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PERFORMANCE COMPARISON OF PID AND FUZZY LOGIC CONTROLLER USING DIFFERENT DEFUZZIFICATION TECHNIQUES FOR POSITIONING CONTROL OF DC MOTORS

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Abstract- In this paper fuzzy logic and proportional-integral-derivative (PID) controllers are compared for controlling the position of direct current (DC) motors. The PID controllers mostly used in industries due to their robust performance in a wide range of operating conditions & their simple tuning methods. This paper presents design of PID controller with Ziegler-Nichols (ZN) technique for controlling the position of the field-controlled with fixed armature current DC motors. A Fuzzy logic controller using smaller rule set is proposed. Simulation results are demonstrated using MATLAB. Performance analysis shows the effectiveness of the designed Fuzzy logic controller as compared to the ZN tuned PID controller & fine tuned PID controller

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Introduction

The best known controllers used in the industries are the proportional - integral - derivative (PID) controller because of their simple structure and robust performance in a wide operating conditions [9].The PID controller is used for a wide range of problems like motor drives, automotive, flight control, instrumentation etc. PID controllers provide robust and reliable performance for most systems if the PID parameters are tuned properly. Fuzzy gain scheduling techniques for PID controllers also available [5,8]. Among the tuning methods, the Ziegler-Nichols (ZN) technique has been very popular. Ziegler-Nichols presented two tuning methods, a step response method and a frequency response method. The frequency response method is more reliable than the step response method. In this paper, we will investigate frequency response method for DC motor position system. A survey of various sophisticated PID software packages & hardware models is found in [4].

Fuzzy control is a control method based on *fuzzy logic*. Just as fuzzy logic can be described simply as "computing with words rather than numbers"; fuzzy control can be described simply as "control with sentences rather than
equations". A fuzzy controller can include empirical rules, and that is especially useful in operator controlled plant .A comprehensive review of the classical design and implementation of the fuzzy logic controller can be found
in the literature [2,3].

This paper has two main contributions. Firstly, a PID controller has been designed for DC motor using Ziegler-Nichols frequency response method and its Performance has been observed. The Ziegler Nichols tuned controller parameters are fine tuned to get satisfactory closed loop performance. Secondly, for the same system a fuzzy logic controller has been proposed with simple approach and smaller number of rules (four rules) as it gives the same performance as by the larger rule set[1,5,6].

Simulation results for DC motor position systems have been demonstrated. A performance comparison between Ziegler Nichols tuned PID controller, fine-tuned PID controller and the proposed fuzzy logic controller is presented for different defuzzification methods. The paper has been organized as follows, Section-II explains generalized model of PID controller. Section-III describes the design consideration for *field controlled* with fixed armature current DC motors. Section IV presents design of PID controller using Z-N technique. Section V presents design of fuzzy logic controller using simple approach and smaller rule base. Section VI finally conclusion close the paper.

Generalised Model Of Pid Controller

A PID controller is described by the following transfer function in the continuous s-domain

$$G_c(s) = P + I + D = K_p + {K_i}/{s} + K_d.s \text{ .... } (1)$$

Or

$$G_c(s) = K_p(1 + {1}/{T_i s} + T_d.s \text{ .... } (2)$$

Where K_p is the proportional gain, K_i is the integration coefficient and K_d is the derivative coefficient. T_i is known as integral action time and T_d is referred to as derivative action time. Tuning a PID controller means setting these parameters to get the best possible control for a particular process. For this reason, it is very difficult and time consuming to tune these three parameters in order to get best performance according to the design specification of the system.

Design Consideration

A PID controller is being designed for a for *field controlled* with fixed armature current DC motor.

The transfer function between the output angular displacement of this motor shaft $\theta(t)$ and its input control action $U(t)$ is given by [7]:

$$\frac{\theta(s)}{U(s)} = \frac{K_m}{s(T_f.s+1)(T_m.s+1)} \text{ .... } (3)$$

Where *Km* is motor gain constant, T_f is time constant of field circuit and T_m is time constant of inertia-friction element. For simplicity, we assume that $K_m = 1$ rad/voltsec, $T_f = 0.1$ second and $T_m = 1\ second$

Fig.1 shows the simulink model of the PID controller and the field controlled DC motor with unity feedback. The authors have proposed design of (i) PID controller using Z-N technique (ii) fuzzy controller so that the closed loop system exhibit small overshoot M_p and settling time t_s with zero steady state error e_{ss}.

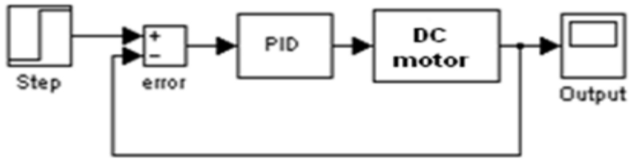

Fig. 1- Field controlled DC Motor with PID controller

Design of PID Controller

Frequency response method suggested by Ziegler-Nichols is applied for design of PID controller. By setting $T_i = \infty$ & $T_d = 0$ and using the proportional control action K_p only, the value of gain is increased from 0 to a critical value K_u at which the output first exhibits oscillations. T_u is the corresponding period of oscillation. The unit step responses for different values of gain K_p were observed. The step response for the $K_p=4.8$ is shown in Fig. 2.

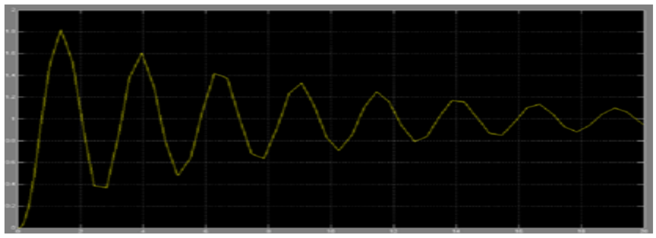

Fig. 2- Step response for K_p=4.8

The above response clearly shows that sustained oscillation occurs for $K_p = K_u = 4.8$. The ultimate period T_u obtained from the time response is 2.22. The value of controller parameters are $K_p = 0.6$, $K_u = 2.88$, $T_i = 0.5$ $T_u = 1.11$, $T_d = 0.125$ $T_u = 0.277$.

The unit step response of the closed loop system with $K_p = 2.88$, $T_i = 1.11$ and $T_d = 0.277$ Td is shown in Fig3. $M_p = 60\%$, $t_s = 12.5\ sec$ and $e_{ss} = 0$. Both M_p and t_s are too large.

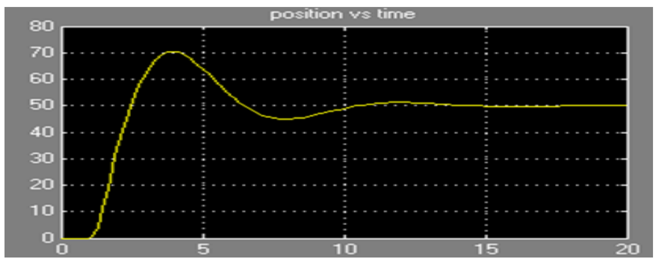

Fig. 3- Unit step response for Kp=2.88, Ti=1.11, Td = 0.277

With the initial values of K_p, T_i and Td obtained from Z-N formula, unit step response for different combination of K_p, T_i

and T_d were observed.

The unit step response for $K_p = 4.4$, $T_i = 2.09$ and $T_d = 0.5$ is shown in fig 4. Which gives $M_p = 24\%$, $t_s = 5.5\ sec$ & $e_{ss} = 0$. Both M_p and t_s are small as compared to the initial values obtained from Ziegler Nichols method.

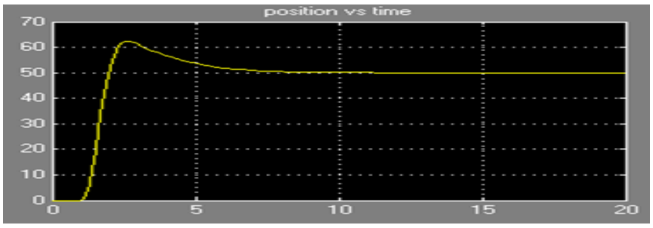

Fig. 4- Unit step response for K_p=4.4 T_i = 2.09 and T_d=0.5

Design Of Fuzzy Logic Controller (Flc)
Simulink model of the fuzzy controller and the DC Motor transfer function with unity feedback is shown in Fig 5.

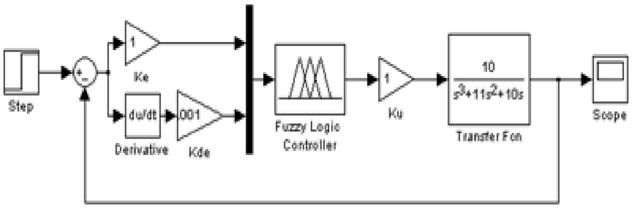

Fig. 5- Field Controlled DC Motor with Fuzzy Logic controller

For a two input fuzzy controller 3,5,7,9, 10 or 11 membership functions for each input are mostly used.

In this paper, only two fuzzy membership functions are used for the two inputs error and derivative of error as shown in fig6.Also only two fuzzy membership functions for the output parameter are shown in Fig 7. Here N means Negative, P means Positive.

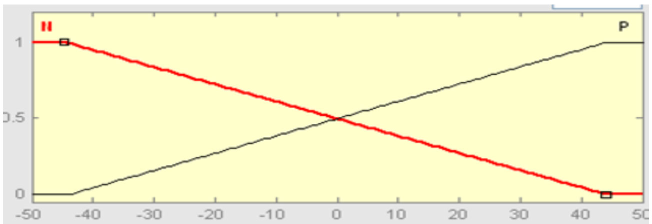

Fig. 6- Membership function for input e &

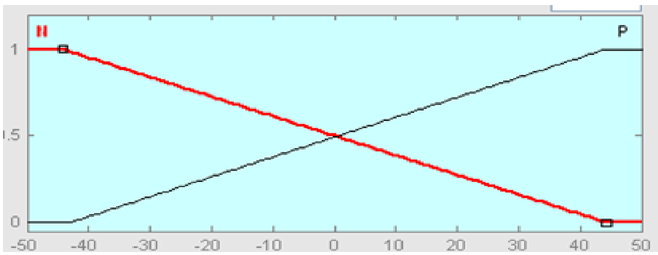

Fig. 7- Membership functions for output (*u*)

Fuzzy Logic Controllers are the knowledge base systems. So, the main requirement for the simulation of fuzzy logic controllers is that , we should know what type of time response is desired from the system. Depending upon the response, we can design the rules that will govern the all possible situation [1,4,5].

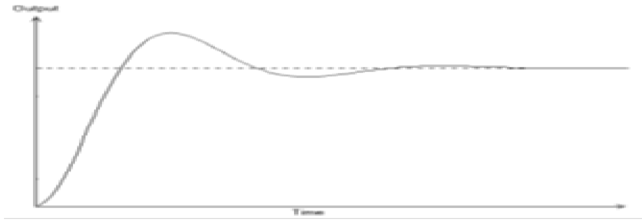

Fig. 8- System step response

The system response can be divided in Here the rules are derived from the system response that the output is above or below the set point. These rules are listed below

Fuzzy Rules

If e is N & $\dot{e}$ is N than u is N.

If e is N & $\dot{e}$ is P than u is N.

If e is P & $\dot{e}$ is N than u is P.

If e is P & $\dot{e}$ is P than u is P.

Step response for a 50 degree position control of the field controlled DC motor in Fig 9 and Fig 10 for different defuzzification method is shown.

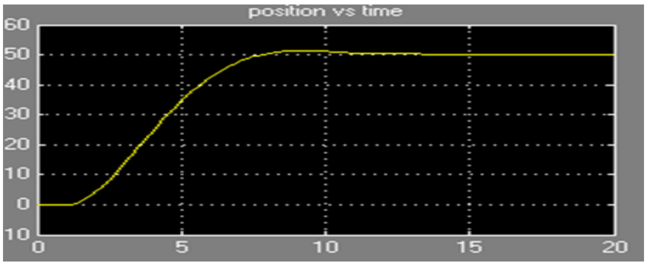

Fig. 9- Step response with FLC using middle of maxima method

The time response parameters percent overshoot (), settling time () and steady state error () for Ziegler Nichols tuned PID controller (ZNPIDC), fine-tuned PID controller (FTPIDC) and fuzzy logic controller (FLC) for the field controlled DC position system are presented in table I.

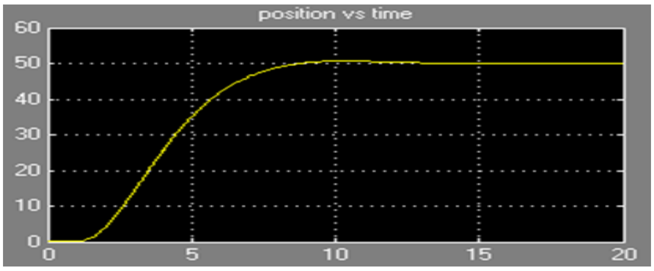

Fig. 10- Step response with FLC using centroid method

Table 1- Time Response Parameter

	M_p (%)	t_s (sec)	e_{ss} (%)
ZNPIDC	60	12.5	0
FTPIDC	24	8	0
FLC (With MOM Defuzzifica ion Method)	0	7.5	0
FLC (With centroid Defuzzification Method)	0	8	0

Summary And Conclusions

In summary, we can conclude that Z-N technique is one of the tuning procedures for PID controllers for controlling the DC motor position. But the fuzzy logic controllers gives better response. Z-N method gives high overshoot and high settling time with zero steady state error. The Fine tuned PID controller gives relatively less overshoot and settling time with no steady state error. But finally the fuzzy logic controller with different defuzzification techniques gives zero % overshoot and lesser settling time.

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