INVESTIGATION & IMPLEMENTATION OF SPEED CONTROL OF DC MOTOR

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Abstract— *DC motor is widely used in many applications like steel mills, electric trains, cranes and much more. In this paper a separately excited dc motor using MATLAB modeling, has been designed whose speed may be investigated using the Proportional, Integral, Derivative (K_P, K_I, K_D) gain of the PID controller. Since, classical controllers like P, PI and PID are failing to control the drive when weight parameters be also changed, Fuzzy logic controller gives superior speed manage result at such condition. The Fuzzy Logic controller is structural according to Fuzzy rule base such that the system are fundamentally robust, therefore Fuzzy system in 25 Fuzzy rule base, the Fuzzy Logic controller has two inputs . One is the motor error speed between the reference and actual speed, other is change in speed (speed error derivative).In this paper a comparison among P, PI, PID and fuzzy logic controller through MATLAB/Simulink software. Have been presented the obtained results are promising and is likely to be utilized by the industries.*

keywords *— DC Motor, Modelling, Simulation, P, PI & PID controller, Fuzzy logic controller, Rule base.*

1. INTRODUCTION

The improvement of great torque performance the motor drives is very essential in built-up and manufacturing used and as well as other purpose applications such as electric trains steel rolling mills, and, automatic manipulators [1].Purpose of this paper is to control the speed of dc motor for the reason that dc motor has been commonly used in commercially even though its maintenance costs are higher than other motors. Generally, a large torque performance the dc motor drive must have superior dynamic speed control tracking and load variable to perform task. The DC motor drives, because of their effortlessness, ease of application, high stability, good cost and flexibilities have long been a spine of manufacturing applications, and residential appliances where position control and speed control of motor are required. The DC motor drives are less versatile with a single phase transfer from AC to DC. An ahead instance the speed torque characteristics of DC motor drive are preferable to that of AC motor drive. A DC motors endue outstanding control of speed for deceleration, acceleration, and positioning. The DC motor drives are normally less precious for most horsepower rating. Now days, Speed control of DC motor has attracted considerable investigate and numerous methods have evolved. For speed control of DC motor, most broadly used controllers are conventional PID [2]. There are various method used to control in DC motor such as P, PI, PID (Proportional Integral Derivative) controller. Tuning of PID is therefore an important character of this implementation.

In this paper the use of a fuzzy logic controller is investigated about fuzzy inference system (FIS) has been five membership functions both are same for input and output parameters. In this paper in Mamdani-type of fuzzy inference system are used. Generally Mamdani-type Fuzzy inference system working on based of approach to human sense and verbal communication at both sides of the system, with the purpose of is, input and output [3]. *Fuzzy set theory, proposed by Lotfi A. Zadeh in 1965.* Which led to a new control method called Fuzzy Control [4]. A fluffy rationale controller gives a distinct option for the PID controller. It is a decent device for the control of frameworks that are hard to demonstrate. The control activity in fluffy rationale controllers can be communicated with basic "if-then" rules. Fuzzy controllers are more adequate than established controllers since they can cover a much more extensive scope of working conditions than traditional controllers and can work with commotion and unsettling influences of an alternate nature[5]. This paper is planned as follows; block model of separately excited DC motor and simulink, modeling of dc motor is given in part 2, conventional controllers is given in part 3, also Fuzzy Logic controller is given in section 4, in part 5, the projected method of Simulation results & discussions has been obtainable to speed control of separately excited DC motor are show in part 6, and finally, conclusion are given in part 7.

2.SEPARATRLY EXCITED DC MOTOR

The SEDC motor drive system through armature control and the voltage apply to armature of the motor is familiar without realignment the voltage functional to the field. Fig.1. shows a separately excited DC motor equivalent model (SEDC). It is assemble of the circuit model of dc motor using MATLAB/Simulink as shown in fig.2.In this a special case through the supply provided a separately to armature winding and field winding. The main a different or distinct form in these types of dc motor is with the main purpose of the field winding in does not flow the armature current because, the field winding is agitated from a separate external source of dc current**.** These systems require programmed control of their principle parameters (position, speed, acceleration, currents) [6].The DC motor is a high performance motor drive. The dc motor drive is based on the principal, when a current carrying conductor is to be found in a magnetic fields, it experience a force which has a tendency to move. This is known as motoring action or rotating function, when magnetic field and electric field work together they produce a mechanical force.

A. CRCUIT MODEL OF DC MOTOR

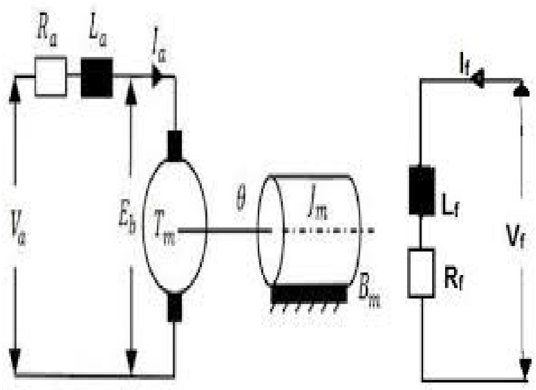

Fig.1.Separately Excited DC Motor

$$V_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t) \quad (1)$$

$$e_b(t) = K_b.\omega(t) \quad (2)$$

$$T_m = K_m.i_a(t) \quad (3)$$

$$T_m(t) = J_m.\frac{d\omega(t)}{dt} + B_m.\omega(t) \quad (4)$$

$$\frac{\omega(s)}{V_a(s)} = \frac{K_m}{L_a.J_m S^3 + (R_a.J_m + L_a.B_m)S^2 + (R_a.B_m + K_b.K_T).S} \quad (5)$$

$$\frac{\theta(s)}{V_a(s)} = \frac{K_m}{L_a.J_m S^3 + (R_a.J_m + L_a.B_m)S^2 + (R_a.B_m + K_b.K_T).S} \quad (6)$$

$$\theta(s) = \frac{1}{s}\omega(s) \quad (7)$$

Where
R_a = armature resistance (Ω- ohm).
L_a = armature inductance (H-henry).
I_a= armature current (A).
$V_a(t)$= armature voltage (V).
E_b= back emf (V).
ω = angular speed (rad/s).
T_m = motor torque (N m).
θ = angular position of rotor shaft (rad).
J_m = rotor inertia (kg m^2).
B_m = viscous friction coefficient (N_m s/rad).
K_m= motor torque constant (Nm/A).
K_b = back emf constant (V s/rad).

B. Simulink Modeling Of Dc Motor

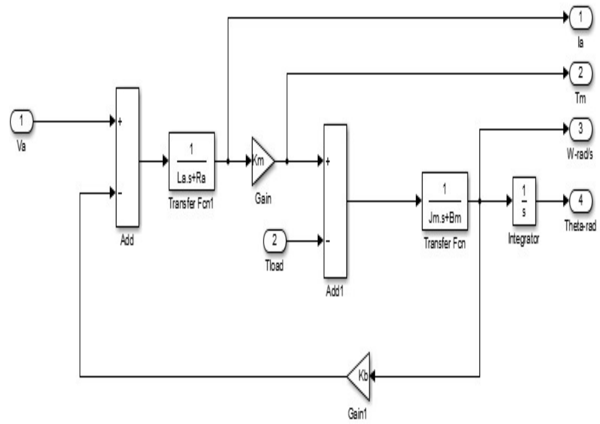

Fig.2. Simulink Modeling of DC Motor

TABLE I. DC MOTOR OF PARAMETERS

PARAMETERS	VALUE
L_a = Armature inductance (Henry) R_a = Armature resistance (ohm) J_m = Rotor inertia (kg m^2) $V_a(t)$= Armature voltage (Volt) B_m = Viscous friction coefficient(N_m s/rad) K_m= Motor torque constant (Nm/A) K_b = Back emf constant (V s/rad) ω = Speed	0.1215H 11.2 Ω 0.02215 kgm^2 240V 0.002953N_ms/rad 1.28 Nm/A 1.28 V s/rad 1500rpm

3. CONTROLLERS

A. Proportional control action

It is simplest class of continuous control law. The controller output u (t) is made proportional to the actuating error signal e (t). The proportional gain is also called proportionality constant, it is denoted by K_P and the control action is written by

$$U(t) = K_P\, e(t) \tag{8}$$

Where e (t) = r (t)-y (t) for unity response system (t) is the error signal, r (t) is reference input of the system, and y(t) is the output of the system.

B. Integral control action

In this a controller with integral control action, the value of the controller productivity is changed at a rate proportional to the actuating error signal. If there zero steady state error is desirable, this means a control mode that is a function of error will be buildup.

$$\frac{du(t)}{dt} = K_I e(t) \tag{9}$$

$$\upsilon(\tau) = K_I \int_0^t e(t)\delta(\tau) \tag{10}$$

Where is K_I an integral gain constant

C. Derivative control action

The used of integral law is sufficient to reduce the steady error to zero however, the dynamic or the transient response may still be broke because of large oscillations, overshoots etc. The derivative control law, sometimes called rate control, is therefore, the magnitude of the controller output is proportional to the rate of change of the actuating error signal.

$$\upsilon(\tau) = K_D \frac{de(t)}{dt} \tag{11}$$

D. PID Controller

PID Controller is a basic control loop of feedback mechanism and is widely used in control system. The disparate symptoms of a the DC motor such as diffusion and invention can degrade the performance of traditional controllers [7].PID Controllers use three basic types of parameter or modes: Proportional (P), Integral (I) and Derivative (D).While proportional and integral control is used as single control approach, a derivative control used is that it improves the transient response of the system. In this paper it is implemented a technique to control the speed of DC motor drive which above is shown in Fig.3. The speed error between the references speed and the actual speed is given as input to a PID controller. The PID controller working on the changes in error its productiveness,

to control the process input such that the error is reduce.Tuning of PID give complete information about the assumption and controllers [8]. A task PID controller is also known as the three-term of main controller parameter, whose transfer function is commonly written in the parallel form given by equation (12) or the ideal form is given by equation (2)[9].

General form of the Transfer function of a PID controller is given as,

$$G(S) = K_P + K_I \frac{1}{S} + K_D S \tag{12}$$

$$K_P \frac{K_I}{S} + K_D S = \frac{K_D S^2 + K_P S + K_I}{S} \tag{13}$$

$$= K_P\left(1 + \frac{1}{T_1 S} + T_D S\right) \quad (14)$$

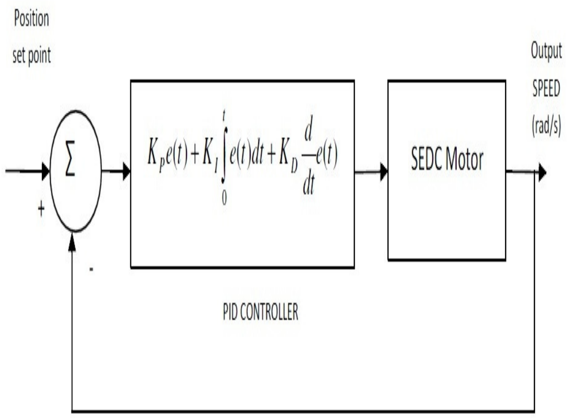

Fig.3 .PID Controller with System

Where e = Error signal
Kp = Proportional Constant
Ki= Integral Constant
Kd = Derivative Constant

$$u(t) = K_P\, e(t) + K_I \int_0^t e(t) + K_D \frac{de(t)}{dt} \quad (15)$$

TABLE.II. Tuning PID Parameters of The Controllers

Controller Parameter	**P Controller**	**PI Controller**	**PD Controller**
P (Proportional)	0.6784	0.50724	1.04683
I (Integral)	–	6.86139	11.82835
D (Derivative)	–	–	89.12201

We would like that the PID controller to propitiate the follow criteria:

- Settling time less than 2 sec
- Overshoot less than 5%
- Steady state error less than 1%

4. BASIC CONCEPT OF FUZZY LOGIC CONTROLLER

The fuzzy logic controller is based on the rule based. The fuzzy logic organization is based on the simulation of people's and judgment to control any system. One of strategy to rearrange complex framework is to endure to imprecision [10]. The operation of FLC is based on the qualitative comprehension about the system being controlled.It comprises of a data, handling and yield stages. The information or fuzzification stage maps sensor or different inputs, for example, switches, thumbwheels et cetera, to the fitting enrollment capacities and truth values. Fuzzy logic's linguistic terms are regularly communicated as sensible ramifications, for example, If-Then guidelines[11]. These tenets characterize a scope of qualities known as fuzzy membership function [12]. The operation of a FLC depends on heuristic information and semantic portrayal to perform an undertaking. The execution of the FLC is then enhanced by changing the principles and enrolment capacity. The composed FLC comprises of three segments fig.4. Shown in below [13].

- Fuzzification of input values
- Fuzzy inference
- Defuzzification of fuzzy output

In this paper fuzzy logic controller takes two input error and change in error and one output to the DC motor Where:

Change in error (CE) = Error – Previous Error

There are two basic approaches in fuzzy logic controller implementation Sugeno and Mamdani . In this paper Mamdani approach has been used.

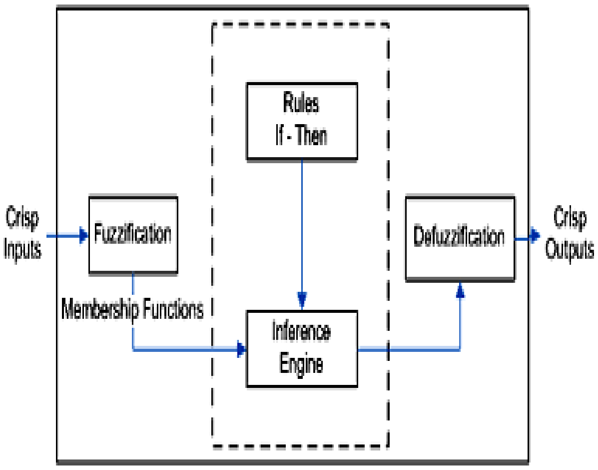

Fig.4. Configuration of Fuzzy Logic Controller

A. Fuzzification

A fuzzification interface changes the form into the crisp inputs to the fuzzy membership values [14]. Membership functions may be multiple or different form, such as the triangular waveform, trapezoidal waveform, Gaussian waveform, bell-shaped waveform, S-curve waveform, sigmoidal waveform and appropriate form [4]. In this paper triangular membership function is used. Error, Change in error and speed consist of 5 triangular membership functions.The control rules that related the fuzzy output to the fuzzy inputs which are derived from general understanding of the system performance is shown in Table III.

B. Rule Base

The set of rules is called a control rule or rule base table. The rules base based on If -Then set-up and officially the If side is known as the situation and the Then side is known the finish. The programming is able to perform the rules and split a control signal depending on the precise inputs error (e) and change in error (CE). In a rule based controller the control approach is stored in a more or less natural verbal communication. A rule base controller is easy to know and easy to maintain for a non- specialist and a correspondent controller have been implemented using techniques [5]. The linguistic variables are defined as {NL, NS, ZE, PS, PL}, where NL means negative large, NS means negative small, ZE means zero, PS means positive small and PL means positive large.

The fuzzy rules are summarized in Table III. The type of fuzzy inference engine is Mamdani used in this paper. The fuzzy inference system in this study follows as: table III rule base matrix.

TABLE III. FLC Rule Base Table

C (e) / **e**	**NL**	**NS**	**NE**	**PS**	**PL**
NL	PVL	PL	PVS	PL	PVL
NS	PVL	PL	PVS	PL	PVL
NE	PVL	PL	PS	PL	PS
PS	PVL	PL	PS	PL	PVL
PL	PL	PVL	PSP	PVL	PVL

C. Inference Engine

Computer programming through create operating information of the inference engine, this is main part of Fuzzy logic controller which processes the rules, cases, objects or other type of information and knowledge system based on the facts of a given situation. Inference engine is an information processing system (such as a computer plan) that systematically employs inference steps related to that of human being brainpower.

D. Defuzzification

Defuzzification is also called the reverse of fuzzification. The used of Fuzzy logic controller originate essential output in natural verbal communication. According to real world situations, the natural verbal communication has been to be changed to crisp output. There are multiple type defuzzification methods but Centre of gravity (COG) method is used.

E. Control Function of FLC

This process is perform in MATLAB with a five membership function type of fuzzy inference arrangement used for the input parameters, that is error and change in error is furthermore designed for the output. Control unit of this system is designed A Mamdani-type fuzzy inference system (FIS) approach is used. The design is shown in fig.5.

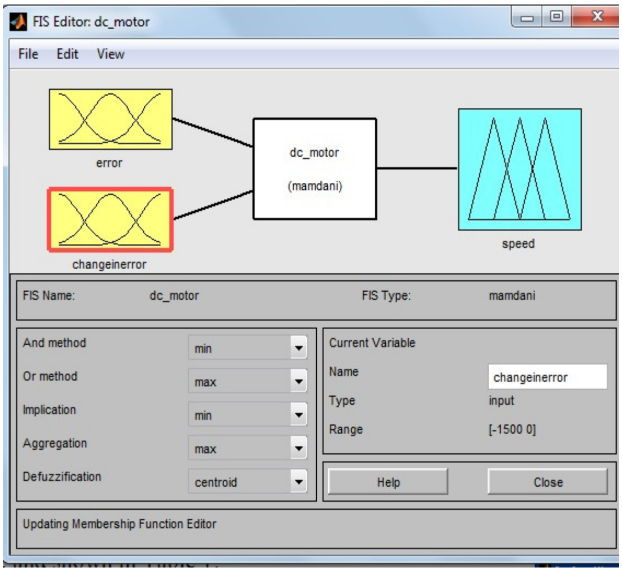

Fig. 5. Mamdani-type fuzzy logic system

Membership functions design of the input to the fuzzy logic controller shown in Fig. 6. The operational rule for the controller is set up design based on specialist knowledge base through according to table, shown in Table III.

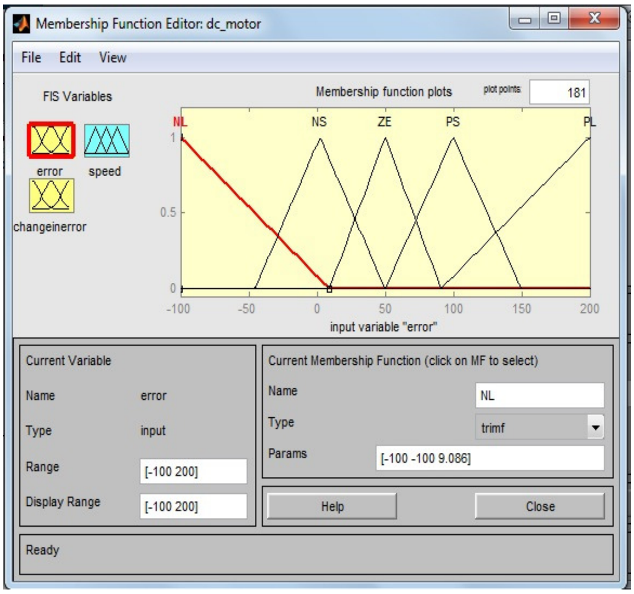

Fig.6. Membership function of the input to the fuzzy logic controller

When the fuzzy logic controller is connect to the dc motor, the simulink model for Fuzzy logic controller set up is show in Fig.7.

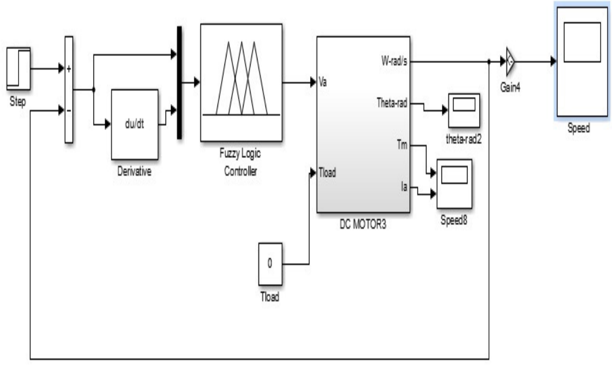

Fig. 7. Fuzzy logic controlled system

Fuzzy logic controller response of the dc motor drive is show in Fig.8. By means of an extension after recreation of framework.

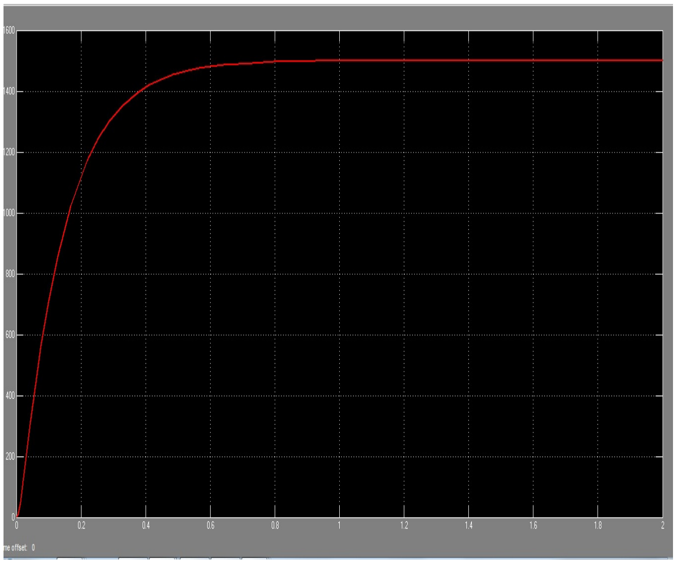

Fig.8. Response of Fuzzy Logic Controlled System

5. COMPARISON MATLAB/SIMULINK SYSTEMS MODEL OF DC MOTOR FOR P,PI,PID AND FUZZY LOGIC CONTROLLER

Finally comparison of MATLAB/simulink model of the fuzzy logic controller and the proportional-integral-derivative controller (PID) with all parameters is show in Fig.8.

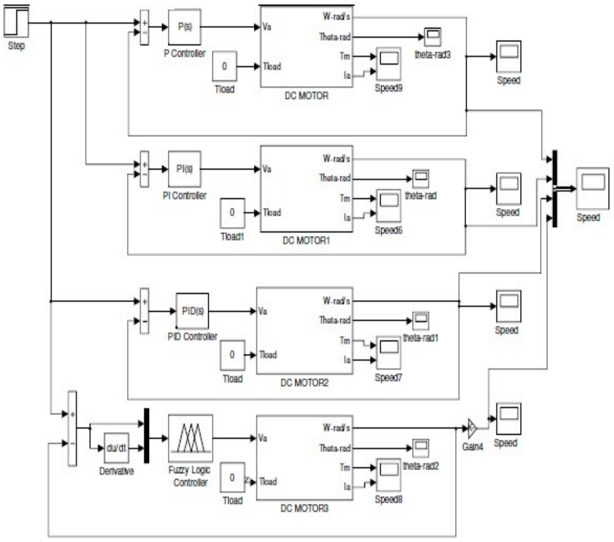

Fig. 8. Arrangement of P.PI, PID and Fuzzy logic controlled system

A. Summary of DC Motor Response for P,PI, , PID and Fuzzy Logic Controller

TABLE IV.Comparison of results of Controllers Response

Response	With P	With PI	With PID	With Fuzzy Logic
Rise Time(sec)	0.342	0.153	0.104	0.120
Settling Time(sec)	1.08	0.543	0.33	0.523
Overshoot (%)	8.37	1.11	9.19	0.5
Peak Time(sec)	0.773	0.331	0.216	0.210

From the recreation results In the above Table IV :it is inferred that by step reaction particulars utilizing Fuzzy controller The rise time of With PID controller is 0.104 sec and with FLC is 0.120sec. From these outcomes it can be see n that Fuzzy controllers have better steadiness, little overshoot and quick reaction. is superior to anything PID controller. Fuzzy controller results in less wavering at the control framework reaction. Less motion implies better controllability and less affectability to change in framework condition.

6. SIMULATION RESULT & DISCUSSIONS

The combined responses using a unit step input signal is applied in this modeling and finally comparing it with the transient response. It is shown in Fig.8. And observed table. IV.

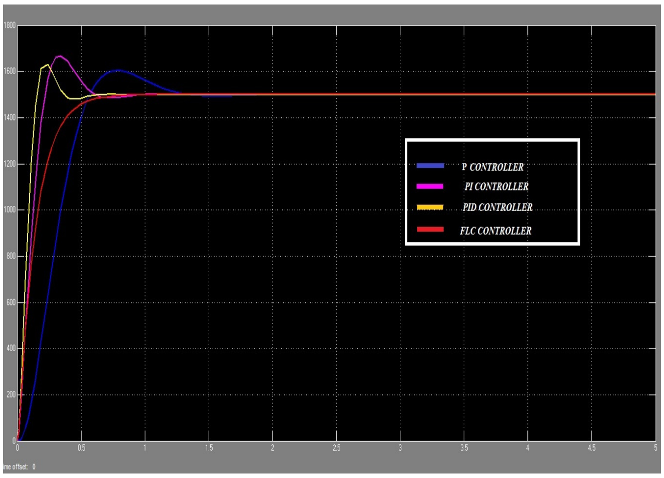

Fig.8. Combined responses of Controller

A. Discussions

The disentanglement or linearization of the non-direct framework under thought must be performed by the traditional control approaches like P, PI, and PID since their development depends on straight framework hypothesis. Thus, these controllers don't any assurance for good execution [15]. These controllers however are not prescribed for higher request and complex frameworks as they can bring about the framework to end up flimsy. Subsequently, a more heuristic methodology is required [16]. In this way, in this paper, we have learned about the essentials of DC motor drives, the fundamental theme of concern being pace control. Our center is to add to a Fuzzy Logic Based Controller in order to accomplish exactness in control. The controller endeavors to achieve a specific level of human insight by using the etymological variables rather than numerical ones. Its fundamental leeway is that it totally evades the numerical calculations, which assuages the fashioner from utilizing bulky methods. Each of the fuzzy logic controller needs is an arrangement of if-then guidelines and an information base, which can be effortlessly given by the software engineer. Consequently it gets to be less complex to execute fuzzy logic for the outline of controllers for higher request frameworks. In the task, we have composed a Fuzzy Logic Controller to be used in the pace control on DC motor. The outlining has been finished with the assistance of MATLAB/Simulink.

This controller takes in fresh inputs, viz. speed error (e) and change in error (Δe) and gives a yield called change in control. We have outline in this paper fuzzy logic (Mamdani-type) controller which demonstrates an apparent execution however not ideal. No tuning is required with Fuzzy logic based controller yet it has a slow reaction to the info flag and can't promptly foresee. The top overshoot of the framework was found to have lessened when contrasted with the before plans of the controllers. Subsequently the proposed FLC is superior to the ordinarily utilized P, PI and PID controller yet it must be enhanced in order to accomplish an ideal quality for the ascent time, settling time and peak overshoot.

7. CONCLUSION

In this paper successfully has been controlled the speed of dc motor by using Fuzzy Logic controller. The FLC approach has least amount overshoot, lower rise time, bare minimum transient and steady state parameters, which is shows more efficiency and competence of fuzzy logic controller than conventional PID controller the simulink model of speed control of dc motor show good results during simulation,the speed recovers very quickly when fuzzy logic controller being used .

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