Tuning of PID Controller Using Particle Swarm Optimization Technique for DC Motor Speed Control

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Abstract— **Design of PID controller for speed regulation of DC motor is presented in this paper. A PID (Proportional Integral Derivative) controller is a common instrument used in industrial control applications. A PID controller can be used for regulation of speed, temperature, flow, pressure and other process variables. Field mounted PID controllers can be placed close to the sensor or the control regulation device and be monitored centrally using a SCADA system. In comparison with conventional PID, FOPID is more flexible and trustworthy to control higher order systems. According to parameters adjustment problems of PID controller, particle swarm optimization (PSO) algorithm is adopted to optimize PID controller parameters. Peak overshoot, rise time and settling time are considered as important factors to minimize using PSO technique. Simulation results give validation of the proposed work and provide effectiveness of PID controller in terms of robustness and control effect as compared to PID controller.**

Keywords: **DC MOTOR, PSO, PID CONTROLLER**

I. INTRODUCTION

For industrial applications, DC motors are mostly preferred. It is reliable, easy in implementation and having low cost . For desired output response and speed control, DC motor is used along with PID controller in closed loop. The conventional PID controller has been facing lots of problem to achieve ideal control effect. For higher order systems, PID has not been working properly.Fractional calculus has introduced the concept of Fractional Order PID controller. In a FOPID controller, order of derivative (11) and order of integral (A) are two extra performance parameters apart from
Proportional (KP), integral (Ki) and derivative (Kd) constants. Hence, for designing FOPID controller, there is a need of proper tuning of five parameters {Kp, Ki,Kd,,:t,J.l}.
This paper proposes a discrete-time ESA-ARNN for autotuning of PID controller parameters . The autotuning scheme of PID controller parameters by applying the discrete time ESA-ARNN. Gives simulation results to validate the effectiveness of the Auto-tuning algorithm proposed and compares them with those obtained by some prevalent techniques.
In 2004, Gaing compared the GA with Simulated Annealing and concluded that GA is faster due to its parallel search techniques, but has the disadvantage of premature convergence. Coelho in 2009 proposed that the Chaotic Optimization Aigorithm has the feature of easy implementation, short execution time and robust mechanism of escaping from local optima . In 2012, Tang, Cui, Hua, Li and Yang used the CAS to tune PID controller and found that it has more chances to explore to global optimum in search space. Gozde and Taplamacioglu in 2011 used ABC algorithm and proposed that ABC has tripie search capability
provided by separate artificial bee colonies. In 2011, Panda proposed the DE Algorithms which is capable of handling non Differentiable, nonlinear and multimodal objective function with few easily chosen control algorithms. In 1995 Kennedy and Eberhart proposed a new algorithm that has root in bird flocking and swarming theory. Among the entire evolutionary algorithm, PSO has the advantage that it requires only primitive mathematical operators and it is computationally inexpensive in terms of both memory requirement and speed. But it has the chance of getting trapped in local optima. To overcome this certain modifications were made in basic PSO. In this study, variants of PSO such as Simplified PSO (MOL) and Adaptive PSO (APSO) that has the advantage of escaping from local optima are used to tune the control parameters of PID controller in the A VR system. Also MOL has the advantage of easy implementation and APSO has the advantage of faster convergence. MOL and APSO differ from the basic PSO in the velocity updation only.

II. MODELING OF DC MOTOR

Consider a mathematical model of DC motor which is shown in fig 1. The armature voItage V.(s) controls the angular velocity wes) of the motor shaft. From mathematical model, the transfer function is given by,

$$G(s) = \frac{\omega(s)}{V_a(s)} = \frac{K_m}{(Ls+R)(Js+K_f)+K_b K_m} \quad (1)$$

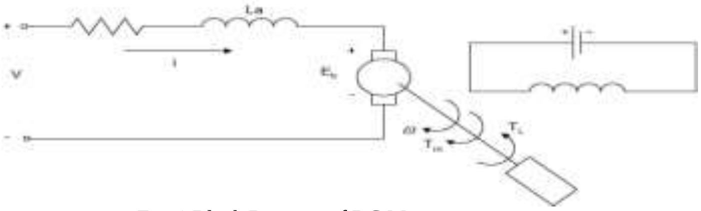


Fig. 1 Block Diagram of DC Motor

By neglecting armature losses and rotational losses, the mechanical power output of the motor is equal to armature input.Hence Km = Kb and Kr = O.
The specifications of motor used in this paper are: R=2 D; Km = Kb = 1.02; L=3 mH ; J = 1.78 e-4 Kg_m2;
The transfer function of DC motor using above specified

$$G(s) = \frac{1.91e006}{s^2+666.7s+1.948e006} \quad (2)$$

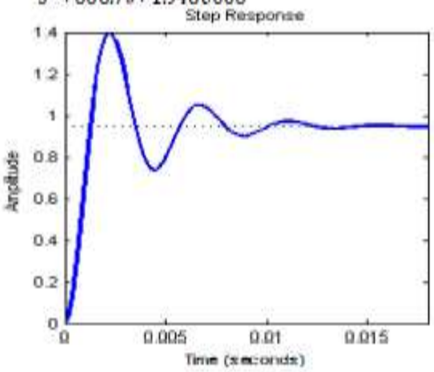


Fig. 2: Step Response of DC Motor

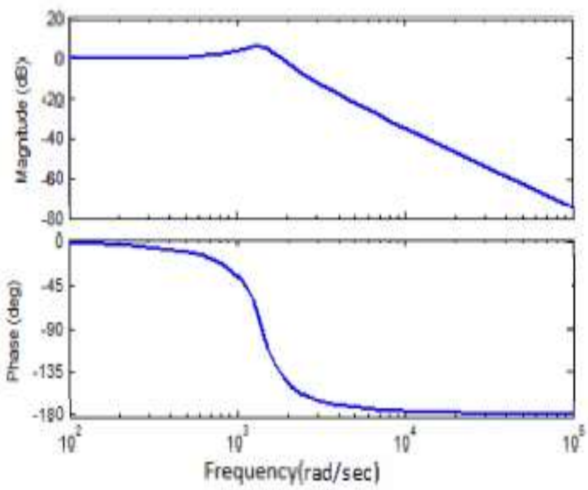


Fig. 3: Bode Plot of Plant

III. DESIGN OF PID CONTROLLER

In this section, PID and FOPID controller has been designed in time domain. To optimize the controller, Particle Swarm Optimization technique minimizes time domain integral performance indices which act as an objective f unction,

A. Particle Swarm Optimization

In PSO technique [10] [11], there are N particles moving in a search space of dimension D. The position of ith particle is given by XO) = (Xil' Xi2 Xi3 ...iD)·Current velocity is given by = (Vi1' Vi;,vi3 ... . . ViD). Each particle moves in a space and trying to achieve best possible location. The best previous location of ith particle (pbest) is given by Pi = (Pil'pi2'pi3 . . . , PiD)' At last, all the moving particles in a search space attained the best position (gbest) denoted as Pg = (Pg1, Pg2'pg ·PgD) · At each step, the velocity and position of each particle is given by:

$$v_{id} = w * v_{id} + c_1 * rand(\,) * (p_{id} - x_{id}) + c_1 * rand(\,) * (p_{gd} - x_{id})$$

$$x_{id} = x_{id} + v_{id}$$

where cl is positive cognitive learning rate and c2 is social learning rate; rand 0 is a random function whose value lies in the range [0, 1]. Standard PSO technique introduced a time decreasing inertia factor w is introduced to overcome the problem of poor velocity control mechanism.

$$w = w_{max} - \frac{w_{max}-w_{min}}{iter_{max}}.iter$$

where itermax and iter are maximum number of iterations and the current number of iterations respectively. The maximum and minimum values of weight factor are denoted by Wmax and wmin.

IV. TUNING OF PID CONTROLLER USING SEVERAL METHODS

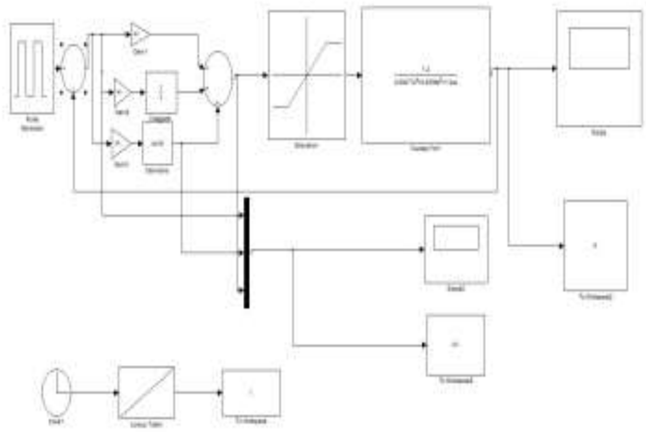
The P, I and D terms need to be "tuned" to suit the dynamics of the process being controlled. Any of the terms described above can cause the process to be unstable, or very slow to control, if not correctly set. These days temperature control using digital PID controllers have automatic auto-tune functions. During the auto-tune period the PID controller controls the power to the process and measures the rate of change, overshoot and response time of the plant. This is often based on the Zeigler-Nichols method of calculating controller term values. Once the auto-tune period is completed the P, I &D values are stored and used by the PID controller.

A. Ziegler-Nichols Tuning Method:

There are two methods for determination of the parameters of PID controllers called Ziegler-Nichols tuning rules. But the widely accepted method for tuning the PID controller is straightforward method. First, set the controller to P mode only. Next, set the gain of the controller to a small value. If is low the response should be Sluggish. Increase by a factor of two and Keep increasing (by a factor of two) until the response becomes oscillatory. Finally, adjust until a response is obtained that produces continuous oscillations. This is known as the ultimate gain or. Note that the period of the oscillations is known as ultimate period. The steps required for the method are given below: - The integral and derivative coefficients have to set (gains) to zero. Gradually increase the proportional coefficient from zero to until the system just begins to oscillate continuously (sustained oscillation). The proportional coefficient at this point is called the ultimate gain. And the period of oscillation at this point is called ultimate period

Table 1: Ziegler-Nichols Tuning Rule Based

Controller Type	Kp	Ki	Kd
PID	Ku /1.7	Tu/2	Tu/8



Fig, 4 Block Diagram for The Complete System Using PID Controller Tuning With Ziegler-Nichols

The Maximum Overshoot, Mp of the system is approximately 0.02. The Settling time, ts is about 0.8 sec. From the analysis above, the system has not been tuned to its optimum. So we have to go for genetic algorithm approach.

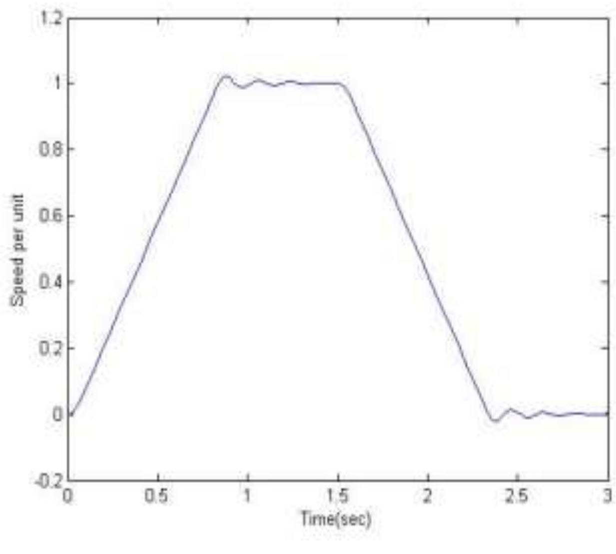


Fig.5 Response of the system Using PID Controller Tuning with Ziegler-Nichol

B. Genetic Algorithm Method:

GA has been recognized as an effective and efficient technique to solve optimization problems. 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 Genetic Algorithm Process Architecture is shown in Figure 6.

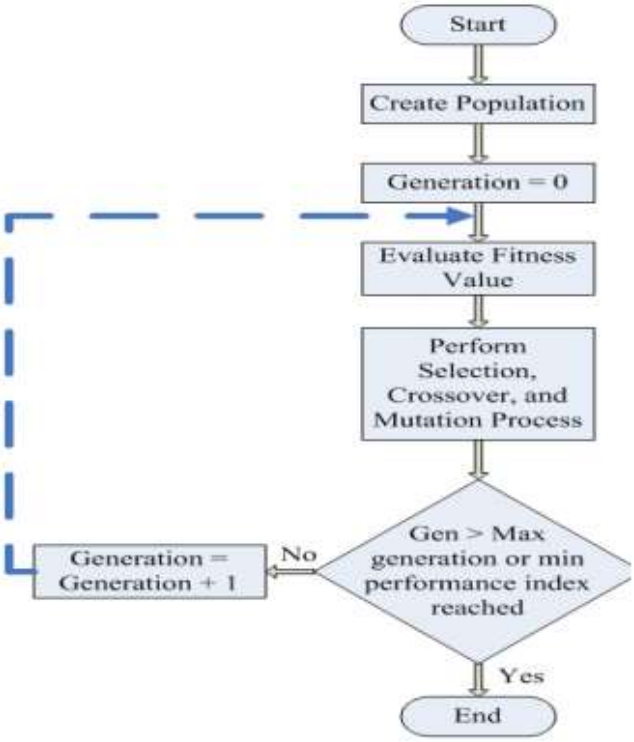


Fig.6 Genetic Algorithm Process Architecture

The proposed PID controller with applying Genetic Algorithm Method is given in Figure (6), and also The genetic algorithm gain values for the tuning is given below in Table(3). The output response of the system is showen in Figure (7), and we can analyse the system for the previous parameters

i Maximum Overshoot, Mp

ii Settling time, ts

The Maximum Overshoot, Mp of the system is approximately zero. The Settling time, ts is about 0.45 sec. we will go for studying the effect of ANFIS for PID controller based on Genetic Algorithm.

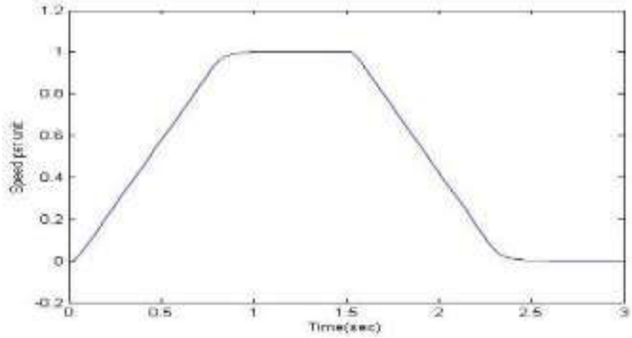


Fig. 7 Response of Genetic Algorithm Based PID controller

Table 2. The GA based PID controller gain values

Gain Parameters	Gain Values
Kp	19.88
Ki	0.1376
Kd	0.5578

C. Adaptive Neuron-Fuzzy Inference System (ANFIS) method:

A model that maps input characteristics to input membership functions, input membership function to rules, rules to a set of output characteristics, output characteristics to output membership functions, and the output membership function to a single-valued output or a decision associated with the output.

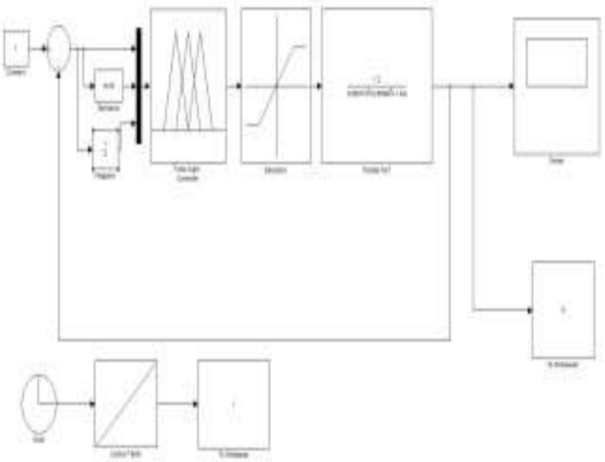


Fig. 8 block diagram for the complete system of ANFIS based PID

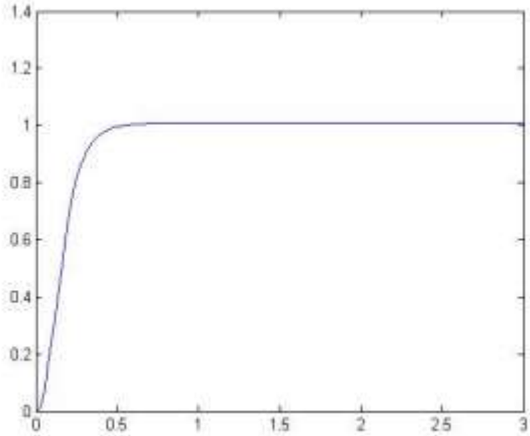


Fig. 9 Response of Adaptive Neuron-Fuzzy Inference System (ANFIS) Based PID Controller,

V. RESULT:

Table 3. Comparison between ZN, GA, and ANFIS Responses

Tuning method	Maximum overshoot	Settling time (sec)
ZN	0.02	0.8
Genetic Algorithm	—	0.45
ANFIS	—	0.5

VI. CONCLUSION:

The designed PID with Adaptive Neuron-Fuzzy Inference System based 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 Adaptive neuron-Fuzzy Inference System based GA designed PID is much better in terms of the rise time and the settling time than the conventional method. Finally the Artificial Intelligence Techniques provides much better results compared to the conventional methods. And also the error associated with the Adaptive neuron-Fuzzy Inference System based GA is much lesser than the error calculated in the conventional scheme.

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