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TUNING OF PID CONTROLLER USING PSO AND ITS PERFORMANCES ON ELECTRO-HYDRAULIC SERVO SYSTEM

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Abstract—PID controllers are widely used in industrial plants because it is simple and robust. So the control engineers are adapting the tuning process. This paper presents an optimization technique method of particle swarm optimization (PSO) algorithm for tuning the proportional-integral-derivative (PID) controller parameters for electro-hydraulic servo system. Ziegler- Nichols, tuning method and automatic tuning method was applied in the PID tuning and results were compared with the PSO-Based PID for optimum control. Simulation results are presented to show that the PSO-Based optimized PID controller is capable of providing an improved closed-loop performance over the Ziegler- Nichols and automatic tuned PID controller Parameters.
Keywords: PID Controller, Particle swarm optimization algorithm, Ziegler- Nichols method, Simulation.

I. INTRODUCTION

Many mobile, airborne and stationary applications employ hydraulic control components and servo systems. Hydraulic servo systems generate very high forces, exhibit fast responses, and have a high power to Weight ratio compared to other techniques [1]. However, the performance of these systems is dynamic so it is highly nonlinear due to phenomena such as nonlinear servo valve flow-pressure characteristics, variations in trapped fluid volumes and stiffness, which, in turn, reason of difficulties in the control of such systems.

Several methods have been proposed for the tuning of PID controllers. Among the traditional PID tuning methods, the Ziegler–Nichols method [3] may be the most famous technique. For a wide range of practical processes, this tuning method works well. However, sometimes it does not provide good tuning and tends to produce a high overshoot. Therefore, this method usually needs retuning before applied to control industrial processes. To improve the performances of conventional PID parameter tuning techniques, many intelligent approaches have been suggested to improve the PID tuning, such as those using genetic algorithms [4]-[6] and the PSO [7]-[8].With the advance of computational methods in the modern times, optimization algorithms are often proposed to tune the control parameters in order to find an optimal performance [7]-[8].

This paper attempts to develop an automatic PID tuning scheme using PSO algorithm that can be optimize the PID parameters for plant operation. The result is expected to show the effectiveness of the modern optimization such as PSO in control engineering applications. PSO algorithm is a algorithm based on principles of natural selection and search algorithm. There, are many evidences of intelligence for the posed areas in animals, plants, and generally living systems. For example, ants foraging, birds flocking, fish schooling, bacterial chemo-taxis are some of the familiar examples in category.

II. PROBLEM FORMULATION

Fig.1. shows the schematic diagram of electro servo valve.

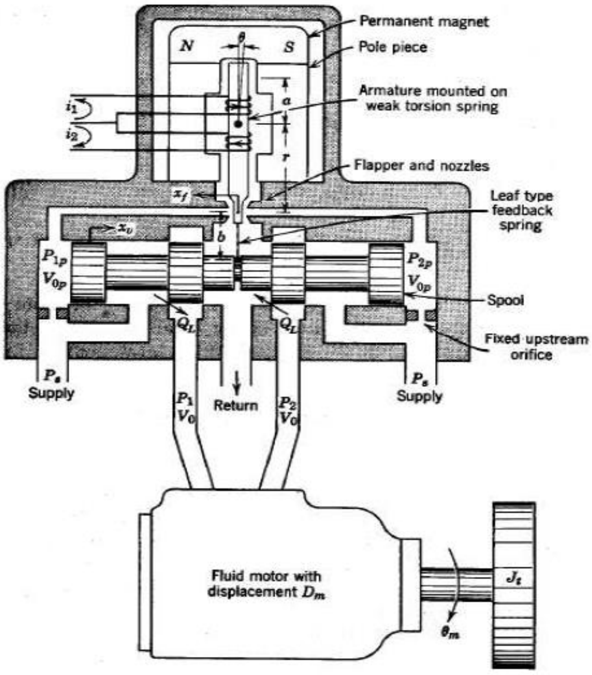

Fig.1. Diagram of MOOG position control valve [11]

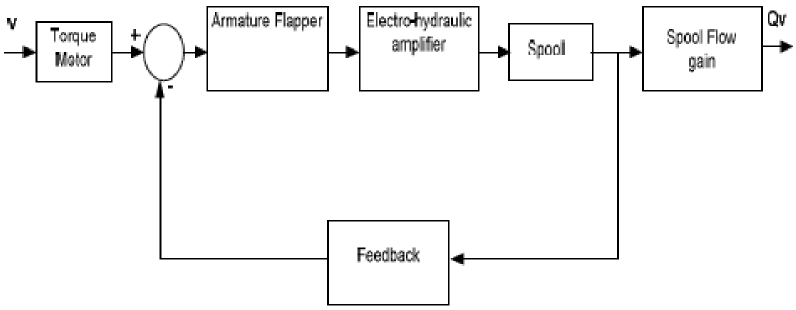

Fig.2. Block diagram of Electro-hydraulic servo Valve system

For example we take the high order transfer function of the problem is given in [9] as

$$G(s) = \frac{25.28s^2+22.20s+3}{s^5+16.60s^4+25.41s^3+17.20s^2+12s+1} \quad (1)$$

Using this technique an 'optimum solution' can often be designed and a set of PID parameters in the system can be adjusted to meet the required specification. The objective in the PSO-based optimization is to seek a set of PID parameters such that the feedback control system has minimum rise time, settling time, overshoot and error.

III. PID CONTROLLER TUNING METHODS

PID controller is very popular in industry due to their applicability, functional simplicity and reliability. Moreover, there is a wide conceptual understanding of the effect of the three terms involved amongst non-specialist plant operators. In general, the synthesis of PID can be described by eq.(2)

$$u(t) = k_p e(t) + k_i \int_0^t e(t)dt + k_d \frac{de(t)}{dt}$$
(2)

Where e (t) is the error, u(t) the controller output, and *kp, ki*, and *kd* are the proportional, Integral and derivative gains. The fundamental structure of a PID control system is shown in Fig. 3.
Basically PID controller contains of three separate parameters: proportionality, integral and derivative values are represented by *kp, ki*, and *kd*. Suitable setting of these parameters will improve the dynamic response of a system. It reduces overshoot, eliminate steady state error and increase stability of the system [10].

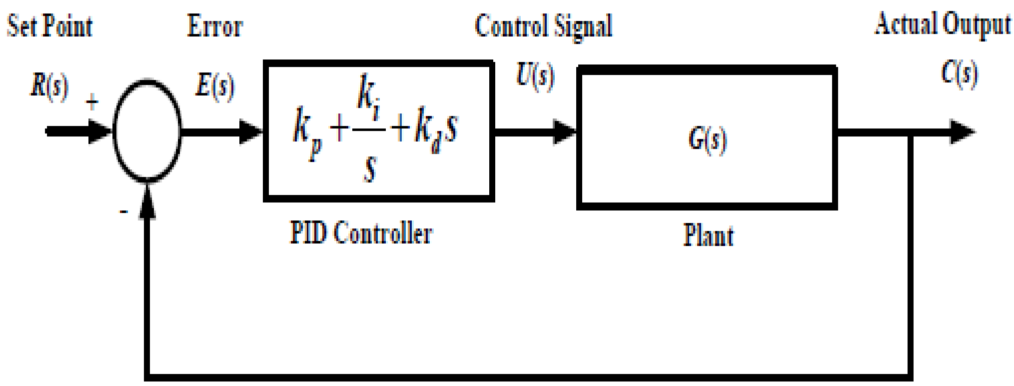

Fig.3.PID Control Structure

The transfer function of a PID controller is:

$$C(s) = \frac{U(s)}{E(s)} = k_p + \frac{k_i}{s} + sk_d$$
(3)

The goal of tuning the PID controller is to determine parameters that meet closed loop system performance specifications, and to improve the robust performance of the control loop over a wide range of operating conditions. There are various techniques are used for the tuning of PID controllers some are conventional and some are intelligent. Ziegler- Nichols method and Cohen and Coon are the famous conventional methods. In this paper we compare three techniques i.e.

(a) Automatic tuning by MATLAB
(b) Ziegler- Nichols method
(c) Particle Swarm Optimization

(a) Automatic tuning by MATLAB

This tuning is directly done by MATLAB. In this technique simulation gives tuned parameters of PID controller. It automatically computes an initial PID design with a balance between performance and robustness. It also provides the PID tuner GUI to help us interactively refine the performance of the PID controller to meet our design requirements.

(b) Zieglor Nichols Method

PID tuning using Ziegler Nichols method is based on the frequency response of the closed-loop system by determining the point of marginal stability under pure proportional control. The proportional gain is increased until the system become marginally stable. At this point, the value of proportional gain known as the ultimate gain, *ku*, together with its period of oscillation frequency so called the ultimate period, *tc*, are recorded. Based on these values Ziegler and Nichols calculated the tuning parameters shown in Table 1.

TABLE 1.Ziegler-Nichols PID Tuning Parameter

Controller	k_p	k_i	k_d
PID	$0.6k_u$	$1.2k_u/t_u$	$0.6k_ut_u/8$

The ultimate gain, *ku*, ultimate period, *tu*, and PID tuning parameters are calculated with the help of MATLAB.

(c) Particle Swarm Optimization

Particle Swarm Optimization (PSO) is a popular optimization technique developed by Eberhart and Kennedy in 1995. In this technique, there is a population of particles which move through the solution space to find the optimal solution. In PSO method the system keeps a track of the best solution obtained till now and each individual particle keeps a track of its own individual best solution. Based on these two, each particle moves to a new position decided by a velocity and its current position. The velocity is dependent on the global and particle's best solution. As put in [8], there are so many researchers who developed the techniques to tune the parameters of controllers. If the i-th particle of the swarm is represented by the D–dimensional vector Xi = (xi1, xi2,..., xiD) and the best particle in the swarm is denoted by the gbest. The best previous position of the i-th particle is recorded and represented as Pi = (pi1, pi2,..., piD), and the location change (velocity) of the i-th particle is Vi =(vi1, vi2 ,..., viD). The particles are manipulated according to the equations,

$$v_{id} = w.v_{id} + c_1.r_1(p_{id} - x_{id}) + c_2.r_2.(p_{id} - x_{id}) \quad (4)$$

$$x_{id} = x_{id} + v_{id} \quad (5)$$

Where d = 1, 2, . , D; i = 1, 2,., N and N is the size of population; w is the inertia weight; c1 and c2 are two positive constants and r1 and r2 are random values in the range [0, 1]. In favors of electro hydraulic servo system the flow chart of PSO is shown in fig. 4.

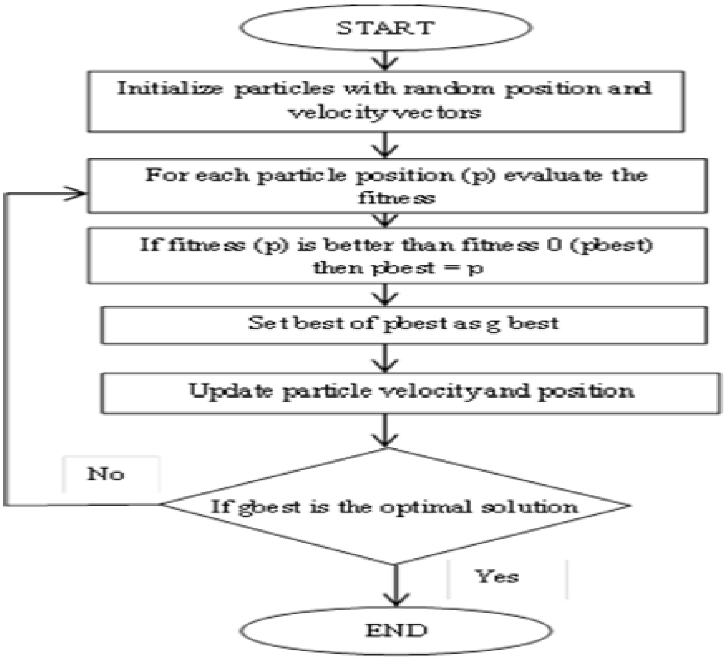

Fig.4. Flow chart of PSO

IV. SIMULATION RESULTS

Implementing control design on any physical system involves some leap of confidence. In this setting, we have attempted to design a controller for an electro-hydraulic servo system. The test model in Fig. 1 shows the block diagram of the control system. In the Z-N tuned method of PID controller, the response of plant produces high overshoot and long settling time, but a better performance obtained with the implementation of PSO-based and automatic PID controller tuning. These are shown in Table 2.

TABLE 2.Optimized PID Parameters

Tuning Methods	k_p	k_i	k_d
Zieglor-Nichols PID	3.9563	4.1688	0.9384
Zieglor-Nichols PID [9]	3.99	4.22	.94
Automatic Tuning	3.9716	1.1276	3.4517
PSO-PID	2.2753	1.7794	3.3330

Simulation results of different tuning methods of PID are shown in Fig.5 , Fig.6 and Fig.7 .

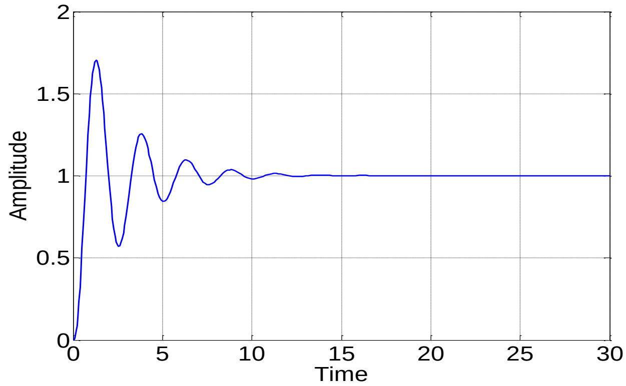

Fig.5. Step response for Z-N PID controllers

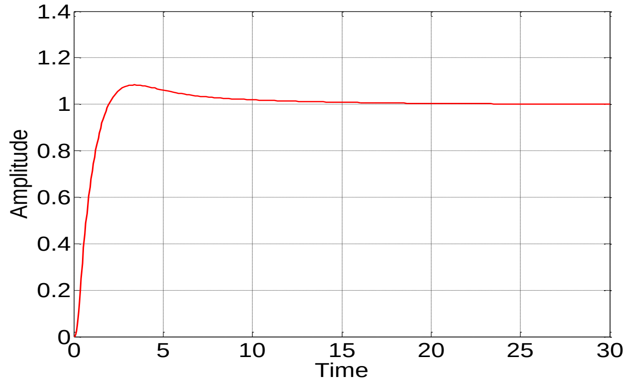

Fig.7. Step response for Automatic Tuning of PID controllers

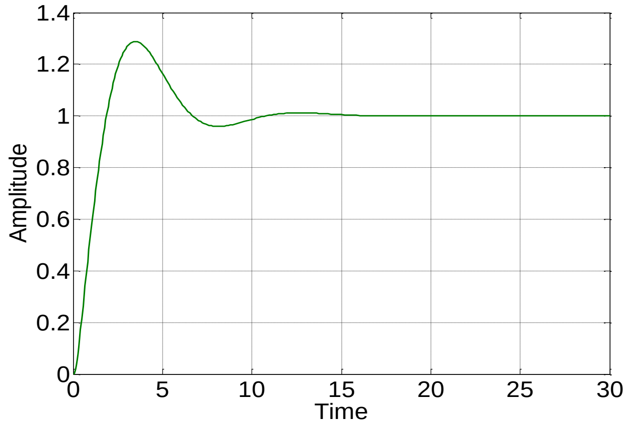

Fig.6. Step response for PSO- PID controller

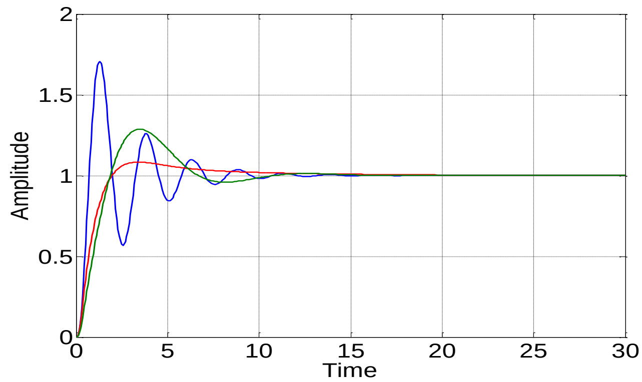

Fig.8. Comparison of the step response for PID controllers

Response Characteristics of the system for a step function is as shown in Table 3.

TABLE 3.Response Characteristics of the system

	Zieglor-Nichols-PID	Zieglor-Nichols-PID[9]	Automatic Tuning of PID	PSO-PID
%age Overshoot	58.4	57.56	6.3269	1.2344
Rise Time(sec)	0.39	0.39	0.2675	0.3211
Settling Time(sec)	10.20	9.18	6.3548	4.6388
Error	0.0068	-	0.0045	0.0013

V. CONCLUSION

PID controller has been tuned using Ziegler-Nichols method, Automatic tuning by MATLAB and Particle Swarm Optimization for a control system. The various results presented above prove better performances of PID controller tuned with PSO than PID controller tuned with Ziegler-Nichols method and Automatic Tuning. The step responses for the system reflect effectiveness of the PSO based PID controller in terms of time domain specifications. The results show that the proposed controller can perform an efficient search for the optimal PID controller parameters.

REFERENCES

[1] J. E. Bobrow and K. Lum, ―Adaptive, high bandwidth control of a hydraulic actuator‖, Journal of Dynamic Systems, Measurement and Control, Transactions of the ASME, vol. 118, no. 4, pp. 714-720, 1996.
[2] K Ogata, 1987, Modern Control Systems, University of Minnesota, Prentice Hall.
[3] K. Krishnakumar and D. E. Goldberg, 1992, Control System Optimization Using Genetic Algorithms, Journal of Guidance, Control and Dynamics, Vol. 15, No. 3, pp. 735-740.
[4] Q.Wang, P Spronck and R Tracht, 2003, An Overview of Genetic Algorithms Applied to Control Engineering Problems. Proceedings of the Second International Conference on Machine Learning and Cybernetics.
[5] T. O.Mahony, C J Downing and K Fatla, 2000, Genetic Algorithm for PID Parameter Optimization: Minimizing Error Criteria, Process Control and Instrumentation, University of Stracthclyde, pp. 148- 153.
[6] Mahmud Iwan Solihin, Lee Fook Tack and Moey Leap Kean, Tuning of PID Controller Using Particle Swarm Optimization (PSO), Proceeding of the International Conference on Advanced Science.
[7] Mohammed El-Said El-Telbany, "Employing Particle Swarm Optimizer and Genetic Algorithms for Optimal Tuning of PID Controllers, A Comparative Study," ICGST-ACSE Journal, vol. 7, no. 2, pp. 49-54, 2007.
[8] A. A. Aly, "Modeling and control of an electro-hydraulic servo motor applying velocity feedback control strategy", International Mechanical Engineering Conference, IMEC2004, Kuwait, 2004.
[9] Mohd S. Saad, Hishamuddin Jamaluddin and Intan Z. M. Darus, "PID Controller Tuning Using Evolutionary Algorithms," Wseas Transactions on Systems and Control, vol. 7, pp. 139-149, October 2012.
[10] K. J. Astrom and T. Hagglund, PID Controllers:Theory, Design, and Tuning. 1995: Instruments Society of America.
[11] H. E. Merrit, "Hydraulic Control Systems", John Wiley & Sons Inc, New York, 1967.
[12] Sachin Kumar Mishra and Kuldeep Kumar Swarnkar, "Tuning of Controller for Electro-Hydraulic System Using Particle Swarm Optimization (PSO)", International Journal of Research in Advance Technology, pp 160-164, vol.2, no.10,2014.

