DC Motor Speed Control Using a Fuzzy Logic Controller

Project Advisor

Mr. Saleem Ata

Submitted by:

Arslan Zafar 081220-079

Aneeq Suhail Janjua 091320-051

Irfan Mureed Hussain 091320-067

Department of Electrical Engineering

School of Science and Technology

University of Management and Technology

DC Motor Speed Control Using a Fuzzy Logic Controller

Project Report submitted to the

Department of Electrical Engineering, University of Management and Technology

In partial fulfillment of the requirements for the degree of

Bachelor of Science

In

Electrical Engineering

Advisor Name: Mr. Saleem Ata

Advisor Signature: _________________ **Coordinator Signature :___________________**

Arslan Zafar 081220-079

Aneeq Suhail Janjua 091320-051

Irfan Mureed Hussain 091320-067

Date: _______________

Abstract

The objective of this report focuses primarily on the design and implementation of DC motor speed control using Fuzzy Logic and provides a brief description about speed control of a DC motor. There are different methods of speed control but we have found that fuzzy control to be the most appropriate/suitable for our project. First of all, in no load condition, the DC motor shall run at its full speed and the speed of the motor shall then be varied and adjusted via a dimmer (variable resistor) and set to a specific number based on revolutions per minute. The speed of the motor will be displayed on an LCD and then a PWM signal shall be generated from the controller and the motor speed shall change. Now if we switch on an electrical load at this speed, the motor speed shall decrease. Fuzzy logic, implemented via an AVR microcontroller, shall then be applied to maintain the previous desired speed. We (group members) have tried our level best to fulfill all the requirements of this project. This report has been written in such a way that it is easy for anyone with basic knowledge in Engineering to interpret and understand it. It all depends upon the reader now to deduce it carefully and to comprehend what we wish to express.

Dedication

We dedicate this project to our respectful parents and teachers.

بسم الله الرحمن الرحيم

In the name of ALLAH, the most BENEFICENT, the most MERCIFUL.

All praises and thanks are to ALLAH for giving us the ideas, the vision and the passion to complete this project successfully.

Acknowledgement

We are highly indebted to the Department of Electrical Engineering for providing us an opportunity to apply our theoretical knowledge in the form of our Final year project. We are highly thankful to our project supervisor, Mr. Saleem Ata, for his useful suggestions on the selection of a project. We would also like to thank Mr. Muhammad Haris for his “support” and suggestions regarding the implementation of the project. We are thankful to the Department of Electrical Engineering for allowing us to use the Project Lab for our project related experiments. We would also like to thank Mr Basit Shahab, Mr. Asif Hussain, and Mr. Salik for their valuable suggestions regarding our project.

Finally, we would like to thank all the valuable readers for taking out the time from their precious time to study this document.

Table of Contents

CHAPTER 1: INTRODUCTION……………………………. ………………………………15

1.1 Introduction……………………………………………………………………………..15

1.2 Background……………………………………………………………………………..15

1.3 Project Overview………………………………………………………………………16

1.4 Project working in nutshell……………………………………………………………..17

1.5 FLC for controlling DC motor speed…………………………………………….……..17

1.6 Problem Statement………………………………………………………….............17

1.7 Problems and their Solutions…………………………………………………………...18

1.8 Scope……………………………………………………………………………………18

1.9 Applications of Fuzzy Logic……………………………………………………………19

CHAPTER 2: DC MOTOR…………………………………………………………………20

2.1 Introduction……………………………………………………………………………20

2.2 Types of DC Motors……………………………………………………………………22

2.2.1 Brushed…………………………………………………………………………….22

2.2.2 Brushless…………………………………………………………………………...23

2.3 DC Generator…………………………………………………………………………...23

2.4 Motor Controllers..………23

2.4.1 Intelligent Controllers…………………………………………………………...24

2.5 Rotational Motor Speed Control……………………………………………………..24

2.5.1 Shunt Field Control……………………………………………………………...25

2.5.2 Armature Voltage Control………………………………………………………25

2.5.3 PWM Speed Control…………………………………………………………….25

CHAPTER 3: FUZZY LOGIC CONTROLLER…………………………………………….28

3.1 Where did fuzzy logic come from?...28

3.2 What is fuzzy logic?..28

3.3 How is FL different from conventional control methods?...28

3.4 Fuzzy logic vs. Conventional logic……………………………………………………..29

3.5 How does fuzzy logic work?..29

3.6 Why use fuzzy logic?...30

3.7 How is fuzzy logic used?..31

3.8 When not to use Fuzzy Logic…………………………………………………………..31

3.9 Fuzzy Logic controller structure……………………………………………………..32

3.10 Linguistic variables……………………………………………………………………33

3.11 The rule matrix………………………………………………………………………...33

3.12 Starting the process……………………………………………………………………34

3.13 Membership functions…………………………………………………………...37

3.14 Putting it all together…………………………………………………………………..40

3.15 Inferencing………………………………………………………………………………42

3.16 Defuzzification - getting back to crisp numbers……………………………………………43

3.17 A "fuzzy centroid" algorithm………………………………………………………………43

3.18 Tuning and system enhancement……………………………………………………..44

3.19 Conclusion………………………………………………………………………………45

3.20 Fuzzy Logic in MATLAB……………………………………………………………………46

3.20.1 Command line FIS functions…………………………………………………………..46

3.20.2 Graphical User Interface (GUI) tools………………………………………………47

3.20.3 SIMULINK blocks……………………………………………………………………..47

CHAPTER 4: HARDWARE DESIGN AND IMPLEMENTATION……………………….54

4.1 Electrical/Mechanical Structure…………………………………………………………...54

4.1.1 Components……………………………………………………………………………..54

4.2 Diode Rectifiers (AC to Fixed DC)………………………………………………………54

4.2.1 Power diode……………………………………………………………………………..54

4.2.2 Diode rectifier…………………………………………………………………………...55

4.3 Rectification……………………………………………………………………………….55

4.3.1 Single Phase Half Wave Rectifier………………………………………………………55

4.3.2 Single Phase Full Wave Rectifier……………………………………………………….57

4.5 DC Motor…………………………………………………………………………………60

4.5 Microcontroller (AVR Atmega16)……………………………………………………….60

4.5.1 Ports Description………………………………………………………………………...62

4.6 Hex Inverter………………………………………………………………………………64

4.7 LCD………………………………………………………………………………………..64

4.8 7805 Voltage Regulator…………………………………………………………………...66

4.9 Power MOSFETs…………………………………………………………...…………..67

4.10 BJTs……………………………………………………………………………………...67

4.11 Fan……………………………………………………………..68

4.12 Capacitor……………………………………………………….......................................68

4.13 Resistors……………………………………………………….......................................69

4.14 Diode (1N4001) ……………………………………………………….............................70

4.15 Light Emitting Diode (LED) ………………………………………………………….70

CHAPTER 5 Fuzzy Logic Controller of DC Motor [Developing an FLC]…………………52

5.1 Developing a fuzzy logic controller………………………………………………………72

5.2 Fuzzification……………………………………………………….......................................72

5.3 Rule-base……………………………………………………….......................................73

5.4 Inference mechanism………………………………………………………………...........74

5.4.1 Output membership function for increase voltage…………………………………………75

5.4.2 Output membership function for decrease voltage………………………………………...75

5.4.3 Output membership function for do nothing……………………………………………75

5.5 Defuzzification………………………………………………………………………………76

5.6 Conclusion…………………………………………………………………………………...76

Chapter 6 Working/Components of the Project……………………………………………...**77**

6.1 Power supply and Controller circuit……………………………………………………...77

6.2 Step down Transformer…………………………………………………………........77

6.3 Dimmers……………………………………………………………..............................78

6.4 Electrical load………………………………………………………………......................78

6.5 DC Motor……………………………………………………………............................79

6.6 MOSFET Module………………………………………………………………...............79

6.7 Hex Inverter Circuit……………………………………………………………..............80

6.8 Amplification Circuit…………………………………………………………….............80

6.9 Complete Project Hardware……………………………………………………………82

6.10 Block Diagrams………………………………………………………………................81

6.11 Proteus Simulation……………………………………………………………..............82

CHAPTER 7 CONCLUSION RECOMMENDATIONS……………………………………84

7.1 Conclusion………………………………………………………………………………..84

7.2 Problems……………………………………………………………………......................84

7.3 Recommendations……………………………………………………………….............84

7.3.1 Mathematical modeling of motor response………………………………………………...85

7.3.2 Hardware improvement……………………………………………………………….....85

7.3.3 Software improvement………………………………………………………………......85

References……………………………………………………………………...............................86

Appendix I……………………………………………………………………..............................87

List of Figures

1. Simple Feedback System.…..…………………………………………………………………16

2. Dc motor……………………………………………………………….............................21

3. PWM waveforms………………………………………………………………............26-27

4. Fuzzy logic controller feedback control system.……………………………………………...32

5. Simple FL control system.…..…………………………………………………………………34

6. Error in simple control system.………………………………………………………………..35

7. Membership function.………………………………………………………………...........38

8. Error membership function.…………………………………………………………………...39

9. Error dot membership function.……………………………………………………………….39

10. Error and Error dot membership function.……………………………………………………40

11. Output membership function.…………………………………………………………………..44

12. FLC Simulink block……………………………………………………………….............48

13. FIS (Fuzzy Inference System) ………………………………………………………………48

14. FIS Editor……………………………………………………………….............................49

15. Membership function editor input MF’s.………………………………………………………..50

16. MF input Error…………………..…………………………………………………....................50

17. MF input Error [2]………..…...……………………………………………………….....51

18. MF input Errordot………….………………………………………………………………….51

19. Membership function editor output MF’s.……………………………………………………52

20. Rule editor………………………………………………………………………………………52

21. Rule viewer……………………………………………………………………………………..53

22. Surface view……………………………………………………………………………………53

23. Half-wave rectifier……………………………………………………………………………...56

24. Input waveform.…………………………………………………………………………………56

25. Output waveform……………………………………………………………………………….56
26. Full-wave rectifier positive…………………………………………………………………..57
27. Full-wave rectifier negative………………………………………………………………….58
28. Single phase bridge rectifier…………………………………………………………………58
29. Input AC waveform………………………………………………………………………….59
30. Without capacitor (ripple)……………………………………………………………………59
31. Output waveform with capacitor…………………………………………………………….59
32. Atmega16 AVR Microcontroller…………………………………………………………….62
33. IC 74HC14…………………………………………………………………………………...64
34. LCD…………………………………………………………………………………………..65
35. Voltage regulator 7805 properties…………………………………………………………...66
36. Connection diagram 7805……………………………………………………………………67
37. IC 75NF75 Power MOSFET………………………………………………………………...67
38. Bipolar Junction Transistor Pins…………………………………………………….......68
39. Fan…………………………………………………………………………………………....68
40. Various capacitors……………………………………………………………………………68
41. Various resistors……………………………………………………………………………...69
42. Diode (1N4001)……………………………………………………………………………...70
43. Light Emitting Diode (LED)…………………………………………………………………71
44. Error membership function…………………………………………………………………..72
45. Error Dot membership function……………………………………………………………...73
46. Rule base in MATLAB……………………………………………………………………....73
47. Voltage Membership function……………………………………………………………….76
48. Power supply and controller circuit………………………………………………………….77
49. Step down transformer……………………………………………………………………….77
50. Dimmers……………………………………………………………………………………...78
51. Load: Fan and LEDs ………………………………………………...…………………78

52. DC Motor………………………………………………………………………….…………79

53. MOSFET Module…………………………………………………………..………..79

54. Hex Inverter circuit……………………………………………………………………..80

55. Amplification circuit……………………………………………………………………80

56. Complete project hardware……………………………………………………………..81

57. Block Diagram 1………………………………………………………………….......81

58. Block Diagram 2………………………………………………………………….......82

59. Complete project simulation on Proteus software……………………………………...82

List of Tables

1. 3x3 Rule matrix……………………………………………………………………………….36

2. LCD Pin Description……………………………………………………………………………..65

3. Voltage regulator 7805 properties………………………………………………………………66

4. 3x3 Rule matrix of motor's FLC…………………………………………………………..74

CHAPTER 1

Introduction

1.1 Introduction

The development of a high performance control system is very important for the industry as well as for other useful/purposeful applications. Generally such a control system must have good dynamic speed command tracking and load regulating response.

1.2 Background

In this part of the chapter we introduce to the reader the reasons for us choosing this project and other possible ways to control the speed of a motor which were considered. There are numerous controllers that can be used to control the speed of a DC Motor. Listed ahead are a few we researched upon before finally deciding on Fuzzy Logic control (implemented via an AVR microcontroller).

-Switched mode power supply

-FPGA (Field programmable gate array)

-PIC Microcontroller

We decided on a Fuzzy logic controller implemented via an AVR microcontroller because it sparked our interest, and opened up a whole new dimension of study; Fuzzy logic and AVR Microcontroller were articles that had not been specifically taught to us at university, so we wanted to do something related to something that had not already been taught to us before. This of course was hard work but had two benefits. 1.) We learned something fresh from scratch completely on our own which is easier said than done, and 2.) We were able to innovate and contribute something new in the field of Engineering to our university via this project, which is again easier said than done.

1.3 Project Overview

In this part we're going to give you a brief overview of what the project really is about. Let's start with the DC motor. The DC Motor has been popular in the control area of the industry for a long time. Namely because they have many good characteristics, for example: High starting torque characteristics, high response performance and they are easier to be linearly controlled. DC motor has a good speed control response, and a wide speed control range. They're widely used in speed control systems that require high control requirements. Such as: A rolling mill, double hulled tanker, high precision digital tools, etc.

DC motor plays a significant role in modern industry. There are several types of applications where the load on the DC motor varies over a speed range. These applications may demand high-speed control accuracy and good dynamic responses.

Now let's talk about how we plan on incorporating Fuzzy logic into our project. In this project we implement a Fuzzy Logic controller using an AVR Atmega32 microcontroller. The fuzzy logic algorithm programmed in C structure compiled in the memory of atmega32 controller. The output of IR sensors has been used to get the speed of the motor which act as input for fuzzy logic controller. As a result the fuzzy logic controller which was developed will be able to generate a PWM signal to drive the DC driver. A simple feedback system is shown below.

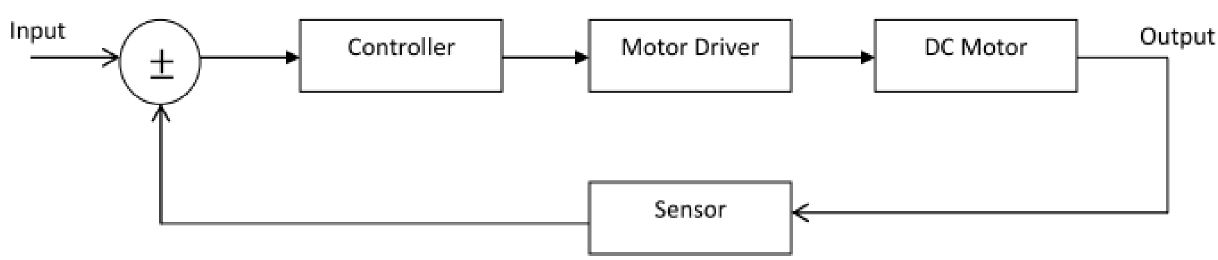

Figure 1 Simple feedback system

1.4 Project working in a nutshell

First of all the motor will run at its full speed according to the applied voltage which shall be adjusted via a dimmer (variable resistor). The speed of the motor will be displayed on an LCD and then the desired speed will be set from the keypad, PWM signal will be generated from the controller and the motor speed shall change. Now if at this speed load is turned on then motor speed will decrease. Fuzzy logic will be applied to maintain the previous desired speed.

1.5 FLC for controlling DC motor speed

DC motor runs on DC Electrical Power. This motor uses DC electrical energy and in turn produces mechanical energy. There are two types of DC motors, brushed and brushless. In this project we have opted to use a brushed DC motor because a brushed DC motor is powered by DC electricity which has a mechanically controlled commutation system instead of an electronically control commutation system, as is in a brushless DC Motor. In these motors current, torque, voltage and RPM are all linearly related.

For this project the controller we have chosen is a Fuzzy Logic controller. The fuzzy logic controller has many advantages when we compare it with the other conventional controllers such as a PID controller. The advantages of fuzzy logic controller are that it’s simple to control and has a low cost. The main advantage of a FLC is that it’s possible to design it without knowing the exact mathematical model of the process, which again contributes to its ease of use. It’s suitable for the applications such as speed control of a DC motor which has nonlinearities.

The structure of a FLC consists of the following 4 major components, which are: The fuzzifier, which is used for measurement of the input or definition of the fuzzy sets that will applied. The second one is fuzzy control or rule base which provides the system with the necessary decision making logic based on the rule base that determines the control policy. The third method is the inference mechanism which decides what methods shall be applied on the rules in the rule base, and the fourth and final step is the defuzzifier which combines the actions that have been decided and produces a single non-fuzzy output that is the control signal of the system.

1.6 Problem statement

While controlling the speed of DC motor we faced many problems. One of the problems that occurred was in terms of losses and efficiency of the motor. To solve this problem a controller is used and for this project Fuzzy Logic controller will be used. There are a lot of different controllers used now a days but FLC is chosen because it is suitable for nonlinear applications. Other than this advantage, it's low in cost and is simple to control. Later on, we're going to discuss the fuzzy logic controller in a lot more detail.

1.7 Problems and their solutions

Problems

1.) To control DC motor speed

2.) To acquire data from the motor

Solutions

1.) Use a Fuzzy logic controller.

2.) Use sensors to get an RPM reading from the motor (We have used a magnetic sensor in our project)

1.8 Scope

The scope of this project is:

1.) Implementation of a FLC to an actual DC motor.

2.) Comparison between simulation and experimental results.

3.) Coding of the FLC using C language.

1.9 Applications of Fuzzy Logic

There are numerous applications of fuzzy logic, some have been listed below:

1.) Robotic Control: Position control and path planning.
2.) Aircraft/Spacecraft: Flight control, engine control, avionics systems, failure diagnosis navigation, and satellite altitude control.
3.) Automated highway systems: Automatic steering, braking and throttle control for vehicles.
4.) Automobiles: Brakes, transmission, suspension, and engine control.
5.) Autonomous vehicles: Ground and underwater.
6.) Manufacturing systems: Scheduling and deposition process control.
7.) Power industry: Motor control, power control, distribution, and load estimation.
8.) Process control Temperature, pressure, and level control, and desalination processes.
9.) Robotics: Position control and path planning.