Performance Analysis of Speed Control of Separately Excited DC motor using Fuzzy logic Controller and Conventional PID

Prerna[1], Mr. Devender Kumar[2]

[1]M. tech Student, R.I.E.M., Rohtak, Haryana
[2]Assistant Professor, Dept. of EEE, R.I.E.M., Rohtak, Haryana

ABSTRACT

Development historically stems from economic growth via industrialization Today's industries totally depend on control systems. Accurate control is critical to each and every process in industry. DC motors have been popular in the industry control area because DC motors have high starting torque characteristics, high response performance, reliability, flexibility and low cost. DC motors are used where speed and position control required. To control the speed of DC motor controllers are required. The control systems suffer from many problems like undesirable overshoot, longer settling time, vibrations and stability while going from one state to another state. PID controllers are used in process control industry but PID controllers do not work satisfactorily for nonlinear systems. Real world systems are linear as well as nonlinear. To deal with nonlinear systems intelligent control approaches are adopted i.e. knowledge based expert system, Fuzzy Logic and neural networks. Here to meet the control problems, Fuzzy Logic approach has been adopted. Fuzzy Logic approach gives satisfactory result than conventional controllers, they cover wide range of operating conditions and can also operate with noise and disturbances of a nature.

Key words: DC Motor, PID Controller, FLC (Fuzzy Logic Controller)

INTRODUCTION

Due to high reliabilities, flexibilities and low costs, DC motor is widely used in industrial application, home appliances, toys, lifts, and robot manipulators where position and speed control of motor are required. Accurate control is critical to every process that leads to various types of controllers which are being widely used in industries. All types of control systems suffering from the problem i.e. undesirable overshoot, longer settling times, vibrations and stability while going from one state to another state. In real world, systems are nonlinear whose accurate modeling is difficult, costly and even impossible. In most cases conventional PID controllers do not give best results for nonlinear systems.
DC motor control is riper than other kind of motors. Advanced control techniques needed to overcome these difficulties and minimize the noise effect. There are three basic approaches to intelligent control: Knowledge based expert systems, fuzzy logic and neural networks. These three approaches are very interesting and promising areas of research and development.

Our main research area is Fuzzy Logic approach. Fuzzy Logic Controllers has been successfully applied to large no. of control actions. Control and analysis of nonlinear, complex and time varying system is a challenging task using conventional techniques due to uncertainties. The most commonly used controller is the PID controller which requires a typical mathematical model for the system. A Fuzzy Logic Controller provides an alternative to the PID controller.

Literature Review

Hussein F. Silliman et.al [1] they used an incremental fuzzy logic (IFL) rule based controller to enhance the performance of D.C. motor drive speed regulation, with smooth starting and acceleration for separately excited or permanent magnet D.C. motor drives. This paper shows that how IFL technique helps to get good speed reference tracking of separately excited D.C. motor drive , for regulating firngagle delay of 3 phase thyristor controlled rectifier, the speed and control errors both are linguistic inputs of IFL controller.

Jong Hawn Kim et. al.[2] compared the fuzzy Logic controller with conventional PID Controllers. They showed that Fuzzy precompensated PID controller have better performance instead of conventional PID.

Paul I. Hai Lin et. Al. [3] presented the comparison of PID and PI controllers for the use in a 486 PC based DC motor positioning system. For the performance calculation accuracy, resolution and settling time too change is command signals are considered and they concluded that FLC controller have better performance in comparisons with the PID Controller. h

Jason T. Teeter et al. [4] have shown experimental approach to improve the performance of a DC motor control system. They analysed the smoothness of response and disturbance rejection of a PI Control system with and without the Fuzzy Compensator and concluded that Fuzzy Logic Compensator improves the performance of DC motor system with nonlinear friction characteristics.

S. Tunyasrirut et al. [5] they designed adaptive fuzzy PI controller for controlling the armature voltage and showed that proposed controller gives the step responses with small overshoot and zero steady state error.

Yodyium Tipsuwan et al.[6] presented an alternative approach to control the speed of DC motor by using a Fuzzy Logic Microcontroller. Main motive of using microcontroller implementation in Fuzzy logic to reduce its size and cost. Its performance is also improved. In this approach velocity control of a DC motor is done using Fuzzy Microcontroller. Due to its smaller size FLC Microcontroller is applicable for smaller application and show good velocity tracking performance under both load and no load condition.

A. Visioli [7] presented comparative analysis between different methodologies which are based on Fuzzy Logic for tuning of PID Controllers In this paper Ziegler Nichols parameters of Fuzzy mechanism is adopted for improving the performance and concluded that Fuzzy Logic has more beneficial towards the nonlinear approaches such as saturation. The easy tuning of fuzzy mechanism parameters also play a vital role for use of this technique practically.

JiashengZang et al. [8] have shown structural research on Fuzzy PID Controllers .They analyzed that accurate control of time delays is not easy in conventional controllers so fuzzy PID approach is applied for the improvement in system performance.

Yo Long CUI et.al [9] adopted fuzzy self-adaptive PID control method. By using this approach they designed DSP based full digital control, 3 phase full control rectification circuit which is highly reliable with improved robustness. They concluded that fuzzy self-adaptive PID controller have good antizamming ad tracking performance over conventional PID controllers.

P. Thepsatom et.al [10] controlled the speed of separately excited D.C. motor by using FLC based on lab view ( ) program. They concluded that the reference speed gains optimal performance and sensitiveness towards the speed variation.

M.M.R. Ahmed et.al [11] used the cascade combination of a diode bridge rectifier and a single ended primary inductance converter (SEPIC) for the close loop speed control of separately excited D.C. motor is fed from A.C. source. To attain wide range of speed and load control the FLC controller is used, which also deals with system non-linearity and parameters change. They analyzed that SEPIC converter offers a fairly sinusoidal supply current with near unity P.F. and performance of motor drive system is insensitive towards motor parameters and operating pt. changes.

Savita Sonoli et al [18] implemented software module (using VHDL) on FPGA based PID controller for the speed control of DC motor. This paper concluded that by using this technique the steady state error is eliminated and desired output speed is obtained.

Dr. Maan M. shaker et.al [19] design and implemented the fuzzy logic system for D.C. motor speed control. For this setup an integrated electronic system is designed. In this approach system utilizes an interface card through parallel port with some additional auxiliary circuits to perform D.C. motor speed control with load and no load condition by using FLC. They shown that all parameters over shoot, setting time, rise time all are very small in comparison with the parameters of the conventional control. Which means that fuzzy controller has higher stability.

Sereyvatha Sarin et.al [12] used 8 bit microcontroller board to design and implement the fuzzy logic PID controller for speed control of D.C. motor. The circuit is designed by using fuzzy PID controller, half bridge driver motor, 4:1 transmission gear, tire and speed sensor. They find that the main drawback of this technique is that it work well for speed upto 1km/h but fails below this and with fix parameters all required responses cannot satisfies.

E. Julie Hepzibah et.al [14] used a D.C. motor drive FPGA for speed monitoring .It provides fast operation in comparison with any other analog or digital methods. In this method for triggering the converter circuit generated PWM is controlled. The pulses for firing the triggering of MOSFET was generated using FPGA. They concluded that the efficiency and speed of control in electric drives and other power electronic systems will increased by using FPGA based technique. FPGA technique also replace the use of DSP & microcontroller from this field.

Chin-Chin WEN et.al [13] design the fuzzy sliding mode controller for D.C. motor. The speed tracking control of separately excited D.C. motor using lyapounov stability, fuzzy and variable structure control theorems is done. Fuzzy methodology is used to estimate the unknown nonlinearities .They shown that fuzzy and variable structure control, is successfully applied for speed tracking control.

Eduardo Gomez Ramirez [16] presented that in industries PID Controllers are used for precise control. PID controllers have typical mathematical formulation but in fuzzy controllers there is no complications like mathematical formulation. Fuzzy

systems decreases the settling time of processes. The simple algorithm is present for tuning of fuzzy controllers. The results depend on the membership functions and settling time.
Miguel Angel Porta Garcia [17] applied simple tuning algorithm to evaluate the effectiveness of a Fuzzy Pulse Width modulation Controller. Another algorithm is applied in addition with the tuning process to get vector of operation points of each input. The result obtain after experimenting is that the value of tuning factor K is nearest to 1 to get fastest system response.
Son Nguyen Thank et.al [15] used 8 bit AVR at mega 16 microcontroller with fuzzy logic controller to control the speed of separately excited D.C. motor. The main purpose of using fuzzy logic controller is that it does not require any mathematical model for the controlled object. They shows that the main advantage of fuzzy logic controller over other conventional controller is that it does not require any mathematical model for controlling the object and other advantage of FLC.

Experimental Process

In Fig No.1 Block diagram, we are taking error signal, i.e., the error between step input and motor output. This error signal and its derivative are fed to the Fuzzy logic controller.

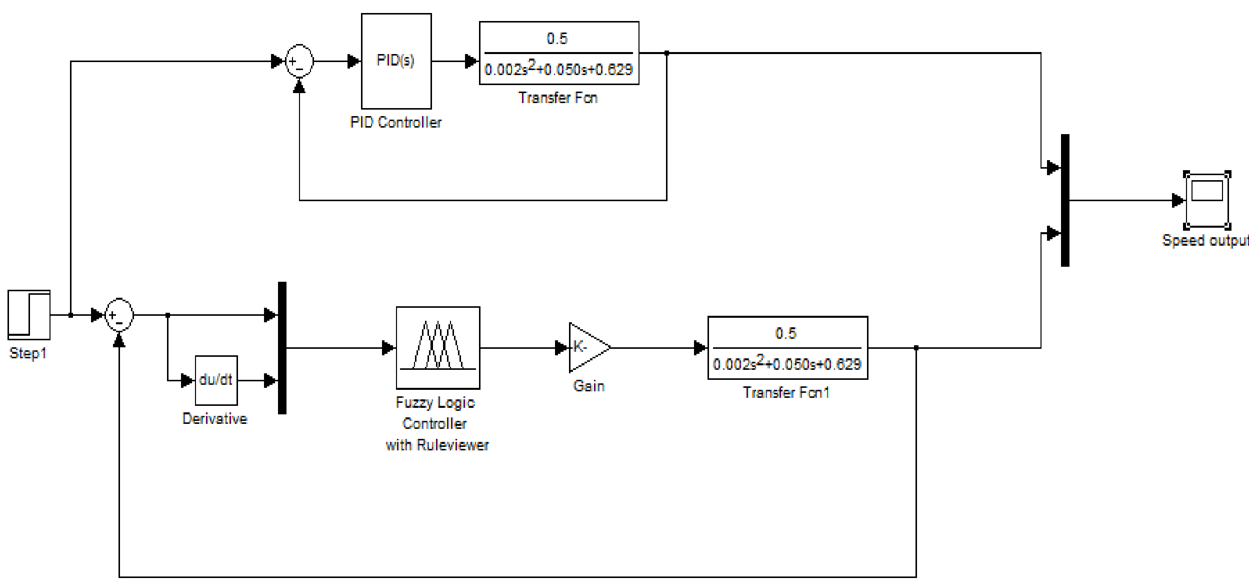

Fig 1: Block Diagram of Seperately Excited DC Motor BY Using FLC

After simplifying the motor model, the overall transfer function will be

$\phi(s) / V_a(s) = K\psi / L_a j_m s2 + R_a J_m s + K2\ \psi 2$
For the DC motor with parameter given in Appendix, overall transfer function of the system is given as:
$\phi(s) / V_a(s) = 0.5/0.002s2 + 0.050s + 0.625$

Fuzzy logic controller

A fuzzy logic model is a logical-mathematical procedure based on an "IF-THEN" rule system that mimics the human way if thinking in computational form.

Generally, a fuzzy rule system has four modules.
- Fuzzification
- Fuzzy Inference
- Rule base
- Defuzzification

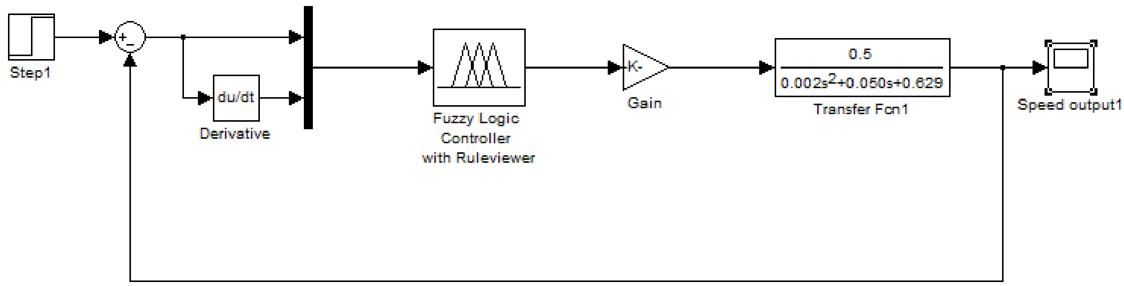

Fig. 2: Matlab /Simulink model of system using Fuzzy Logic controller

Fuzzification

Fuzzification transforms crisp normalized input data into membership grades of fuzzy sets defined on normalized UODs of input variables. Here we require fuzzy sets. We are using triangular fuzzy sets for input variables, where input variables are error and rate of change of error.

Fuzzy inference

After transforming crisp values into fuzzy sets, inference is drawn on it. For this, we require a rule base consisting of if-then rules. Using these rules, the controller infers the control action that has to be taken.
Under inference, the truth value for the premise of each rule is computed, and applied to the conclusion part of each rule. This results in one fuzzy subset to be assigned To each output variable for each rule. Mostly MIN or PRODUCT is used as inference rules. In MIN inference, the output membership function is clipped off at a height corresponding to the rule premise's computed degree of truth (fuzzy logic AND). In PRODUCT inference, the output membership function is scaled by the rule premise's computed degree of truth.

Rule base

For the rule bases a classic interpretation of Mamdani was used. Under rule base, rules are constructed for outputs. The rules are in "If Then" format and formally the If side is called the conditions and the Then side is called the conclusion. A rule base controller is easy to understand and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.

Defuzzification

Defuzzification transforms fuzzy values back to crisp values which control the actuators. For this, we again require fuzzy sets. We are using triangular fuzzy sets for output variable, i.e., control action that has to be taken over the motor actuators. This output is then scaled that denormalize it and bring it back to the operating range. This is then supplied to the motor to serve our purpose.

Designing procedure

A methodology for rule base fuzzy logic controller applied to a system. Before running the simulation in MATLAB/SIMULINK, the Fuzzy Logic Controller is to be designed. This is done using the FIS editor. FIS file is created using the Fuzzy logic toolbox.
The design of a Fuzzy Logic Controller requires the choice of Membership Functions. After the appropriate membership functions are chosen, a rule base is created. The set of linguistic rules is the essential part of a fuzzy controller. The various linguistic variables to design rule base for output of the fuzzy logic controller are enlisted in Table I. The response of the fuzzy logic controller is obtained using in MATLAB/SIMULINK. A two input which is Speed Error (e) & Change in Error (ec) and one – output Change in control, fuzzy controller is created and
the membership functions and fuzzy rules are determined. The membership functions (MF) for inputs are shown below in Fig. 3(a), 3(b) and the MF for output is shown in fig. 3(c).

1) Membership functions for inputs and output variables

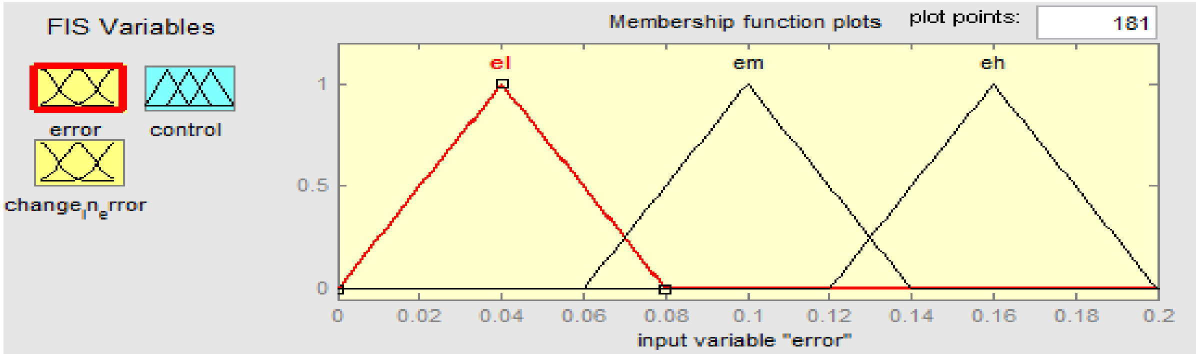

Fig 3(a) Fuzzy input variable "error"

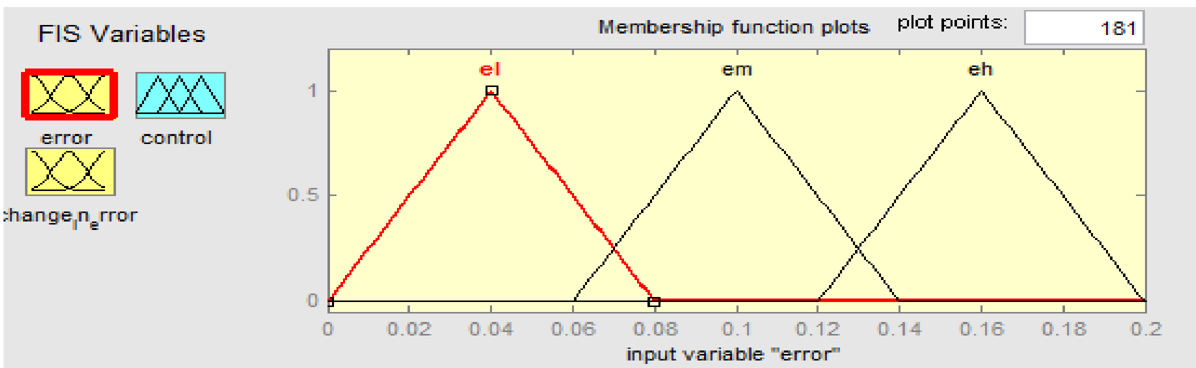

Fig 3(b) Fuzzy input variable "change in Error"

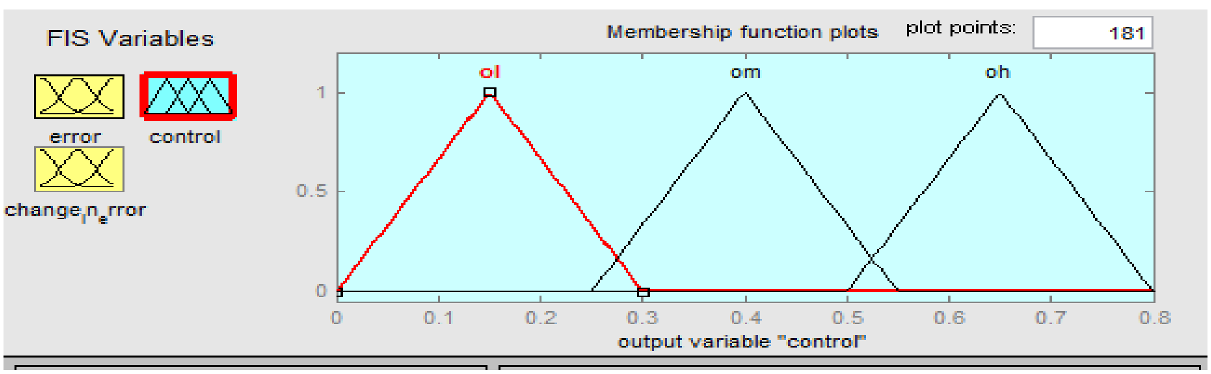

Fig 3(c) Fuzzy output variable "control"

Fuzzy inference rule

TABLE I: RULE TABLE FOR OUTPUT VARIABLE"CONTROL"

e/ec	ecl	ecm	ech
el	ol	om	om
em	ol	om	oh
eh	om	om	oh

Construction of rules and rule viewer

In figure 3.4(A) fuzzy if-then rules are shown and in figure 3.4(B) Analysis of the two inputs (error and change in error) and output are shown. There are total 9 rules output variable.

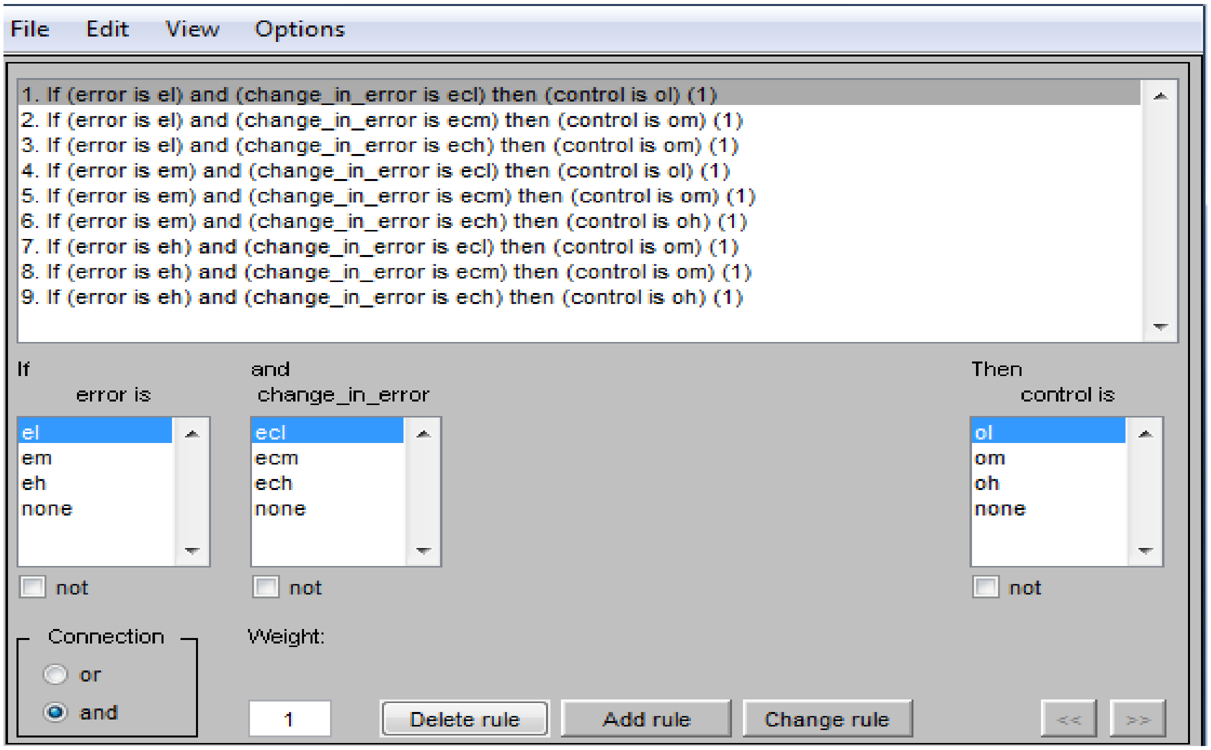

Fig 3.4(a): Fuzzy IF –Then rules

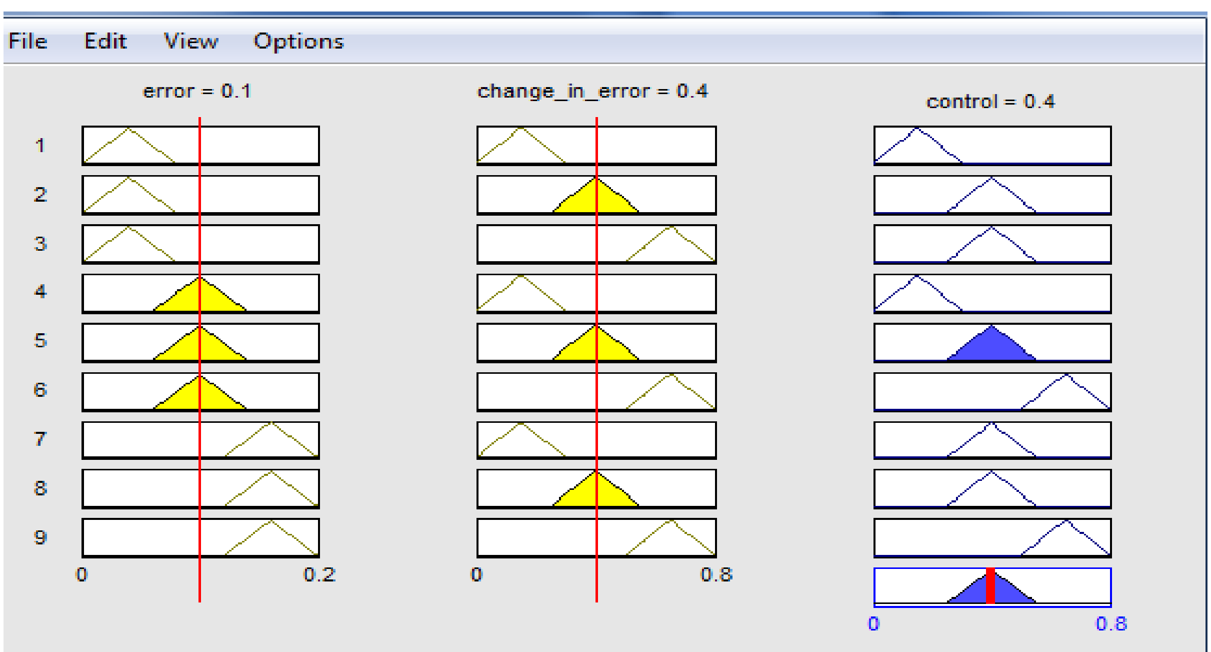

Fig 3.4(b): Analysis of both the inputs and output

SIMULINK IMPLEMENTATION AND RESULTS

The results of the system with using different type of controllers are shown here. The responses of the system with several controllers such as PID, Fuzzy Logic Controller are being applied. In this section transfer function of the separately excited dc motor is used as a system and find out the response of the system applying the step function as an input.

A. PID controller

Figure 4 shows the PID control system designed in MATLAB/Simulink where controller parameters are adjusted using (Z-N) method.

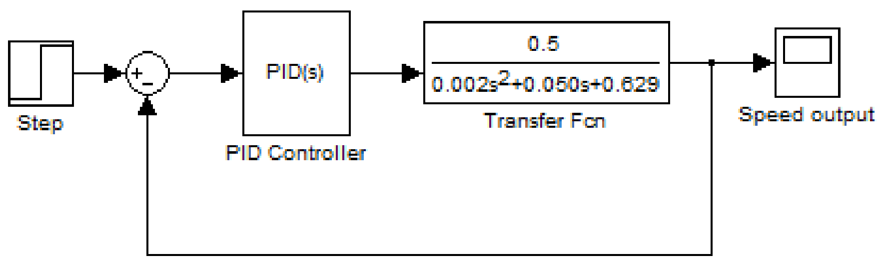

Fig 4: Matlab/Simulink model of system using PID controller

The simulation output of the PID Controller for 2nd order system is represented in Fig 5

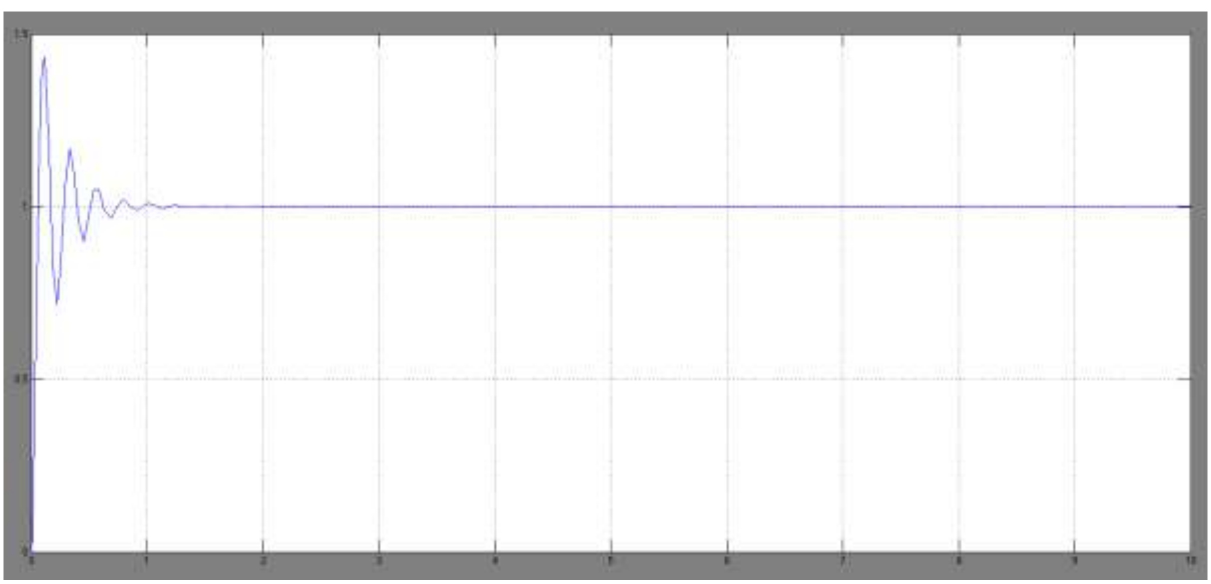

Fig 5 Step Response of the system with PID Controller

As can be seen from the figure, the PID controlled response of the system has considerably high overshoot and larger settling time values. Hence, an attempt is made to further improve the response of the system using fuzzy logic controller.

C. Step responses

The simulation output of the Fuzzy Logic Controller for System is represented in Figure.6

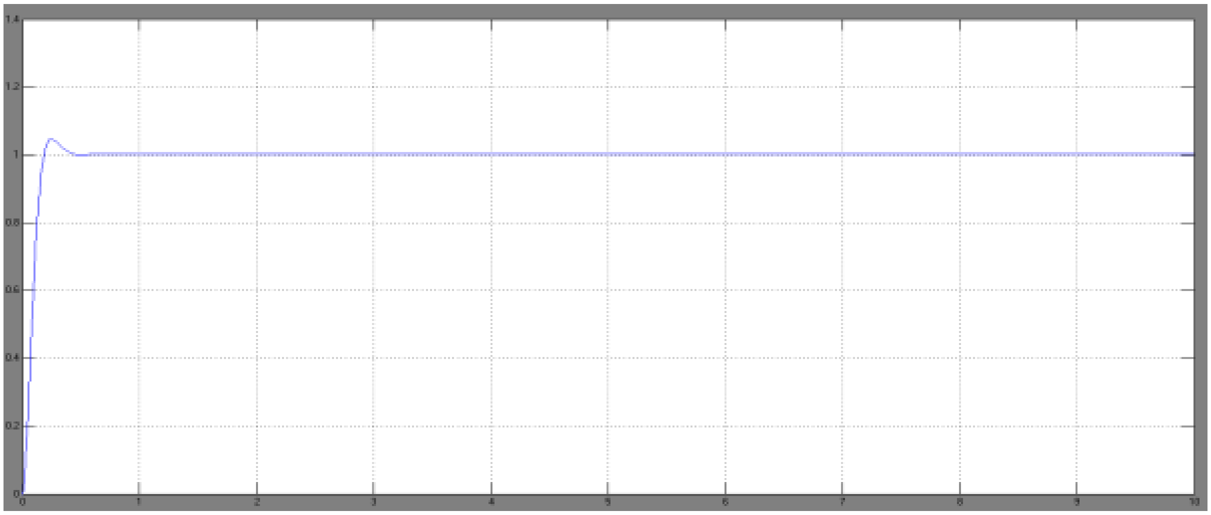

Fig 6 Step response of system using fuzzy logic controller

From above figure, it can be easily seen that the overshoot has been considerably reduced with fuzzy logic controller as compared to the PID using classic ZN method. Comparative step response for PID regulated system and FLC controlled system is shown in figure 7.

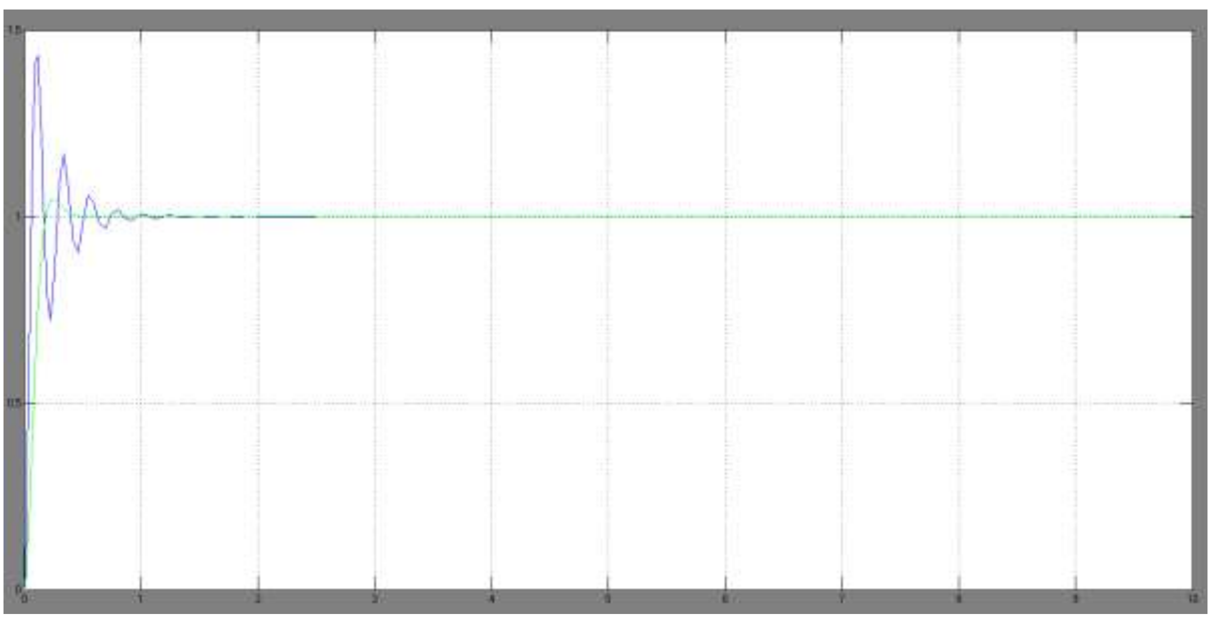

Fig 7 Step response of system using PID and fuzzy logic controller

Figure 7 shows that the response of the system has greatly improved on application of fuzzy logic controller (FLC). The overshoot of the system using FLC has been reduced, settling time, peak time of the system also shows appreciable reduction as analyzed in Table II.

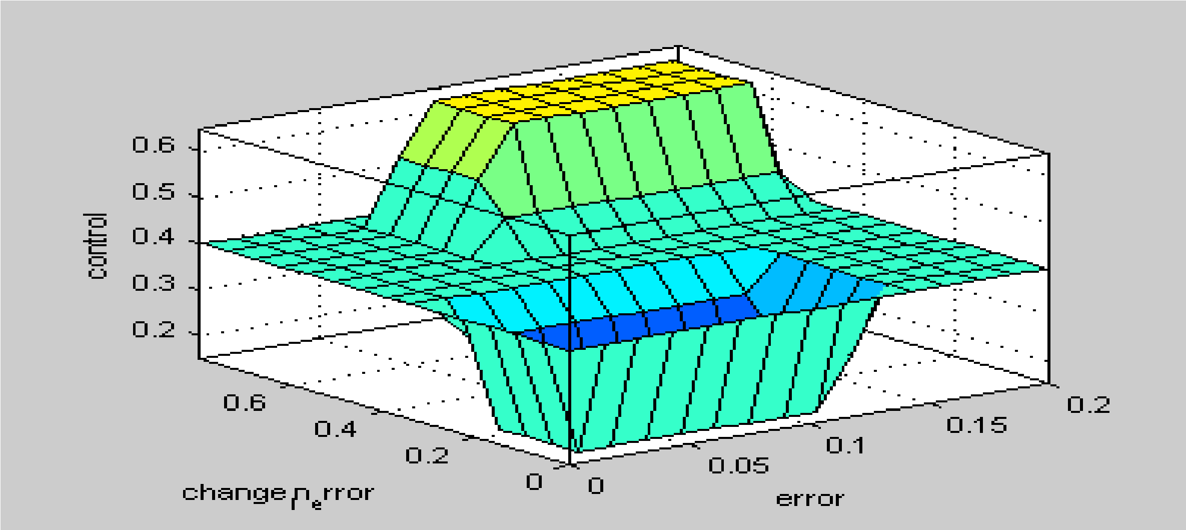

Fig 8: Three dimensional view of Fuzzy logic response

RESULT:

Fig. 5 shows the response obtained by using PID controller for speed control of motor. Fig 6 shows the response obtained when PID controller was replaced by Fuzzy logic controller. Fig 7 shows a direct comparison between PID and Fuzzy controller for speed control of DC motor. A tabulated comparison is shown in the following table:

Table 2 : Comparison between the output responses for controllers

Title	PID Controller	Fuzzy Logic controller
Rise time(sec)	1.3	0.3
Peak time(sec)	0.2	0.3
Settling time(sec)	0.75	0.3
% Overshoot	40%	10%
Steady State Error	0%	0%

CONCLUSION AND FUTURE SCOPE

In this paper, the speed of a DC motor has been controlled using PID and Fuzzy controller. The simulation results are obtained using MATLAB/SIMULINK. From the results obtained, it is clear that Fuzzy logic controller gives better response than a conventional PID controller. The proposed Fuzzy logic controller has advantages like higher flexibility, control, better dynamic and static performance. Also, the results can be made better by tuning the parameters of Fuzzy controller like membership functions tuning, scaling factors tuning etc.

REFERENCES

[1]. Hussein F. Soliman, A.M. Shmf, M. M. Mansour, S.A. Kandil, M. H. El-Shafii "*AN* Incremental Fuzzy Logic Controller For A Separately Excited Dc Motor-Rectfier Fed Drive System", Canadian Conference on Electrical and Computer Engineering, IEEE Conference Publications 1994.

[2]. Jong-Hwan Kim, Kwang-Choon Kim, and Edwin K. P. Chong "Fuzzy Precompensated PID Controllers" IEEE Transactions On Control Systems Technology, Vol.2 , NO. 4, DECEMBER 1994

[3]. Paul I-Hai Lin, Santai Hwang and John Chou "Comparison On Fuzzy Logic And Pid Controls For A Dc Motor". Industry Applications Society Annual Meeting, 1994., Conference Record of the 1994 IEEE Year: 1994 Pages: 1930 - 1935 vol.3, DOI: 10.1109/IAS.1994.377695 Cited by: Papers (4) IEEE Conference Publications

[4]. Jason T. Teeter, MO-yuen Chow, and James J. Brickley "A Novel Fuzzy Friction Compensation Approach to Improve the Performance of a DC Motor Control System", IEEE Transactions On Industrial Electronics, Vol. 43, No. 1, February 1996.

[5]. S. Tunyasrirut, J. Ngamwiwit& T. Furuya "Adaptive Fuzzy PI Controller for Speed of Separately Excited DC Motor" Systems, Man, and Cybernetics, 1999. IEEE SMC '99 Conference Proceedings. 1999 IEEE International Conference on Year: 1999, Volume: 6 Pages: 196 - 201 vol.6, DOI: 10.1109/ICSMC.1999.816518 Cited by: Papers (1) IEEE Conference Publications
[6]. Yodyium Tipsuwan, Mo-Yuen Chow "Fuzzy Logic Microcontroller Implementation For Dc Motor Speed Control". Industrial Electronics Society, 1999. IECON '99 Proceedings. The 25th Annual Conference of the IEEE Year: 1999, Volume: 3 Pages: 1271 - 1276 vol.3, DOI: 10.1109/IECON.1999.819394 Cited by: Papers (16) IEEE Conference Publications
[7]. A.Visioli "Tuning of PID controllers with fuzzy logic". Control Theory and Applications, IEE Proceedings - Year: 2001, Volume: 148, Issue: 1 Pages: 1 - 8, DOI: 10.1049/ip-cta:20010232 Cited by: Papers (65) IET Journals & Magazines
[8]. Jiasheng Zhang Dingwen Yu Shiqing Qi "Structural research of fuzzy PID controllers" 2005 International Conference on Control and Automation (ICCA2005)June 27-29, 2005, Budapest, Hungary
[9]. YU-LONG CUI, HAI-LONG LU, JIAN-BO FAN3 "Design And Simulation Of Cascade Fuzzy Self - Adaptive Pid Speed Control Of A Thyristor-Driven Dc Motor",Proceedings of the Fifth International Conference on Machine Learning and Cybernetics, Dalian, 13-16 August 2006.
[10]. P. Thepsatoml , A. Numsomran, V. Tipsuwanpo, M and T. Teanthong "DC Motor Speed Control using Fuzzy Logic based on LabVIEW", SICE-ICASE International Joint Conference 2006, Oct. 18-2 1, 2006 in Bexco, Busan, Korea.
[11]. M.M.R. Ahmed and G.A. Putrus" Fuzzy Logic Speed Control Of D.C. Motors Fed By Single-Ended Primary Inductance Converters (Sepic)",Universities Power Engineering Conference, 2006. UPEC '06. IEEE Conference Publications
[12]. Sereyvatha Sarin, HilwadiHindersah, ArySetijadiPrihatmanto "Fuzzy PID Controllers Using 8-Bit Microcontroller for U-Board Speed Control" International Conference on System Engineering and Technology (ICSET), 2012,IEEE Conference Publications
[13]. Chien-Wen Chung, Hui-Min Wang, Yaote Chang "Design of the fuzzy sliding mode controller for DC Motor", 2013 Second International Conference on Robot, Vision and Signal Processing
[14]. E. Julie Hepzibah, ReebaKorah "FPGA Implementation for Speed Monitoring and Speed Control of a DC Motor using Fuzzy Logic".International Conference on Emerging Trends in Electrical Engineering and Energy Management (ICETEEEM-2012)
[15]. Son Nguyen Thanh, Khang Nguyen Thanh, Cong Nguyen The, Phi Pham Hung, Hoa Ha Xuan "Development of Fuzzy Logic Controller for DC Motor Using Personal Computer and Inexpensive Microcontroller" 13th International Conference on Control, Automation, Robotics & Vision Marina Bay Sands, Singapore, 10-12th December 2014 (ICARCV 2014)
[16]. Eduardo Gomez-Ramirez "Simple Tuning of Fuzzy Controllers". Simple Tuning of Fuzzy Controllers, StudFuzz208, 115–133 (2007)
[17]. Miguel Ángel Porta García, Iliana Marlen Meza Sánchez, Oscar Montiel1, Roberto Sepúlveda, Oscar Castillo "Simple Tuning of a Fuzzy Pulse Width Modulation Controller for a DC Motor Application".
[18]. SavitaSonoli ,Nagabhushan Raju Konduru "Implementation of FPGA based PID Controller for DC Motor Speed Control System". Sensors & Transducers Journal, Vol. 114, Issue 3, March 2010.
[19]. Dr.Maan M. Shaker, Yaareb M.B. Ismeal Al-khashab, "Design and Implementation of Fuzzy Logic system for DC motor Speed Control" 1st International Conference on Energy, Power and Control (EPC-IQ), Basrah, Iraq, November 30 - December 2, 2010.