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Performance Analysis of optimization techniques and Intelligence Techniques for speed control of DC motor

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Abstract: Aim of This paper Performance Analysis of controllers such as PID controller, fuzzy logic controller and G.A based PID for speed control of DC motor. Simulation results have established that the use of Self Tuned fuzzy logic and GA-PID results in a good dynamic behaviour of the DC motor, a great speed tracking with lowest overshoot, gives better performance and high forcefulness than those obtained by use of the other controller. The DC motor is broadly used in many applications like steel mills, electric trains, cranes and much more. In this paper a separately excited dc motor using MATLAB modelling has been outlined whose velocity might be examined utilizing the Proportional, Integral, Derivative (KP, KI , KD) addition of the PID controller. Since, established controllers PID are neglecting to control the drive when weight parameters be likewise changed The principle point of this paper is to dissect the execution of Optimization techniques viz. The Genetic Algorithm (GA) for improve PID controllers parameters for speed control of DC motor and list their points of interest over the traditional tuning strategies. The output speed error and its derivative as feedback damping signals. Through this simulation the performance of the GA-PID is compared with that of the Fuzzy Logic controller. The GA-PID optimized but FLC gives better performance in terms of delay time, peak time, steady state error.

Keywords: DC motor, PID controller, Optimization techniques Genetic algorithm (GA), Objective function, IAE, Fuzzy logic.

I. INTRODUCTION

The change of incredible torque execution the motor drives is exceptionally key in developed and assembling utilized and other reason applications, for example, electric trains steel moving factories, and, programmed controllers [1].Purpose of this paper is to control the speed of dc motor for the reason that dc motor has been generally utilized as a part of financially despite the fact that its support expenses are higher than different motor. For the most part, an extensive torque execution the dc motor drive must have predominant element speed control following and load variable to perform undertaking. The DC motor drives are regularly less valuable for most pull rating. Presently days, Speed control of DC motor has pulled in impressive explore and various strategies have advanced. For pace control of DC motor, most generally used controllers are conventional PID [2]. DC drives have simplicity, ease of application, flexibility, high reliability and favourable cost The controllers that desired to control the speed of DC motor are of several conventional and numeric types e.g. Proportional Integral (PI), Proportional Integral Derivative (PID), Fuzzy Logic Controller (FLC) or combinations of them e.g. Fuzzy-NN, Fuzzy-GA, Fuzzy-Ants Colony, Fuzzy-Swarm. The Proportional Integral Derivative (PID) controller operates in majority of the control systems in the world [3] typically; the DC engine drive frameworks have uncertain and nonlinear sort which degenerate execution of controllers. In view of these reasons Proportional-Integral-Derivative (PID) controllers have been successfully utilized as a part of control applications since 1940s and are the generally commonly utilized mechanical controllers today. PID controllers cover various noteworthy sorts. It gives input. As PD enhances Transient reaction (i.e. it have the capacity to expect the progressions amid subordinate activity) and PI enhances execution of consistent state reaction (i.e. lessen enduring state

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balance amid fundamental activity or law), mix of two might be utilized to advance general time reaction of the framework. Notwithstanding this, PID controllers have exceptionally uncomplicated control structure and are less expensive [4]. The target of this paper is to investigate the execution of Genetic Algorithm (GA) for ideal tuning of PID controllers parameters and count their points of interest over the ordinary tuning systems Genetic Algorithms (GA) are versatile heuristic inquiry taking into account transformative thoughts of normal choice and hereditary qualities. Hereditary Algorithms are powerful and clever decisions under the most favourable conditions arrangement among the space of every attainable arrangement. The Genetic Algorithms were utilized to assess the ideal PID controller addition values where performance indices, IAE were utilized as the objective function. It was tentatively established that the Integral of Absolute Magnitude of the error (IAE) execution foundation delivers the best PID controller when contrasted and other execution paradigm. The proposed procedures were confirmed utilizing a third order physical model of plant as DC motor (separately excited dc motor) where tuning calculations were driven for the most part by the obtained framework information and the coveted execution parameters determined by the client are effectively fulfilled. Resultant upgrades on the stride reaction conduct of DC motor speed control framework are appeared for two cases. This paper is composed as takes after: system modelling of DC motor is displayed in Section II, PID controller brief describe in section III, brief prologue to genetic algorithm is talked about in Section IV, main work of this paper describe in section V as a tuned methodology and last two Section VI and VII individually describe simulation result and conclusion of this paper speed control of dc motor.

II. 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. Figure.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 Figure.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. DC motors gives outstanding control of speed for motors require of their main parameters such as position, speed, acceleration etc [5]. 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.

Circuit Model of DC Motor

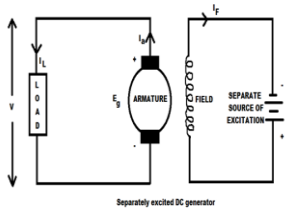

Figure 1: Separately Excited DC Motor.

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

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

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

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

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

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

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

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).

Simulink Modelling of Dc Motor

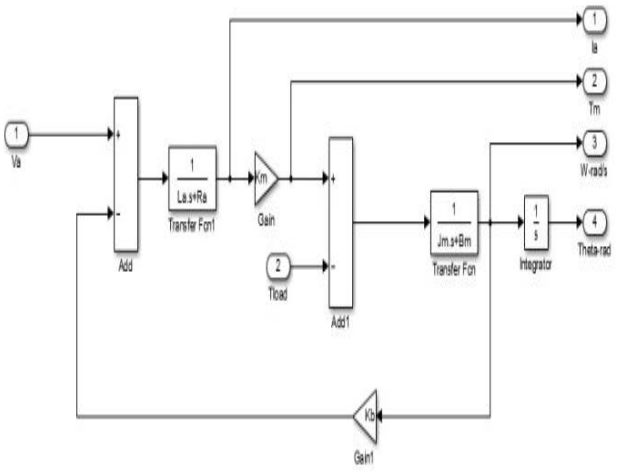

Figure 2: Simulink Modeling of DC Motor

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

Table 1: DC motor of parameters

III. PID CONTROLLER

PID controllers have been for the most part used for control framework. The most essential step for applying the PID controller is the tuning of its parameters. The tuning handle needs an extensive measure of time and effort. In the most sceptical situation, the awful tuning prompts a poor execution of the controlled system. PID Controller is a crucial control circle of info segment and is by and large used as a piece of control structure. The distinctive reactions of a the DC motor, for instance, scattering and creation can corrupt the execution of standard controllers [6].PID Controllers use three vital sorts of parameter or modes: Proportional (P), Integral (I) and Derivative (D).While comparing and indispensable control is used as single control approach, a subordinate control used is that it upgrades the transient reaction of the framework. In this paper it is executed a methodology to control the pace of DC motor drive which above is showed up in Figure.2. The speed botch between the references speed and the honest to goodness rate is given as information to a PID controller. The PID controller taking a shot at the modification in oversight its productiveness, to control the technique information such that the screw up is decreases. Tuning of PID give complete information about the suspicion and controllers [7].The goal of the tuning methodology is to choose the PID controller parameters that satisfy the execution points of interest of the controlled system, for instance, the rising time, the most amazing overshot, the settling time and steady state error . In any case, it is difficult to gain the charming estimations of these necessities in the meantime. As showed up in Table I, for case, greater estimations of relative expansion results in speedier response while overshoot is extended. Consequently, a perfect tuning strategy is of phenomenal essentialness. PID Controller is a noteworthy control circle of input instrument and is exhaustively utilized as a bit of control system. The novel indications of the DC motor , for example, disseminating and improvement can decline the execution of standard controllers [8].PID Controllers utilize three vital sorts of parameter or modes: Proportional (P), Integral (I) and Derivative (D). PID controller as showed up in appeared in Fig. 3. The PID controller taking a shot at the adjustments in misunderstanding its productiveness, to control the procedure data such that the goof is diminishes. PID controller is for the most part called the three-term of rule controller parameter, whose exchange farthest point is routinely made in the parallel structure given by relationship (12) or the perfect structure is given by numerical clarification (2) [9].An undertaking PID controller is generally called the three-term of essential controller parameter, whose trade limit is conventionally made in the parallel structure given by examination (12) or the ideal structure is given by scientific proclamation (2). General form of the Transfer function of a PID controller is given as,

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

$$K_P \frac{K_I}{S} + K_D S = \frac{(K_D S^2 + K_P S + K_I)}{S} \qquad (13)$$

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

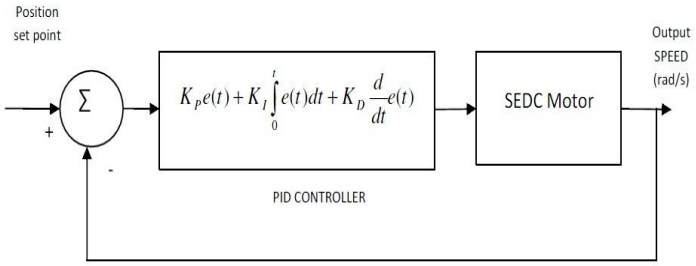

Figure 3: PID Controller with System

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

Parameter	Rise Time	Overshoot	Settling time	Steady state error
K_p	Decrease	Increase	Small change	Decrease
K_I	Decrease	Increase	Increase	Reduce
K_D	Small change	Decrease	Decrease	Small change

Table 2: Effects of increasing the pid controller parameters.

IV. GENETIC ALGORITHM

The genetic algorithm is a technique for explaining both compelled and unconstrained enhancement issues that depends on normal choice [10].]. genetic algorithms fit in with the bigger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover [11].The GAs were initially proposed by John Holland in 1970 [12]. As a way to discover great answers for issues that were generally computationally unmanageable. Holland's composition hypothesis, this hypothesis is likewise called the basic hypothesis of hereditary calculations, is broadly taken to be the establishment for clarifications of the force of hereditary calculations. It says that short, low request schemata with above-normal wellness increment exponentially in progressive eras [9].In this paper, GA is utilized to decide the ideal estimations of the PID controller parameters that fulfil the required element execution qualities of the DC motor drive

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system. Fig. 3 demonstrates the steps of procedure GA based tuning of PID controller parameters. In the primary, GA is introduced. At that point, it makes a starting populace of PID controller parameters. The populace is created haphazardly, covering the whole scope of conceivable arrangements. The populace is made out of chromosomes. Every chromosome is a competitor answer for the issue. Fig.4 demonstrates the chromosome structure, in which the three parameters (Kp, Ki and Kd) are incorporated. The chromosomes are connected in the DC motor drive system and the dynamic execution attributes of the system are resolved for every chromosome. At that point, the wellness esteem for every chromosome is assessed utilizing the goal capacity. In light of the wellness estimations of the original, a gathering of best chromosomes is chosen to make the following populace. After choice, hybrid and change are connected to this surviving populace so as to enhance the following generation [13]. The procedure proceeds until the end standard is accomplished or the quantity of eras is come to its greatest worth. Hereditary calculation is likewise talked about in part 3 the stream graph of GA is appeared in figure (5). Creating the beginning populace is the initial step of GAs. The populace is made out of the chromosomes that are parallel piece string. The relating assessment of a populace is known as the (wellness work) the wellness quality is greater and the execution is better

K_P	K_I	K_D

Figure 4: Chromosome structure.

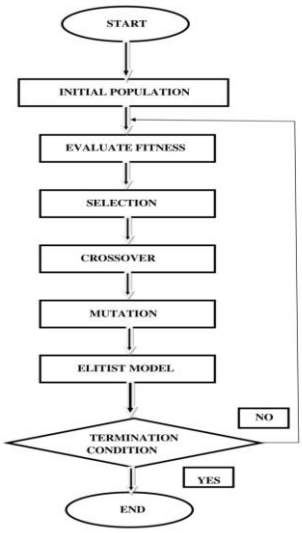

Figure 5: Flowchart of GA for PID tuning

V. FUNDAMENTAL OF FUZZY LOGIC CONTROLLER

Fuzzy logic provides an approximate effective mean of describing the behaviour of some complex system. Unlike traditional logic type, Fuzzy logic aspire to model the vague modes of human reasoning and decision making, which are essential to our ability to make rational decisions in situations of uncertainty and imprecision [14]. Fuzzy logic can be employed to evaluate output variable when an exact mathematical relation of the output variable with input variable not be formulated. Fuzzy logic deal with linguistic variable. The input variable is characterized by membership

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function. A Fuzzy system is represented by input linguistic variables, output linguistic variables along with definitions of linguistic terms and Fuzzy IF-THEN rule base. Basic block diagram of Fuzzy logic controller is shown in the figure.

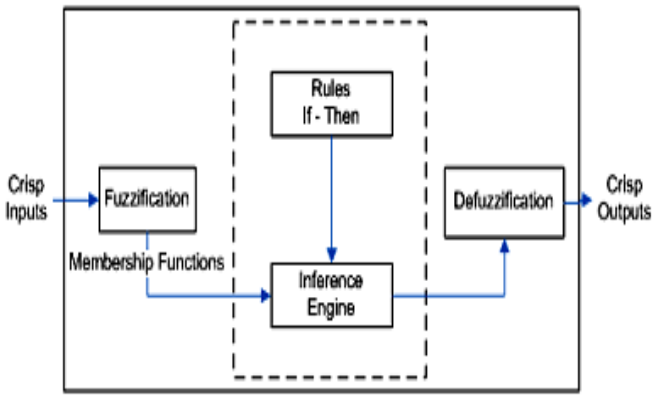

Figure 6: Configuration of Fuzzy Logic Controller

The Fuzzy Logic controller consists of four fundamental components: fuzzification, a inference engine, knowledge base, and a defuzzification. Each section affects the success of the fuzzy controller and the behaviour of the controlled system [16]. 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 [17].

The Fuzzy inference algorithm implement using Fuzzy IF-THEN rules in a large domain of practical problems such as control, classification, pattern recognition, diagnostics, modeling, and general decision making. There are three principal elements to a Fuzzy logic controller

- Fuzzification module (Fuzzifier)
- Rule base and Inference engine
- Defuzzification module (Defuzzifier)

VI. TUNING METHODOLOGY

Conventional PID controller Tuning Method

Keeping in mind the end goal to decide the parameters of the routine PID controller utilizing delicate figuring tuning as a part of a MATLAB is created. The stride reaction of the uncontrolled DC motor is appeared in Figure 6. It is clear that the uncontrolled DC motor has a reasonable step reaction since the settling time is very poor and not proper working condition second of the reference speed. Then applying PID controller whose speed may be investigated using The Proportional, Integral, Derivative (K_P, K_I, and KD) gain of the PID controller. Since, classical controllers PID are failing to control the drive when load parameters be also changed The main aim of this paper is to analyse the implementation of Evolutionary Computation (EC) techniques viz. Genetic Algorithm (GA) for optimize PID controllers parameters for speed control of dc motor and enumerate their advantages over the conventional tuning methodologies**.** The emphasis point is resolved, the digression line is drawn.

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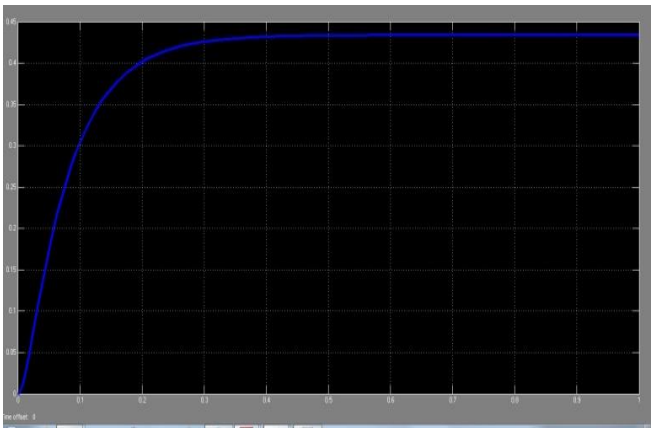

Figure 7: Step input of uncontrolled DC motor drive system

GA-based optimization

The fitness function is the key to use the GA [14]. The most essential stride in applying GA tuning strategy is to pick the target work that is utilized to assess the fitness value of every chromosome. In this paper, an objective functions are utilized and their execution is looked at. The first depends on integral of the absolute error (IAE) index and these papers in objective function additionally plan through the MATLAB coding. The parameters of GAs in this study are set as in Table IV. The GA advancement process based IAE index Fig. 6. For every case, the PID controller parameters are resolved. The objective function is given as:

$$IAE = \int_0^T |e(t)|\, dt \quad (16)$$

Parameter	Value
Lower bound [Kp Ki Kd]	[0 0 0]
Upper bound [Kp Ki Kd]	[500 500 500]
Populations	25
Generations	50
Population type	Double vector
Ranges of PID parameters	0-500
Crossover fraction	0.8
Mutation rate	0.01
Elite count	5
Selection function	Tournament
Plot function	Best fitness, Best individual

Table 3: Settings of GA parameters values

The planned PID controller with applying genetic algorithm method is specified Fig.10. And also the genetic algorithm gain values for the tuning is given below in table .the output response of the system is shown in Fig and we analyze the system for the previous parameters

- Maximum overshoot, M_P
- Settling time,t_s
- Rise time, t_r

the maximum overshoot , M_P of the system is around zero .the settling time is about then we have go for studying the consequence of fuzzy logic controller for system and compare the PID based genetic algorithm.

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Self tuned Fuzzy Logic Controller

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 Figure 5.

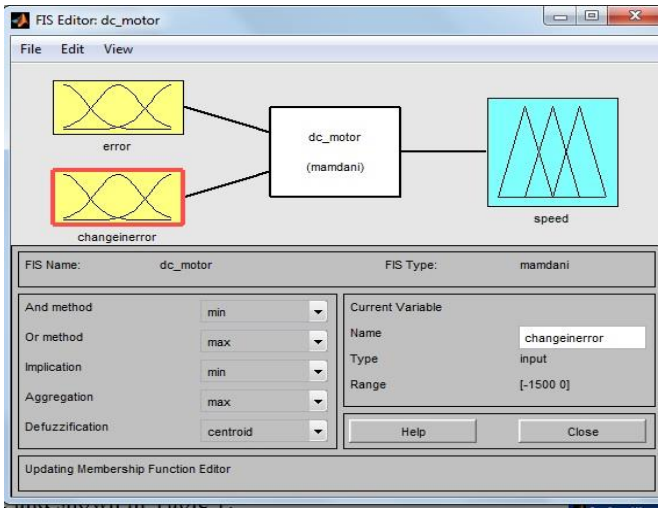

Figure 8: Mamdani-type fuzzy logic system

Rule Base

The situate 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. 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.

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

Table 3: FLC rule base table.

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VII. SIMULATION RESULTS AND DISCUSSION

This paper in objective function a dedicated software using 'C' programming language is developed for this problem in MATLAB. The range of.Kp, Ki and Kd is chosen between (0-500) respectively. Values of Kp, Ki and Kd are plotted through a the objective function in Fig.6. shows the variation of the fitness of the best solution with generation, where best solution is defined as the one which gives minimum rise time, settling time, zero overshoot and nearly zero steady state error in the fitness of the best solution in each generation until it reaches a maximum possible value can be attributed to the novel selection procedure adopted namely combination of Tournament selection with Elitism.

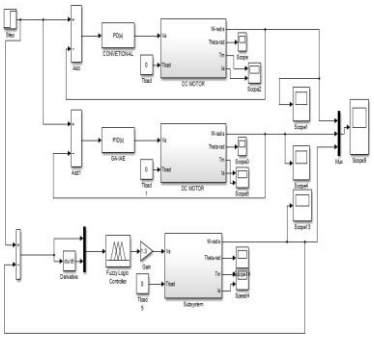

Figure 9: Simulink of dc motor with controller

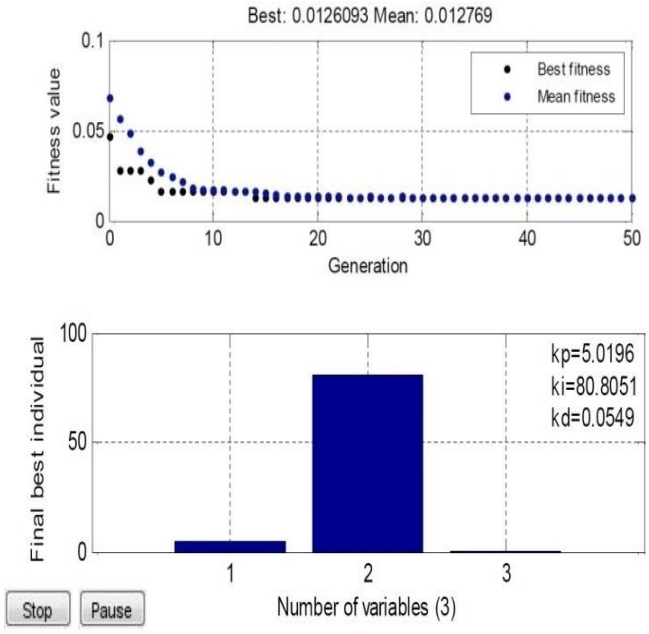

Figure 10: GA optimization progression based objective function (IAE) index

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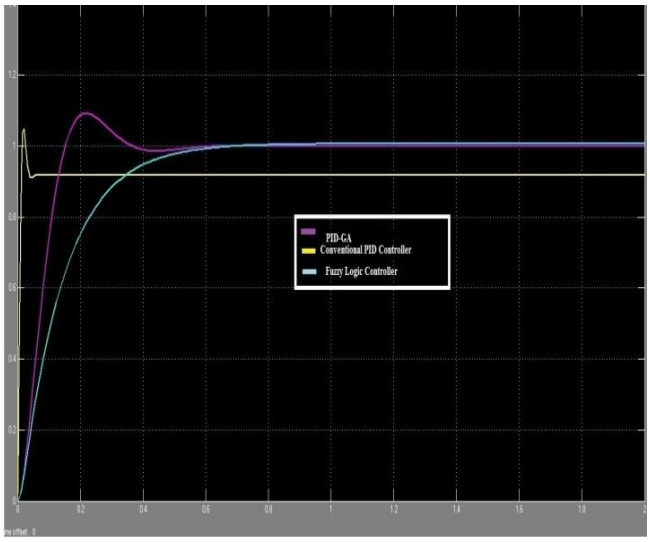

Figure 11: Step input of controlled DC motor drive system

	Tuning method		
PARAMETERS	**Conventional PID**	**Genetic Algorithm IAE**	**Fuzzy Logic Controller**
K_P	14.7312	5.0196	-
K_I	105.15	80.8051	-
K_D	0.547	0.0549	-
Rise time(sec)	0.00822	0.745	0.0663
Settling time(sec)	0.0837	0.12	0.116
Overshoot (%)	47.40%	0.523	0%
Peak	1.41	0.5	1.02

Table 4: Performance comparison of parameters PID & with GA

VIII. CONCLUSIONS

In this paper we have discussed the speed control of DC motor Drive by different approach of controller. It is clear result that the ordinary PID controller is not getting the exact result but rather through the developmental calculation procedures to the ideal tuning of PID controller prompted an agreeable close circle reaction for the framework under thought. Examination of the outcomes as appeared in Table IV and Fig.10. This paper exhibits another tuning technique for speed control of DC motor utilizing genetic algorithm (GA) based The PID controller. Target of this paper of PID parameters upgrade through the genetic algorithm based distinctive target work, this tuning technique keeping in mind the end goal to accomplish least ascent time, settling time overshoot and steady state error but fuzzy logic controller is gives the better results than all the controller the final results show in Fig.11.that gives more enhanced execution when contrasted with traditional PID controller for the considered system and thus, demonstrated the prevalence of the genetic algorithms. In this finally go to fuzzy best result than other controllers.

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