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Analysis Fuzzy Self Tuning of PID Controller for DC Motor Drive

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Abstract- This paper presents Fuzzy Self Tuning of PID Controller for DC Motor Drive .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

DC machines play an important role in industries and in our daily life. The outstanding advantage of DC machines is that they offer easily controllable characteristics. Their main disadvantage is high initial investment. In spite of this, DC machines still hold a strong competitive position for industrial applications because of their attractive features. Large DC motors are used in machine tools, printing press, conveyors, pumps, hoists cranes, paper mills and so forth. Small DC Machines (in fraction horse power rating) are used preliminary as control devices such as tacho-generators for speed sensing and servo motors for positioning and tracking. DC Motors still dominate traction motors used in transit cars and locomotives as torque speed characteristics of DC motors can be varied over a wide range while retaining high efficiency. DC Motors possess excellent torque-speed characteristics and offer a wide range of speed control. Though efforts are being made to obtain wide range speed control with AC motors, yet the versatility and flexibility of DC motor can't be matched by AC motors. 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.

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, Ra = 7.56 ohm, Armature winding inductance, La**=** 0.055 H, Friction coefficient (Bm) = 0.008 N. m/rad/sec, Sampling period, T = 40ms.
The PSO algorithm is an adaptive algorithm based on a social-psychological metaphor; a population of individuals (referred to as particles)adapts by returning stochastically

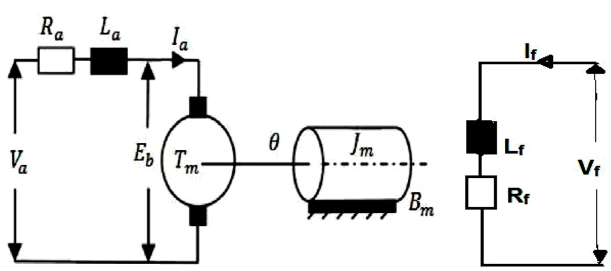


Figure.1: Separately excited DC motor model

The armature voltage equation is given by:
$V_a = E_b + I_a.R_a + L_a. (dI_a/dt)$ (1)
For normal operation, the developed torque must be equal to the load torque plus the friction and inertia, i.e.:
$T_m = J_m. d\omega/dt + B_m .\omega + T_L$ (2)
Where: T_L is load torque in Nm.

SPEED CONTROL OF DC MOTOR

For DC motor there are basically three method of speed control and these are:

- Armature control
- Field control
- Chopper control

ARMATURE CONTROL

This method is further sub divided into two categories

Armature resistance control: - In this method an external resistance is inserted in series with the armature circuit to obtain the speed below the base speed.

The disadvantages of this method are

i) Lower efficiency and higher operational cost at reduced speeds and

ii) Poor speed regulation with fixed controller resistance in armature.

Armature voltage control: - In this method speed of DC motor can be controlled by varying the armature terminal voltage. This can be achieved by either Ward-Leonard system or controlled rectifier.

FIELD CONTROL

The field flux and hence speed of a shunt motor can be controlled by varying the field regulating resistance. This method gives the speed above the base speed only.

The disadvantages of this method are:

The top speed are obtained with very weak field, Armature may get overheated due to increase of armature current.

3. DESIGN OF CONTROLLERS

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} ,τ_i =0.5T and τ_d =0.125T.

For the PID controller used, the values of tuning parameters obtained are P= 18, I= 12, D=8.0

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.

Table1: Inference rules for main fuzzy logic

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

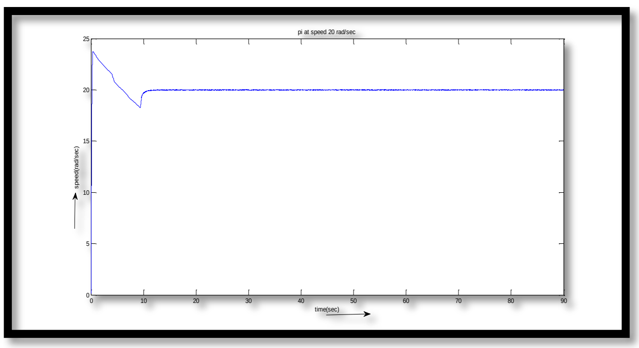
Table2: Inference rules for tuning the input gain Ge

	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

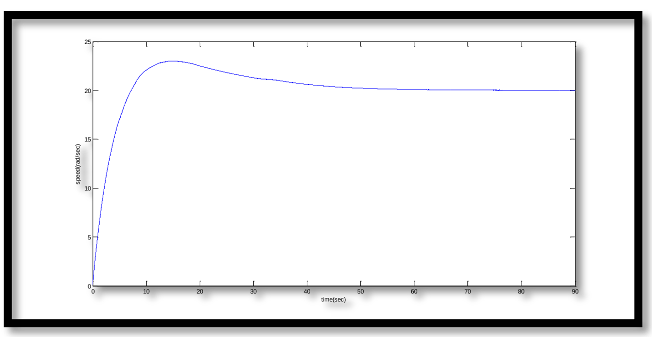
To tune another input scaling factor Gde on the derivative error side, the entries in Table (2) are considered in the opposite manner, such as PB replaced by NB, PS replaced by NS and so on, while constructing the fuzzy rule base. Here also, the two input variables are the error and the derivative error but Gce is the output.

4. Simulation Results

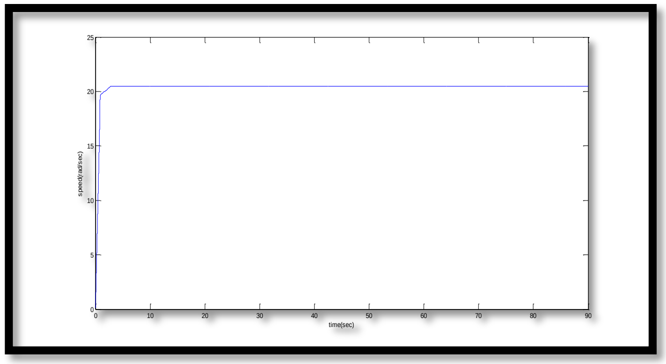
Simulink models of different controllers are developed & simulated using MATLAB software. To test the robustness of the different controllers, a reference speed of 20 red/sec is chosen. Figures 6 represent the variation of motor speed w.r.t. time, while using PI, PID controller, self tuned fuzzy controller;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



PI



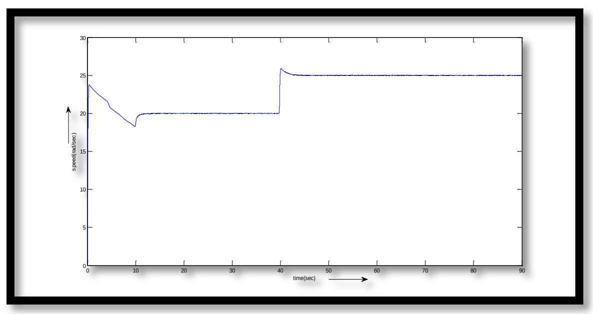
PID



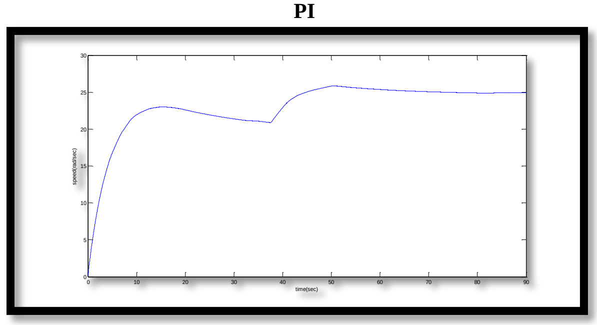
SELF TUNED FUZZY

Figure2. The speed time characteristic

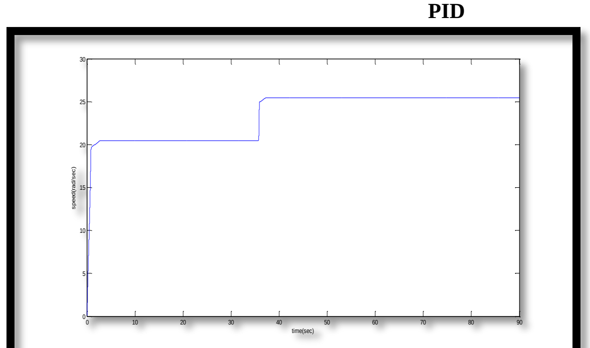
It is clear that use of PI controller results in negligible steady state error but overshoot and undershoot are quite large. In order to improve the response, when Ziegler-Nichols tuned PID controller is used, undershoot and overshoots are minimized. Use of adaptive self tuned FLC helps to decrease settling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



PI



PID



SELF TUNED FUZZY

Figure 3.The speed time characteristics obtained with different controllers

It is clear from fig 3 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 (ANFIS) are used for D.C. motor speed control. From simulations, it is concluded that the use of ANFIS 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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