Chapter One

Introduction and Aims of the Works

1.1 Introduction

DC motor is a power actuator which transforms electrical energy into mechanical energy. DC motor is widely used in many industrial applications where wide speed ranges are required. The advantage of dc motors may be speed control. The term speed control stand for intentional speed variation carried out automatically and manually. DC motors are most suitable for wide range speed control and are therefore used in many adjustable speed drives. Since speed is directly proportional to armature voltage and inversely proportional to magnetic flux produced by the poles and adjusting the armature voltage and/or the field current will change the rotor speed. DC motors have been widely used in many industrial applications such as electric cranes, electric vehicles, and robotic manipulators due to wide, simple, and continuous control characteristics. Proportional-Integral-Derivative (PID) controller has been used for several decades in industries for process control applications. At the same time PID controller has some disadvantages namely; the undesirable speed overshoot and the sluggish response due to sudden change in load torque and the sensitivity to controller gains KI and KP. The performance of this controller depends on the accuracy of system models and parameters. Therefore there is need of a controller which can overcome disadvantages of PID controller [1].

PID controllers are widely used in industrial plants because it is simple and robust. Industrial processes are subjected to variation in parameters and parameter perturbations, which when significant makes the system unstable. So the control engineers are on look for automatic tuning procedures. From the control point of view, DC motor exhibit excellent control characteristics because of the decoupled nature of the field. Recently, many modern control methodologies such as nonlinear control, optimal control, variable structure control and adaptive control have been extensively proposed for DC motor. However, these approaches are either complex in theoretical bases or difficult to implement. PID control with its three term functionality covering treatment to both transient and steady-states response, offers the simplest and yet most efficient solution too many real world control problems. In spite of the simple structure and robustness of this method, optimally tuning gains of PID controllers have been quite difficult

The particle Swarm Optimization (PSO) methods have been employed successfully to solve complex optimization problems. PSO first introduced by Kennedy and Eberhart is one of the modern heuristic algorithms; it has been motivated by the behavior of organisms, such as fish schooling and bird flocking. Generally, PSO is characterized as a simple concept, easy to implement, and computationally efficient. Unlike the other heuristic techniques, PSO has a flexible and well-balanced mechanism to enhance the global and local exploration abilities. In this work, a scheduling PID tuning parameters using particle swarm optimization strategy for a DC motor speed control is proposed. This paper has been organized as follows: in section 2 the mathematical model DC motor is described. In section 3, the PID controller is described. Section 4 the fitness function, section 5 the particle swarm optimization method is reviewed. A comparison between the results obtained by the proposed method and GA method via simulation the DC motor speed control is presented in section 6. The paper is concluded in section7 [2]

The issue of power by static converters and power electronics circuits is a topic of particular interest in light of developments in the electronics industry and the modernization of equipment in the field. Operation circuits and electronic devices requires the power supply voltage source. Huge progress made by power electronics and microelectronics in recent years have demanded the creation of voltage sources with high reliability, good performance, lightweight and low volume. Any DC machine needs to operate to be supplied with DC voltage. Typically this voltage has to be produced starting from the AC supply voltage. DC machines usually are not satisfied with a voltage obtained by simple filtration and recovery, requiring a continuous variation of it. Continuous change of the supply voltage can be done by changing the AC voltage [3].
When variable dc voltage is to be obtained from fixed dc voltage, dc chopper is the ideal choice. Use of chopper in traction systems is now accepted all over the world. A chopper is inserted in between a fixed voltage dc source and the dc motor armature for its speed control below base speed. In addition, chopper is easily adapt able for regenerative braking of dc motors and thus kinetic energy of the drive can be returned to the dc source. This results in overall energy saving which is the most welcome feature in transportation systems requiring frequent stops, as for example in rapid transit systems Chopper drives are also used in battery-Operated vehicles where energy saving is of prime importance. In four-quadrant dc chopper drives, a motor can be made to work in forward motoring mode (first quadrant), forward regenerative braking mode (second quadrant), reverse motoring mode (third quadrant) and reverse regenerative-braking mode (fourth quadrant)

1.2 Aim of the Work:

The main objectives of the present work include the following points:-

1) Design and simulate a mathematical model for separately excited direct current motor.

2) Design and simulate a speed control system using four quadrant chopper feed the dc motor.

3) controlling the motor speed using PI speed controller tuned using particle swarm optimization technique for optimizing the controller performance.

1.3 Project Organization

The thesis can be divided into five chapters as follows:

- Chapter one is an introduction, aim of the work and project organization.
- Chapter two intends for overview of dc motor speed control system.
- Chapter three presents the particle swarm optimization technique.
- Chapter four presents the designing and simulation results for SEDM complete control system.
- Chapter five summarizes the main conclusions of the accomplished work and offers some suggestions for future work.[4]

Chapter Four

Simulation & Results

4.1 Introduction

This chapter deals with three main topics;

i) **The first topic** is the designing and simulation a mathematical model of the SEDM for control studies depending on it's mechanical and electrical dynamic equations.

ii) **The second topic** is the designing and simulation of the speed control system for SEDM using four quadrant chopper and PI controller.

iii) **The third topic** is the optimizing of the PI controller using PSO technique.

The speed control system consists of two control loops, **the first control loop** is the outer loop known as speed control loop which is responsible for sensing the speed error and pass it to the next control loop using a PI controller. While **the second control loop** is the inner loop known as current control loop which is responsible for controlling the motor current and ensure it is not exceed the motor acceptable limits.

This Chapter describes how the motor can be controlled by varying the armature voltage using chopper circuit to vary the dc voltage levels in order to control the motor speed and it is assumed that the field is excited by a constant voltage. In this work , the armature speed control method is used. The results are obtained when loading the motor at its full-load.

4.2 Motor Rating & Parameters

Table (4.1) shows the motor parameters which used in this project.

Table (4.1): SEDM parameters

Motor ratings and parameters	values
Power	5 HP (3.73 Kw)
Armature voltage	240 V
Speed	183.26 radian/second
Field voltage (V_f)	150 V
Armature resistance (R_a)	0.78Ω
Armature inductance (L_a)	0.016 H
Field resistance (R_f)	150 Ω
Field inductance (L_f)	112.5 H
$K_v = K_t$	1.234 H
Inertia of the rotor (J)	0.05 $Kg.m^2$
damping coefficient (B)	0.01 N.m.s

4.3 Motor Simulation

The first step in analysis and designing the controllers for the SEDM is to use the mathematical model of the SEDM which is more reality to the actual plant rather than linear transfer function model in the control design and studies. The simulation of SEDM is performed using MATLAB/SIMULINK.

The Simulink of the SEDM mathematical model is shown in Figure (4.1) to Figure (4.4).

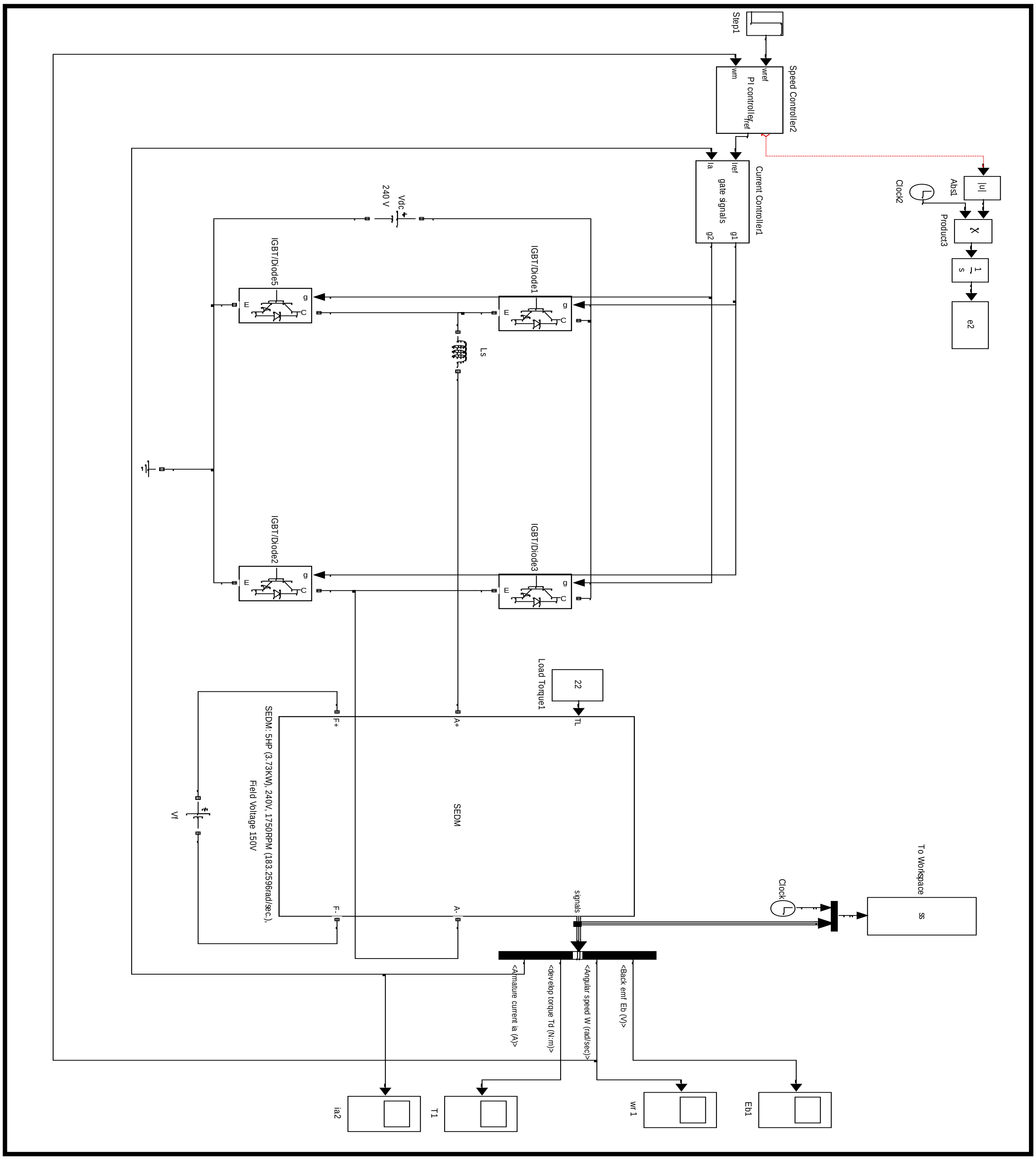

Figure (4.1): Simulink of SEDM with complete control circuit

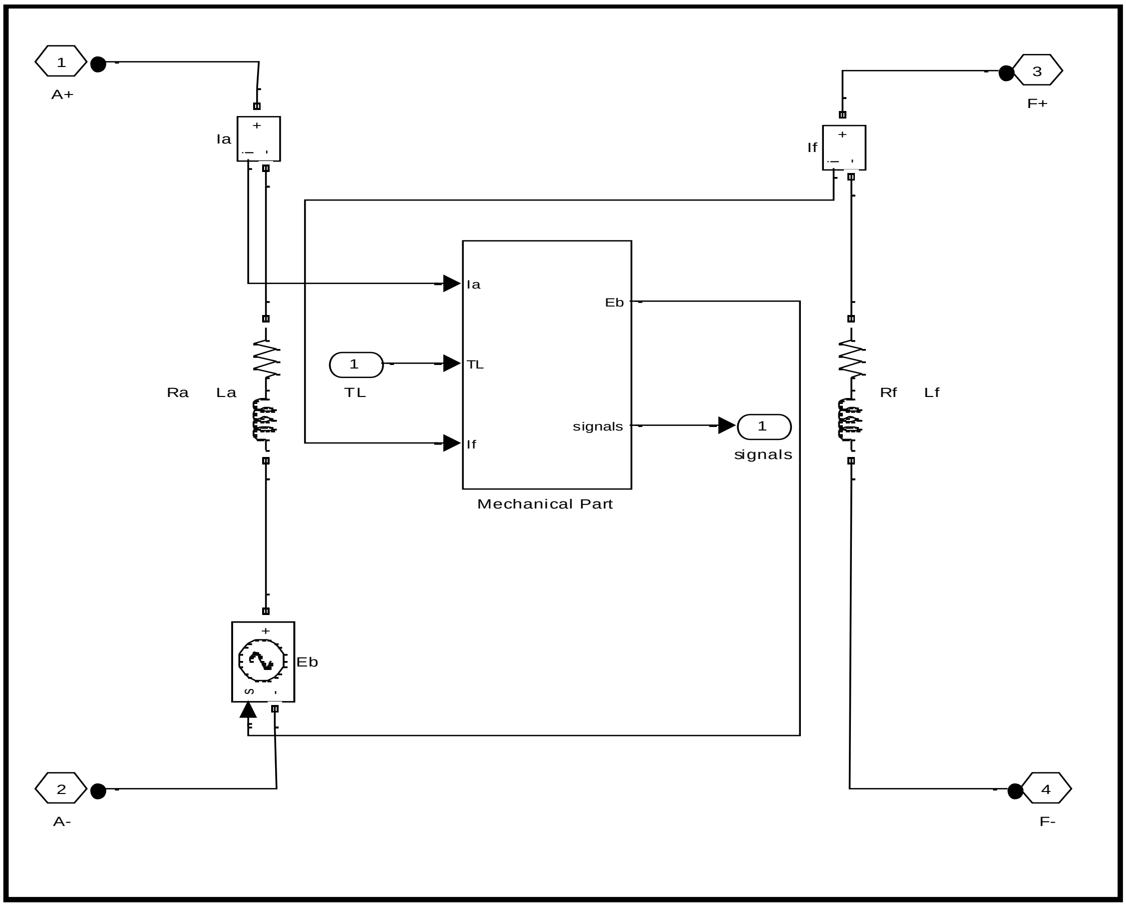

Figure (4.2):Simulink of SEDM

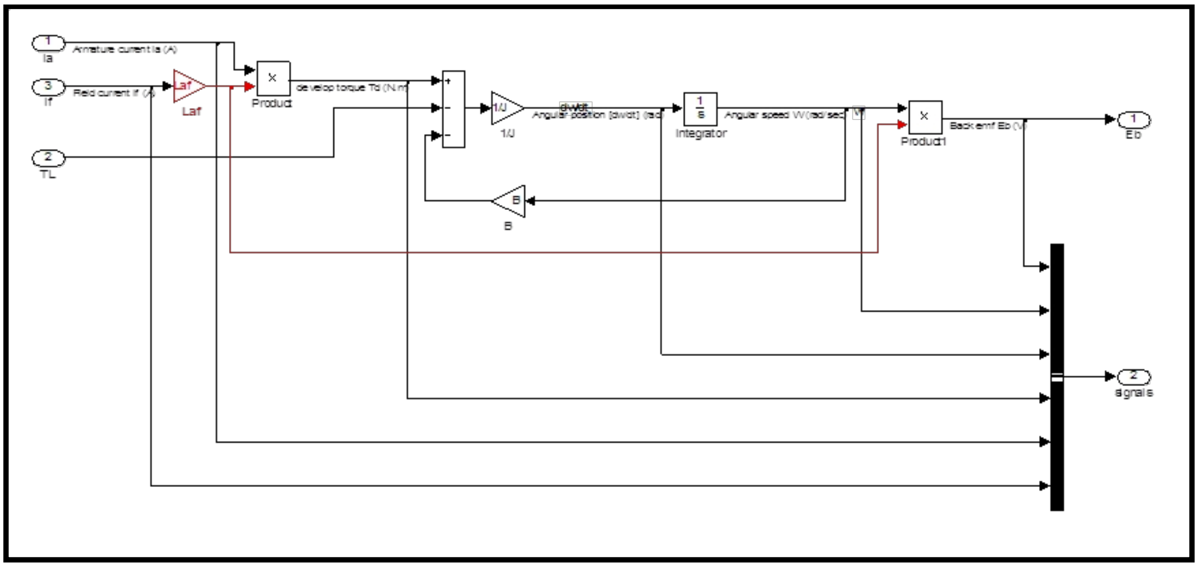

Figure (4.3):Simulink of mechanical part of SEDM

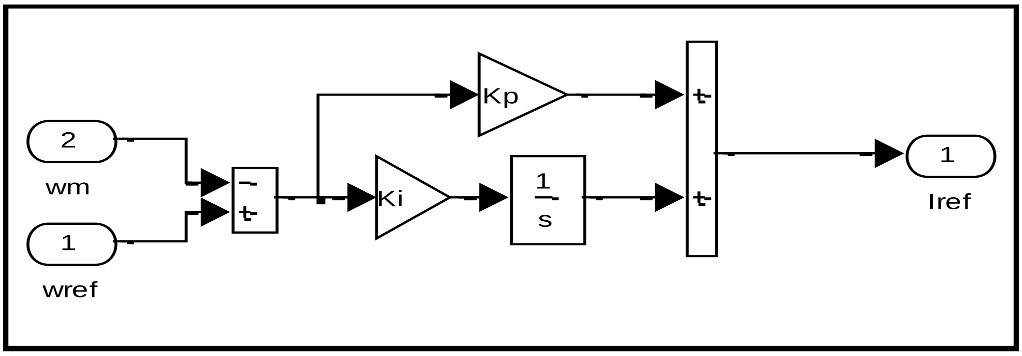

Figure (4.4):Simulink of PI controller

4.4 Results

The PI speed controller is tuned using PSO algorithm and the obtained parameters of PI controller are (K_P= 72.0752, K_I = 2.543). When the load is changed on motor, the speed of motor is fall so the difference between reference speed and actual speed increased so there is an error speed presented to PI speed controller. The current controller is responsible for operating the chopper circuit (IGBT/DIODE blocks) according to the motor quadrant operation.

The PSO parameters are shown in Table (4.2).

Table (4.2): The parameters of PSO algorithm

parameters	Value
Size of swarm	40
Number of iterations	40
C1	1.2
C2	1.2
W	0.5

Figure (4.5) to Figure (4.8) shows the motor back EMF, speed, Torque and armature current step responses.

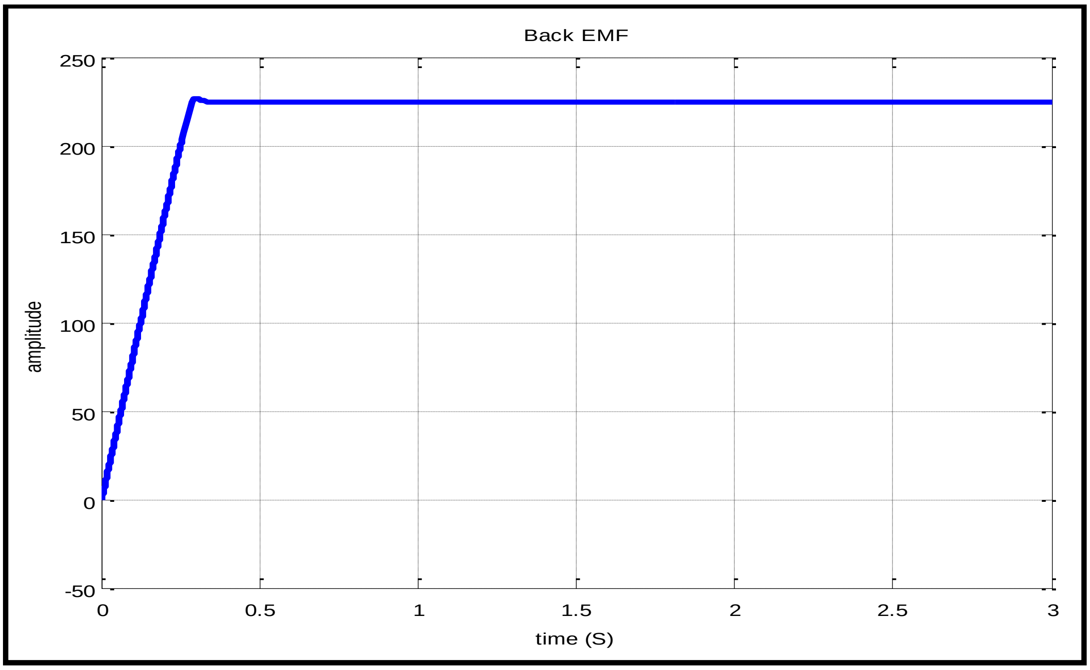

Figure (4.5): Motor back EMF

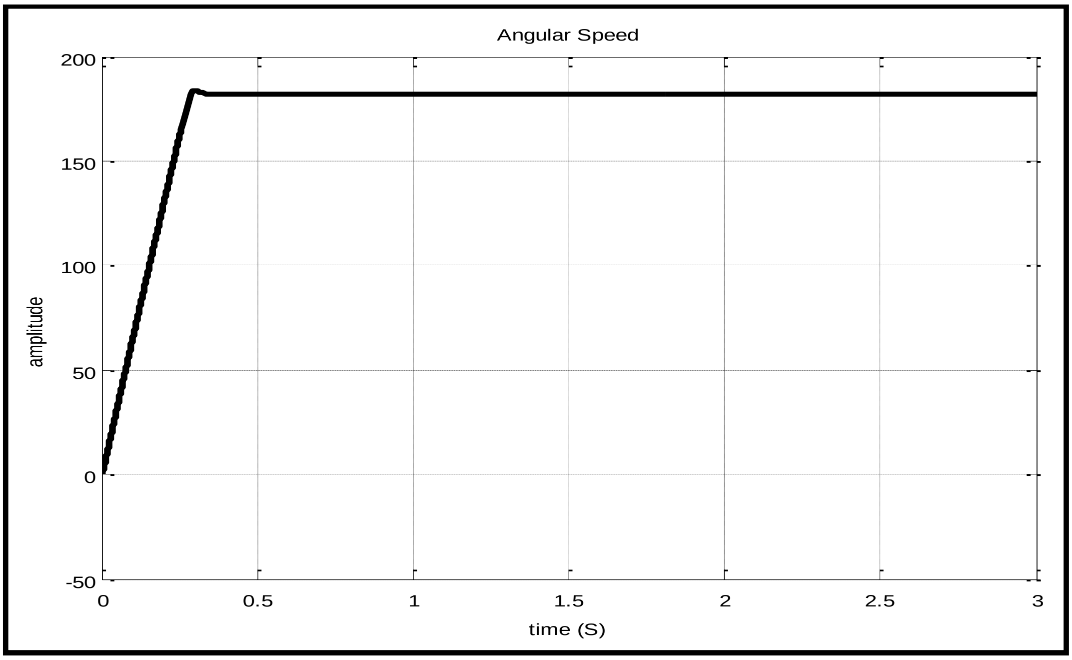

Figure (4.6): Motor Speed

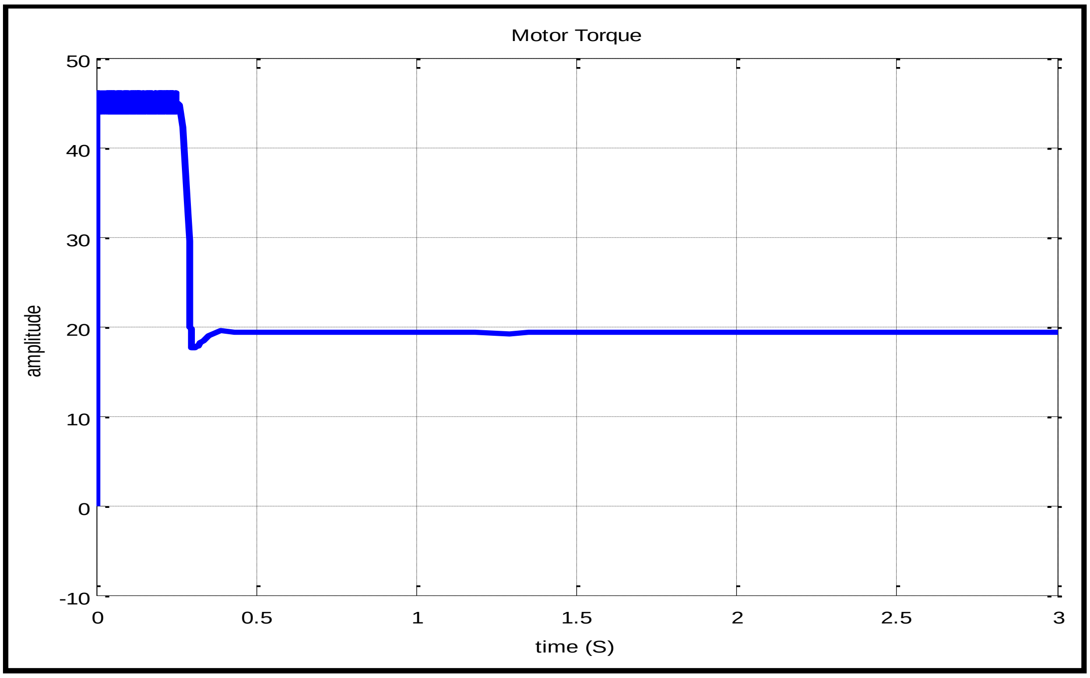

Figure (4.7): Motor Torque

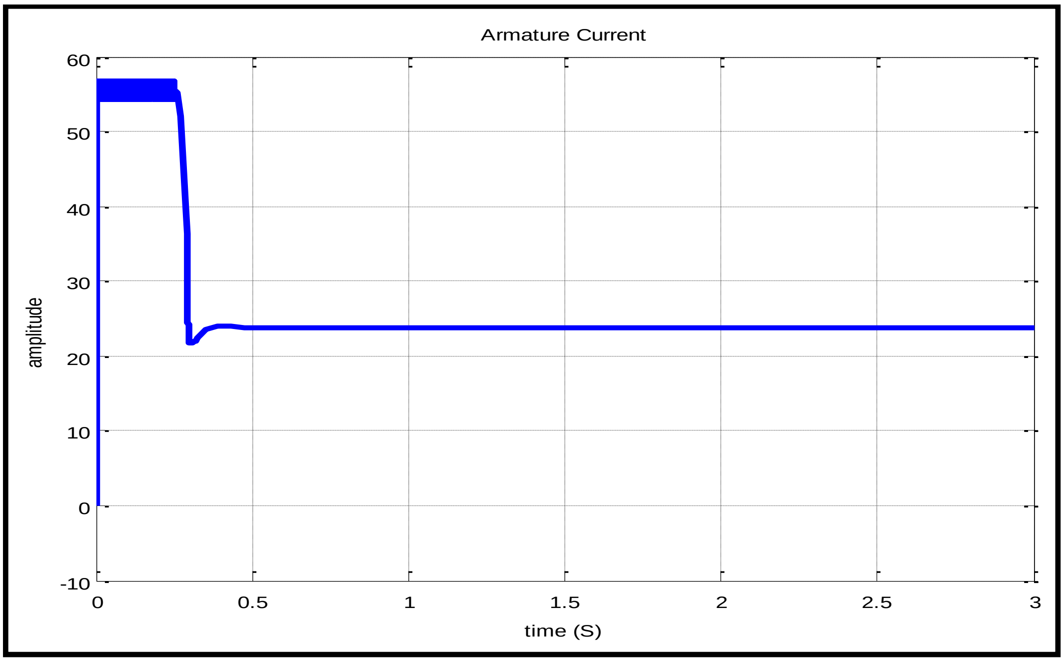

Figure (4.8): Motor Armature Current

The motor performance is improved using PI controller tuned by PSO algorithm. The motor speed response is improved by eliminating the overshoot and decreasing the rise time, settling time. The Particle Swarm Optimization tuning method is better than traditional tuning method such as Ziglller-Nicholes method because it depends on the cognitive behavior of the social swarms.

Chapter Five

Conclusions & future works

5.1 Introduction

In this work the design and simulation of SEDM speed control is presented based on MATLAB/TOOLBOX. The mathematical model of SEDM is simulated depending on the electrical and mechanical equations of SEDM which is more reality and accurate to the actual system . A four qudrant chopper is designed and simulated for controlling the motor speed in the four quadrant operation.

Two control loops are used; one for speed control is known as (outer control loop or speed control loop). The speed control loop depend on PI controller for sensing the speed error. The second is used for controlling the motor current to ensure the motor current don't exceed its acceptable limits and is known as (inner control loop or current control loop).

This work also concerned with PI controller design that depend Artificial Intelligence technique.

The main concluding remarks can be summarized as follows:

1) PI controller is used in the industrial applications because it has simple structure, and the ability to apply for a wide range of situations.
2) The selection of the controller gains depending on traditional methods such as (Z-N) don’t give accurate results and may cause large peak over shoot, settling time & steady state error.
3) PSO technique gives best results for controller parameters tuning which leads to improve the controller performance.

4) The tuning process depends on PSO algorithm parameters such as swarm size, number of iterations, random position of swarm, velocity of swarm, acceleration factors and inertia weight.
5) Increasing swarm size and number of iterations leads to increase search space of swarm which leads to increase the execution time, but gave more accurate results.

5.2 Suggestions for Future Work

The work presented may be extended in the future and developed to take into account the following points:

1) Controlling the motor speed for wide range of loading conditions ranging from no-load to full-load as well as for stair change in loads.
2) Using other Swarm optimization methods (i.e. ACO, GA, BFO, BC, …etc) for tuning PI parameters.
3) Using Neural network controllers for controlling the speed of SEDM instead of PI controller.
4) Apply the PSO technique for other engineering optimization problems.

DEDICATION

.... For our Beloved Families

……….. Friends

………. Classmate

………………… Lecturers

شكــــــــــر وتقديــــــــر

لابد لنا ونحن نخطو خطواتنا الأخيرة في الحياة الجامعية من وقفة نعود إلى أعوام

قضيناها في رحاب الجامعة مع أساتذتنا الكرام الذين قدموا لنا الكثير باذلين بذلك جهودا كبيرة في بناء جيل الغد لتبعث الأمة من جديد ...

وقبل أن نمضي تقدم أسمى آيات الشكر والامتنان والتقدير والمحبة إلى

الذين حملوا أقدس رسالة في الحياة ...

إلى الذين مهدوا لنا طريق العلم

والمعرفة ...

إلى جميع أساتذتنا الأفاضل ....

"كن عالم .. فإن لم تستطع فكن متعلما

، فإن لم تستطع فأحب العلماء ،فإن لم

تستطع فلا تبغضهم"

وأخص بالتقدير والشكر الى:

ألاستاذ وسام نجم الدين العبيدي

الذي نقول له بشراك قول رسول الله

صلى الله عليه واله وسلم:

"إن الحوت في البحر ، والطير في

السماء ، ليصلون على معلم الناس

الخير "

Ministry of Higher Education
and Scientific Research
University of Diyala
College of Engineering
Electronic Engineering Department

Design and Simulation of Four-Quadrant DC Drive Motors

A project

Submitted to the Electronic Engineering Department - Collage of Engineering - University of Diyala, in Partial Fulfillment of the Requirements for the Degree of Bachelor in (Electronic Engineering)

By

Suha Sabah Habeeb

Israa Ali Hussein

Supervised By

Wisam Najm Al-Din Al-Obaidi

2015-2016

Examination Committee Certificate

We certify that we have read this project entitled **"Design and Simulation of Four-Quadrant DC Drive Motors"** and as an examining committee, examined the student **" Israa Ali Hussein & Suha Sabah Habeeb**" in its contents, and that in our opinion it meets the standard of a thesis for the Degree of **Bachelor of Science in Electronic Engineering**.

Signature:
Name:
Title:
(Chairman)
Date: / / 2016

Signature:
Name:
Title:
(Member)
Date: / / 2016

Signature:
Name:
Title:
(Member)
Date: / / 2016

Signature:
Name: *Wisam Najm Al-Din Al-Obaidi*
Title: Assistant Lecturer
(Supervisor)
Date: / / 2016

Approved for the Electronic Engineering Department, Engineering College, University of Diyala, Diyala, Iraq.

Signature:
Name:
(Head of the Department)
Date: / / 2016

Abstract

The aim of this project is to design a speed control system of a Separately Excited Direct Current Motor using a proportional-integral (PI) controller based on Particle Swarm Optimization (PSO) algorithm for optimal tuning parameters of the (PI) controller.

The speed control system is done using four quadrant chopper circuit (DC-DC Converter). The four quadrant chopper is used to control the motor speed in the four quadrant operation ($\mp I_a , \mp V_a$) forward and reverse direction of rotation. The speed control system consists of two control loops, the outer loop or speed control loop and the inner loop or current control loop.

The speed control system consists of two control loops; the first is the outer or speed control loop and the second is the inner or current control loop.

The speed control loop consists of PI controller sensed the speed error and feed it to the second control loop.

The armature voltage speed control method is used by varying armature voltage using chopper circuit while field voltage keep constant. In this work the motor speed is controlled when loading it at full-load.

List of Symbols

Symbol	Description
V_o	Load Voltage
V_s	Source Voltage
ω	motor speed, rad/s
B	viscous friction constant, N. m/rad/s
K_v	voltage constant,v/a-rad/s
K_t	torque constant
L_f	field circuit inductance, H
L_a	armature circuit inductance, H
R_a	armature circuit resistance, ohm
R_f	field circuit resistance, ohm
T_L	load torque, N. m

List of Abbreviations

Abbreviation	Description
PI	Proportional-Integral
DC	Direct Current
SEDM	Separately Exicted Direct Current Motor
PSO	Particle Swarm Optimization
4Q	Four Quadrant
CH	Chopper

List of Content

Chapter Four: Simulation and Result

Chapter Five: Conclusions & future works