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Tuning of PID Controller for A Linear Brushless DC Motor using Swarm Intelligence Technique

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Abstract
An Optimal Design of PID Controller is proposed in this paper. The Methodology of PSO Algorithm is utilized to search the optimal parameters of Proportional Integral Derivative (PID) Controller for BLDC Motor. PSO is an Evolutionary Optimization Technique. A Linear Brushless DC Motors are known for higher efficiency and lower maintenance. The Brushless DC Motor is modeled in Simulink & tuning of PID controller using PSO is implemented in MATLAB. This Method was more efficient for Step Response Characteristics.
Keywords—Brushless DC Motor, Particle Swarm Optimization ,PID Controller, Optimal Control.

I. INTRODUCTION

There are two types of DC Motors which are used on a large scale in industries or many applications .They are Conventional DC or Brushless DC motor .The first one is the conventional DC motor where the flux is produced by current through field coil of stationary pole structure [1] .The Second one is BLDC Motor where permanent Magnet Provides the necessary air gap flux instead of wire wound field poles.

BLDC Motor has the advantage of No Mechanical Commutator, Lower Maintenance also has simple structure, higher efficiency, and high force & has a high Starting Torque versus falling speed Characteristics which helps high starting torque & helps to prevent sudden load rise [2]. The BLDC Motors are especially used in the industries, production, aeronautics, medicine; consumer & industrial automations .The BLDC Motors are well driven by dc voltage. They have no commutation that is done by electronics application (Hall effect Sensors).Recently Many Control methodologies such as optimal control[4] ,nonlinear control[3], variable structure control[5] & adaptive control[6] have widely used for Linear Brushless DC motor .However These approaches are either complex in theoretical Bases or difficult to implement[7].

The PID (proportional integral & derivative) Controller is widely used in various field as control engineering, if there are stability is desired, then PID Controller could be very useful. PID controller is the controller parameters tuning process. In a PID controller, each mode (proportional, integral and derivative mode) has a gain to be tuned, giving as a result three variables involved in the tuning process. PSO algorithm is used to select optimal control gains.

The Design of BLDC Motor involves a complex process such as modeling, control scheme selection, simulation & parameters tuning etc .various control solutions methods are proposed for speed control design of BLDC Motor. However, PSO PID Controller Algorithm is an easy implementation, flexible & highly reliable. It is firstly introduced by Kennedy & Eberhart [14] is one of the method Of learning algorithms .it is Motivated by the behavior of organism , such as fish schooling & bird flocking .it is a well Balanced mechanism to enhance the Global & local exploration abilities.

In This Paper, an optimal PID Controller for a general second Order system is developed using PSO approach. The new PID tuning Algorithm is applied to the speed control of BLDC Motors.

II. BRUSHLESS DC MOTORS

BLDC motors are a derivative of the most commonly used DC motor, the brushed DC motor, and they share the same torque and speed performance curve characteristics. The major difference between the two is the use of brushes. BLDC motors do not have brushes (hence the name "brushless DC") and must be electronically commutated [17]. Commutation is the act of changing the motor phase currents at the appropriate times to produce rotational torque .DC motors use mechanical commutators and brushes to achieve the commutation .BLDC Motors use Hall Effect sensors in place of commutators.

The stators of BLDC motors are the coils, and the rotors are the permanent magnets. The stators develop the magnetic fields to make the rotor rotating .The BLDC Motor operates in many modes (phases), but the most common is the 3-phase.The 3-phase has better efficiency and gives quite low torque. The 3-phase has a very good precision in control .The characteristics equations of BLDC motors can be represented as:

v_{app} (t) = L$\frac{di(t)}{dt}$+R. i (t) + v_{app} (t) (1)

v_{emf} = K_b.ω (t) (2)

T (t) =K_i. i (t) (3)

T(t) = J $\frac{d\omega(t)}{dt}$ + D.$\omega(t)$ (4)

Where v_{app} (t) is the applied voltage, ω (t) is the rotor speed,
L is the inductance of the stator, i(t) is the current of the circuit, R is resistance of the stator, v_{emf} (t) is the back electromotive force , T is the torque of motor, D is viscous coefficient , J is the moment of inertia , K_t is the motor torque constant , and K_b is the back electromotive force constant.
Fig.1 shows the block diagram of BLDC Motor, from the characteristics equations of the BLDC motor, the transfer function of speed model is obtained:

$$\frac{\omega(s)}{v_{app}(s)}=\frac{K_t}{L.J\ .S^2+(LD+RJ\ )S+K_t\,K_b} \quad (5)$$

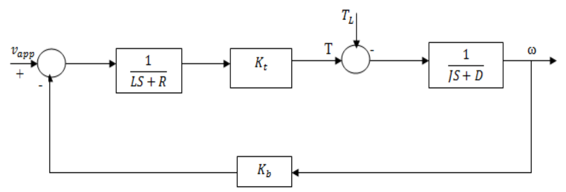

Fig.1 The block diagram of BLDC motor

The parameters of the motors used for simulation are as follows:

Table I
PARAMETERS OF THE MOTOR

PARAMETERS	Values and units
R	21.2 Ω
K_b	0.1433 Vs rad^{-1}
D	1*10^{-4}Kg-m s/ rad
L	0.052 H
K_b	0.1433 Kg-m/A
J	1*10^{-5}Kgm s^2/rad

III. OVERVIEW OF PARTICLE SWARM OPTIMIZATION

PSO is an easy & smart artificial techniques and a evolutionary computation technique which is developed by Kennedy & Eberhart [13] .it is used to explore the search space of a given problem to find the settings or parameters required to optimize a particular objective. It is based on following two concepts: (i) The idea of swarm intelligence based on the observation of swarming habits by certain kinds of animals (such as birds and fish), (ii) The field of evolutionary computation .The assumption is basic of PSO [16].

For n-variables optimization problem a flock of particles are put into the n-dimensional search space with randomly chosen velocities and positions knowing their best values, so far (P_{best}) and the position in the n-dimensional space. The velocity of each particle, adjusted accordingly to its own experience and the other particles flying experience. For example, the i_{th} particle is represented as:

X_i =(x_{i1},x_{i2},x_{i3}……………..x_{id})in the d-dimensional space,

the best previous positions of the i_{th} particle is represented as:
P_{best} =
($P_{best\ i,1}$,$P_{best\ i,2}$,$P_{best\ i,3}$………………$P_{best\ i,d}$)

The index of the best particle among the group is g_{best} . Velocity of the i_{th} particle is represented as:
V_i = ($V_{i,1}$,$V_{i,2}$$V_{i,3}$…………$V_{i,d}$)

The updated velocity and the distance from $P_{best\ i,d}$ to $g_{best\ i,d}$ is given as[13] :
$v_{i,m}^{(t+1)}$=w.$v_{i,m}^{(t)}$+c_1*rand()*($Pbest_{i,m}$-$x_m^{(t)}$)+c_2* rand()*$gbest_m$ - $x_{i,m}^{(t)}$)
(6)
$x_{i,m}^{(t+1)}$=$x_m^{(t)}$+$v_m^{(t+1)}$
(7)

i= 1, 2........, n
m= 1, 2,......d

n	Number of particles in the group
d	Dimension
t	Pointer of iterations (generations)
$v_{i,m}^{(t)}$	Velocity of particle I at iteration t
w	Inertia weight factor
c_1,c_2	Acceleration constant
rand ()	Random number between 0 and 1
$x_{i,d}^{(t)}$	Current position of particle i at iterations
$Pbest_i$	Best previous position of the ith particle
g_{best}	Best particle among all the particles in the population

IV. IMPLEMENTATION OF PSO-PID FOR BLDC MOTOR

In This paper a time domain criterion is used for evaluating the PID Controller .A set of good control parameters P,I and D

Can yield a good step response that will result in performance criteria minimization in the time domain .These performance criteria in the time domain include the overshoot, rise time,
Settling time, and steady state error [13]. Therefore, the performance criterion is defined as follows:
W (K) = (1- $e^{-\beta}$).(M_p + E_{ss}) + $e^{-\beta}$.(t_s - t_r)
where K is [P,I,D]and β is weightening factor. The performance criterion W (K) can satisfy the designer requirement using the weightening factor β value. β can set to be larger than 0.5 to reduce the overshoot and steady state error, also can set smaller 0.5 to reduce the rise time and settling time. The optimum selection of β depends on the designer's requirement and the characteristics of the plant under control. In BLDC motor speed control system the lower β would lead to more optimum responses. In this paper, due to trial, β is set to be 0.5 to optimum the step response of speed control system.

The fitness function is reciprocal of the performance criterion, in the other words,

$$f = \frac{1}{W(K)}$$

In this paper a PSO-PID controller is used to find the optimal values of BLDC speed control system.

Fig.2 shows the block diagram of optimal PID control for the BLDC motor.

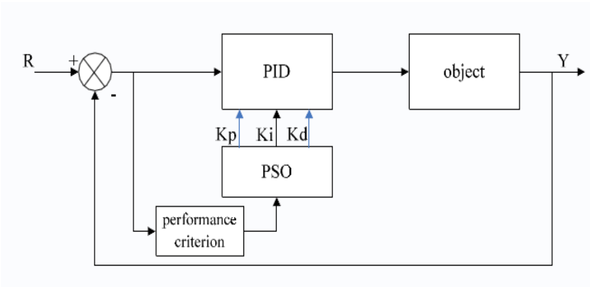

Fig.2 optimal PID control

In the proposed PSO method each particle contains three members *P*, *I* and *D*. It means that the search space has three dimension and particles must 'fly' in a three dimensional space.

The flow chart of PSO-PID controller is shown in Fig. 3.

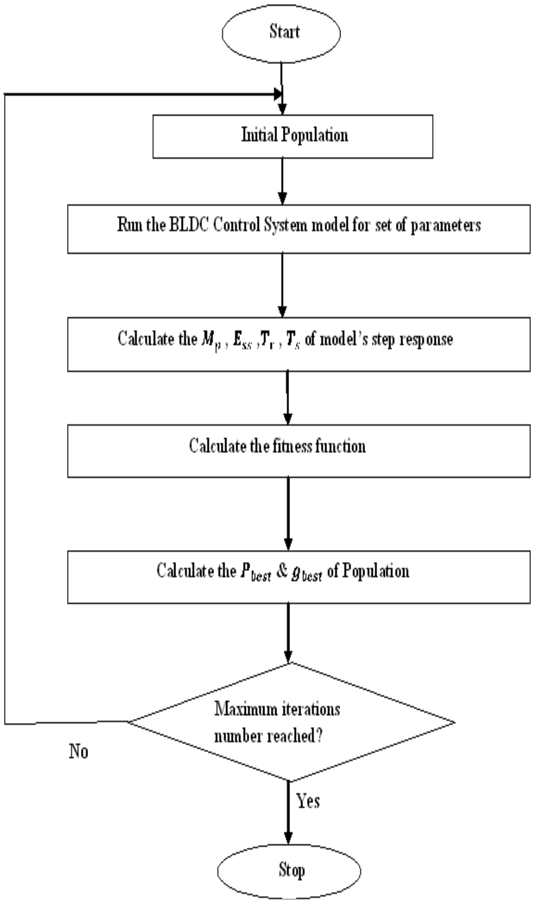

Fig.3 Flowchart of PSO-PID control system

V. RESULTS

To control the speed of LBDC motor at 500rpm, according to the trials, the following PSO parameters are used to verify the performance of the PSO-PID controller parameters:

- population size : 25
- w_{max} = 0.9 , w_{min} = 0.4
- c_1 =c_2= 0.5
- Iteration = 100;

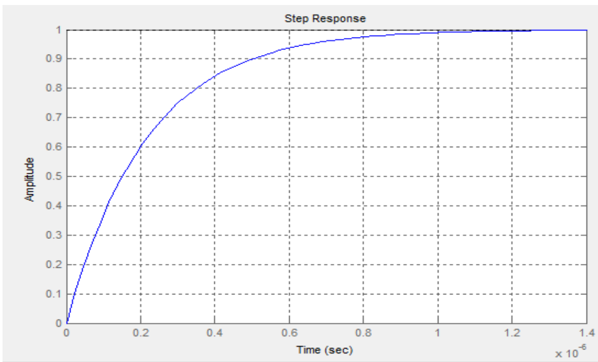

Fig.4 Step response of BLDC motor with PSO tune PID controller

TABLE II
PERFORMANCE OF THE PSO-PID CONTROLLER

Parameters	Proposed Method	Mehdi Nasri et. Al. [21]
[K_P K_I K_D]	[90.3281,85.2238 ,16.7163]	[190.0176,5 0,0.039567]
Rise Time(ms)	4.7733e-004	0.3038
Max Overshoot (%)	0	0
Steady State error	0.5000	0.77186
Settling time	8.5014e-007	0.60116

VI. CONCLUSIONS

In this paper a novel method to determine PID controller parameters using the PSO method is proposed. Obtained through simulation of BLDC motor, the results show that the proposed controller can perform an efficient search for the optimal PID controller. This method can improve the dynamic Performance of the system in a better way.

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