Design of Fuzzy Pi Controller for the Speed Control of PMDC Motor

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Abstract - ***PMDC motors are widely used in instrumentation applications, particularly in robotics and computer peripherals. The speed of PMDC motor can be controlled by many controllers. In this paper PID, pole placement and Fuzzy controller are used .The advantages and disadvantages of each controller for different conditions under no load, load and disturbance conditions using software MATLAB are being discussed. Pole placement controller can be employed to obtain speed control of PMDC motor. An addition of integrator reduced the noise disturbances in pole placement controller and this makes it a good choice for industrial applications. An intelligent controller is introduced with a DC chopper to make the PMDC motor speed control smooth and almost no steady state error is observed. To prove the robustness of the proposed Fuzzy PI controller, three different controllers are compared and concluded from the results that Fuzzy controller performs to PID controller in terms of steady state error and smooth step response.***

Key Words: *DC motor, Fuzzy Controller, Pole Placement Controller, PID controller*

1. INTRODUCTION

PMDC motors is commonly used in robotic application and industrial machinery. The beauty of this motor is it provide high torque load sustaining properties. It describes about the general DC motor and about its motion. For this paper PMDC series wound motor is selected after comparing with others wounding techniques. It discuss about the background work in this field. The remarkable work is presented in this section of some previous researchers on PMDC motor speed control. It discuss the suitable equations of PMDC motor and electrical equations and mechanical equations are developed to check the system using Matlab software. State space representation and transfer function is obtained. It discuss the motor speed control with PID controller and first system is checked without controller on loaded and unloaded condition then add PID controller and system is tuned using its existing tuning methods. After it system is further tuned in order to get desired value with less steady state error. And then discuss the results.

It discuss the speed control of motor by Pole Placement Controller. This controller is developed by using transfer function of DC motor system and check the system on load disturbance and found that results are not satisfactory. In order to reduce noise factor integrator is added with reduced the effect of disturbance. It discuss the speed control with the help of Fuzzy controller. Fuzzy controller provide better control strategies than other controllers. Fuzzy controller with simulink model describes in this chapter and a new way for faster response and smooth output Dc chopper is added in the model and results are better than the previous controllers. It discuss the comparison of these three controllers' results. From the results it proved that Fuzzy Controller is the best controller.

DC motor has the simplest decoupled electromagnetic structure.The armature controlled method for speed control of DC motor is considered here. The armature current is controlled to generate desired electromagnetic torque and the armature voltage is controlled for the load. The field excitation is kept constant to produce rated flux. For a constant field excitation the armature circuit electrical equation of a separately excited

DC motor is written as:

$$L_a \frac{dI_a}{dt} + I_a R_a + E_b = E_a \quad (1)$$

where E_a is the Applied Voltage, R_a is the armature resistance, L_a is the Equivalent armature inductance, Ia current flowing through armature circuit, Eb is the back emf. The dynamics of the mechanical system is given by the torque balance equation.

$$J\frac{d^2\theta}{dt^2}+B\frac{d\theta}{dt}+T_l=T_m=K_t I_a$$

(2)

where T_m is the developed torque, T_l is the load torque, J is the moment of inertia, B is the damping constant, and K_t = Torque constant. E_b represents electromotive force in V given by

$$E_b(t) = K_b\omega(t) \quad (3)$$

Where K_b is the back emf constant in Vs/rad. The input terminal voltage V_a is taken to be the controlling variable. One can write state model with the ω and I_a as state variables and V_a as manipulating variable, as given below

Let

$$x_1 = \theta$$

$$x_2 = \dot{x_1} = \dot{\theta} = \omega$$

$$x_3 = I_a$$

$$\dot{x} = \begin{bmatrix}\dot{\omega} \\ \dot{I_a}\end{bmatrix} = Ax+Bu = \begin{bmatrix} -\frac{b}{J} & \frac{k_t}{J} \\ -\frac{k_b}{L_a} & -\frac{R_a}{L_a}\end{bmatrix}\begin{bmatrix}x_2 \\ x_3\end{bmatrix}+\begin{bmatrix}0 \\ \frac{1}{L}\end{bmatrix}u$$

(4)

$$\frac{\omega(s)}{U(s)} = \frac{\frac{k_m}{JL}}{\left(\left[s^2+\left(\left(\frac{b}{J}\right)+\left(\frac{R}{L}\right)\right)s+\frac{(Rb+k_e k_m)}{JL}\right]\right)}$$

(5)

2.PID CONTROLLER

Proportional, integral and derivative are the basic modes of PID controller. Proportional mode provides a rapid adjustment of the manipulating variable, reduces error and speeds up dynamic response. Integral mode achieves zero offset. Derivative mode provides rapid correction based on the rate of change of controlled variable. The controller transfer function is given by

$$C_{PID}(s) = \left(K_p + \frac{k_i}{s} + k_d s\right) \quad (6)$$

where, K_p, K_i and K_d are the proportional, integral and derivative constants of PID controller respectively. PID controller tuning is based on Ziegler-Nichols technique and the preference is given to the load disturbance rejection. As in this project the target is to control the speed so speed is send back for checking the system in closed loop and tuned PID controller. The method used for tuning is Ziegler–Nichols method. According to Ziegler–Nichols method run the controller by taking only P value then increase P value of the system until it self oscillating with constant amplitude then then take controller gain time period

3.FUZZY LOGIC CONTROLLER

Fuzzy logic is a type of multi valued logic. It deals with approximate reasoning rather than precise. Fuzzy logic derived from fuzzy set theory. Fuzzy logic was first proposed by Lotfi Zadeh in 1965. Fuzzy logic has currently used in control theory, artificial intelligence systems specially to control complex aircraft engines and control surfaces, helicopter control, messile guidance, automatic transmission, wheel slip control, auto focus cameras and washing machines, railway engines for smoother drive and fuel consumption and many industrial processes. Fuzzy logic provide better results if we compared it with PID controller.

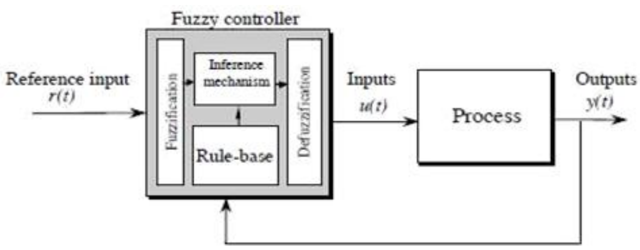

Fig.1.Fuzzy madmani inference system

Fuzzy set of theory represent the human reasoning with knowledge that is almost impossible to represent in quantitative measures or for that control plants that are hard to control or ill defined. Fuzzy inference system model the system using if-then rules. Fuzzy set theory proposed the membership function at range of numbers

[0, 1] or False or true membership function. This theory provides the mathematical strength to check the uncertainties connected with human thinking or reasoning. Fuzzy logic is suitable for a model that is hard to control or non linear models. allow decision making with incomplete information. Human reasoning can also be known as multi valued 'imprecise'.

TABL.1. Rules for PMDC motor speed control

	Change in error 'de'					
Error 'e'	'du' output	NL	NZ	ZZ	PZ	PL
	NL	NL	NL	NZ	NZ	ZZ
	NZ	NL	NZ	NZ	ZZ	PZ
	ZZ	NZ	NZ	ZZ	PZ	PZ
	PZ	NZ	ZZ	PZ	PZ	PL
	PL	ZZ	PZ	PZ	PL	PL

4.POLE PLACEMENT CONTROLLER

Pole placement controller provides excellent control as designer can adjust the time to reach on the reference point by adjusting poles. This controller use most straight forward design. It starts with assumption that what controller wants to do. From the assumption symbolic characteristic equation is formed, and poles determined which leads to design overshooting rise time. In this controller mostly equation is 2nd order and most equation have more that 2 poles

By this way equation can be formed and model is formulated as discrete transfer function. Disturbance model is not used when designer use pole placement design. Integrator design is used to drive steady state error to 0. In pole placement poles are placed in closed loop transfer function in reasonable position.

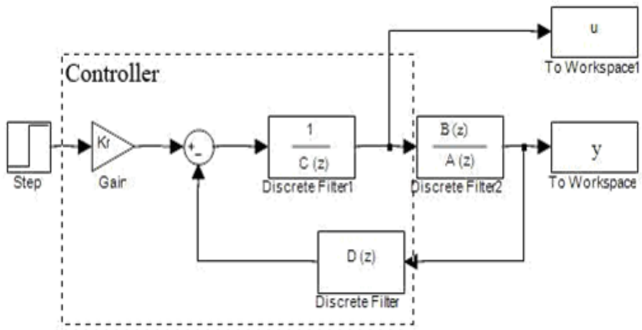

Fig.2. Pole placement design

5.RESULTS AND DISCUSSION

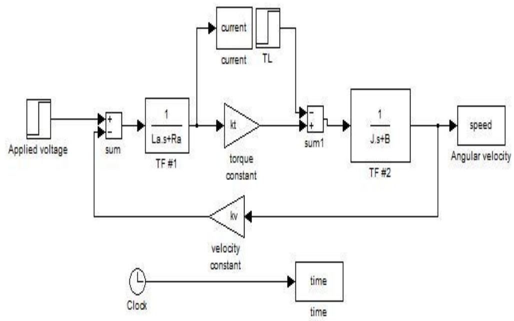

Fig. 3. Simulink model of DC motor

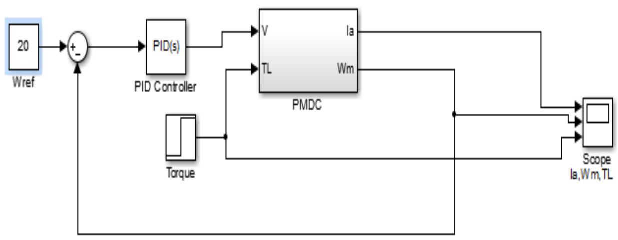

Fig.4. Simulink model of PMDC motor using PID controller

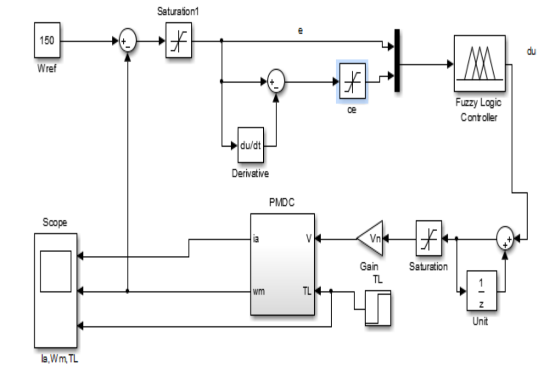

Fig.5. Simulink model of PMDC motor using Fuzzy logic controller

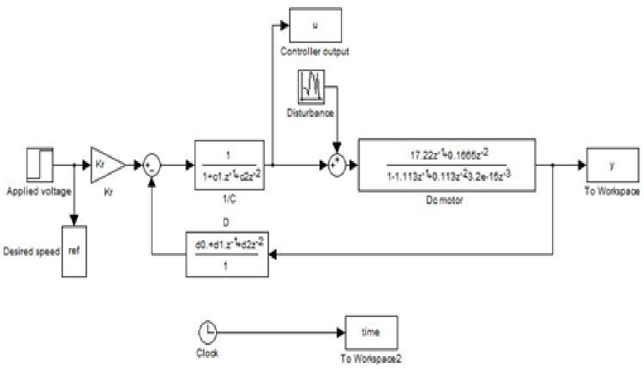

Fig.6. Simulink model of PMDC motor using Pole placement controller

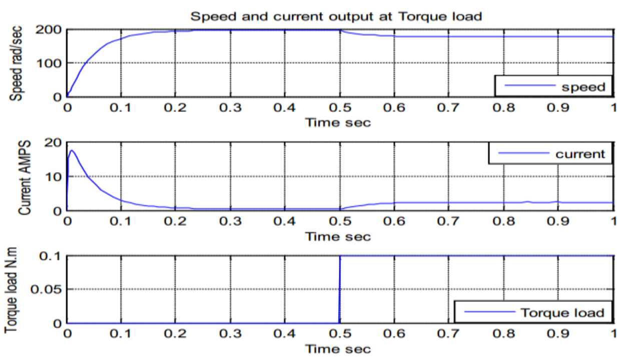

Fig. 7. DC motor output put at Torque load

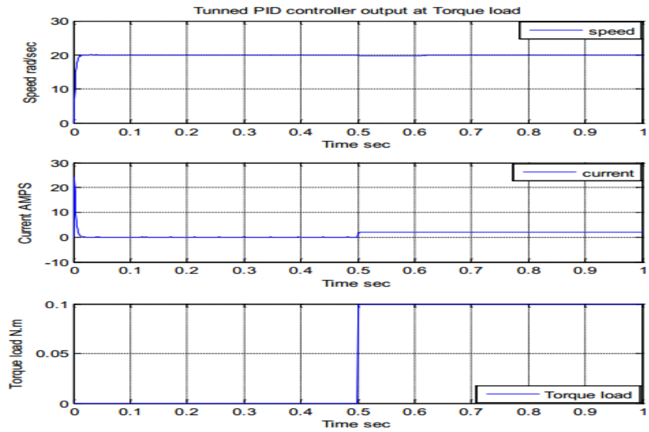

Fig.8.DC motor output with PIDcontroller put at Torque load

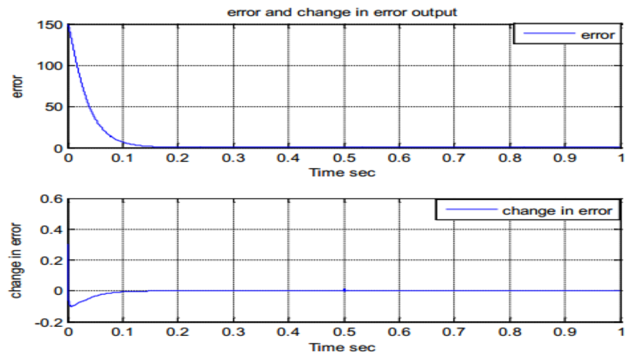

Fig.9. error and change in error in Fuzzy logic controller

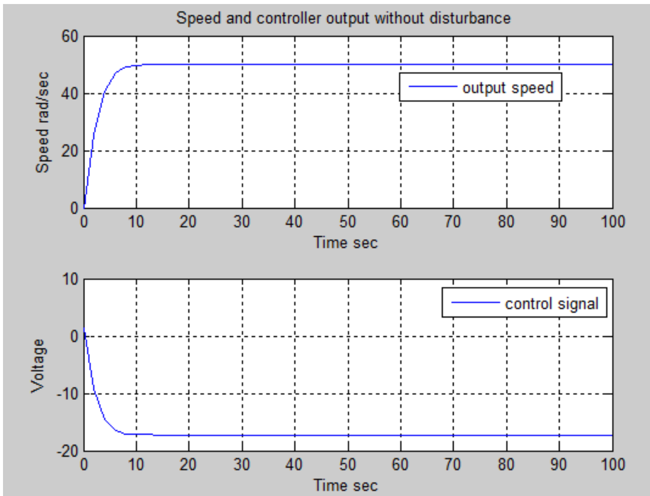

Fig.10.Pole placemen controller output at poles 0.2

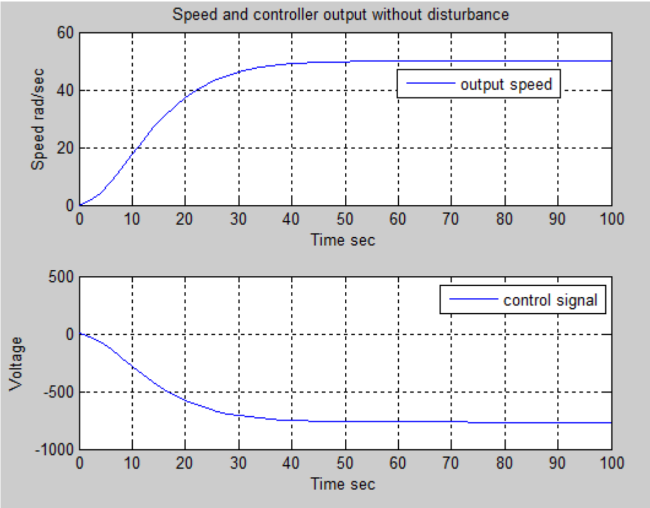

Fig.11.Pole placemen controller output at poles 0.7

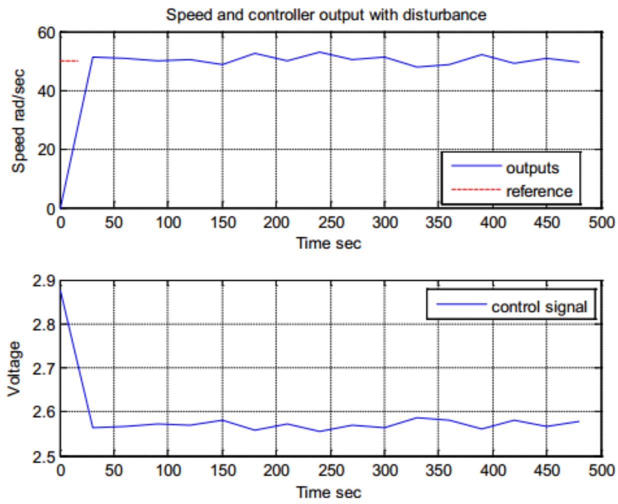

Fig.13.Dead beat controller with disturbance

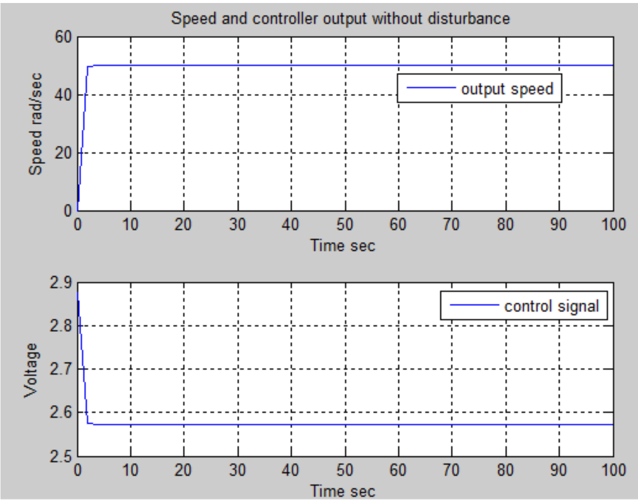

Fig.12.Dead beat controller

6.CONCLUSION

In the present paper, the control of PMDC motor is done using PID, fuzzy logic controller and pole placement controllers. From the results, it is clear that Fuzzy controller is best for control applications of PMDC motor. Chopper is also introduced in this paper to get more smooth output and less steady state error . Though, the Pole placement controller provide good results in noisy systems , but it is observed that fuzzy controller is better to sustain torque load condition as its speed remain same whatever torque load change or not.

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