Strategic Comparison Of PMDC Drive Performance Based On Conventional And Genetic Algorithm Based Tuning Of PID

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Abstract

The Permanent Magnet DC motors are preferred today because of the cost, affordability and variety they offer in choice of application involving the fractional horsepower which can be increased up to 3 horsepower in most of the DC motors. In practice, controlled systems usually have some features, such as nonlinearity, time–variability, and time delay, which make controller parameter tuning more complex. Moreover, in some cases, system parameters and even system structure can vary with time and environment. As a result, the traditional PID parameter tuning methods are not suitable for these difficult calculations. Using genetic algorithms to perform the tuning of the controller will result in the optimum controller being evaluated for the system every time. A comparison analysis has been made to show the Permanent Magnet DC drive Control with PID controller conventional tuning and Genetic Algorithm based tuning. The mathematical analysis has been carried out and the transfer function has been analyzed in the system with MATLAB.

Keywords: Permanent Magnet DC motors, PID parameter tuning methods, Genetic Algorithm.

1. INTRODUCTION

Nowadays there is a huge requirement of high performance motor drives in industrial as well as other purpose applications such as steel rolling mills, electric trains and robotics. Generally, a better performance motor drive system has good dynamic response which perform task to speed command tracking and load regulating response [1,6]. DC drives consist of fewer complexes with a single power conversion from AC to DC. This is as a result of its simplicity, low cost design and robust performance in a wide range of operating conditions [2].The major problems in applying a conventional control algorithm (PI, PD, PID) in a speed controller are the effects of non-linearity in a DC motor Speed control of DC motor has attracted considerable research and several methods have created. Proportional Integral Derivative (PID) controllers have the advantage of simple structure, good stability, and high reliability [3]. Accordingly, PID controllers are widely used to control system outputs, especially for systems with accurate mathematical models. The key issue for PID controllers is the accurate and efficient tuning of parameters. In practice, controlled systems usually have some features, such as nonlinearity, time– variability, and time delay, which make controller parameter tuning more complex [4]. Moreover, in some cases, system parameters and even system structure can vary with time and environment. As a result, the traditional PID parameter tuning methods are not suitable for these difficult calculations [5, 7]. The aim of this paper is to design a DC motor control using Ziegler and Nichols and Genetic Algorithm [9]. Genetic Algorithm or in short GA is a stochastic algorithm based on principles of natural selection and genetics. Genetic Algorithms (GA) are a stochastic global search method that mimics the process of natural evolution [10]. Genetic Algorithms have been shown to be capable of locating high performance areas in complex domains without experiencing the difficulties associated with high dimensionality or false optima as may occur with normal PID techniques [11]. Using genetic algorithms to perform the tuning of the controller will result in the optimum controller being evaluated for the system every time[12]. This can be seen by comparing the result of the GA optimized system against the classically tuned system [13]. Genetic algorithm is a computational procedure that mimics the natural process of evolution [14]. It works by evolving a population of solutions over a number of generations. For each generation, solutions are selected from the population based on the fitness value [15]. These solutions by crossover (merging previous solutions) and by mutation (modifying the solutions) generate new population. Since it searches many peaks in parallel, the trapping at local minima is avoided [16].

2. DC MOTOR MATHEMATICAL MODEL

The DC motor mathematical model provided below where,

R : the armature resistance,

L : the armature inductance,

i : the armature current,

E_a : the input voltage,

I : the field current,

e : the back electromotive force (EMF),

T : the motor torque,

v : angular velocity of rotor,

J : rotating inertial measurement of motor bearing ,

B : a damping coefficient.

Because the back EMF e_b is proportional to speed ω directly, then

$$e_b(t) = K_b \frac{d\theta(t)}{dt} = K_b \omega(t) \quad (1)$$

Making use of the KCL voltage law can get

$$e_a(t) = R_a i_a(t) + L_a \frac{di_a(t)}{dt} + e_b(t) \quad (2)$$

From Newton law, the motor torque can obtain

$$T_m(t) = J \frac{d^2\theta(t)}{dt^2} + B\frac{d\theta}{dt} = K_T i_a(t) \quad (3)$$

Take (1), (2), and (3) into Laplace transform respectively, the equations can be formulated as follows:

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

$$E_a(s) = K_b \Omega(s)$$

$$T_m(s) = B\Omega(s) + Js\Omega(s) = K_T I_a(s)$$

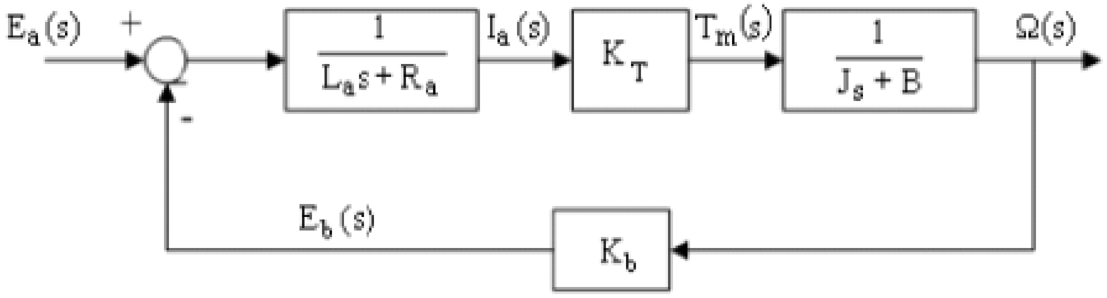


Fig.1 Function block diagram of DC motor

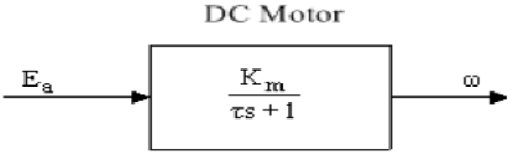
The transfer function of DC motor speed with respect to the input voltage can be written as follows:

$$G(s) = \frac{\Omega(s)}{E_a(s)} = \frac{K_T}{(L_a s + R_a)(Js + B) + K_b K_T}$$

From the above Equation the armature inductance is very small in practices, hence, the transfer function of DC motor speed to the input voltage can be simplified as follows,

$$\frac{\Omega(s)}{E_a(s)} = \frac{K_m}{\tau s + 1}$$

Where $K_m = \frac{K_T}{R_a B + K_b K_T}$ is a motor gain and $\tau = \frac{R_a J}{R_a B + K_a K_T}$ is motor time constant.



3. PID Controller

The PID controller includes a proportional term, integral term and derivative term, where the proportional term is to adjust the output of controller according to all of the magnitude of error, the integral term is used to remove the steady state error of control system and improve the steady state response, the derivative term is used to predict a trend of error and improve the transient response of the system. These functions have been enough to the most control processes. Because the structure of PID controller is simple, it is the most extensive control method to be used in industry so far. The PID controller is mainly to adjust an appropriate proportional gain (K_P), integral gain (K_I), and differential gain (K_D) to achieve the optimal control performance. The PID controller system block diagram of this paper is shown in Fig. 2

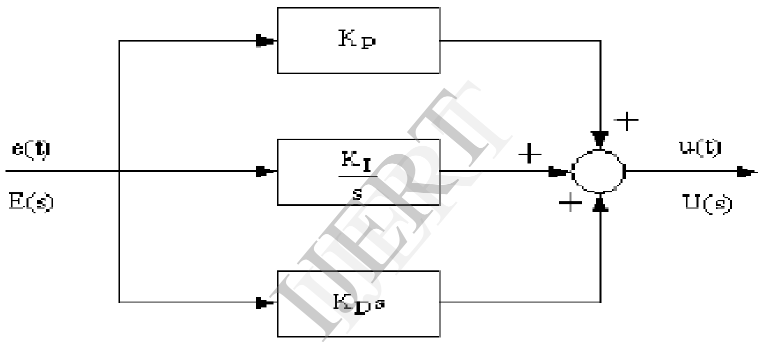


Fig.2.The schematic diagram of PID controller.

The relationship between the input $e(t)$ and output $u(t)$ can be formulated in the following

$$u(t) = K_p e(t) + K_I . \int_0^t e(t)\,dt + K_D \frac{de(t)}{dt}$$

The above equation can be expressed as follows.

$$C(s) = \frac{U(s)}{E(s)} = K_P + \frac{K_I}{s} + K_D s$$

The block diagram representation for PID based DC motor.

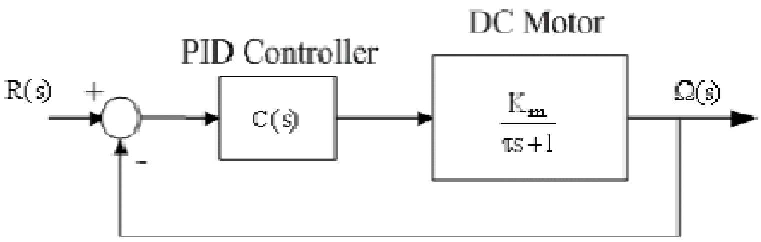


Fig.3. The block diagram representation for PID based PMDC

Closed loop transfer function of the DC motor speed control system

$$G(s) = \frac{\Omega(s)}{R(s)} = \frac{(K_P + \frac{K_I}{s} K_D s)\frac{K_m}{1+\tau s}}{1 + (K_P + \frac{K_I}{s} + K_D s)\frac{K_m}{1+\tau s}} = \frac{(K_D s^2 + K_P s + K_I)K_m}{(K_D K_m + \tau)s^2 + (1 + K_P K_m)s + K_I K_m}$$

Tuning method for PID controller is very important for the process industries.

4. Genetic Algorithm

Genetic algorithm (GA) is a heuristic mimicking the natural evolution process and is routinely used to generate useful solutions to optimization problems. In this work the genetic algorithm is used to derive the PID controller parameters by optimizing the error in the DC motor angular velocity. In GA, a population of strings called chromosomes encodes the possible solutions of an optimization problem and evolves for a better solution by process of reproduction. The process of evolution starts from a population of randomly generated individuals. Optimization is achieved in generations where in each generation, the fitness function evaluates each individual in the population and multiple individuals are selected stochastically based on their fitness. These selected individuals are modified to form a new population. The algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population. The various steps in GA based optimization.

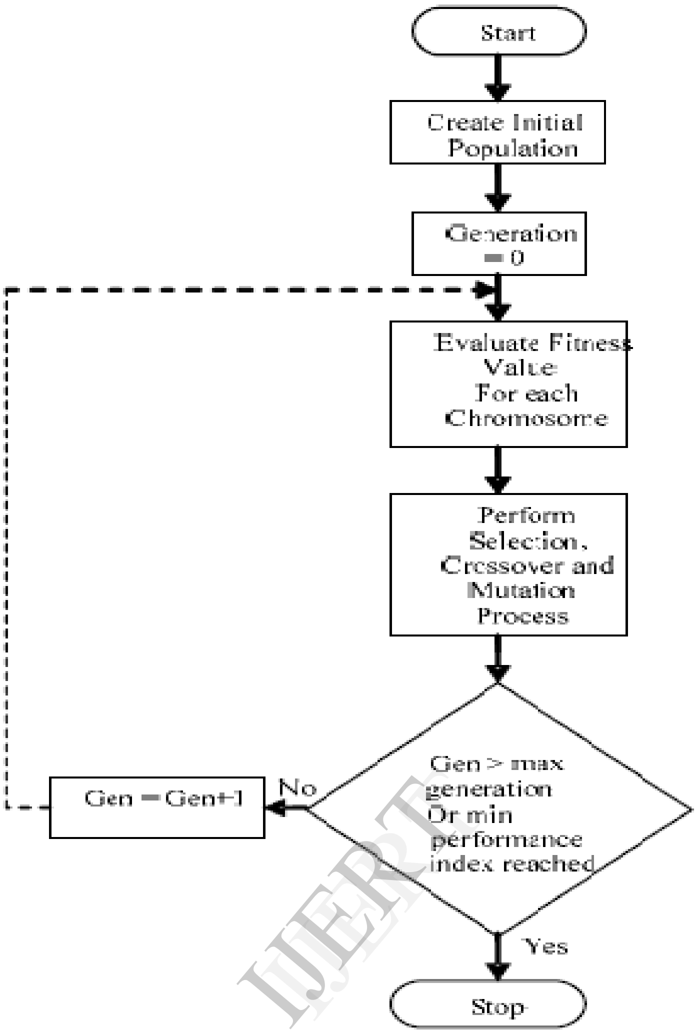


Fig.4.1 The Genetic Algorithm approach

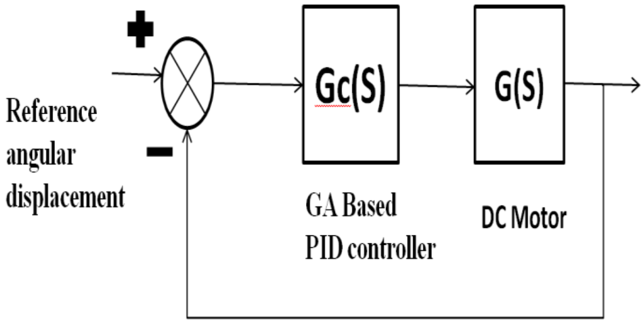


Fig: 4.2. Block diagram representation of GA based PID tuning of PMDC drive.

5. Result Analysis

In order to analysis the performance characteristics of PMDC drive the following observations are discussed.

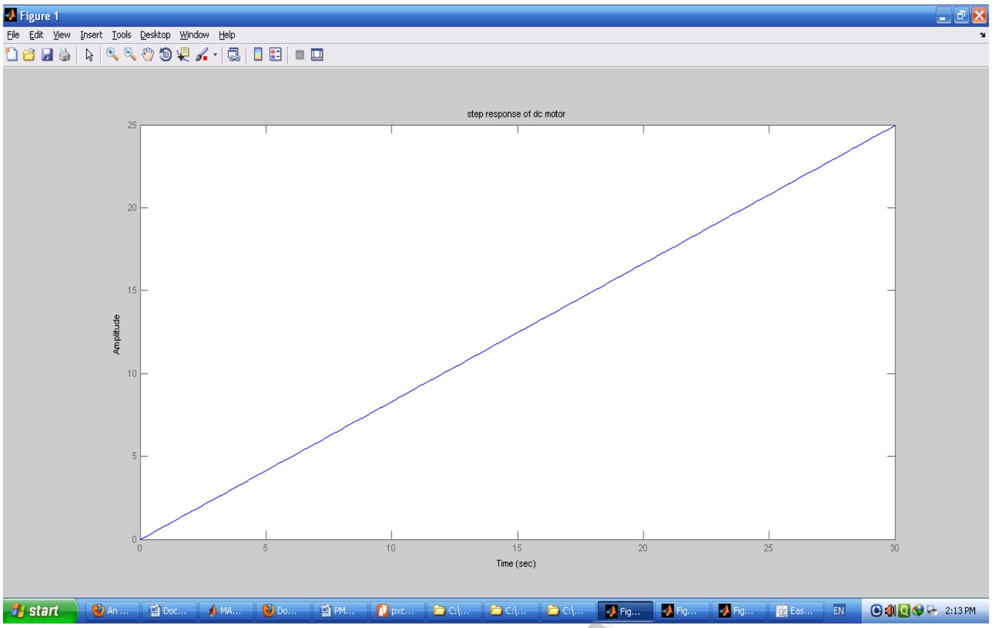


Fig 5.1 Step response of the motor

Motor transfer function is given as $\dfrac{1.2}{0.00077s^3 + 0.0539s^2 + 1.441s}$

The time range is between 0 to 30 sec with a division of multiples of 5 Sec.

When the given transfer function is applied with a step response, the observation is obtained as per the fig.5.1

PMDC drive performance with application PID Conventional tuning in MATLAB Tool.

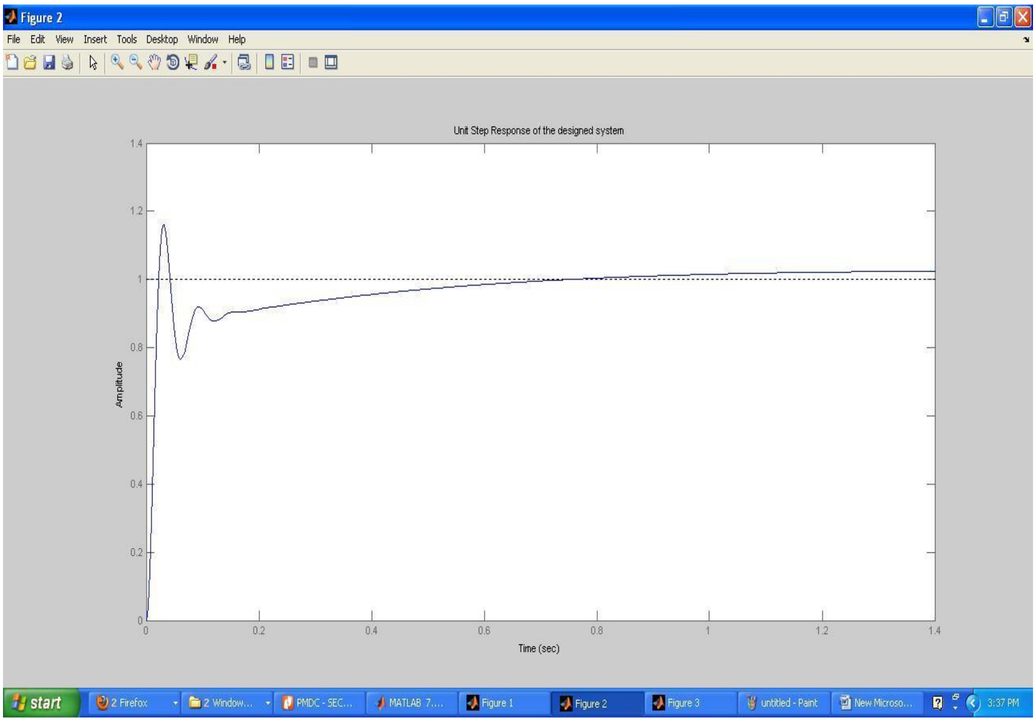


Fig.5.2.The response of the Conventional tuning based PID controller

As the mathematical model is solved with Mat lab with PID controller conventional tuning the dynamic system response is not approach to its steady state immediately but it will be having some damping oscillations initially. The main problem of the system is the in appropriate the steady state parameter. The gain constants of the PID controller are motioned below.

Parameters obtained in PID based conventional tuning: K_P=16, K_i=0.37, K_d= 0.017

A. **Rise time (t_r) = 0.2Sec**

B. **Settling time (t_s) = 0.25Sec**

C. **Steady state error (e_{ss}) = 0.36**

Response of PMDC in Genetic Algorithm based Approach

When unstable system is applied with Genetic algorithm for its PID controller the response will be like above mentioned fig.5.3. As the problems of instability observed with conventional tuning based PID controller, those parameters are tuned in a better manner.

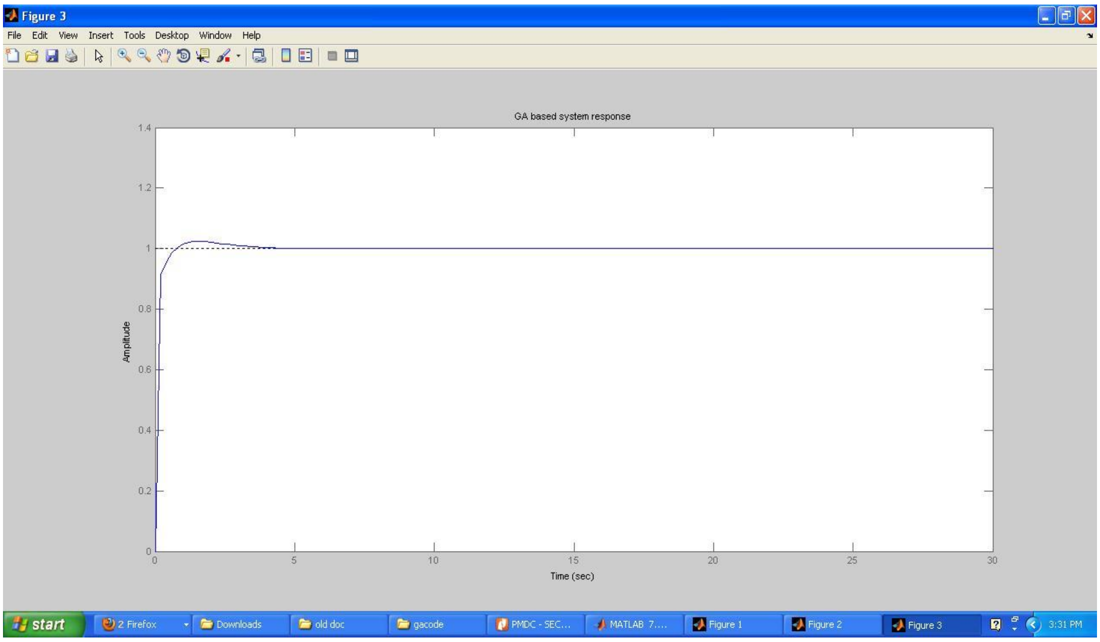


Fig.5.3 The response of PMDC for Genetic algorithm based PID controller tuning.

The observed values of gain parameters of PID and improved steady state response parameters are mentioned below.

K_p = 18.5 ; K_i =0.125; K_d= 0.53 values of the PID controller tuning under GA.

A. Rise time (t_r) =0.1Sec

B. Settling time (t_s) = 0.1 Sec

C. Steady state error (e_{ss}) =0.003

7. Conclusion

In this paper a comparison analysis of PMDC drive performance based on conventional PID tuning and GA based PID tuning has presented. The system mathematical analysis has carried out and implemented with MATLAB. The behavior of PMDC drive response has verified with the Genetic algorithm based tuning of PID controller. The changes in terms of peak overshoot, rise time and settling time founded in considerable manner when compared to conventional tuning of PID controller. The final conclusion has drawn that GA based PID tuning can be implemented for many industrial applications.

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