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Analysis of Computational Technique on Speed Control of DC Motor

Lokesh Kumar[1], Dr. Kamal Sharma[2], Himansu Gupta[3]
[1]Student, M. Tech, EMGOI, Ambala
[2]Professor, Dept. of ECE, E-Max group of Institutions, Ambala
[3]Assistant Professor, Dept. of EEE, E-Max group of Institutions, Ambala

Abstract— **The currently existing complex plants cannot be accurately controlled by traditional rigorous techniques, and there is increasing needs for highly accurate control the conventional approaches for understanding and predicting the behavior of such systems based on analytical techniques can prove to be inadequate. These difficulties have lead the challenging problems of embedding the human intelligence into a machine, because there is a huge gap between the human intelligence and the machine intelligence. It has been observed that one of the major challenges in speed control of dc motor is to reduce rise time as well as peak overshoot.introduced an artificial neural network based high performance speed control system for a dc motor. Performance of the identification and control algorithms was evaluated by simulating them on a typical dc motor model.**

Keywords- **Membership function (MF)), proportional–integral–derivative controller (PID), fuzzy logic controller(FLC)**

I. Introduction

DC machines still hold a strong competitive position for industrial applications because of their attractive features. The outstanding advantage of DC machines is that they offer easily controllable characteristics. 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. Thus, the demand for DC motors would continue undiminished even in future.

1.1 CONSTRUCTION OF DC MOTOR

The stator of dc motor has poles which are excited by dc current to produce magnetic field. The rotor has ring shaped laminated iron core with slots. Coils with several turns are placed in the slots. The distance between the two legs of the coil is about 180 electric degrees. The coils are connected in series. To keep the torque on dc motor from reversing every time the coil moves through the plane perpendicular to the magnetic fields, split ring device called a commutator, is used to reverse the current at that point. The commutator consists of insulated copper segments mounted in a cylinder. The electrical contacts to the rotating ring are called "brushes". Modern motor normally use spring loaded carbon contacts. Two brushes are pressed to the commutators to permit current flow. The brushes are placed in neutral zone to reduce arcing. The stator of large DC machine consists of several poles. The interpoles reduce the field in to the neutral zone and eliminate the arcing of the commutator. A compensation winding is placed on the main poles to increase field during hard load. The iron core is supported by cast iron frame. The rotor iron core is mounted on the shaft. Coils are placed in the slots.

A dc motor is rarely installed in a situation where it is required to run at a constant speed under constant load, since an AC induction motor performs such duties satisfactorily with cost only a fraction of price of DC machine of equal power and speed and requires minimum maintenance. Many simple speed variable systems are inherently stable in operation, so that steady state behavior of DC motor is frequently all that an engineer needs to take into consideration. For simple system a DC shunt motor excited from single source is often satisfactory and provides a reasonable range of adjustable speeds and torque.

1.2 TYPES OF DC MOTOR

On the basis of excitation there are in general two types of dc motors:

- Separately excited
- Self-excited
- Separately excited dc motor

When the field winding of dc motor is connected to separate or external DC source motor is said to be separately excited dc motor. The voltage of external dc source has no relation with the armature voltage.

1.2.1 Self-exited dc motor

When the field winding is excited by its own armature, motor is said to be self-exited DC motor. A self-exited DC motor can be sub divided into two forms.

Shunt dc motor: In this type of motor, field winding is connected in parallel or in shunt with the armature. Therefore the voltage across armature terminal and shunt field is same.

Series DC motor: In this type of motor, the field winding is connected in series with armature. Therefore field current depends on the armature current.

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1.3 PRINCIPLE OF OPERATION

In any electric motor, operation is based on simple electromagnetism. A current carrying conductor generates a magnetic field when placed in an external magnetic field; so it will experience a force proportional to the current in the conductor and to the strength of the external magnetic field. The internal configuration of a DC motor is designed to harness the magnetic interaction between a current carrying conductor and an external magnetic field to generate rotational motion.

The geometry of the brushes, commutator contacts and rotor winding are such that when power is applied the polarities of the energized winding and the stator magnets are misaligned and rotor will rotate until it is almost aligned with the stator's field magnet. As the rotor reaches alignment the brushes move to the next commutator contact and energize the next winding. Current direction change as the conductor passes through the neutral zone.

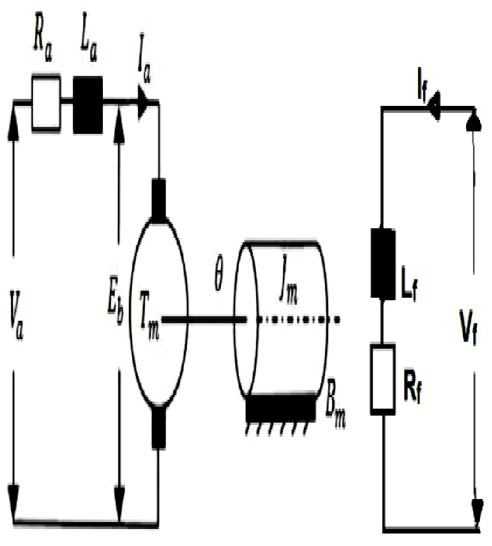

Figure.1.1: model of Separately excited DC motor model

1.4 TORQUE SPEED CHARATERISTIC OF DC MOTOR

In case of DC shunt motor, for larger torque, larger armature current is required and this has the effect of reducing the air gap flux due to saturation and armature reaction. As a result, the speed drops more rapidly with the increase of torque. In case of dc series motor if saturation and armature reaction are neglected then speed torque characteristic is a hyperbola. Above a certain value of torque speed torque characteristic approaches a straight line i.e. speed drop at increased load torque is almost negligible. Figure 1.2 shows the relation among speed ,torque and power.For ω_{base} to the be the base speed which corresponds to the rated V_a, rated I_a and rated I_f. the complete region can be divided into two sub regions:

• Constant Torque region ($\omega > w_{base}$) In this region I_a and I_f are maintained constant to meet torque demands. V_a is varied to control the speed. As a result power increases with speed.

• Constant Power region ($\omega > w_{base}$) In this region V_a is maintained at the rated value and I_f is reduced to increase speed. However, the power developed by the motor (= torque x speed) remains constant. This phenomenon is known as field weakening.

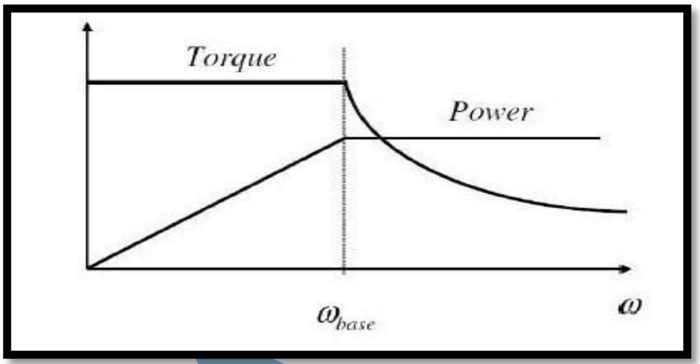

Figure 1.2 the relation among speed ,torque and power

1.5 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

II. RECENT WORK

The currently existing complex plants cannot be accurately controlled by traditional rigorous techniques, and there is increasing needs for highly accurate control the conventional approaches for understanding and predicting the behavior of such systems based on analytical techniques can prove to be inadequate. These difficulties has lead the challenging problems of embedding the human intelligence into a machine, because there is a huge gap between the human intelligence and the machine intelligence. A number of computational techniques have also been developed by imitating the human/natural intelligence. These techniques are known as intelligent techniques. Some of intelligent techniques are:

- Fuzzy Logic
- Neural Network

III. DISCUSSION OF RESULTS

3.1 PID CONTROLLER

A proportional–integral–derivative controller (PID controller) is a generic control loop feedback mechanism (controller) widely used in industrial control systems – a PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting process control inputs. In the absence of knowledge of the underlying process, a PID controller process control inputs. In the absence of knowledge of the underlying process, a PID controller is the best controller. However, for best performance, the PID parameters used in calculation must be

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tuned according to nature of the system-while the design is generic, the parameters depend on the specific system.

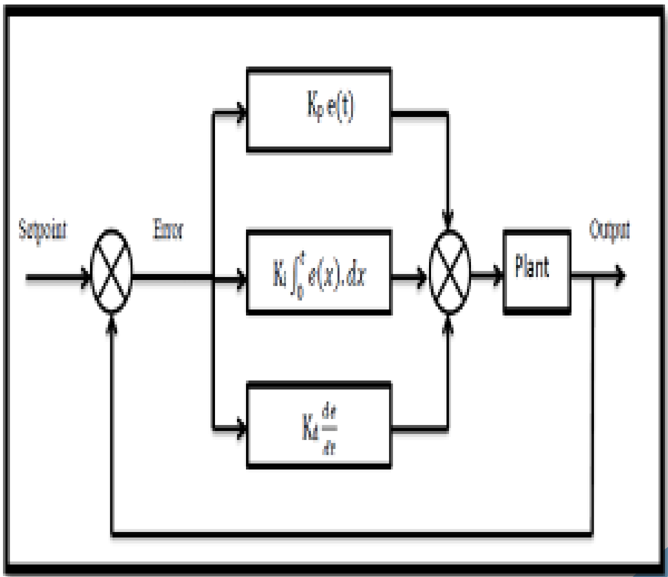

Figure 3.1:- Block diagram of PID controller

The PID controller calculation (algorithm) involves three separate parameters, and is accordingly sometimes called three-term control: the proportional, the integral and derivative values, denoted P, I, and D. Block diagram of PID controller is shown in Figure 3.1.The proportional value determines the reaction to the current error, the integral value determines the reaction based on the sum of recent errors, and the derivative value determines the reaction based on the rate at which the error has been changing. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve or the power supply of a heating element. Heuristically, these values can be interpreted in terms of time: P depends on the persent error, I on the accumulation of past errors, and D is a prediction of future errors, based on current rate of change. By tuning the three constants in the PID controller algorithm, the controller can provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the set point and the degree of system oscillation. The use of the PID algorithm for control does not guarantee optimal control of the system or system stability. For PID controller presented in (Figure 3.1), Output of PID controller is

$$U(t) = K_P\ e(t) + K_I \int_0^t e(x)dx + K_d \frac{de(t)}{dt}$$

Where,
Error, e(t)= set-point of plant output
K_P = proportional gain,
K_I = Integral gain,
K_d = derivative gain

3.2.1 Steps for implementation of PID controller

Simulink model of PID controller is connected with the motor transfer function as we give 20 rad/sec as a reference speed. The Simulink model of chopper driven separately excited D.C motor using PID controller is shown in fig 3.2. Reference speed is set equal to 20 rad/sec.The proportional gain K_P, integral gain K_I, and derivative gain K_D, represent the strengths of different control action. Proportional action can reduce the steady-state error, but too much of it can cause the stability to deteriorate. Integral action will eliminate the steady-state. Derivative action will improve the closed loop stability. The gains used for PID controller have been calculated using Ziegler Nichols.The values K_P, K_I , K_d by use of this method are as follows

K_p=18,
K_i=12,
K_d=8.

In fig 3.2 shows the simulink model of PID controller and fig 3.3 shows the PID gains used in simulink model.

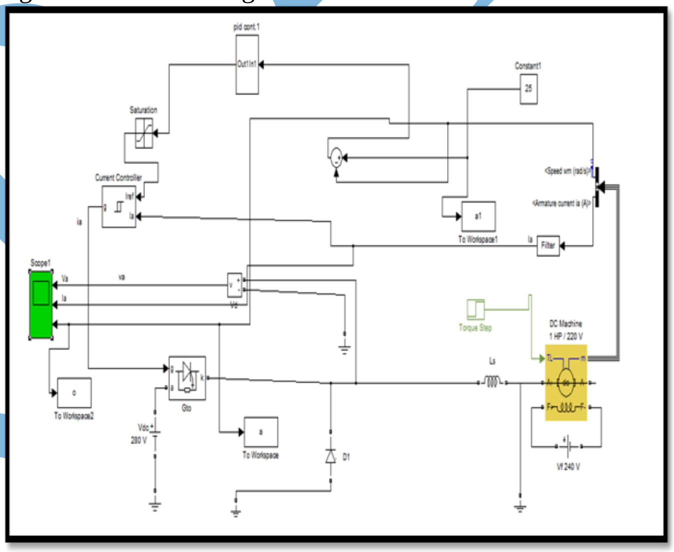

Figure 3.2: The Simulink model of PID controller

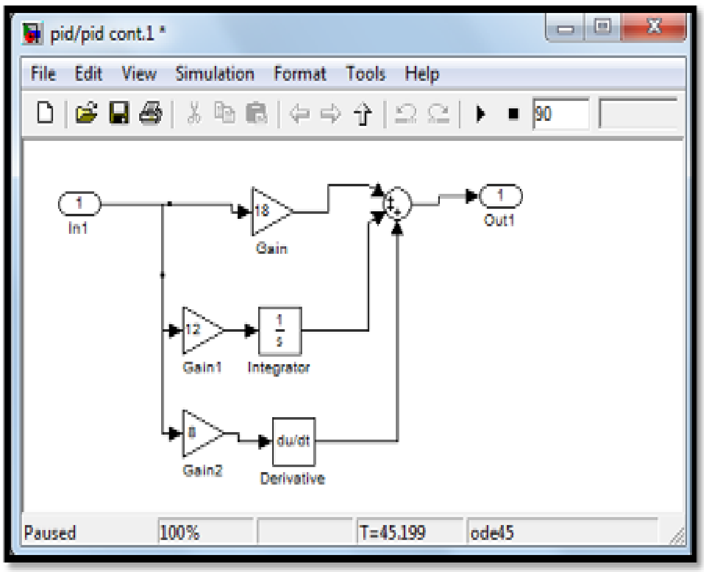

Figure3.3: The PID gains

3.2.2 Fuzzy tuned PID Controller

Structure of fuzzy tuned PID controller is shown in fig 3.5.The FLC is added to the conventional PID controller to adjust the parameters of the PID controller on-line according to the change of the signals error and change of the error. The controller proposed also contain a scaling gains inputs (K_e, $K\Delta_e$) as shown in fig 3.4, to satisfy the operational ranges (the universe of discourse) making them more general.

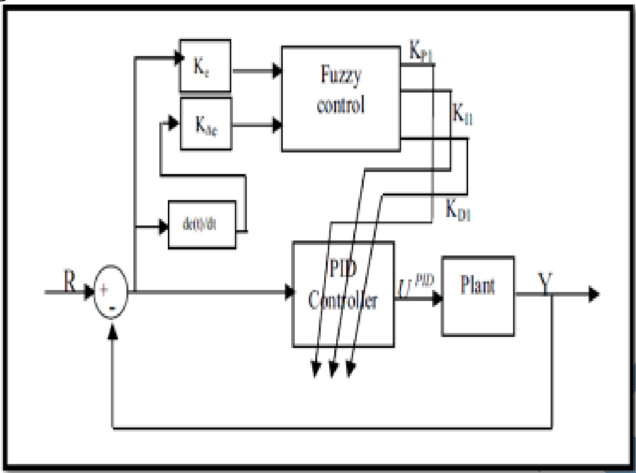

Fig.3.4: Fuzzy tuning proposed.

Simulink model of proposed controller is shown in figure 3.5 and figure 3.6 shows the sub system representing fuzzy PID controller.

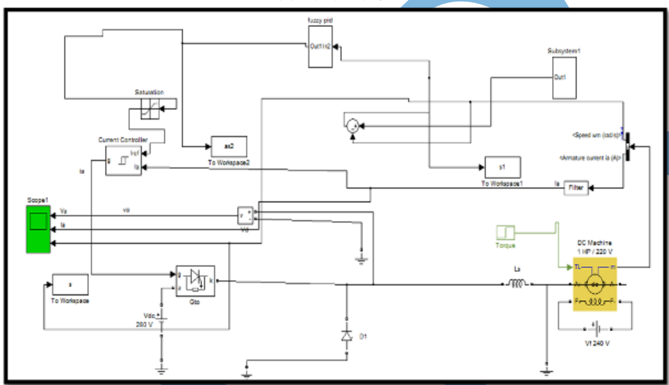

fig.3.5 simulink model of fuzzy PID controller

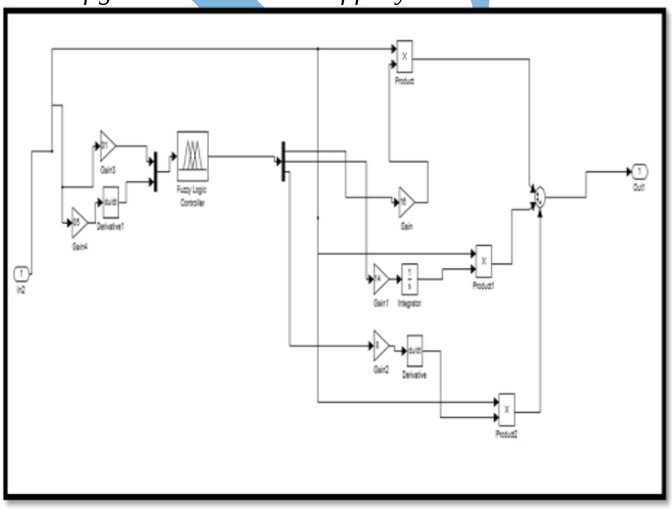

Fig 3.6 fuzzy PID subsystem

3.2.3 Implementation of FLC Used for tuning PID controller

The FIS editor for proposed fuzzy logic controller is shown in figure 3.7. two inputs used are error(e) and derivative of error(e*) and three outputs K_p, K_i, K_d.

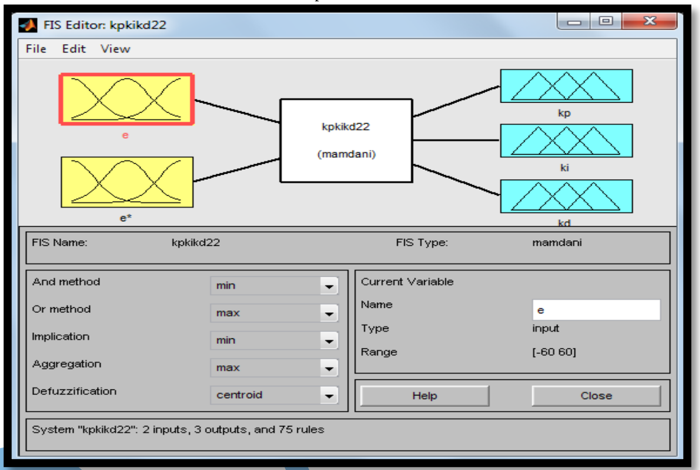

Figure3.7:Fis Editior for fuzzy

UOD for error (e) variables is [-60 60]. UOD for error (e*) variables is [-800 800].There is one output variable (c), for which UOD used is [0 1].Figure. 3.7a and 3.7b shows the membership function used for input variables.

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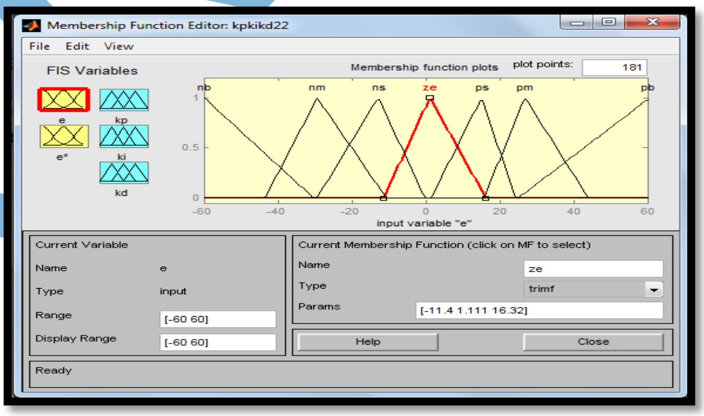

Figure. 3.7(a)

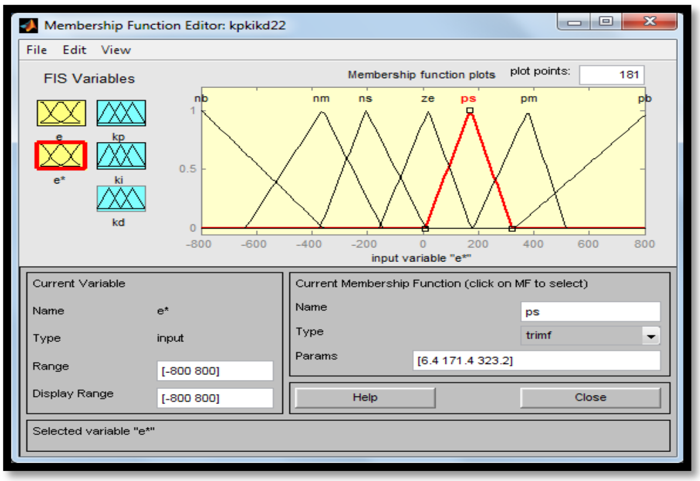

Figure. 3.7(b)

The member ships functions used for output variables of outputs (K_{P1}, K_{I1}, and K_{D1}) are shown in figure .3.7c

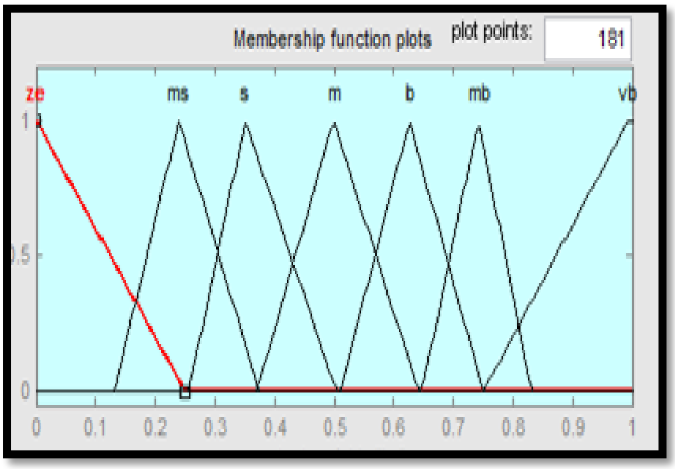

Figure. 3.7c Member ships functions of outputs (K_{P1}, K_{I1}, and K_{D1}).

The structure of the rule base used for three output variables can be visualized from table (i), (ii) and (iii)

ė/e	NB	NS	ZE	PS	PB
NB	VB	VB	VB	VB	VB
NS	B	B	B	MB	VB
ZE	ZE	ZE	MS	S	S
PS	B	B	B	MB	VB
PB	VB	VB	VB	VB	VB

Table 3.1

ė/e	NB	NS	ZE	PS	PB
NB	M	M	M	M	M
NS	S	S	S	S	S
ZE	MS	MS	ZE	MS	MS
PS	S	S	S	S	S
PB	M	M	M	M	M

Table 3.2

ė/e	NB	NS	ZE	PS	PB
NB	ZE	S	M	MB	VB
NS	S	B	MB	VB	VB
ZE	M	MB	MB	VB	VB
PS	B	VB	VB	VB	VB
PB	VB	VB	VB	VB	VB

Table 3.3

IV. COMPARISION BETWEEN METHODS

The speed control of a DC motor drive is done using various controllers such as chopper PI, PID, Fuzzy PID

The speed time characteristics obtained with the help of different controllers with a reference speed of 20 rad/sec is shown in figure 4.1

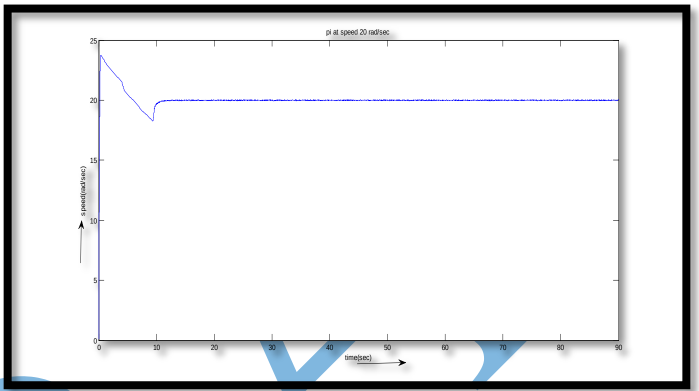

Fig-4.1 PI

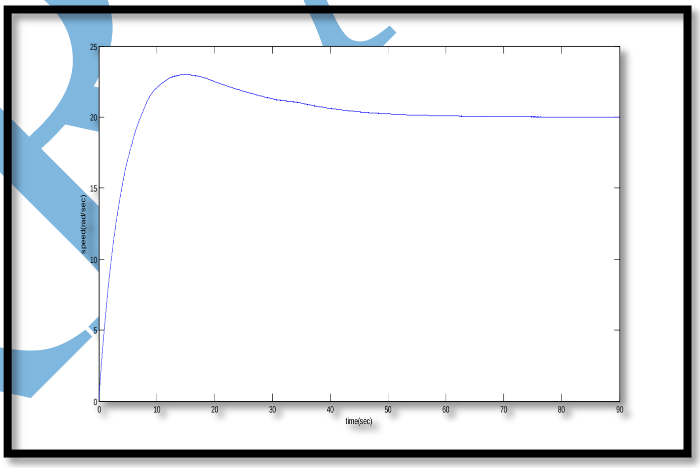

Fig -4.2 PID

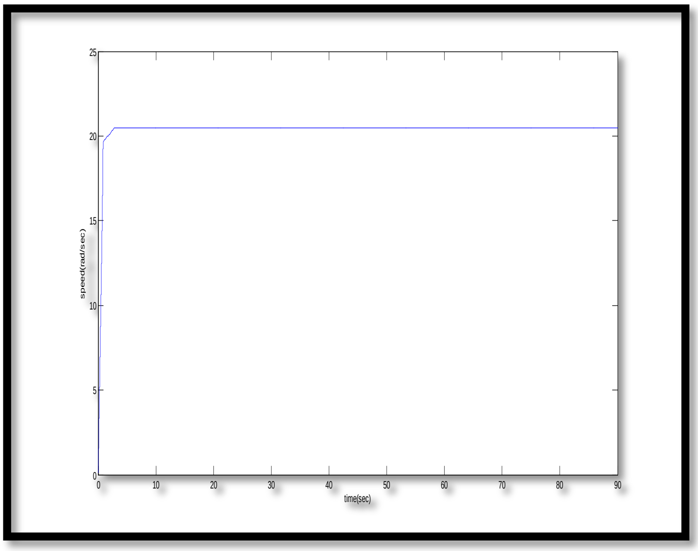

Fig -4.3 self tuned fuzzy

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Figure4.1: The speed time characteristic obtained with the help of different controllers at a reference speed of 20 rad/sec (a).PI (b).PID (c). Self tuned Fuzzy

Parameters ⇓	Controllers ⇒	PI	PID	SELF TUNED FLC
Settling Time (sec)		9.9	6.8	2.4
Max. overshoot (rad/sec)		3.58	3.00	00
Max. undershoot (rad/sec)		1.63	00	00
Steady state error (rad/sec)		0.000	0.000	0.42

Table 4.1 performance with different controllers

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

This controller gives the satisfactory performance even for variable speed as shown in fig 4.2

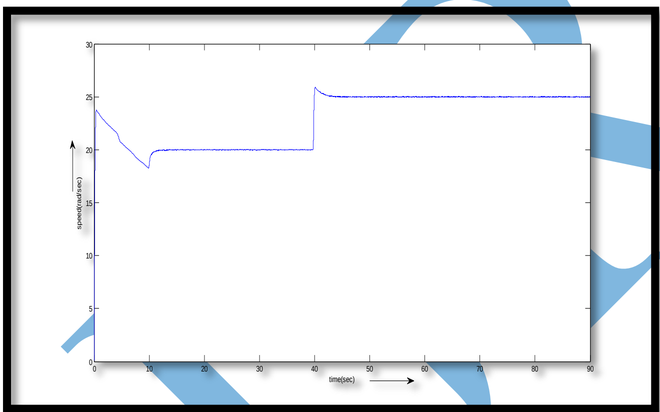

Fig-4.4 PI

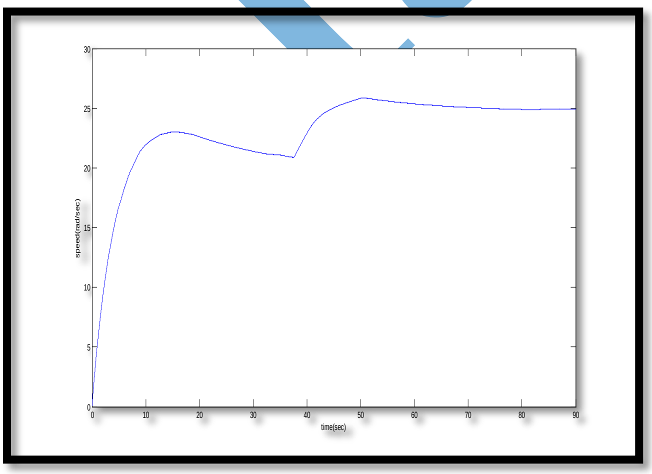

Fig -4.5 PID

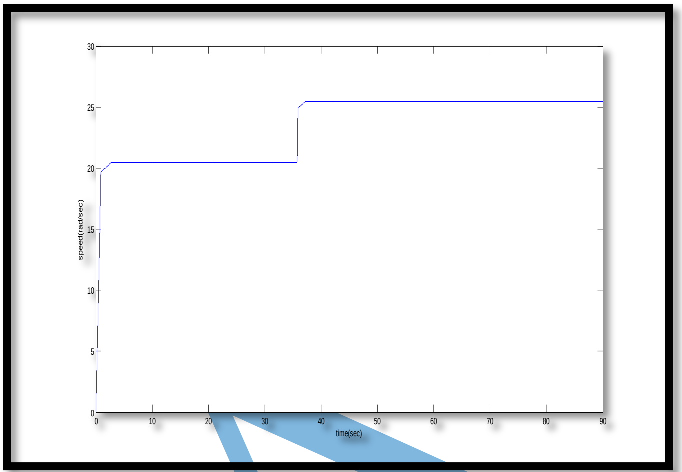

Fig -4.6 self tuned fuzzy

Figure4.2:The speed time characteristics obtained with different controllers with a change in reference speed from 20 to 25 rad/sec at a time interval of 40 sec (4.4).PI (4.5).PID (4.6). Self tuned Fuzzy.

V. CONCLUSION

The intelligent controllers result in improvement of speed of response of system. Hybrid control schemes such as GA-FUZZY PID controller results in better responses than fuzzy controller when used separately.

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