ISSN: 2395 - 2180

Available online at http:// www.ijemmr.co.in

International Journal of Engineering, Management & Medical Research (IJEMMR)

VOL - 5, ISSUE - 7, JULY - 2019

ANALYSIS OF DIFFERENT SPEED CONTROLLER FOR CHOPPER FED DC MOTOR

BABITA KUMARI[1], ANURAG TAMRAKAR[2]

1. M.TECH SCHOLAR, DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING. SVN UNIVERSITY, SAGAR (M.P.) INDIA

2. HEAD, DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING. SVN UNIVERSITY, SAGAR (M.P.) INDIA

ABSTRACT:

This dissertation presents a comparative study of speed control of a separately excited DC motor by using different type of controllers. Speed of separately excited DC motor can be varied below and above the rated speed by various techniques. It can be varied above rated speed by field flux control and below rated speed by terminal voltage control .Conventional controllers are commonly being used to control the speed of the DC motors in various industrial applications. It's found to be simple, robust and highly effective when the load disturbance is small. But during high load or rapid variation of load, the fuzzy technique based controllers proves to be fast and reliable. Using chopper input voltage can be varied and thus speed can be varied. For better performance of the DC motor various kind of controller namely P-I, I-P controller are used. Proportional-Integral type controller is used to eliminate the delay and provides fast control. However, the P-I controller has some disadvantages such as: sluggish response to a sudden load change, the high starting overshoots and sensitivity to controller gains. So, the relatively new Integral Proportional (I-P) controller is proposed to overcome the disadvantages of the P-I controller .After obtaining the model of separately excited DC motor, it is simulated using MATLAB (Simulink) environment. Then fuzzy logic controller has been designed and performance has been observed. Finally a comparative study is done between all the controllers.

KEYWORDS:

CHOPPER, MATLAB, CONTROLLER, DC MOTOR.

I. INTRODUCTION

1.1 Introduction:

High performance motor drives are very much essential for industrial application. Most of the industries demand variable speed operation of motor. As synchronous motor is a constant speed motor so it is used in industries which demands constant speed operation of motor. Speed of DC motor can be varied below and above the rated speed by terminal voltage control and field flux control respectively. So DC motor is used in many applications such as steel rolling mills, electric vehicles, electric trains, electric cranes and robotic manipulators require speed controller to perform its tasks smoothly. DC motors provide good control of speed for acceleration and deceleration. Speed controller of dc motors is carried out by means of voltage control in 1981 by Ward Leonard for the first time.

Because of their simplicity, reliability, and low cost DC drives have long been used in industrial applications. Compared to AC drives system DC drives are less complex .For low horsepower ratings DC drives are normally less expensive. DC motors have been used as adjustable speed machines since long and a wide range of options have evolved for this purpose. DC motors are capable of providing starting and accelerating torque 4 times the rated torque . DC motors have long been the primary means of electric traction. They are also being used for mobile equipment like quarry, golf carts, and mining applications. DC motors are portable and well fit to special applications, like industrial equipment and machineries that are not easily run from remote power sources.

DC motor is a SISO (Single Input and Single Output) system which has torque/speed characteristics compatible with most mechanical loads. This makes a DC motor controllable over a wide range of speeds by proper adjustment of the terminal voltage. 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, GTO and IGBT have been used as electric switching devices. As the theory of DC motor speed control is extendable to other types of motors as well, hence DC motors are always a good option for advanced control algorithm.

Speed control means intentional variation in speed by applying different techniques. Natural change of speed due to load variation is not considered in speed control.

Speed of DC motor can be controlled by:

i. Varying terminal voltage

ii. Varying field flux

1.2 Different Methods For Speed Control Of Dc Motor:

i. Varying terminal voltage using Rheostatic method for low power DC motors.

ii. Use of conventional PID controllers.

iii. Neural Network Controllers.

iv. Constant power motor field weakening controller based on load-adaptive multi- input multi-output linearization technique (for high speed regimes).

v. Single phase uniform PWM AC-DC buck-boost converter with one switching device used for armature voltage control.

II. CHOPPER

2.1 Principle of Chopper Operation:

A chopper is a high speed on-off switch which converts fixed DC input voltage to a variable DC output voltage. A Chopper is considered as a DC equivalent of an AC transformer as they behave in an identical manner. Choppers are more efficient as they involve one stage conversion.

Choppers are now being used all over world for rapid transit systems. These are also used in marine hoist, trolley cars, mine haulers and forklift trucks. It is predicted that in future electric automobiles will be using choppers for their speed control and braking purpose. Chopper offer high efficiency smooth control, regeneration facility and faster response. The power semiconductor devices used for a chopper circuit can be force commutated thyristor, power BJT, IGBT, GTO and MOSFET based chopper are also used. These devices are represented by a switch. When the switch is being "off", current does not flow. Current flows through the load when switch is "on". When we switch it "on" it connect the load with source and when we put it at "off" it disconnect the load from source at a very fast speed .The on-state voltage drop of power semiconductor devices is nearly 0.5V to 2.5V across them. But for the sake of simplicity, the voltage drop across these devices is considered to be zero but practically it is not zero.

As mentioned above, a chopper is considered to be DC equivalent of AC transfer. Voltage can be step up or step down by varying the duty ratio of chopper as it is done by varying the turns ration in a transformer. from the figure we can see that during the period Ton, chopper is on and hence load voltage is equal to source voltage Vs and during the period Toff, chopper is off and hence load voltage is zero. In this way, a chopped dc voltage is produced at the load terminal

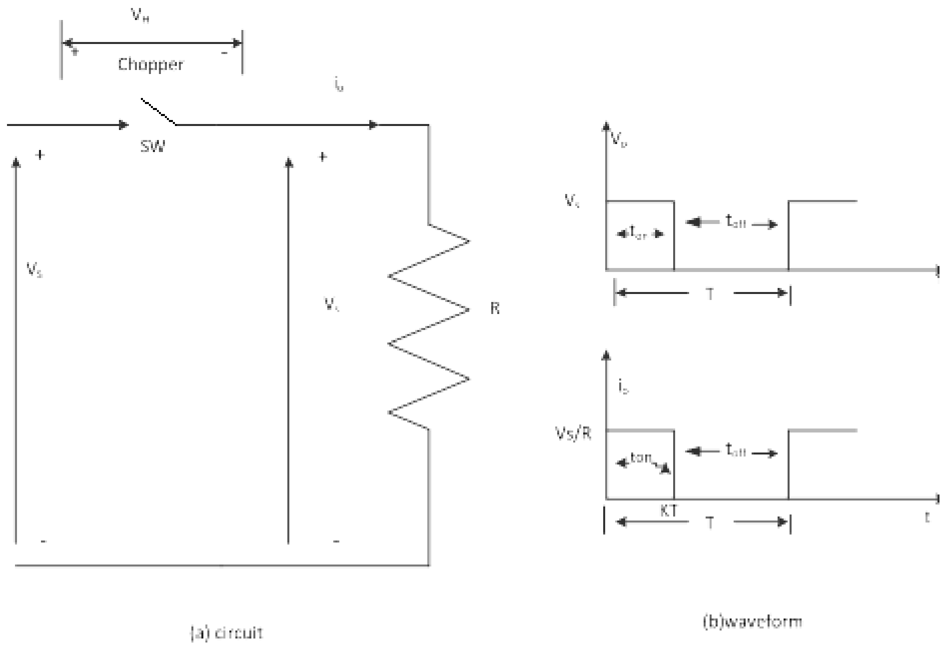

Figure 2.1: Chopper Circuit and Voltage and Current Waveform.

Average Voltage, Vo= (Ton/ (Ton+Toff)) Vs

Vo = (Ton/T)*Vs =αVs (4)

Where Ton=on-time and Toff=off-time.

T=Ton+Toff = Chopping period and α =Ton/T.

Hence the voltage can be controlled by varying duty cycle α.

2.2 Control Methods:

The average value of output voltage Vo can be controlled through changing duty cycle by opening and closing the semiconductor switch periodically. Followings are the different control strategies for varying duty cycle : 11

1. Time ratio Control (TRC)
2. Current-Limit Control.

III. SEPARATELY EXCITED DC MOTOR AND SPEED CONTROL MODELLING

3.1 Modelling Of Separately Excited Dc Motor :

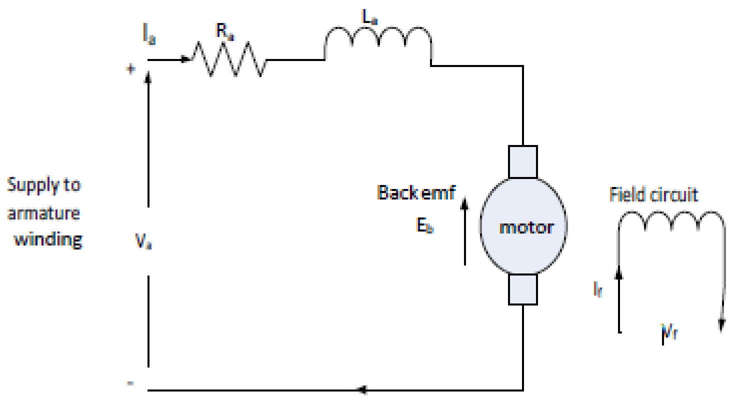

Figure 3.1: Separately Excited DC motor model.

The armature equation is shown below:

$Va = Eb + IaRa + La\,(dIa/dt)$ (5)

Where

Va is the armature voltage in volts. Eb is the motor back emf in volts.

Ia is the armature current in amperes. Ra is the armature resistance in ohms.

La is the armature inductance in Henry.

Now the torque equation can be given by:

$Td = J d\omega/dt + B\omega + TL$ (6)

Where: TL is load torque in Nm.

Td is the torque developed in Nm.

J is moment of inertia in kg/m^2.

B is friction coefficient of the motor.

ω is angular velocity in rad/sec.

Taking Back EMF Constant as Kb and Electrical toque constant as KT Equation for back emf of motor can be written as :

$Eb = Kb\,\omega$ (7)

And also, $Td = KTIa$ (8)

From motor's basic armature equation, and taking Laplace Transform on both sides of the equation, we will get:

Ia(S) = (Va – Eb)/(Ra + LaS) (9)

And from the Torque equation, we have

ω(s) = (Td - TL)/JS+B (10)

3.2 Types Of Controller:

i. P Controller(proportional)

ii. PI Controller (proportional plus integral) and IP Controller(integral plus proportional)

iii. PID Controller (proportional-integral-derivative)

iv. Fuzzy logic Controller

3.3 A Comparative Study of P-I & I-P Controller:

A comparative study of PI & IP control scheme for a dc drive has been done here. The response of both P-I and I-P the controller for a change in speed reference and load torque is discussed. A one quadrant GTO chopper is used as power conditioning unit in the experimental set up using a separately excited dc motor. Most DC motor drives are operated as closed-loop speed control system.

A simple proportional gain in the speed loop may not be sufficient to provide a precise control on the speed of drives. This may results in a high overshoot and also an undesirable steady state error in speed. Therefore some kind of compensation technique has to be employed to improve the performance of the drive. The mostly used compensation method for DC motor drive is the proportional plus integral (P-I) control.

3.3.1 Proportional-Integral (P-I) Controller:

The block diagram of the motor drive with the P-I controller has one outer speed loop and one inner current loop, as shown in Fig. 1. The speed error EN between the reference speed NR and the actual speed N of the motor is fed to the P-I controller, and the Kp and Ki are the proportional and integral gains of the P-I controller. The output of the P-I controller E1 acts as a current reference command to the motor, C1 is a simple proportional gain in the current loop and KCH is the gain of the GTO thyristor chopper. For analysis the electrical time constant can be neglected, since it is very small as compared to mechanical time constant of the motor

P-I TRANSFER FUNCTION MODEL:

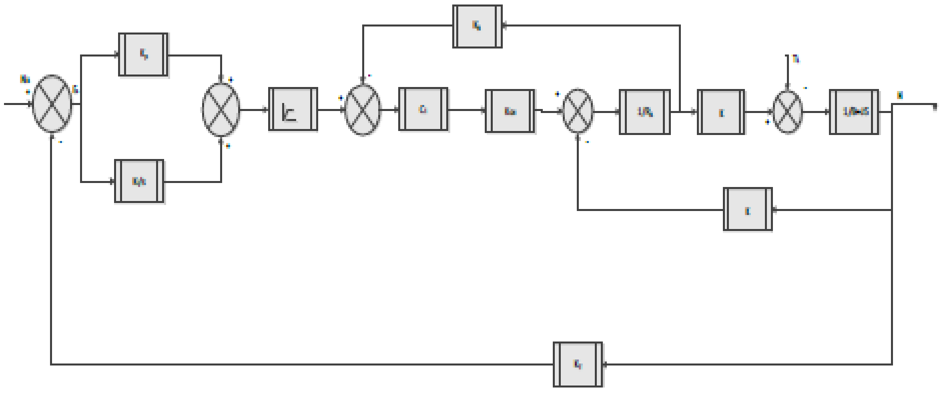

Figure 3.3: P-I Controller transfer function model

MATLAB/SIMULINK Model for P-I Controller:

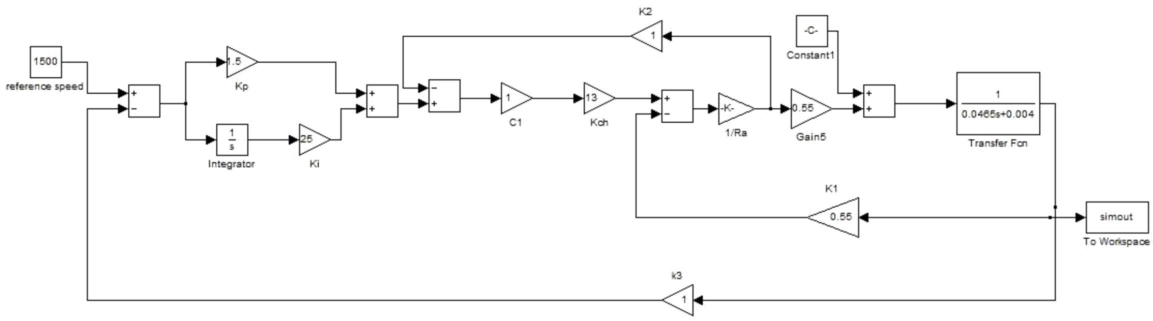

Figure.3.4: MATLAB/SIMULINK Model for P-I Controller

Simulation Results:

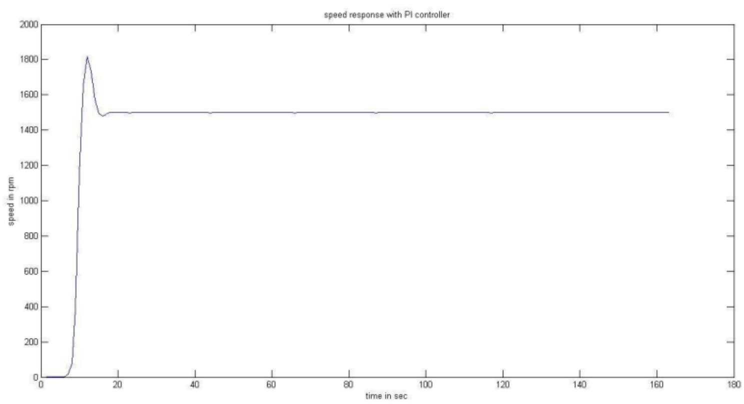

Figure 3.5:speed response with P-I controller

The P-I controller can be designed without much overshoot. However, the speed recovery from a load disturbance, in this case, deteriorates and becomes very slow, which is undesirable.

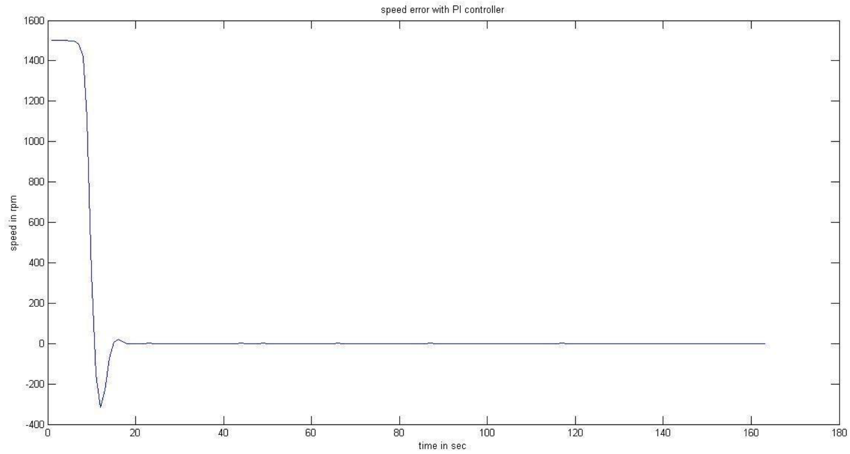

Figure 3.6: speed error with P-I controller

3.3.2 Integral Proportional (I-P) Controller:

The block diagram of motor drive with the I-P controller has the proportional term KP moved to the speed feedback path. There are three loops one speed feedback loop, one inner current loop, and one feedback loop through the proportional gain KP. The speed error EN is fed to a integrator with gain KI and the speed is feedback through a proportional gain KP.

I-P TRANSFER FUNCTION MODEL:

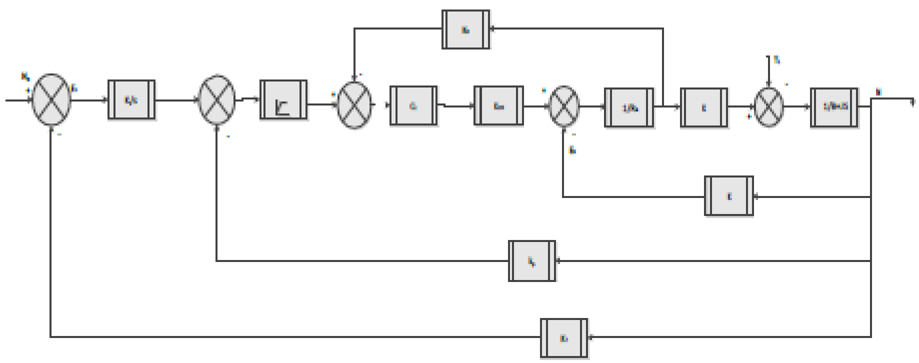

Figure 3.7: I-P transfer function model

The transfer function between the output actual speed N and the reference speed NR is given by

$$\frac{N(S)}{N_R(S)} = \frac{AK_1}{K_1S^2+K_2S+K_3}$$

When the characteristic equations for both P-I and I-P controllers are compared, zero is introduced by the P-I controller which is absent in I-P controller, and thus the overshoot with an I-P controller is expected to be very small

$$\frac{N(S)}{TL(S)} = -\frac{SK_4}{K_1S^2+K_2S+K_3}$$

MATLAB/SIMULINK model of I-P controller:

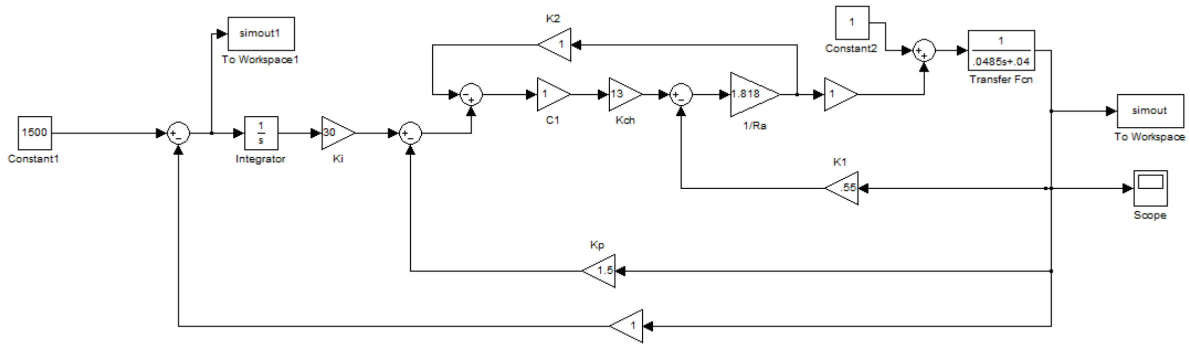

Fig.3.8:MATLAB/SIMULINK model of P-I controller

Simulation Results:

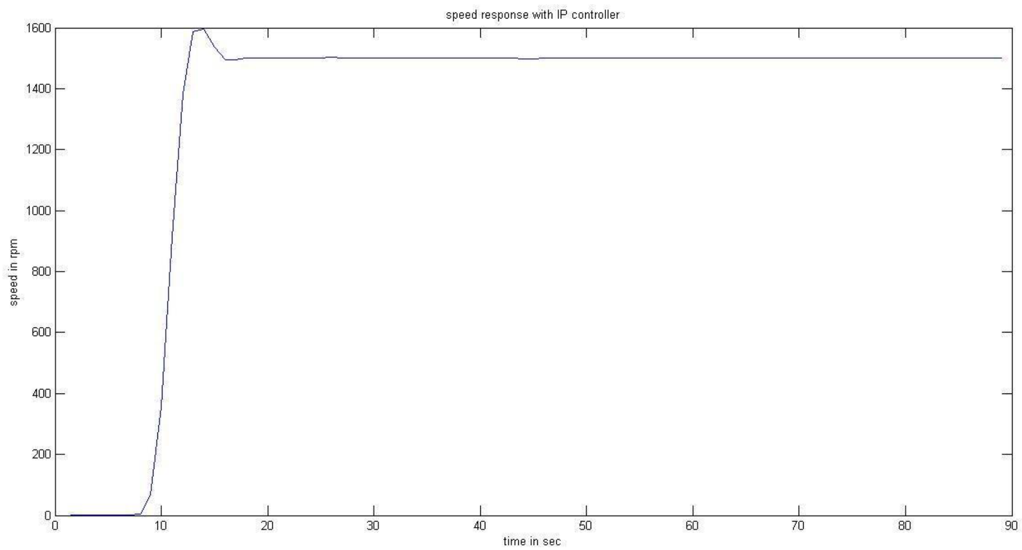

Figure 3.9: speed response with I-P controller

ISSN: 2395 - 2180 Available online at http:// www.ijemmr.co.in

International Journal of Engineering, Management & Medical Research (IJEMMR)

VOL - 5, ISSUE - 7, JULY - 2019

3.3.3 Comparison Of P-I And I-P Controller:

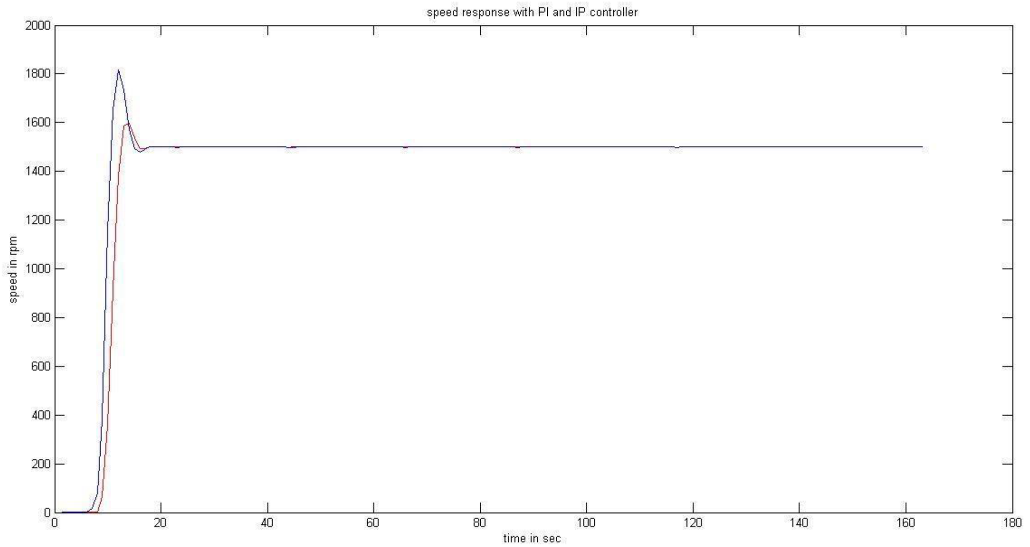

Figure 3.11: speed response with P-I & I-P controller

In case of the P-I controller an overshoot in speed can be seen , but the I-P scheme shows Negligible overshoot. It is clear from Figs.12 that the I-P controller performs slightly better than the P-I controller. The following table shows a comparison between PI and IP controller.

Table 3.1:comparison between PI and IP controller

	P-I Controller	I-P Controller
% Mp	20%	7.67%
Rise Time	10.4 sec	12 sec
Settling Time	18 sec	19 sec

IV. CONCLUSION

The background of DC Motor is studied. The study of Characteristics of separately excited DC motor is done. The steady state operation and its various torque-current, torque-speeds characteristics of DC motor are studied. First a comparison has been done between the performance of P-I and I-P controller for dc motor control by setting the reference speed to 1500 rpm. The response is shown in Figs.12. It is clear from Figs.12 that the I-P controller performs slightly better than the P-I controller. We have studied basic definition and terminology of fuzzy logic with the help of Matlab and Wikipedia and some other websites. Due to simple formulas and computational efficiency, both triangular membership functions has been used to design fuzzy industrial controllers especially in real-time implementation. The speed of a separately excited DC Motor has been successfully controlled by using fuzzy logic controller technique. The performance of fuzzy controller is compared by setting the reference speed to 1500 rpm from the initial condition. The performance of fuzzy controller is also tested by applying a large step change in the load disturbance at time 6 sec. It has been found that fuzzy logic controller performs in a better way than the other conventional controllers with less overshoot and no oscillations. Graph for the speed response of separately excited DC Motor using fuzzy logic controller is compare with graph for the speed response of separately excited DC Motor without fuzzy logic controller.

REFERENCES:

[1] M. I. Jahmeerbacus, M. K. Oolun, C. Bhurtun and K. M. S. Soyjaudah, "Speed-Sensor less Control of converter-fed Dc Motor", In Africon.IEEE'99, pp.453-456, 1999.

[2] J. Nie, and T.H. Lee, (1997). Self-organizing rule-base control of multivariable nonlinear servomechanisms, Fuzzy set and systems 91: 285-304.

[3] D.A. Likens and S.B. Hasnain. "Self-organizing Adaptive Fuzzy Controller." Fuzzzy set and systems, Vol. 80,1996, pp. 295-313.

[4] G .K Dubey, Fundamentals of Electrical Drives. New Delhi, Narosa Publishing House, 2009.

[5] Li-Xim Wang. A Course in Fuzzy System and Control. Prentice-Hall International, Inc. 1997.

[6] E. H. Mamdani "Applications of Fuzzy Algorithm for simple Dynamic Plant." Proceeding IEEE., Vol.121, No.12, 1974. pp. 1585-1588.

[7] P.K. Nandam, and P.C. Sen, "A comparative study of proportional integral(P-I) and integral-proportional (I-P) controllers for dc motor drives," Int. Jour. of Control, Vol. 44, pp. 283-297, 1986.

[8] Gilberto C.D. Sousa, and Bimal K. Bose, "A fuzzy set theory based control of phase- controlled converter dc machine drive", IEEE Trans. Industry Applications,Vol. 30, No.1, pp. 34-43, 1994.

[9] Zadeh, L. A. et al. 1996 Fuzzy Sets, Fuzzy Logic, Fuzzy Systems, World Scientific Press, ISBN 9810224214.

[10] Yodyium Tipsuwan and Mo-Yuen Chow, "Fuzzy Logic microcontroller implementation for DC motor speed control", IEEE Transactions on Power Electronics, V0l.11, No.3, June 1999, pp 1271-1276.

[11] V.S.C. Raviraj and P.C. Sen, "Comparative Study of Proportional- Integral, Sliding Mode, and Fuzzy Logic Controllers for Power Converters", IEEE Trans. on Industry Application, vol.33, no. 2, Mar/Apr 1997 pp.518- 524.