سامية محمد مصطفى

شبكة المعلومات الجامعية

# بسم الله الرحمن الرحيم


سامية محمد مصطفى

شبكة المعلومات الجامعية

# شبكة المعلومات الجامعية

# التوثيق الالكتروني والميكروفيلم

سامية محمد مصطفى

شبكة المعلومات الجامعية

# جامعة عين شمس

## التوثيق الإلكتروني والميكروفيلم

# قسم

## نقسم بالله العظيم أن المادة التي تم توثيقها وتسجيلها علي هذه الأقراص المدمجة قد أعدت دون أية تغيرات

# يجب أن

## تحفظ هذه الأقراص المدمجة بعيدا عن الغبار

سامية محمد مصطفى

شبكة المعلومات الجامعية

# بعض الوثائق الأصلية تالفة

سامية محمد مصطفى



# بالرسالة صفحات لم ترد بالأصل

**Minoufiya University**
**Faculty of Engineering**
**Electrical Engineering Department**

# Pulse Width Modulation-Based Control Technique of a DC Motor

A thesis submitted
by

***Eng. Saied Ahmed Soliman EL Absawy***
***Arab Company For Special Steel (ARCOSTEEL), Sadat, Egypt.***

For the Award of the Degree of Master of Science
In
Electrical Engineering

**Supervised by**

**Prof. Dr. Shokry Saad Shokralla**
Shokry Saad Shokralla
Professor of control of Electrical Machines.
Faculty of Engineering,
Minoufiya Uinveristy.

**Prof. Dr. Ahmed Hassanien Morsi**
Professor of Electrical Machines
Faculty of Engineering,
Minoufiya Uinveristy.

**Dr. Elwy Eissa El-Kholy**
Assoc. Prof., Elect. Eng. Dept.,
Faculty of Engineering,
Minoufiya Uinversity.

A.M.Khawy



**2002**

Minoufiya University
Faculty of Engineering
Electrical Engineering Department

# Pulse Width Modulation-Based Control Technique of a DC Motor

A thesis submitted
*By*

**Eng. Saied Ahmed Soliman EL Absawy**
Arab Company For Special Steel (Arcosteel), Sadat, Egypt.

**For the Award of the Degree of Master of Science**
**In**
**Electrical Engineering**

*Approved by*

Prof. Dr. Mohammed Abd El-Rehem Bader
( M. Bader )
Professor of Electrical Machines
Vice-dean of Faculty of Engineering
Ain Shams University

Prof. Dr. Sabry Abd El-Latif Mahmoud
( )
Professor of Control of Electrical Machines
Dean of Faculty of Engineering
Minoufiya University

Prof. Dr. Shokry Saad Shokralla
( S. S. Shokralla )
Professor of Control of Electrical Machines
Faculty of Engineering
Minoufiya University

Prof. Dr. Ahmed Hassanien Morsi
( )
Professor of Electrical Machines
Faculty of Engineering
Minoufiya University

**2002**

# Acknowledgement

The auther would like to express his deepest gratitude and sincere appreciation to Prof. Dr. S.S. Shokralla, prof. Dr. A. Hassanien Morsi, and Dr. Elwy Eissa El-Kholy; for their guidance, valuable suggestions, encouragement and help throughout the course of this work. Thanks are due to the Faculty of Engineering, Menoufiya University for providing facilities to carry out this search.

Further, I acknowledge with thanks to Arab company for special steel for their kind permission for getting valuable data that are required for this work.

Special thanks to the following individuals: foremost to my loving wife for her tolerance and endless support, to my best friends Eng. Salah EL Gendy and Eng. Hany Abd EL Monem. Thanks to my family, their support made working on this thesis possible.

Finally many thanks are also extended to every one who had helped me.

Eng. Said Ahmed Soliman El Absawy

# ABSTRACT

In industrial applications, speed control is required over a wide range to follow accurately a certain command trajectory and to recover quickly from sudden load applications. The precise control of a DC motor is necessary when the dynamic responses greatly affect the quality of the product. The design of conventional control drives therefore should take another dimension due to the restricted requirements of the modern industrial applications. Improving the performance of such drives has become the principle aim of many researchers. Artificial intelligence (AI) Fuzzy Logic Controller will be implemented to solve the undesired undershoot that get the process in special steel rolling mill out of control. Comparing the performance of DC motor, controlled by PI speed controller, PI Speed with PI current controller and fuzzy speed controller, will be done and these systems will be emulated practically. As Fuzzy Logic Control has steady state error due to load variation, so, two methods will be implemented to improve the fuzzy controller performance to allow it to solve the steady state error problem. These methods are:

1- Using Fuzzy Speed and PI current Controller.

2- Using a Hybrid Fuzzy-PI controller.

A Complete modeling and simulation is carried out for the system under study which consists of a separately excited DC motor fed from an uniform pulse width modulation converter through a power MOSFET and controlled by the previous controllers. Also, transient and steady state conditions are investigated. The proposed Hybrid Fuzzy-PI controller technique is applied to the system under study, this technique can solve the common problems associated with rolling mill application. The entire drive system is implemented using a high speed digital signal processor (DSP). The experimental results validate the theoretically simulated speed and current responses at different operating conditions.

# Contents

**Acknowledgement** I
**Abstract** II
**Contents** III
**List of Figures** VI
**List of Tables** VIII
**List of Symbols** IX

**Chapter 1** 1
Introduction 1
1-1 general 2
1-2 Control methods of DC motor 2
1-3 Uniform pulse width modulation 3
1-4 Fuzzy controller 5
1-5 Rolling Mill Theory 6
1-5-1 Types of Control Used In Rolling Mill 6
1-6 Thesis objectives 10
1-7 Thesis layout 10
**Chapter 2** 12
Description And Modeling Of The System 12
2-1 General 13
2-2 DC motor modeling 13
2-3 Principle of operation 14
2-4 Modes of operation 16
2-5 The comparator modulator algorithm 19
2-6 History of Fuzzy logic control 21
2-7 Fuzzy Logic Principles 22
2-7-1 Fuzzification 23
2-7-2 Knowledge-base 25
2-7-3 Fuzzy inference engine 26
2-7-4 Defuzzification 26
2-8 Fuzzy Controller design 27
2-8-1 Fuzzify Inputs 27
2-8-2 Apply Fuzzy Operator 29
2-8-3 Apply Implication Method 30
2-8-4 Aggregate All Outputs 31

2-8-5 Defuzzification 32
**Chapter 3** **34**
Hardware Implementation And Experimental Results Of Speed And Current Control Of DC Motor 34
3-1 General 35
3-2 Experimental Set-up 35
3-3 Hardware Implementation 35
3-4 Software Development 36
3-5 Simulation and Experimental results 37
3-6 Open-Loop Steady-State Characteristics 38
3-7 Closed Loop Using a Proportional Integral Speed Controller 42
3-7-1 System Description and Controller Equations 42
3-7-2 The Motor Run-up 44
3-7-3 Reference Speed Step Change 46
3-7-4 Load Change 48
3-8 Closed-Loop Using a Proportional Integral Speed and Current Controllers 49
3-8-1 System Description and Equations of The Speed and Current Controller 49
3-8-2 The Motor Run-up 51
3-8-3 Reference Speed step Change 54
3-8-4 Load Change 56
3-9 Closed-Loop Using a Fuzzy Logic Speed Controller 58
3-9-1 Fuzzy Logic Approach 58
3-9-2 Fuzzy Logic Controller 58
3-9-3 The Motor Run-up 61
3-9-4 Reference Speed Step Change 64
3-9-5 Load Change 65
**Chapter 4** **67**
Implementation of Different Control Methods With Fuzzy Controller 67
4-1 Introduction 68
4-2 Closed Loop Using Fuzzy Speed Controller with PI Current Controller 69
4-2-1 System equations 69
4-2-2 The Motor Run up 71
4-2-3 Reference Speed Step Change 74
4-2-4 Load Change 75
4-3 A Hybrid Fuzzy-PI Speed Controller For a High Performance Separately Excited DC Motor Drive System 76
4-3-1 The Hybrid Fuzzy PI Speed Controller 77
4-3-2 Switching Control Strategy 78
4-3-3 Simulation and Experimental Results For Hybrid Fuzzy- PI Speed Controller 80
**Chapter 5** **84**
Conclusion 85

**References** 87
**Appendix 1** 94

# List Of Figures


Figure (1-1) Basics of Rolling Mill 8
Figure (1-2) Arcosteel rolling mill line 8
Figure (1-3) Block diagram of rolling mill drive system 9
Figure (1-4) Loop position hysteresis band 9
Figure (2-1) Schematic diagram for the system 15
Figure (2-2) Principle of UPWM control waveforms 16
Figure (2-3 ) Modes of operation for the system 20
Figure (2-4) Fuzzy system structure 23
Figure (2-5) Membership functions 24
Figure (2-6) Membership function 27
Figure (2-7) Schematic diagram for Fuzzification 29
Figure (2-8) Schematic diagram for Fuzzy operator (AND) 30
Figure (2-9) Schematic diagram for implication method (min) 31
Figure (2-10) Schematic diagram for aggregation method (MAX) 33
Figure (2-11) Defuzzification method ( centroid ) 33
Figure (3-1) Experimental set-up for DSP-based control of DC motor drive 37
Figure (3-2) Block diagram of DS1102 Controller board 38
Figure (3-3) Simulation and Experimental waveforms for the drive circuit and gate pulses. 39
Figure (3-4) Simulation and Experimental waveforms for the motor voltage, the motor speed, the motor current, the supply voltage and the supply current 41
Figure (3-5) The block diagram of the closed loop PI speed control 42
Figure (3-6) Simulation and Experimental results for run-up behavior for 0.4 of rated load torque and $\omega_{ref}$ = 1350 r.p.m 44
Figure (3-7) Variation of the motor speed and current due to a step up in reference speed 45
Figure (3-8) Variation of the motor speed and current due to a step down in reference speed 46
Figure (3-9) Variation of Motor Speed and Current due to Increasing and Decreasing Load Torque 47
Figure (3-10) The block diagram of the closed loop PI speed and current controller 49
Figure (3-11) Simulation and Experimental results for run-up behavior for 0.4 of rated load torque and $\omega_{ref}$ = 1350 r.p.m. 52
Figure (3-12) Variation of motor speed and current due to a step up in reference speed 53
Figure (3-13) Variation of motor speed and current due to a step down in reference speed 54