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Analysis of PMDC Drive Performance Based on PSO Algorithm Based Tuning of PID Controller

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Abstract

The practical swarm optimization algorithm has accepted for many speed control applications because of its simple implementation and few algorithm parameters. This paper deals with optimal tuning of PID controller with particle swarm optimization PSO for improving performance of PMDC drive. The PSO application smoothen the starting torque; it provides the improvement in acceleration and speed control. The dynamic error driven controller regulates the firing delay angle (alpha) using the particle swarm optimization PSO tuning PID blocks. The control voltage signal is used to regulate the firing delay angle alpha of the power converter. The proposed tuned PID controller is based on the minimization of the absolute of total Error.

Index terms: Permanent Magnet DC motors, PID parameter tuning methods, PSO Algorithm.

Introduction

Nowadays there is a huge requirement of high performance motor drives in industrial as well as other purpose applications such as steel rolling mills, electric trains and robotics. Generally, a better performance motor drive system has good dynamic response which perform task to speed command tracking and load regulating response [1,2]. DC drives consist of fewer complexes with a single power conversion from AC to DC. This is as a result of its simplicity, low cost design and robust performance in a wide range of operating conditions [3].The major problems in applying a conventional control algorithm (P,PD, PID) in a speed controller are the effects of non-linearity in a DC motor. Speed control of DC motor has attracted considerable research and several methods have created. Proportional Integral Derivative (PID) controllers have the advantage of simple structure, good stability, and high reliability [4]. Accordingly, PID controllers are widely used to control system outputs, especially for systems with accurate mathematical models. The key issue for PID controllers is the accurate and efficient tuning of parameters. In practice, controlled systems usually have some features, such as nonlinearity, time– variability, and time delay, which make controller parameter tuning more complex [5]. Moreover, in some cases, system parameters and even system structure can vary with time and environment. As a result, the traditional PID parameter tuning methods are not suitable for these difficult calculations [6,7]. The aim of this paper is to design a DC motor control using Ziegler and Nichols and Genetic Algorithm [8,9]. Genetic Algorithm or in short GA is a stochastic algorithm based on principles of natural selection and genetics. Genetic Algorithms (GA) are a stochastic global search method that mimics the process of natural evolution [10]. Genetic Algorithms have been shown to be capable of locating high performance areas in complex domains without experiencing the difficulties associated with high dimensionality or false optima as may occur with normal PID techniques [11]. Using genetic algorithms to perform the tuning of the controller will result in the optimum controller being evaluated for the system every time [12,13]. This can be seen by comparing the result of the GA optimized system against the classically tuned system [14]. Genetic algorithm is a computational procedure that mimics the natural process of evolution [15]. Certain optimization problems (they are called variant problems) cannot be solved by means of genetic algorithms [16,17]. This occurs due to poorly known fitness functions which generate bad chromosome blocks inspite of the fact that only good chromosome blocks cross-over [18]. In this paper presents the optimal tuning of PID controller with particle swarm optimization PSO for improvement of performance of PMDC drive [19].

Dc Motor Mathematical Model

The DC motor mathematical model provided below where,

R: the armature resistance,

L: the armature inductance,

i : the armature current,

E_a: the input voltage,

I : the field current,

e : the back electromotive force (EMF),

T: the motor torque,

v: angular velocity of rotor,

J: rotating inertial measurement of motor bearing,

B: a damping coefficient.

Because the back EMF e_b is proportional to speed ω directly, then

$$e_b(t) = K_b \frac{d\theta(t)}{dt} = K_b \omega(t) \tag{1}$$

Making use of the KCL voltage law can get

$$e_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t) \qquad (2)$$

From Newton law, the motor torque can obtain

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

Take (1), (2), and (3) into Laplace transform respectively, the equations can be formulated as follows:

$$E_a(s) = (R_a + L_a s)I_a(s) + E_b(s)$$

$$E_a(s) = K_b\Omega(s)$$

$$T_m(s) = B\Omega(s) + Js\Omega(s) = K_T I_a(s)$$

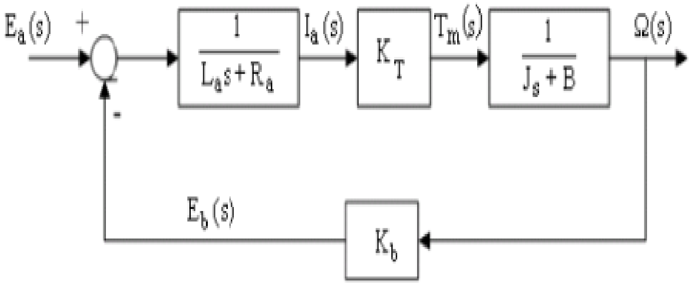


Figure 1: Function block diagram of DC motor

Fig.1 shows the functional block diagram of DC motor, Fig.2 shows DC motor representation. The transfer function of DC motor speed with respect to the input voltage can be written as follows:

$$G(s) = \frac{\Omega(s)}{E_a(s)} = \frac{K_T}{(L_a s+R_a)(Js+B)+K_b K_T}$$

From the above Equation the armature inductance is very small in practices, hence, the transfer function of DC motor speed to the input voltage can be simplified as follows,

$$\frac{\Omega(s)}{E_a(s)} = \frac{K_m}{\tau s + 1}$$

Where $K_m = \frac{K_T}{R_a B+K_b K_T}$ is a motor gain and $\tau = \frac{R_a J}{R_a B+K_a K_T}$ is motor time constant.

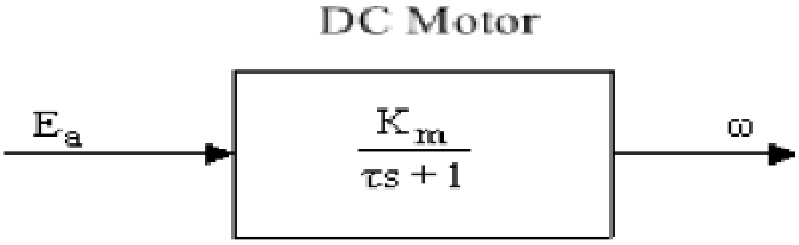


Figure 2: DC motor representation

PID Controller

The PID controller includes a proportional term, integral term and derivative term, where the proportional term is to adjust the output of controller according to all of the magnitude of error, the integral term is used to remove the steady state error of control system and improve the steady state response, the derivative term is used to predict a trend of error and improve the transient response of the system. These functions have been enough to the most control processes. Because the structure of PID controller is simple, it is the most extensive control method to be used in industry so far. The PID controller is mainly to adjust an appropriate proportional gain (K_P), integral gain (K_I), and differential gain (K_D) to achieve the optimal control performance. The PID controller system block diagram of this paper is shown in Fig. 3.

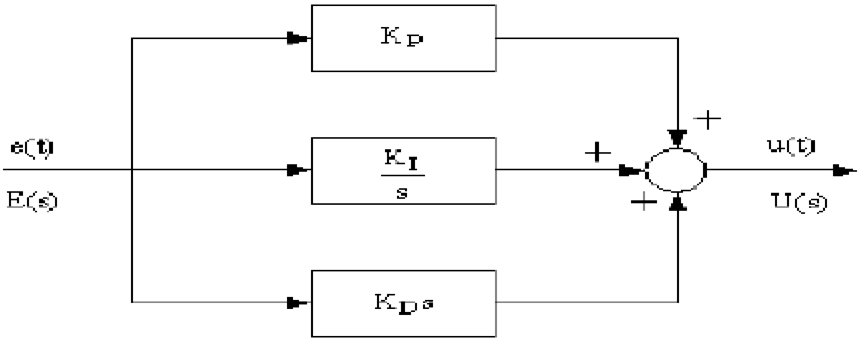


Figure 3: Schematic diagram of PID controller

The relationship between the input $e(t)$ and output $u(t)$ can be formulated in the following

$$u(t) = K_p e(t) + K_I . \int_0^t e(t)\,dt + K_D \frac{de(t)}{dt}$$

The above equation can be expressed as follows.

$$C(s) = \frac{U(s)}{E(s)} = K_P + \frac{K_I}{s} + K_D s$$

Fig.4 shows the block diagram representation for PID based DC motor.

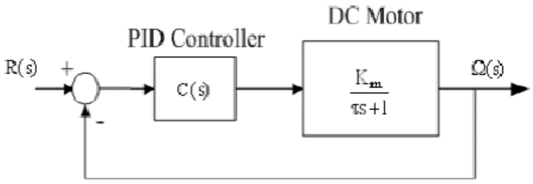


Figure 4: Block diagram representation for PID based PMDC

Closed loop transfer function of the DC motor speed control system is shown below.

$$G(s)=\frac{\Omega(s)}{R(s)}=\frac{(K_P+\frac{K_I}{s}K_Ds)\frac{K_m}{1+\tau s}}{1+(K_P+\frac{K_I}{s}+K_Ds)\frac{K_m}{1+\tau s}}=\frac{(K_Ds^2+K_Ps+K_I)K_m}{(K_DK_m+\tau)s^2+(1+K_PK_m)s+K_IK_m}$$

Tuning method for PID controller is very important for the process industries. Simulink model for DC Motor driving a mechanical load of inertia J. Fig.5 shows simulink model for DC motor driving load and Fig.6 shows PMDC motor drive scheme with multi-loop dynamic controller.

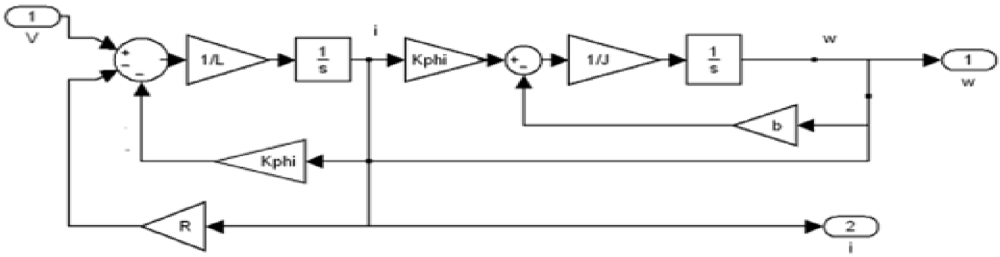


Figure 5: Simulink model for DC motor driving load

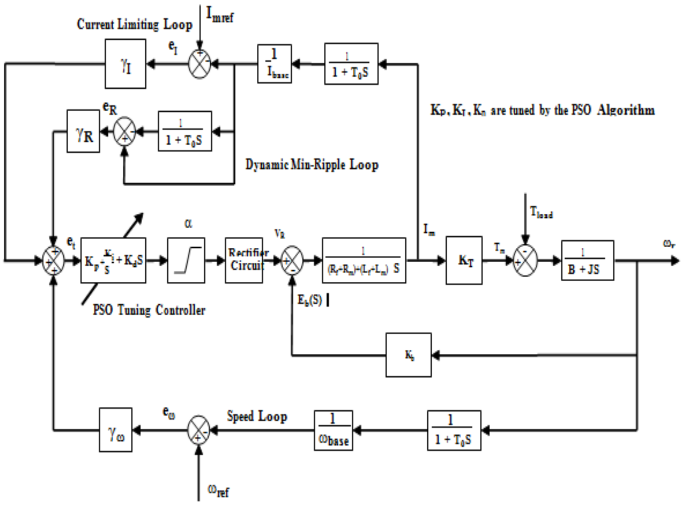


Figure 6: PMDC Motor Drive Scheme With Multi-Loop Dynamic Controller

PSO Algorithm

PSO is one of the optimization techniques and a kind of evolutionary computation technique. The method has been found to be robust in solving problems featuring nonlinearity and non differentiability, multiple optima and high dimensionality through adaptation, which is derived from the social-psychological theory. The technique is derived from research on swarm such as fish schooling and bird flocking. According to the research results for a flock of birds, find food by flocking (not by each individual). The observation leads the assumption that every information is shared inside flocking. Moreover, according to observation of behavior of human groups, behavior of each individual (agent) is also based on behavior patterns authorized by the groups such as customs and other behavior patterns according to the experiences by each individual. The assumption is a basic concept of PSO. Fig.7 shows block diagram representation of proposed system. In the PSO algorithm, instead of using evolutionary operators such as mutation and crossover, to manipulate algorithms, for a d-variable optimization problem, a flock of particles are put into the d-dimensional search space with randomly chosen velocities and positions knowing their best values so far (Pbest) and the position in the d-dimensional space. The velocity of each particle, adjusted according to its own flying experience and the other particle's flying experience.

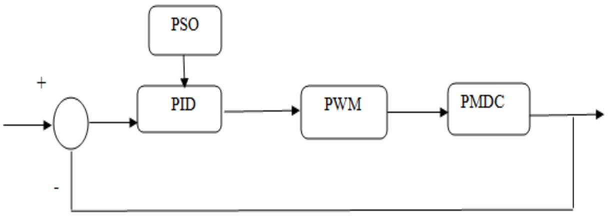


Figure 7: Block diagram representation of proposed system

Algorithm for PSO

- The ith particle in the swarm is represented asXi = (xi1, xi2, xi3,..................xid) in the d-dimensional space.
- The best previous positions of the ith particle is represented as: Pbest = (Pbesti,1,Pbesti,2,Pbesti,3..........Pbesti,d)
- The index of the best particle among the group is Gbestd. Velocity of the ithparticle is represented as Vi = (Vi,1 Vi,2 Vi,3..........Vi,d).
- The updated velocity and the distance from Pbestidto Gbesti,dis given as ; Vi,mt+1=W*Vi,mt+C1*rand()*(Pbesti,m – Xi,mt) + C2*rand()*(Gbestm–Xi,mt)-

Xi,m(t+1)= Xi,m(t)+Vi,m(t+1) For i=1,2,3.......n.14m = 1,2,3.....d.

Flow Chart Representation For PSO Implementation

Fig.8 shows flow chart of PSO-PID system.

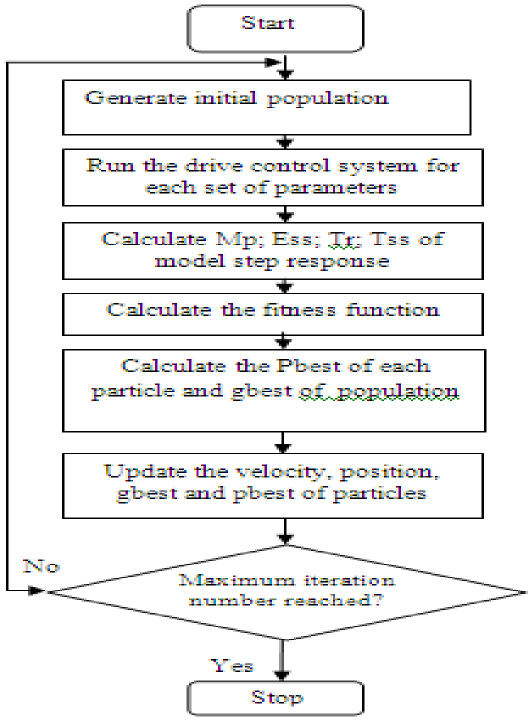
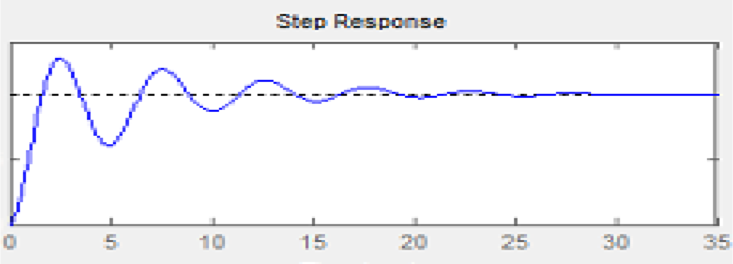


Figure 8: Flow chart of PSO-PID system

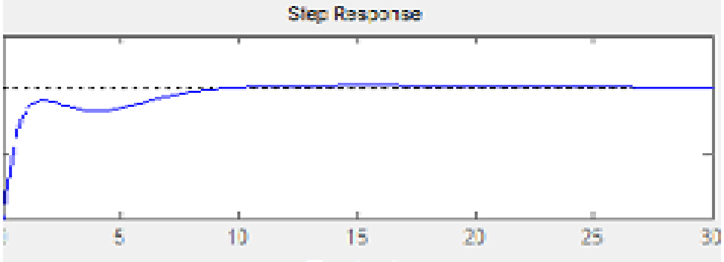
Where,
n:- Number of particles in the group.
d:- dimension index.
t:- Pointer of iteration.
Vi,m (t):- Velocity of particle at iteration i.
W:- Inertia weight factor.
C1 , C2:- Acceleration Constant.
rand() :- Random number between 0 and 1.
Xi,d(t):- Current position of the particle 'i'
At iteration.
Pbesti- Best previous position of the
i th particle.
Gbest:- Best particle among all the particle in the swarming population.

Result Analysis

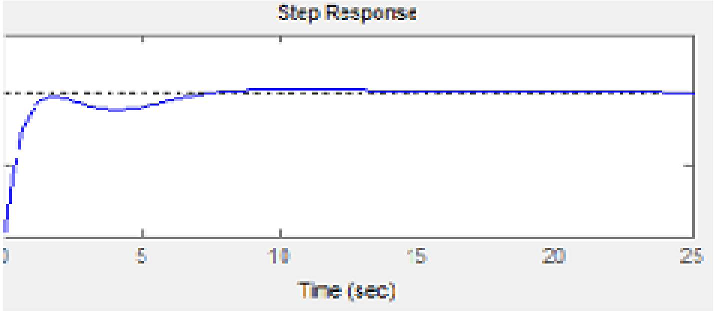
The improvement of dynamic system repose has been challenging issue in many applications; the PSO based tuning of PID controller has shown a considerable impact on speed performance of PMDC drive, the speed response is represented in following figures. Fig.9a shows the dynamic system response at 50th iteration, Fig.9b shows the dynamic system response at 100th iteration, Fig.9c shows the dynamic system response at 150th iteration, Fig.9d shows the dynamic system response at 200th iteration. It is clearly observed that steady state parameters have a drastic improvement in the dynamic response. The response of the system with application of step excitation is represented in the Figure 9d. The tuning of the system with PSO has been showed in a better response. Table 1 shows the analysis results.



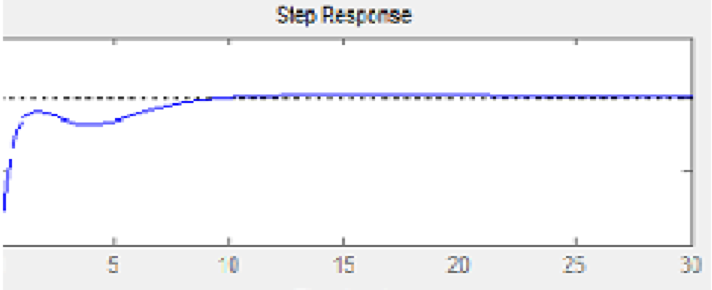
(a) 50th iteration



(b) 100th iteration



(c) 150th iteration



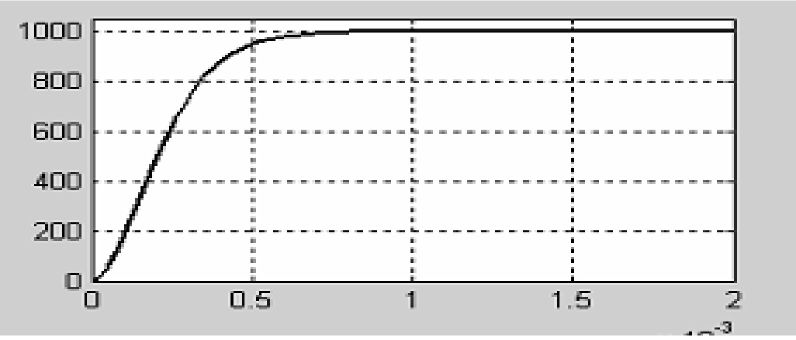
(d) 200th iteration

Figure 9: Dynamic System Response

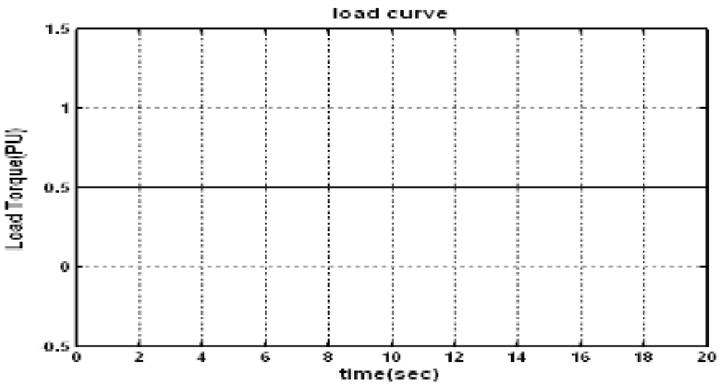
Table 1: Analysis Results

Iteration count	Kp	Ki	Kd	Total error (Ess)
50	17.724962157795	6.607932536271	2.824873743461	0.24886719
100	25.821611906533	11.256752917424	11.489903078369	0.13096854
150	35.774888117042	5.5574577498203	13.747650132991	0.15139525
200	45.699542090841	22.898164629719	10.363603736861	0.01956727

A mechanical load on the PMDC drive response has represented in Figure 10a. It has been shown constant at 0.5pu. The terminal voltage of PMDC drive represented in per unit based in Figure 10b. Armature current of PMDC drive observed constant at a particular time period and started decreasing at Figure 11a. Fig.11b shows the armature current of DC motor.

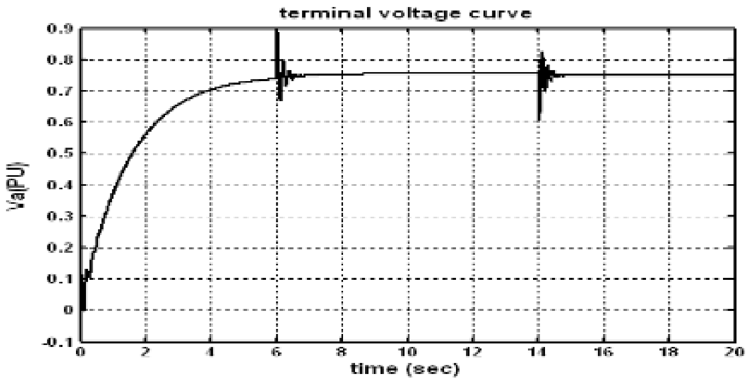


(a) Step response

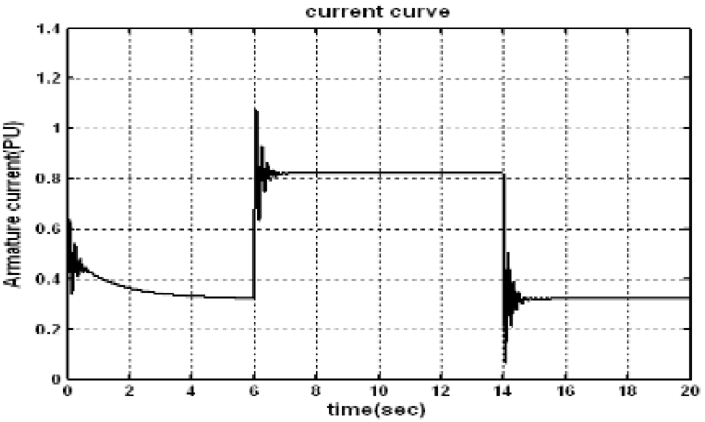


(b) Load curve

Figure 10: PMDC drive with PSO based PID tuning



(a) Terminal voltage



(b) Armature current

Figure 11: PMDC Motor

Performance of PSO PID Controller

- Rise Time (ms) - 0.3038
- Max overshoot (%) - 0
- Steady State Error -0.77186
- Settling Time (ms) -0.60116

Conclusion

In this paper a new design method to determine PID controller parameters using the PSO method is presented. The tuning algorithm proposed has shown a considerable approach when compared to conventional algorithm. The response of the system at different iterations is shown. The performance characteristics of PMDC based on PSO PID has presented. It shows that this method can improve the dynamic performance of the system in a better way. According to the analysis done on the basis of results obtained, conclusion that for the design of a PID controller for the low damping plant Particle swarm optimization technique gives a better result than other optimization technique.

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