SPEED CONTROL OF DC MOTOR BY USING FUZZY LOGIC CONTROLLER

KHAIRUL AFIQ BIN ZAKARIA

A thesis submitted in fulfillment of the
requirements for the award of degree of
Bachelor of Electrical Engineering (Power System)

Faculty of Electrical & Electronics Engineering
Universiti Malaysia Pahang

JUNE 2012

ABSTRACT

The automatic control has played a vital role in the advance of engineering and science. Nowadays in industries, the control of direct current (DC) motor is a common practice thus the implementation of DC motor of controller speed is important. The main purpose of motor speed control is to keep the rotation of the motor at the present speed and to drive a system at the demand speed. The DC Series Wound Motor is very popular in industrial application and control systems because of the high torque density, high efficiency and small size. The main purpose of this project is to control speed of DC Series Wound Motor using four controllers which are PID, PI, P, and Fuzzy Logic Controller (FLC). Initially all the controllers are developed by using MATLAB simulink model. In this project, PID, PI, and P controller are developed and tuned in order to get faster step response and the Fuzzy Logic Controller (FLC) is design based on the membership function and the rule base. The expectation of this project is the Fuzzy Logic Controller will get the best performance compared to other controllers in terms of settling time (Ts), rise time (Tr), peak time (Tp), and percent overshoot (%OS). Finally a GUI of these controllers are developed which allow the users to select any controller and change its parameters according to the different conditions under loaded and unloaded scenarios.

ABSTRAK

Kawalan automatik telah memainkan peranan yang sangat penting dalam memajukan bidang kejuruteraan dan bidang sains. Pada masa sekarang, setiap industri menggunakan kawalan arus terus terhadap motor dan pelaksanaan dalam mengawal kelajuan dc motor adalah sangat penting. Tujuan utama dalam pengawalan kelajuan dc motor adalah untuk mengekalkan putaran motor pada kelajuan tertentu terhadap kelajuan yang telah ditetapkan oleh industri. Penggunaan motor jenis DC Series Wound Motor adalah sangat popular di dalam sistem aplikasi dan kawalan industri kerana motor jenis ini menghasilkan tork yang tinggi, mempunyai kecekapan yang tinggi, dan juga disebabkan saiz motor yang kecil. Tujuan utama projek ini adalah untuk mengawal kelajuan DC Series Wound Motor menggunakan empat pengawal iaitu PID, PI, P, dan Fuzzy Logic Controller. Pada mulanya, kesemua pengawal dibuat dan diaplikasikan dalam model MATLAB. Dalam projek ini, cara penghasilan pengawal jenis PID, PI, dan P adalah berdasarkan nilai yang telah diubah sehingga mendapat nilai 'step response' yang pantas, manakala Fuzzy Logic Controller dihasilkan berdasarkan 'membership function' dan juga 'rule' yang telah ditetapkan. Jangkaan projek ini adalah pengawal jenis Fuzzy Logic Controller mendapat prestasi yang terbaik berbanding dengan jenis pengawal yang lain dari segi masa penetapan (Ts), masa naik (Tr), masa puncak (Tp), dan percent overshoot (%OS). Akhirnya, MATLAB GUI dibina untuk membenarkan pengguna memilih jenis pengawal yang ditetapkan dan melihat graf yang akan dipaparkan dalam GUI ini dalam dua jenis keadaan yang berbeza iaitu antara situasi yang menggunakan beban sebagai tambahan dan juga situasi yang tidak mengunakan beban pada motor.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AC	-	Alternating Current
DC	-	Direct Current
FLC	-	Fuzzy Logic Controller
GUI	-	Graphical User Interface
P	-	Proportional
PI	-	Proportional-Integral
PID	-	Proportional-Integral-Derivative
SISO	-	Single Input Single Output
MIMO	-	Multi Input Multi Output

CHAPTER 1

INTRODUCTION

1.1 Background

The speed control is one of important component in Direct Current motor (DC motor) operation. In controlling the speed of a DC motor, some improvement needs to be done toward speed regulation during transient loading conditions. The control includes a regulating circuit that having an output for controlling the armature voltage to the motor. An input speed reference signal corresponding to the desired speed is provided to the regulating circuit. A feedback signal proportional to armature voltage is also provided to the regulating circuit to establish an error signal for operating the control to regulate the voltage to the motor and therefore the motor speed.

This project approaches many type of controller which are PID, PI, and P controller, but fuzzy logic controller is the best tool in controlling the speed of the DC motor. Fuzzy Logic is based on the theory of fuzzy sets, where an objects membership of a set is gradual rather than just member or not. Fuzzy Logic uses the whole interval of real numbers between zero (False) and one (True) to develop logic as a basis for rule of interference enables computers to make decisions using fuzzy reasoning rather than exact. The employment of fuzzy control is commendable for very complex processes, when there is no simple mathematical model and for highly nonlinear processes. Then, if the processing of linguistically formulated expert knowledge is to be performed the fuzzy control can be employed.

For acquire an accurate of fuzzy, Fuzzy Logic Toolbox 2.1 which is one of the applications in MATLAB software is used. Generally in fuzzy logic system, it is most important to define the range of input and output membership function in the fuzzy interference engine. Then, with the appropriate fuzzy rules, the accurate controlling system will be developed for the DC motor speed control. Therefore, the speed of DC motor that used Mamdani-style fuzzy inference system, which is composed of each one input, and output variable.

1.2 Problem Statement

There are some problems occur while controlling the DC Series Wound Motor, the problem is this type of motor does not provide excellent speed control [3]. To encounter this problem, the controller is needed and this project Fuzzy Logic Controller will be used. The selection of series wound motor because it provides excellent torque load properties to the system which other motor of this class cannot provide.

There are many types of controllers nowadays, each one of them have its own advantages and disadvantages, so in this project four controllers are used which are PID controller, PI controller, P controller, and Fuzzy Logic Controller (FLC).

1.3 Objectives

The objectives of this project are:

i. To control the DC series wound motor speed with PID, PI, P, and Fuzzy Logic Controller (FLC) in MATLAB simulink.
ii. To compare and analyze the performance of each controllers.
iii. To develop GUI (Graphical User Interface) for DC series wound motor control using MATLAB software.

1.4 Scope of Project

Scopes of the project are:

i. Simulation of DC series wound motor.
ii. Analyze the performance of each controller : Settling time (Ts), Rise Time (Tr), Peak Time (Tp), and Percent Overshoot (%OS)

CHAPTER 2

LITERATURE REVIEW

2.1 DC Motor

The electric motor is a motor that convert electrical energy into mechanical energy. There are two types of motor which are AC motor, and DC motor. A simple DC motor use electricity and magnetic field for producing torque which rotate the motor. Permanent magnet DC motor (PMDC) outperforms to AC motor because it provides better speed control on high torque loads and use in wide industrial application. DC motors are more usable as it designed to use with batteries and solar cells energy sources, which provide portability where we required it and thus provide cost effective solution, because it is not possible to have AC power supply in every place, DC motor show its response at both voltage and current. The applied voltage describes the speed of motor while current in the armature windings shows the torque. If applied load increased in the shaft of motor, then in order to sustain its speed motor draws more current from supply and if supply is not able to provide enough current then motor speed will be affected. Generally, it can be said that applied voltage affect speed while torque is controlled by current. DC motors provide more effective results if chopping circuit is used. Low power DC motor usually use in lifting and transportation purposes as low power AC motors do not have good torque capability. DC motor used in railway engines, electric cars, elevators, robotic applications, car windows and wide verify of small appliances and complex industrial mixing process where torque cannot be compromised. There are several types of DC motor but most common are brushed DC motor, brushless DC motor, stepper motor, and servo motor. These DC motors have three winding techniques such as shunt DC motor, series DC motor, and compound DC motor [5].

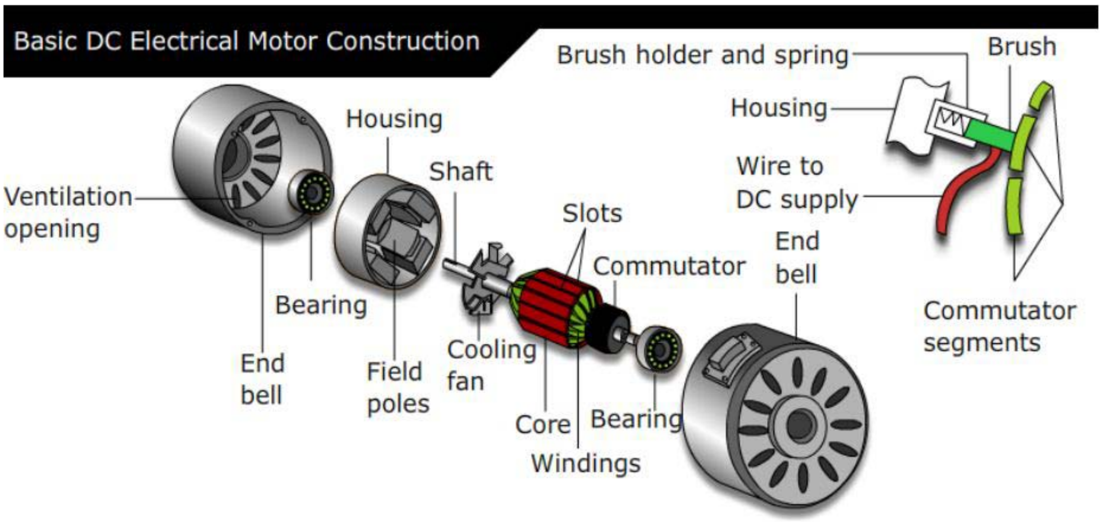

Figure 2.1 DC motor parts

2.1.1 Brushed DC Motor

The brushed DC motor has permanent magnets and its rotor has electrical magnets which move and generate torque according to applied DC power. This motor works on principle of Lorentz force, according to that if a current carrying conductor placed in magnetic field then it experiences a force or torque. This motor has low initial costs, high reliability and it is simple in speed control which considered its advantages while high maintenance, and low life time is its disadvantages. Cleaning and replacing of brushes (carry current) and springs (attached to one end brushes so it attached to brushes) involves in maintenance. [5] This motor use different wound techniques which are as follows.

a) Shunt-Wound

This motor has shunt field coils in parallel with armature. So current is independent of one another between armature and field coils as shown in Figure 2.2. This motor provides excellent speed control. This type of motor used where the requirement of power needed is more [3].

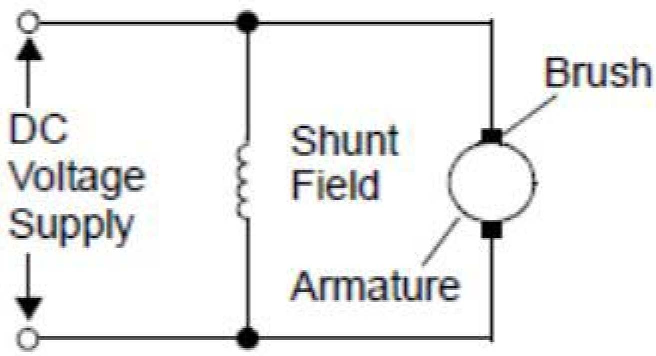

Figure 2.2 Shunt wound DC motor

b) Series-Wound

This motor has shunt field coils in series with the armature as shown in Figure 2.3. So, the current is dependent of one another, this motor provide high torque applications because current increased in armature and stator when high load is applied to it. This motor does not provide excellent speed control. [3]

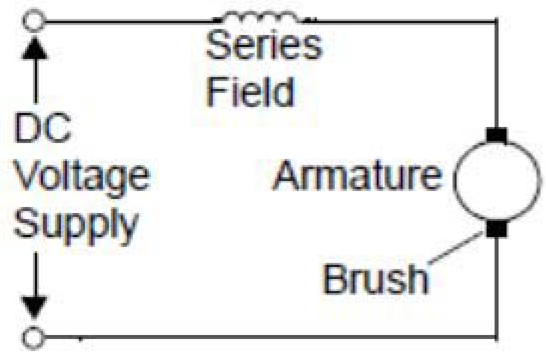

Figure 2.3 Series wound DC motor

c) This type of motor is combination of a shunt wound and series wound motors as shown in Figure 2.4. These motors provide the properties of both motors, it provides high torque as well as speed control as compared to series-wound and shunt wound.

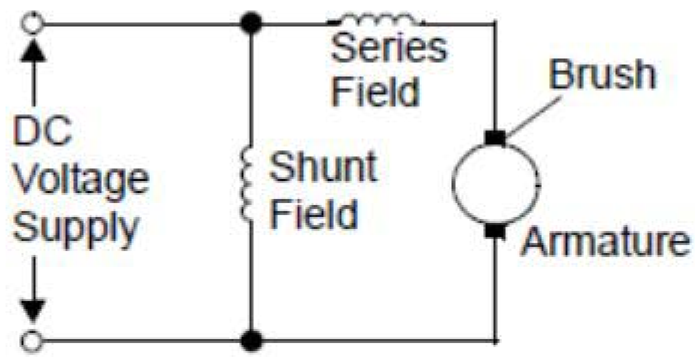

Figure 2.4 Compound-wound DC motor

2.1.2 Brushless DC Motor

Brushless motor is a type of synchronous electric motor run on DC current with electronic communication system. This motor not has commentator or brushes like mechanical parts. This motor has rotating permanent magnet in rotor and its stator have no moving permanent magnets. Long life time, little maintenance and high efficiency are its advantages while high initial costs and more complicated controller are its disadvantages. This motor is similar to AC motor and required an external communication to generate torque. This motor has two subtype motors which are stepper motor, and reluctance motor [3].

2.2 Speed Control of a DC Motor

The speed of DC motors can be adjusted within wide boundaries so that this provides easy controllability and high performance. DC motors used in many applications such as still rolling mills, electric trains, electric vehicles, electric cranes, and robotic manipulators require speed controllers to perform their tasks. Speed controller of DC motor is carried out by means of voltage control in 1981 firstly by Ward Leonard. The regulated voltage sources used for DC motor speed control have gained more importance after the introduction of thyristor as switching devices in power electronics. Then semiconductor components such as MOSFET, IGBT, and GTO have been used as electric switching devices [6].

In general, the control of system is difficult due to their high nonlinearity properties. To overcome this difficulty, Fuzzy Logic Controller can be developed. The best applications of Fuzzy Logic Controller are the time variant system that is nonlinear

[7]. One of the most important, FLC applications in real life is the metro system in the city Sendai of Japan in 1987 [8]. Nowadays, Fuzzy Logic Controller applications are successfully used in many fields including automatic focus cameras, household materials such as dishwashers and also automobile industry.

The speed response of a DC motor exposed to fixed armature voltage was investigated for both under loaded and unloaded operating conditions. The first, the DC motor was operated for a required reference speed under loaded and unloaded operating conditions using PI control method. Then, to make performance comparison, the speed of the system designed for operating at fixed speed under different load conditions are simulated at MATLAB/Simulink environment. In this study, chopper circuit was act as a motor driver.

2.3 Fuzzy Logic Controller (FLC)

Fuzzy logic is a type of multi valued logic. It deals with approximate reasoning rather than precise. Fuzzy logic derived from fuzzy set theory [1]. Fuzzy logic was first proposed by Lotfi Zadeh in 1965. Fuzzy controller is an innovative technology that modifies the design of systems with engineering expertise. Fuzzy logic use human knowledge to implement a system. It is mostly use in system where there are no mathematical equations for handling system. Common sense, human thinking and judgement are fuzzy rules. It helps engineers to solve non linear control problems. It mathematically emulates human knowledge for intelligent control system and complex application.

Fuzzy Logic Controller (FLC) has some advantages compared to other classical controller such as simplicity of control, low cost, and the possibility to design without knowing the exact mathematical model of the process. Fuzzy logic incorporates an alternative way of thinking which allows modelling complex systems using higher level of abstraction originating from the knowledge and experience. Fuzzy logic can be described simply as “computing words rather than numbers” or “control with sentence rather than equations”.

There are two famous type of system currently used in fuzzy logic which are Mamdani fuzzy inference, and Sugeno fuzzy inference.

2.3.1 Mamdani fuzzy inference

The most common method used currently is fuzzy inference system. In 1975, Professor Ebrahim Mamdani of London University introduced first time fuzzy systems to control a steam engine and boiler combination. He applied a set of fuzzy rules experienced human operators. The mamdani system usually done in four steps (referred Figure 2.5). The steps are fuzzification of the inputs, rule evaluation, aggregation of the rules, and defuzzification [2]. Fuzzifications convert input data to degree of membership functions. In this process data is matched with condition of the rule and determined how well data is matched with rule at particular instance. Thus a degree of membership function is developed.

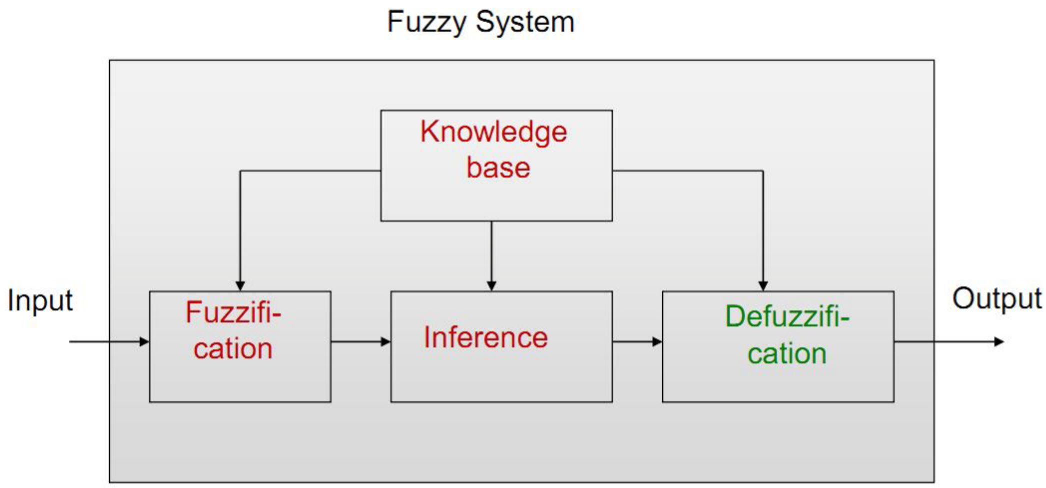

Figure 2.5 Fuzzy Mamdani inference system

Then in Rule-base block rules are written according to system requirement. In case of DC motor, there are two input variables error and change in error is selected. Usually rules are in if, and, then form. In inference engine aggregation is done in which degree of fulfilment is calculated of the condition specifics by a rule. Defuzzification block converted resulting fuzzy set into a number that is sent to the system and this number is actually the control signal. There are seven defuzzification methods which are Centre of gravity (COG), Centre of gravity method for singletons (COGS), Bisector of area (BOA), Mean of Maxima (MOM), and Left most maximum (LM), and right most maximum (RM).

2.3.2 Sugeno fuzzy inference

Mamdani style is not computationally efficient as it find the centroid of two dimensional shapes by integration of carrying function. Michio Sugeno proposed a new method to use single spike, a singleton, as a membership function inputs. Its mean fuzzy set is at unity point at one particular point on the universe of discourse and zero at remaining area. This system is almost same of Mamdani method but with the exception of consequent change and instead of fuzzy set it use a mathematical function as input variable. [2]

2.4 PID Controller Design

PID (proportional integral derivative) control is one of the earlier control strategies. Its early implementation was in pneumatic devices, followed by vacuum and solid state analog electronics, before arriving at today’s digital implementation of microprocessors. It has a simple control structure which was understood by plant operators and which they found relatively easy to tune. It is a generic control loop feedback mechanism and used as feedback controller. PID working principal is that it calculates an error value from the processed measured value and the desired reference point. The work of controller is to minimize the error by changing in the inputs of the system. If the system or plant is not clearly known then applying PID controller provide the best results if it is tuned properly by keeping parameters of the system according to the nature of system. [13]

$$\frac{u(s)}{e(s)} = Gc\ (s) = \ Kp\ (1 + \frac{1}{Tis} + Tds) \qquad (1)$$

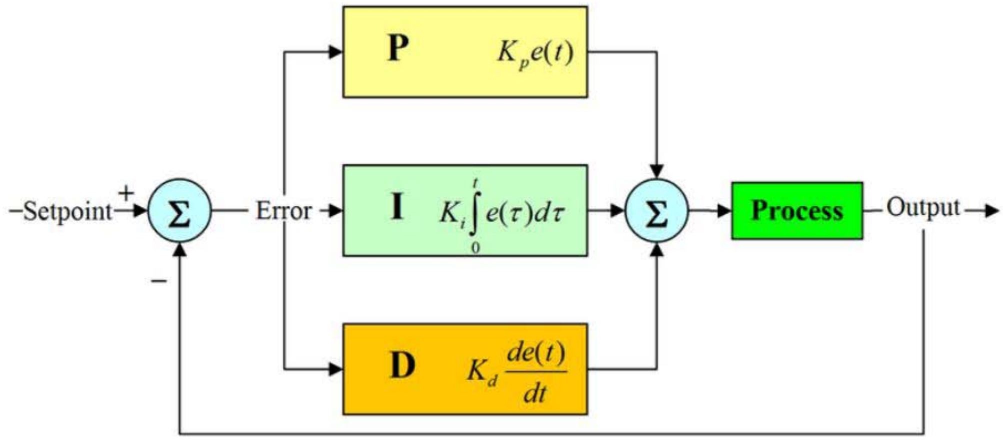

Figure 2.6 Block Diagram of PID controller

The PID measurement depends upon three parameters which are called proportional (P), the integral (I) and derivative (D) part. For the P part, it determines the reaction to current error. I part determines reaction to the sum of recently appeared errors. Then D determines the reaction according to the rate of error changing. As derivative action is sensitive to noise so mostly the controller are PI controller rather than PID as it is not possible a system without the disturbances. Integral part helps the system to reach onto its target value while P part is increase overshoot. [13]

2.4.1 PID tuning methods

There are many methods can be used in PID tuning. The most effective way is that in which a model is developed and select P, I, and D values. Every method has some advantages and disadvantages shown in Table 2.1 which discussed later.