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Design An Intelligent Controller Based On Genetic-PID Algorithm For DC Motor Control

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Abstract

Intelligent techniques used to solve problems that are difficult to address with traditional techniques. This paper describes an implementation of Genetic–PID controller to enhance a permanent magnet direct current (DC) motor system response; Genetic Algorithm is searches algorithm with high-quality solution effectively to improve the transient response of the controlled system. The proposed algorithm can find a PID control parameter set effectively so that the controlled DC motor system has a better control performance. Finally the proposed approach has been tested and compared without controller and with classical PID controller. The simulation has been performed using MATLAB (version.7).

Keywords: PID ,intelligent control, classical control .

تصميم مسيطر ذكي باستخدام الخوارزمية (الجينية – تناسبي تكاملي تفاضلي) للسيطرة على محرك تيار مستمر

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الخلاصة

التقنيات الذكية الحديثة تستخدم لحل المشاكل والتي من الصعوبة التعامل معها بالطرق التقليدية (الكلاسيكية) . هذا البحث يصف تمثيل وتطبيق مسيطر ذكي (جيني- تناسبي تكاملي تفاضلي) لتحسين استجابة نظام سيطرة لمحرك تيار مستمر نوع المغناطيس الثابت . تم اقتراح دالة الملائمة الجديدة لغرض تصميم المسيطر (الجيني – الثلاثي تناسبي تكاملي تفاضلي) لمحرك المغناطيس الثابت، حيث أن خوارزمية البحث المستخدمة تبحث عن حل فعال لتحسين الاستجابة العابرة لنظام السيطرة .تم تطبيق الخوارزمية المقترحة لنظام السيطرة، تم عرض ومقارنة النتائج بواسطة المحاكاة .لقد تبين ان الخوارزمية المقترحة مع دالة الملائمة هي فعالة في الحصول على مجموعة ثوابت سيطرة لغرض تحسين أداء السيطرة للنظام .المحاكاة نفذت بأستخدام برنامج ال (MATLAB version 7) .

1. Introduction

PID controllers continue to be the main components of the industrial control application. New methods were developed through the improvement of the shortcomings of PID controllers in the last century .More than 90% of industrial controllers are still implemented based upon PID algorithms, particularly at lowest levels [1]**.** With its three-term functionality covering treatment to both transient and steady-state responses, proportional- integral-derivative (PID) control offers the simplest and yet most efficient solution to many real-world control problems[2]. There are three coefficients: proportional coefficient, differential coefficient, and integral coefficient in the PID controller. By tuning these three parameters (coefficients), the PID controller can provide individualized control requirements .In recent years, many intelligence algorithms are proposed to tuning the PID parameters.

Tuning PID parameters by the optimal algorithms such as the Simulated Annealing (SA), Genetic Algorithm (GA) [3].However, it has been known that conventional PID controllers generally do not work well for nonlinear systems, higher order and time-delayed linear systems therefore various types of modified conventional PID controllers such as auto tuning and adaptive PID controllers were developed [4],[5]. The PID control strategy shows the improvement in various control parameters like maximum overshoot, settling time for the DC motor control as compared with PID control strategy. This paper is organized; introduction, Proportional-Integral-Derivative control, Genetic Algorithms, DC Motor system, Genetic-PID Structure, simulation and finally the conclusions are explained.

2. Proportional-Integral-Derivative (PID) control

Control system engineers are concerned with controlling a part of an environment known as a plant or system in order to produce desired products for society. A prior knowledge of the plant to be controlled is often critical in designing effective control systems. The application of different engineering principles like that of electrical, mechanical, and/or chemical in order to achieve the desired output make control engineering a multi-faceted engineering domain [3]. Control systems can be categorized as open-loop control or closed-loop feedback control systems depending on the system architecture and control method applied. Feedback control systems can be further differentiated as single-input-single-output (SISO) or multiple-input-multiple-output (MIMO), often called multivariable control systems [3]&[6].

PID control logic is widely used in the process control industry. PID controllers have traditionally been chosen by control system engineers due to their flexibility and reliability[3]. PID controller is the most common form of feedback. It was an essential element of early governors and it became the standard tool when process control emerged in the 1940s. In process control today, more than 95% of the control loops are of PID type, most loops are actually PI control. PID controllers are today found in all areas where control is used [2].

By tuning these PID controller gains, the controller can provide control action designed for specific process requirements [3]. Whose transfer function is generally written in the "parallel form" given in Eq. 1 or its ideal form which is given in Eq. 2.

$$G(s) = K_P + K_I \times \frac{1}{s} + sK_D \qquad (1)$$

$$G(S) = K_P (1 + \frac{1}{T_1 s} + T_D s) \qquad (2)$$

Where K_p is the proportional gain, K_I the integral gain, K_D the derivative gain, T_1 the integral time constant and, T_D the derivative time constant. The "three-term" functiona1ities are highlighted by the following [7]:

- The proportional term providing an overall control action proportional to the error signal through the all-pass gain factor.
- The integral term reducing steady-state errors through low-frequency compensation by an integrator
- The derivative term improving transient response through high-frequency compensation by a differentiator.

The proportional term drives a change to the output that is proportional to the current error. This proportional term is concerned with the current state of the process variable. The integral term (K_I) is proportional to both the magnitude of the error and the duration of the error. It (when added to the proportional term) accelerates the movement of the process towards the set point and often eliminates the residual steady-state error that may occur with a proportional only controller. The rate of change of the process error is calculated by determining the differential slope of the error over time (i.e., its first derivative with respect to time). This rate of change in the error is multiplied by the derivative gain [3].

The controllers come in many different forms. There are standalone systems in boxes for one or a few loops, which are manufactured by the hundred thousand yearly. PID control is an important ingredient of a distributed control system.

The controllers are also embedded in many special purpose control systems. PID control is often combined with logic, sequential functions, selectors, and simple function blocks to build the complicated automation systems used for energy production, transportation, and manufacturing. Many sophisticated control strategies, such as model predictive control, are also organized hierarchically. PID control is used at the lowest level; the multivariable controller gives the set points to the controllers at the lower level. It is an important component in every control engineer’s tool box. PID controllers have survived many changes in technology, from mechanics and pneumatics to microprocessors via electronic tubes, transistors, integrated circuits. The microprocessor has had a dramatic influence on the PID controller [2]&[8]. Practically all PID controllers made today are based on microprocessors. This has given opportunities to provide additional features like automatic tuning, gain scheduling, and continuous adaptation. The PID controller is used to improve the dynamic response as well as to reduce or eliminate the steady-state error. The derivative controller adds a finite zero to the open-loop plant transfer function and improves the transient response. The integral controller adds a pole at the origin, thus increasing system type by one and reducing the steady-state error due to a step function to zero. The PID controller transfer function is [6]. The three-Term Functionality and the Parallel PID controller Structure [2] may be considered as an extreme form of a phase lead-lag compensator with one pole at the origin and the other at infinity. Similarly, its cousins, the PI and the PD controllers, can also be regarded as extreme forms of phase-lag and phase-lead compensators, respectively. A standard PID controller is also known as the "three-term" controller as shown in **Figure (1)**.

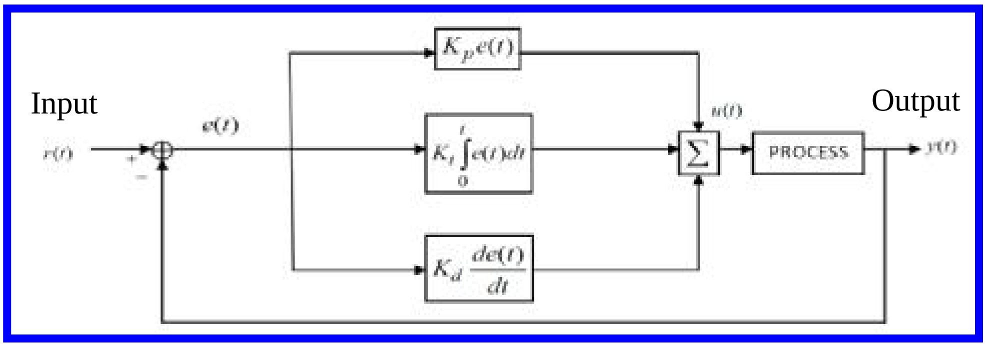

Fig .(1) PID control logic Figure 1 . PID control logic

3. Genetic Algorithms (GAs)

This section outlines the operation of a basic genetic algorithm (GA). A basic GA consists of five components. These are a random number generator, “fitness” evaluation unit and genetic operators for “reproduction”. “Crossover” and “mutation” operation. The algorithm is summarized in **Figure (2)** [9]. The initial population required at the start of the algorithm, is a set of number strings generated by the random generator. Each string is a representation of a solution to the optimization problem being addressed.Binary strings and real string are commonly employed. Associated with each string is fitness value as computed by the evaluation unit. A fitness value is a measure of the goodness of the solution. The aim of the genetic operators is to transform this set of strings into sets with higher fitness [9]. Typically, the GA starts with little or no knowledge of the correct solution depending entirely on responses from interacting environment and their evolution operators to arrive at optimal or near optimal solutions. In general, GA includes operations such as reproduction, crossover, and mutation. Reproduction is a process in which a new generation of population is formed by selecting the fittest individuals in the current population. Crossover is the most dominant operator in GA. It is responsible for producing new offsprings by selecting two strings and exchanging portions of their structures. The new offsprings may replace the weaker individuals in the population. Mutation is a local operator which is applied with a very low probability. Its function is to alter the value of a random position in a string [7], [8]& [9].

Initialization

Initially many individual solutions are randomly generated to form an initial population. The population size depends on the nature of the problem, but typically contains several hundreds or thousands of possible solutions [8].

Selection

Selection is a genetic operator that chooses a chromosome from the current generation's population for inclusion in the next generation's population. Individual solutions are selected through a fitness-based process, where fitter solutions (as measured by a fitness function) are typically more likely to be selected [9].

Crossover

The next step is to generate a second generation population of solutions from those selected through genetic operators: crossover (also called recombination), and/or mutation. For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously [8]&[9].

Mutation

Mutation is a genetic operator that alters one ore more gene values in a chromosome from its initial state. This can result in entirely new gene values being added to the gene pool. With these new gene values, the genetic algorithm may be able to arrive at better solution than was previously possible. [7]&[9].

Termination

This generational process is repeated until a termination condition has been reached. A solution is found that satisfies minimum criteria Fixed number of generations reached. Allocated budget (computation time/money) reached the highest ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results [9].

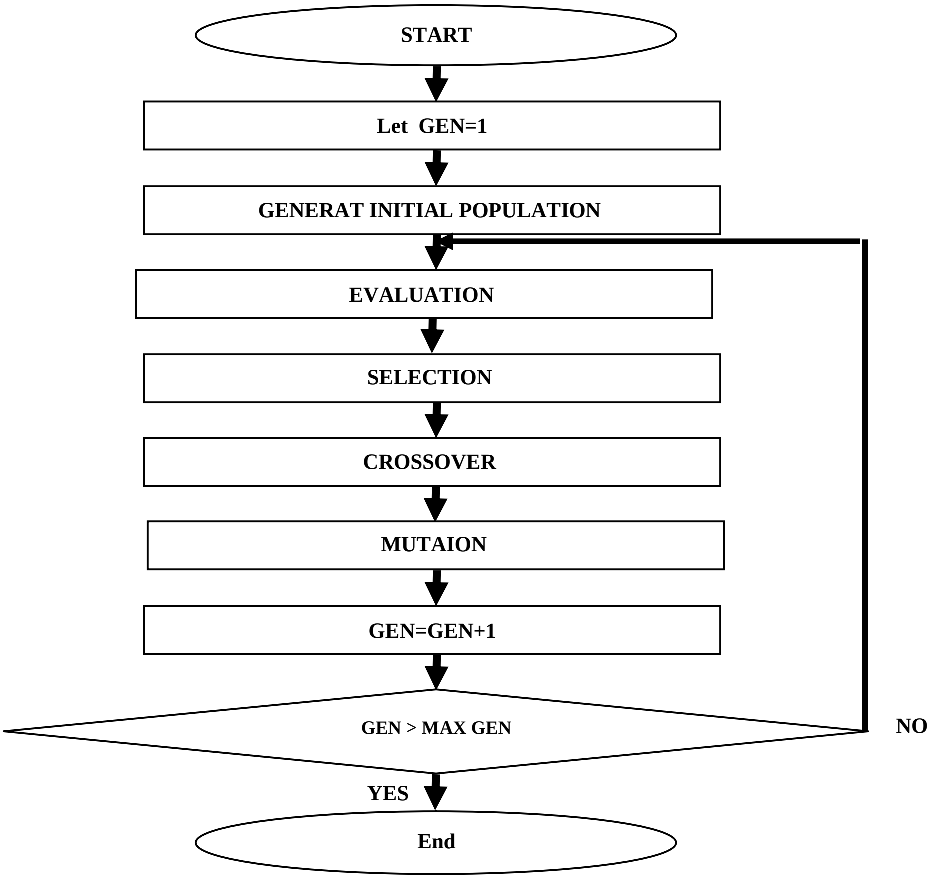

Fig .(2): Basic genetic algorithms operator

4. DC Motor plant

A permanent magnet direct current (DC) motor is a very common component within many dynamic systems. This case study describes the physics of a standard DC motor. The transfer function is explained to describe the motor's dynamic behavior [10]&[11]. The block diagram for this plant is shown in **Figure (3)**

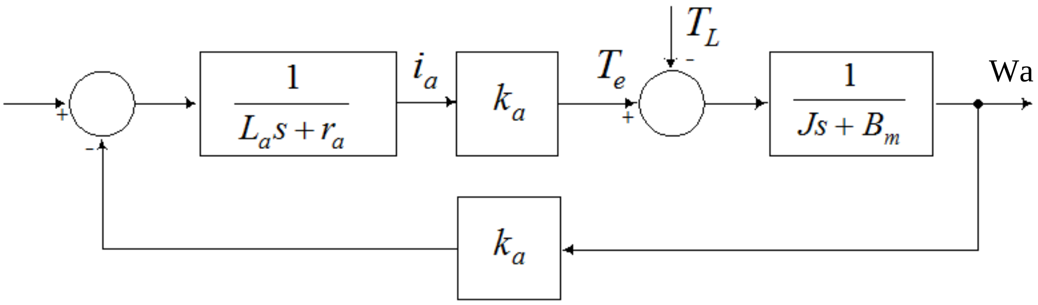

Fig .(3): Feedback control system with DC MOTOR plant

The overall transfers function between the output (angular velocity) and input applied voltage given as:

$$\frac{W_a}{V_a} = \frac{k_a / L_a J}{S^2 + [(R_a J + L_A B)/L_a J]s + (R_a B + k_a k_v)/L_a J} \qquad (3)$$

Where:

V_a: Voltage source across the coil of armature

I_a : Armature current

L_a: Inductance, which represent the electrical equivalent of the armature coil

R_a: Resistance of armature

V_c: Induced voltage which opposes the voltage source, which generated by rotation of the electrical coil through the fixed flux lines of the permanent magnets

k_a: Torque constant

J: Inertia of rotor and the equivalent mechanical load

B: Damping coefficient associated with mechanical rotational system of machine

W_a: Angular velocity.

The parameters are shown in this table (1) [10]& [11]

Table (1): system parameters

Ra	La	K_a	*J*	B
5 ohm	0.01 H	0.2 V-sec/rad	0.0005 kg-m^2	0.00001 N-m-sec/rad

5. Genetic-PID Controller Structure

In this section the Genetic- PID (GPID) controller will be explained, also the proposed algorithm structure for this controller. **Figure (4),** shows the general block diagram for GPID controller .The GA algorithm is used to adjust the PID controller parameters (K_P, K_I K_D), to obtain the optimal three parameters which gives the best response.

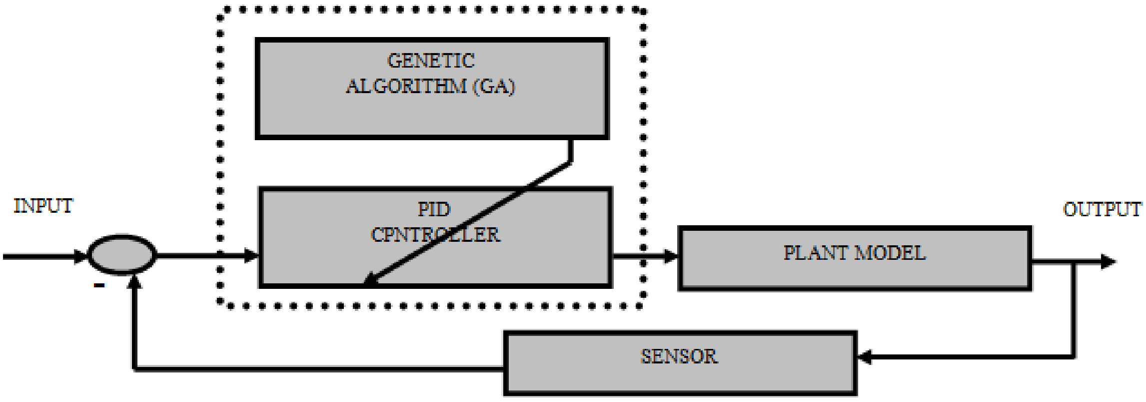

Fig .(4): GENETIC- PID- controller Structure

The performance of the proposed controller evaluated by rise time , peak time, error steady stat, peak time and integral square error ISE ; which can be demonstrated in **Figure(5)** :

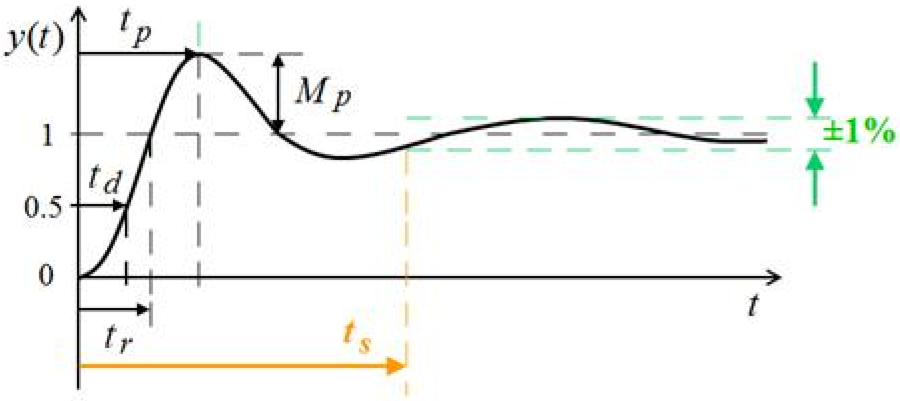

Fig .(5): Time response parameters

- The peak time is the time required for the response to reach the first peak of the overshoot.
- The maximum overshoot is the relative maximum peak value of the response curve measured from the final value.
- The settling time is the time required for the response curve to reach and stay within a range about 1% or 2% of the final steady-state value

6. Simulation Result:

In this section, the proposed controller is presented and tested for a permanent magnet direct current (DC) motor plant. The simulation results showed that the proposed controller provide an improvement in the responses of the system. The effect of the controller can be realized from decrement of steady state error (e_{ss}), setting time (t_s), rise time (t_r), and integral of squared error (ISE).

The GA parameters are:
Maximum number of Generation (MaxGen) = 80.
Population Size (Pop) = 40.
Probability of Crossover PC= 0.9.
Probability of Mutation PM= 0.01.
Fitness function Fit: 1/(ISE+0.001)
The chromosome representation shown in **Figure (6)**

K_p	K_I	K_d

Fig .(6): chromosome representation

Figure (7) and **Figure (8)** show the DC motor system response without controller for open and closed loop response with step input.

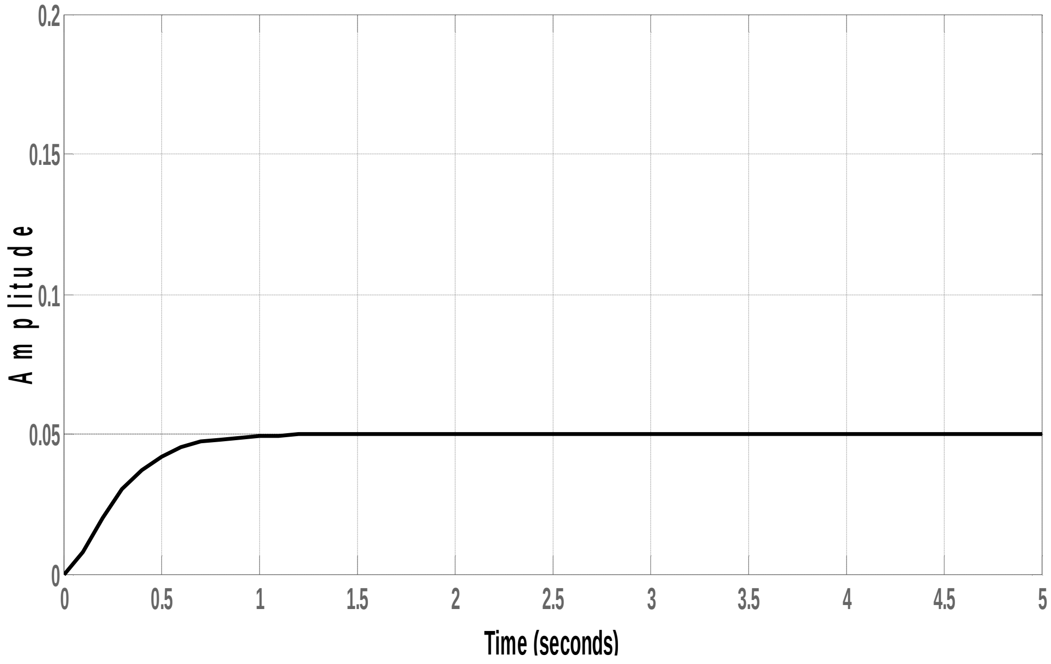

Fig .(7): Open loop response for DC motor system without controller with step input

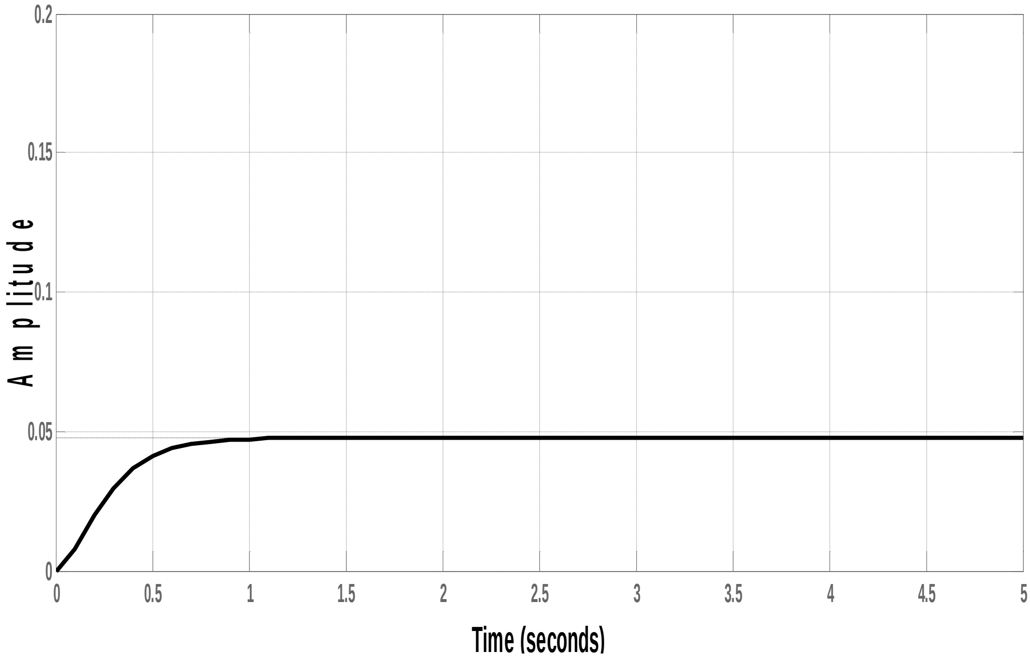

Fig .(8): Closed loop step-response for DC motor system without controller

Very bad response with high overshot in previous figures. To enhance the output response for the system, the PID controller is used

The control action transfer function for the PID is:

$$U(S) = Kp\,(1 + \frac{1}{TiS} + TdS\,)\,E(S) \qquad (4)$$

Where *Kp*, *Ti* and *Td* are the proportional gain, integral time and derivative time, respectively, *E(s)* and *U(s)* are Laplace transforms of the control signal and the error between the reference signal and the plant output. The PID-controller proposed by Clarke [10, 11] is used because of its better derivative part.

The controller is of the form

$$U(S) = Kp(1 + \frac{1}{TiS} + TdS)E(S) - \frac{KpTds}{1 + aTds}Y(s) \qquad (5)$$

Where a is the filtering constant at the interval (0,1), and *U(s)* is Laplace transform of the plant output. The output response with classical PID controller is shown in **Figure (9).**

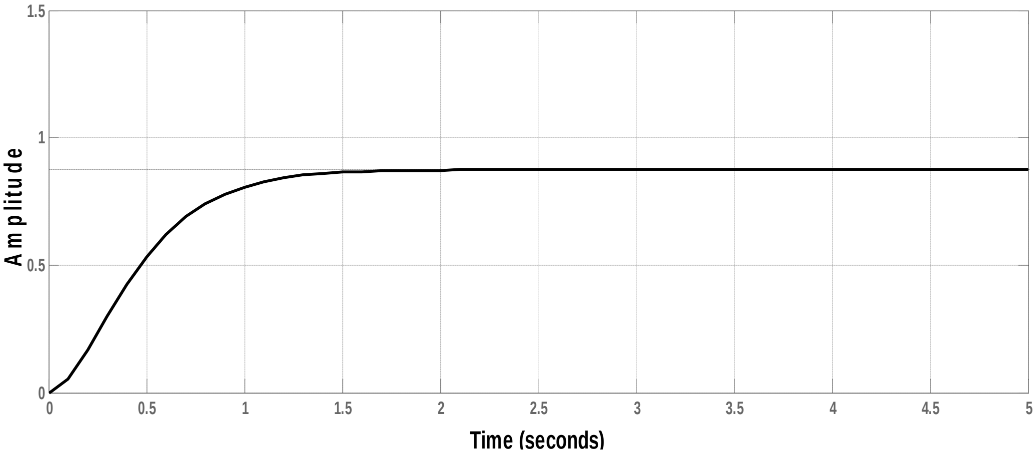

Fig .(9): Closed loop step-response for DC motor system with PID controller

For more enhancements the Genetic-PID controller is used as shown in **Figure (10).**

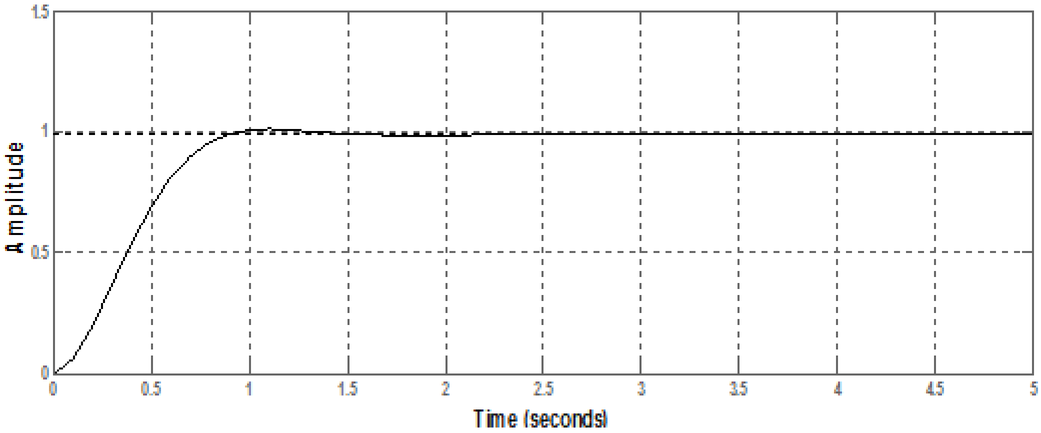

Fig .(10): DC motor step response with GPID controller

Table (2): Step input Time response parameters with ISE for DC plant

Controller type	Peak Time	Settling time	Rise Time	(e_{ss})(2%)	ISE
Without controller	0.0476	0.96469	0.*66161*	0.951	48.2576
PID	1.6204	0.99925	0.81267	o.125	11.5699
GPID	1.0105	0.94358	0.68377	0.134	1.08444

(Integral square error) is a performance index and can be calculated by:
e_{ss} (Steady state error) can be calculated by:

$$e_{ss} = e(\infty) = \lim_{t\to\infty}[r(t) - y(t)] \qquad (6)$$

In order to demonstrate clearly; **Figure 11** shows all responses in one graph

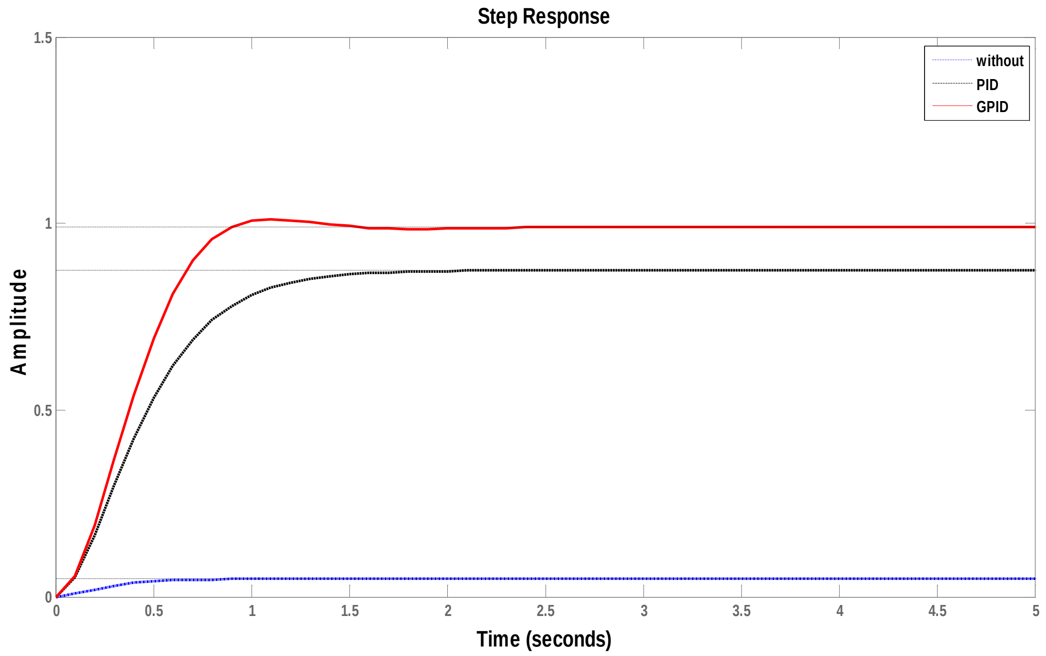

Fig .(11): without controller; with PID; and with GPID controller responses in one graph

7. Conclusion

This paper has presented an intelligent controller (Genetic–PID), and compared with a classical PID controller, also the output responses without any controller are plotted.
From the simulation results:

- GPID controller is really very good method, since the ISE decreased from high value to very small value.
- The proposed approach can perform an efficient three term controller, when two parameters of the controller are tuned; a little better performance at settling time is achieved comparing with one parameter adjustment case. Also the proposed controller is a good controller, since the good responses with step input are obtained.
- More robust stability and good performance.

8. References

1. **Pirabakaran K. and Becerra V.M., "Automatic Tuning of PID controllers using Model reference adaptive control technique", 27th Annual Conference of IEEE industrial Electronics Society ,IECON01,2001.**
2. **Ang, K. H. G. Chong, and Li Y." PID Control system analysis , Design and technology " IEEE transaction on control sytems technology , Vol.13 No. 4 July, 2005.**
3. **Ching-Chang Wong*, Shih-An Li and Hou-Yi Wang “Optimal PID Controller Design for AVR System” Tamkang Journal of Science and Engineering, Vol. 12, No. 3, pp. 259_270, 2009.**
4. **Jones A.H. and Oliveira P.B.D "Genetic autotuning of PID controllers " proc. inst. electrical engineering conf. genetic algorithms eng. System pp.141-145, Sept. 1995.**
5. **Viljamaa P. and Koivo H.N., “Fuzzy Logic in PID Gain Scheduling”, Third European Congress on Fuzzy and Intelligent Technologies EUFIT’95, Aachen, Germany, August 2831, 1995.**
6. **Awang N.I. Wardana "PID-Fuzzy Controller for Grate Cooler in Cement Plan" Control Department ,Indonesia Cement and Concrete Institute Jalan Raya Ciangsana, Bogor, 16969, Indonesia,2002.**
7. **Ching-Chang Wong, Shih-An Li and Hou-Yi Wang “Optimal PID Controller Design for AVR System” Tamkang Journal of Science and Engineering, Vol. 12, No. 3, pp. 259_270 ,2009.**
8. **Ajlouni N. and S. Al-Hamouz "Genetic Design of Fuzzy Mapped PID Controllers for Non-linear Plants"Faculty of Computer Science and Information Technology, Applied Science University, Jordan-11931, Amman, Information and Technology Journal, 3 (1): 44-48, 2004.**
9. **Mitcell, M., "An Introduction To Genetic Algorithms " first MIT press paperback edition, united state of America 1996.**
10. **Kundur P., 'Power System Stability and Control', McGraw-Hill, 1994.**
11. **Saadat H. ' power system analysis' New York , McGraw-hill 1999.**