Position Control of DC Motor Using Genetic Algorithm Based PID Controller

Neenu Thomas, Dr. P. Poongodi

Abstract –**The aim of this paper is to design a position controller of a DC motor by selection of a PID parameters using genetic algorithm. The model of a DC motor is considered as a third order system. And this paper compares two kinds of tuning methods of parameter for PID controller. One is the controller design by the genetic algorithm, second is the controller design by the Ziegler and Nichols method. It was found that the proposed PID parameters adjustment by the genetic algorithm is better than the Ziegler & Nichols' method. The proposed method could be applied to the higher order system also.**

Keywords- **DC motor, Genetic algorithm, PID controller, Ziegler Nichols Method**

I. INTRODUCTION

Due to its excellent speed control characteristics, the DC motor has been widely used in industry even though its maintenance costs are higher than the induction motor . As a result, position control of DC motor has attracted considerable research and several methods have evolved. Proportional-Integral Derivative (PID) controllers have been widely used for speed and position control of DC motor.

This paper endeavors to design a system using Genetic Algorithm. Genetic Algorithm or in short GA is a stochastic algorithm based on principles of natural selection and genetics. Genetic Algorithms (GAs) are a stochastic global search method that mimics the process of natural evolution. Using genetic algorithms to perform the tuning of the controller will result in the optimum controller being evaluated for the system every time. The objective of this paper is to show that by employing the GA method of tuning a system , an optimization can be achieved. This can be seen by comparing the result of the GA optimized system against the classically tuned system.

Neenu Thomas is with the Karunya University, Karunya Nagar, Coimbatore, Tamil Nadu, 641114, India (corresponding author to provide phone: 09943050530; e-mail: neenujasmin@gmail.com).
Dr. P. Poongodi, is with the Karunya University, Karunya Nagar, Coimbatore, Tamil Nadu, 641114, India (corresponding author to provide phone: 09363147648; e-mail: poongodiravikumar@yahoo.co.in).

The following section II formulates the system model of a DC motor. The focus of section III is on conventional PID Controller, it's tuning by Ziegler Nichols Method and how it can be applied to DC motors. A brief review of Genetic Algorithm Based PID Controller is brought up in section IV. Also discusses the structure of the GA based controller and it's implementation in the system. In section V, simulation results of the corresponding system are obtained and compared.

II. SYSTEM MODEL

As reference we consider a DC shunt motors as is shown in figure 1. DC shunt motors have the field coil in parallel (shunt) with the armature. The current in the field coil and the armature are independent of one another. As a result, these motors have excellent speed and position control. Hence DC shunt motors are typically used applications that require five or more horse power. The equations describing the dynamic behavior of the DC motor are given by the following equations;

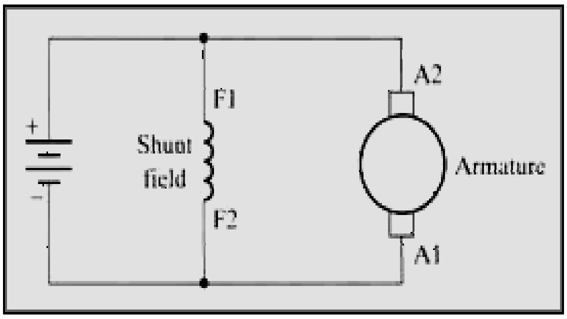

Fig.1.Diagram of DC shunt Motor

$$v = Ri + L\frac{di}{dt} + e_b \qquad (1)$$

$$T_m = K_T\, i_a(t) \qquad (2)$$

$$T_m = J\frac{d^2\theta(t)}{dt^2} + B\frac{d\theta(t)}{dt} \qquad (3)$$

$$\text{eb}= e_b(t) = K_b\frac{d\theta(t)}{dt} \qquad (4)$$

After simplification and taking the ratio of θ(s)/ v(s) we will get the transfer function as below,

$\Theta(s) / v(s)=K_b / [J\ L_a\ S^3 + (Ra\ J+B\ La)S^2 +(Kb^2+Ra\ B)S]$ (5)

Where, R=Ra=Armature resistance in ohm, L=La=Armature inductance in henry ,i=ia= Armature current in ampere ,v= Va=Armature voltage in volts ,eb= e(t)=Back emf voltage in volts, Kb=back emf constant in volt/(rad/sec), K= Kt=torque constant in N-m/Ampere, Tm=torque developed by the motor in N-m, θ(t)=angular displacement of shaft in radians, J=moment of inertia of motor and load in Kg-m^2/rad, B=frictional constant of motor and load in N-m/(rad/sec)

A. *Numerical Values*

The DC motor under study has the following specifications and parameters

a) Specifications
2hp, 230 volts, 8.5 amperes, 1500rpm

b) Parameters:

Ra=2.45 ohm, La=0.035 H, Kb=1.2 volt/(rad/sec), J=0.022Kg-m^2/rad ,B=0.5*10^-3 N-m/(rad/sec).The overall transfer function of the system is given below,

$$\frac{\Theta(s)}{Va(s)} = \frac{1.2}{0.00077\ s^3+0.0539\ s^2+1.441s}$$

III. TUNING OF PID CONTROLLER USING CONVENTIONAL APPROACH

A. *Conventional Approach - Ziegler Nichols Method*

The control system performs poor in characteristics and even it becomes unstable, if improper values of the controller tuning constants are used. So it becomes necessary to tune the controller parameters to achieve good control performance with the proper choice of tuning constants. Controller tuning involves the selection of the best values of kc, Ti and TD (if a PID algorithm is being used). This is often a subjective procedure and is certainly process dependent. It is widely accepted method for tuning the PID controller. The method is straightforward. First, set the controller to P mode only. Next, set the gain of the controller (kc) to a small value. Make a small set point (or load) change and observe the response of the controlled variable. If kc is low the response should be sluggish. Increase kc by a factor of two and make another small change in the set point or the load. Keep increasing kc (by a factor of two) until the response becomes oscillatory. Finally, adjust kc until a response is obtained that produces continuous oscillations. This is known as the ultimate gain (ku). Note the period of the oscillations (Pu). The steps required for the method are given below. We have to set the integral and derivative coefficients are zero. Gradually increase the proportional coefficient from 0 to until the system just begins to oscillate continuously. The proportional coefficient at this point is called the ultimate gain Ku. And the period of oscillation at this point is called ultimate period Pu. The Ku=gain margin of the system and the Pu=(2*pi)/$w_{cg.}$ Where, the $w_{cg.}$ is the gain cross over frequency. Gain margin is the reverse of amplitude ratio. The control law settings are then obtained from the following table 1 and also the $w_{cg.\ PID}$ gain values after simulation is given below table 2,

Table 1 Control law settings

Controller	Kp	Ti	Td
P	Ku/2		
PI	Ku/2.2	Pu/1.2	
PID	Ku/1.7	Pu/2	Pu/8

Table 2 PID controller gain values

Gain Coeff.	Kp	Ki	Kd
Values	18	0.045	0.0182

From the above algorithm the step response of the system with conventionally tuned PID controller is shown in Fig 2.

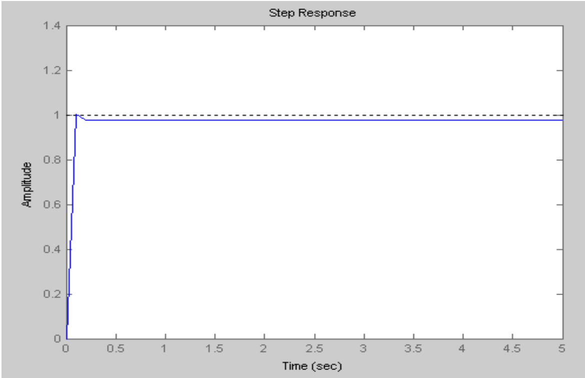

Fig2. Response of the system with conventionally tuned PID controller

B. Analysis of conventionally tuned PID controller

From the above response, we can analyze the system. We can analyze the following parameters:

- Rise time, tr
- Maximum Overshoot, Mp
- Settling time, ts

The rise time, tr is the time taken to reach 10 to 90 % of the final value is about 0.2 sec. The Maximum Overshoot, Mp of the system is approximately 1.01. Finally the Settling time, ts is about 0.25sec. From the analysis above, the system has not been tuned to its optimum. So in order to achieve the following parameters we have to go for genetic algorithm approach. Our system requirements are given below,

Table 3 System Requirements

System specifications	Maximum overshoot	Rise time(sec)	Settling time(sec)
	1	< 0.2	<0.25

IV. TUNING OF PID CONTROLLER USING GENETIC ALGORITHM APPROACH

A. Overview of Genetic Algorithm

GA is a stochastic global adaptive search optimization technique based on the mechanisms of natural selection. Recently, GA has been recognized as an effective and efficient technique to solve optimization problems. Compared with other optimization techniques. GA starts with an initial population containing a number of chromosomes where each one represents a solution of the problem which performance is evaluated by a fitness function.

Basically, GA consists of three main stages: Selection, Crossover and Mutation. The application of these three basic operations allows the creation of new individuals which may be better than their parents. This algorithm is repeated for many generations and finally stops when reaching individuals that represent the optimum solution to the problem. The GA architecture is shown in Fig.3.

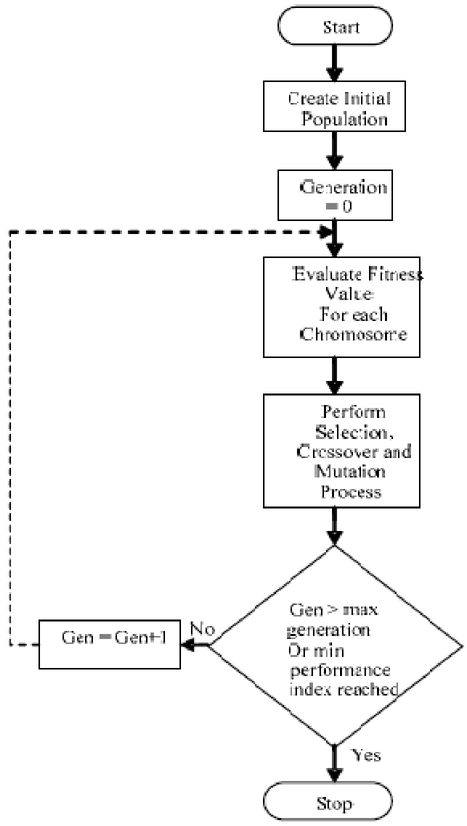

Fig. 3 Genetic Algorithm Architecture

B. Implementation of GA based PID controller

GA can be applied to the tuning of PID position controller gains to ensure optimal control performance at nominal operating conditions. The block diagram for the entire system is given below and also the genetic algorithm parameters chosen for the tuning purpose are shown below,

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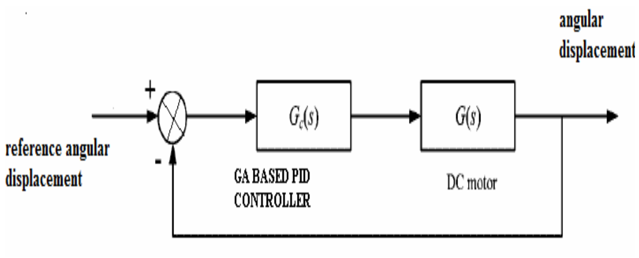

Fig 4 Block diagram of the entire system

Table 4 Parameters of GA

GA property	Value/Method
Population Size Maximum Number of Generations	60 20
Performance index/fitness function	Mean square error
Selection Method	Normalized Geometric Selection
Probability of selection	0.05
Crossover Method	Arithmetic Crossover
Number of crossover points	3
Mutation Method	Uniform Mutation
Mutation Probability	0.1

After giving the above parameters to GA the PID controllers can be easily tuned and thus system performance can be improved. The system performance can be given below,

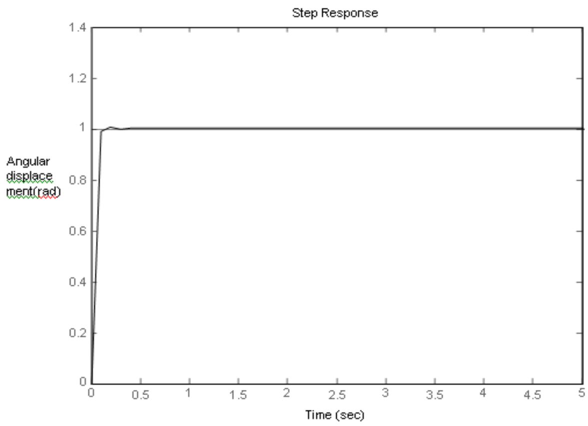

Fig 5 Response of the system with GA based PID controller

Table 5 GA based PID controller gain values

Gain parameters	Kp	Ki	Kd
Gain Values	19.88	0.1376	0.5578

V. ANALYSIS OF RESULT

In the implementation of conventionally tuned PID controller is not getting the accurate results but the proper optimized gain values of controller are obtained with the implementation of GA based PID controller. Comparative results are given below,

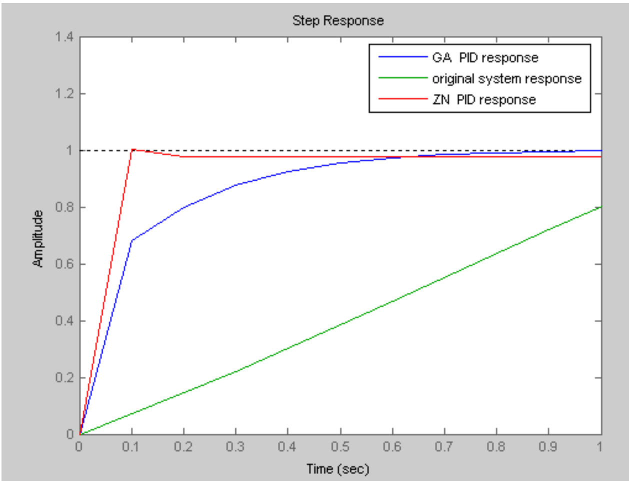

Fig 6.comparitive responses

Table 6.comparison of results

Tuning Method	Kp	Ki	Kd	Maximum overshoot	Rise time(sec)	Settling time(sec)	Mean square error
ZN method	18	0.045	0.0182	1.01	0.2	0.25	0.3639
Genetic algorithm approach	19.88	0.1376	0.5578	1	0.1	0.1	0.0033

VI. CONCLUSION

The designed PID with GA has much faster response than response of the classical method. The classical method is good for giving us as the starting point of what are the PID values. However the GA designed PID is much better in terms of the rise time and the settling time than the conventional method. Finally the genetic algorithm provides much better results compared to the conventional methods. And also the error associated with the genetic based PID is much lesser than the error calculated in the conventional scheme. In this paper, implementation of the genetic algorithm based PID controller for the DC motor position control system is covered. In future GA based PID controller will be implemented in DC motor position control system using LabVIEW.

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