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BBO_PI Controller for DC Motor

Salam Waley Shneen
Energy and Renewable Energies Technology Center, University of Technology, Baghdad, Iraq
Email address: salam_waley73@yahoo.com, 50054@uotechnology.edu.iq

Abstract**—** *DC Motor one of the drive system that used in many applications. To simulation DC Motor with BBO_PI controller. To test dynamic performance design, analyses and control by MATLAB/Simulink. The results obtained from the BBO-PI comparative with PI Controller based drive system are not only superior in the rise time, settling time and overshoot but can prevent from voltage and has improved power quality.*

Keywords**—** *Dc motor, PI Controller and BBO.*

I. INTRODUCTION

Increasing orientation for the use of Dc motor in industry for many electrical applications, EV, Elevator, Robot, etc. [1-3]. PI control is one of classical controller that can used to in speed control in Dc motor. BBO one of the modern controller [4]. BBO and PI control are using to improve the performance of the control for drive systems [5]. In this paper, to improve the performance of the DC Motor control that was selecting BBO and PI control. The proposed BBO has been compared with traditional PI control with respect to the DC Motor of response [6]. Simulation and experimental results have proved that BBO was proposed is superior to the traditional PI. This BBO can be a good solution for the high-performance DC Motor systems. A modern approach to control the speed of load using BBO to improve the algorithm parameters observer PI control. Simulate the system under different operating year conditions is prepared and the experimental setup. Use BBO algorithm and optimization make a powerful engine, with faster response and higher resolution dynamic and sensitive to load variation [7].

II. DIRECT CURRENT MOTOR

To convert the electrical energy to mechanical energy by using the drive system like Direct Current (DC) Motor is a device that produces rotational force. It developed for different specific purposes that have brought about one of advance in the fields of technology. It is running by DC source. The Motor Classification to, AC (alternating current) electrical motors, DC (Direct Current) motor and Special Types of Motor. DC Motor has two port first port or input port (electrical) that include the voltage (V) and current (I) and the second port or output port (mechanical) include speed (ω) and torque (T). In figure (1), Show the Model of DC Motor.

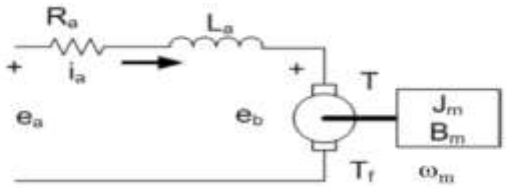

Fig. 1. Show the Model of DC Motor.

A. Mathematical Model of DC Motor

In figure (1) the model of DC motor include the Electrical part and Mechanical part which have Electromechanical Relationships to analysis mathematical model of DC motor by the following equation (1-11):

$$T = K_T . i_a - T_f \qquad N - m \tag{1}$$

$$e_a = i_a . R_a - e_b \qquad V \tag{2}$$

$$e_b = K_e . \omega_m \qquad V \tag{3}$$

$$P = \omega_m . T \qquad V \tag{4}$$

$$\omega_m = \frac{K_T . e_a - (T - T_f) . R_a}{K_T . K_e} \tag{5}$$

$$\omega_m = \frac{e_a - i_a . R_a}{K_e} \tag{6}$$

$$\omega_m = \frac{K_T . e_a + (T_f) . R_a}{K_T . K_e} \tag{7}$$

Electrical Equations and Mechanical Equations
(Electromechanical Relationships)

Electrical:

$$e_a(t) = R_a . i_a(t) + L \frac{d i_t(t)}{dt} + e_b(t) \tag{8}$$

Mechanical:

$$T(t) = j_m \frac{d\omega_{m\,(t)}}{dt} + B_m . \omega_{m\,(t)} \tag{9}$$

Electromechanical:

$$e_b(t) = K_E . \omega_m(t) \tag{10}$$

$$T(t) = K_T . i_a(t) \tag{11}$$

Laplace Transform of:

Electrical;

$$E_a(s) = L . s . I_a(s) + R_a + I_a(s) \tag{12}$$

$$I_a(s) = \frac{1}{L . s . R_a} [E_a(s) - E_b(s)] \tag{13}$$

Mechanical;

$$T(s) = (j_m . s + B_m) . \omega_m(s) \tag{14}$$

$$\omega_m(s) = [1/(j_m . s + B_m)] . T(s) \tag{15}$$

Electromechanical;

$$e_b(s) = K_E . \omega_m(s) \tag{16}$$

$$T(s) = K_T . i_a(s) \tag{17}$$

Where:

ia(t)= armature current, eb(t)= back emf, ea(t)= armature terminal voltage, ω_m= motor speed (rad/sec), T= motor torque, Tf= static friction torque, Ra= armature resistance, La= armature inductance, Jm= rotational inertia, Bm = viscous friction, KT = torque constant, Ke=back emf constant and P = shaft power.

B. Transfer Function of DC Motor

A transfer function for a dc motor that relates input voltage to shaft position. The transfer function for an armature controlled dc motor. Represent a mechanical load using a mathematical model. How negative feedback affects dc motor performance.In figures (2&3),Block diagram of DC Motor with load and Block diagram of DC Motor with no load (Tf=0). A transfer function of DC motor by the following equation (18-24):

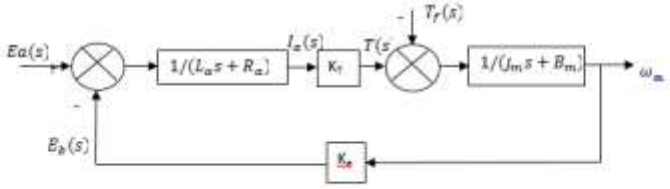

Fig. 2. Block diagram of DC Motor with load

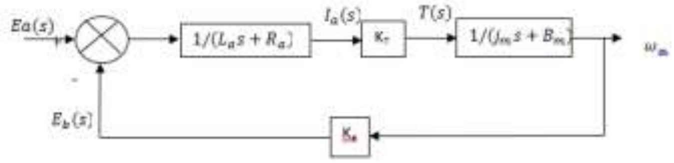

Fig. 3. Block diagram of DC Motor with no load (Tf=0)

In equations (18-21), F.B, F.W and T.F formula:

$$\omega_m(s) = G(s) \tag{18}$$

$$G(s) = \frac{K_T}{(L_a.s + R_a)(j_m.s + B_m)} \tag{19}$$

F.W formula:

$$E_a(s) = 1 + G(s).H(s) \tag{20}$$

F.B formula:

$$H(s) = K_E \tag{21}$$

T.F formula:

$$\frac{\omega_m(s)}{E_a(s)} = \frac{G(s)}{1+G(s).H(s)} \tag{22}$$

Simplify T.F formula:

$$\frac{\omega_m(s)}{E_a(s)} = \frac{\frac{K_T}{(L_a.s+R_a)(j_m.s+B_m)}}{1+\left[\frac{K_T}{(L_a.s+R_a)(j_m.s+B_m)}\right].K_E} = \frac{K_T}{(L_a.s+R_a)(j_m.s+B_m)+K_T.K_E}$$

Final T.F formula:

$$\frac{\omega_m(s)}{E_a(s)} = \frac{G(s)}{1+G(s).H(s)} = \frac{K_T}{L_a j_m.s^2+(R_a j_m+B_m L_a).s+(K_T.K_E+R_a.B_m)} \tag{23}$$

Parameters of DC motor:

$\omega_m = 500\, {}^{rad}/_{s}$, $I_a = 2A$, $K_e = 0.06V\frac{s}{rad}$, $K_T = 0.06N\frac{m}{A}$, Tf=0.012 N-m, Ra=1.2ohm ,jm=6.2*10-4N-m-s/rad, Bm=1*10-4N-m-s/rad, La=0.02H

$$T.F = \frac{\omega_m(s)}{E_a(s)} = \frac{16.13}{1+0.201s+0.00333\,s^2} \tag{24}$$

C. *Parameters Mathematical results of DC Parameters:*

Tf=0.012 N-m, Ra=1.2 ohms, Ke =0.06 N-m/A, KT=0.06 V-s/rad , ia=2A and ω=500rad/s

Mathematical results:

By using: Equation.(1): T=(0.06*2)-0.012=0.108 N-m

Equation.(2):ea=(1.2*2)+(0.06*500)=32.4 Volt

Equation.(4): P=500*0.108=54 watt

Equation.(7): ωm=(0.06*32.4)+[(1.2*0.012)/(0.06*0.06)]=536rad/s

III. OPTIMIZATION AND CONTROLLER

Optimization and Controller (Classical controller type PI Controller, Expert System type FLC and Optimization type and PSO), Electric system driven is formulated by the motor.

A. *PI Controller Modeling*

In the PI controller DC Motor, the actual value is compared with the reference value and the error is the nth sampling interval as

ωe[n] = ωr*[n] – ωr[n] (25)

The output of the DC Motor controller gives the reference. Hence the output of DC Motor controller at the nth sampling interval is

T[n] = T[n-1] + Kp(ωe[n] – ωe[n-1]) + Ki.ωe[n]..(26)

For constant air gap flux operation reference quadrature axis current is given as

iq* = T[n]/Kt (27)

The limiter is used to limit the maximum value of output of speed controller. The maximum machine rated current and device current of the converter dictate the limit.

Where,

ωe[n] is speed error at nth instant, ωr*[n] is the reference speed at nth instant

ωr[n] is the actual machine speed at nth instant, ωe[n-1] is the speed error at (n-1)th instant

T[n] is the reference torque at nth instant, T[n-1] is the reference torque at (n-1)th instant

Kp is proportional gain of the speed controller

Ki is integral gain of the speed controller is reference quadrature axis current

Kt is torque constant

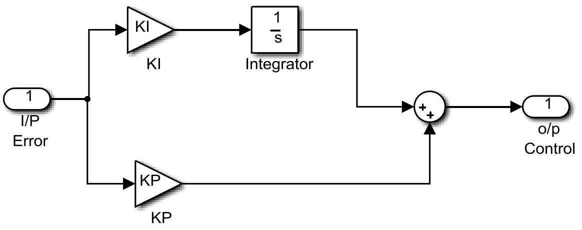

Fig. 4. Block diagram of the PI controller

B. *BBO_PI Controller*

The implementation of BBO in this work is same what complex, because the performance of the system must be examined in each iteration and particles position during the optimization algorithm. Therefore, the optimization algorithm is implemented by using MATLAB m-file program and linked with the system simulation program in MATLAB SIMULING, to check the system performance in each iteration. In this paper, the problem summarized in optimizing three variables, they are: one output and two inputs (current and the change in current), each one has three dimensional spaces, represented as the prams of the triangle memberships of PIC. A random of 100, Habitats were assumed and optimization algorithm of 100 iterations is used to estimate the optimal values of the PIC controller parameters. The fitness function FF which illustrated in equation (28).

$$FF = ITSE = \int_0^t t * e^2(t)\,dt \qquad (28)$$

IV. ADVANCED IMPLEMENTATION FOR DC MOTOR

To use different control systems, like Classical PI Controller, Expert System Fuzzy Logic Controller and Optimization PSO Controller. It used to control for Implementation for DC Motor. The simulation model as shown in figures (5-8), by used all types to get the result and analysis it with compared to see the advanced implementation for DC Motor:

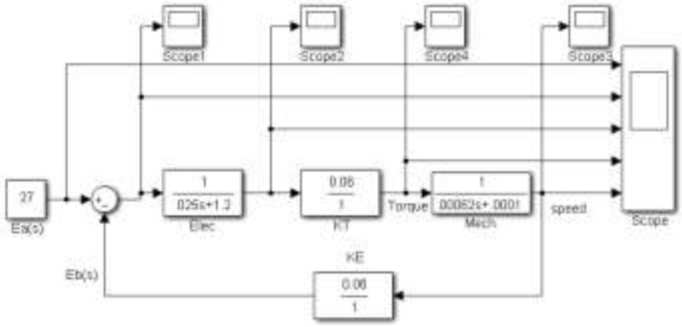

Fig. 5. The simulation model for DC Motor

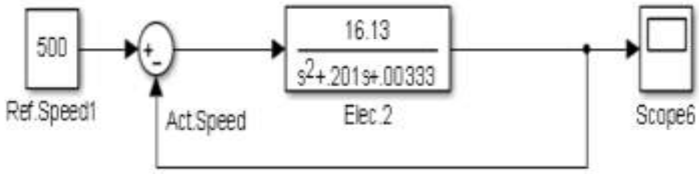

Fig. 6. The simulation model for DC Motor without control

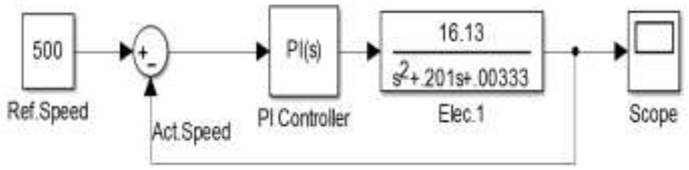

Fig. 7. The simulation model for DC Motor with PI control

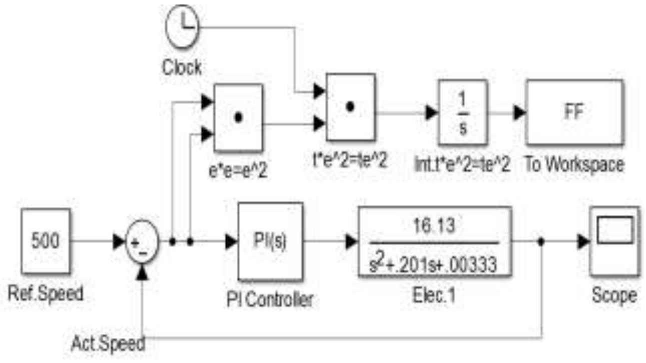

Fig. 8. The simulation model For DC Motor with BBO-PI control

V. RESULTS AND ANALYSIS

Final step, use different control systems, Like Classical PI Controller and Optimization BBO Controller to analysis all result. Simulation models (Classical PI Controller and Optimization BBO Controller of this step). Simulation Response (pu) Of PI Control, & BBO_PI Control. The results obtained from the BBO-PI based drive are not only superior in the rise time, settling time and overshoot but can prevent from voltage and has improved power quality. The simulation Results for DC Motor with in and without controller, By used the simulation model for DC Motor without control in figure (5,6)and with PI control, BBO_PI to get the simulation results for DC Motor with controller in figures (7,8). In Figure (9) show the simulation speed response for T.F of DC Motor without Controller and in Figure (10) show the simulation speed response for T.F of DC Motor with PI Controller. Figure 11-simulation speed response for T.F of DC Motor with BBO_ PI Controller.

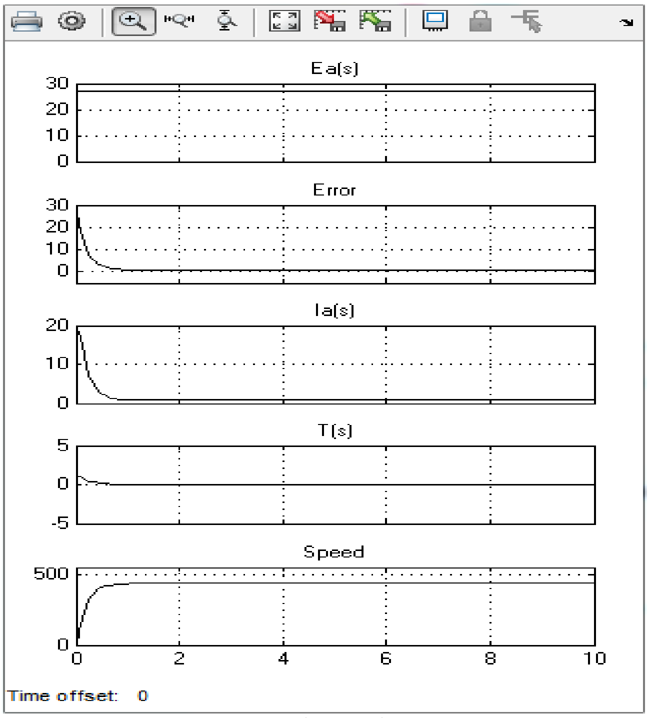

Fig. 9. Simulation speed response for T.F of DC Motor without Controller

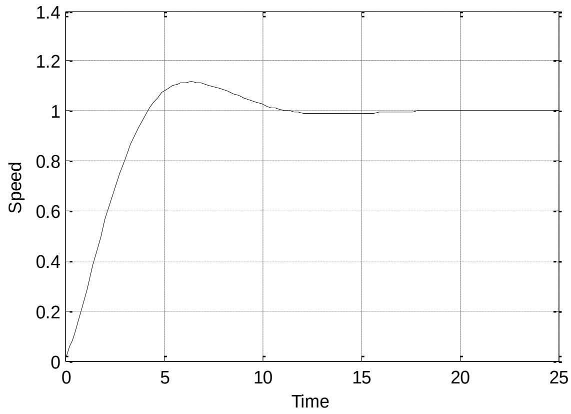

Fig. 10. Simulation speed response for T.F of DC Motor with PIC

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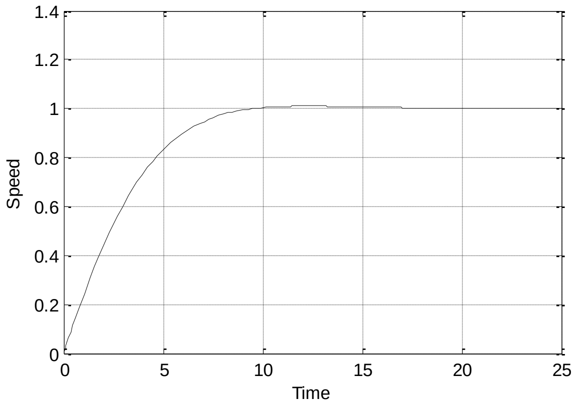

Fig. 11. Simulation speed response for T.F of DC Motor with BBO_ PIC

Figure 11 shows the convergence of Fitness Function in 100 iterations and the comparison between GA and BBO. Figure 12, 13 the step response with load and no load using proposed controller and GA-PIC and PI controller tuned by conventional method trial and error. Figure 11: The convergence of Fitness Function in 100 iterations Figure 12: Step response of load in different controllers, GA-PIC and BBO-PIC and PI Controller:

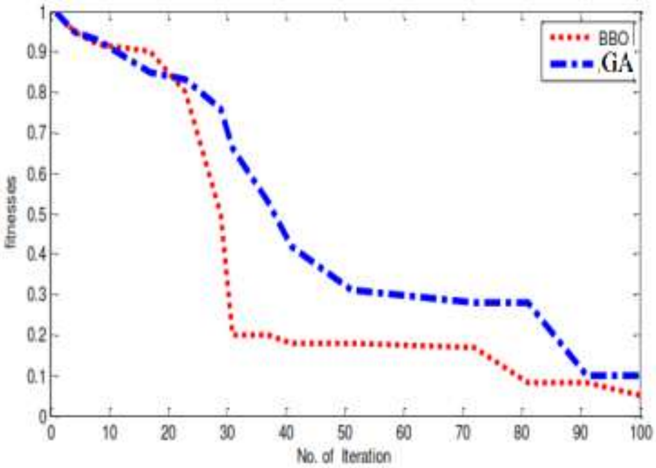

Fig. 12. The convergence of Fitness Function in 100 iterations

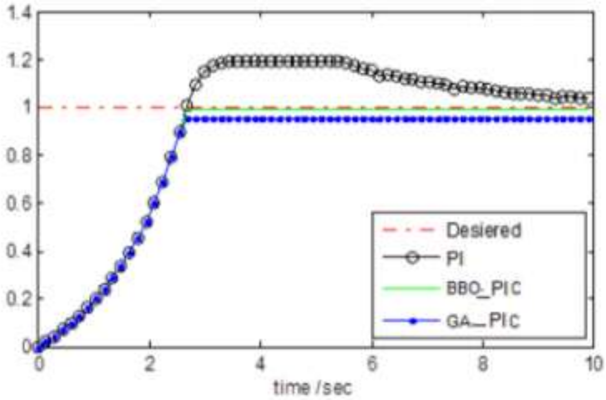

Fig. 13. Step response of load in different controllers, GA-PIC and BBO-PIC and PI Controller

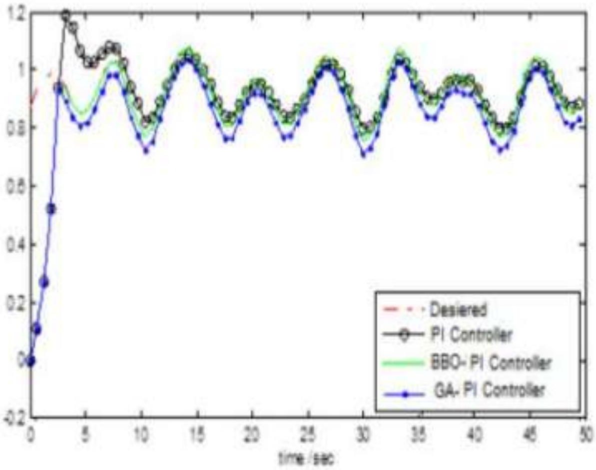

Fig. 14. An arbitrary load between (1.1pu and 0.7pu)

VI. CONCLUSION

To use different control systems as a case studies. To achieve this objective which characterizes each part of a system such as a DC Motor module, controller and Optimization. After that to investigate the design connection topology for all components of a DC Motor system in order to study the operation of the system for different environmental conditions. The simulation circuits for DC Motor controllers include all realistic components of the system. These results also confirmed that the maximum permissible value. Modeling, analysis, testing and simulation a DC Motor under different conditions using MATLAB. The performance of DC Motor system are controlled and Optimization by PI and BBO_PI Controller.

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