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Optimal Tuning of PID Controller for PMBLDC Motor using Cat Swarm Optimization

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Abstract

This paper proposes the optimal tuning of PID controller with Cat Swarm Optimization (CSO) algorithm for the speed control of Brushless DC Motor. Proportional Integral Derivative controllers are most popular controllers because of their effectiveness and easy to implement. However, in PID controller it is difficult to obtain the proper values of the controlling parameters Kp, Ki and Kd. In this paper, CSO is proposed to adjust the parameters of the controller in order to improve the performance of the system and run the BLDC motor at desired speed. The speed control of PMBLDC motor is done by the conventional PID controller and the CSO based PID controller. The variation of speed has been tested for both conventional and CSO based PID controller. The results shows a better system performance while using the CSO based PID controller than the conventional PID controller and also the speed of PMBLDC is improved by using the CSO.

Keywords: Proportional Integral Derivative Controller, Permanent Magnet Brushless DC Motor, Cat Swarm Optimization.

I. INTRODUCTION

The absence of brushes and the commutator in permanent magnet brushless motors offers many advantages over other motors, such as high efficiency, small size and quick response time [1-4]. Brushless DC motor is becoming very popular in industries such as appliances, automotive, aerospace, consumer, medical, industrial automation for its reliability, high efficiency, high power density, low maintenance requirements and lower electromagnetic noise than the DC brushed motor [5]. The most common speed controller used in industrial applications is the PID controller. PID controller improves both transient and steady state response, offers simplest most efficient solution to real world control problems [6]. The controller parameters are chosen to meet prescribed performance criteria, specified in terms of rise time settling time, overshoot, and steady state error, following a step change in the demand. The CSO algorithm was developed based on the common behavior of cats. It has been found that cats spend most of their time resting and observing their environment rather than running after things as this leads to excessive use of energy resources. The proposed algorithm identifies the optimal values of Kp, Ki and Kd so as to achieve the desired speed. CSO algorithm is one of the more recent optimization algorithm based on swarm intelligence [7-8].

II. PERMANENT MAGNET BRUSHLESS DC MOTOR

BLDC motors are a type of synchronous motors, the magnetic field generated by the stator and the magnetic field generated by the rotor rotate at the same frequency. All brushless PM motors are constructed with electrical windings on the stator and permanent magnets on the rotor. This construction is one of the primary reasons for the increasing popularity of brushless PM motors.

BLDC motors are designed in single-phase, 2-phase and 3-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, 3-phase motors are the most popular and widely used. The MATLAB (The Math Works, Natick, Massachusetts, USA) system identification toolbox is used to find the transfer function of the motor and its drive circuit [9]. There are two main control methods of the BLDC motors, first one is sensor mode and another is sensor less mode control [10-12].

The transfer function of the motor and its drive circuit is

$$G_p(s) = \frac{312.3s + 1.7774e^4}{s^2 + 10.2s + 54.32} \tag{1}$$

III. PID CONTROLLER

The tuning of PID parameters is related to the characteristics of the system. Thus, the properly tuned PID parameters are needed to approach the required performance. The transfer function of PID controller is

$$G_C(s) = Kp + \frac{Ki}{s} + s.Kd \tag{2}$$

where, Kp, Ki and Kd denotes the proportional gain, integral gain and derivative gain respectively.

In this paper, the strategies of CSO is implemented for the optimum search of the controller parameters for speed control of brushless DC motor according to the criteria of performance index. This criterion includes the WGAM2(weighted goal attainment method 2).

$$WGAM2 = \frac{1}{(1-e^{-\beta})(M_p + e_{ss}) + (e^{-\beta})(t_s - t_r)} \tag{3}$$

Where, β is weighting factor

e_{ss} is steady state error

M_p is maximum overshoot

t_r is rise time

t_s is settling time

The closed loop system [13] which explains the structure of PID tuning system is shown in Fig1.

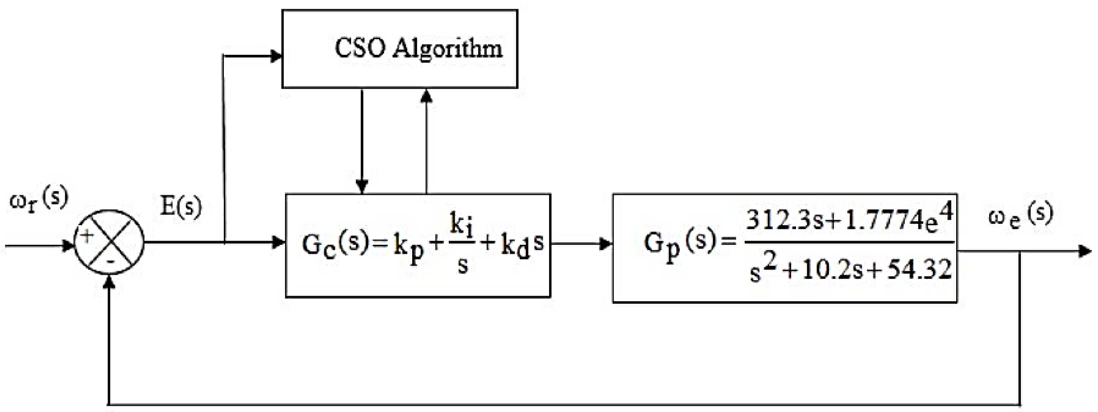

Fig 1. Structure of closed loop system with PID tuning algorithm.

IV. CAT SWARM OPTIMIZATION

CSO is developed based on cat's behavior. Applying CSO to solve problems of optimization, the first step is to decide how many individuals to use. The individuals in CSO is called cats, and every cat has its own position composed of M-dimensions, velocities for each dimension, a fitness value representing the accommodation of the cat to the benchmark function, and a flag to identify whether the cat is in seeking mode or tracing mode. The final solution would be the best position of one of the cats in the solution space. CSO keeps the best solution until it reaches the end of the iterations. CSO has two sub modes, namely seeking mode and tracing mode. These two modes individually represent different procedures in the algorithm to imitate the behavior of cats, and they are dictated to join with each other by a Mixture Ratio(MR).

The process of CSO is described as follows:

1. Create N cats in the process.
2. Randomly sprinkle the cats into the M-dimensional solution space and randomly assign values, which are in-range of the maximum velocity. Then haphazardly pick number of cats and set them into tracing mode according to Mixture Ratio(MR), and the others set into seeking mode.
3. Evaluate the fitness value of each cat by applying the positions of cats into the fitness function, which represents the criteria of our goal, and keep the best cat into the memory. Note that we only need to remember the position of the best cat () due to it represents the best solution so far. Xbest
4. Move the cats according to their flags, if catk is in the seeking mode, apply the cat to the seeking mode process, otherwise apply it to the tracing mode process. The process steps of seeking and tracing mode are as follows,

- Steps involved in seeking mode
  - Make j copies of the present position of cat k, where j = SMP (Seeking Memory Pool). If the value of SPC (Self Position Consideration) is true, let j = (SMP-1), then retain the present position as one of the candidates.
  - For each copy, according to CDC (Counts of Dimension to Change), randomly plus or minus SRD (Seeking Range of the selected Dimension) percent’s the present values and replace the old ones.
  - Calculate the Fitness values (FS) of all candidate points.
  - If all FS are not exactly equal, calculate the selecting probability of each candidate point according to equation (4); otherwise set all the selecting probability of each candidate point to be 1.
  - Randomly pick the point to move to from the candidate points, and replace the position of cat $_k$.

$$P_i = \frac{|FS_i - FS_b|}{FS_{max} - FS_{min}} \tag{4}$$

Where, $0 < I < j$

  - If the goal of the fitness function is to find the minimum solution, let $FS_b = FS_{max}$ otherwise $FS_b = FS_{min}$.

- Steps involved in tracing mode:

  In this mode, the case of the cat in tracing targets. Once a cat goes into tracing mode, it moves according to its own velocities for each dimension.

- Update the velocities for every dimension $v_{k,d}(t)$ for the cat $_k$, at the current iteration according to equation (5).

$$V_{k,d}(t) = V_{k,d}(t-1) + r_1 \cdot c_1[X_{best,d}(t-1) - X_{k,d}(t-1)] \tag{5}$$

Where, $X_{best,d}(t-1)$ is the position of the cat, who has the best fitness value at the previous iteration; $X_{k,d}(t-1)$ is the position of cat_k, at the previous iteration, c_1 is a constant and r_1 is a random value in the range of [0,1], d=1,2,--------,M.

- Check if the velocities are in the range of maximum velocity. In case the new velocity is over-range, it is set equal to the limit.
- Update the position of cat k according to equation

$$X_{k,d}(t) = X_{k,d}(t-1) + V_{k,d}(t) \tag{6}$$

5. Re-pick number of cats and set them into tracing mode according to MR, then set the other cats into seeking mode.
6. If the termination condition is satisfied, terminate the program, otherwise repeat Step3 to Step5.

V. RESULTS AND DISCUSSIONS

The optimal parameters Kp, Ki and Kd of PID controller are obtained from the CSO algorithm and the results are observed. The step response of BLDC motor for Conventional PID Controller, step response of BLDC motor with CSO based PID control and convergence characteristics of CSO is shown in the Fig2, Fig3 and Fig4 respectively. Table1 shows the input parameters of the cat swarm optimization.Table2 shows the parameters of BLDC motor.Table3 shows the parameters of the PID controller for both conventional and cat swarm optimization based PID controller. It is clearly observed from Fig2 and Fig3, cat swarm optimization based PID controller has been improve the speed performance of the BLDC motor.

Table1: CSO Algorithm Parameters

Population size	20
No. of Iterations	200
SRD	20%
CDC	80%
MR	2%
SMP	5
Constant (c_1)	2
Random value (r_1)	[0,1]

Table2: BLDC Motor Parameters

Power	370 W
Speed	2000 rpm
Voltage	220 V
No. of Poles	4
Armature Resistance	2.8750 Ω
Armature Inductance	8.5 mH
Moment of Inertia	0.0008 Kg.m^2
Coefficient of Friction	0.0003 N.m.sec/rad
EMF constant	0.175 V.sec

Table3: PID Controller Parameters

Parameters	Conventional controller	CSO based Controller
k_p	0.15	1.366
k_i	2.4	4.0
k_d	0.01	0.103
Rise time (sec)	0.0342	0.035
Settling time (sec)	0.378	0.058
Overshoot	3.37	0.00000702
Peak	1.0337	1
Peak time (sec)	0.1	0.09

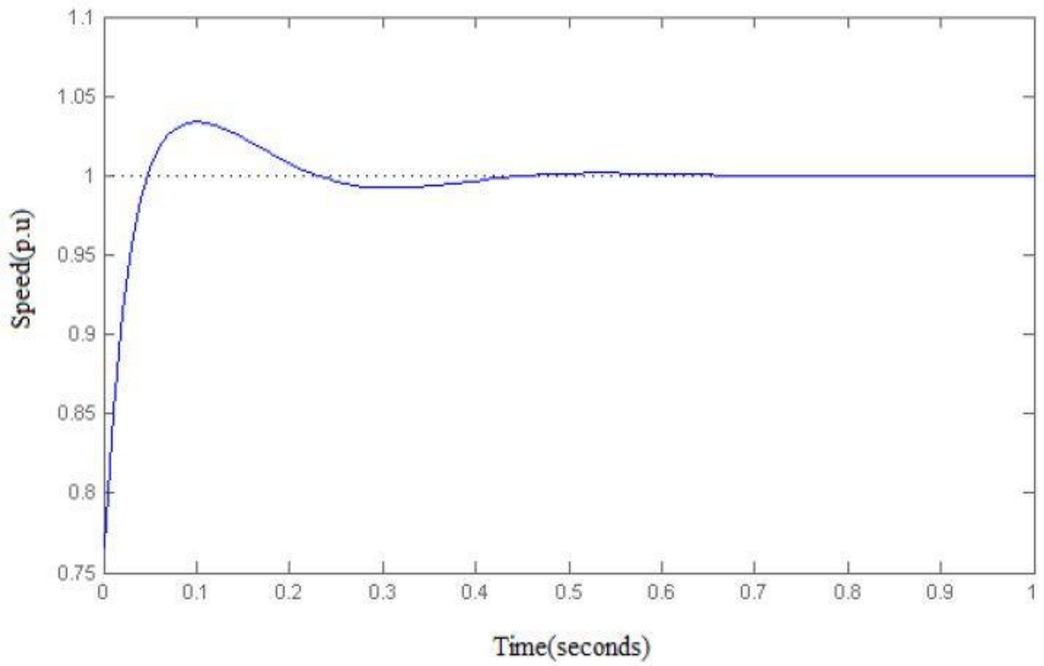

Fig2. Step response of BLDC motor with Conventional PID control

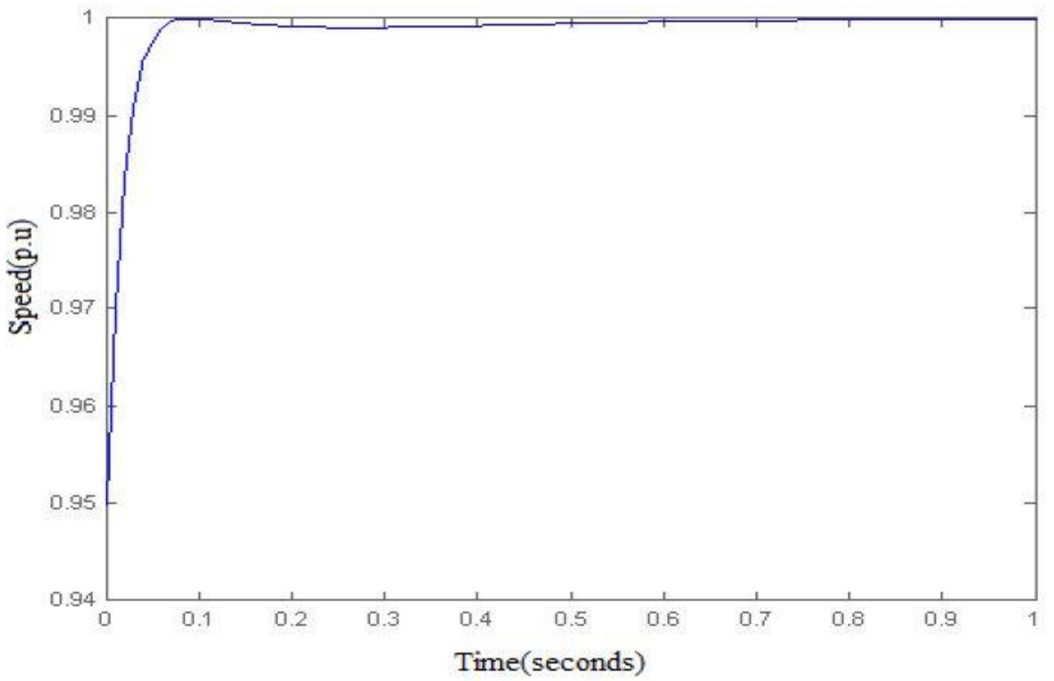

Fig3. Step response of BLDC motor with CSO based PID control

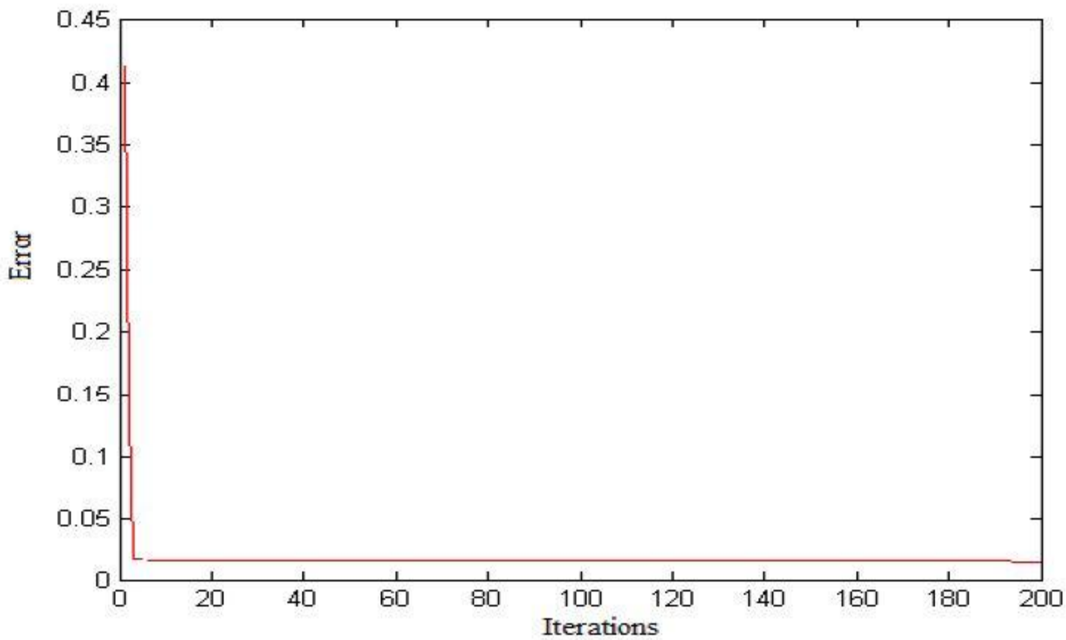

Fig4. Convergence characteristics

VI. CONCLUSION

In this paper, cat swarm optimization is presented by modeling the behaviors of cat for solving the optimization problem. Cat swarm optimization is discussed to determine the optimal parameters of PID controller. The obtained results shows that, the CSO can perform an efficient search for optimal PID controller and can improve the dynamic performance of the system. The CSO based PID controller improves the speed performance. Cat swarm optimization based PID controller reduces the rise time, settling time, maximum overshoot and steady state error. Thus, the speed of the Brushless DC Motor is regulated.

REFERENCES

[1] T. Kennnjo and S. Nagamori, "Permanent magnets brushless dc motors," Clarendon press, Oxford, 1985.
[2] T.J.E Miller, "Brushless magnets and reluctance motor drive," Clarendon press, Oxford, 1989.
[3] J.F. Gieeras, "Permanent magnets motor technology design and applications," Marcel Dekker, New York, 1997.
[4] Bhim Singh, "Recent advances in permanent magnets brushless dc motors," Sadhana, vol.22, pp 837-853, December,1997.
[5] Dariusz gwierczyEski, "Direct torque control with space vector modulation (DTC- SVM) of inverter-fed permanent magnet synchronous motor drive," Ph.D. Thesis, 2005.
[6] K. Ang, G. Chong, and Y. Li, "PID control system analysis, design, and technology," IEEE Trans. control system technology, vol. 13, pp. 559- 576, July 2005.
[7] S-C Chu, P-W Tsai and J-S. Pan. "Cat swarm optimization," proceedings of the 9th pacific Rim International Conference on Artificial Intelligence, LNAI 4099, Guilin, pp. 854-858, 2006.
[8] J.-C. Hwang, J.-C. Chen and J.-S. Pan, "CSO and PSO to solve optimal contract capacity for high tension customers," proceedings of 8th international conference on power electronics and drive systems, PEDS, pp.76-81, 2009.
[9] El-Wakeel, A. S., Hassan, F., Kamel, A., and Abdel-Hamed, "Optimum tuning of PID controller for a permanent magnet brushless DC motor," Int. J. Elect. Eng. Technol., vol. 4, pp.53–64, 2013.
[10] Antony, T. Cicily, Varghese, M. Beena, Gopinath and Anish, "Poly phase BLDC motor drive with ten step commutation," IEEE Annual International

Conference on Emerging Research Areas: Magnetics, Machines and Drives (AICERA/ICMMD), No:392, 2014.

[11] C. Rusu, I. Birou, M.M. Radulescu and A. Bara, "Developing embedded control system platform for testing PMSM drives," IEEE International Conference and Exposition on Electrical and Power Engineering, pp.677-682,2014.

[12] M.L. Corradini and A. Cristofaro, "Fault-tolerant dynamic control allocation for permanent magnet synchronous motors," IEEE American Control Conference, pp.1585-1590, 2015.

[13] Amged Saeed El-Wakeel, Abou El-Eyoun Kamel Mohamed Ellissy and Alaa Mohamed Abdel-hamed2 "A Hybrid bacterial foraging-particle swarm optimization technique for optimal tuning of proportional integral derivative controller of a permanent magnet brushless DC motor" vol.43, pp.309–319, 2015.