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Speed Control of DC Motor Using Different Optimization Techniques Based PID Controller

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ABSTRACT

This paper presents a new approach for design a speed controller of a DC motor by selection of PID parameters using Particle Swarm Optimization (PSO) method. Because of excellent control characteristics of DC motor, it has been widely used in the objective functions. So it is important to obtain the best performance of DC motor. Due to conducting simulation based on PSO, cost functions with different scenarios are considered. Also, the effects of different cost functions on performance of system were analyzed. To show the efficiency of PSO to finding the global optimum parameters of PID controller, simulation results were compared with Genetic Algorithm (GA) method. By comparing two methods, we obtained that PSO has good performance to find the optimum PID controller to speed control of DC motor. Also, we obtained that to speed control of DC motor, Time domain cost function has good efficiency to finding the most appropriate PID controller due to the importance of time domain parameters in performance of DC motor.

KEYWORDS: Speed Control of DC Motor, PID Controller, Particle Swarm Optimization, Genetic Algorithm, Cost Function.

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INTRODUCTION

DC motor has been widely used in industry even though its maintenance costs are higher than the induction motor [1]. Eventually, speed control of DC motor has attracted considerable research and several methods have developed. Proportional-Integral Derivative (PID) control technique has been widely used for speed and position control of DC motor.

PID controller is a generic control loop feedback mechanism widely used in industrial control systems. PID is the most commonly used feedback controller. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process control inputs.

Kennedy and Eberhart [2] proposed a swarm-intelligence-based parallel optimization algorithm, Particle Swarm Optimization (PSO) in 1995. PSO shows a realistic performance on pattern classification, optimization and controller parameters design [3].

Genetic algorithms are an optimization methodology. The study of the genetic algorithms began in 1970[4].These algorithms simulate the natural selection mechanism, where the chromosomes of the engineering problem are the set of its independent variables. The healthiest individual transcends their genes into the next generation so that the new population is better adapted to the environment. Likewise, the independent variables are optimized so that they lead to a better solution of the problem [5].Nowadays; there are many engineering fields where they are employed.

This paper proposes a new method to design a speed controller of a DC motor by selection of PID parameters using PSO. To show the efficiency of PSO, the results of this method are compared with GA method.

As to the organization of the paper: Section II indicates formulation of DC motor. Section III explains the PID controller and problem definition using PSO algorithm. In the Section IV, PSO is applied to a DC motor and the results are compared with GA.

I. FORMULATION OF DC MOTOR

We consider a DC shunt motor as is shown in Fig.1. DC shunt motors have the field coil in parallel (shunt) with the armature. The current in the field coil and the armature are independent of one another. As a result, these motors have excellent speed and position control. Hence DC shunt motors are typically used applications that require five or more horse power. The equations describing the dynamic behavior of the DC motor are given by the following equations [6]:

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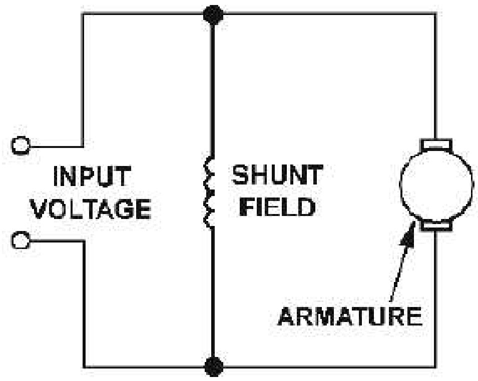

Figure.1. Diagram of DC shunt motor

$$V = Ri + L\frac{di}{dt} + e_b \quad (1)$$

$$T_m = K_T\, i \quad (2)$$

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

$$e_b = K_b\,\frac{d\theta}{dt} \quad (4)$$

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

After simplification and taking the ratio of ω(s)/v(s) we will get the transfer function as below:

$$\frac{\omega(s)}{V(s)} = \frac{K_b}{(JS+B)(LS+R)+{K_b}^2+RB} \quad (6)$$

where

- R: Armature resistance in ohm
- L: Armature inductance in henry
- i: Armature current in ampere
- V: Armature voltage in volts
- e_b: Back emf voltage in volts
- K_b: Back emf constant in volt/ (rad/sec)
- K_T: Torque constant in N.m/Ampere
- T_m: Torque developed by the motor in N.m
- θ (t): Angular displacement of shaft in radians
- J: Moment of inertia of motor and load in Kg.m^2/rad
- B: Frictional constant of motor and load in N.m/ (rad/sec)

II. CONTROLLER DESIGN

A. *Problem Description*

The typical feedback PID system is as showed at Fig.2, where *r(t)* is reference input, *u(t)* is control signal, *y(t)* is output, *d(t)* is external disturbance, *e(t)* is the error of output and reference input, and also is the input signal of controller C(s) is PID controller as follow form :

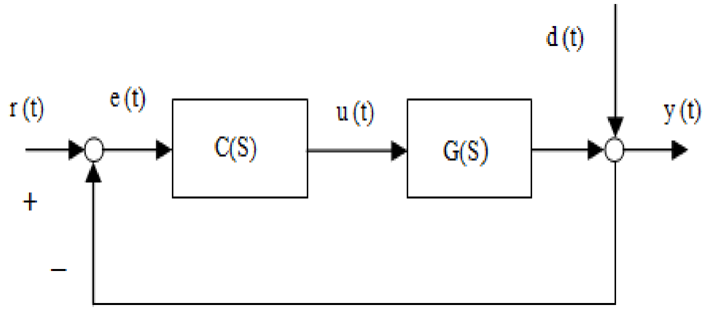

Figure.2. Control system diagram.

$$C(S) = K_p + \frac{K_i}{S} + K_d\, S \quad (7)$$

where K_p, K_i and K_d is proportion constant, integral constant and derivative constant respectively. The time domain of these parameters is as follows:

$$\Delta_f = \{(K_p, K_i, K_d) \in R^3 : K_p > 0, K_i > 0, K \quad (8)$$

Also, the plant block in Fig.1 represents the transfer function of DC motor which is expressed in equation (6).

Therefore, the problem of designing the controller can be described as finding the global optimum PID parameters (i.e. K_p, K_i and K_d) to make a good performance for the objective system.

B. Cost Function

As you know, controllers could provide robust performance for a special system if they guarantee the closed-loop stability and achieve the desired performance [7] .In this paper, to obtain the best PID controller, common cost function, within which different typical criteria to design the PID controllers using Particle Swarm Optimization (PSO) are considered.

There are many evaluation criteria for controller performance, such as Integral of Absolute Error (lAE), Integral of Squared-error (lSE) and Integral of Time Weighted- Squared-Error (ITSE) and so on. Though IAE and ISE cause small overshoot, they enlarge the settling time, because these two criteria gave same weight to error in the time horizon. The definition of these two criteria is as follow [3]:

$$IAE = \int_0^\infty |r(t) - y(t)|\, dt = \int_0^\infty |y(t)|\, dt \quad (9)$$

$$ISE = \int_0^\infty e(t)^2\, dt \quad (10)$$

Recently, a new cost function is reported [8]. It use rising time t_r , settling time t_s and overshoot σ % represent dynamic performance, use static state error e_{ss} to showing static state performance, use gain margin G_m and phase margin P_m represent frequency domain performance. Finally a sum of weighted criteria is formed as cost function:

$$J(\gamma) = w_1 t_r + w_2 t_s + w_3\, e_{ss} + w_4 \int_0^\infty |e(t)|\, dt + \frac{w_5}{PM} + \frac{w_6}{GM} \quad (11)$$

where γ is the PID controller parameters as follows:

$$\gamma = [K_p\ K_i\ K_d] \quad (12)$$

To study the effect of different criteria, we choose three representative situations within enumerated criteria, which cover *IAE*, time domain and frequency domain. Time domain cost function is the sum of weighted rising time t_r settling time *ts* percent overshoot σ % and static state error e_{ss}. According to equation (11), Total cost function is the sum of weighted mutual of gain margin GM and phase margin PM used as supplementation when other cost function cannot satisfy design requirements .The weight factors must properly be set in order to attain the desired specification.

This paper presents to control the DC motor .Therefore, it is necessary to consider all aspects of response in time domain. In the practical function, we expect that DC motor has a good command following with a good speed in response and so on. Because of this reasons, time domain cost function is considered separately.

C. Implementation of Particle Swarm Optimization to Design of PID Controller

For SISO system, from the perspective of design purpose, controller design is a multi-object optimization problem, which involves the dynamic and static, time and frequency characteristics. But due to the un-decoupling feature between performance criteria, the affect on one performance criterion will unavoidably affects the others, thus the controller design problem is down to a single object problem that optimize a function who reflects comprehensive system performance [3]. To solve this problem, Particle Swarm Optimization (PSO) Algorithm is used to finding the global optimum of PID parameters.

Kennedy and Eberhart developed a PSO algorithm based on the behavior of individuals (i.e. particles or agents) of a swarm [4]. It has been perceived that members within a group seem to share information among them, a fact that causes to increased efficiency of the group. An individual in a swarm approaches to the optimum by its present velocity, previous experience, and the experience of its neighbors [2], [9].

In a physical n-dimensional search space, parameters of PSO technique are defined as follows:

$X_i = (x_{i1}, \dots, x_{in})$: Position individual i.

$V_i = (v_{i1}, \dots, v_{in})$: Velocity individual i.

$Pbest_i = (X_{i1}^{Pbest}, \dots, X_{in}^{Pbest})$: Best position of individual i.

$Gbest_i = (X_{i1}^{Gbest}, \dots, X_{in}^{Gbest})$: Best position neighbors of individual i.

Using the information, the updated velocity of individual i is modified by the following equation in the PSO algorithm [9]:

$$V_i^{k+1} = wV_i^k + c_1 rand_1 \times (Pbest_i^k - X_i^k) + c_2 rand_2 \times (Gbest_i^k - X_i^k) \quad (13)$$

where

V_i^k: velocity of individual i at iteration k

ω: weight parameter

c_1, c_2: weight factors

$rand_1$, $rand_2$: random numbers between 0 and 1

X_i^k: position of individual i at iteration k

$Pbest_i^k$: best position of individual i until iteration k

$Gbest_i^k$: best position of the group until iteration k

Each individual moves from the current position to the next position by equation (14)

$$X_i^{k+1} = X_i^{k+1} + V_i^{k+1} \quad (14)$$

The search mechanism of the PSO using the modified velocity and position of individual i based on equations (13) and (14) is illustrated in Fig.3 [9].

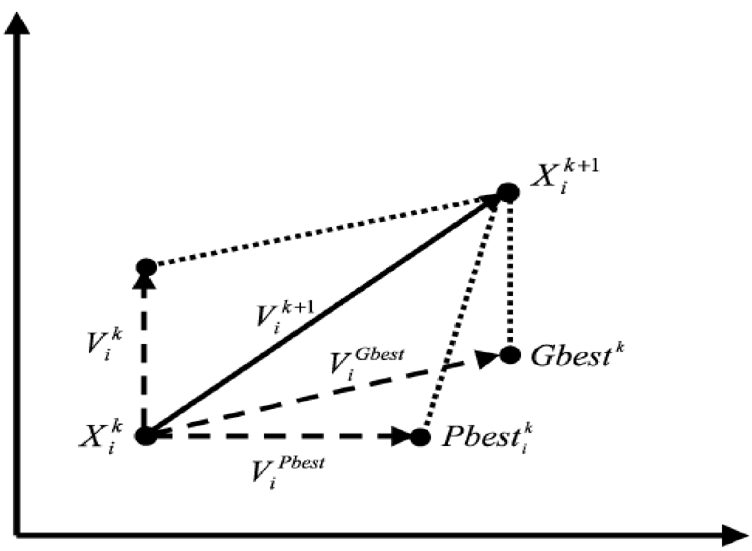

Figure.3. The search mechanism of the particle swarm optimization

III. CASE STUDIES

To assess the efficiency of suggested method, the PSO algorithm is applied to design the PID controller for typical DC motor. The DC motor under study has the following specifications and parameters:

TABLEI. The parameters of DC motor

Specification of DC motor	***R***	***L***	***K_b***	***J***	***B***
	1	0.5	0.01	0.01	0

By these data, the overall transfer function of the system is given below:

$$\frac{\omega(s)}{V(s)} = \frac{0.01}{0.005\,S^2+0.006\,S+0.1001} \qquad (15)$$

The control system has adverse performance in characteristics if improper cost function is used. So it is necessary to tune the controller parameters to achieve good control performance with the proper choice of cost function. To finding the best cost function to design controller, the PSO algorithm has applied to three cost functions (i.e. IAE, time domain and total cost function). By comparing the best result of 10 trial of each cost function by using PSO algorithm given in Table.II, one can find out that the time domain cost function has good performance to design a PID controller due to the importance of time domain parameters (i.e. percent overshoot, settling time, rising time and steady state error) in speed control of DC motor.

Whereas in practice, we need a short rising and settling time and small percent overshoot, time domain cost function is preferred.

TABLEII. The best result of ten trial for three cost functions

Cost function	σ%	t_r	t_s	IAE	e_{ss}
Time	2.11	0.2	0.24	0.1712	-1.8477×10^{-4}
Total	2.33	0.24	0.4	0.2342	-3.73×10^{-4}
IAE	8.39	0.12	0.48	0.1622	-2.45×10^{-5}

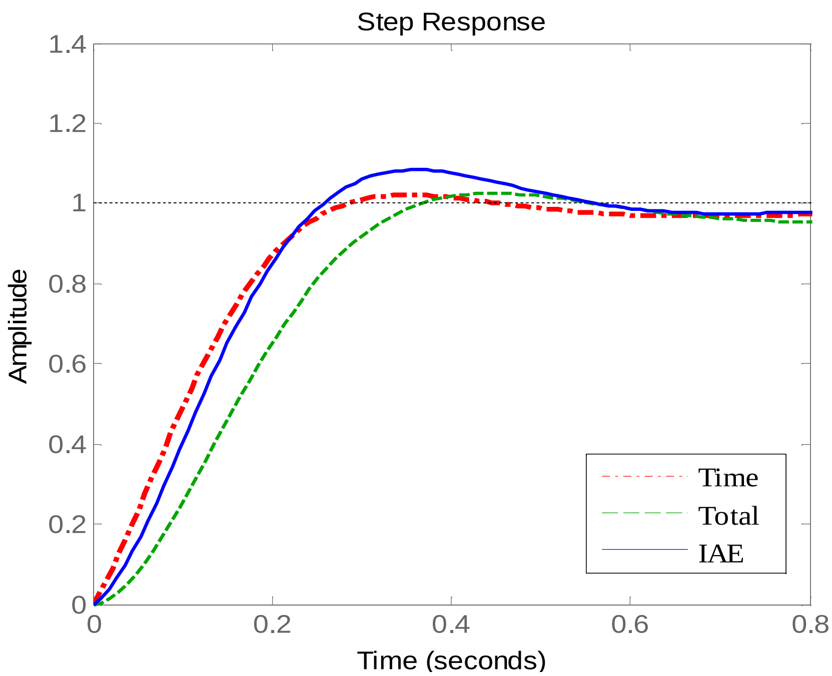

Figure.4. Unit step response of three cost functions

Also, Fig.4 illustrates the best result of ten trial of PSO algorithm to design the PID controller for each three cost functions.

Considering time domain cost function, we have employed the PSO algorithm in 100 trials and the best PID controller has obtained. The best PID parameters by using the PSO algorithm are given in Table.III.

TABLEIII. Controller parameters using PSO

K_p	K_d	K_i
58.0048	1.7927	73.0337

Fig.5 illustrates some of the best results of PSO algorithm to design the PID controller:

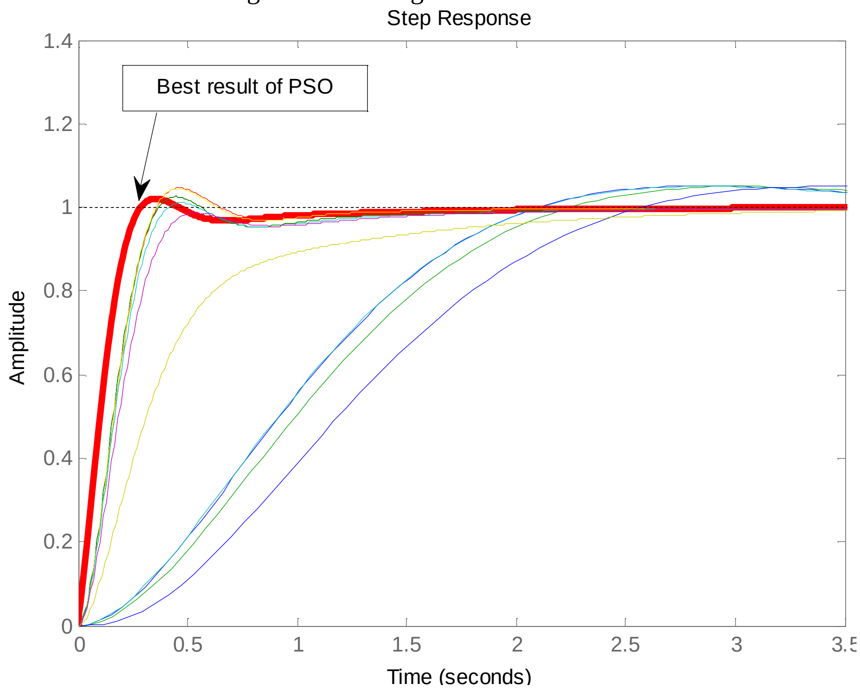

Figure.5. The best results of speed control of DC motor by using PSO.

To show the efficiency of proposed method and verify the obtain results; the results are compared with Genetic Algorithm (GA). The best result of PSO and GA are given in Table.IV. Also, the response of system with designed PID controller by each method is shown in Fig.6.

TABLEIV. Performance comparison for different methods

Characteristics	σ%	t_r	t_s	IAE	e_{ss}
PSO	2.11	0.2	0.24	0.1622	-1.8477×10^{-4}
GA	4.97	1.32	1.88	1.0603	2.4×10^{-3}

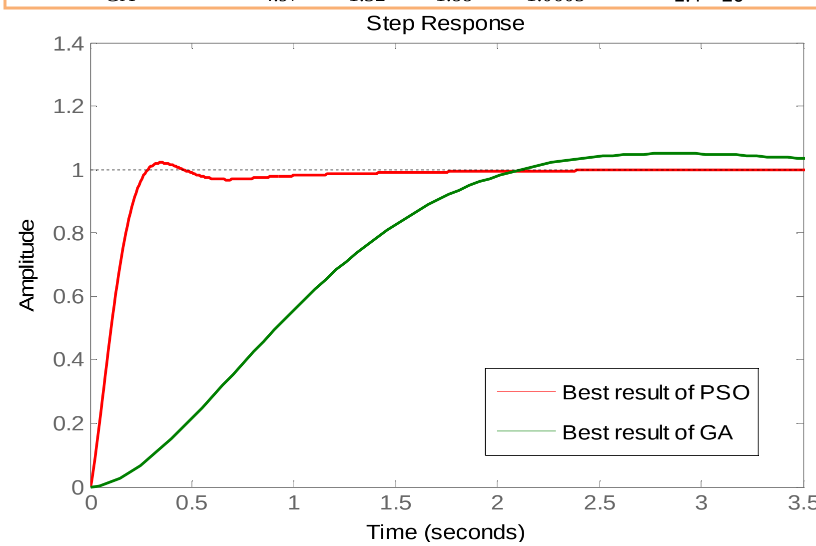

Figure.6. Unit step response of system using different methods.

By comparing these results, one can find out that PSO algorithm has a good accuracy and very good performance to finding the appropriate PID parameters for speed control of DC motor.

By comparing the results with [1], one can find out that the cost functions was used in this paper have good performance to design the PID controller. We considered the different cost functions (i.e. IAE, time domain and total cost function) and analyzed three cost functions to find the best cost function to speed control of DC motor. But in [1], just considered the overshoot, rising time and settling time. According to (11), we considered many system characteristics to obtain the suitable results (i.e. frequency characteristics and time domain characteristics). Also, the PSO algorithm has a good performance to find the global optimum PID parameters. In Ref [1], the GA was employed to minimize the fitness function that was sum of weighted sections (i.e. rising time, settling time and overshoot). So by comparing the results, we can know that the PSO algorithm has best efficiency than GA method.

IV. Conclution

This paper suggests a new approach to design a PID controller for the speed of DC motor using Particle Swarm Optimization (PSO) algorithm. To obtain a good performance of DC motor, different cost functions are considered. We have successfully employed PSO algorithm to finding a global optimum PID parameters by minimizing the typical cost functions. In this paper, PSO algorithm applied to IAE, Time domain, and Total cost function .We obtained that to speed control of DC motor, Time domain cost function has good efficiency to finding the most appropriate PID controller due to the importance of time domain parameters in performance of DC motor. To verify the results and show the accuracy of the proposed algorithm, the simulation results are compared with Genetic Algorithm (GA). By these results, one can find that PSO algorithm has two unique features .The obtained results of PSO are more favorable in this case and another is the PSO has good speed in program running.

V. REFRENCES

[1] Neenu Thomas, Dr. P. Poongodi, 2009. Position Control of DC Motor Using Genetic Algorithm Based PID Controller, Proceedings of the World Congress on Engineering 2009 Vol II WCE 2009, London, U.K.

[2] J. Kennedy and R. Eberhart, 1995. Particle swarm optimization, in Proc.IEEE Int. Conf. Neural Networks (ICNN'95), vol. IV, Perth, Australia, pp. 1942–1948.

[3] Yongwei Zhang, Fei Qiao, Jianfeng Lu, Lei Wang, Qidi Wu,2010. Performance Criteria Research on PSO-PID Control System, College of Electronics and Information Engineering, Intelligent Computing and Cognitive Informatics (ICICCI)

[4] Holland JH, 1975. Adaptation in Natural and Artificial Systems, The University of Michigan Press , Ann Arbor

[5] Rovira A, Valdés M, Casanova J, 2005. A New Method To Solve Non Linear Equations Systems Using Genetic Algorithm, Application to Combined Cycle Gas Turbine Simulation. International Journal for Numerical Methods in Engineering

[6] Benjamin C. Kuo, Farid Golnaraghi, 2009. Automatic Control Systems, 9th ed., John Wiley & Sons

[7] Ming-Tzu Ho and Yi-Wei Tu, 2005. PID Controller design for a Flexible-link Manipulator, proceedings of the 44th IEEE Conference on Decision and Control, and the European Control Conference, Seville, Spain

[8] M. Zamani, N. Sadati and M. K. Ghartemani, 2009. Design of an H∞ PID Controller Using Particle Swarm Optimization, International Journal of Control, Automation, and Systems, vol. 7, pp. 273-280.

[9] Jong-Bae Park, Ki-Song Lee, Joong-Rin Shin, Lee, K.Y., 2005. A particle swarm optimization for economic dispatch with nonsmooth cost functions, Power Systems, IEEETrans. Vol 20