View metadata, citation and similar papers at core.ac.uk
brought to you by CORE
provided by ethesis@nitr

SOME STUDIES ON CONTROL OF A DC-SERVO MOTOR

Green Maraiya

Department of Electrical Engineering
National Institute of Technology, Rourkela
2012-2014

SOME STUDIES ON CONTROL OF A DC-SERVO MOTOR

A thesis submitted in partial fulfillment of the
Requirements for the degree of

Master of Technology
In
Electrical Engineering

By

GREEN MARAIYA

(212EE3234)

UNDER THE SUPERVISION OF

PROF.SANDIP GHOSH

Department of Electrical Engineering
National Institute of Technology, Rourkela
2012-2014

Department of Electrical Engineering
National Institute of Technology, Rourkela

C E R T I F I C A T E

This is to confirm that the thesis entitled, "**SOME STUDIES ON CONTROL OF DC-SERVO MOTOR**" put together by **Mr. GREEN MARAIYA** in halfway satisfaction of the prerequisites for the recompense of Master of Technology Degree in **ELECTRICAL ENGINEERING** with specialization in "**CONTROL & AUTOMATION**" at the National Institute of Technology, Rourkela is a genuine work did by him under my supervision and direction.

To the least complex of my data, the matter exemplified inside the theory has not been submitted to the next University/ Institute for the grant of any Degree or endorsement

Date:

Place**: Rourkela**

PROF.SANDIP GHOSH
Electrical Department
National Institute Technology
Rourkela-769008

ACKNOWLEDGEMENTS

This project is without a doubt the most critical achievement in my life and it would be unimaginable without individuals who backed me and had confidence in me.

I might want to augment my appreciation and my genuine on account of my noteworthy, regarded **Prof.Sandip Ghosh**. He is an incredible instructor with profound vision as well as above all a kind individual. I genuinely thank for his excellent direction and support. His trust and backing enlivened me in the most critical minutes of settling on right choices and I am happy to work under his supervision.

I might want to thank all my companions and particularly my comrades for all the mindful and brain animating exchanges we had, which provoked us to think past the self-evident. I have appreciated their brotherhood such a great amount of throughout my stay at NIT, Rourkela.

To wrap things up I might want to thank my guardians, who taught me the quality of diligent work by their case. They rendered me huge help being separated throughout the entire residency of my stay in NIT Rourkela.

Green Maraiya

National Institute of Technology

Rourkela-769008

CONTENTS

List of Figure……..i

List of Table……...iii

Abstract……...iv

Chapter1 Control of dc motor using sliding mode…….1

1.1 Introduction……1

1.2Motivation……...1

1.3Sliding mode control……...1

1.3.1 Switching function……2

1.3.2 Control law design……4

1.4 Example: DC motor speed control using sliding mode control…….5

1.4.1 Simulink model of sliding mode control for dc motor……7

1.5 Simulation results……...8

Chapter 2 Modeling of digital dc-servo motor……10

2.1 Introduction……..10

2.2 Mathematical modeling of dc servo control……10

2.3 Model estimation process of dc-servo motor……...13

2.3.1 Starting a new session in the system identification tool GUI……...14

2.4 Modelling of digital dc-servo motor……15

2.5 Chapter summary……18

Chapter 3 PID controller design for dc-servo motor……19

3.1 Introduction ……19

3.1.1 Objective……19

3.2 Tuning of PID controller……..20

3.2.1PID tuning of Ziegler and Nichols rules……20

3.3.2 Design PID controller for dc-servo motor……22

3.3.3 Finding the value of gain parameter……24

3.3.4 Design PID controller where output as angular position……..26

Chapter 4 Experiment study on the digital servo motor set-up……...29

4.1 Introduction……29

4.1.1 Overview……29

4.1.2. Working Procedure of Servo……29

4.2. Description of servo setup……30

4.3. Mechanical unit of servo set-up……32

4.4. Digital unit of servo set-up……33

4.5. PID control of dc servo motor……34

4.5. Results……35

Chapter 5 Conclusion and Future work……36

References……..37

Fig no.	LIST OF FIGURE	Page no.
1.1	Simulink model of dc motor	7
1.2	Simulink model of dc motor using sliding mode control	7
1.3	output of dc motor using SMC	8
1.4	Control input of motor	8
1.5	Phase portrait of the motor	9
1.6	Sliding surface	9
2.1	Circuit diagram of dc motor	10
2.2	System identification toolbox	14
2.3	Running motor with voltage as input and output as speed.	15
2.4	System identification toolbox after importing input and output	15
2.5	Input output response of importing data.	16
2.6	Transient response of the model	16
2.7	Estimation of process model	17
2.8	Simulated and measured output model of dc-servo motor	18
3.1	Basic control configuration	19
3.2	block diagram of proportional controller	20
3.3	Ziegler-Nichols second method corresponding time P_{cr}	21
3.4	open loop response of dc motor	22
3.5	Root-locus for open loop transfer function	23
3.6	PID Controller for dc-servo motor	25
3.7	output of DC-servo motor	25
3.8	Measured and simulated output model of dc motor	26
3.9	Bode plot of the open loop transfer function of dc motor	27

3.10	Block diagram of PID controller	28
3.11	Angular position output of dc-servo motor	28
4.1	Digital unit of servo set-up	31
4.2	Servo Mechanical Unit 33-100	32
4.3	Digital Unit 33-120	33
4.4	Experimental set-up for PID controller	34
4.5	Simulink model of a general PID controller	34
4.6	Reference voltage of the motor	35
4.7	position outputof the motor	35
4.8	Error output of the motor	36
4.9	Output of the PID controller on dc servo set-up	36

Table no.	List of Table	Page no.
1.1	Parameter of dc motor	5
3.1	Ziegler-Nichols second method tuning rules	21

ABSTRACT

Dc motor has been widely utilized as a part of much mechanical provision for their exact, basic and nonstop control attributes. We have different controller for control dc motor speed/position PID,PI and sliding mode using software Matlab and experiment set up. The brushless dc motor extensively used for control system and industrial application because small in size, high efficiency and high torque density Design PID controller to get fast step response. The PID controller gives very good response and the controller further tuned to decrease overshoot and steady state error. In industries PID controller are better than other controller. PID controller is not difficult to tune and modest. PID control technique is unable to balance out the nonlinear plants or in the vicinity of limited however high instabilities. Sliding mode control strategy is powerful to matched vulnerabilities and the fancied execution is accomplished. The chattering is principle impairment of SMC.

This thesis an extensive study to control speed/position of dc motor by different Controller like PID, Sliding mode in Matlab simulation as well as experimental Study on dc servo set up. The system identification technique is used to get the accurate transfer function of dc motor system identification is the technique where we give some input to the motor and get output corresponding input and output we get the process model with measured and simulation mode through is model get the best fit percentage result after find the transfer function of plant we have design the different controller to control the speed/position of the motor. We have design PID controller for both speed and position control.

SPEED CONTROL OF DC MOTOR USING SLIDING MODE

CHAPTER 1

1.1INTRODUCTION

To definition of any control issue there will ordinarily issue interferes with the genuine plants and to plan the numerical model for controller. The bungle may be comes because of the unmodelled flow, variety in the framework model. The specialist needs to beyond any doubt that the aftereffect of the controller need to capacity to process the obliged execution levels in handy, for example, plant and model bungles. To defeat this issue we have strong control system. The hearty controller configuration is the alleged sliding mode control.[1][9]

1.2MOTIVATION

Everybody is determined by inspiration. My aspiration to be a necessary a piece of the pioneers of present day advances tempted me to pick designing as my vocation. Cutting edge human progress is computerized development. Here very nearly each and every control movement is carried out digitally.as I am a M.tech scholar of control and automation specialization I have enormous enthusiasm toward computerized & control field. Adjoining that I have experienced the different control framework course in my undergrad and additionally postgraduate which make more push in this field.

1.3 SLIDING MODE CONTROL

The sliding mode control chips away at the rule of variable structure control. In numerous zones for the commonsense issue to lessen the dismissal and the craved reaction are obliged so SMC is connected such framework whose conduct are direct and additionally non-liner the primary work of the sliding mode outline the controller. Variable structure framework is

depicted as the shut circle the state passes or re-passes through the surface is called exchanging surface or sliding surface and consistent lies on that surface, when the slip and subsidiary of failure is zero. This kind of movement is called sliding movement when the trajectory proceeds onward the surface is inside controlled by called comparable control.[1][9]

In Monsees (2002) introduce the following way to design sliding mode control

Consider a linear plant

$$\dot{x} = Ax + Bu \quad \ldots\ldots (1.1)$$

Where $x \in \mathbb{R}^n, u \in \mathbb{R}$ and the matrices $A \in \mathbb{R}^{n\times n}, B \in \mathbb{R}^n$ the matrix has full rank and (A, B) is controllable. The control law u is define as

$$u = -Ksgn\sigma \quad \ldots\ldots (1.2)$$

Where K is positive constant and σ is the switching function

1.3.1 *switching function*

For design the switching function we have to finding matrix $S \in \mathbb{R}^n$ this is define switching function.

$$\sigma = Sx \quad \ldots\ldots (1.3)$$

This gives the desired performance in sliding mode to find the transformation matrix

$$\tilde{x} = Tx \quad \ldots\ldots (1.4)$$

Transform 1.4 into a regular form,

$$\dot{\tilde{x}}_1 = \tilde{A}_{11}\tilde{x}_1 + \tilde{A}_{12}\tilde{x}_2 \quad \ldots\ldots (1.5)$$

$$\dot{\tilde{x}}_2 = \tilde{A}_{21}\tilde{x}_1 + \tilde{A}_{22}\tilde{x}_2 \quad \ldots\ldots (1.6)$$

Where $\tilde{x}_1 \in \mathbb{R}^{n-1}, \tilde{x}_2 \in \mathbb{R}, \tilde{A}_{11} \in \mathbb{R}^{(n-1)\times(n-1)}$

$\tilde{A}_{12} \in \mathbb{R}^{n-1}, \tilde{A}_{21} \in \mathbb{R}^{n-1}, \tilde{A}_{22} \in \mathbb{R}\ and\ \tilde{B}_2 \in \mathbb{R}$

The equation 1.3 is transformed into a new coordinates

$$\sigma = \tilde{S}_1\tilde{x}_1 + \tilde{S}_2\tilde{x}_2 \quad \ldots\ldots (1.7)$$

Where $\tilde{S}_1 \in \mathbb{R}^{n-1}, \tilde{S}_2 \in \mathbb{R}$

Defining the sliding surface as $\sigma = 0$. the controller which bring the system in the sliding mode,

From the equation (1.7) the state variable $\tilde{x}_2$ is

$$\tilde{x}_2 = -\tilde{S}_2^{-1}\tilde{S}_1\tilde{x}_1 \quad \ldots\ldots (1.8)$$

The matrix $\tilde{x}_2$ is assumed to be invertible. Substituting equation (1.8) into the (1.5) and (1.6) result in dynamics of sliding mode

$$\dot{\tilde{x}}_1 = \left(\tilde{A}_{11} - \tilde{A}_{12}\tilde{S}_2^{-1}\tilde{S}_1\right)\tilde{x}_1 \quad \ldots\ldots (1.9)$$

It is necessary to choose product of matrix$\tilde{S}_2^{-1}\tilde{S}_1$. The common choice is

$$\tilde{S}_2 = \tilde{B}_2^{-1} \quad \ldots\ldots (1.10)$$

The matrix $\tilde{S}_2$ is invertible. The Eigen value of the matrix is $(\check{A}_{11} - \tilde{A}_{12}\tilde{S}_2^{-1}\tilde{S}_1)$ can be put some state feedback law e.g pole placement method and matrix $\tilde{S}_1$ will be substitute. From the equation (1.3) the matrix S is

$$S = \left[\tilde{S}_1 \;\; \tilde{S}_2\right] T \quad \ldots\ldots (1.11)$$

1.3.2 *control law design*

To find the controller in sliding mode control to the system from equation (1.5) and (1.6)

Occur in finite time. The transformation matrix is

$$\begin{bmatrix}\tilde{x}_1\\ \sigma\end{bmatrix} = \begin{bmatrix} I & 0 \\ \tilde{S}_1 & \tilde{S}_2\end{bmatrix}\tilde{x} \qquad \dots\dots(1.12)$$

Apply transformation (1.12) on the system (1.5) and (1.6) bring the system in the form of

$$\dot{\tilde{x}}_1 = \tilde{A}_{11}\tilde{x}_1 + \tilde{A}_{12}\tilde{x}_2 \qquad \dots\dots(1.13)$$

$$\dot{\sigma} = \tilde{A}_{21}\tilde{x}_1 + \tilde{A}_{22}\sigma + u \qquad \dots\dots(1.14)$$

The control law is chosen as

$$u = u_c + u_d \qquad \dots\dots(1.15)$$

The u_c is the continuous component and u_d is the discontinuous are given by

$$u_c = -\tilde{A}_{21}\tilde{x}_1 - \tilde{A}_{22}\sigma \qquad \dots\dots(1.16)$$

$$u_d = -K_s sgn\sigma - K_p\sigma \qquad \dots\dots(1.17)$$

To study stability the Lyapunov function is defined

$$V(\sigma) = \frac{1}{2}\sigma^2 \qquad \dots\dots(1.18)$$

This function can be apply to reaching law

$$\dot{V}(\sigma) = \sigma.\dot{\sigma} \leq -\eta|\sigma| \qquad \dots\dots(1.19)$$

η is positive Constant. Substituting (1.14)-(1.17) into (1.19) result is

$$-K_s|\sigma| - K_p\sigma^2 \leq -\eta|\sigma| \qquad \dots\dots(1.20)$$

Dividing (1.20) by $|\sigma|$the condition (1.20) is

$$K_s + K_p|\sigma| \geq \eta \quad \ldots\ldots(1.21)$$

This condition is always satisfied when $K_s \geq \eta$ and $K_p \geq 0$ .which is used to convergence of the trajectory to the switching surface. If this condition is met, the closed loop system will reach the sliding mode in finite time.

1.4 Example: DC motor speed control using sliding mode control

The parameter of dc motor is given in the table 1.1 [15]

$R_a = 0.6$	$K_b = 0.8vs/rad$
$L_a = 0.012H$	$J = 0.0167kgm^2$
$K_t = 0.8Nm/A$	$f_0 = 0.0167$

Table 1.1 parameter of dc motor

Transfer function given below:

$$\frac{\omega_a}{V_a} = \frac{K_t}{(R_a+sL_a)(Js+f_0)+K_tK_b} \quad \ldots..(1.22)$$

From the equation 1.1 we have

$$\frac{\omega_a(s)}{V_a(s)} = \frac{399.015}{s^2+51s+51.39} \quad \ldots\ldots(1.23)$$

The equation in term of time domain is

$$\ddot{\omega}(t) + 51\dot{\omega}(t) + 52.39\omega(t) = 399.015V_a(t) \quad \ldots\ldots(1.24)$$

Now consider

$$x_1 = \omega(t) \; and \; u = V_a \qquad \text{.....(1.25)}$$

Now, this system is converted to controllable canonical form:

$$\dot{x_1} = x_2$$

$$\dot{x_2} = -51.39x_1 - 51x_1 + 399.015U \qquad \text{.....(1.26)}$$

$$y = x_1$$

Now the error between reference speed and actual speed is given below:

$$e(t) = \omega_{ref}(t) - \omega(t) \qquad \text{....(1.27)}$$

$$\ddot{e}(t) + 51\dot{e}(t) + 51.39e(t) = 399.015u \qquad \text{.....(1.28)}$$

Now, The Switching function of the sliding mode is:

$$s = ce(t) + \dot{e}(t) \qquad \text{....(1.29)}$$

$$\dot{s} = c\dot{e}(t) + \ddot{e}(t)$$

$$\dot{s} = 0$$

The equivalent control is

$$u_{eq} = 51.39e(t) - (c - 51)\dot{e}(t) \qquad \text{.....(1.30)}$$

The total control law is

$$u = u_{eq} + u_l \qquad \text{.....(1.31)}$$

Where $u_l = ksign(s)$

From equation 1.31

$$u = \frac{1}{399.015}(51.35e(t) - (c - 51)\dot{e}(t) + ksign(s) \qquad \text{.....(1.32)}$$

1.4.1 Simulink model of sliding mode control for dc motor

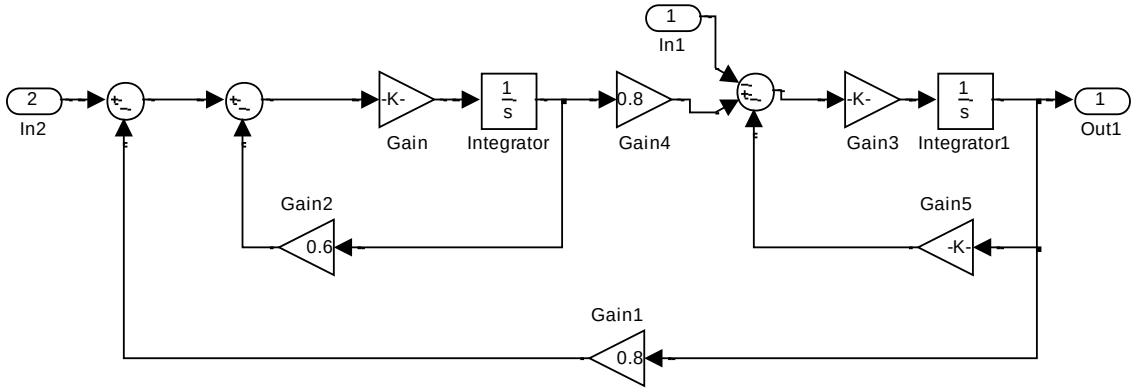

Figure 1.1 Simulink model of dc motor

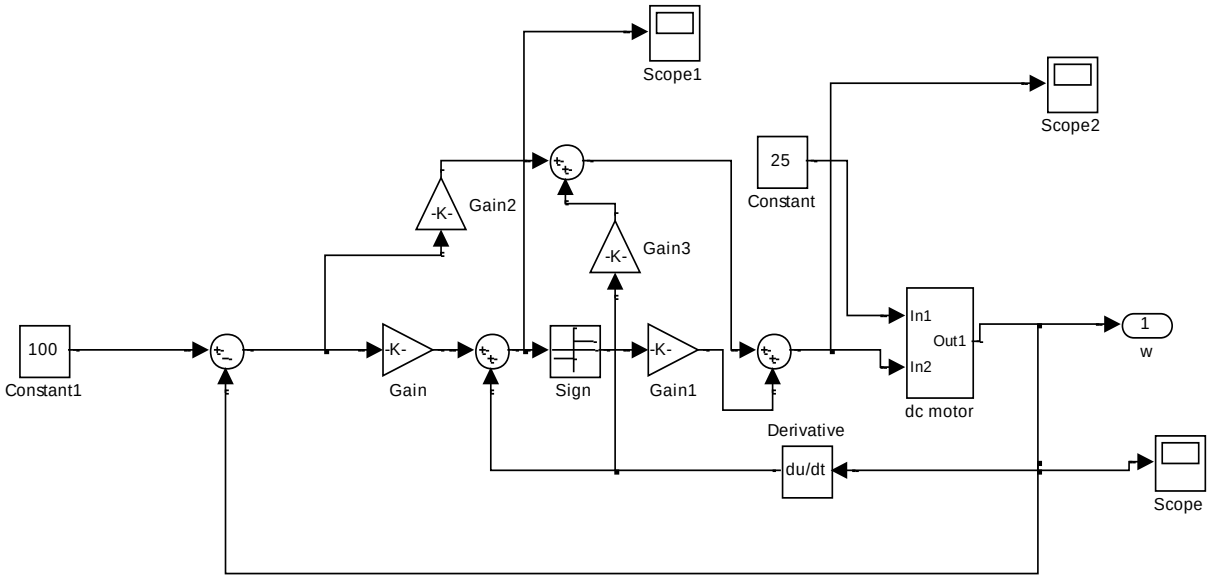

Figure 1.2 Simulink model of dc motor using sliding mode control

1.5 Simulation results:

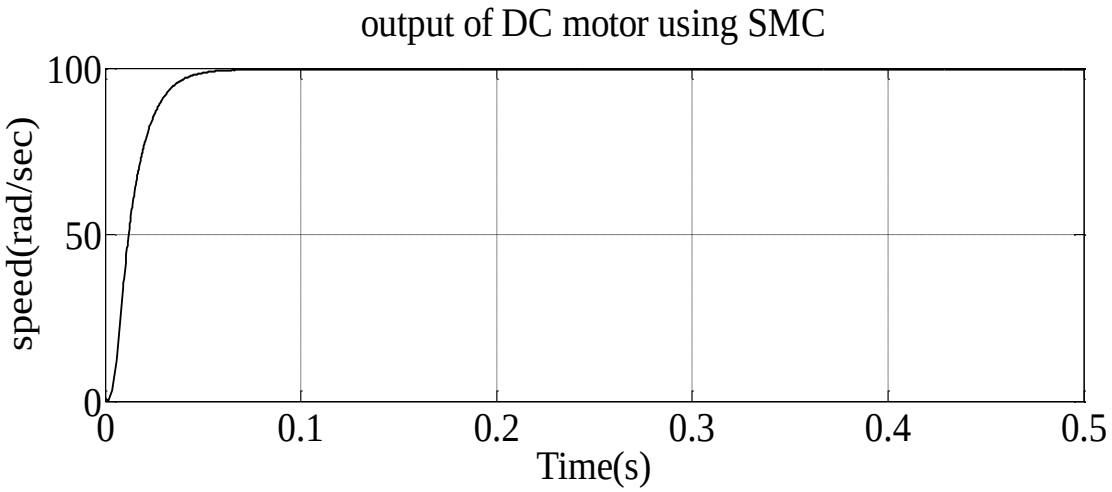

Figure1.3 output of dc motor using SMC

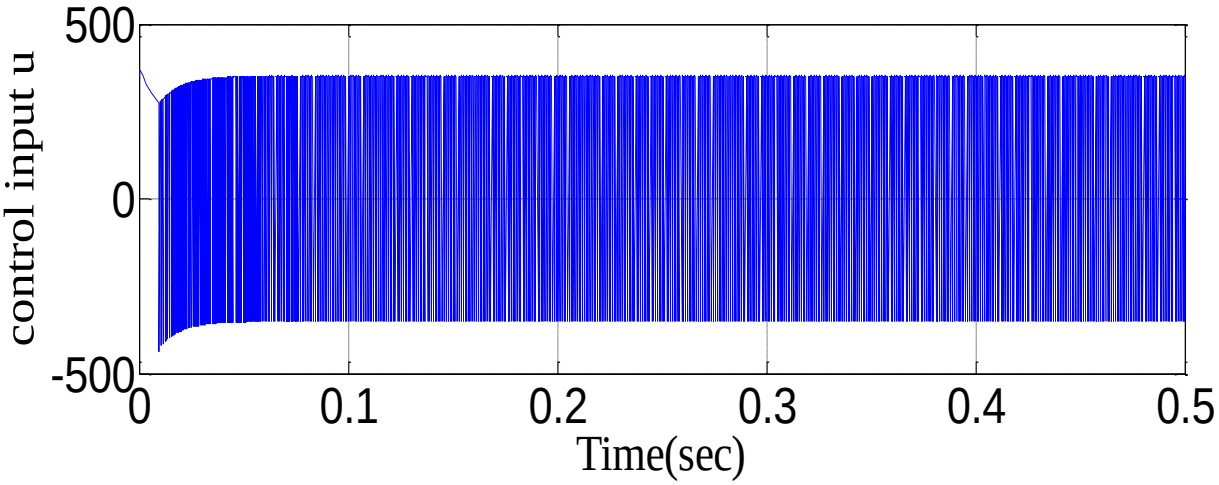

Figure1.4 Control input of motor

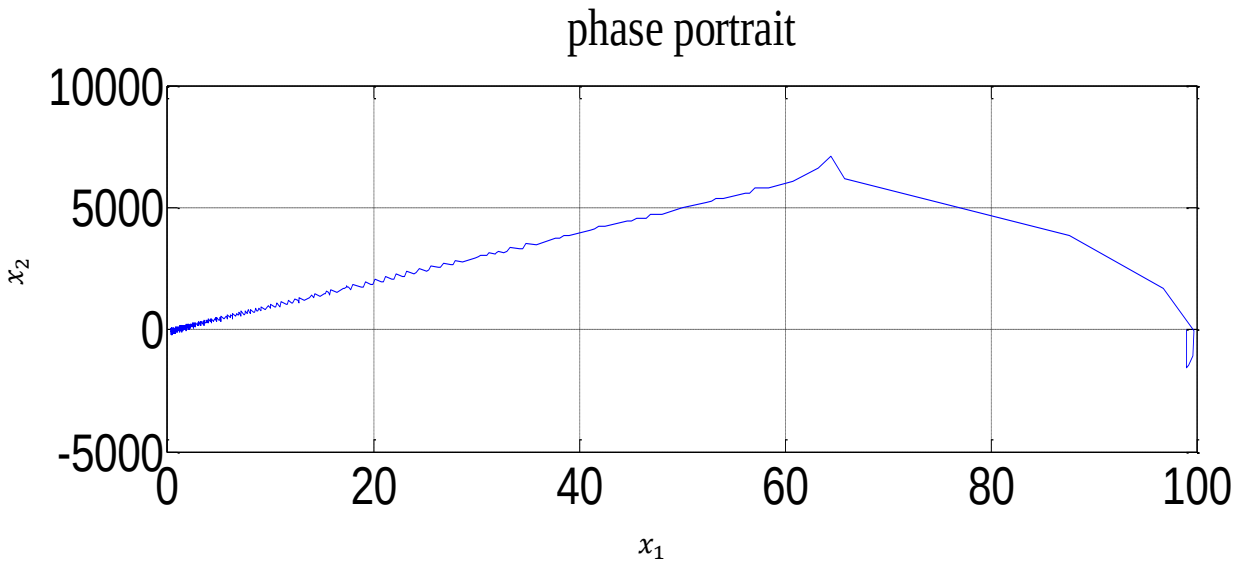

Figure1.5 Phase portrait of the motor

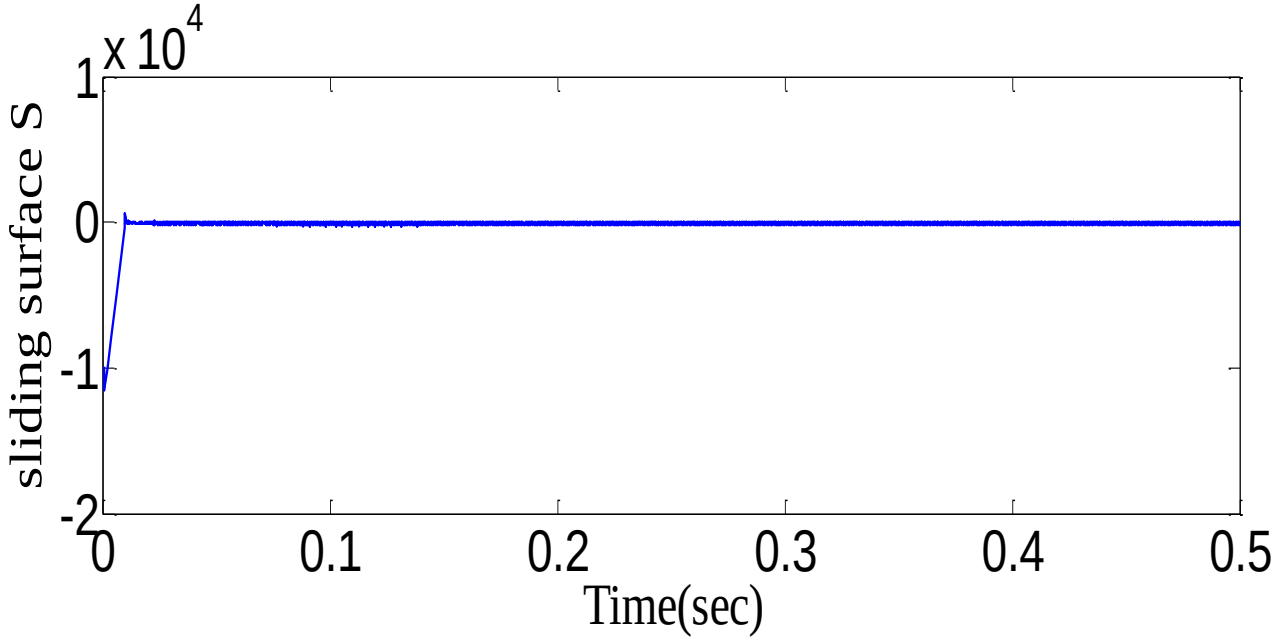

Figure1.6 sliding surface

MODELING OF DIGITAL DC-SERVO MOTOR

CHAPTER 2

2.1INTRODUCTION

In this chapter the mathematical and mathematical modeling of digital dc servo is done. The mathematical modeling is done by system identification tool box. The system identification toolbox gives us the transfer function of the plant after finding the plant transfer function we have design the PID controller to control the both angular velocity and angular position of the motor.

2.2 MATHEMATICAL MODELING OF DC SERVO CONTROL

Dc servo motor is broadly utilized for modern and domesticated reason. It is important to build the numerical model of DC servo motor here we are utilizing armature control DC motor to control speed and position of Dc motor. In armature control of DC motor the resistance R_a and inductance L_a connected in series and voltage e_b is representing the back emf of DC servo motor. The motor parameter and variable define as follow. Consider armature control dc motor shown in fig2.1[15]

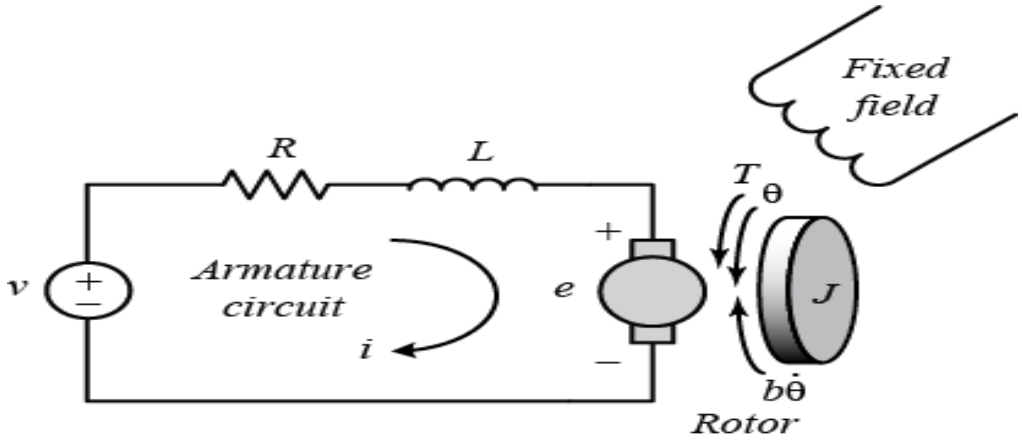

Figure2.1 Circuit diagram of dc motor

$R_a = resistance\ of\ armature$

$L_a = inductamce$

$i_a = armature\ current$

$e_b = Back\ emf$

$v_a = armature\ voltage$

$i_f = field\ current$

$\theta = angular\ position$

$J = moment\ of\ inertia$

$f_0 = viscous\ coefficient\ friction$

$.T_m = torque$

The air gap flux $\varphi \propto i_f$

$\varphi = k_f i_f$

Where k_f is the constant

$T_m \propto \varphi i_a$

$T_m = K_1 K_f i_f i_a$

Where K_1 is the constant

The field current is kept constant in armature control dc motor, the becomes

$T_m = K_T i_a$

Where K_T is motor torque constant

Now,

$e_b \propto \omega_m$

$$\therefore\ \omega_m = \frac{d\theta_m}{dt}$$

$$e_b = K_b \frac{d\theta_m}{dt}$$

Where K_b is the back emf constant

Apply KVL in the circuit

$$v_a - e_b = L_a \frac{di_a}{dt} + R_a i_a$$

The torque equation is given as

$$j\frac{d^2\theta}{dt} + f_0 \frac{d\theta}{dt} = T_m$$

Taking Laplace transform of equation, assuming zero initial condition, we get

$$E_b = K_b s\theta_m$$

$$(L_a s + R_a) I_a(s) = V_a(s) - E_b(s)$$

$$(Js^2 + f_0 s)\theta_m(s) = T_m(s) = K_T I_a(s)$$

$$\frac{\theta_m(s)}{V_a(s)} = \frac{K_T}{s[(R_a + sL_a)(Js + f_0) + K_T K_b}$$

Here, we can see that $\theta_m(s)$ is the angular position of the shaft and $V_a(s)$ is applied voltage.

2.3. MODEL ESTIMATION PROCESS OF DC-SERVO MOTOR

We are finding the model of dc-servo position control by the help of system identification toolbox in Matlab system identification session represent the total progress, including ant data of set and process model in system identification tool box.

The following steps in the system identification GUI is:

- Running the motor with some known input and save the input and output in Matlab workspace.
- In Matlab command window type ‘ident’ and start a new session in system identification toolbox.
- In Matlab workspace import data corresponding the starting time and sampling interval.
- Specify the data of estimation and validation.
- Select the process model by different model technique.
- We can choose the type and order of model to identify.
- After above step, we can check model output, transient response, frequeny response,noise spectrum, pole zero location. The maximum best fit percentage will give us good accuracy and for mode matching.
- Export model to the Matlab workspace for further analysis.

2.3.1. A NEW SESSION IN THE SYSTEM IDENTIFICATION TOOL GUI

In the system identification toolbox GUI start a new session while, typing the command in command window 'ident'

On the other hand, we can begin another session by selecting **start > toolbox >system identification**> framework recognizable proof tool stash GUI in the Matlab desktop this movement open framework ID GUI

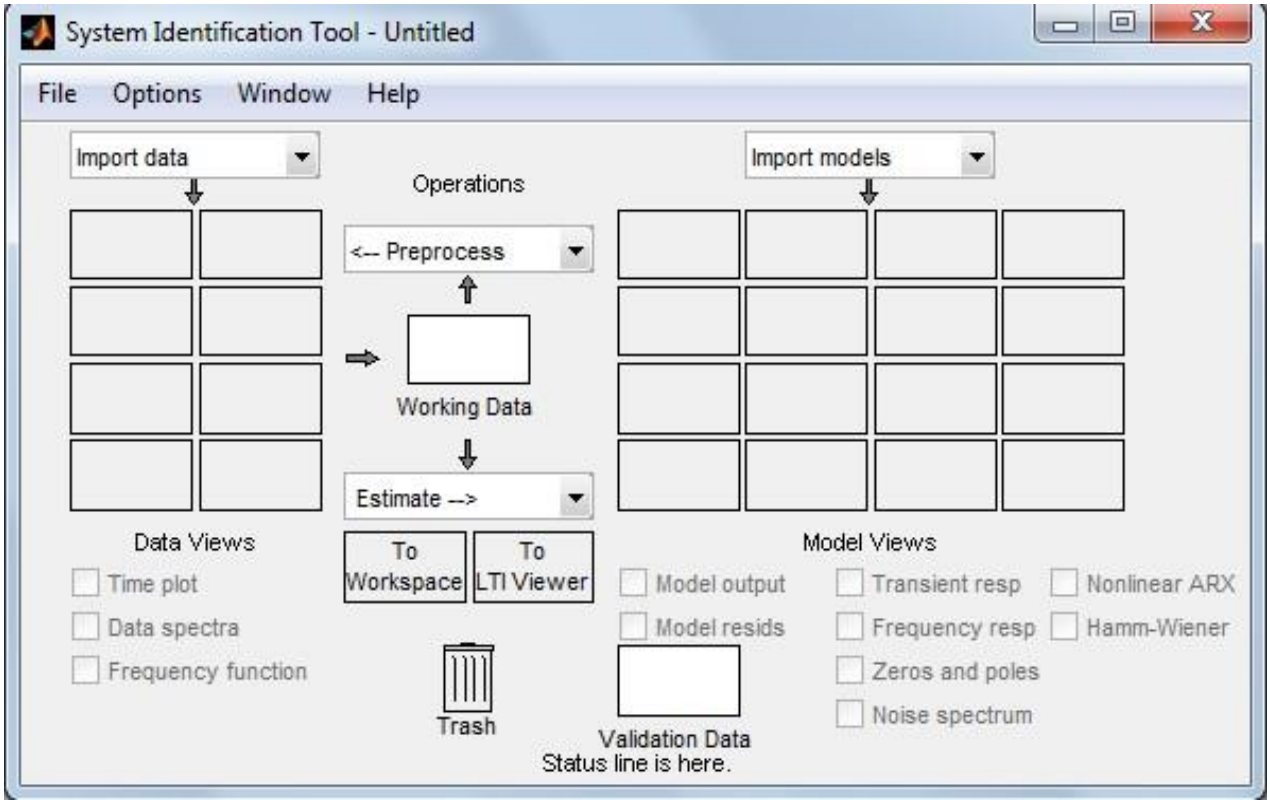

Figure2.2 System identification toolbox

We can additionally begin another session by shutting the current session utilizing **File > Close session**. This tool kit prompts you to spare your current session on the off chance that it is not effectively spared

2.4 MODELLING OF DIGITAL DC-SERVO MOTOR

The model estimation is done by the system identification toolbox in matlab. We have run the motor with some known input (voltage) and collect the output (angular velocity) whlie performing the experimet on dc-servo set-up.

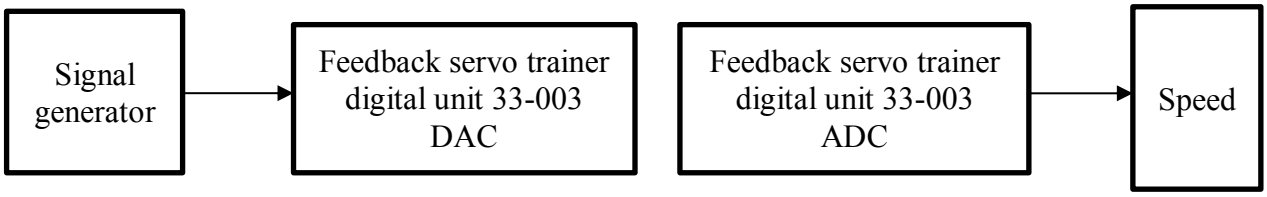

Figure2.3 Running motor with voltage as input and output as speed.

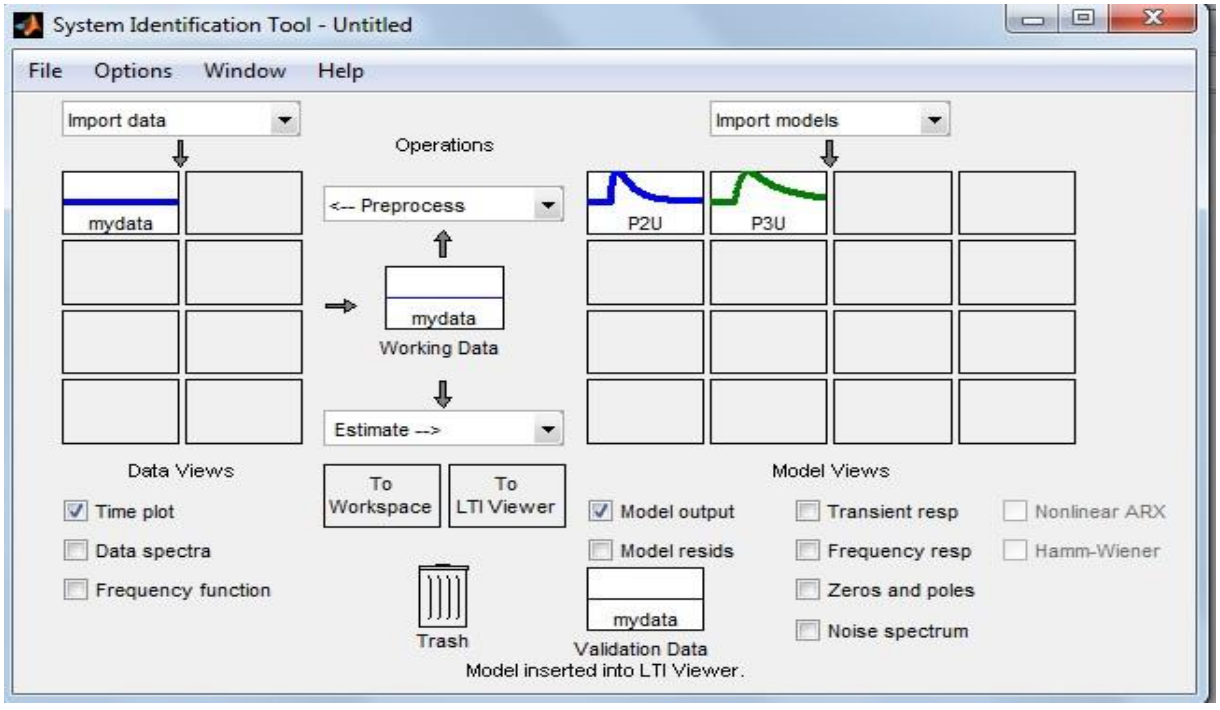

Figure2.4 System identification toolbox after importing input and output

After collect the input output from the dc-servo motor .we import the data from system identification toolbox. Seen figure 2.4

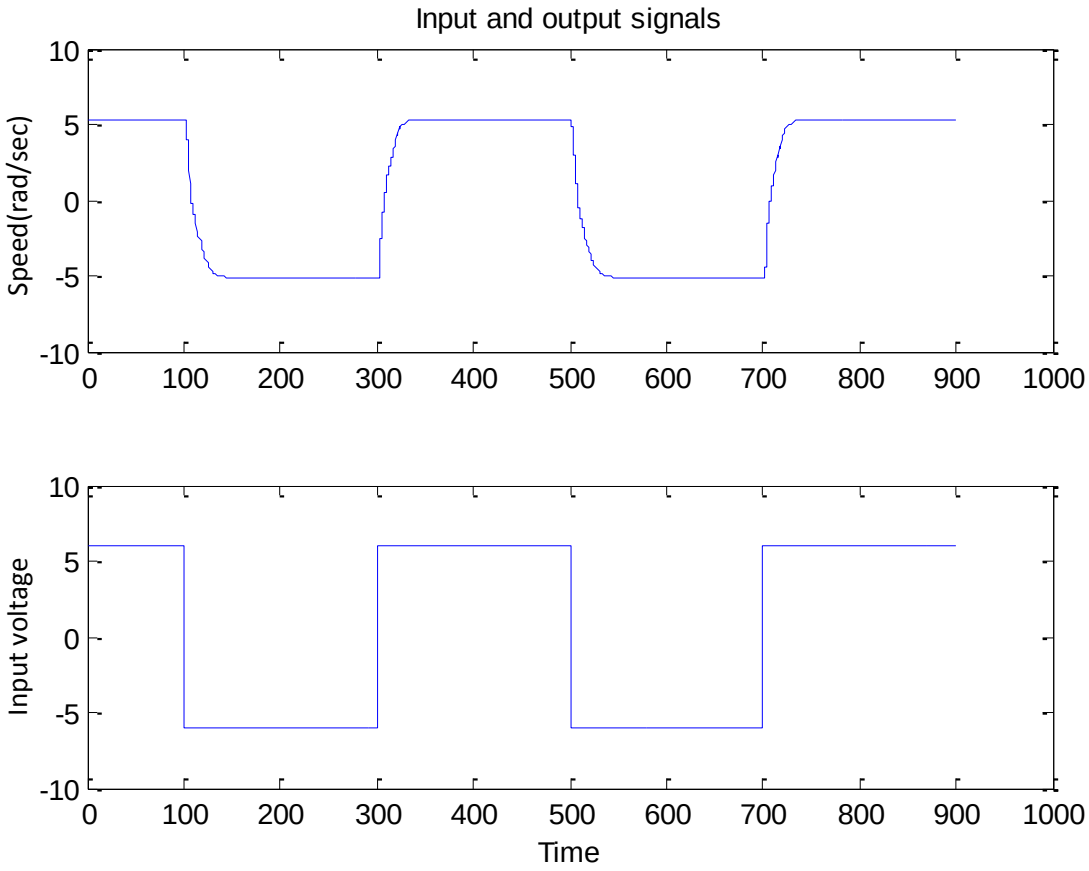

Figure 2.5 Input output response of importing data.

In the dial box figure2.7 we can enter how many poles to estimate and delay and zero to numerator to the transfer function of the process model. we can also add the integrator to the process model. Moreover, we can give all the poles as real and under-damped (complex pole) from the above case the process model is best fit in third order model P3U in figure 2.8.In figure 2.8 we can see that the output of process model exactly follow the input of the process model.

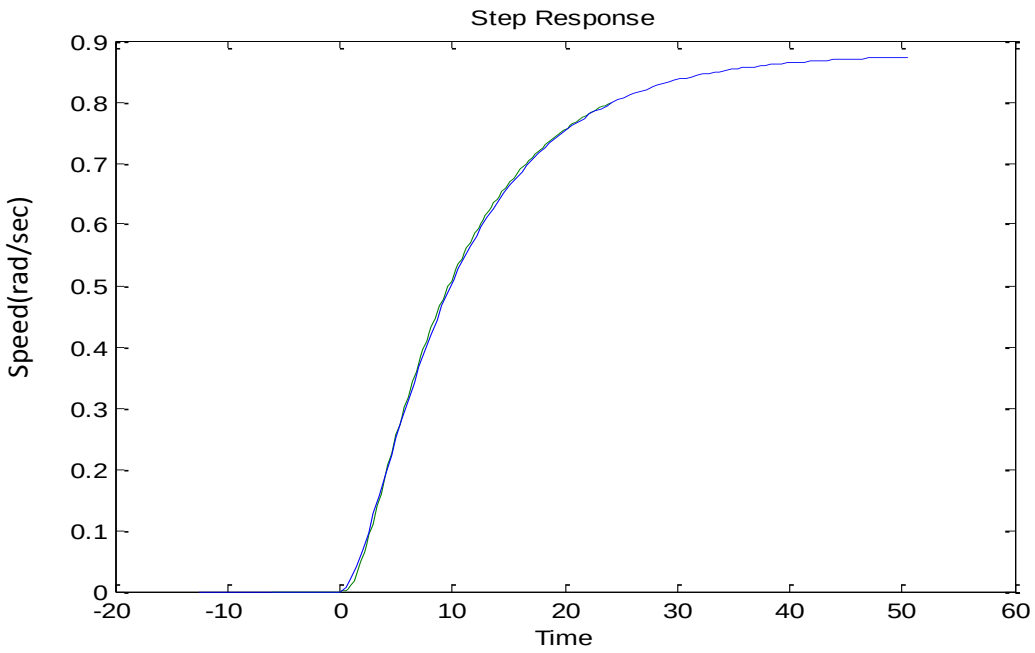

Figure2.6 Transient response of the model

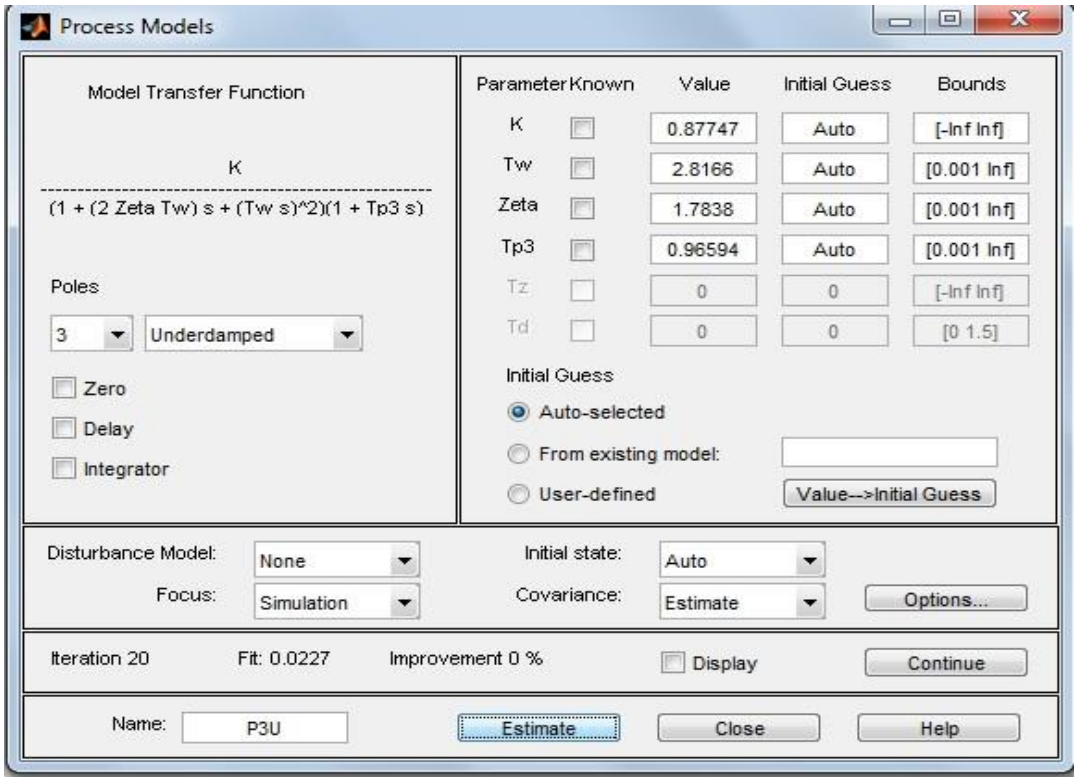

Figure2.7Estimation of process model

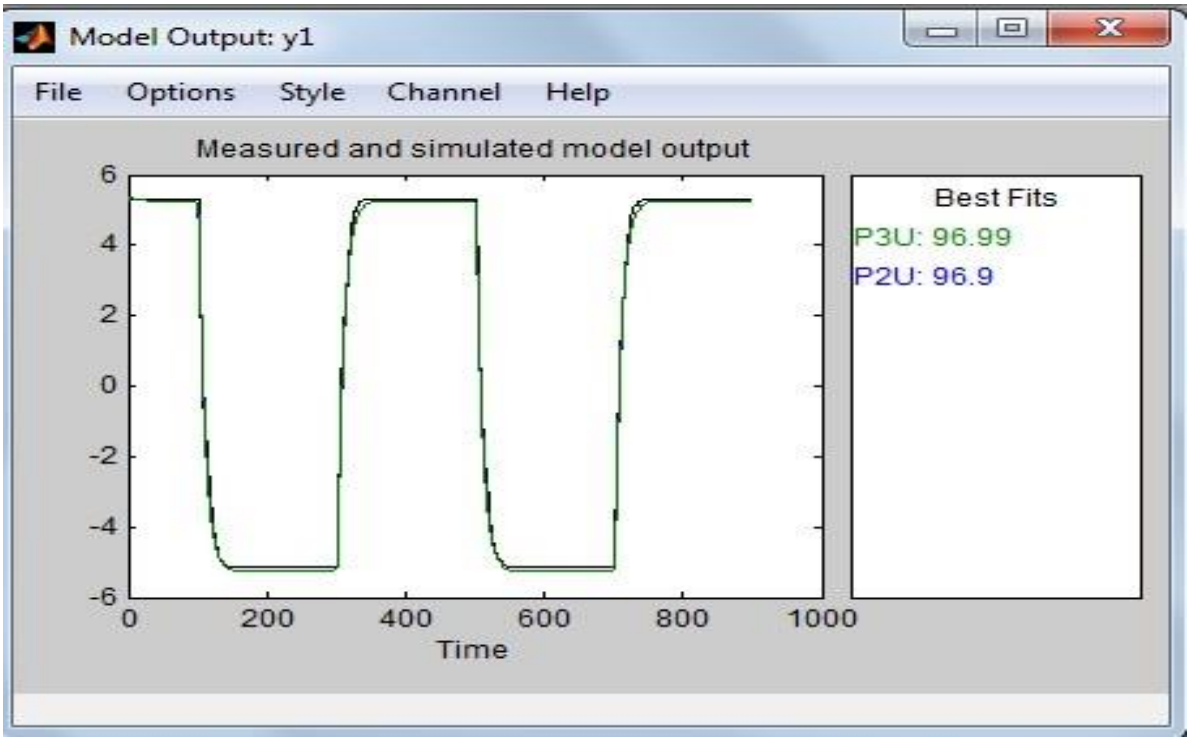

Figure 2.8 Simulated and measured output model of dc-servo motor

The open loop transfer functions of the dc-servo motor whereas angular velocity is the output and voltage as input given below.

$$\frac{\omega_a(s)}{V_a(s)} = \frac{0.8775}{7.022s^3 + 17.13s^2 + 10.24s + 1}$$

2.5 CHAPTER SUMMARY

This chapter gives mathematical modeling of dc-servo motor and a detail of model estimation of system identification toolbox.

PID CONTROLLER DESIGN FOR DC-SERVO MOTOR

CHAPTER 3

3.1 INTRODUCTION

Proportional-integral-derivative (PID) controllers in commonly used in process control industries so, we have various process for tuning PID controller to get performance index for system dynamics response the for determine the parameter of PID dynamic response of the plant.

The PID control info is the error between the coveted yield and the real output. The error is controlling by the controller PID to handle a summon sign for the plant as indicated by the relationship.[12]

$$U(s) = \left(1 + \frac{1}{\tau_i} + \tau_d s\right)$$

In time domain $u(t) = K_p[e(t) + (1/\tau_i)\int_{-\infty}^{t} edt + \tau_d(de/dt)]$

Where K_p= proportional gain

τ_i= integral time constant

τ_d= derivative time constant

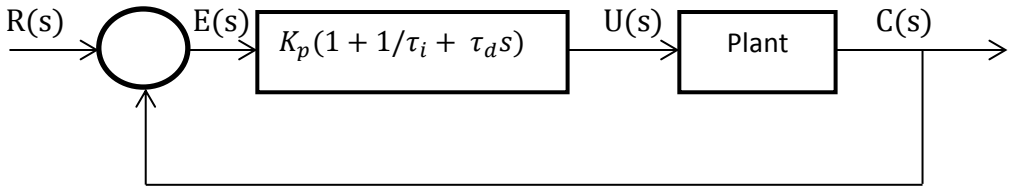

Figure3.1 Basic control configuration

3.1.1 Objective

In this chapter we have control the speed and angular position of dc servo motor by the help of PID controller. we have find the PID gain by the tuning method of Ziegler and Nichols after finding the PID gain the controller is design to control the angular velocity and angular position of the motor.

3.2 TUNING OF PID CONTROLLER

The methodology of the selecting the controller parameter to meet given execution determination is known as controlling tuning. Zeigler and Nichols principle tuning of PID controller intending to set the worth of focused around step reaction as well as focused around the relative increase result is barely steady when the corresponding consistent is utilized**.**

3.2.1METHOD FOR TUNING OF ZIEGLER AND NICHOLS RULES:

i. First method
ii. Second method

First method : Obtain the response of the plant through an experiment with unit step response .If the plant does not involve any dominant complicated conjugate pole, then such unit step response look in s-shaped formed type.[12]

Such response curve may be generated experimentally or form dynamic simulation of the plant.

Second method

First we set the value of $T_i = \infty$ and $T_d = 0$

We increase the value of proportional gain from 0 to critical gain K_{cr} till first sustained oscillate come.[12]

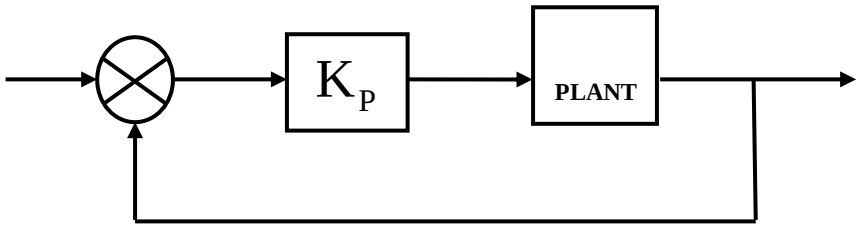

Figure 3.2 block diagram of proportional controller

Ziegler-Nichols tuning coefficients for P, PI, and PID controllers are given in Table 3.1

Type of controller	K_p	τ_i	τ_d
P	$0.5\ K_{cr}$	∞	**0**
PI	$0.45\ K_{cr}$	$\frac{1}{1.2} P_{cr}$	**0**
PID	$0.6\ K_{cr}$	$0.5\ P_{cr}$	$0.125\ P_{cr}$

Table 3.1 Ziegler-Nichols second method tuning rules

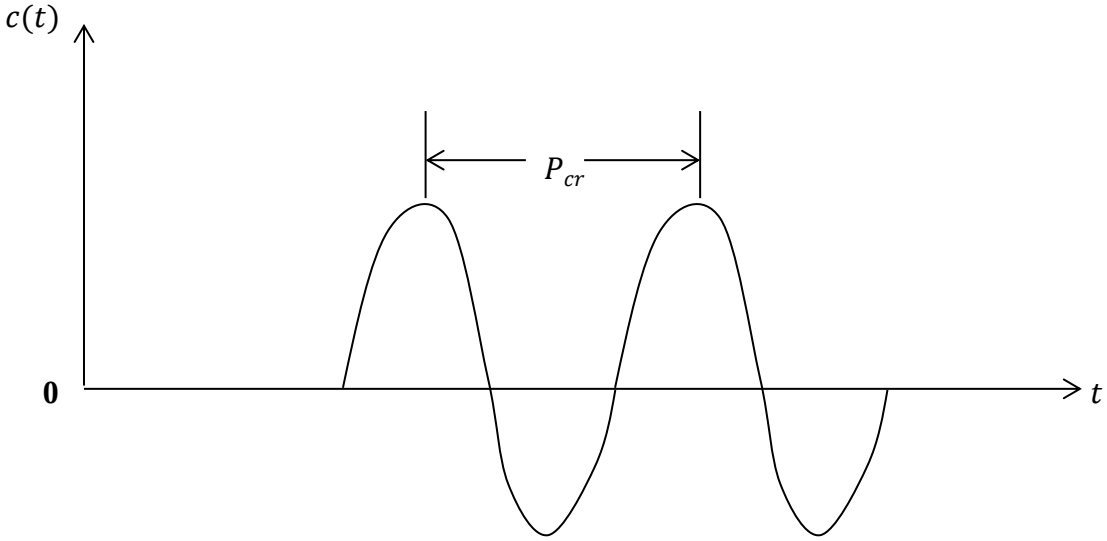

Figure 3.3 Ziegler-Nichols second method corresponding time P_{cr}

3.3.2DESIGN PID CONTROLLER FOR DC-SERVO MOTOR

From the system identification toolbox we have find The open loop transfer function of the dc-servo motor whereas angular velocity is the output and voltage as input given below:

$$\frac{\omega_a(s)}{V_a(s)} = \frac{0.8775}{7.022s^3 + 17.13s^2 + 10.24s + 1}$$

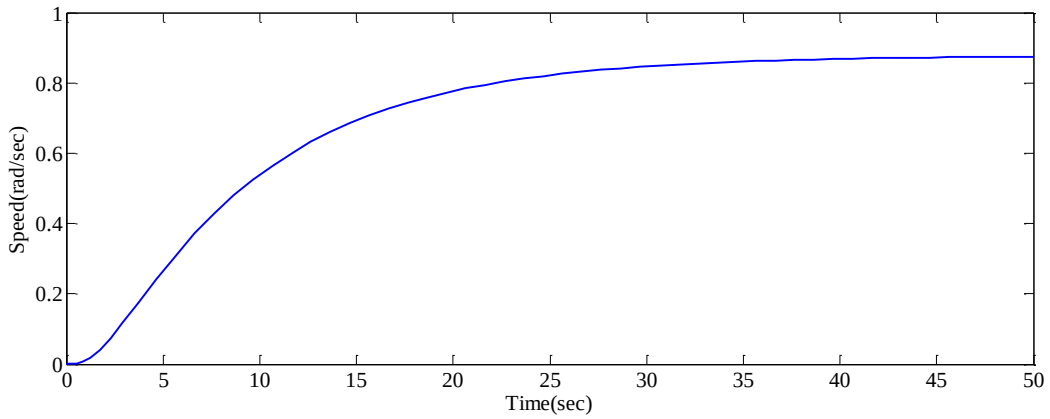

Figure3.4 open loop response of dc motor

From the figure we can see that the output of dc motor is not perfectly match to the step input so, to match the output to the input we need controller here, we have design PID controller to control the angular velocity of the motor.

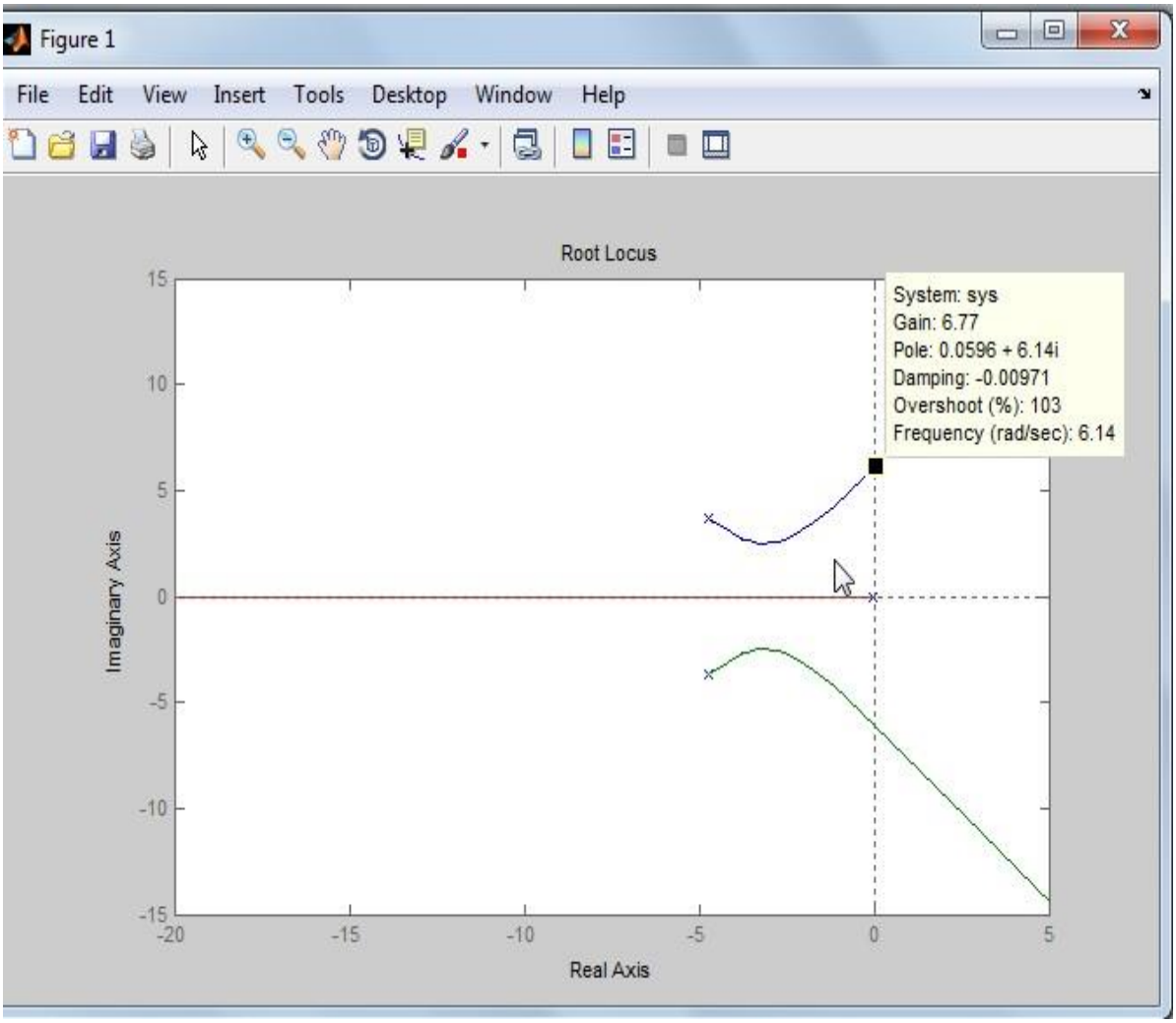

Figure3.5 Root-locus for open loop transfer function

We can see in the figure the graph cut the imaginary axis at gain 6.77 at the frequency 6.14 where, gain 6.77 is the critical gain where we the sustained oscillation. From the value of gain (K_{cr}) and the frequency we can find the value of proportional gain, integral gain and derivative gain by the help of Ziegler and Nichols tuning method.

3.3.3FINDING THE VALUE OF GAIN PARAMETER K_p , K_d , K_i .

Now, we have K_{cr} = 6.77 and corresponding ω_{cr} = 6.14

From the table tuning of Ziegler Nichols the parameter of PID is given below:

K_p =0.6 K_{cr}

T_i = 0.5 P_{cr}

T_d = 0.12 P_{cr}

Where, $P_{cr} = \frac{2\pi}{\omega_{cr}}$

From the above value we have find the gain from the table 3.1

K_p =16.3362

P_{cr} =5.1927

T_i =2.5964

T_d =0.6491

$K_i = \frac{K_p}{T_i}$ =6.2919

$K_d = K_p T_d$ =10.6039

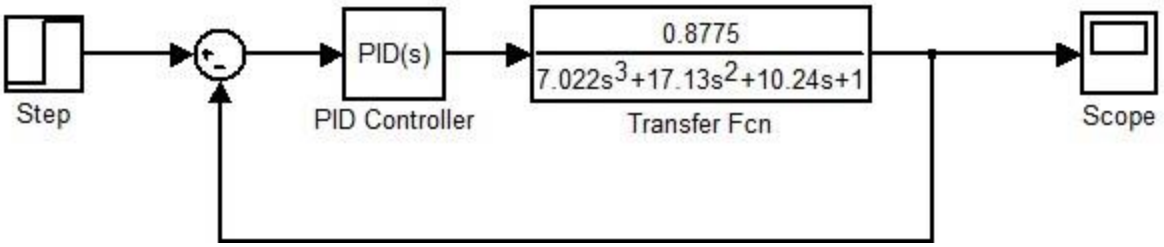

Figure3.6 PID Controller for dc-servo motor

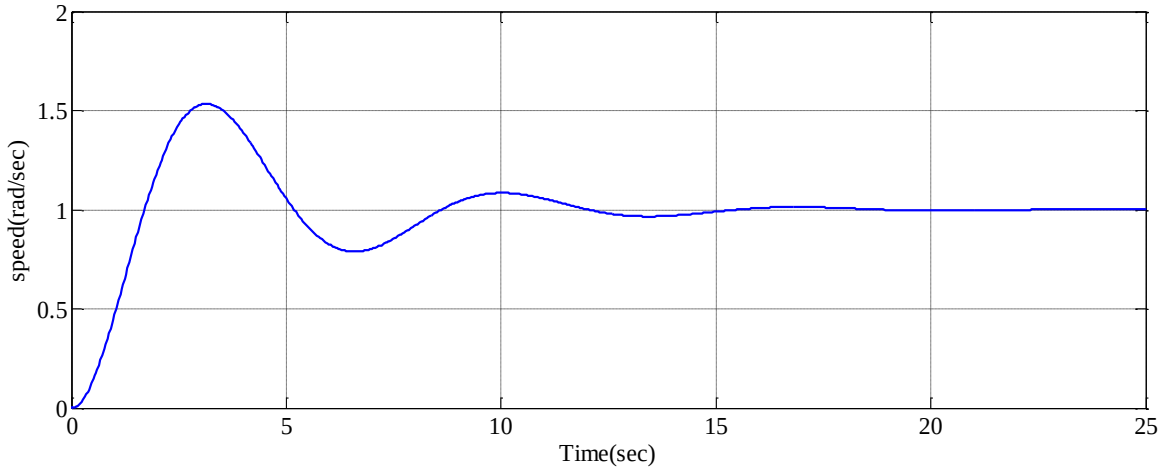

Figure3.7 output of DC-servo motor

3.3.4 Design PID controller where output as angular position.

Now, controller PID design where output as angular position and input is applied voltage. so from the system identification toolbox we find the open loop transfer function .

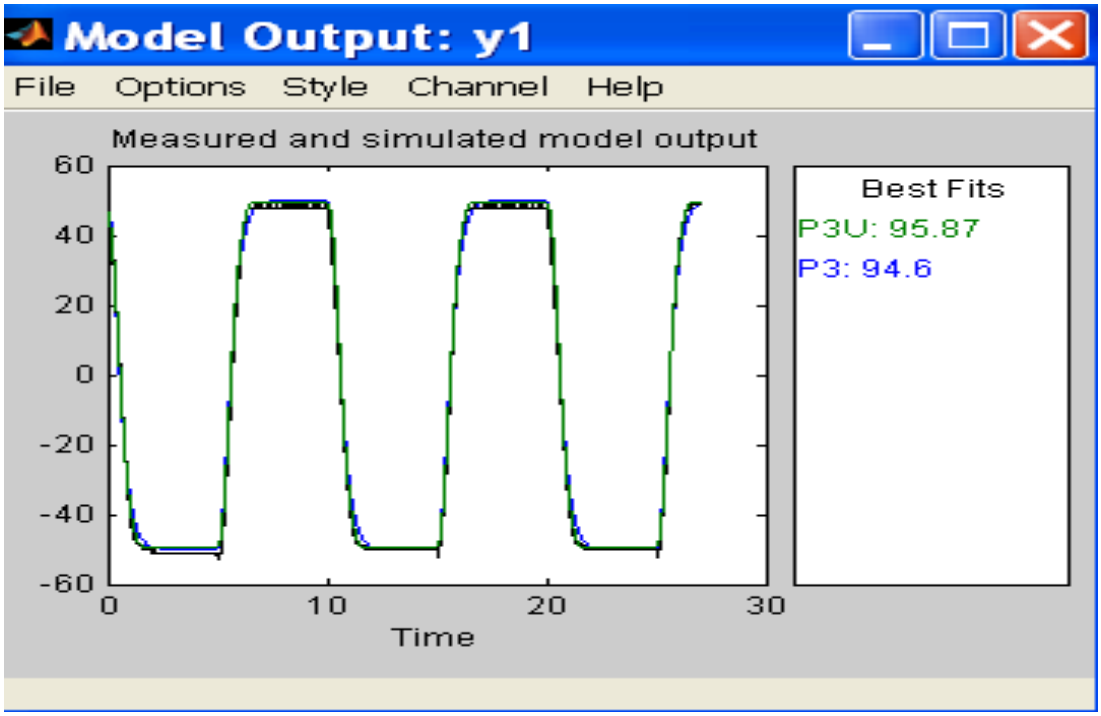

Figure3.8 Measured and simulated output model of dc motor

We can see that from the figure 3.8 the most effective match proportion is from third order therefore currently we have open loop transfer perform is given below.

$$\frac{\theta(s)}{V_a(s)} = \frac{53.27}{s^3 + 9.48s^2 + 36.18s + 0.8211}$$

$\theta(s)$ is the angular position of the dc-servo motor and $V_a(s)$ is the applied voltage of dc motor.

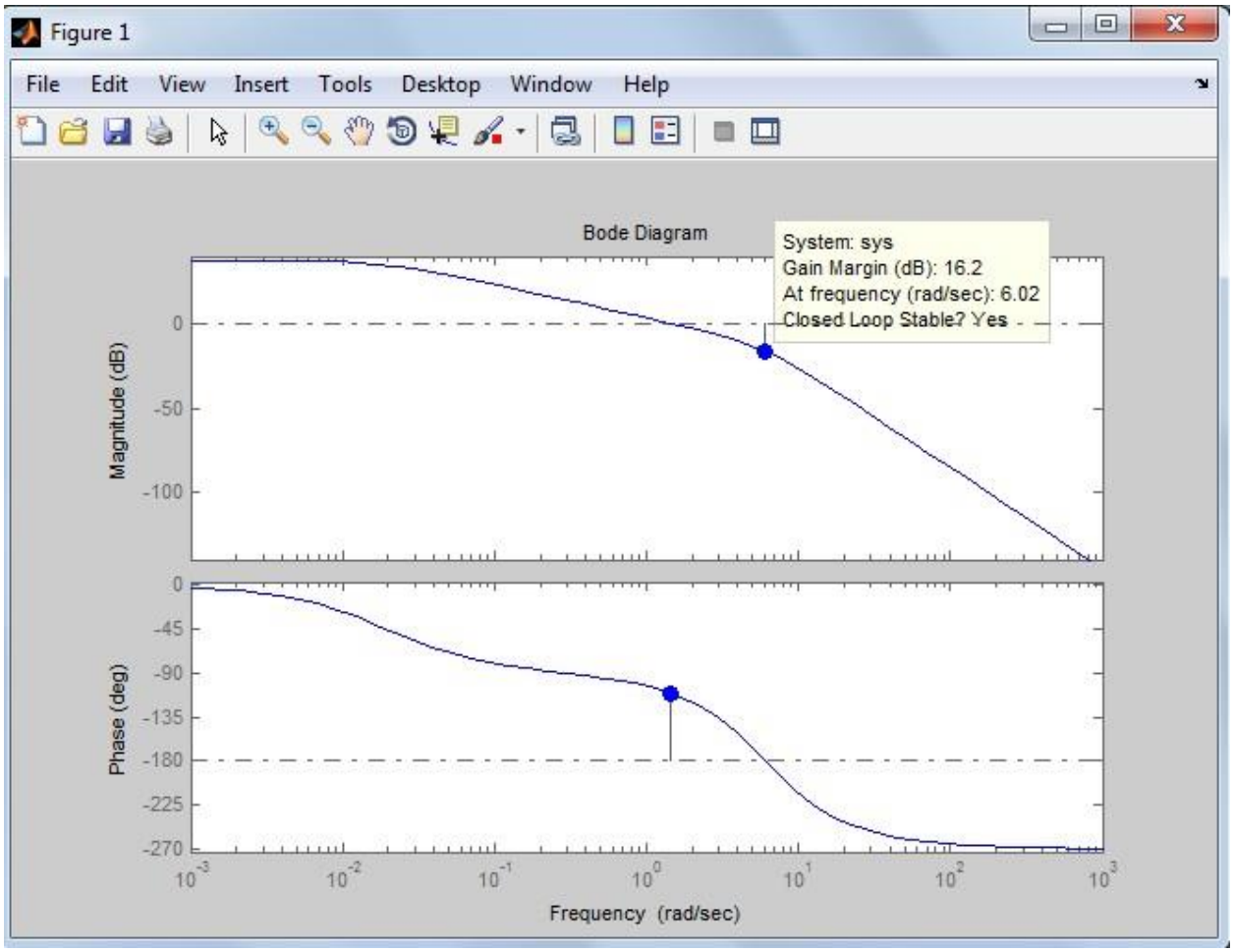

Figure3.9 Bode plot of the open loop transfer function of dc motor.

From the figure we can see that the gain margin is 16.2 corresponding frequency is 6.02.

We know,

$$GM = 20log_{10}K_{cr}$$

Where K_{cr} is the critical gain.

$16.2=20log_{10}K_{cr}$

$K_{cr} = 6.45$

From the value of critical gain the tuning parameter find from the table.by Ziegler Nichols technique we have

K_p= 3.56

K_i= 0.1

K_d = 0.56

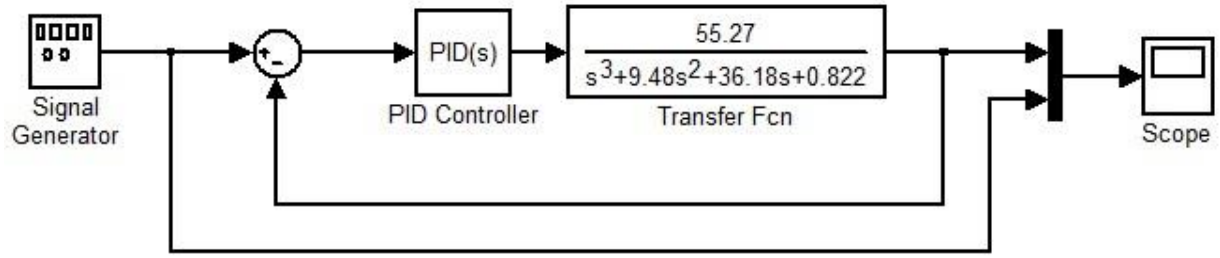

Figure3.10 Block diagram of PID controller

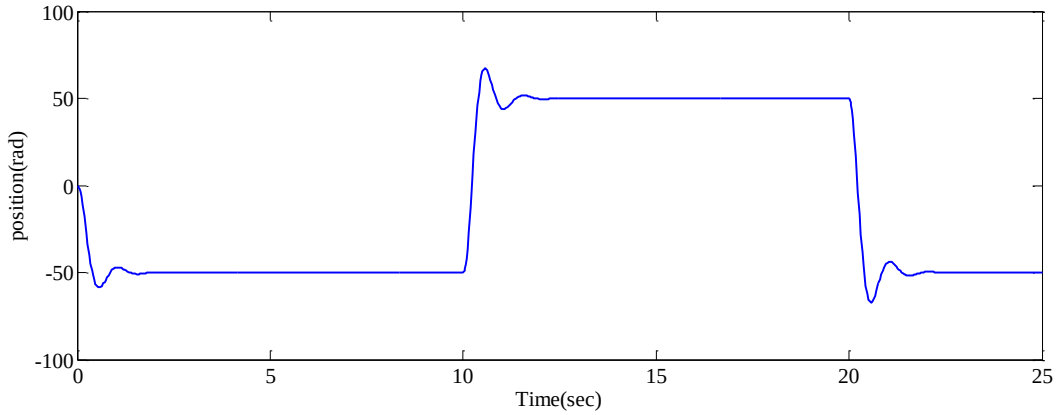

Figure3.11 Angular position output of dc-servo motor

EXPERIMENT STUDY ON THE DIGITAL SERVO MOTOR SET-UP

CHAPTER 4

4.1. INTRODUCTION

In this chapter we have study and perform experiment on digital servo set-up where we have control the position and speed of the motor.

4.1.1 Overview

A servo is an engine that is joined to a position input gadget. By and large there is a circuit that permits the engine to be told to go to a specified "position". An exceptionally basic utilization of servos is in Radio Controlled models. Servos are to a great degree valuable in mechanical technology. The engines are little and are to a great degree effective for their size. It likewise attracts power corresponding to the mechanical burden. A gently stacked servo, thusly, doesn't devour much vitality. Servos are built from three fundamental pieces, an engine, a reaction gadget, and a control board. The engine, through an arrangement of riggings, turns the yield shaft and the potentiometer at the same time. The potentiometer is bolstered into the servo control circuit and when the control circuit catches that the position is right, it stops the engine.[6][10]

4.1.2. Working Procedure of Servo

The servo engine has some control circuits and a potentiometer (a variable resistor, otherwise known as pot) that is joined with the yield shaft. The potentiometer permits the control hardware to screen the current point of the servo engine. In the event that the pole is at the right point, then the engine stops. In the event that the circuit finds that the plot is not right, it will turn the engine the right bearing until the edge is right. The yield shaft of the servo is fit for voyaging some place

around 180 degrees. Typically, it is some place in the 210 degree range, yet it differs by maker. An ordinary servo is utilized to control a rakish movement of between 0 and 180 degrees. A typical servo is mechanically not equipped for turning any more remote because of a mechanical stop based on to the fundamental yield gear. The measure of force connected to the engine is relative to the separation it needs to travel. Along these lines, if the pole needs to turn a vast separation, the engine will run at full speed. On the off chance that it needs to turn just a little sum, the engine will run at a slower speed. This is called relative control. The control wire is utilized to impart the point. The point is controlled by the term of a beat that is connected to the control wire.[6][10]

4.2 DESCRIPTION OF SERVO SETUP

The framework involves three units which permit the examination of the essentials of simple and advanced servo control:

- A Mechanical unit
- An Analogue Unit
- A Digital unit

The mechanical unit conveys a force enhancer, dc motor and tachogenerator; outright and incremental computerized encoders include and yield simple potentiometers, an advanced rate and voltage presentation and a sine, square and triangle waveform generator for testing purposes. The Analog Unit conveys a four information error amplifier, a controller with autonomous P, I and D channels and offices for single enhancer recompense circuits.[6][10]

The Digital Unit conveys ADC and DAC for indicator change, exchanging and multiplexing circuits, encoder yield and presentation and liner and PWM engine drive. Access is given to the information and yield potentiometers empowering an extensive variety of straight and computerized frameworks to be examining.

Disclosure programming is accommodated utilization with the Digital Unit. Interconnection between units is by lace link and framework interconnection is by stopped patch heads on the simple or advanced units, which convey clear realistic formats.

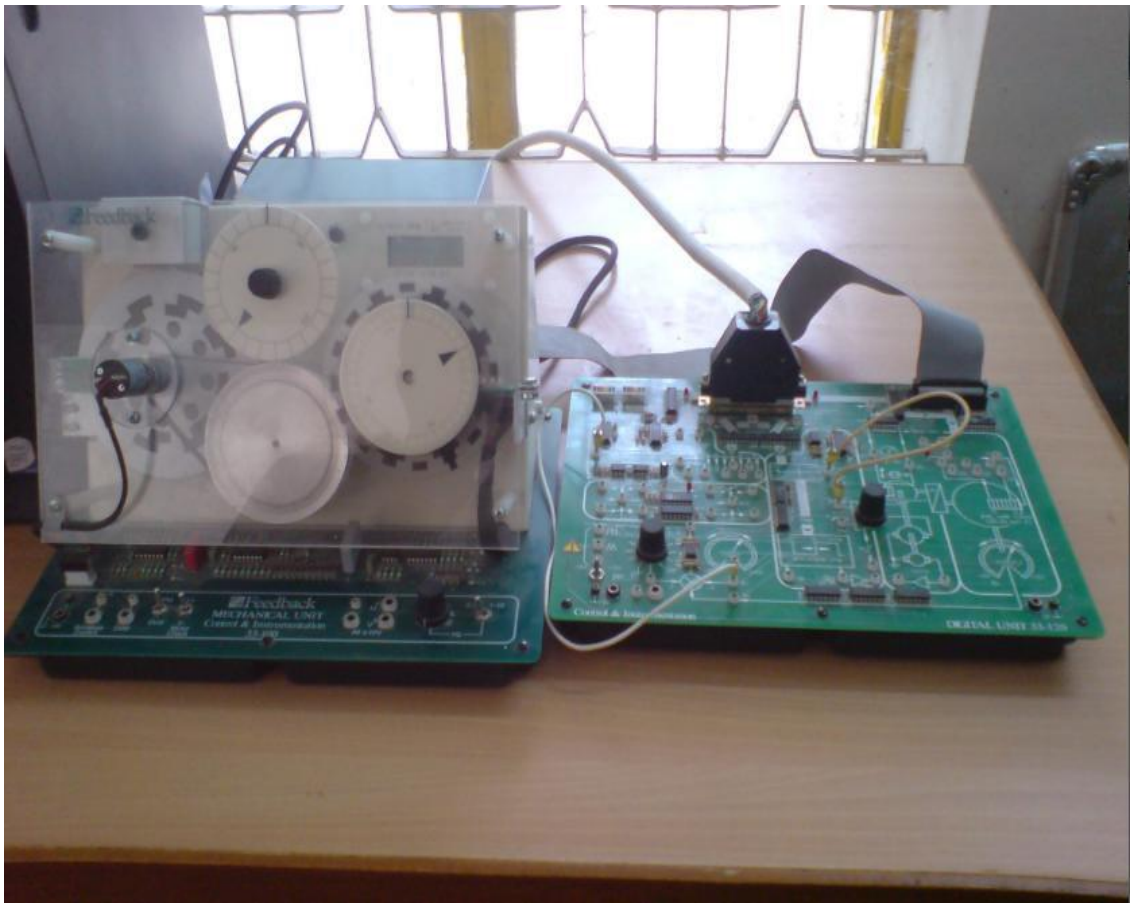

Figure 4.1 Digital unit of servo set-up

A force supply is incorporated which gives the greater part of the fundamental dc voltage supplies needed by the framework. The framework is adaptable. For simple control showing just the Mechanical and Analog units are needed. For Digital control showing just the Mechanical and Digital units are needed. These alternatives are accessible independently. In this task I obliged just mechanical Unit and Digital unit in light of the fact that these two units are just utilized within Digital servo examination.

4.3. MECHANICAL UNIT OF SERVO SET-UP

The mechanical unit comprises of an open-board design get together convey the mechanics of the framework in addition to its supporting gadgets as indicated in fig.4.2. The electromechanical segments embody dc engine, a simple tachogenerator, simple enter and yield potentiometers, outright and incremental advanced encoders and attractive brake. The supporting gadgets includes: the force intensification; a low recurrence sine, square and triangle waveform generator for testing purposes; encoder perusing hardware and LCD velocity show and DVM.The force supply for the basics mentor to this unit.[6][10]

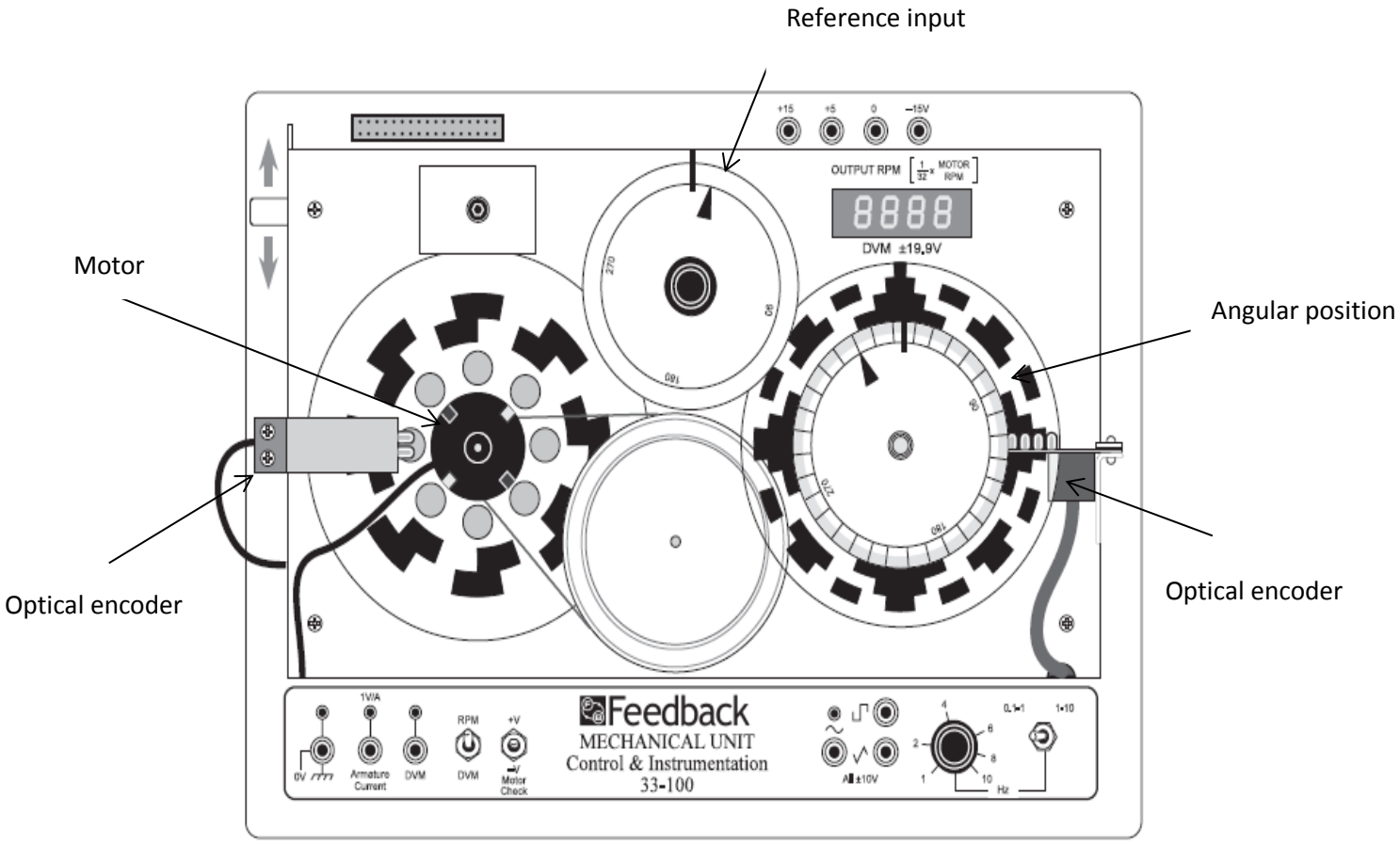

Figure 4.2 Servo Mechanical Unit 33-100

4.4. DIGITAL UNIT OF SERVO SET-UP

The Digital unit goes about as the interface between the Mechanical Unit and a PC, or perfect microcomputer as indicated if fig. 4.3.

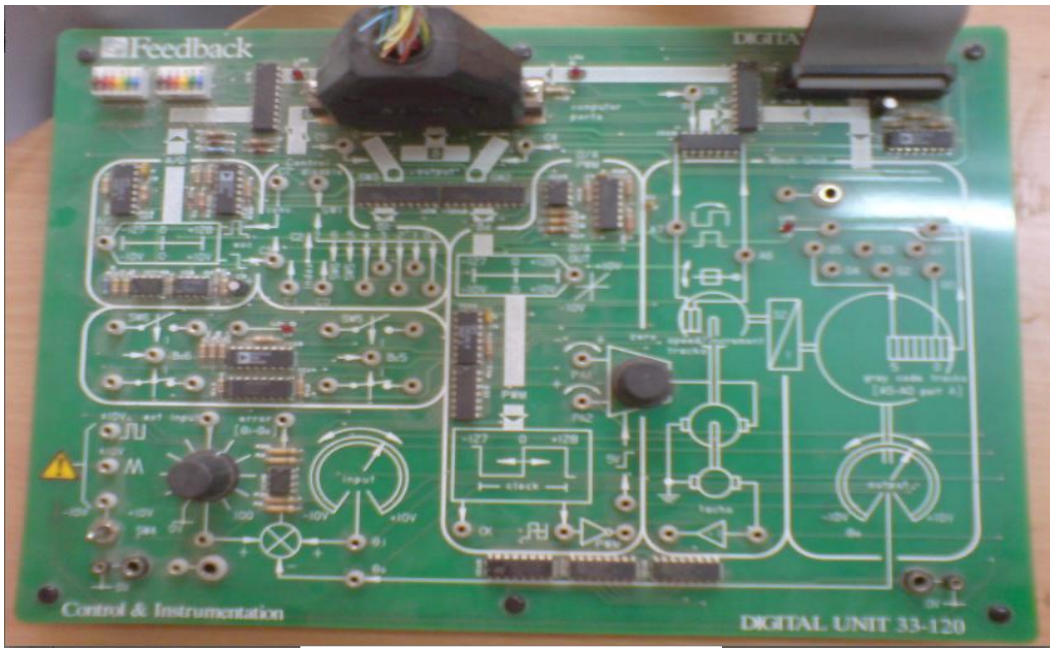

Figure 4.3 Digital Unit 33-120

Specification:

- Give access to have PC, or perfect microcomputer.
- 8-way includes and yield transports.
- Additional control lines accessible.
- ADC and DAC for liner framework operation.
- Liner or PWM motor accessible.
- LED showcase of incremental and outright encoders.
- Manual fixing with machine controlled arrangement and multiplexing.
- Switched deficiencies circulated through framework.

4.5 PID CONTROL OF DC SERVO MOTOR

Test set-up for PID controller is indicated in fig.4.4.the PID controller is intended for our wanted DC servo motor exchange capacity inferred from framework system identification tool kit more detail depiction given at chapter2 the reaction of the PID controller for our plant is discovered to be steady.[10]

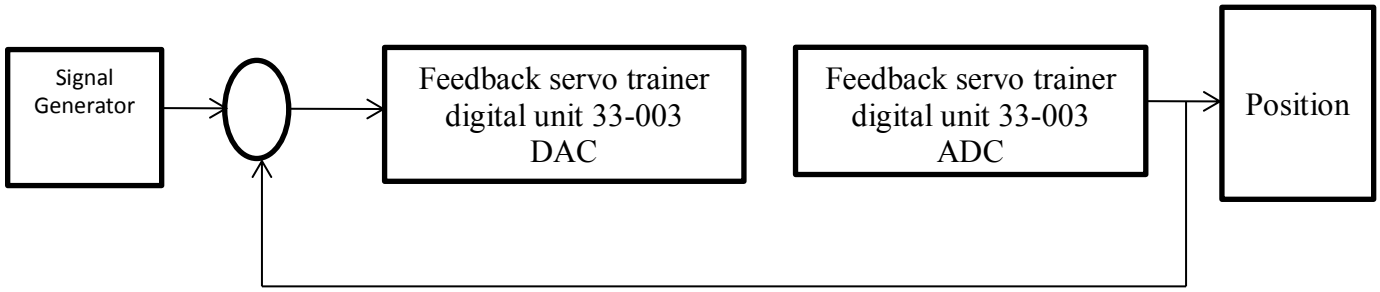

Figure 4.4. Experimental set-up for PID controller

Figure 5.5 represents the Simulink model of a general PID controller. Input to the model is a square wave of amplitude 50v and frequency of 0.05 Hz with sampling time of 0.05sec.

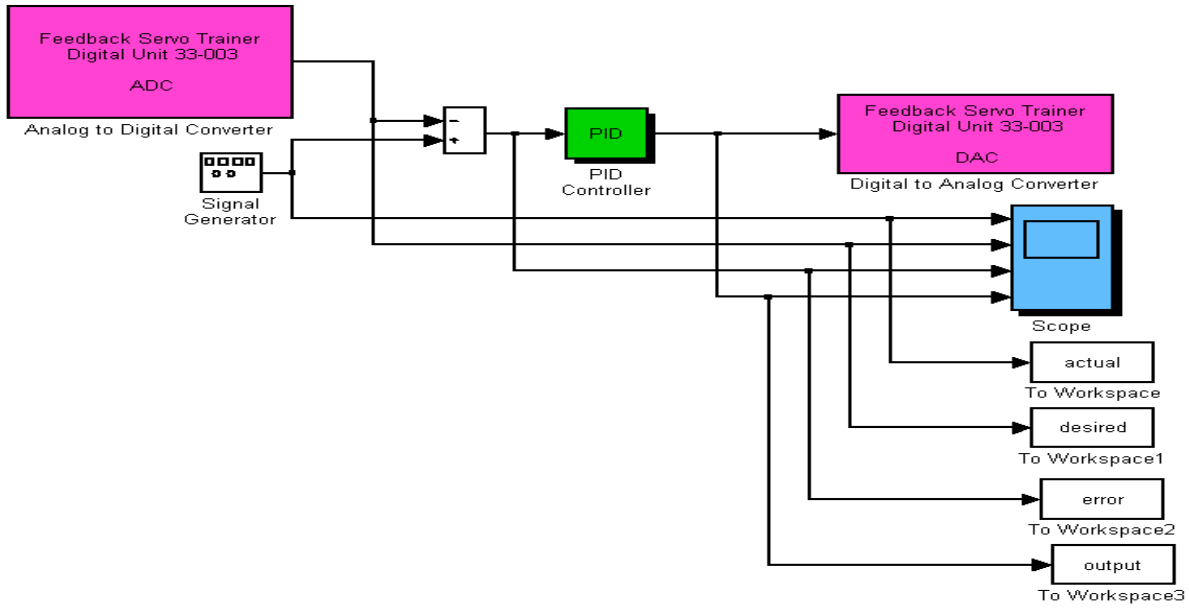

Figure.4.5.Simulink model of a general PID controller

4.5 Results:

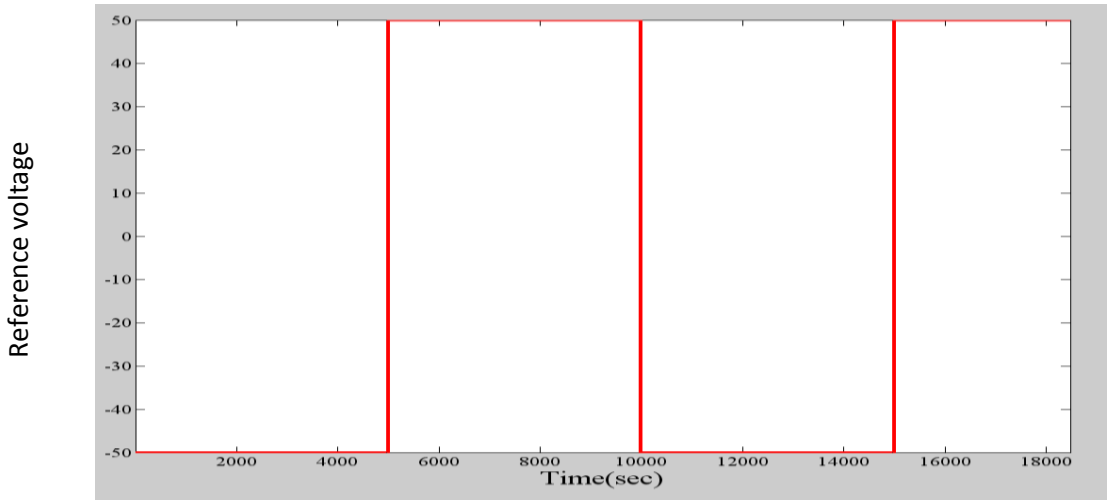

Figure 4.6.Reference voltage response of the motor

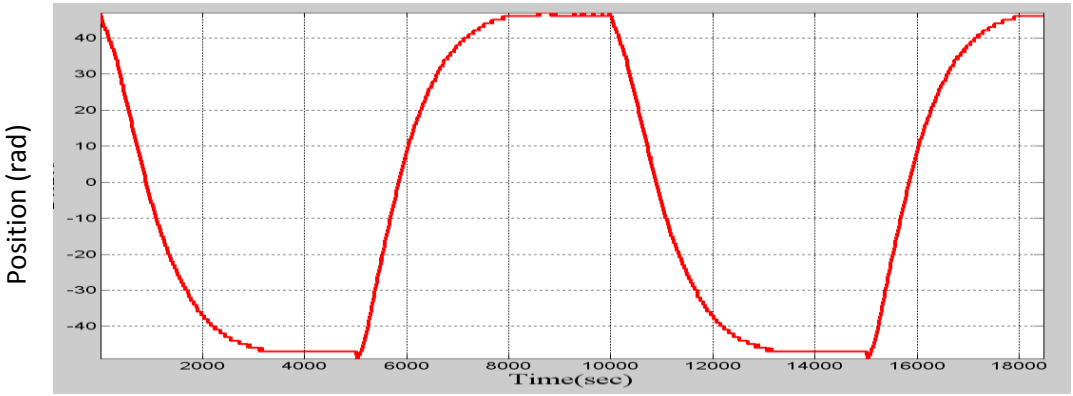

Figure 4.7. position response of the motor

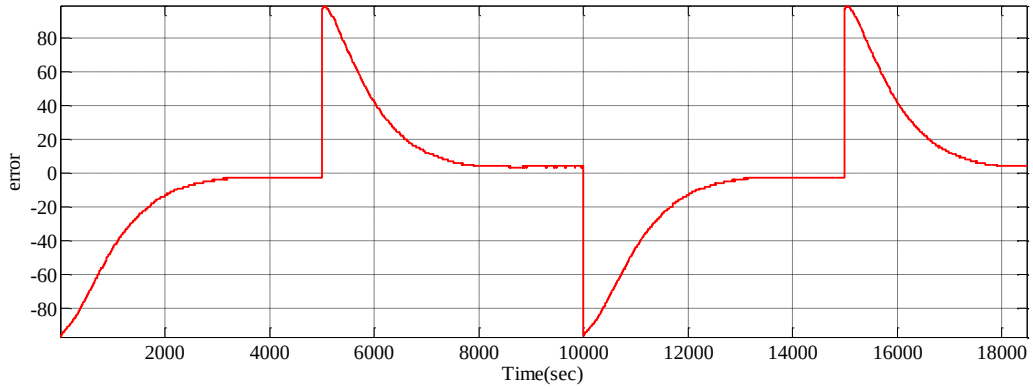

Figure 4.8 Error output of the motor

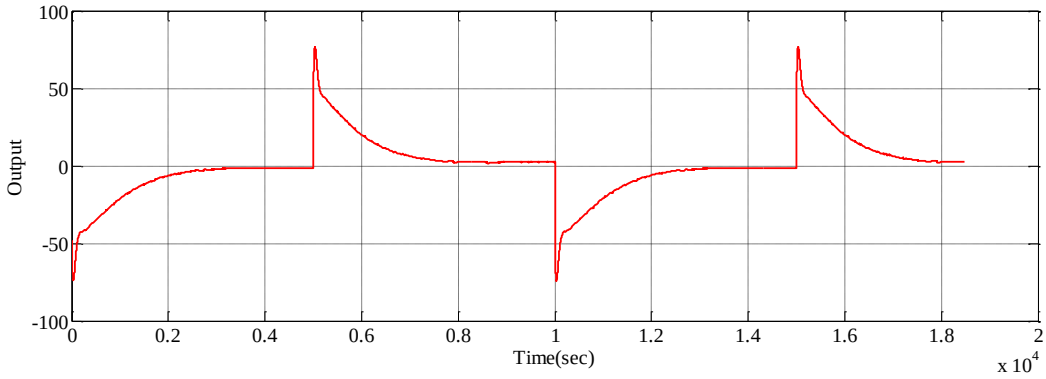

Figure4.9 Output of the PID controller

CONCLUSIONS AND FUTURE WORK

CHAPTER 4

Conclusion:

We have seen that the in PID controller the overshoot is high and setting time take more time to settle down to overcome this problem we have deign the sliding mode control by the help of sliding mode control we can reduce the overshoot as well as settling time. We conclude that the sliding mode control is more robust and gives quick reply to the system.

Scope for future work:

The Digital servo framework in which we lived up to expectations is just good with MATLAB (version 6.5).this is the real hindrance of this framework we found. Because of this contrarily issue we are not equipped to perform some development tests that are accessible in higher request version of MATLAB.

REFERENCES:

[1] Vadim I. Utkin, "*Variable structure systems with sliding modes*", IEEE Transactions on Automatic Control, vol. AC-22, pp. 212–222, April 1977.

[2] John Y. Hung, Weibing Gao and James C. Hung, "*Variable structure control: A survey*," IEEE Transactions on Industrial Electronics, vol.40, no.1, pp.2-22, February 1993.

[3] K.D. young, V.I. Utkin and U. Ozguner, "*A control Engineer's guide to sliding mode control*," IEEE Transactions on Control System Technology, vol.7, pp.328-342, 1999.

[3] Hung, J. Y., W. Gao and J. C. Hung (1993), "Variable Structure Control: A Survey," IEEE Transactions on Industrial Electronics, v.40, n.1, pp.2-22.

[4] J. J. Slotine, "*Sliding controller design for nonlinear systems*," *Int* .J**.** Contr., vol. 40, no. 2, pp. 421-434, 1984.

[5] J. Nilsson, *'Real-time control systems with delays'*, Ph.D. dissertation, Lund Institute of Technology, 1998.

[6] The feedback servo 33-120 manual, 2008.

[7] J. Eker and A. Cervin. A Matlab toolbox for real-time and control systems co-design. In Real-Time Computing Systems and Applications, 1999. RTCSA '99. Sixth International Conference on, 1999.

[8] A. Sabanovic and D. Izosimov, "*Application of Sliding modes to induction motor control*," IEEE Trans. Industiy Applications, vol. LA-17**,** no. 1, pp. 41-49, 1981.

[9] C. Edwards and S. K. Spurgeon, Sliding mode control: *Theory and Applications. Taylor and Francis,*1998.

[10] Bollepally Raju a Mtech research '*Time delay compensation schemes with application to networked control system'* at National Institute of Technology Rourkela 2009.

[11] Srinibas Bhuyan a Mtech research, '*Development and control of networked servo system'* at National Institute of technology, Rourkela 2011.

[12] Katsuhiko Ogata, Modern Control Engineering, Upper Saddle River, NJ, Prentice Hall, 2002.

[13] W.Gao and J.CHing,"*Variable Structure Control of Nonlinear System*, A new approach", IEEE Trans, Ind. Elec. Pp. 45-55, Vol.40 N 1, 1993.

[14] D.S. Lee, M.J.Youn, "*Controller design of variable structure systems with nonlinear sliding surface*," Electronics Letters, vol. 25, no. 25, pp.1715-1716, 1989.

[15] Uma maheswaraoo.ch and Y.S.Kishore babu,*'Sliding Mode Speed Control of DC Motor*' ieee conference on communication system and network technologies.2011

[16] K. K. Zhil'tsov, *Approximation Methods of Variable Structure System Design*. Moscow: Nauka, 1974 (in Russian).