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COMPARATIVE STUDY ON DC MOTOR SPEED CONTROL USING VARIOUS CONTROLLERS

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ABSTRACT*:* Electrical machines like DC motors, brushless DC motors, permanent magnet DC motors are being controlled with power electronics converters. The control has become precise with invention of Micro Controller and power devices like IGBT, Power MOSFET. In this paper the attempt is made to simulate a speed control of separately excited DC motor with PID and fuzzy controller. The aim of this paper is providing efficient method to control speed of DC motor using analog Controller. With the availability of MATLAB/SIMULINK, Fuzzy Controller for comprehensive study of modeling analysis and speed control design methods has been demonstrated.

Keywords*:* DC motor, speed control, PID controller and Fuzzy logic controller

I INTRODUCTION

The field of electrical energy will be divided into three areas: Electronics, Power and Control. Electronics basically deals with the study of semiconductor devices and circuits at lower power. Power involves generation, transmission and distribution of electrical energy. The electric motors are perhaps the most widely used energy converters in the modern machine tools and robots. These motors require automatic control of their main parameters such as speed, position, acceleration etc [1]. In this paper to control the speed of DC motor, separately excited DC drive system is used, since their simplicity, ease of applications such as reliability and favorable cost have long been a backbone of industrial applications and it will have a long tradition of use as adjustable speed machines and a wide range of options have evolved for this purpose. In these applications, the motor should be precisely controlled to give the desired performance [2].

Many varieties of control schemes such as proportional, integral, derivative, proportional plus integral (PI),proportional plus derivative(PD), proportional plus integral plus derivative(PID),Adaptive control, and Fuzzy Logic controller, have been developed for speed control of dc motors. The important aspect of the speed control of a dc motor is the armature voltage control method. By varying voltage to the armature of a dc motor, the speed of the motor can be varied.

Here mainly concentrated on speed control of separately excited DC motor. the design of a mathematical model of the separately excited DC motor using MATLAB code has been done and SIMULINK model is used for studying the performance characteristics of dc motor and mainly concentrated on the design of PID controller and Fuzzy logic controller using MATLAB/ SIMULINK environment.

II. MATHEMATICAL MODELING OF SEPARATELY EXCITED DC MOTOR

In order to build the DC motor’s transfer function, its simplified mathematical model has been used. This model consists of differential equations for the electrical part, mechanical part and the interconnection between them. The electric circuit of the armature and the free body diagram of the rotor are shown in the Fig.1 and the physical parameters of the motor are shown in Table1 [3].

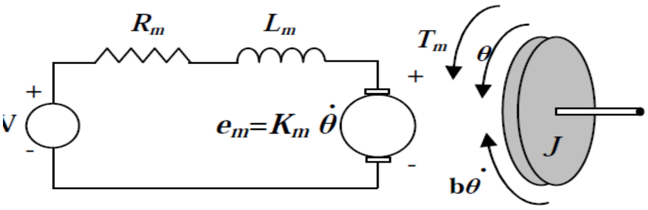

Fig.1: The electric circuit of the armature and the free body diagram of the rotor for a DC Motor

Table 1: Physical parameters of the DC motor

J	Moment of Inertia of the Rotor(kg.m^2)	0.01
B	Damping ratio of the Mechanical System (Nms)	0.1
Km	Motor Constant (Nm/A)	0.01
Rm	Motor Electric Resistance(Ω)	1
Lm	Motor Electric Inductance(H)	0.5
V	Input Voltage(Volt)	6
&	Rotating Speed(r/s)	600

From Fig.1, the following equations can be written based on Newton's law combined with Kirchhoff's laws.

$$J\ddot{\theta}+b\dot{\theta}=K_m i-T_L\ldots\ldots\ (1)$$

$$L_m\frac{di}{dt}+R_m i=V-K_m\dot{\theta}..(2)$$

The motor torque, T_m, is related to the armature current (I), by a constant factor K_t. The back emf (e_m) is related to the rotational speed by the following equations:

$$T_m=K_t I \quad \ldots\ldots\ldots\ldots(3)$$
$$e_m=K_e\dot{\theta} \quad \ldots\ldots\ldots\ldots(4)$$

Assuming that, K_t(torque constant) =K_e (electromotive force constant)

Using Laplace Transforms, the above equations (1) and (2) can be expressed in terms of s-domain.

$$s(Js+b)\dot{\theta}(s)=K_m I(s)-T_L(s)\ldots\ldots\ldots(5)$$

$$(L_m(s)+R_m)I(s)=V(s)-K_m s\theta(s)\ldots(6)$$

By eliminating I(s), the following open-loop transfer function can be obtained, where the rotational speed is the output and the voltage V is the input. When the motor is used as a component in a system, it is described by the appropriate transfer function between the motor voltage and its speed. For this purpose assuming (load torque) T_L=0, even though it will not affects the transfer function.

$$\left.\frac{\dot{\theta}(s)}{V(s)}\right|_{T_L(s)=0} = \frac{K_m}{(Js+b)(L_m s+R_m)+K_m{}^2} \quad \ldots\ldots(7)$$

This is called the transfer function of DC motor.

III. SIMULINK MODEL OF PID CONTROLLER

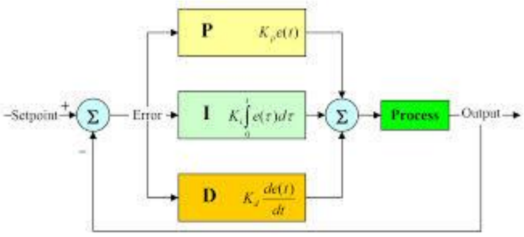

Fig.2: PID implementation

The PID control is most widely used in industrial applications. It is implemented to control the speed of DC motor which is shown in Fig.2. The error between the reference speed and the actual speed is given as input to a PID controller. The PID controller depending on the error changes its output, to control the process input such that the error is minimized. Detailed information about the theory and tuning of PID controllers is given in [4][5]. The Transfer function of a PID controller is given as,

$$C(s) = K_p\left(1 + \frac{1}{T_I * s} + T_D * s\right) \ldots\ldots\ldots\ldots (8)$$

The proportional control (K_p) is used so that the control signal u(t) responds to the error immediately. But the error is never reduced to zero and an offset error is inherently present. To remove the offset error the integral control action (T_I) is used. The Derivative control (T_D) is used to damped out oscillations in the process response. By tuning the gains of the PID controller and producing the optimum response using trial and error method. With the help of MATLAB/Simulink environment, the performance of separately excited DC motor with simulink model as shown in Fig.3 and it is tested with MATLAB/simulink corresponding test results with and without are shown in tabulated in Table 2.The response of DC motor without PID controller as shown in fig.4 and with PID controller as shown in fig. 5.

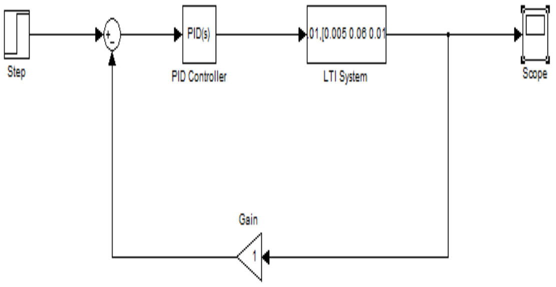

Fig.3: Simulink model of PID controller

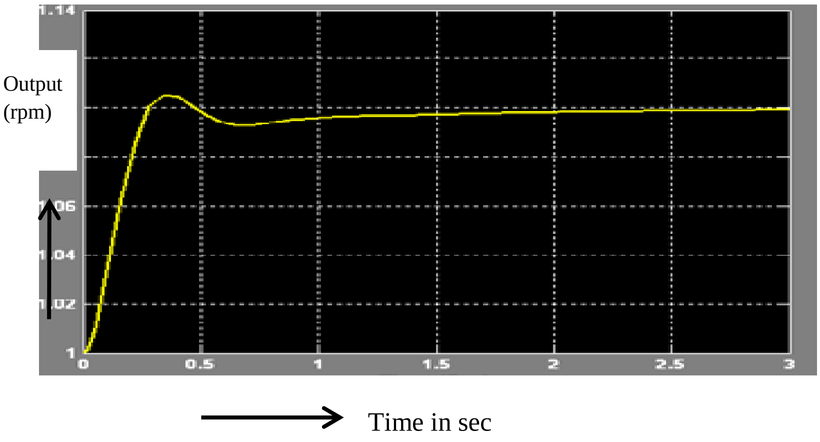

Fig.4: System Response without PID controller

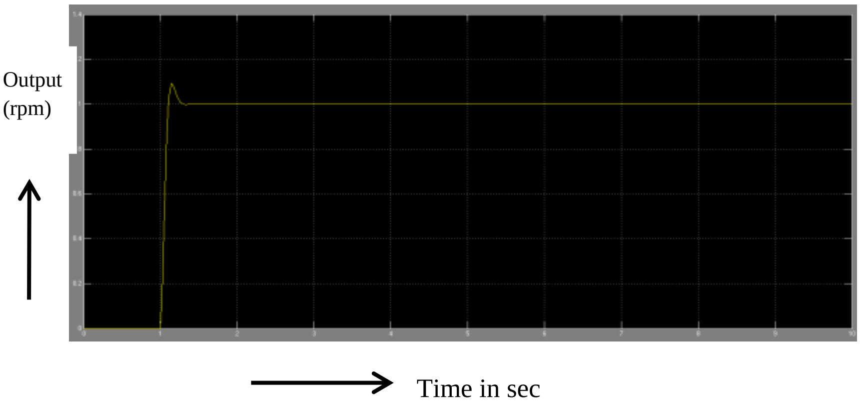

Fig.5: System Response with PID controller

Table 2: PID controller responses

Response	Without PID controller	With PID controller
Rise Time(sec)	1.1362	0.7195
Settling Time(sec)	2.900	1.6587
Overshoot(sec)	0	8.7813
Peak Time(sec)	5.2388	0.2337
Dead Time(sec)	0	1

In the above table the comparative results of with and without PID controller were provided. The rise time of without PID controller is 1.1362sec and with PID controller is 0.7195sec. The rise time response of with PID controller had got better performance than without PID controller. There is significant change of Peak time from 5.2388 seconds to 0.2337. Coming to settling time there is a drastic change from 2.900 to 1.6587. But coming to Dead time there is change from 0 to 1 sec. Coming to Overshoot time there is a drastic change from 0 to 8.7813, this is not desirable .This drawback can be overcome by fuzzy logic controller. This is discussed in the next section.

IV. FUZZY LOGIC CONTROLLER

Fuzzy logic control (FLC) is a control algorithm based on a linguistic control strategy which tries to account the human’s knowledge about how to control a system without requiring a mathematical model. The approach of the basic structure of the fuzzy logic controller system is illustrated in Fig.6.

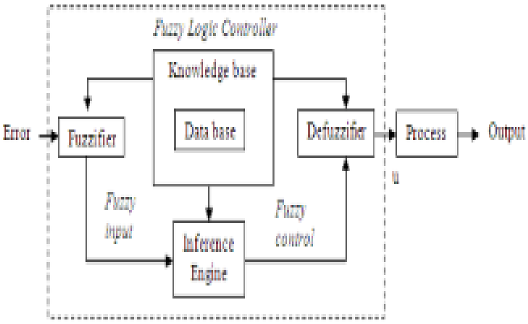

Fig.6. Fuzzy Logic Controller

The Fuzzy Logic controller consists of four basic components: fuzzification, a knowledge base, inference engine, and a defuzzification interface. Each component affects the effectiveness of the fuzzy controller and the behavior of the controlled system [6]. In the fuzzification interface, a measurement of inputs and a transformation, which converts input data into suitable linguistic variables, are performed which mimic human decision making. The results obtained by fuzzy logic depend on fuzzy inference rules and fuzzy implication operators. The knowledge base provides necessary information for linguistic control rules and the information for fuzzification and defuzzification. In the defuzzification interface, an actual control action is obtained from the results of fuzzy inference engine.

From Fig.7, shows the simulink model for FUZZY controller the Input and outputs are non-fuzzy values and the basic configuration of FLC is featured. In the system presented in this study, Mamdani type of fuzzy logic is used for speed controller. Inputs for Fuzzy Logic controller are the speed error (e) and change of speed error. Speed error is calculated with comparison between reference speed, ω ref and the actual speed, ω act.

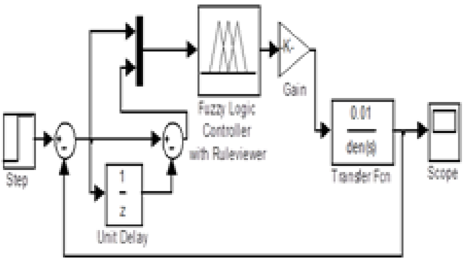

Fig.7: Simulink model of FUZZY controller

The control rules that relate the fuzzy output to the fuzzy inputs which are derived from general knowledge of the system behavior is shown in Table 3. Some of the control rules are developed using trial and error method. To illustrate the control of motor by the fuzzy rule matrix, 5valid rules from the rule matrix table are identified for Zero & Positive small of error and change in error[7]. With the help of MATLAB/SIMULINK environment, the performance of separately excited DC motor with FIZZY controller was tested and the corresponding response as shown in Fig.7 and tested results are tabulated in Table 4.

Table 3: FLC Rule Matrix Table

De **e**	**NB**	**N**	**Z**	**P**	**PB**
NB	NVB	NB	N	NS	Z
N	NB	N	NS	Z	PS
Z	N	NS	Z	PS	P
P	NS	Z	PS	P	PB
PB	Z	PS	P	PB	PVB

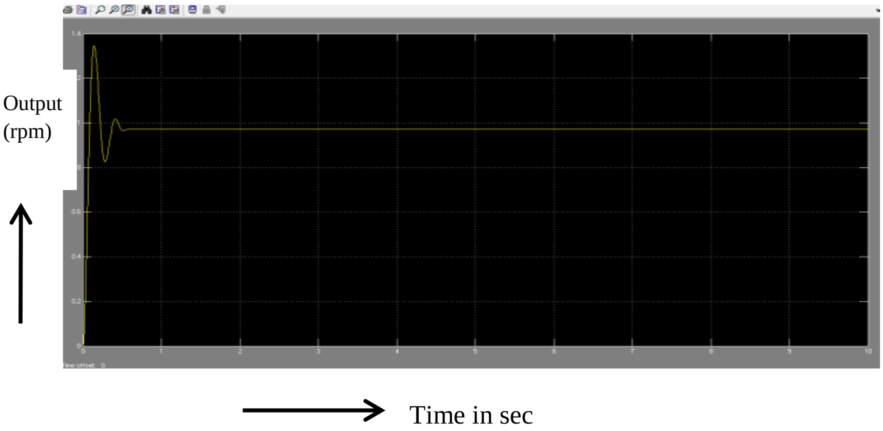

Fig.8: System Response with FUZZY controller

Table 4: Comparison of results

Response	Without PID	With PID	FUZZY
Rise Time(sec)	1.1362	0.7195	0.2
Settling Time(sec)	2.900	1.6587	0.6
Dead time(sec)	0	1	0
Peak Time(sec)	5.2388	0.2337	0
Overshoot (sec)	0	8.7813	0

The above Table.4 shows a great change in the performance of the system. However there is peak overshoot and steady state error. This steady state error can be removed by increasing the gain and peak overshoot automatically will reduce as load is employed on the system. Hence these will not pose any problem on system performance.

From Fig.8 there is no dead time in the system i.e. dead time is 0, with that of without PID controller and with PID controller as shown Table 4. i.e. dead time is 0 and 1 sec. Similarly there is a considerable decrease in rise time which is in the order of 0.2sec. This shows how fastly the system is responding it is better performance than without and with PID controller. i.e. rise time is 1.1362 and 0.7195sec. System has reached its steady state before 0.6 seconds. The settling time response of Fuzzy controller had got better performance than with and without PID controller. From Table.2 and Table.4, shows that system the performance has been improved and increases the transient response i.e. fast response system.

V.CONCLUSIONS

Speed response characteristics of separately excited dc motor were obtained by mathematical model using MATLAB coding and SIMULINK model. The response is found to be not satisfactory i.e. response doesn’t satisfy the desired design requirements like rise time, settling time, peak value, steady state error and dead time etc. There exists a dead time of 1 sec which is a major drawback to the system by conventional method.

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To overcome the above drawback we employed PID controller design, by proper tuning of K_p, K_i and K_d to improve the characteristics like steady state error. But the above designed system failed to reduce the dead time of the system. Hence in order to reduce the dead time modern technique like FUZZY controller was employed. FUZZY controller is proposed to replace conventional PID controller to improve the system characteristics. The corresponding step response is very smooth and ripples free.

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BIOGRAPHY

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