PID Tuning Using Genetic Algorithm For DC Motor Positional Control System

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Abstract— Proportional–integral-derivative (PID) controller is used in controlling mostly industrial and non industrial applications. The tuning aspect of (PID) controllers is a challenging task for researchers and plant operators. This paper proposes tuning of PID controller using genetic algorithm to improve the performance of the position control system of DC motor. Genetic algorithm is a soft computing technique which is used for optimization. In this work, it compares Ziegler Nicholas tuning method with genetic algorithm optimization techniques. Simulation of these methods are done through MATLAB software and compare various parameters like rise time(tr), settling time(ts), steady state error(e_{ss}) and maximum peak overshoot (Mp). In the conclusion, by a comparative analysis between the conventional PID tuning methods and optimization carried out using genetic algorithms offers lesser oscillatory and better response.

Keywords—PID Controller; Ziegler Nicholas tuning; GA (genetic Algorithm); Matlab; Simulink

I. INTRODUCTION

DC motors are important equipment in applications. They are widely used in robotics and in positioning control system. In these applications, motor should be precisely controlled so as to give desired performance. DC motor position control is challenging task under varying parameters and external disturbance. Mostly PID controller is used to control these types of applications. The paper focuses on the optimization of the response of PID controllers by using the genetic algorithms. The development of the model has been carried out in MATLAB and Simulink environment and the optimization has been done using Global Optimization toolbox. From the results obtained in this paper, it is evident that Genetic Algorithm offers best results by improving transient and steady state parameters of the system.

II. PID CONTROLLER AND TUNING

A. Introduction of PID

Proportional Integral and Derivative –PID controllers are playing an important role for regulating the closed loop response in industrial controls. The "*Fig* 1 shows block diagram of PID controller based system. The general equation of PID controller is:

$$u(t) = K_p e(t) + K_i \int_0^t e(t)\,dt + K_d \frac{de}{dt} \qquad (1)$$

Where K_p=Proportional Gain, K_i=Integral Gain, K_d=Derivative Gain, e=error.

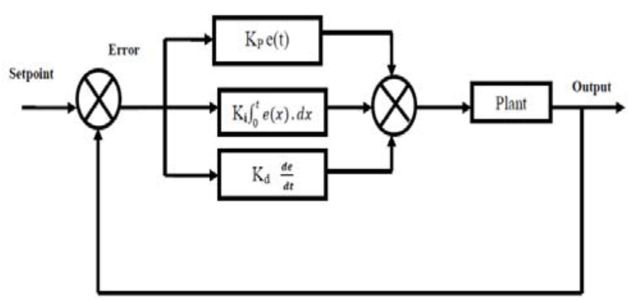

Fig. 1 Block Diagram of PID controller

B. *Introduction to tuning*

Tuning means to find out value of K_p, K_i and K_d such the system provide desired performance. Several methods have been proposed for the tuning of PID controllers. Manual tuning method is very time consuming and lead to poor performance. One of the convention and very popular method is the Ziegler–Nichols (ZN) method. But sometimes it just provides starting point of tuning parameters and produce big overshoot.

C. *Soft Computing techniques*

Now a days the Soft-Computing techniques, being lesser prone to error when compared to conventional methods like Fuzzy Logic, Genetic Algorithms, Particle Swarm Optimization, Tunings methods based on optimization technique has been implemented by using software . In these methods the design criterion is based on minimization of certain performance criterion such as integral of square error (ISE) ,Integral of error(IE), integral of time multiplied by absolute error (ITAE).

III. DC MOTOR MODEL

The motor used is a field controlled with fixed armature current type DC motor. The transfer function between the output angular displacement of this motor shaft and its input control action is given by:

$$\frac{\theta(s)}{U(S)} = \frac{K_m}{s(T_f S + 1)(T_m S + 1)} \quad \text{....} \qquad (2)$$

Where Km is motor gain constant, T_f is time constant of field circuit and T_m is time constant of inertia-friction element. For simplicity, we assume that K_m=1radian/volt-sec, T_f=0.1 sec and Tm=0.1sec. So transfer function is:

$$\frac{1}{0.1s^3 + 1.1s^2 + s} \qquad (3)$$

The control objective is to keep the various performance specifications such as rise time tr, settling time ts, maximum overshoot Mp, maximum undershoot Mu and steady state error ess within desirable limit.

IV. CONVENTIAL PID TUNING METHOD

A. *Ziegler- Nichols Method :*

This Method proposed by John G. Ziegler and Nathaniel B. Nichols, in 1942, this popular method is based on frequency response analysis of the process it employs the following steps.

1. Place the controller in close loop with low gain; no integration and derivative contribution.

2. Adjusting the gain to make the control system in continuous oscillation. The corresponding gain is referred to as the ultimate gain (Ku) and the oscillation period is termed as the ultimate period (Pu).

3. Using the values of Ku and Pu, Ziegler and Nichols recommended the following tuning parameters for various modes of controllers.

TABLE I PID CONTROLLER PARAMETRS FOR ZN METHOD

Controller	**Kp**	**Ti**	**Td**
P	0.5 Ku	∞	0
PI	0.4 Ku	Pu /1.2	0
PID	0.6 Ku	0.5 Pu	0.125 Pu

For analysis purpose system model is developed in MATLAB Simulink software. And adjust the gain such that system is continuously oscillated.

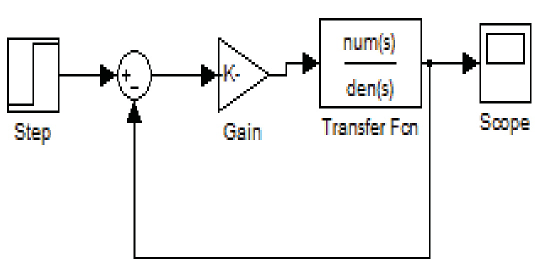

Fig. 2 Simulink diagram in MATLAB

Fig. 3 shows the simulated result at gain=11. As per ZigelerNicholaus rule Ku=11 and Pu=2. As per the table I for PID controller the value of K_p = 6.6, K_i =1/Ti = 1 and K_d = 0.25. With the above values of K_p, K_i and K_d, step response of system is shown in Fig. 4. Mp = 62.8.7%, tp = 1.21 sec,tr=0.401 sec ts = 8.39 sec, ess = 0.

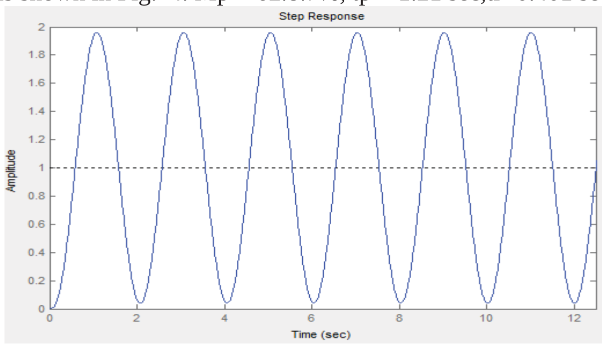

Fig. 3Critical gain using ZN method

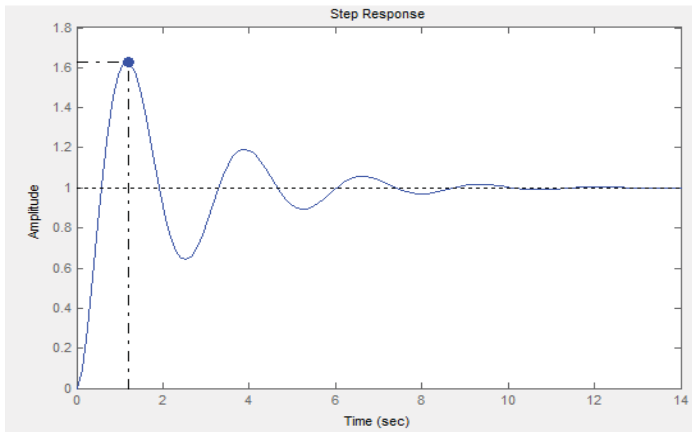

Fig. 4 System response using ZN method

But the limitation of Z-N method is it provides large overshoot which is undesirable for some system and another limitation is that it provides just starting point so fine tuning is required before actually applied to real system.

B. Modified Ziegler-Nicholas Method:

For some control loops the measure of oscillation, provided by ¼ decay ratio and the corresponding large overshoots for set point changes are undesirable therefore more conservative methods are often preferable such as modified Z-N settings.
These modified settings are shown in Table 2 are some
overshoot and no overshoot.

TABLE II PID CONTROLLER PARAMETRS FOR MODIFIEDZN METHOD

Controller	Kp	Ti	Td
Some overshoot	0.33ku	Pu/2	Pu/3
No overshoot	0.4ku	Pu/2	Pu/3

As per the TABLE IIfor PID controller the value of K_p = 3.63, K_i =1/Ti = 1 and K_d = 0.66. With the above values of K_p, K_i and K_d, step response of system is shown in Fig 5. Mp=48.8.7%, tp = 1.65 sec, tr=0.636 sec ts = 7.13 sec, ess = 0.

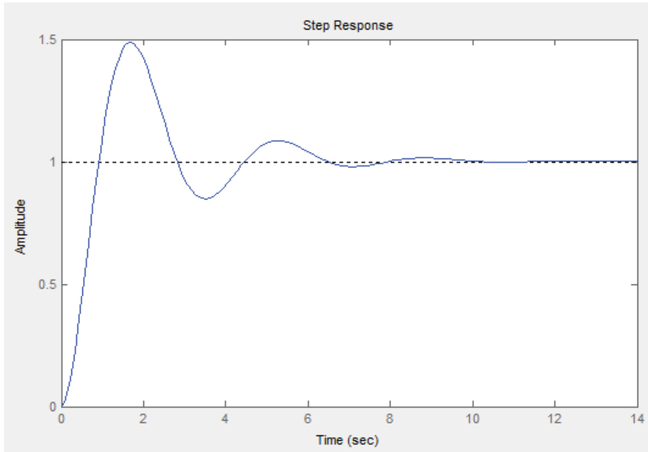

Fig 5 System response using Modified ZN method

V. GENETIC ALGORITHM OVERVIEW

Genetic Algorithms (GA's) are a stochastic global search method .It is a powerful optimization searching technique based on the principles of natural genetics and natural selection. A genetic algorithm is typically initialized with a random population consisting of between 20-100 individuals. This population is represented by a real-valued number or a binary string called a chromosome. Each chromosomes represents a solution of the problem which performance is evaluated by a fitness function. The fundamental components of GA are reproduction, 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 the optimum solution to the problem.

The steps involved in creating and implementing a genetic algorithm are as follows:

1. Generate randomly a population of chromosomes.
2. Calculate the fitness for each chromosome in the population.
3. Create offspring's by using genetic operators.
4. Stop if the search goal is achieved. Otherwise continue with Step 2.

A. THE OBJECTIVE FUNCTIONS FITNESS VALUES for PID Tuning

The most crucial step in applying GA is to choose the objective functions that are used to evaluate fitness of each chromosome. To optimize the performance of a PID controlled system, the PID gains of the system are adjusted to maximize or minimize a certain performance index. The performance index is calculated over a time interval T , normally in the region of s $0 \le T \le t$ where t is the settling time of the system. The performance indices used were mentioned in TABLE III

TABLE III PERFROMANCE INDICES FOR GA

Performance Indices	**Equation**
Integral of Time multiplied by Absolute Error (ITAE)	$\int \lvert te(t) \rvert dt$
Integral of Absolute Magnitude of the Error (IAE)	$\int \lvert e(t) \rvert dt$
Integral of the Square of the Error (ISE)	$\int e(t)^2 dt$

The PID controller is used to minimize the error signals. And because the smaller the value of performance indices of the corresponding chromosomes the fitter the chromosomes will be.

B. Implementation of work

The optimization of the system has been designed and simulated in MATLAB and Genetic Algorithm toolbox, with population size of 20 , scattered crossover, selection based on stochastic uniform and migration direction in both sides.

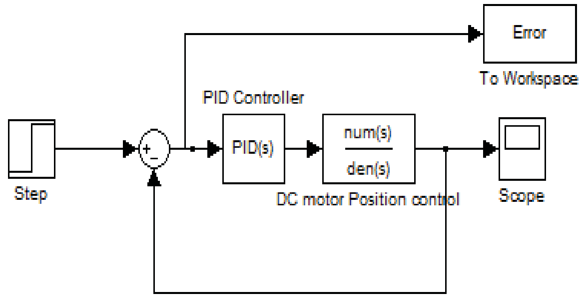

Fig 6   PID tuning simulation diagram for GA

Optimized the system by using GA toolbox and using various performance indices, evaluated value of tuning parameters of PID controller which is mentioned in Table IV.

TABLE IV Tuning Parameters

Performance Indices	Kp	Ki	Kd
ITAE	11.4984	0.6061	0.4078
IAE	15.0046	0.2322	2.4839
ISE	6.6684	0.2379	6.9178

With the above values of K_p, K_i and K_d, step response of system is shown in Fig 7, 8and 9. From the step response find the value of various transient and steady state parameters..

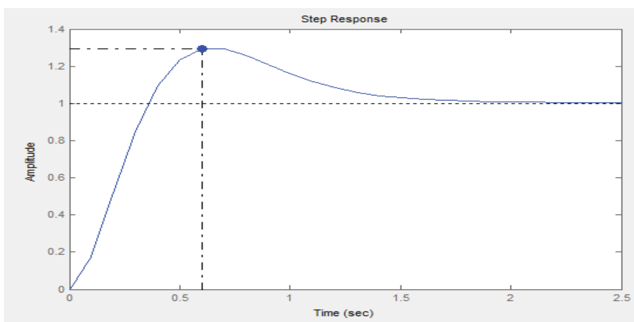

Fig 7   System response using GA ITAE as a fitness function

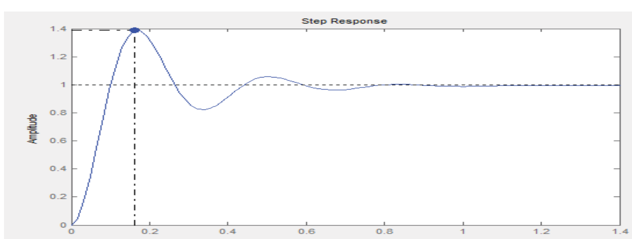

Fig 8 System response using GA IAE as a fitness function

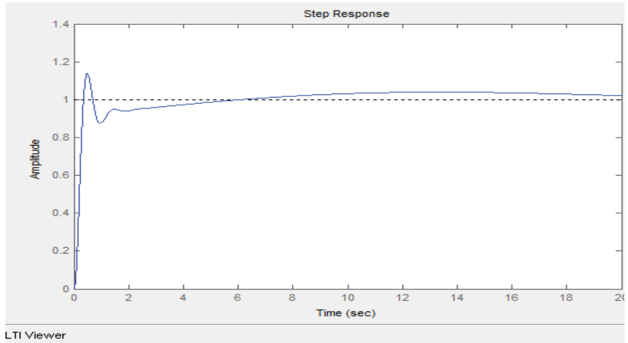

Fig. 9 System response using GA ISE as a fitness function

VI. Simulation Result

Simulation is carried out in MATLAB software to compare the performance between Ziegler-Nicholas method and Genetic Algorithm to tune PID controller for DC motor positional control system. System response is shown in Fig. 10. The transient and steady state parameters are shown in Table-V.

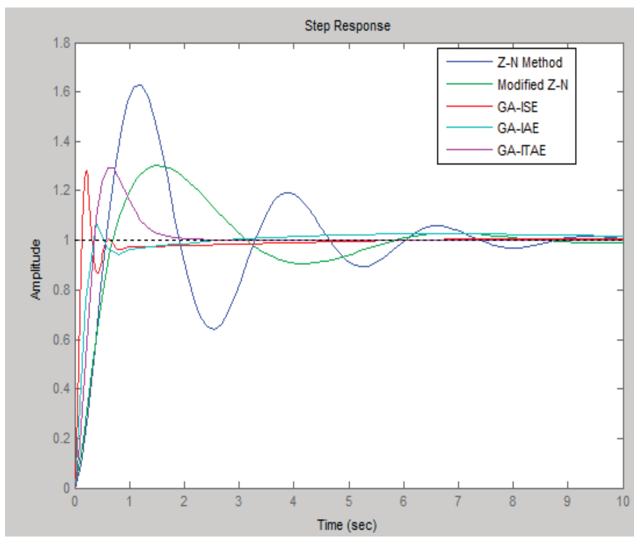

Fig 10 Comparision of system response using various tuning Methods

TABLE V Transient and steady state parameters

Tuning Method	Mp (%)	tp(sec)	tr(sec)	ts(sec)
ZN method	62.8.7	1.21	0.40	8.39
Modified ZN	48.8.7	1.65	0.63	7.13
GA-ITAE as fitness	29.6	0.6	0.265	1.63
GA-IAE as fitness	38.7	0.16	0.06	0.741
GA-ISE as a fitness	14.4	0.48	0.63	6 .01

VII. Conclusion

The use of Genetic Algorithms for optimizing the PID controller parameters as presented in this paper is more efficient method as compared to convential Ziegler Nichols tuning method. Simulation result show that GA offers less overshoot, rise time and settling time . Genetic Algorithms have proved better in achieving the transient and steady-state response parameter.

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