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Speed control of a DC Motor Using PID controller, FUZZY logic controller and GA based PID Controller

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Abstract - The aim of this paper is to control the speed of a DC motor by selection of a PID parameters using genetic algorithm. This paper compares three kinds of tuning techniques namely PID controller FUZZY controller and GA controller. It was found that the proposed PID parameters adjustment by the genetic algorithm is better than the simple PID and FUZZY controller. The proposed method could be applied to the higher order system also. With the help of three types of Controllers the output response of the system is obtained, namely, PID and fuzzy logic controller and GA based controller. The output of the designed fuzzy controller and classic PID Speed controller and GA based controller is compared. Finally, the result shows that the GA based PID is much better. FLC has minimum overshoot, minimum transient and steady state parameters, which shows its more effectiveness and efficiency of than conventional PID controller.

Keywords- PID control, GA, Fuzzy logic controller, Simulation, DC motor, Membership function, Fuzzy inference system.

I. INTRODUCTION

To accurate control of every process that leads to various types of controllers which are being widely used in process industries is very critical. For process industries, Tuning methods for these controllers are very important. It has excellent speed control characteristics that are why the DC motor has been widely used in industry even though its maintenance costs are higher than the induction motor. Now days, Speed control of DC motor has attracted considerable research and several methods have evolved. For controlling speed and position control of DC motor Proportional-Integral Derivative (PID) controllers have been widely used . [1] This paper proposes a new method to design a speed controller of a DC motor by selection of PID, Fuzzy Logic Controller(FLC),PID parameters using GA To show the efficiency of GA. the results of GA is best among all methods are compared together. Using genetic algorithms to perform the tuning of the controller gives best results in the optimum controller being evaluated for the system every time. The main objective of this paper is to find out the best value of crossover, mutation of PID controller, settling time, peak value.

II. SYSTEM MODELING OF SEPARATELY EXCITED DC MOTOR

The word controlling of speed means intentional speed variation carried out manually or automatically. For wide range speed control DC motors are mostly used and are there for many adjustable speed drives.

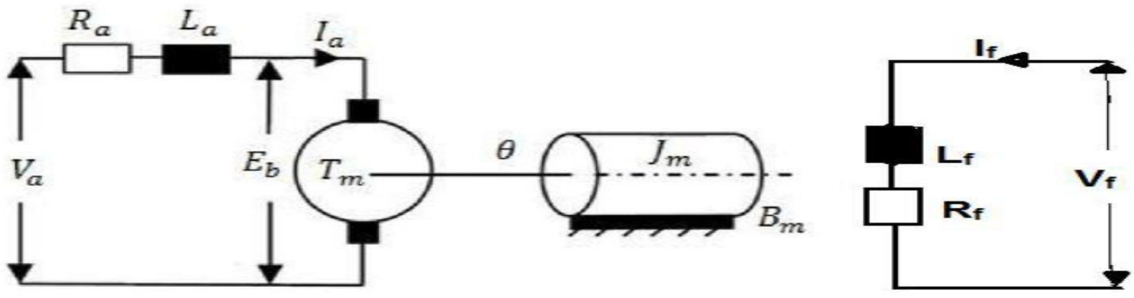

Fig.1 separately excited dc motor model

The equation for armature voltage is given by:

$\mathbf{V_a = E_b + I_aR_a + L_a(\frac{dI_a}{dt})}$(1)

Now the torque balance equations shown as:

$\mathbf{T_m = J_m(\frac{dw}{dt}) + B_mw + T_L}$(2)

Friction in rotor of motor is very small (can be neglected), so Bm = 0 Therefore, new torque balance equation will be given by:

$\mathbf{T_m = J_m(\frac{dw}{dt}) + T_L}$(3)

Assuming field flux as Φ and Back EMF Constant as K. for back e.m.f of motor's equation s will be:

$\mathbf{E_B = K}$ (4)

Also,

$\mathbf{E_B = K\phi I_a}$(5)

Voltage equation ,after taking Laplace transform for the motor's armature:

$\mathbf{I_a(s) = (V_a - E_b)/R_a + LaS}$(6)

From equation (4) , we get:

$\mathbf{I_a(s) = \frac{V_a - K\,\phi_w}{R_a} + R_aLaS}$(7)

And

$\mathbf{W(s) = \frac{T_m - T_L}{Js} = (K\phi I_a - T_L) = J_mS}$(8)

Armature Time Constant

$\mathbf{T_a = L_a/R_a}$(9)

After solving the motor model given above , the transfer function will be

$\mathbf{\phi(s)/V_a(s) = K\phi/(L_aJ_mS^2 + R_aJmS + K^2.\phi^2)}$(10)

For the DC motor with parameters given in Appendix A, the overall transfer function of the system is given as:

$\mathbf{\Theta(s)/V_a(s) = 0.5/(0.002s^2 + 0.0505s + 0.629)}$(11)

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III. BLOCK DIAGRAM

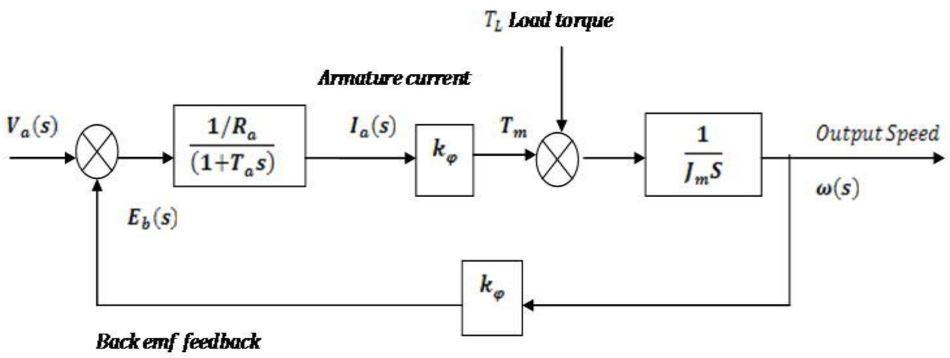

Fig.2 block diagram of separately excited dc motor

IV. CONVENTIONAL PID CONTROLLER

A. Fundamentals of PID controller

PID controllers are the most widely-used type of controller for industrial applications. They are structurally simple and exhibit robust performance over a wide range of operating conditions. Without knowing the complete knowledge of the process these types of controllers are the most efficient of choices. The three main parameters used are Proportional (P), Integral (I) and Derivative (D). The proportional part is responsible for following the desired set-point, while the integral and derivative part account for the accumulation of past errors and the rate of change of error in the process respectively.

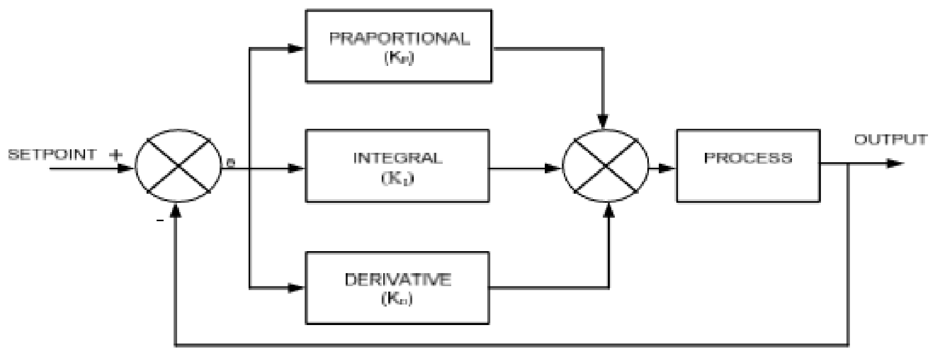

Fig.3-Block diagram of PID controller

Y(t) = $e(t)Kp + Ki\int_0^t e(t)dt + Kd\frac{de(t)}{dt}$….(12)

Equation (12) shows the output of the PID controller

Where e = Error signal

Kp = Proportional Constant

Ki= Integral Constant

Kd = Derivative Constant

V. FUZZY LOGIC CONTROLLER

Fuzzy logic control is based on logical relationship. Fuzzy knowledge [2], [3] which are used to show linguistic variables. The similarities between fuzzy logic and fuzzy set theory that is similar that of relation between Boolean logic and set theory. Fig. 2 shows a general FLC structure.
FLC is processed for linguistic definitions, while other controllers work on the accuracy and parameters of system model. In the designing FLC, never need knowledge of system model, as a controller. Weather, little knowledge of control process may result unsatisfactory [4].

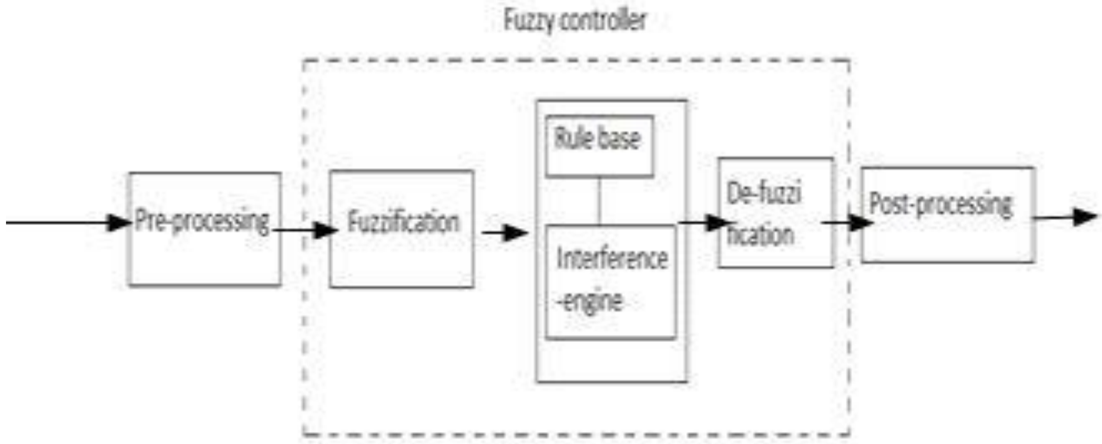

Fig. 4 Process blocks for a fuzzy controller

A fuzzy logic model is a logical-mathematical procedure based on an “IF-THEN” rule system that mimics the human way if thinking in computational form. Generally, a fuzzy rule system categorized in four modules.
- Fuzzification
- Fuzzy Inference
- Rule base
- Defuzzification

Fuzzification
The process of converting a numerical variable (real number or crisp variables) into a linguistic variable (fuzzy number) is called Fuzzification. By compairatively small number of membership functions to variable , In another manner it means the assigning of linguistic value.

Fuzzy inference
The truth value for the premise of each rule is computed under inference, and follow on the conclusion part of each rule. For each rule this results in one fuzzy subset to be assigned to each output variable. Mostly inference rules is used as MIN or PRODUCT. The output membership function is clipped off in MIN inference, at a height corresponding to the rule premise's computed degree of truth (fuzzy logic AND).The output membership function is scaled by the rule premise's computed degree of truth in PRODUCT inference

Rule base
For the rule bases a classic interpretation of Mamdani was used. Under rule base, outputs rules are constructed. The rules arranged in “If Then” format and formally the If side is called the conditions and

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the Then side is called the conclusion. A rule base controller is simply understandable and easy to maintain for a non- specialist end user and an equivalent controller could be implemented using conventional techniques.

Defuzzification

Defuzzification is a process in which crisp output is obtained by the fuzzy output. In other words, process to convert fuzzy output into crisp number. Here in Defuzzification methods in which two of the more common Techniques are named as CENTROID and MAXIMUM methods. According to the CENTROID method, In crisp value of the output Variables are computed by finding the variable value of the centre of gravity of the membership function for the fuzzy Value. In the MAXIMUM method, one of the variable values at which the fuzzy subset has its maximum truth value is chosen as crisp value for the output variable [5].

VI. GENETIC ALGORITHM

TUNING OF PID CONTROLLER USING GENETIC ALGORITHM APPROACH

.A. Overview of Genetic Algorithm

On the concept of natural selection, GA technique based. Recently To solve optimization problems, GA has been found as an very effective and highly efficient technique Compared with another techniques. It starts with an initial population containing a number of chromosomes where each one have a solution of the problem By fitness function whose performance is evaluated[6]. GA consists of three main stages: Selection, Crossover and Mutation. It allows the creation of new individuals which may be better than their parents. For many generations This algorithm is repeated itself until it reaches to individuals that represent the optimum solution to the problem. The architecture of GA is shown in Fig.3.

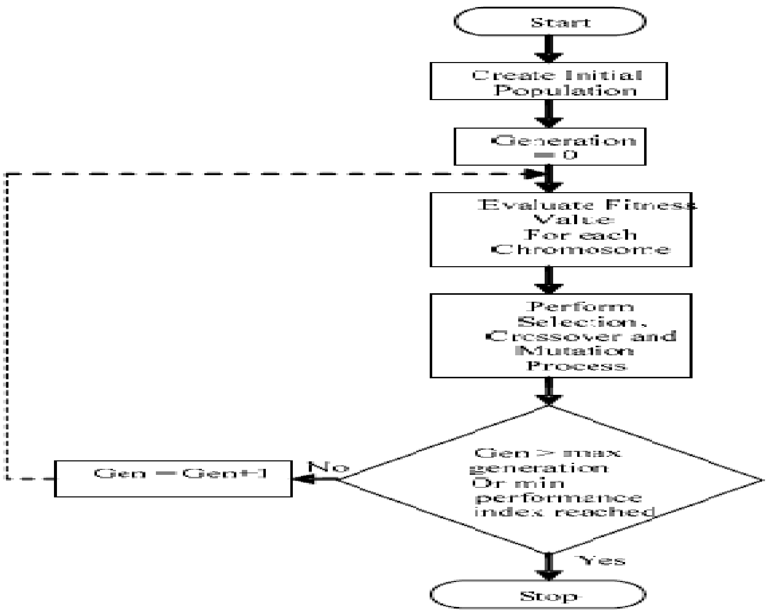

Fig. 5 Genetic algorithm architecture

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B. Implementation of GA based PID controller

We applied here GA to the tuning of PID controller gains to ensure optimal control performance .we can use GA tool box also to get value of P,I and D .In block diagram shown bellow,we can see how we applied GA based PID controller.

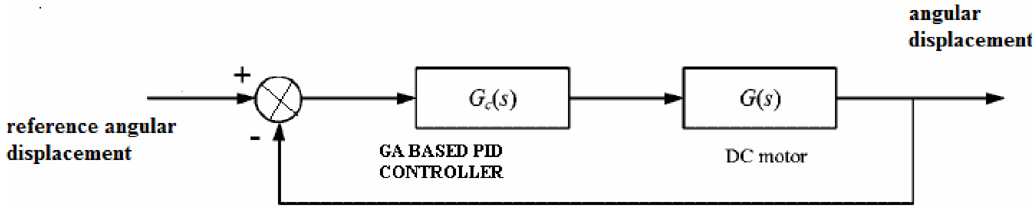

Fig.6-Block of GA based PID controller in plant

VII. SIMULINK IMPLEMENTATION AND RESULTS

The results of the system with using different type of controllers are shown here. The responses of the system with other controllers such as PID, Fuzzy Logic Controller are being applied. In this section transfer function of the separately excited dc motor is used as a system and find out the response of the system applying the step function as an input.

A .By using PID controller

Designing of PID control system in MATLAB/Simulation shown in fig. 6, where controller parameters are adjusted.

Fig. 7 MATLAB/simulation model of system using pid controller

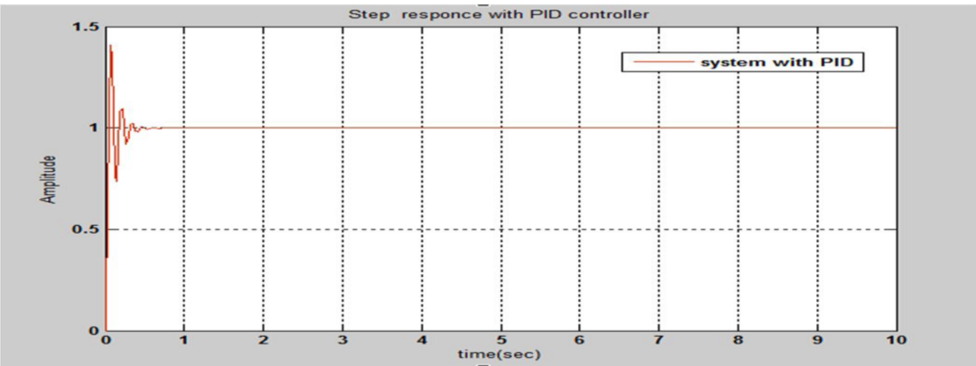

Fig. 8 Step response of the system with pid controller

From the figure, it can be seen that the PID controlled response of the system has considerably high overshoot and Larger settling time values. Hence, By using fuzzy logic controller, it upgrade the response of the system .

B. By using Fuzzy logic controller

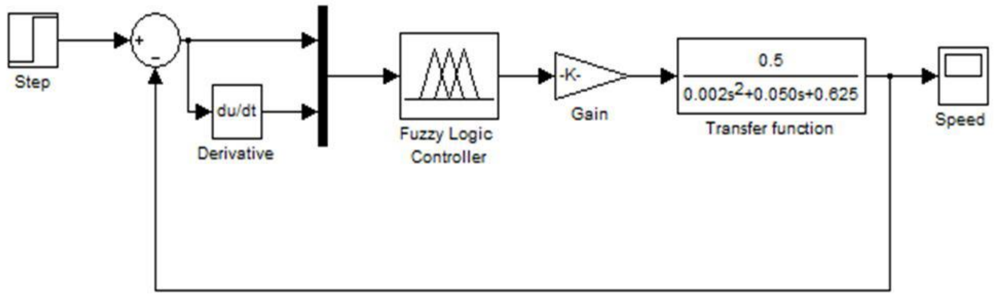

Fig. 9 MATLAB/simulation model of system using fuzzy logic controller

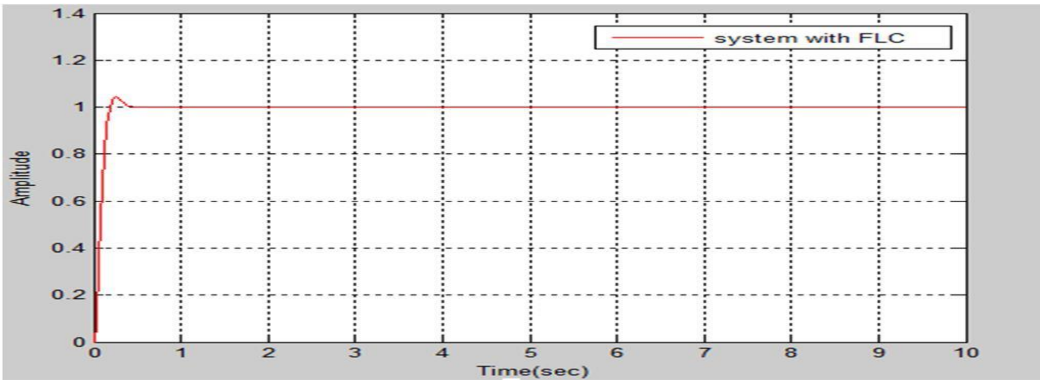

Fig. 10 step response of system using fuzzy logic controller

From above shown figure, it can be seen that the overshoot has been considerably reduced with fuzzy logic controller.

With respect to the PID. It shows that the response of the system has greatly improved on application of fuzzy logic controller (FLC). The overshoot of the system using FLC has been reduced, settling time; peak time of the system also shows appreciable reduction as analyzed in Table I.

C. By using GA based PID controller

By creating GA programmer, we found the result shown bellow.

With respect to the PID and fuzzy logic controller. It shows that the response of the system has greatly improved on application of GA based PID controller. The overshoot of the system using FLC has been reduced to 0, settling time; peak time of the system also shows appreciable reduction as analyzed in Table I.

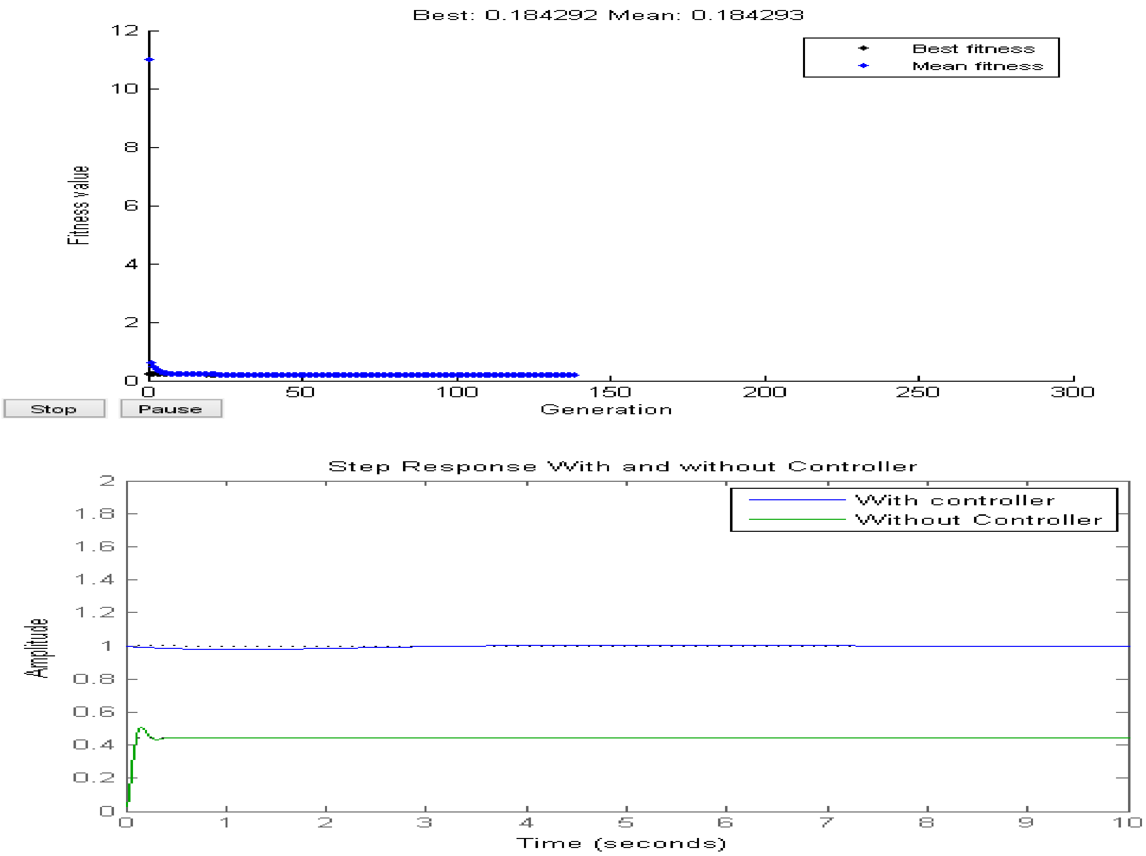

Fig12-Output of GA based PID controller

TABLE 1. Comparison between the output responses for controllers

Title	PID controller	Fuzzy logic controller	GA based PID controller
Rise time (sec)	0.0279	0.1198	0.000295874
Peak time (sec)	1.0649	0.2873	0.0014
Settling time(sec)	1.4104	0.3578	0.000542727
% Overshoot	39.5260	4.3854	0.0

VIII. CONCLUSION

Research work has been carried out to get an optimal PID tuning by using GA, and fuzzy. Simulation results demonstrate the tuning methods that have a better control performance compared with the conventional ones.PID controller tuning is a small-scale problem and thus computational complexity is not really an issue here. It takes some time to solve the problem. After comparing to conventionally tuned system, PID, fuzzy, GA based PID controller has good steady state response and performance indices.

The results show that the overshoot, settling time, peak time and control performance has been improved greatly by using GA based controller. The GA based controller has more advantages, such as higher flexibility, control, better dynamic and static performance compared with conventional controller. Hence, GA based PID CONTROLLER was proposed and implemented.

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