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Speed Control of Separately excited D.C Motor Using COMPUTATIONAL METHOD

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Abstract

This paper presents a comparison of performance of controllers such as PI, PID controller, Self tuned fuzzy controller for DC motor speed control. Simulation results have demonstrated that the use of Self Tuned FIS results in a good dynamic behaviour of the DC motor, a perfect speed tracking with no overshoot, gives better performance and high robustness than those obtained by use of the other controllers.

Keywords

DC Motor speed control, Fuzzy controller.

1 INTRODUCTION

With the development of power electronics resources, the direct current machine has become more and more useful. The speed of DC motor can be adjusted to a great extent as to provide easy controllability and high performance. There are several conventional as well as intelligent controllers to control the speed of DC motor such as: PID Controller, Fuzzy Logic Controller etc. The Adaptive Fuzzy Inference System (AFIS), developed in the early 90s by Jang, combines the concepts of fuzzy logic that enhances the ability to automatically learn and adapt. Hybrid systems have been used by researchers for modeling and predictions in various engineering systems.

2 MATHEMATICAL MODELING & CONTROLLER DESIGN

Motor to be controlled is a separately excited dc motor (as shown in figure.1.) with name plate ratings of 1 hp, 220v and 550 rpm. Various parameters associated with the motor are:
Moment of Inertia of the motor rotor with attached mechanical load,
$J = 0.068$ Kg-m^2
Torque Constant, $K = 3.475$ Nm A^{-1}
Armature winding resistance, $R_a = 7.56$ ohm
Armature winding inductance, $L_a = 0.055$ H

Friction coefficient (B_m) = 0.008 N.m/rad/sec
Sampling period, T = 40ms

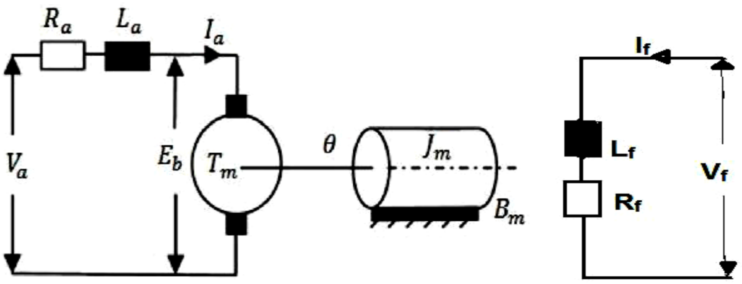

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Figure.1: Separately excited DC motor model

The armature voltage equation is given by:

$V_a = E_b + I_a.R_a + L_a.(dI_a/dt)$ (1.1)

For normal operation, the developed torque must be equal to the load torque plus the friction and inertia, i.e.:

$T_m = J_m. d\omega/dt + B_m.\omega + T_L$ (1.2)

Where: T_L is load torque in Nm.

3.Design of Controllers

3.1 PID Controller AND TUNING:

A feedback control system measures the output variable and sends the control signal to the controller. The controller compares the value of the output signal with a reference value and gives the control signal to the final control element.

The equation of ideal PID controller is

$$u = K_p\left(e + \frac{1}{T_i}\int_0^t e * d\tau + T_d\frac{de}{dt}\right)$$

The real PID controller is

$$u(s) = K_c\left(\frac{1+\tau_i s}{\tau_i s}\right)\left(\frac{1+\tau_d s}{1+\alpha\tau_d s}\right)e(s)$$

The PID controller is traditionally suitable for second and lower order systems. It can also be used for higher order plants with dominant second order behaviour. The Ziegler-Nichols (Z-N) methods rely on open-loop step response or closed-loop frequency response tests. A PID controller is tuned according to a table based on the process response test. According to Zeigler-Nichols frequency response tuning criteria

$Kp=0.6\ k_{cu}$, $\tau_i = 0.5T$ and $\tau_d = 0.125T$

For the PID controller used, the values of tuning parameters obtained are

P= 18, I= 12, D=8.0

3.2 Self Tuned Fuzzy Logic Controller

The Fuzzy controller developed here is a two-input single output controller. The two inputs are the deviation from set point i.e. error, e and error change rate, Δe . The single output is the change of actuating input, Δu.

u(t)		e(t)						
		NB	NM	NS	ZO	PS	PM	PB
Δe(t)	NB	NB	NB	NB	NB	NM	NS	ZO
	NM	NB	NB	NB	NM	NS	ZO	PS
	NS	NB	NB	NM	NS	NS	PS	PS
	ZO	NB	NM	NS	ZO	ZO	PM	PM
	PS	NM	NS	ZO	PS	PS	PB	PB
	PM	NS	ZO	PS	PM	PM	PB	PB
	PB	ZO	PS	PM	PB	PB	PB	PB

Table1: Inference rules for main fuzzy logic

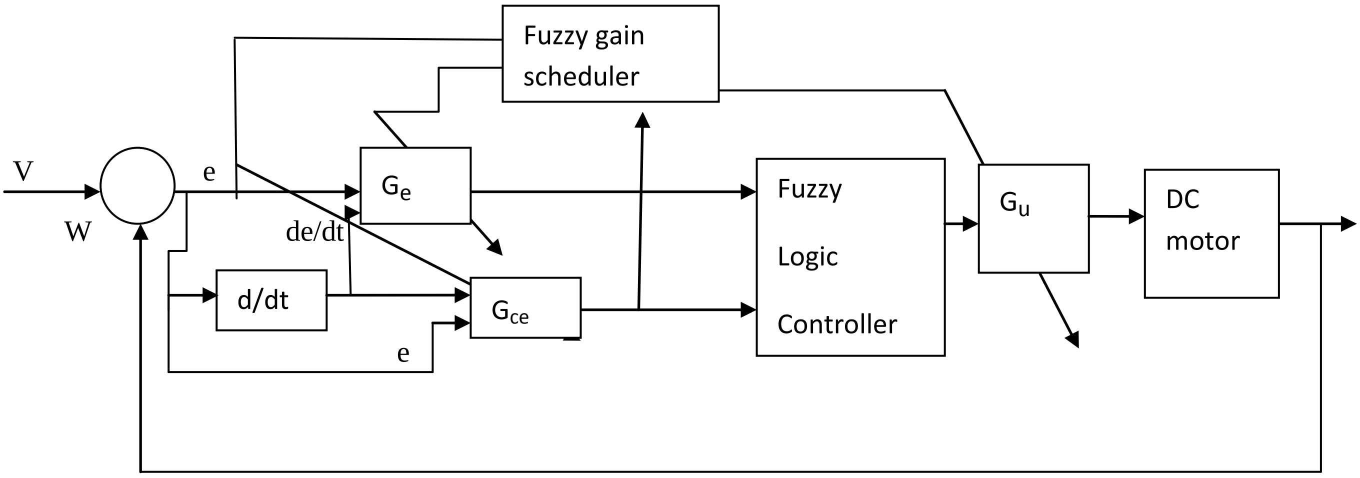
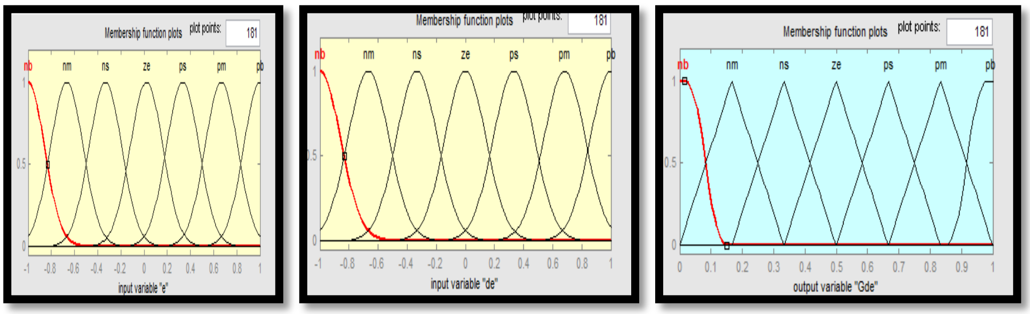


Fig2. Structure of self-tuning FLC

The membership functions of G_e sets are shown in Figure 3.



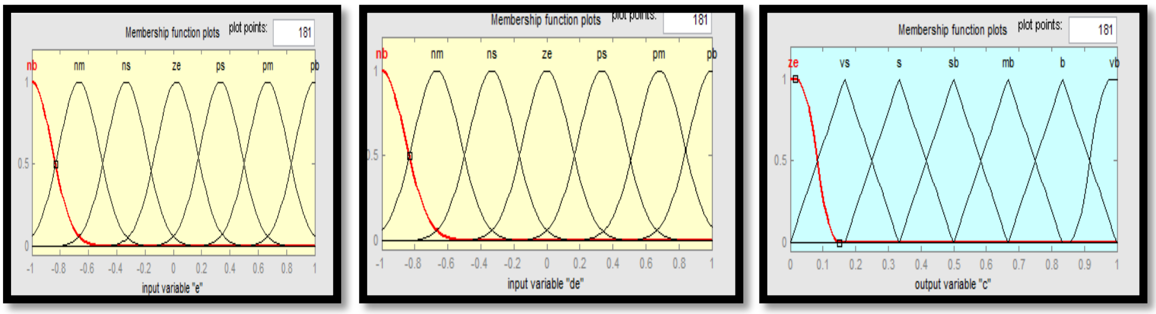
(a) (b) (c)

Figure 3: Membership function of variables for error .(a) error (b) change of error. (c). Output

	E	NB	NM	NS	ZE	PS	PM	PB
ΔE	G_e							
NB		PB	PB	PB	PB	PM	ZE	ZE
NM		PB	PB	PB	PB	PM	ZE	ZE
NS		PM	PM	PM	PS	ZE	NS	NS
ZE		PM	PM	PS	ZE	NS	NM	NM
PS		PS	PS	ZE	NS	NM	NM	NM
PM		ZE	ZE	NM	NB	NB	NB	NB
PB		ZE	ZE	NM	NB	NB	NB	NB

Table2: Inference rules for tuning the input gain G_e

To tune another input scaling factor Gde on the derivative error side, the entries in Table (2) are considered in the opposite manner, such as PB replaced by NB, PS replaced by NS and so on, while constructing the fuzzy rule base. Here also, the two input variables are the error and the derivative error but Gce is the output. Membership functions used for input & output variables are shown in fig 4 The membership functions of G_{de} sets are shown in Figure 4.



(a) (b) (c)

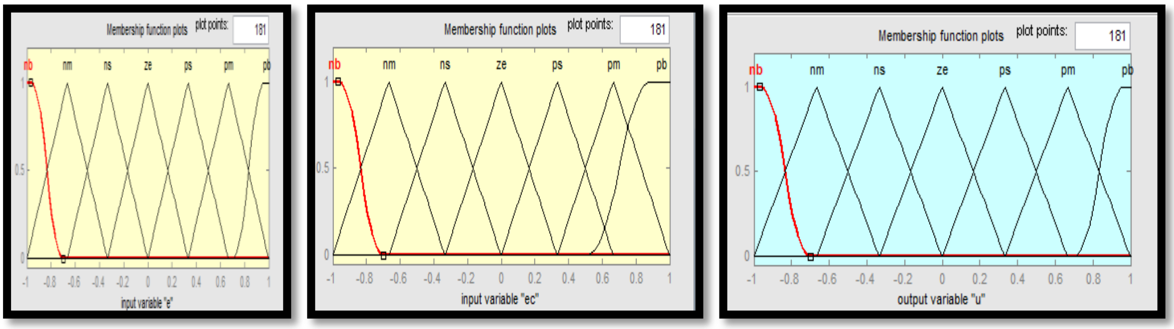
Figure 4: Membership function of variables for input gain e.(a) error (b) change of error. (c). Output

The structure of the rule base used for output gain can be visualized from table 3

Δe / e	NB	NM	NS	ZE	PS	PM	PB
NB	VB	VB	VB	B	SB	S	ZE
NM	VB	VB	B	B	MB	S	VS
NS	VB	MB	B	VB	VS	S	VS
ZE	S	SB	MB	ZE	MB	SB	S
PS	VS	S	VS	VB	B	MB	VB
PM	VS	S	MB	B	B	VB	VB
PB	ZE	S	SB	B	VB	VB	VB

table (3)

The membership functions of G_u sets are shown in Figure 5.

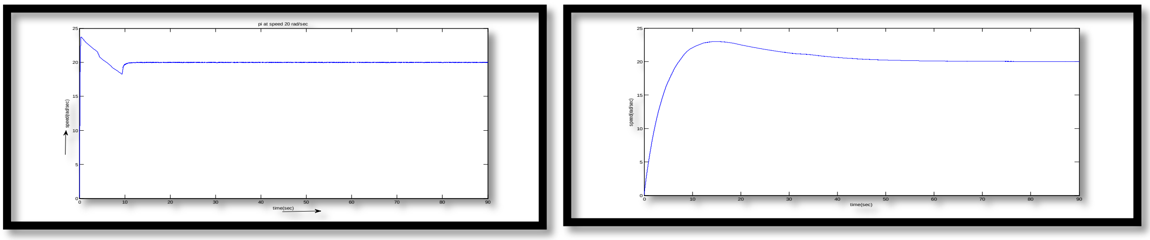


(a) (b) (c)

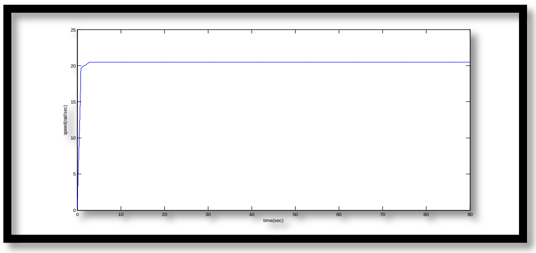
Figure 5: Membership function of variables.(a) error (b) change of error. (c). Output

4 SIMULATION RESULTS

Simulink models of different controllers are developed & simulated using MATLAB software. To test the robustness of the different controllers, a reference speed of 20 red/sec is chosen. Figures 6 represent the variation of motor speed w.r.t. time , while using PI, PID controller, self tuned fuzzy controller, GA Tuned fuzzy PID & Self tuned ANFIS respectively. Results shows that ANFIS controller provides the best control minimizing overshoots and settling time.



(a) PI (b)PID



(c)SELF TUNED FUZZY

Figure6**:** The speed time characteristic obtained with the help of different controllers at a reference speed of 20 rad/sec (a).PI (b).PID (c). Self tuned Fuzzy

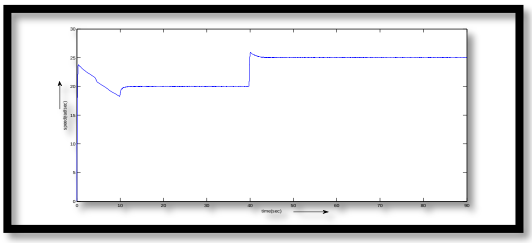
Table 4 summarizes the results obtained with different controllers.

Parameters	Controllers	PI	PID	SELF TUNED FLC
Settling Time (sec)		9.9	20	2.6
Max. overshoot (rad/sec)		3.68	3.00	00
Max. undershoot (rad/sec)		1.73	00	00
Steady state error (rad/sec)		0.000	0.000	0.47

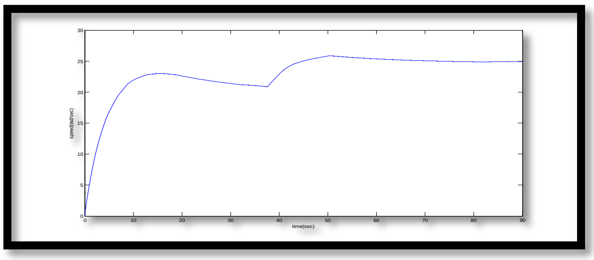
Table 4 performance with different controllers

It is clear that use of PI controller results in negligible steady state error but overshoot and undershoot are quite large. In order to improve the response, when Ziegler-Nichols tuned PID controller is used, undershoot and overshoots are minimized. Use of adaptive self tuned FLC helps to decrease settling time but steady state error increases with no overshoots and undershoots.

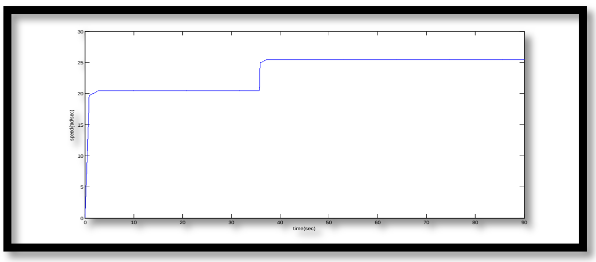
This controller gives the satisfactory performance even for variable speed as shown in fig 6.2



(a) PI



(b)PID



(c) SELF TUNED FUZZY

FIGURE6.2: The speed time characteristics obtained with different controllers with a change in reference speed from 20 to 25 rad/sec at a time interval of 40 sec (a).PI (b).PID (c). Self Tuned Fuzzy

It is clear from fig 6.2 that proposed self tuned FIS controller gives best response even when there is change in the reference speed from 20rad/sec to 25 rad/sec. Its use results in maximum speed of response and minimum steady state error. It has the best capability on tracking the reference signal.

5. CONCLUSION

In this paper , intelligent techniques such as Fuzzy logic Controllers & their hybrid are used for d.c. motor speed control. From simulations, it is concluded that the use of self tunned FIS reduces design efforts. Also, it results in minimum overshoots & undershoots & increases the speed of response. Its response is even best under variable reference speed which is shown from the results of second set of simulations.

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