

A Comparative Study on Speed Control of D.C. Motor using Intelligence Techniques

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Abstract

Now a days, the D.C motor has been widely used in industries because of its salient features like reliability, wide range of torque –speed control range, high efficiency, higher starting torque, less electrical noise and high weight/torque ratio. For speed control of DC motor different controllers are used. Mathematical model and simulink model of separately excited dc motor is designed. In this paper, the performance of DC motor is tested/ evaluated with conventional controller such as PID controller and the results have been compared with the fuzzy based PID controller. When compared to conventional controller we found that Fuzzy based PID controller provides better speed response but conventional controller provides better speed response by changing load at the cost of very long settling time. MATLAB/SIMULINK environment is discussed to verify the above investigation.

Keywords: Separately excited D.C motor, PID controller, fuzzy –PID Controller, speed control.

1. Introduction

Most of the industries use mainly two types of motor: (i) permanent magnet brushless DC motors (PMBLDCM) where the permanent magnet provides the required air gap flux instead of wire wounded field poles (ii) DC motors where the flux is provided by the current via shunt or field coils of the stationary pole structure. For speed control of DC motor, most widely used controllers are conventional PID controllers [2]. But due to non-linearity of DC motor these controllers faces problems. The problems of non-linearity arises due to armature current limitation, change in loads and drive inertia [1] . Hence to achieve desired speed control conventional PID controllers combines with the intelligence techniques such as FUZZY logic are in widely use [8] .

2. Mathematical Modelling of Separately Excited DC Motor

The performance characteristics of DC motor with conventional controller as well as combination of intelligent controllers have been investigated.

The armature voltage equation is given by:

$$V_a = E_b + I_a R_a + L_a (dI_a/dt) \quad \dots\dots\dots(1.1)$$

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

$$T_m = J_m d\omega/dt + B_m \omega + T_L \quad \dots\dots\dots 1.2)$$

Where T_L is load torque in Nm

Friction in rotor of motor is very small (can be neglected), so $B_m = 0$

Therefore new torque balance equation will be given by:

$$T_m = J_m d\omega/dt + T_L \quad \dots\dots\dots 1.2a)$$

Taking field flux as Φ and back EMF constant as K . Equation for back emf of the motor will be :

$$E_b = K \Phi \omega \quad \dots\dots\dots(3)$$

$$T_m = K \Phi I_a \quad \dots\dots\dots(4)$$

Taking laplace transform of the motors armature voltage equation we get:

$$I_a(s) = (V_a - E_b) / (R_a + L_a s) \quad \dots\dots\dots(5)$$

Put E_b in equation (4) now equation become

$$I_a(s) = (V_a - K \Phi \omega) / (R_a + L_a s) \quad \dots\dots\dots(6)$$

$$\omega(s) = (T_m - T_L) / JS = (K \Phi I_a - T_L) / J_m s$$

(Armature time constant) $T_a = L_a / R_a$

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

$$\omega(s) / V_a(s) = [K \Phi / R_a] / J_m s (1 + T_a s) / [1 + (K^2 \Phi^2 / R_a) / J_m s (1 + T_a s)] \quad \dots\dots(7)$$

3. Speed Control Of Dc Motor

3.1 PI controller

The transfer function of proportional plus integral controller in s-domain is given by:

$$G_c(s) = (sK_p + K_i) \quad \dots\dots\dots(8)$$

$e(t)$ is the instantaneous error in the signal [6].

It is used to decrease the steady state error without effecting stability. Since a pole at origin and a zero is added [3].

3.2 PID controller

A PID controller is a simple three term controller . It is used to decrease the steady state error and to increase the stability. Since pole at origin and two zeros are added. One zero compensate the pole and other zero will increase the stability[4]. Transfer function is given by:

$$G_c(s) = (K_p + K_i / s + K_D s)$$

$$G_c(s) = (K_D s^2 + K_p s + K_i) / s \quad \dots\dots\dots(9)$$

3.3 Fuzzy logic controller (FLC)

FLC based on linguistic control strategy uses human interface to optimize the system performance without knowing the mathematical model of the system. Fig(1) shows the basic configuration of FLC.

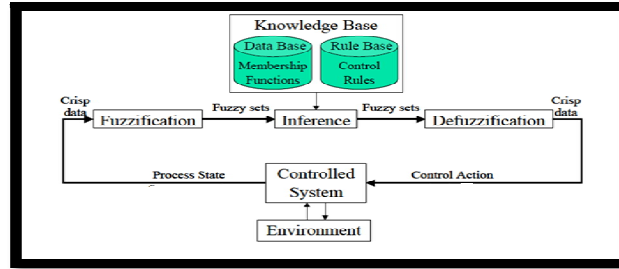


Fig. 1: Block diagram of fuzzy logic system

Table 1: Parameter used for simulation of DC motor.

Voltage	220v
Rpm	550 rpm
Moment of inertia (J)	0.068 kg m ²
Armature resistance (R_a)	7.56 ohms
L_a	0.055 H
D	0.03475 Nms
Torque	40 ms
B_m	0.003 Nm/rad/sec

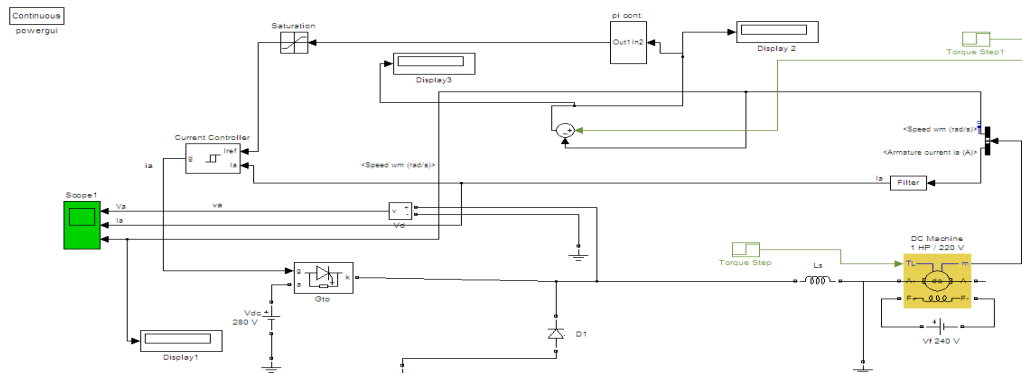


Fig. 2: The Simulink model of FUZZY-PID controller.

In present work, Mamdani based fuzzy system has been used. To control the speed of DC motor, error in speed and rate of change in speed are taken as the input variables and the gains (K_p , K_i , K_d) are taken as the output variables. Hence in present work a fuzzy system with two input and three outputs are simulated [5]. The triangular membership has been used for its simplicity and great performance. Each universe of discourse has been developed into seven fuzzy sets such as negative big (NB), negative medium (NM), negative small (NS), positive small (PS), positive medium (PM),

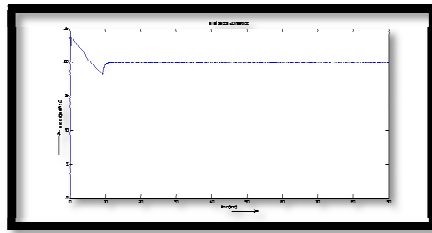
positive big (PB). A rule base consisting of forty nine rule has been developed based on the predefined membership functions of the two inputs (e is the error, ce is the change in error) and the three outputs (K_p , K_i , and K_d) [9].

The structure of the rule base used can be visualized from table (2) given below.

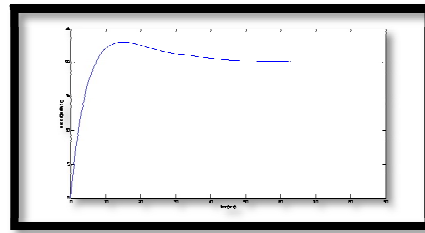
e/e^*	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NM	NS	Z	PS
NM	NB	NB	NB	NM	Z	PS	PM
NS	NB	NB	NM	NS	Z	PM	PB
Z	NB	NM	NS	Z	PS	PM	PB
PS	NB	NM	Z	PS	PM	PB	PB
PM	NM	NS	Z	PM	PB	PB	PB
PB	NS	Z	PS	PM	PB	PB	PB

4. Simulation Results and Discussion

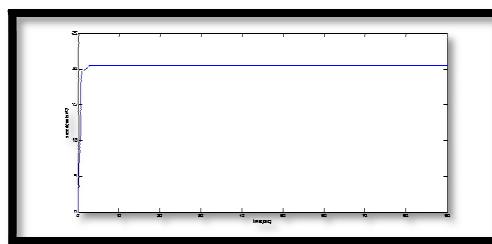
The gain values K_p , K_i , and K_d are obtained by tuning the controllers using Ziegler–Nicholas and fuzzy method.



4(a). PI



4 (b). PID



4(c). FUZZY-PID

The speed time characteristics obtained with the help of different controllers with a reference speed of 20 rad / sec is shown in fig. 4(a), 4(b), 4(c).

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. Hybrid techniques such as GA tuned fuzzy PID controller further improve the responses. Moreover, there are no overshoots and undershoots.

Table 3: Summarizes the results obtained with different controllers

Parameters 	Controllers 	PI	Pid	self tuned FLC	GA TUNED fuzzy PID
Settling Time (sec)		9.9	6.8	2.4	0.42
Max. overshoot (rad/sec)		3.58	3.00	00	00
Max. undershoot (rad/sec)		1.63	00	00	00
Steady state error (rad/sec)		0.000	0.000	0.42	0.00

5. Conclusion

Performance of DC motor with conventional as well as intelligent controllers has been simulated and discussed in this paper. From the simulation results it has been found that Use of intelligent controllers result in improvement of speed of response of the system.

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