ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 6, June 2014

Optimization of PID Parameter for Position Control of DC-Motor using Multi-Objective Genetic Algorithm

MD Amanullah[1], Mohit Jain[2], Pratibha Tiwari[3], Sidharth Gupta[4], Geeta Kumari[5]

M.Tech Scholar, EEE Department, SHIATS, Allahabad, INDIA [1,4,5]

Assistant Professor, EEE Department, GLA University, Mathura, INDIA [2]

Assistant Professor, EEE Department, SHIATS, Allahabad, INDIA[3]

Abstract: The ambition of this paper is to design a position controller of a DC motor by selection of a PID parameter using genetic algorithm. The Proportional plus Integral plus Derivative (PID), controllers are most widely used in control theory as well as industrial plants due to their ease of execution and robustness performance. The aspiration of this deed representation capable and apace tuning approach using Genetic Algorithm (GA) to obtain the optimized criterion of the PID controller so as to appropriate the essential appearance designation of the technique below consideration. This scheme is a simulation and experimental analysis into the development of PID controller using MATLAB/SIMULINK software. There are several techniques which are used for tuning of PID controller to control the speed control of DC motor. Tuning of PID parameters is considerable because these parameters have a admirable effect on the stability and performance of the control system. Using genetic algorithms to perform the tuning of the controller results in the optimum controller being appraise for the system every time.

Keywords: PID Controller, DC-Motor, Tuning Methods, Genetic Algorithm, Optimization Technique

I. INTRODUCTION

DC motor is a power actuator which transforms electrical energy into mechanical energy. DC motor is widely used in various industrial applications where wide speed ranges are required. The advantage of DC motors may be speed control. The term speed control stand for intentional speed variation carried out automatically and manually. DC motors are most suitable for wide range speed control and are therefore used in many adjustable speed drives. Since speed is directly proportional to armature voltage and inversely proportional to magnetic flux produced by the poles and adjusting the armature voltage and/or the field current will change the rotor speed. DC motors have been widely used in many industrial applications such as electric cranes, electric vehicles, and robotic manipulators due to wide, simple, and continuous control characteristics. 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. Now a day's world wide PID controller sweepingly used for an optimum solution gives a superior efficiency. For obtaining the better efficiency the absolute output needed to match set output. For this aspiration requirement of a controller. PID controller is the widely used in the process industry like petrochemical, paper, pulp, oil & gas, as well as missile control systems, because of its easy design and robust implementation in a broad range of operational condition. Unluckily, it was completely complex tune properly the gains of the PID controllers because various industrial plants are frequently loaded down with difficulties such as high order, time delays, and nonlinearities. During the long time various heuristic program procedures have been proposed during the tuning of PID controllers.

These conventional procedures are very famous amid control engineers because one and only can use them, especially as no or small observation about the plant under control is available. These procedures provide stable, healthy and completely great Achievers in spite of this the gains are not at all assured of being optimal. Even, those conventional tuning process frequently breaks down to accomplish suitable Achievement in the case of plants having nonlinearity, higher order or time delay. Thus, intelligence techniques have been introduced by the researchers according to established the tuning an easier one. As for a latest scheme of PID tuning is recommended based on the Fuzzy gain programming approach. A neural networks tuned PID controller with the help of fuzzy criteria is presented. As for this paper presents a PID tuning approach founded with respect to Multi-objective Genetic Algorithm (MOGA) and his performance is matched by

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 6, June 2014

conventional techniques of tuning. The MOGA tuned PID (MOGA-PID) controller is well-tried on several sophisticated techniques.

II. SYSTEM MODEL

As reference we consider a DC shunt motor 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

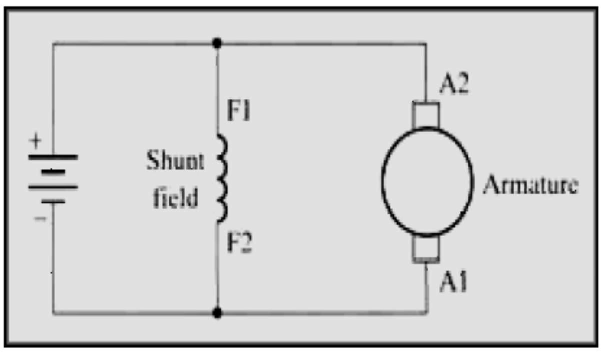

Figure (1):- Diagram of DC shunt Motor.

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

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

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

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

After simplification and taking the ratio of

$\frac{\theta(s)}{V(s)}$ we will get the transfer function as below:

$$\frac{\theta(s)}{V(s)} = \frac{K_b}{S(Js+b)(Ls+R)+K^2b} \left[\frac{rad}{V}\right] \qquad (5)$$

Where,

- R: Armature resistance in ohm
- L: Armature inductance in henry
- i: Armature current in ampere
- V: Armature voltage in volts
- e_b: Back emf voltage in volts
- K_b: Back emf constant in volt/ (rad/sec)
- K_T: Torque constant in N.m/Ampere
- T_m: 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/ $[\frac{rad}{sec}]$

A. Numerical values

The DC motor under study has the following specifications and parameters

1. Specifications:-

2hp, 230 volts, 8.5 amperes, 1500rpm

2. Parameters:-

J = 3.2284× $10^{-6} Kg - m^2/rad$
b = 3.5077× 10^{-6} $N - m/(\frac{rad}{sec})$
K = 0.0274 $volt/(rad/sec)$
R = 4 ohm
L = 2.75× 10^{-6} H

The overall transfer function of the system is given by

$$\frac{\theta(s)}{V(s)} = \frac{0.0274}{8.878\times10^{-12}s^3+1.1291\times10^{-5}s^2+0.0007648\,s} \qquad (6)$$

The PID controller has been brodly used since it invented in 1910. The combination of proportional control action, integral control action and Derivative control Action is Termed proportional plus Integral plus derivative control Action. It improves both the transient and steady state response characteristics. It is similar to lead lag compensator or band reject filter, it reduces the rise time. The peak overshoot depends on properly tuned values of T_i and T_d. It eliminates the steady state error between input and output. It increases the TYPE and ORDER by the system is One. The three main parameters involved 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.

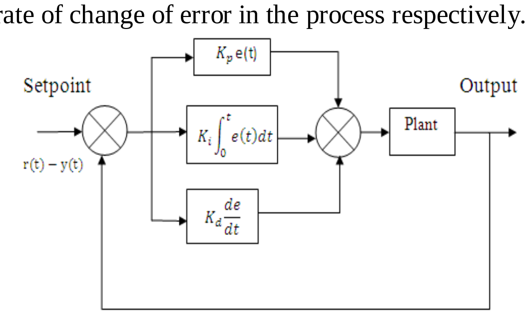

Figure (2):- Block diagram of a conventional PID controller

$e(t) = r(t) - y(t)$ is called as error signal and $u(t)$ is the controller output for this specific error signal.

$$u(t) = K_p e(t) + K_i \int e(t)d(t) + K_d \frac{d(t)}{dt} e(t) \quad (7)$$

Where,

Error, $e(t)$ =Set point- Plant output

K_P= Proportional gain

K_i = Integral gain

K_d = Derivative gain

Also, the equation (6) can be rewritten in Laplace form as:

$$u(s) = e(s)(K_p + K_i/s + K_d s) \quad (8)$$

Finally, under the above strategy the transfer function of the PID controller or the control law is established by

$$C(s) = \frac{u(s)}{e(s)} = K_p + \frac{K_i}{s} + K_d s \quad (9)$$

Tuning of PID by MOGA:-

Commonly, the PID controller scheme method using the integrated absolute error (IAE), integral of squared-error (ISE), integrated of time-weighted-squared-error (ITSE) is frequently occupied with control system design on account of it can be classified experimentally in the frequency domain.

$$IAE = \int_0^t r(t) - y(t)dt = \int_0^t e(t)\, d(t) \quad (10)$$

$$ISE = \int_0^t e^2(t)d(t) \quad (11)$$

$$ISTE = \int_0^t te^2(t)d(t) \quad (12)$$

It is the preferred of the control engineer so that which individual criterion of the control system requirement additional consideration. So as per the demand a higher weight can be allowed, although given the other requirement specification at the same time. Yet, the total sum of the weights in an objective function must be equal to one, in order to the total performance of the system may be confirmed. It shows the resilience in PID tuning while applying MOGA.

III. About Genetic Algorithm

John Holland was the father of genetic algorithm who discovered in early 1970. Genetic algorithms (Gas) are adaptive heuristic search algorithm based on the evolutionary ideas of natural expansion. As such the denote

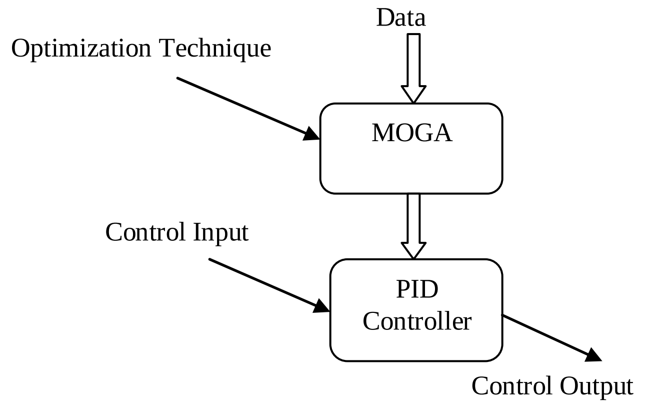

Figure (3):- MOGA based PID Tuning Scheme.

and intellectual victimization of a random search used to optimization problems. Although randomized, GAs are absolutely not in random, instead the deed of historical knowledge to direct the search into the reason of excellent performance in the search space. The key technique of the GAs is designed to fabricate processes in general system mandatory for evolution, mainly those follow on the ethics first laid down by Charles Darwin of "survival of the fittest." GA has been studied as a satisfactory and effective method for finding out difficult optimization problems. By exactly avoiding local minima, it converges to global minima. It originates from an initial population obtaining a number of chromosomes where for each one correlate to a result of the given problem. Then the achievements of each original are calculated by using a correct fitness function. Essentially, GA consists of five significant steps: initial population, fitness function, Selection, Crossover and Mutation. These are also known as GA drivers. The application of five basic operators confesses the formation of new children, which may be located excellent than their parents. This algorithm is repeated for several generations and finally stops when meeting product that is denoted the optimum result of the problem.

(a) Initial population:-

Its starts with Randomly Originated states, these states are satisfactory to the problem. The population size of its create on the nature of the problem, even so typically consist of various hundreds or thousands of feasible solutions. Commonly, the population is originated randomly; admit the perfect range of possible solutions. Infrequently, the solutions can be "sown" in the range, where optimal solutions are possible to be established.

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 6, June 2014

(b) Fitness function:-

A fitness function is a certain type of objective function that is familiar with summarize, because a single figure of merit, however close to a given design solution is to complete the set of goals. In the range of genetic programming and genetic algorithms, a single design solution is denoted by a string of numbers (specified as a chromosome). After every overall testing or simulation, the concept is to remove the 'n' worst design solutions, and to create 'n' new ones as from the best design solutions. Each and every design solution have to be rewarded a figure of merit, to illustrate how close it comes to meet the overall requirement, and it is developed by put into use the fitness function to the test or simulation, solutions are obtained from that solution.

Two main parts of fitness functions survive: the one where the fitness function does not change while optimizing a fixed function or testing with a fixed set of test cases and another one where the fitness function is changeable, while niche separation or develop the set of test cases.

(c) Selection:-

Two pairs are selected at random to reproduce. They are selected based on their fitness function score. One may be selected more than one, whereas one may not be selected at all. Make a copy the selected programs to the new population. The regeneration process may be subdivided into two parts, first is Fitness Evaluation and second is Selection. The fitness function is how is operated the evolutionary process and its view is to identify how well a string (particular) solves the problem, admitting as an evaluation of the respective performance of each population member. Basically four most common methods of the selection:

1. Tournament Selection
2. Normalized geometric selection
3. Roulette Wheel selection
4. Stochastic Universal is sampling

(d) Crossover:-

For each pair to be mated, a crossover point is preferred at random from within the bit string. The offspring is developed by interchange between the parents at the crossover point. Population is different early in the process, these reasons the crossover to be large in the beginning. However, it will settle down in future generations. Hence, There are several types of crossover operators like single point crossover, two point crossover, arithmetic crossover etc.

(e) Mutation:-

Mutation is a genetic operator familiar with a cure for genetic difference from one generation of a population about genetic algorithm chromosomes to the next. It is related to biological mutation. Mutation change more than one gene values in a chromosome from its initial state. In mutation, the solution may completely change from the last solution. Hence, GA may come to a better solution by using mutation. Mutation occurs during evolution by a user-definable probability. This has probably been set low. If it is set too high, the search will become an original random search.

Genetic Algorithm performs the following **steps**:

1. Originate an Initial Population randomly or heuristically.
2. Calculate and save the fitness for each particular in the current population.
3. Specify the selection probability at single that it is reciprocal to its fitness
4. Originate the next current population by most probabilities selecting the individuals from the earliest current population, in order to goods product of genetic operators.
5. Repeat step 2 until a sufficient result is obtained.

A flow chart of the general scheme of the implementation of the GA is shown in Figure.

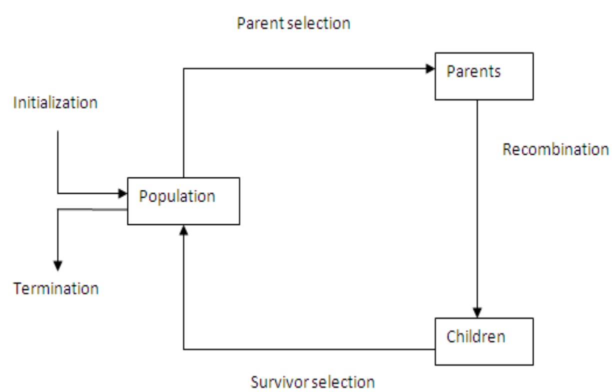

Figure (4):- flow chart of the general scheme of the implementation of the Genetic Algorithm.

Eliminate the negative error components by the help of ISE. $ISE = \sum_{k=1}^{q} e^2(k)$ In this simulation, the objective is to decrease the cost function. During that motive the objective function is preferred for the Integral Square Error (ISE). The ISE squares the error to eliminate negative error components.

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526
INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 6, June 2014

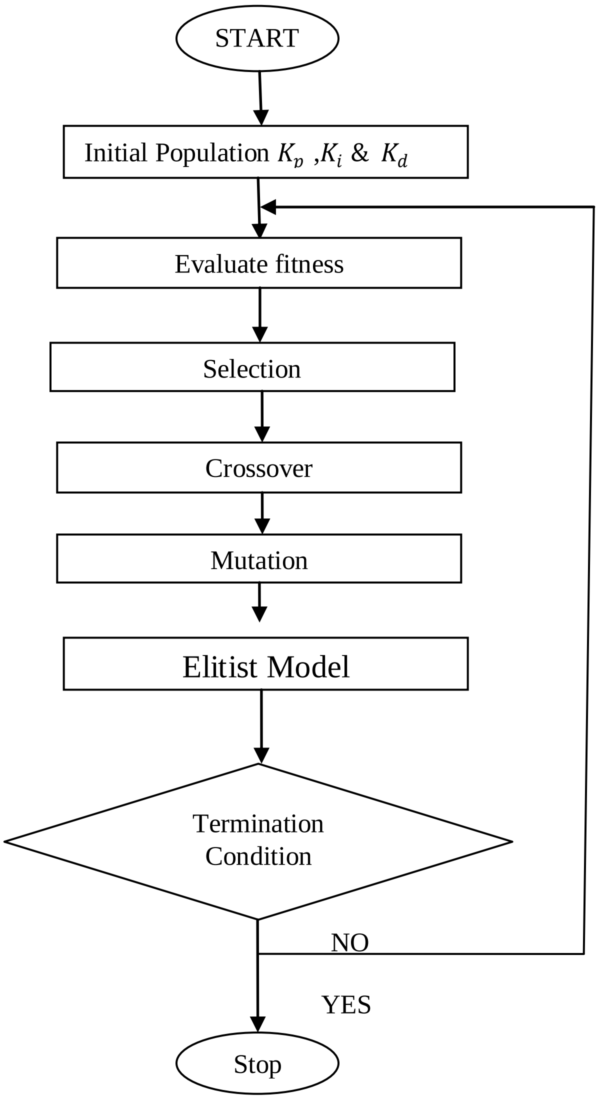

Figure (5) :- Flow chart of MOGA-PID Controller.

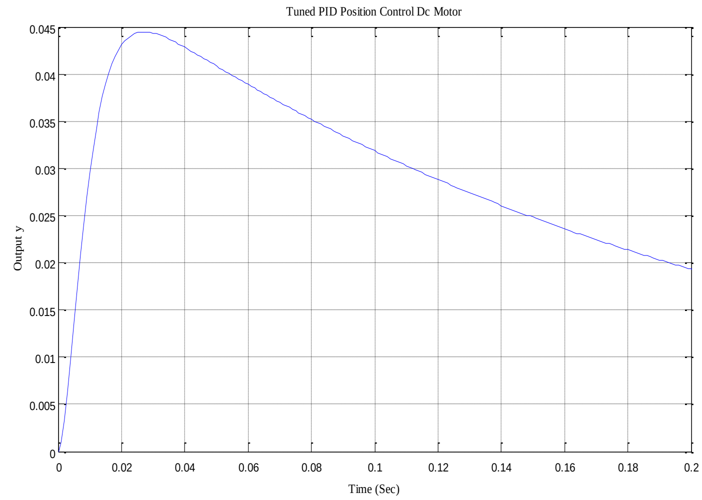

Figure (6):- Tuned PID position Control of DC Motor without MOGA

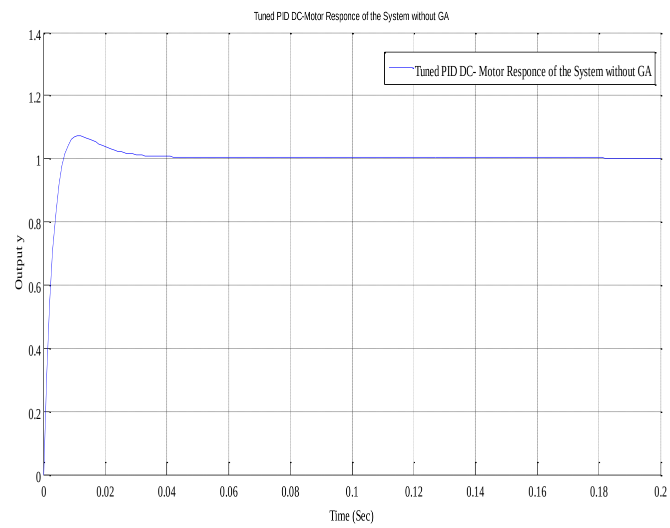

Figure (7):- Tuned PID DC Motor Response without MOGA

IV. SIMULATION & RESULTS

A. Analysis of conventionally tuned PID Controller without Genetic Algorithm

Here we are using DC motor Position Control with PID Controller without G.A. By the use of MATLAB programming PID controller is tuned & the result is given below.

B. Analysis of conventionally tuned PID Controller with Genetic Algorithm

Multi Objective Genetic Algorithm (MOGA) PID Controller performance depends on the convergence rate. The criteria like population type, population size, creation, function, selection and much more are also affecting the convergence rate. Hence, its order to decline precocious convergence of Genetic Algorithm, so this extremely strategies to select the suitable operators and criteria for it. Table I display the criteria and operators of GA that are accomplish by accurate experimental research of this work.

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 2, Issue 6, June 2014

Table I:-Display the Criteria & Parameters of GA

GA Parameter	**Value/Method**
Population type	Double Vector
Population size	20
Creation function	Feasible population
Selection	Tournament
Mutation	Adaptive feasible
Crossover	Arithmetic crossover
Generation	65

From the above table all the parameter values are apply to G.A the PID controller with DC motor Position Control is optimized. The system response is given below.

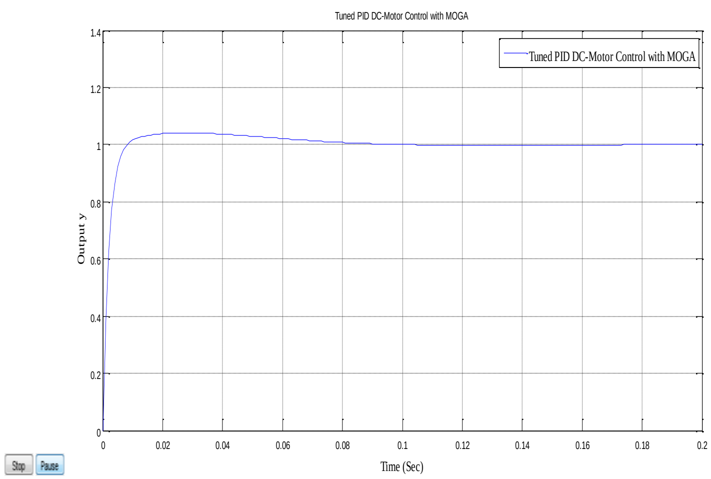

Figure (8):- Tuned PID DC-Motor Control with MOGA

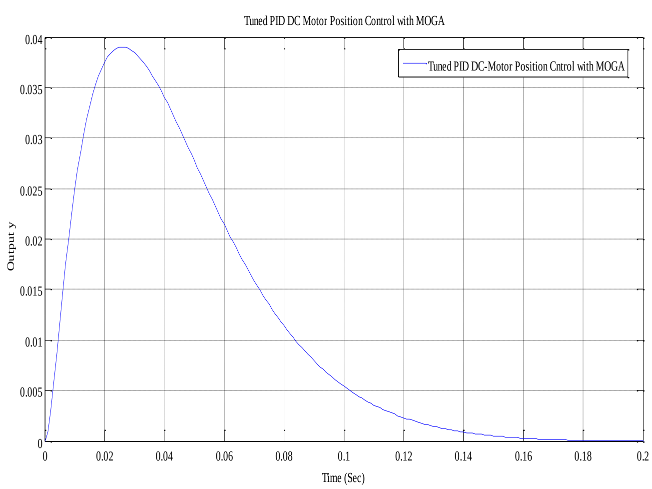

Figure (9):- Tuned PID DC Motor Position Control with MOGA.

Table II: - COMPARISON OF PARAMETER WITH PID & MOGA-PID

Parameter	K_p	K_i	K_d	t_r	t_s	$\%OS$
PID	17.7641	391.2849	0.2209	0.0042	0.0054	4.7735
MOGA-PID	21	100	0.1700	0.0045	0.0169	6.9969

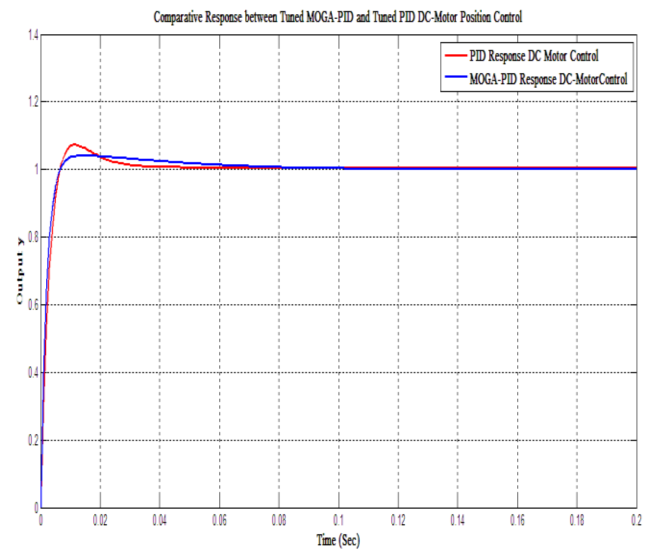

Figure (10):- Comparative Response between MOGA-PID and PID

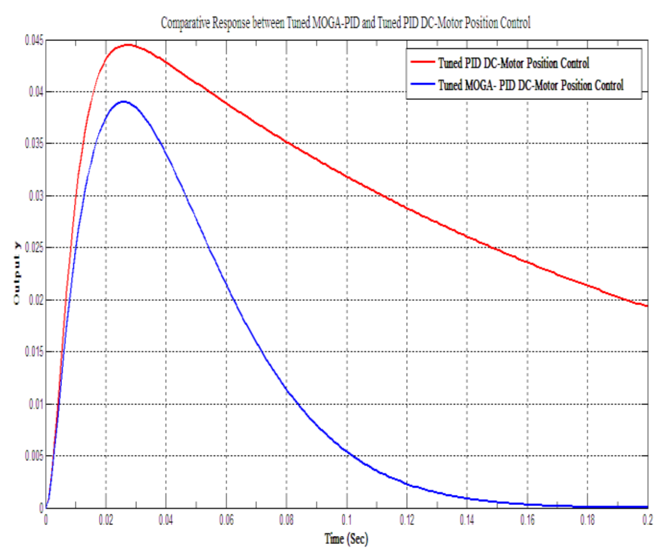

Figure (11):- Comparative Response between MOGA-PID and Tuned PID DC-Motor Position Control

V. 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 Mat lab 7.10. G.A is applied to find optimal solution for the parameter of DC motor with PID controller & indicates that G.A is powerful global searching method. This review article is also presenting the current status of tuning of PID controller for speed control of DC motor using soft computing techniques.

REFERENCES

[1] Neenu Thomas, Dr.P.Poongodi, 2009. Position Control of DC Motor Using Genetic Algorithm Based PID Controller,Proceedings of the World Congress on Engineering 2009 Vol II WCE 2009, London, U.K.
[2] T. O..Mahony, C J Downing and K Fatla, "Genetic Algorithm for PID Parameter Optimization: Minimizing Error Criteria", Process Control and Instrumentation 2000 26-28 July 2000, University of Stracthclyde, pg 148- 153.
[3] K Ogata, Modern Control Systems, University of Minnesota, Prentice Hall, 1987
[4] B.Nagaraj ,Dr.N.Murugananth" A Comparative Study of PID Controller Thning Using GA, EP, PSO and ACO" ICCCCT-10 IEEE Trans
[5] Phillip David Power, "Non Linear Multi Layer Perceptron Channel Equalisation",Chapter 4 „Genetic Algorithm Optimisation‟, *in IEEE Transactions*,The Queen University of Belfast,April 2001.
[6] Kalyanmoy Deb, Optimization for Engineering Design Algorithm & Examples ,Indian Institute Of Technology Kanpur, Prentice Hall, 2005.
[7] Liu Fan, Er Meng Joo" Design for Auto-tuning PID Controller Based on Genetic Algorithms" Nanyang Technological University Singapore IEEE Trans on ICIEA 2009
[8] Grefenstette, Optimization of control parameters for geneticalgorithms. IEEE Trans on SMC, 1986, 16(1):122-128.
[9] ASTROM K.J., HAGGLUND T.: „The future of PID control‟, Control Eng. Pract., 2001, 9, (11), pp. 1163–1175.
[10] B. C. Kuo, "Automatic Control Systems," 5th ed. Englewood Cliffs Prentics-Hall, 1987.
[11] J. G. Ziegler and N. B. Nichols, "Optimum settings for automatic controllers," Trans. ASME, vol. 64, pp. 759-768, 1942.
[12] M. Ge, M. S. Chiu and Q. G. Wang, "Robust PID controller design via LMI approach," Journal of Process Control, vol. 12, no.1, pp. 3-13, 2002
[13] David E. Goldberg, "Genetic Algorithms in Search, Optimization and Machine Learning." The University of Alabama, Addison-Wesley Publishing Company Inc, 1989
[14] Chipperfield, A. J., Fleming, P. J., Pohlheim, H. and Fonseca, C. M., A Genetic Algorithm Toolbox for MATLAB, Proc. "International Conference on Systems Engineering, Coventry, UK", 6-8 September,1994.
[15] Q.Wang, P Spronck and R Tracht, An Overview Of Genetic Algorithms Applied To Control Engineering Problems, Proceedings of the Second International Conference on Machine Learning And Cybernetics, 2003.
[16] K. Krishnakumar and D. E. Goldberg, Control System Optimization Using Genetic Algorithms, Journal of Guidance, Control and Dynamics, Vol. 15, No. 3, pp. 735-740, 1992.
[17] A.Varsek, T. Urbacic and B. Filipic, Genetic Algorithms in Controller Design and Tuning, IEEE Trans. Sys. Man and Cyber, Vol. 23, No. 5, pp1330-1339, 1993.