DOI: http://dx.doi.org/10.30684/etj.36.3A.7

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Received on: 31/01/2017
Accepted on: 20/07/2017

Tuning of a PID Controller by Bacterial Foraging Algorithm for Position Control of DC Servo Motor

Abstract- *Controlling the position of Direct Current servo motor is the first aim of this paper, by Bacterial Foraging Algorithm (BFA), the best Proportional – Integral - Derivative (PID) controller parameters were obtained through Mat-Lab application, including the simulation and modeling of Direct Current servo motor, BFA controller and conventional PID Controller as benchmark to the performance of BFA. Proportional – Integral - Derivative controller is a closed loop system, the error made by the Direct Current motor was corrected and determine the correct position to the desired point were controlled By integrating the Proportional – Integral - Derivative controller.* K_p, K_i *and* K_d *parameters was tuned to the find best values, which make the Direct Current Motor reached quickly the accurate position without any mistake.*

Keywords- *DC servo motor, position control, PID, BFA.*

How to cite this article: M.H. Jasim, "Tuning of a PID Controller by Bacterial Foraging Algorithm for Position Control of DC Servo Motor," *Engineering and Technology Journal*, Vol. 36, Part A, No. 3, pp. 287-294, 2018.

1. Introduction

Direct Current motor is widely used because it comes in many shapes and sizes, so that its application is quite easy and flexible, and high reliabilities and low cost. Speed and position control are required in industrial applications, robot manipulators and home appliances [1]. Because of accurate and efficient tuning of parameters for PID controller, it has become very important for the Process industries, it is simple structure, good stability, and high reliability. Changing the controller parameters is difficult in custom application due to the non-linearity, time–changeability, and time slow down, furthermore, parameters and structure of the system can differ due to the time and location from time to time, so that tuning of the PID parameters customary is not appropriately in some complex calculations [2]. In industrial process like pneumatic systems, the control system action is poor in characteristics and unstable because they effected to the unstable in the values of parameters, so to improve this case it must tuned the controller parameters to synchronized the controller with the controlled variable, this make the process to be in the correct operation condition at a suitable tuning constant, so that there is a need to provide automatic tuning and continuously updating the controller parameters [3]. In case of simple structure, optimal tuning of PID controllers gains are very difficult, recently, intelligence computational proposed bacterial foraging (BF) technique [4]. The mechanism of the animals in finding and consuming nutrient can be viewed as the controller because it depend on the point that animals try to obtained and consume nutrient by maximizing the power which obtain from nutrient sources for each unify time spent for foraging, and the environment and reminder organism as a 'plant'[3]. Animals in foraging perform non-gradient optimization for 'search', because they conducted an optimization without analytical expression for the gradient, because it is impossible for them to know how the nutrient concentration will change depending on the variation in location, since there is no reminiscence to amass on it and there is a lot of uncertainty about the surrounding live in [3]. In this paper, the optimizing and analyzing of model E. coli Bacterial Foraging was achieved to controlling the position of Direct current Servo Motor by tuning the parameters of Proportional – Integral - Derivative (PID) controller.

2. System Model

A mathematical relationship between voltage input to the Direct Current motor and the shaft angular position can be derived physically.
Direct current servomotor can be considered as multi-input system, the field coil of Direct Current servomotors separately with the armature, controlling the speed and position is very good in this motor because there is no relation between armature and playing field current of one more, this is show in Figure1

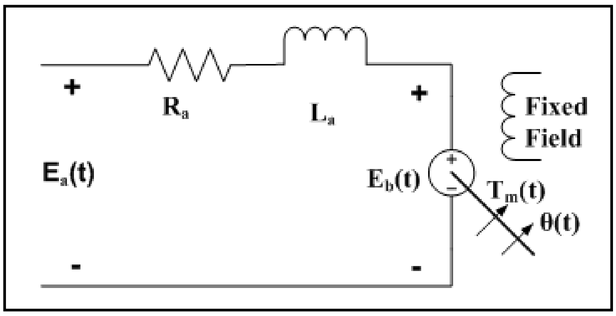

Figure1: Schematic Diagram of a Direct Current Servo motor

Dynamic behavior of the Direct Current motor analyzed mathematically as below:

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

$T_m(s) = K_t I_a$

$E_b(s) = K_b s \theta(s)$

$T_m(s) = (J_m s^2 + D_m s)\theta(s)$

The block diagram of the equation above is illustrated in Figure.2.

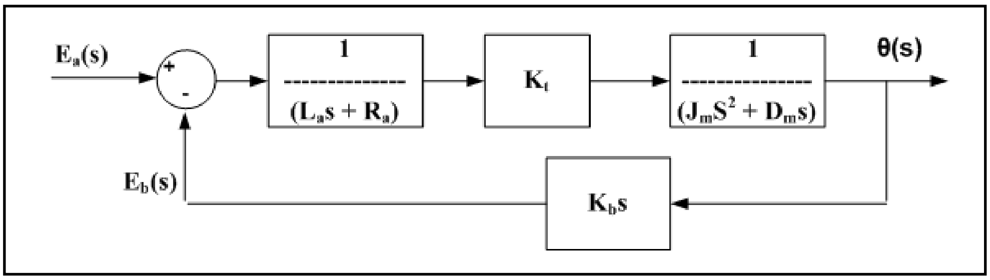

Figure 2: Block Diagram Representation of MATLAB/Simulink Direct Current motor

R_a = Armature Confrontation (Ω)
L_a = Armature Inductance (H)
I_a = Armature Current (A)
E_a = Armature Voltage (V)
E_b = Rear EMF (V)
K_b = Rear EMF constant (V/radians/second)
K_t = Torque Steady (N-m/A)
T_m = Torque urbanized through the motor (N-m)
$\theta(t)$ = Beam angular dislocation (radians)
J = Motor instant of inactivity and weight (Kgm^2/radians)
D_m=Motor frictional steady and weight (Nm/(radians/second)

The transfer function after simplification and taken the $\Theta(s) / E_a(s)$ is:

$$G(s) = \frac{K_t}{L_a J_m s^3 + (R_a J_m + L_a D_m)s^2 + (K_b K_t + R_a D_m)s} \quad (1)$$

The final simulation model for position without controller can be developed in "MATLAB" as shown in Figure.3 [5-8].

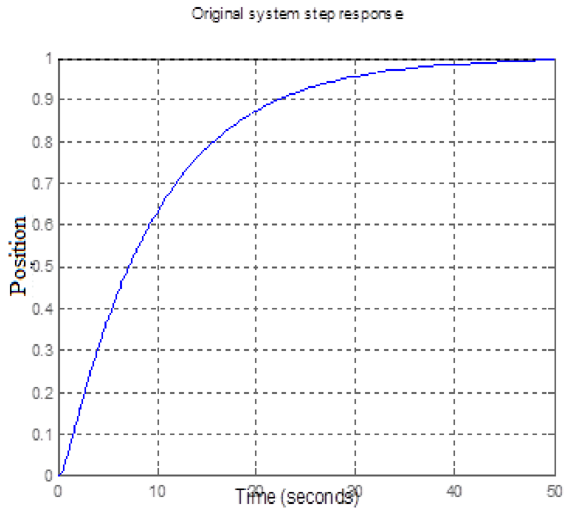

Figure 3: Position Response without Controller

3. PID Controller Algorithm

The transfer function of Direct Current servomotors is:-

$$G(s) = \frac{K}{a_3 s^3 + a_2 s^2 + a_1 s} \quad (2)$$

Comparing equation (1) with equation (2) we have:

$a_3 = L_a J_m$,
$a_2 = R_a J_m + L_a D_m$,
$a_1 = K_b K_t + R_a D_m$,

The PID Controller transfer function is:-

$$C(s) = K_p + \frac{K_I}{s} + K_D s$$

So that the overall unity feedback systems transfer, function is:

$$T_s = \frac{G(s)C(s)}{1+G(s)c(S)} \quad (4)$$

The transfer function can be calculated as:

$$T(s) = \frac{K(K_D S^2 + K_p s + K_I)}{a_3 s^4 + a_2 s^3 + (a_1 + K_D K)s^2 + K_P K_s + K_I K} \quad (5)$$

The roots of the equation is the actual pole location

$$a_3 s^4 + a_2 s^3 + (a_1 + K_D K)s^2 + K_p K s + K_I K = 0 \quad (6)$$

The necessary extremity locations are equal to:

$$(s^2 + 2\varepsilon w_n s + w_n^2)(KK_D s^2 + KK_p s + KK_I) = 0 \quad (7)$$

W_n and ε are transient parameters,

For solving for three unknowns K_P , K_I , K_D will get five equations from comparing (6) and (7) so that it required to optimize, so that the technique provide a good starting for the initial solution to optimize the results, The position system model controlled by the PID controller can be expressed by Figure.4.The PID controller calculations involve three parameters that must be determined for the given process, to give the desirable output and the correct parameters were obtained quickly[8-10].

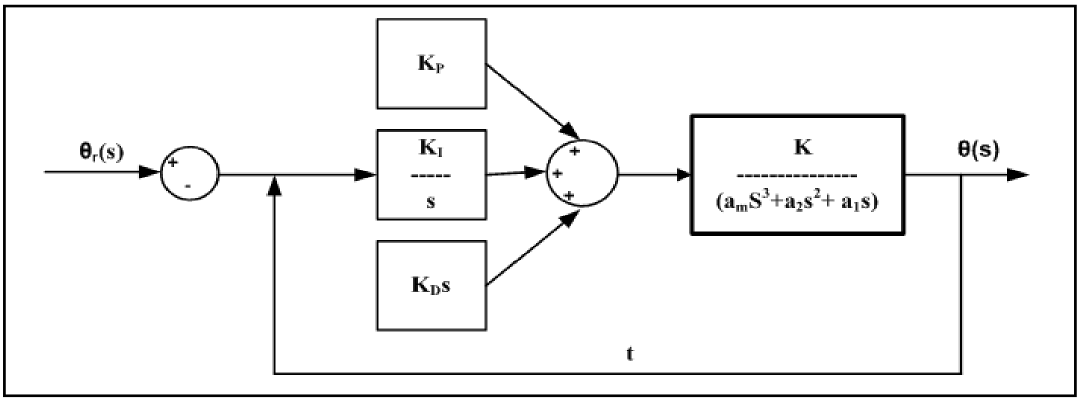

Figure 4: Block Diagram Representation for Direct Current Servo motor with PID Controller

In this paper, to determine the position of servo Direct Current(DC) motor, test with mistake technique was used to obtain the most excellent result for PID controller parameters which are :. K_P=100, K_I= 5, and K_D= 30.5, that give a transient system response to the unit step input:

- Settling time = 3 sec.
- Rise time =1.4 sec
- Stable condition mistake = 0 %.

The System output presentation is shown in Figure.5.

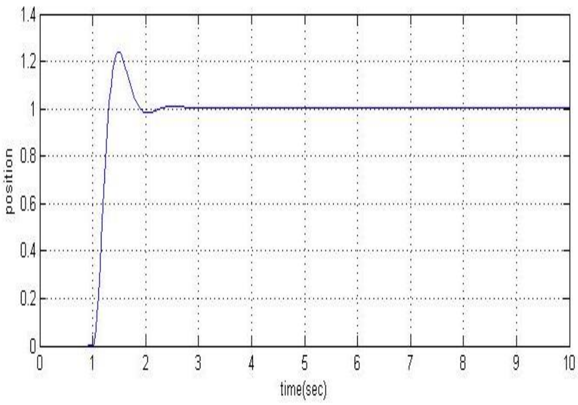

Figure 5: Position Response with PID Control

4. Bacterial Foraging Optimization Algorithm

BFA is an influential method in optimization evils. E. coli bacteria attempt to make the most of the energy eating for each time so that BFA mimics the foraging strategy, in BF-system there is four main mechanisms, which are:

I. Chemotaxis:

Is a Simulation of the changing of an E.coli cell through swimming and plummeting by means of flagella, if:

$\theta_i(j,k,l)$ = i'th bacterium on j'th chemotaxis, k'th reproductive, l'th elimination-dispersal move.

C(i) = range of move used randomly which particular through the fall (flow duration element). Bacterium movement during computational chemotaxis is:

$$\theta^j(j+1,k,l) = \theta^i(j,k,l) + c(i)\frac{\Delta(i)}{\sqrt{\Delta^t(i)\Delta(i)}} \quad (8)$$

Δ: random target vector, whose elements be positioned within [-1, 1].

II. Swarming:

Through moving up the nutrient inclining a collection of E. coli cells position themselves and a itinerant circle while located amidst a semisolid environment by means of a particular nutrient chemo effecter observed as an interesting group behavior. In E. coli swarm the cell-to-cell, signaling is determined by:

$$J_{cc}(\theta, P(j,k,l) = \sum_{i=1}^{S} Jcc(\theta, \theta^i(j,k,l)$$

$$Jcc = \sum_{i=1}^{S}\left[-d_{attractant}\, t^{\theta^{(-w_{attractant}\sum_{m=1}^{P}(\theta_m-\theta_m^i)^2}}\right] + \sum_{i=1}^{S}\left[-h_{repellant}\, t^{2^{(-w_{repellant}\sum_{i=1}^{P}(\theta_m-\theta_m^i)^2}}\right] \quad (9)$$

J_{cc} (θ, P(j, k, l)) = object purpose worth, S = the sum of bacteria,

P = the sum of variables there in bacterium which optimizing,

θ = $\theta_1, \theta_2, \ldots, \theta_p$ = a point in the p dimensional hunt area.

III. Reproduction

The better bacteria asexually tear into two bacteria, and then located in the similar location while the least strong bacteria finally die. So that the swarm dimension steady

V. Elimination-dispersal

It is the event, which takes place for killing, or grouped in a new position, all bacteria in the area, this due to some changes appear in the environment of bacterium population.

Size of population 'S': the computational complexity of the algorithm can be significantly increased by increasing S.

Length of chemotaxis step 'C(i)' : C(i) is a kind of a 'movement dimension' for the algorithm.

Chemotactic step 'Ns': creates a prejudice in the un-regular movement.

Reproduction number 'Nre': the algorithm may join impulsively at a small rate of 'Nre', when 'Nre' increased the difficult of computational increase.

Elimination - Dispersal number 'Ned': selecting 'Ned' appropriately, the algorithm swoop of restricted optima furthermore addicted to best worldwide.

Parameters important cell-to-cell attractant functions 'Jcc': high 'Jcc' incomes the cells to have a burly tendency to group, small 'Jcc' incomes a small tendency to group, so that the equilibrium among the strengths of the cell-to-cell attractant signals with nutrient concentrations is extremely significant [11-13].

Figure.6 shows the sequence of BFA Flowchart.

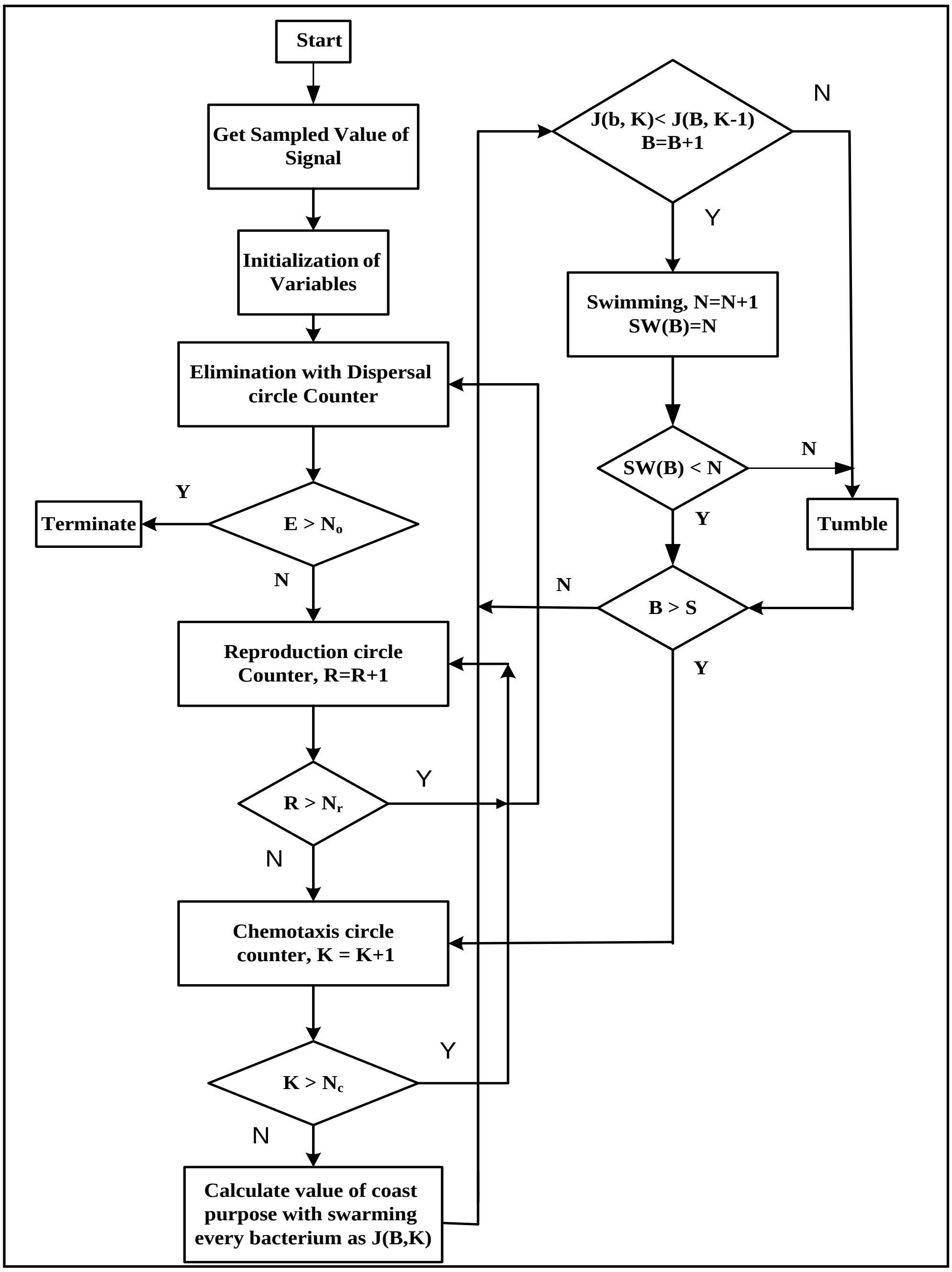

Figure 6: Flowchart of BFA

5. PID Tuning by BFA

I. Fitness function

To calculate the overall response for each of PID sets values a fitness evaluation function is needed then from the response generating a fitness value for each set of individual expressed by

$$f(t) = \int_0^t t|e(t)|dt \tag{10}$$

Finding a set of PID parameters is important for giving a minimum fitness value over the period [0, t]

II. BFA-PID Controller

Finding the best values for the PID parameters controlling the position of the direct current servomotor using BFA is achieved by this work; Figure.7 shows the system block diagram. MATLAB m-File program was linked with MATLAB/simulation program, to verify the presentation of the system at each part. PID controller gains, which were obtained with Bactria foreign Optimization Algorithm (BFOA), give the smallest amount of fitness function using Integral Squared Error (ISE) technique, which gives the best presentation of the system. The specification of the designed BFA technique is shown in Table 1

Table 1: Specification of the BFA

The amount of Bacteria	10
Total of chemot axis steps	5
Restrictions the span of a swim	4
Total of reproduction steps	4
Total of elimination dispersal events	2

Every bacterium in the inhabitants has a location, the location was determined through three variables which is PID controller gains accordingly measurement of a look for area is represented through three variables, p = 3.

Starting the first bacterium location must be selected, the significant object at this time be presentation (t_R , t_S , e_{ss} , p.o.s). For a look for area BF method replicates the fitness function to be as little as probable.

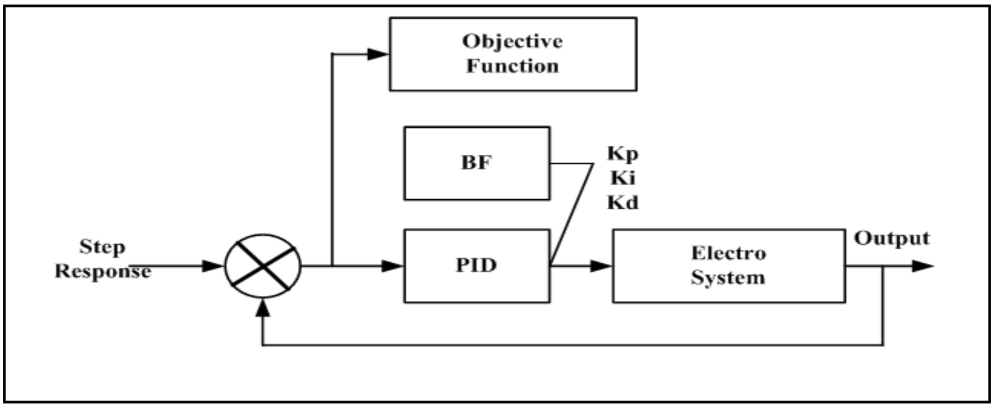

Figure7: Simulink model of BPID to the Electro system

6. Analysis of the Results

Through the completion of BFA the gain principle of PID was optimized in MATLAB, the parameters, which describe the direct current servomotor, are [14].

J = 0.01 Kg/m^2, b = 0.1 n.m.s, k_b = 0.01 V/ °/s, K_m = 0.01 N.m/A, R_a = 1Ω, L= 0.5 H.

So that $$\frac{\theta(s)}{V_a(s)} = \frac{0.01}{0.005S^3+0.06S^2+0.1001S} \quad (11)$$

The system performance of BFA-PID controller is shown in Figure.8.

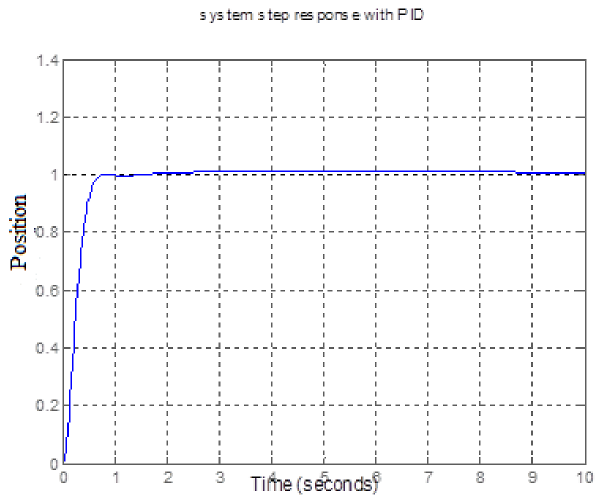

Figure 8: System performance of BFA-PID tuning method

The BFA algorithm was simulated. The optimum parameter values that have achieved better solution are listed in Table 2, which show the optimal parameters values of the position controlling system controlled by PID controller using Bacterial Foraging Optimization algorithm (BFOA).

Table 2: The position response gives by the unit step input

Original System without PID		Rise Time: 20.6428 Settling Time: 37.3312 Settling Min: 0.9022 Settling Max: 0.9993 Over Shoot: 0 Under Shoot: 0 Peak: 0.9993 Peak Time: 68.6512	
K_P = 37.2242; K_i = 2.8023; K_d = 20.6051;	Rise Time: 0.2855 Settling Time: 1.0073 Settling Min: 0.9113 Settling Max: 1.0770 Over Shoot: 7.6956 Under Shoot: 0 Peak: 1.0770 Peak Time: 0.6109	K_P = 37.6075; K_i = 1.2336; K_d = 20.8703;	Rise Time: 0.3892 Settling Time: 0.6152 Settling Min: 0.9041 Settling Max: 1.0009 Over Shoot: 0.0921 Under Shoot: 0 Peak: 1.0009 Peak Time: 0.8214
K_P = 5.0352	Rise Time: 3.0959 Settling Time: 5.2894 Settling Min: 0.9007 Settling Max: 1.0001 Over Shoot: 0.0080 Under Shoot: 0 Peak:1.0001 Peak Time: 8.7698	K_P = 4.9863	Rise Time: 3.1352 Settling Time: 5.3738 Settling Min: 0.9010 Settling Max: 0.9999 Over Shoot: 0 Under Shoot: 0 Peak: 0.9999 Peak Time: 8.7644
K_P=36.5617; K_d=20.4094;	Rise Time: 0.4027 Settling Time: 0.6567 Settling Min: 0.9063 Settling Max: 0.9994 Over Shoot: 0 Under Shoot: 0 Peak: 0.9994 Peak Time: 3.0259	K_P = 36.2932; K_d = 20.4094;	Rise Time: 0.4047 Settling Time: 0.6663 Settling Min: 0.9040 Settling Max: 0.9985 Over Shoot: 0 Under Shoot: 0 Peak: 0.9985 Peak Time: 2.4859
K_P = 5.0525; K_i = 0.043311;	Rise Time: 2.9771 Settling Time: 4.7869 Settling Min: 0.9049 Settling Max: 1.0165 Over Shoot: 1.6527 Under Shoot: 0 Peak: 1.0165 Peak Time: 9.1075	K_P = 5.5133; K_i = 0.051302;	Rise Time: 2.6690 Settling Time: 4.2211 Settling Min: 0.9010 Settling Max: 1.0182 Over Shoot: 1.8172 Under Shoot: 0 Peak: 1.0182 Peak Time: 6.9353

The position of the Direct Current Motor is precisely controlled; it could reach the desired location rapidly with no mistake as shown in Figure.8.

The simulation was done using m.File and Simulink package available in MATLAB. The position response is simulated using BFA based PID controller.

7. Assessment of the Consequences

Table.3 shows the relationship between different controllers for active performances used for managing location of direct current servo motor. Comparing between settling time and rise time with the movement input pace. The Table show that BFA-PID controller exhibits comparatively good presentation through extremely fewer settling time and passing oscillations.

Table 3: The relationship between different controllers

Results	Without-Con	With PID-Con	BFA-PID
Rise Time(Sec)	20.64	1.4	0.28
Settling Time(Sec)	37.33	3	1.007

8. Conclusion

Position controller for Direct Current servo Motor by using BFA in controlling the PID controller was proposed in this paper. The model outcome points to that the BFA working efficiently and provides an excellent relation between the PID Controller and active reaction of the scheme to be controlled. The results show that tuning PID controller-based BFA provides high performance for the considered system and showed the superiority of the BFA, which provides the optimal controller parameters successfully. The work represents a good fluctuation decrease and the control system in a good way and good response.

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