ISSN: 2319-5967
ISO 9001:2008 Certified
International Journal of Engineering Science and Innovative Technology (IJESIT)
Volume 2, Issue 2, March 2013

Performance Analysis of Fuzzy based DC Motor Drive

Astha Tiwari, Dr. S. P. Dubey
M.E. (Power Electronics) RCET, Bhilai, Professor & Dean RCET, Bhilai

Abstract- This paper presents a simulation of speed control of a DC motor drive using fuzzy logic control at MATLAB environment. Separately excited DC motor is used and armature voltage control method is applied. Required control voltage based on motor speed error (e) and it changes (ce). The performance of DC motor drives system was evaluated through digital simulation using simulink toolbox of MATLAB. DC chopper is used as a diver in this work to change the average value of load voltage applied from a fixed DC source. To control average output voltage, pulse width modulation (PWM) technique is used. Fuzzy logic is used for defining membership function and rule for FLC. Fuzzy logic controller is able to cope with system uncertainty which is the disadvantage of traditional controller. Simulation result show that proposed controller gains optimal performance and wide range of speed control is possible by means of fuzzy logic controller.

Index Terms: **DC Motor, Fuzzy Logic, Speed Control.**

I. INTRODUCTION

DC motors are widely used having good starting and breaking performance in such technologies as electric power drive automatic control system, such as, rolling mills mining machines and mine hoist machines. Because of their high reliabilities, flexibilities and low costs, DC motors are widely used in industrial applications, robot manipulators and home appliances where speed and position control of motor are required [1]. We are using armature voltage method, in the armature voltage control method, the voltage applied to the armature circuit; Va is varied without changing the voltage applied to the field circuit of the motor. Therefore, the motor must be separately excited to use armature voltage control. Because of the flexible control characteristics, separately excited d.c. motors or permanent magnet field d.c. motors are used in servo applications. In the past, the series motor was mainly used in traction. Presently, the separately exited motor is also employed in traction. The high starting torque was the main reason for using the series motor. However, the series motor has a number of limitations. The field of series motor cannot be easily controlled by static means. If field control is not employed, the series motor must be designed with its base speed equal to the highest desired speed of the drive. The higher base speeds are obtained using fewer terns in the field windings. However, this reduces the torque per ampere at zero and the low speed. Further, there are a number of problems with regenerative braking of series motor. On the other hand, regenerative braking of a separately exited motor is fairly simple and can be carried out down to very low speed. Because of the limitations of series motor, separately exited motors are now preferred even for traction applications. DC choppers used as a driver in this work change the average value of load voltage applied from a fixed DC source by switching a power switch such as thyristor, BJT.

II. DRAWBACK OF CONVENTIONAL CONTROL METHOD

The process equipment may not be available for experimentation, the procedure would usually be very costly, and for a large number of input values it is impractical to measure the output and interpolation between measured outputs would be required. The disadvantages are several: Linear techniques are valuable because they provide good insight. Besides, there exists no general theory for the analytic solution of nonlinear differential equations and consequently no comprehensive analysis tools for nonlinear dynamic systems. Two main problems encountered in motor control are the time-varying nature of motor parameters under operating conditions and existence of noise in system loop. Fuzzy control system is able to cope with system uncertainty. Fuzzy logic controller is chosen as a controller for this project because it consist several advantages. It provides parallel or distributed control, linguistic control, robust control, and It is suitable for application such as the speed control of dc motor which has non linearity. In this study FLC system design for operating at fixed speed under different load conditions are simulated at MATLAB/ Simulink environment.

III. MOTOR MODEL

The resistance of the field winding and its inductance of the motor used in this study are represented by R_f and L_f, respectively. The resistance of the armature and its inductance, Ra and La are respectively in dynamic model. The fixed voltage V_f is applied to the field and the field current settles down to a constant value.

A linear model of a simple DC motor consists of a mechanical equation and electrical equation as determined in the following equations:

$$J_m \frac{d\omega_m}{dt} = K_m.\emptyset.I_a - b.\omega_m - M_{load} \qquad (1)$$

$$L_a \frac{dI_a}{dt} = V_a - R_a.I_a - K_b.\emptyset.\omega_m \qquad (2)$$

The dynamic model of the system is formed using these differential equations and Matlab Simulink blocks as shown in Fig. 1,

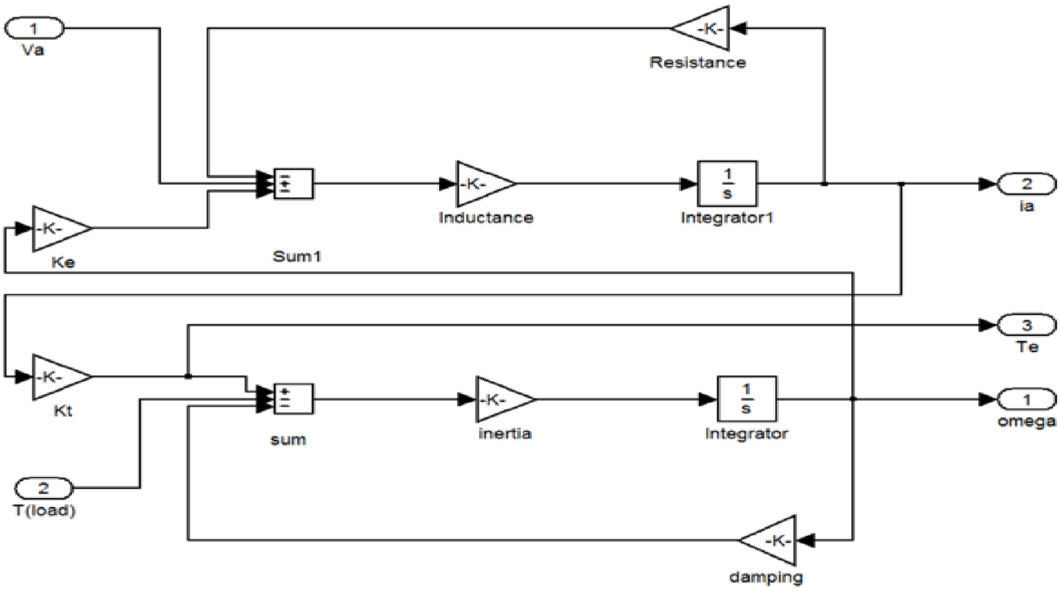

Fig. 1 Matlab/Simulink model of DC motor

IV. FUZZY LOGIC CONTROLLER (FLC)

Description and Design- Fuzzy set theory which led to a new control method called Fuzzy Control which is able to cope with system uncertainties. A fuzzy set is represented by a membership function defined on the universe of discourse [2]. Fuzzy control can be successfully applied to control nonlinear complex systems using an operator experiences or control engineering knowledge without any mathematical model of the plant. Fuzzy control provides a formal methodology for representing, manipulating, and implementing a human's heuristic knowledge about how to control a system [3], [4]. Fig. 2 shows a basic FLC structure.

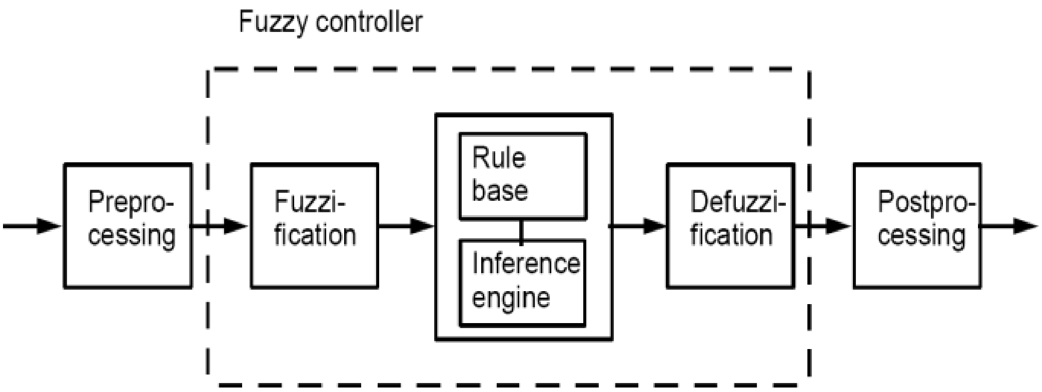

Fig. 2 Process blocks for a fuzzy controller

In addition to this, if there is not enough knowledge about control process, FLC may not give satisfactory results [5].

FLC uses error (e) and change of error (ce) for linguistic variables which are generated from the control rules. Equation (3) determines required system equations. The output variable is the change in control variable ($c\alpha$) of motor driver. $c\alpha$ is integrated to achieve desired alpha value. Here a is a angular value determining duty cycle of DC-DC converter designed. In this study FLC is designed to minimise the speed error [6].

$$e(k) = [wr(k) - wa(k)] \times K1_E$$

$$ce(k) = [e(k) - e(k-1)] \times K2_{CE} \qquad (3)$$

$$c\alpha(k) = [\alpha(k) - \alpha(k-1)] \times K3_{c\alpha}$$

Here $K1_E$, $K2_{cE}$ and are each gain coefficients and k is a time index.

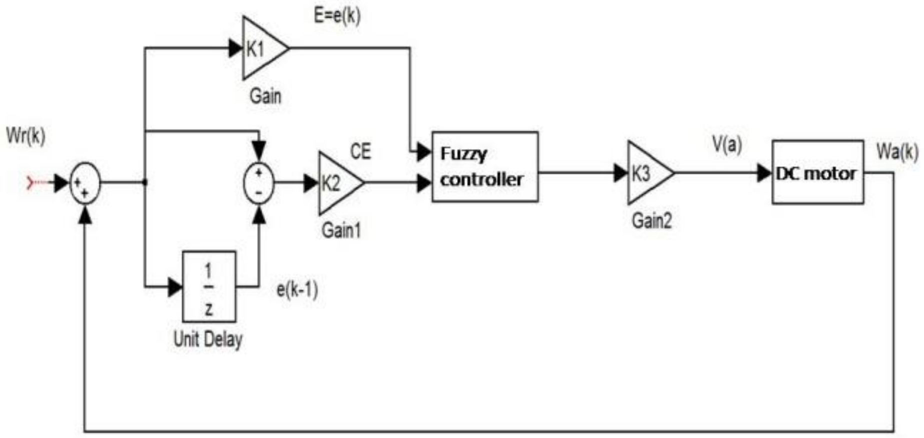

Fig. 3 Block diagram of DC motor control

The error (e) approaches to its smallest value when the motor speed is attained to nominal value. If we reverse this value, the error interval can be defined between -200 and 200.

When the simulation of system was performed at unloaded condition. The change of error can be seen between -1.6 and 0.1 intervals. Then this change was optimized between -1 and 1 in the membership functions.

In order to optimize the speed control, the intervals of membership functions are found after some manual changes as follows:

$$e\omega: -150\ and + 150\frac{rad}{s}$$

$$ce\omega: -1\ and + 1\frac{rad}{s}/s$$

$$c\alpha = 150.10^3\ and - 150.10^3$$

The gain values are determined for these intervals in simulation model as

$$KI_E = \frac{I}{150}, K2_{CE} = 1\ and\ K3_{Ca} = 150 \times 10^3$$

Defining membership functions and rules:

System speed comes to reference value by means of the defined rules. Here we are using forty nine rules:

S.No.	Rule Details
1.	If (e is NL) and (ce is NL) then (cu is PL) (1)
2.	If (e is NL) and (ce is NM) then (cu is PL) (1)
3.	If (e is NL) and (ce is NS) then (cu is PL) (1)
4.	If (e is NL) and (ce is Z) then (cu is PL) (1)
5.	If (e is NL) and (ce is PS) then (cu is NM) (1)
6.	If (e is NL) and (ce is PM) then (cu is Z) (1)

7.	If (e is NL) and (ce is PL) then (cu is Z) (1)
8.	If (e is NM) and (ce is NL) then (cu is PL) (1)
9.	If (e is NM) and (ce is NM) then (cu is PL) (1)
10.	If (e is NM) and (ce is NS) then (cu is PL) (1)
11.	If (e is NM) and (ce is Z) then (cu is PM) (1)
12.	If (e is NM) and (ce is PS) then (cu is PS) (1)
13.	If (e is NM) and (ce is PM) then (cu is Z) (1)
14.	If (e is NM) and (ce is PL) then (cu is Z) (1)
15.	If (e is NS) and (ce is NL) then (cu is PL) (1)
16.	If (e is NS) and (ce is NM) then (cu is PM) (1)
17.	If (e is NS) and (ce is NS) then (cu is PS) (1)
18.	If (e is NS) and (ce is Z) then (cu is PS) (1)
19.	If (e is NS) and (ce is PS) then (cu is PS) (1)
20.	If (e is NS) and (ce is PM) then (cu is Z) (1)
21.	If (e is NS) and (ce is PL) then (cu is Z) (1)
22.	If (e is Z) and (ce is NL) then (cu is PL) (1)
23.	If (e is Z) and (ce is NM) then (cu is PM) (1)
24.	If (e is Z) and (ce is NS) then (cu is PS) (1)
25.	If (e is Z) and (ce is Z) then (cu is Z) (1)
26.	If (e is Z) and (ce is PS) then (cu is NS) (1)
27.	If (e is Z) and (ce is PM) then (cu is NM) (1)
28.	If (e is Z) and (ce is PL) then (cu is NL) (1)
29.	If (e is PS) and (ce is NL) then (cu is Z) (1)
30.	If (e is PS) and (ce is NM) then (cu is Z) (1)
31.	If (e is PS) and (ce is NS) then (cu is NM) (1)
32.	If (e is PS) and (ce is Z) then (cu is NS) (1)
33.	If (e is PS) and (ce is PS) then (cu is NS) (1)
34.	If (e is PS) and (ce is PM) then (cu is NM) (1)
35.	If (e is PS) and (ce is PL) then (cu is NL) (1)
36.	If (e is PM) and (ce is NL) then (cu is Z) (1)
37.	If (e is PM) and (ce is NM) then (cu is Z) (1)
38.	If (e is PM) and (ce is NS) then (cu is NS) (1)
39.	If (e is PM) and (ce is Z) then (cu is NM) (1)
40.	If (e is PM) and (ce is PS) then (cu is NL) (1)
41.	If (e is PM) and (ce is PM) then (cu is NL) (1)
42.	If (e is PM) and (ce is PL) then (cu is NL) (1)
43.	If (e is PL) and (ce is NL) then (cu is Z) (1)
44.	If (e is PL) and (ce is NM) then (cu is Z) (1)
45.	If (e is PL) and (ce is NS) then (cu is NM) (1)

46.	If (e is PL) and (ce is Z) then (cu is NL) (1)
47.	If (e is PL) and (ce is PS) then (cu is NL) (1)
48.	If (e is PL) and (ce is PM) then (cu is NL) (1)
49.	If (e is PL) and (ce is PL) then (cu is NL) (1)

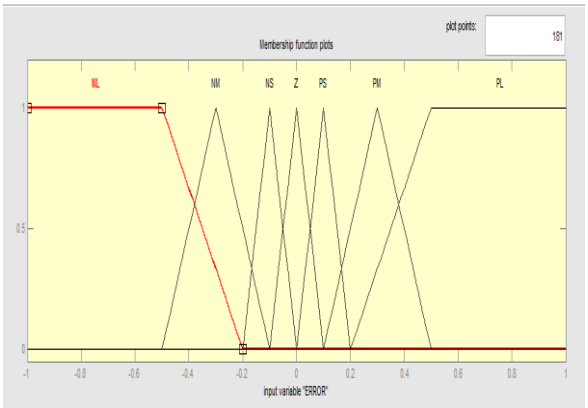

Fig. 4 Membership function of input variable error

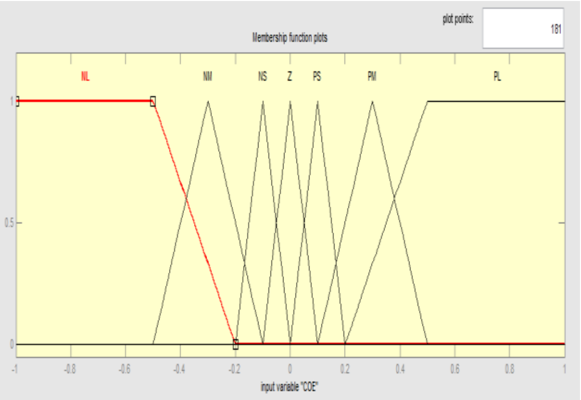

Fig. 5 Membership function of input variable change of error

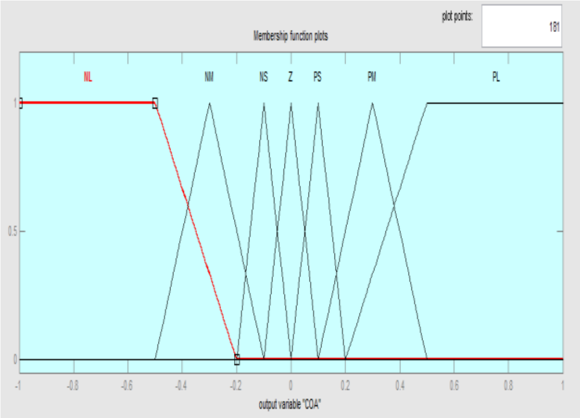

Fig.6 Membership function of output variable change of alpha

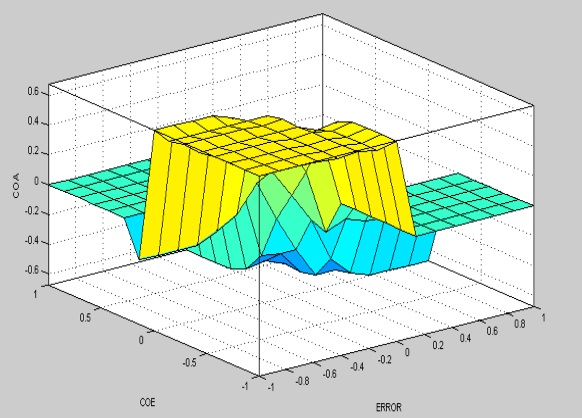

Fig. 7 Surface view from surface viewer

To be calculated FLC output value, the inputs and outputs must be converted from 'crisp' value into linguistic form. Fuzzy membership functions are used to perform this conversion [7]. In this paper, all membership functions are defined between -1 and 1 interval by means of input scaling factors KI_E and $K2_{CE}$ and output scaling factor $K3_{C\alpha}$. Thus, since simple numbers are now processed in controller after scaling, fuzzy computation is performed in a shorter time. The linguistic terms for input and output values are represented by seven membership functions as shown in Fig. 4, 5 and 6.

V. DRIVER CIRCUIT AND MODELLING

The average value of load voltage applied from a fixed DC source by switching a power switch such as thyristor, BJT. With wide usage ranges in power electronic, separately excited and serial DC motor speed control can be mentioned as the most important application area of DC choppers [8].

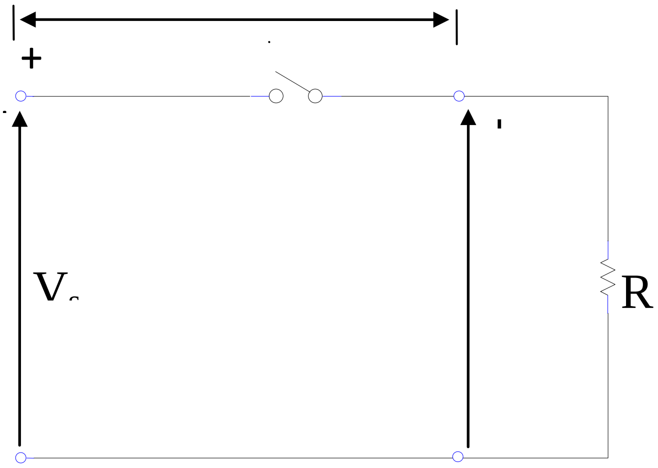

Fig. 8 operating principle and output waveform of driver

Using Fig. 8, the average output voltage can be calculated as

*Hold t_{off} fixed and change t_{on} (frequency modulation)

*Hold period (t_{on}+ t_{off}) fmed and change t_{off} / t_{on} rate (pulse width modulation)

*Change t_{off} and t_{on} separately. (Combination of first and second method)

$$V_{do} = \frac{t_{on}}{t_{on}+t_{off}}V$$

Where V is the DC source voltage. V_{do} can be controlled using three methods :

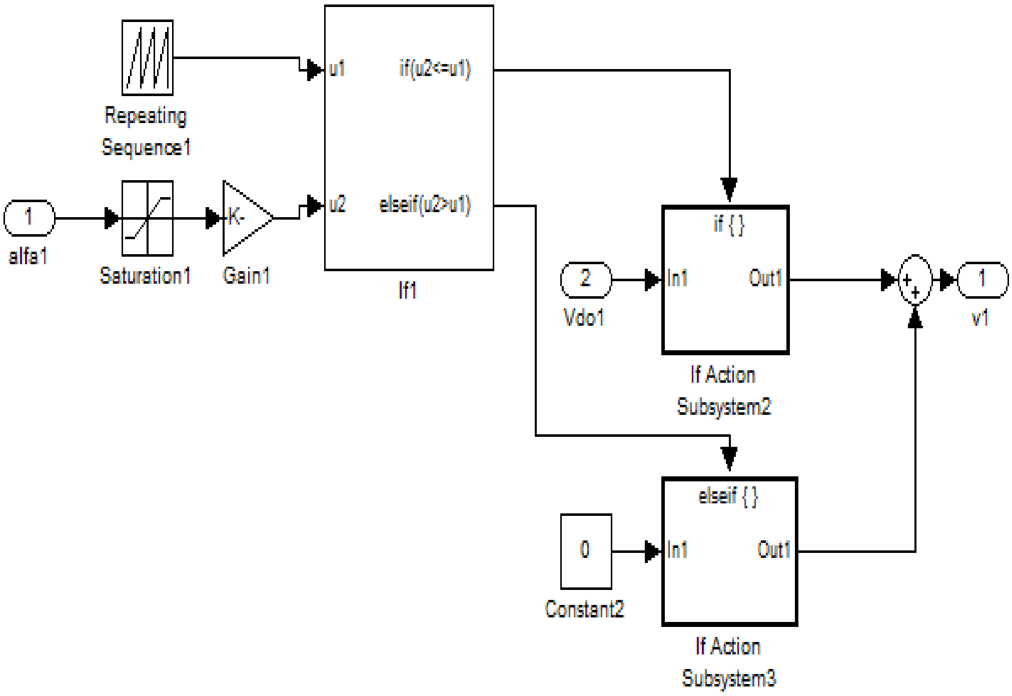

Fig. 9 DC chopper model

DC chopper model used in simulation model is shown in Fig.9. To control average output voltage, Vdo, pulse width modulation (PWM) technique is used.

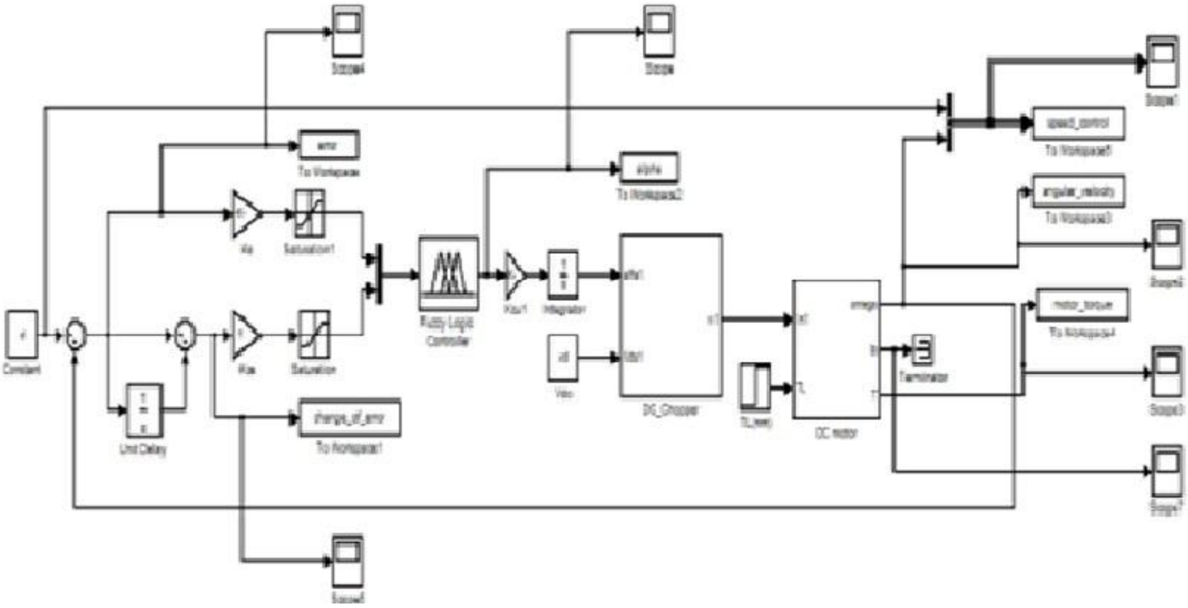

Fig: 10 Fuzzy logic control simulink model

VI. RESULT AND ANALYSIS

Simulink model of fuzzy logic speed control of DC motor is shown in Fig 10. The simulink model was evaluated for the wave form of angular velocity, current, torque, error and change of error, when 10Nm load was applied to dc motor at 0.4 s. The wave forms are presented below. Fig 11 is simulation result of angular velocity. Sudden change in load is applied to the motor from No load to 10 Nm load at t = 0.4 s. At t = 0.4s, when load is applied, wave form is distorted for few second or there is fluctuation in speed for few second and at time t = 0.43 s, motor again attained to nominal speed 200rad/s . Fig.12 is simulation result of current. at the starting time current increases because of friction loss after a few seconds current will become constant. When 10 Nm load is applied at t = 0.4 s, current will again increase and after some time it will be constant. Fig.13 is simulation result of torque .Torque has also the same changes as in current. It increase at starting time and will become constant. When 10 Nm load is applied at t = 0.4 s it increase again and will become constant in few seconds. Fig 14 is simulation result of fuzzy controller input error. The error (e) approaches to its smallest value when motor speed is attained to nominal value. A small distortion in waveform is found, when 10 Nm load is applied at t = 0.4 s. Fig.15 is simulation result of change of error. The change of error (coe) approaches to its smallest value when motor speed is attained to nominal value. A small distortion in waveform is found, when 10 Nm load is applied at t = 0.4 s.

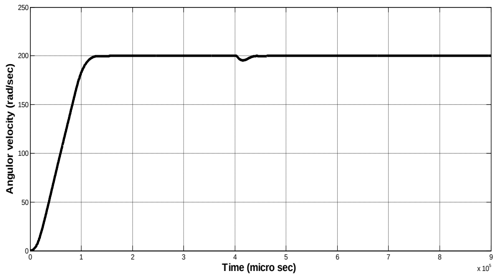

Fig. 11 Simulation result of angular velocity when 10 Nm load is applied to motor at 0.4 s (TL =10Nm, t=0.4 s

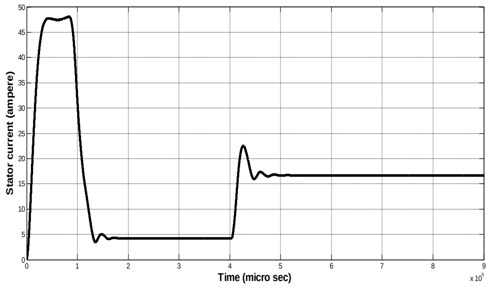

Fig. 12 Simulation result of current when 10 Nm load is applied to motor at 0.4 s (TL =10 Nm, t=0.4 s)

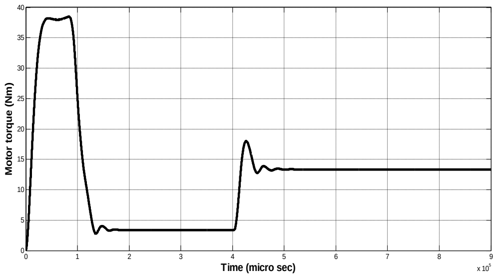

Fig. 13 Simulation result of motor torque when 10 Nm load is applied to motor at 0.4 s (TL =10 Nm ,t=0.4 s)

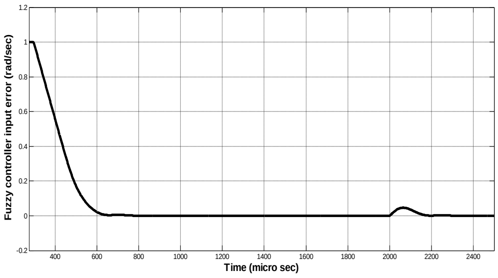

Fig. 14 Simulation result of error when 10 Nm load is applied to motor at 0.4 s (TL =10 Nm, t=0.4 s)

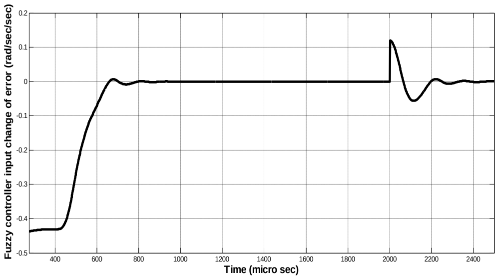

Fig. 15 Simulation result of change of error when 10 Nm load is applied to motor at 0.4 s (TL =10 Nm, t=0.4 s)

VII. CONCLUSION

Separately excited DC motor speed control has been performed in MATLAB simulink environment. DC motor speed has been controlled with FLC and also designed a circuit model as a drives to get more reasonable results from the simulink results. It is inferred that wide range of speed control is possible by means of FLC. It is shown there that is fast system control response even when the load changes. These results show the proposed controller gains optimal performance. This system overcomes sensitiveness to variation of speed with drive system of DC motor, which is disadvantage of conventional control system.

REFERENCES

[1] Pavol F., and Daniela P., “A simple fuzzy controller structure” Acta Electrotechnica et Informatics. 2005, 4(50, 1-4.

[2] Assilian, S. and Mamdani, E.H., An Experiment in Linguistic Synthesis with a Fuzzy Logic Controller. International Journal of Man-Machine Studies, 1974, 7(1), 1-13.

[3] Kickert, W. J. M. and van Nauta Lemke, H. R., Application of a Fuzzy Controller in a Warm Water Plant. Automatic, 1976, 12(4), 301-308,.

[4] Zadeh, L. A., Fuzzy Sets. Information and Control. 1965, 8, 338-353.

[5] Tipsuwan, Y., Chow, Y., “Fuzzy Logic Microcontroller Implementation for DC Motor Speed Control”. IEEE. 1999.

[6] Jantzen, J., Foundations of Fuzzy Controller, WS: John Wiley & Sons, Ltd., 2007.

[7] Manafeddin N. and Onur B. “DC motor position control using fuzzy proportional-derivative controllers with different defuzzification methods.” TJFS: Turkish Journal of Fuzzy Systems (eISSN: 1309–1190) An Official Journal of Turkish Fuzzy Systems Association 2010. 1(1), 36-54.

[8] D’Azzo J. J. and C. H. Houpis, “Linear control system analysis and design,” McGraw-Hill, New York, 1995.

[9] Chapman S. J., “Electric machinery fundamentals,” 3rd ed., WCB/McGraw-Hill, New York, 1998.

[10] Herrera Espinosa J., V M Salazar Del Moral and A R Portillo Méndez, “Simulation of a Takagi -Sugeno Fuzzy Speed/Frequency Controller for a DC Motor-Alternator with Current Loop” Journal of Vectorial Relativity JVR 4 .2009, 66-76.