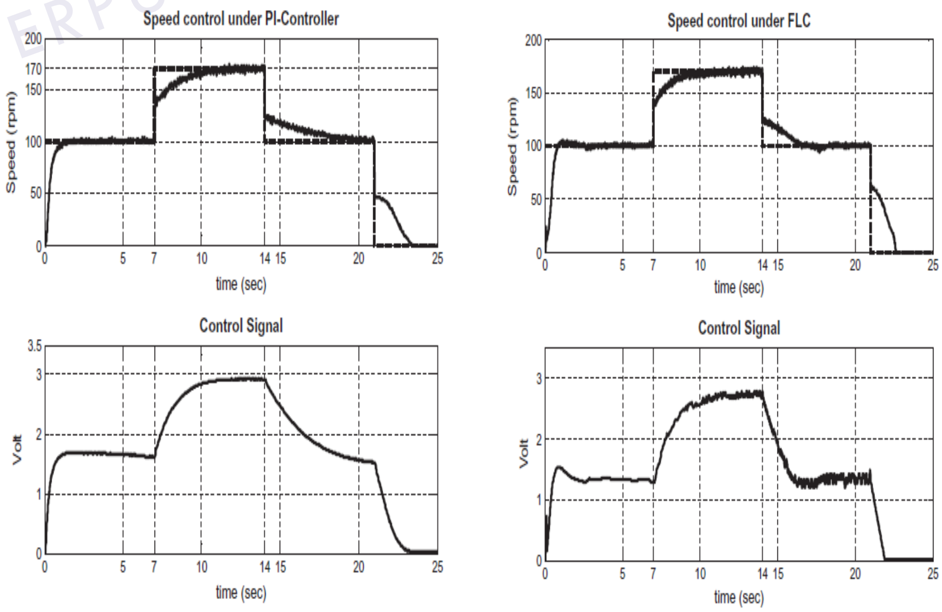

Figure 2.8: System response for PI and FLC for change in the operating point

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