International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

Optimization for Fractional PID Control Parameters on DC Motor Based on Artificial Bee Colony Optimization Algorithm

Maryam Najari, Saeed Balochian, Gholamreza Alikhani
Department of Electrical Engineering, Gonabad Branch,
Islamic Azad University, Gonabad, Iran

Abstract – **The aim of this work is to design a speed controller of a DC motor by selection of PID parameters using bio-inspired optimization technique of Artificial Bee Colony Optimization (ABC). Here, model of a DC motor is considered as a second order system for speed control. In this work bio-inspired optimization technique in controllers and their advantages over conventional methods is discussed using MATLAB/Simulink. This proposed optimization methods could be applied for higher order system also to provide better system performance with minimum errors. The main aim is to apply ABC technique to design and tune parameters of PID controller to get an output with better dynamic and static performance. The application of ABC to the PID controller imparts it the ability of tuning itself automatically in an on-line process while the application of optimization algorithm to the PID controller makes it to give an optimum output by searching for the best set of solutions for the PID parameters.**

Keywords – **Artificial Bee Colony Optimization Algorithm (ABCOA), PID Parameters Tuning, DC Motor, Fractional Order PID.**

I. Introduction

As PID controller has simple structure, easy to understand, and the tuning technique provides adequate performance in the vast majority of applications, the PID controller is widely used in most industrial processes despite continual advances in control theory. Most PID tuning rules use conventional methods such as frequency response [1]. This requires considerable technical experience to apply tuning formulas to determine PID controller parameters. Due to these difficulties, PID controllers are rarely tuned optimally and engineers must search for highly tuning technology. To improve PID controller tuning performance for processes with changing dynamic properties, proposed tuning strategies include automatic tuning PID, adaptive PID, and intelligent controllers. These controllers have recalibration to cope with little a priori knowledge and significant changes in process dynamics. Over the last 50 years, many ways have been developed to determine PID controller parameters for stable processes suitable for auto- tuning and adaptive control [1–9]. Some use information about open-loop step response such as the Coon-Cohen reaction curve, while others use knowledge of the Nyquist curve, the Ziegler-Nichols frequency response, etc. Such tuning uses only a small amount of information about the system’s dynamic behavior and often does not provide good tuning. Gain and phase margins (GPM) have served as important measures of robustness [4, 7, and 8]. The phase margin is related to the damping of the system from classical control theories, and also serves as a performance measurement. Solutions are usually obtained numerically or graphically by trial-and-error Bode plots. Evolutionary algorithm caused serious concern in the optimization fields, various evolutionary algorithms emerged in endlessly. Colonies of social insects such as ants and bees have instinct ability known as swarm intelligence [10, 11]. This highly organized behavior enables the colonies of insects to solve problems beyond capability of individual members by functioning collectively and interacting primitively amongst members of the group. In a honey bee colony for example, this Behavior allows honey bees to explore the environment in search of flower patches (food sources) and then indicate the food source to the other bees of the colony when they return to the hive. Such a colony is characterized by self organization, adaptiveness and robustness. Adopting the Matlab/simulink software and taking the IATE standards of the optimization design as objective function, Artificial Bee Colony Optimization Algorithm was applied for the optimization of the three parameters of PID controller of DC motor. Simulation results show that the proposed method is an effective tuning strategy and has good performance.

II. Model of DC Motor

The direct current motors are different kinds and several methods are presented for controlling of their speed. In this essay DC motor was chosen for speed control and by controlling the supply voltage was controlled it in nominal less speed.

The electric circuit of the armature and the free body diagram of the rotor are shown in Figure 1

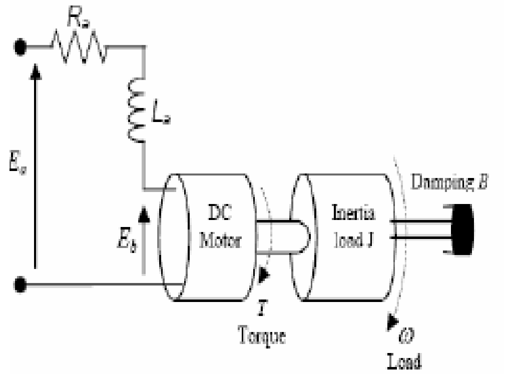

Fig.1. The structure of a DC motor

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

$$V_t = R_a I_a + L_a \frac{dI_a}{dt} + E_a \quad (1)$$

$$T = J\frac{d\omega}{dt} + B\omega - T_i \quad (2)$$

$$T = K_T I_a \quad (3)$$

$$E_a = K_a \omega \quad (4)$$

$$\frac{d\omega}{dt} = \varphi \quad (5)$$

With the following physical parameters:
Ea: The input terminal voltage (source), (v);
Eb: The back emf, (v);
Ra: The armature resistance, (ohm);
Ia: The armature current (Amp);
La: The armature inductance, (H);
J: The moment inertial of the motor rotor and load,(Kg.m2/s2);
T: The motor torque, (Nm)
w : The speed of the shaft and the load (angular velocity),(Rad/s);
f : The shaft position, (Rad);
B: The damping ratio of the mechanical system, (Nms);
T k: The torque factor constant, (Nm/Amp);
B k: The motor constant (v-s/rad).
Block diagram of a DC motor is shown in Figure 2 [12].

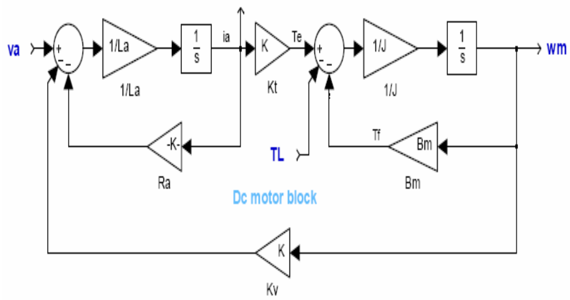

Fig.2. The block diagram of a DC motor

After applying the parameter values of DC motor as shown in the table below

Table 1: Parameter values of DC motor

Speci-fication of DC motor	R 1Ω	L 0.5H	K 0.01	J = 0.01 kg-m2	B = 0.1 Nm*s/rad

$$G_p(s) = \frac{0.01}{0.005s^2 + 0.006s + 0.1001} \quad (6)$$

III. Fractional Order Controllers

The differential equation of fractional order controller $PI^{\alpha} D^{\beta}$ is described by [2]:

$$u(t) = K_p e(t) + K_i D_t^{-\lambda} e(t) + K_d D_t^{\delta} e(t). \quad (7)$$

The continuous transfer function of FOPID is obtained through Laplace transform, which is given by:

$$G_c(s) = K_p + K_i s_t^{-\lambda} + K_d s^{\delta} \quad (8)$$

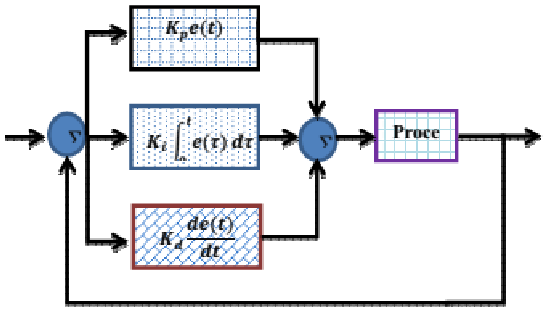

Fig.3. Generic closed loop control system with a PID controller

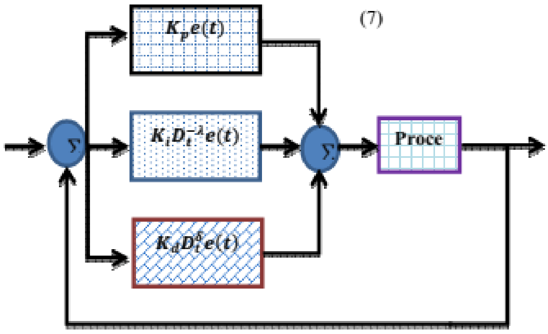

Fig.4. Generic closed loop control system With a FOPID controller

It is obvious that the FOPID controller not only need design three parameters,Kp Ki and, Kd but also design two orders, λ, δ of integral and derivative controllers. The orders, λ, δ are not necessarily integer, but any real numbers. As shown in Fig. 3 the FOPID controller generalizes the conventional integer order PID controller and expands it from point to plane. This expansion could provide much more flexibility in PID control design [13].

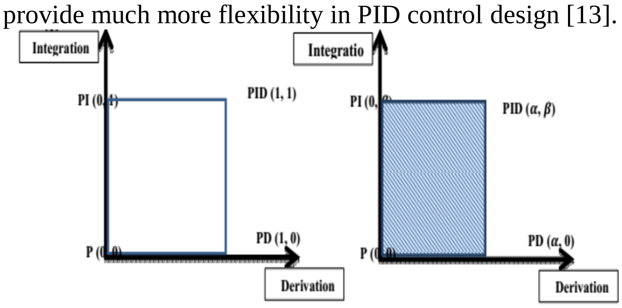

Fig.5. PID controllers with fractional orders

IV. Artificial Bee Colony Optimization Algorithm

In a real bee colony, there are some tasks performed by specialized individuals. These specialized bees try to maximize the nectar amount stored in the hive by performing efficient division of labor and self-organization. The minimal model of swarm-intelligent forage selection in a honey bee colony, that ABC algorithm adopts, consists of three kinds of bees: employed bees, onlooker bees, and scout bees. Half of the colony comprises employed bees and the other half includes the onlooker bees. Employed bees are responsible

International Journal of Electronics Communication and Computer Engineering
Volume 5, Issue 4, ISSN (Online): 2249–071X, ISSN (Print): 2278–4209

from exploiting the nectar sources explored before and giving information to the other waiting bees (onlooker bees) in the hive about the quality of the food source site which they are exploiting. Onlooker bees wait in the hive and decide a food source to exploit depending on the information shared by the employed bees. Scouts randomly search the environment in order to find a new food source depending on an internal motivation or possible external clues or randomly. Main steps of the ABC algorithm are given below:

Step 1 Initialize the food source positions

Step 2 Each employed bee produces a new food source in her food source site and exploits in the better source

Step 3 Each onlooker bee selects a source depending on the quality of her solution, produces a new food source in selected food source site and exploits the better source.

Step 4 Determine the source to be abandoned and allocate its employed bee as scout for searching new food sources.

Step 5 Memorize the best food source found so far.

Step 6 Repeat steps 2-5 until the stopping criterion is met.

In the first step of the algorithm$\bar{x}_i = (1,2, \ldots SN)$, solutions are randomly produced in range of parameters where SN is the number of the food sources. In second step of the algorithm, for each employed bee, whose total number equals to the halt of the number of food sources, a new source is produced by$v_{ij} = x_{ij} + \varphi_{ij}(x_{ij} + x_{kj})$ where φ_{ij} is a uniformly distributed real random number within the range [-1,1], k is the index of the solution chosen randomly from the colony $k = int(rand * SN + 1)$ and D is the dimension of problem, for optimization of PID(namely K_p, K_i and K_d) there is D=3.After producing $\bar{v}_i$ this new solution is compared to $\bar{x}_i$ solution and the employed bee exploits the better source. In the third step of the algorithm, an onlooker bee chooses a food source with the probability $p_i = fit_i / \sum_{j=1}^{SN} fit_j$ where fit_i is the fitnessof the solution$\bar{x}_i$ after all onlookers are distributed to the sources; sources are checked whether they are to be abandoned. If the number of cycles that a source cannot be improved is greater than a predetermined limit, the source is considered to be exhausted. The employed bee associated with the exhausted source becomes a scout and makes a random search in problem domain by

$$x_{ij} = x_{ij}^{min} + rand * \left(x_i^{max} - x_j^{min}\right) \quad (9)$$

The above method is used for unconstrained optimization problems [11]. Based on Matlab software, the program ABC1.0 of Artificial Bee Colony Optimization Algorithm with hybrid Discrete variables for the proposed algorithm was developed with Matlab.

V. Simulation Result

Table 3: PID parameter

	kp	ki	kd
PID_BEE	20	20	29.342

Table 4: step information DC motor with PID controller

stepinfo(ClosedLoop)
RiseTime: 0.0236
SettlingTime: 0.0437
SettlingMin: 0.9003
SettlingMax: 1.0019
Overshoot: 0.1914
Undershoot: 0
Peak: 1.0019
PeakTime: 0.0838

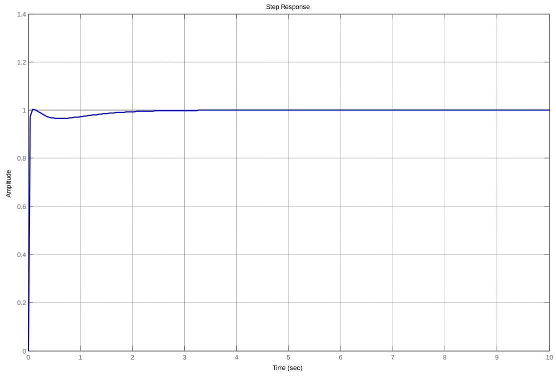

Fig.6. Simulated step results BEE_PID of DC motor

Table 5: Fractional order PID parameter

	kp	ki	kd	vi	vd
FOPID_BEE	20	20	29.342	0.9942	1.1715

Table 6: Step information DC motor with FOPID controller

stepinfo(ClosedLoop)
RiseTime: 0.0217
SettlingTime: 0.0711
SettlingMin: 0.9011
SettlingMax: 0.9987
Overshoot: 0
Undershoot: 0
Peak: 0.9987
PeakTime: 0.1583

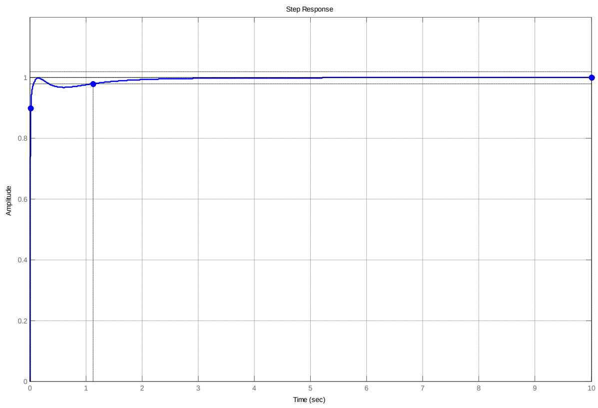

Fig.7. Simulated step results BEE_FOPID of DC motor

VI. Conclusions

Performance comparison of different controllers has been reviewed and it is found that Artificial Bee Colony optimization is best among the all methods which are used for tuning the parameter of FOPID and PID controller for which settling time and rise is found to be less. The conventional controllers however are not recommended for higher order and complex systems as they can cause the system to become unstable. Hence, a heuristic approach is required for choice of the controller parameters which can be provided with the help of Bio inspired methods such as Artificial Bee Colony Optimization where we can define variables in a subjective way.

Compared to PID controllers and FOPID observed that the FOPID controller step response shows appropriate

References

[1] Youxin Luo and Zhaoguo Chen, The Second International Conference on Computer Molding and Simulation, pp. 40-43, 2010.
[2] K. J. Astrom, T. Hagglund, C. C. Hang, and W. K. Ho, IFAC J, Control Eng. Practice, vol.1, no.4, pp. 699-714, 1993.
[3] K. J. Astrom and T. Hagglund, Automatica, vol.20, no.5, pp. 645-651, 1984.
[4] K. J. Astrom and T. Hagglund, PID controllers: theory, design, and tuning, Research Triangle Park, NC: ISA, 1995.
[5] J. Astrom, T. Hagglund, and J. IFAC, Control Engineering Practice, vol.9, pp. 1163-1175, 2001. 46
[6] X. Xu, Y. M. Pok, C. Liu, and C. C. Hang, IEEE Trans. on Systems, Man, and Cybernetics – Part A: Systems and Humans, vol.28, no.5, pp. 685-691, 1998.
[7] X. Xu, C. Liu, and C. C. Hang, ISA transactions, vol.35, pp. 79-91, 1996.
[8] G. Ziegler and N. B. Nichols, Trans. ASME, vol.64, pp. 759-768, 1942.
[9] Nakrani and C. Tovey, Adaptive behavior, vol. 12, no. 3-4, pp. 223-240, 2004.
[10] Teodorovic and M. Dell'orco, Advanced OR and AImethods in transportation, pp. 51-60, 2005.
[11] Karaboga and B. Basturk, Applied soft computing, vol. 8, no.1, pp. 687-697, 2008.
[12] MahbubehMoghaddas, MohamadRezaDastranj, NematChangizi, ModjtabaRouhani. PID Control of DC motor using Particle swarm Optimization PSO Algorithm."Journal of mathematics and computer.
[13] Dastranj, Mohammad Reza, Mojtdaba Rouhani, and Ahmad Hajipoor. "Design of Optimal Fractional Order PID Controller Using PSO Algorithm." International Journal of Computer Theory and Engineering 4.3 (2012).

Author's Profile

Maryam Najari

received the B.S. Degree in control & automation engineering in 2012 at the Islamic Azad University, Gonabad Branch. Currently she is M.S. Student at the Islamic Azad University, Gonabad Branch in Iran. Her research interests focus on evolutionary algorithms and optimal control.

Saeed Balochian

received the B.S. degree in communication engineering in 2005 and M.Sc. degree in control and automation engineering in 2007. He completed his Ph.D. in control engineering in 2011 at the Islamic Azad University, science and research branch of Tehran. Currently he is assistant professor at Islamic Azad University of Gonabad branch. Currently, he has published 49 journal papers. His main research interests include Fractional derivative systems control, nonlinear systems, and robust control systems.

Gholamreza Alikhani

he finished him B.S from Islamic Azad University Gonabad branch, Iran in 2006. He was graduated in Control Engineering, Islamic Azad University Gonabad branch Iran, in 2014 GONABAD. Also interested in the field of evolutionary algorithms and fuzzy system.