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Tuning of PID controller for Electro-hydraulic servo system using Soft Computing techniques - A Review

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Abstract: Electro hydraulic servo system is used in industries in a wide number of applications. Its variances are extremely time-varying and broad breadth of model unpredictability and exterior interrupts. To improve the reliability, controllability and also want desired system response as change in input. Proportional Integral Derivative (PID) controller is attached to the electro hydraulic servo system to control the angled move. The tuning of PID controller parameters is the very difficult task. This paper gives the review about various soft computing techniques for tuning of PID controller to control the electro hydraulic servo system. Tuning of the PID parameters continues to be important as these parameters have a great effect on the stability and performance of the control system.

Keywords: PID controller; Electrohydraulic servo system; Genetic Algorithm(GA); Particle Swarm Optimization(PSO); Evolutionary Algoritm.

I. INTRODUCTION

Electro-hydraulic servo systems are widely used in many industrial applications because of their high power to weight ratio, high payload capability, and high stiffness, and at the same time, achieve fast responses and high degree of both accuracy and performance [1,2]. The behaviour of these systems is very time varying because of phenomena such as time varying servo valve flow pressure characteristics, imbalance in trapped fluid volumes and related constraint which cause difficulties in the control of such systems.

Control techniques used to resolve the time varying behaviour of hydraulic systems attached with adaptive control, sliding mode control and feedback linearity. Adaptive control techniques are state by researchers by assuming that the system model is linear in nature. The controllers have the capability to struggle with small variations in system parameters in the manner that valve flow coefficients, the fluid bulk modulus, and flexible loading. Yet it is not fixed that the linear adaptive controllers will remain stable when large changes in the system parameters occurs [3]. Controllers are developed for electro hydraulic servo systems. These controllers are prosperous to large parameter changes, but discrete control signal fire system variables and reduce performance of the system. This problem can be resolve by improving the continuity in edged layer adjoining the sliding manifold [4,5]. The time varying behaviour of the system causes by valve flow properties and actuator time variations taken into tab in uses of the feedback linearity technique [6]. The disadvantage of the linearity control law is that it works on deletion of the time varying quantity.

Ayman A. Aly [7] gives the time varying mathematical model which permits exploring of the characteristic of an electro hydraulic position control servo system. Angled displacement of motor shaft due to step input obtained by applying velocity feedback control strategy. To improve the time varying response characteristics and based on the mathematical model driven, the execution of self tuning fuzzy logic controller (STFLC) technique was look over for arranging the servo motor system as a time varying plant [8]. Practicability and robustness of such application was assured. Still it is very difficult to build an organised standard design method for fuzzy logic control system like PID controller.

So far many different techniques are proposed to achieve the optimum control parameters for PID controllers. Many new techniques developed for tuning PID controllers. They are not slow in hunting to accomplish the arrive methods based on the evolution principle.

The block diagram for tuning of PID controller with unit feedback for electro hydraulic servo system using soft computing shown in figure 1 [9].

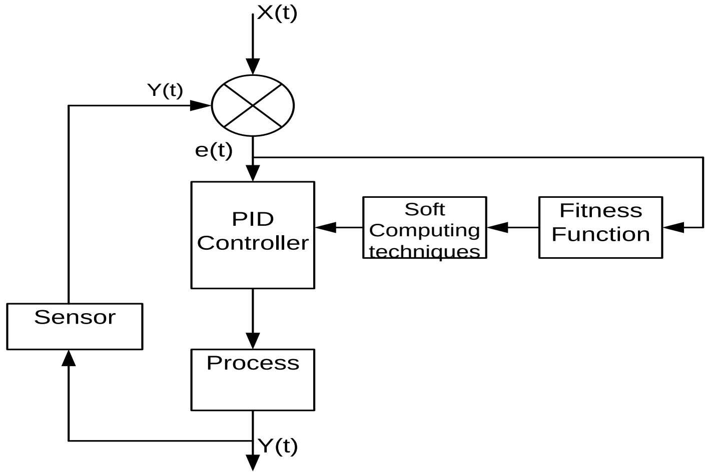

Fig. 1: Block Diagram of Intelligent PID Controller

Equation (1) shows the output of Intelligent PID controller.

$$Y(t) = e(t)\, K_P + K_I \int_0^t e(t)\, dt + K_D \frac{de(t)}{dt} \qquad (1)$$

Where

$e(t)$ = Error signal
K_P = Proportional Constant
K_I = Integral Constant
K_D = Derivative Constant

A fitness evaluation function is required to calculate the overall responses for each of the sets of PID values and from the responses generates a fitness value for each set of individuals expressed by:

$$f(t) = \int_0^t t|e(t)|dt$$

II. SELECTION OF SOFT COMPUTING TECHNIQUE

A. Approximations

Approximations are reruired to apply such that the tuning rules become more simple [10].

B. Model classification

There are many methods which are used to process the different types of model, like first order plus dead time model (FOPDT). We need to reduce the complexity of the model [10].

C. Point of refrence for Designing

These methods are used to tune some point of reference for design such that distinguish the properties of the closed loop system. Some of the points of reference are phase margin and gain, closed loop bandwidth, and non identical cost functions for load changes [10].

The purpose of this paper is to explore many soft computing techniques for parameter tuning of PID controller used in electro hydraulic servo system like GA, PSO and Evolutionary Algorithm. This is used to improve the performance of PID controller.

III. GENETIC ALGORITHIM

Elbayomy, et. al [11] proposed that PID controller is designed and attached to electro hydraulic servo actuator system (EHSAS) to control the angled position of the spinning actuator which control the portable surface of space vehicles. The parameters of PID gain are tuned by the GA. The effectiveness of the PID controller is robust by GA to control the angled position of the spinning actuator as compared with the classical PID controller and the compensator controller. The GA is applied to enhance the parameters of PID controller. The gain parameters K_P, K_I, and K_D are tuned by using the GA in off line simulation. On comparing the compensator and classical PID controllers, the optimized PID improves the performances of the hydraulic servo actuator system.

Jingzhou, et. al [12] suggested that the software of auto-tuning parameters of PID control is developed for plant controller. The response curve of control system is identified, and the outlook of the controller parameters is given to achieve desired control index by pattern recognition based fuzzy tuning rules. The PID parameters are tuned by GA for the optimization function of integrated time, absolute error, over shoot and decay rate indicators for response of system. The technique of auto-tuning parameters of PID controller based on fuzzy GA by pattern recognition, the software is used in the semi-physical simulation system of stream power plant and the control quality of the pressure of stream power is enhanced significantly by using electro hydraulic servo system. The tuning method is effective and the tuning software can be applied to industrial PID controllers for electro-hydraulic servo system.

Panda, et. al [13] says that design of an optimal controller requires tuning of multiple performance measures that are regularly no proportional and challenging with each other. Design of such a controller is truly a multi-objective optimization issue. Non-Dominated Sorting in Genetic Algorithms-II (NSGA-II) is a popular non-domination based genetic algorithm for resolving multi-objective optimization problems. The design objective is to enhance the damping of power system when dominated to interruptions with minimum control exercises. The proposed technique is applied to generate Pareto set of global optimal solutions to the given multi-objective optimization issue. Then a fuzzy-based membership value assignment method employed to choose the best solution from the obtained Pareto solution set. The proposed design approach is extended to a multi-machine power system to damp the modal oscillations with minimum control exercises.

Jue, et. al [14] gives that a novel method for achieving a set of parameters of appropriative PID controller in an electro-hydraulic servo control system is presented. This technique gives designs a complex system genetic algorithm (CSGA) is modelled that accommodate complex system theory into genetic algorithm and renovates GA elements like mutation operator, crossover operator and selecting operator. The performance criterion attaching the information of overshoot, settling time, rise time and steady state error is also proposed as our fitness function. Suggested method is used to find optimal PID parameters more impressively and rapidly immediately.

Sarkar, et. al [15] advised that electro-hydraulic systems are used for many distant and bitter applications. Against the low bandwidth, dead band and flow irregularities in proportional valve and highly time varying friction in industry cylinders that comprise systems, their maintenance is not very simple and also very sensitive and delicate servo control and servo cylinder systems. The aim of making the simple maintenance system to perform comparably to a servo system, a feed forward control is designed for rejecting the time variations. A PID feedback of the piston displacement is employed in tandem for suspending the unmodeled effects. All the parameters of controller are tuned by a real coded GA. The parameters of a real time tandem feed forward PID controller for a electro-hydraulic system are tuned by a real coded genetic algorithm. Sub modular options of tuning can be combined and coded with a view to implementing it online. This algorithm is known for motivating the search to the globally best solution. The tuned controller gives tracking performances which more referred to latest by much more delicate servo systems. The minimization of cost in realizing a system and tuned controller, the profits of the used controller hardware are simple in maintenance and ability to work in rough working conditions. Limitation of the controller is the large number of tuning parameters. An approach would lead to feed forward PID controller structure with wider applicability including systems.

IV. PARTICLE SWARM OPTIMISATION

Jun, et. al [16] advised that advantage of PSO can be implemented easily, as evolution algorithm can search for optima more rapidly in multidimensional solution arena. On the bases of PSO and classical PID controlling theory, PSO-PID controller is using weighted error function as a fitness function. The PSO-PID controller is used to search the optimal controller parameters on-line. The good performance of PSO-PID can be verified by the application of hydraulic edger screw down system in Baosteel 2050 rough mill. The PSO-PID controller got better performance than the classic PID controller, mainly in the case of variable working conditions.

Chen, et. al [17] suggested that PID controllers can be used to operate process loops with electric-hydraulic servo system of parallel platform. Obtaining optimal PID gain is not simple for control loops with interrupts. Since the gain of the PID controller is to be tuned manually by trial and error. Tuning of the PID controller may not envelope a plant with complex variations like inverse response, large dead time, and highly time varying characteristic without control experience. Since natural selection of item tends to reject items with poor foraging strategies for locating, capturing, and ingesting food, they got required food to active them to regenerate after many generations; poor foraging strategies are either rejected or shaping them. Tuning is used for social foraging where gang of parameters convey to together forage in engineering. We propose intelligent tuning of PID controllers with the help of a new algorithm that combines bacterial foraging algorithm (BFA) with particle swarm optimization (PSO) algorithm for electric-hydraulic servo system of parallel platform.

Luo, et. al [18] proposed that PID controllers are used to conduct process loops including electric-hydraulic servo system of parallel platform. The parameters of PID control are necessary to performance of hydraulic servo control system. Obtaining optimum values of PID control parameters is very difficult issue. To resolve the issue of low convergence speed and sensitivity to local convergence with the quantum behaved particle swarm optimization (QPSO) to fix optimum problem, a innovative technique of judging the local convergence by the deviations of the population's fitness was proposed, the chaos quantum-behaved particle swarm optimization algorithm (CQPSO) is used to improve searching strength. The program CQPSO1.0 was introduced. This algorithm has no need of any special requirements on the characteristics of optimal designing problem, which contains a fairly good universal capability and a trusted operation of program with a strong capability of overall convergence and high efficiency. Based on Matlab/simulink software and taking the IATE standards of tuning design as objective function, the proposed method is applied for the optimization of the three parameters of PID controller of electric-hydraulic servo system of 6-DOF parallel platform. The parameter optimum method is an effective tuning strategy and good performance.

Zhao, et. al [19] state that two lbests multi-objective particle swarm optimization (2LB-MOPSO) is applied to design multi-objective robust PID controllers for two MIMO systems, distillation column plant and longitudinal control system of the super manoeuvrable F18/HARV fighter aircraft. Multi-objective robust PID controller design problem can define by minimizing integral squared error (ISE) and robust performance norms. 2LB-MOPSO can focus on small regions in the parameter space in environ of the best faces. When the lbests are selected from the best faces in a non-domination sorted foreign annals of justly big size, the child obtained is more distinct with best fitness. The performance of various optimal PID controllers can compare in terms of the balanced robust performance criteria and sum of ISE. For comparison, 2LB-MOPSO, NSGA-II and Riccati, IGA and OSA methods are used. The performance of PID controllers is achieved using 2LB-MOPSO is better than others. Comparisons based on hyper volume are used to show the best performance of 2LB-MOPSO over NSGA-II. The results reveal that 2LB-MOPSO yields better robustness and accuracy in terms of the sum of ISE and balanced robust performance criteria than different PID controllers.

V. EVALUTIONARY ALGORITHM

Kim, et. al [20] sated that parameters of PID controller are tuned for an electro-hydraulic position control system through evolution strategies (ESs). The optimal controller gains for the control system can obtained by improving fitness function designed particularly to obtain the system performance. For an electro-hydraulic position control system which was represent a hydraulic mill stand for the roll-gap control in plate hot rolling, the time delay controller (TDC) is described, and three control parameters of this controller was directly tuned through experiments using this method. It was shown that the approximately optimal values of the controller are obtained. The optimal controller gains were experimentally confirmed by investigating the fitness function methods that represent system performance in the gain space. It was found that some local optimums are obtained in fitness function methods so that the tuning of the three control parameters of a TDC by manual tuning may be a cause of difficulty. The tuned results through the ES correspond with the maximum peak point in this method. That maximum peak is known as global optimum. It is also tells that the given method has an effective scheme for saving of time and labour in tuning the controller gains of fluid power systems. The proposed ES is the volume-oriented search characteristic.

Che, et. al [21] proposed that PID controller is commonly used to operate process loops including electric-hydraulic servo system of parallel platform. The parameters of PID control are very important for performance of hydraulic servo control system. It is the very difficult task to find faster the optimum values of PID control parameters. Since the PID controller gain can be tuned manually by trial and error. Tuning of the PID controller may not achieve a plant with complex dynamics such as large dead time, inverse response, and a highly time varying characteristic without any control experience. Based on Matlab/simulink software and taking the IATE standards of the optimization design as objective function. A global search tuning method is used which is called the elite multi-parent crossover evolutionary algorithm. This method was applied for the tuning of the three parameters of PID controller of electric-hydraulic servo system of 6-DOF parallel platform. The proposed innovative algorithm does not need any special requirements on the characteristics of optimal designing problems, which have a very good universal flexibility and a reliable operation of program with a powerful ability of global convergence. The proposed parameter optimum method is an effective tuning metrology and has best performance and decent response.

Luo, et. al [22] advised that it is difficult for control loops to achieve optimal PID gain in the presence of interrupts for electro hydraulic servo control system. Tuning of the PID controller may not cover a project with complex variations, such as large dead time, inverse response, and nonlinear characteristic. On the bases of Matlab/simulink software and taking the IATE standards of the optimization design as objective function, global search optimization method called Evolutionary Cellular Automata Algorithm which is a digging operator and two learning operators named as dual arithmetic crossover operator and chaos-peak-jumping operator is applied for the optimization of the three PID controller parameters of electric-hydraulic servo system of 6-DOF parallel workspace. The proposed novel algorithm has no special need on the characteristics of optimal designing problems which is extremely good universal acceptability and a reliable operation of program with a strong capability of global convergence. Controlled system having satisfactory response and the stated parameter optimum method is an impressive tuning strategy.

Saad, et. al [23] suggested that PID controller is tuned using Ziegler-Nichols method and modern algorithms such as DE and GA. The tuned PID control parameters are applied for a high order system with time delay and non-minimum phase system. In the same population crossover rate and number of generation both tuning strategy indicate the same performance for searching the best value of MSE and IAE. This is needed to be noted that for high order system and system with delay. DE and GA give approximately the same transient performance for the objective function MSE and IAE. Both techniques are struggled to achieve the globally minimum value of its objective functions. Reliability between DE in constantly maintaining minimum MSE is also considered. DE tuned by MSE gives improved performance with the commendations to the bargain between settling time, maximum overshoot and drop of non-minimum phase system. For reliability, DE offer consistency in concluding its globally minimum fitness value. The convergence rate for all the attempts for higher order system with time delay and non-minimum phase system are approximately the same.

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CONCLUSION

In this paper, an attempt has been made to review various literatures for the soft computing techniques introduced by the different researchers for tuning of PID controller for electro-hydraulic servo system to optimize the best result. This review article is also presenting the current status of tuning of PID controller for electro-hydraulic servo system using soft computing techniques.

REFERENCES.

[1]. Noah Manring, “Hydraulic Control Systems” John Wiley & Sons Inc, New york, 1991.

[2]. John watton, “Fundamental of Fluid Power Control” Prentice Hall, New Jersey, 2009.

[3]. Jianyong Yao, Zongxia Jiao, Bin Yao “High Bandwidth Aduptive Robust Control for Hydraulic Rotary Actuator,” International conference on Fluid Power Mechatronics (ICFPM), pp. 81-85, Augest 17-20, 2011.

[4]. Ayman A. Aly, “Velocity Feedback Control of a Mechatronics System,” I.J. Intelligent Systems and Applications, vol. 8, pp. 40-46, July 2013.

[5]. R.-F. Fung and R.-T. Yang, “Application of Variable Structure Controller in Position Control of a Nonlinear Electrohydraulic Servo System,” Computers & Structures, vol. 66, No. 4, pp. 365-372, 1998.

[6]. Mark Karpenko, Nariman Sepehri, “On quantitative feedback design for robust position control of hydraulic actuators,” control Engineering Practice, vol. 18, pp. 289-299, Issue 3, March 2010.

[7]. A. A. Aly, “Modeling and Control of an Elec-tro-Hydraulic Servo Motor Applying Velocity Feedback Control Strategy,” International Mechanical Engineering Conference, IMEC2004, Kuwait, 2004.

[8]. Hideki Yanada, Kazumasa Furuta, “Adaptive control of an electrohydraulic servo system utilizing online estimate of its natural frequency,” Mechatronics, vol. 17, issue 6, pp. 337-343, April 2007.

[9]. Mehdi Nasri, Hossein Nezamabadi-pour, and Malihe Maghfoori "A PSO-Based Optimum Design of PID Controller for a Linear Brushless DC Motor," World Academy of Science, Engineering and Technology 26, 2007.

[10]. Mohd S. Saad, Hishamuddin Jamaluddin, Intan Z. M. Darus, “PID Controller Tuning Using Evolutionary Algorithms,” Wseas Transactions on Systems and Control, vol. 7, pp. 139-149, October 2012.

[11]. Karam M. Elbayomy, Jiao Zongxia, Zhang Huaqing, “PID Controller Optimization by GA and Its Performances on the Electro-hydraulic Servo Control System,” Chinese Journal of Aeronautics,Elservier vol. 21, pp. 378-384, June 2008.

[12]. FEI Jingzhou,MA Xiuzhen,Shi Yong, “The software of auto-tuning parameters of PID controller based on fuzzy genetic algorithm,” International Confrence on Computational Intelligence and Software Engineering, pp. 1-4, 2010.

[13]. Sidhartha Panda, “Multi-objective PID controller tuning for a FACTS-based damping stabilizer using Non-dominated Sorting Genetic Algorithm-II,” Electrical Power and Energy Systems, vol. 33, pp. 1296-1308, June 2011.

[14]. Yu Jue, Zhuang Jian, Yu Dehong, “Parameter optimization of PID controller based on Complex System Genetic Algorithm in Electro-hydraulic Servo Control System,” Proceedings of the 10th World Congress on Intelligent Control and Automation July 6-8, 2012, Beijing, China, p 30-35.

[15]. B. K. Sarkar, P. Mandal, R. Saha, S. Mookherjee, D. Sanyal,” GA optimized feed forward PID tracking control for a rugged electrohydraulic system design,” ISA Transactions, Elservier, vol. 52, pp. 853-861, July 2013.

[16]. Zou Jun, Fu Xin, Yang Huayong, Zhang Jianmin, “A Particle Swarm Optimization Approach for PID Parameters in Hydraulic Servo Control System,” Proceedings of the 6th World Congress on Intelligent Control and Automation, June 21 - 23, 2006, Dalian, China, p 7725-7729.

[17]. Zhaoguo Chen, Youxin Luo, Yuehua Cai, “Optimization for PID Control Parameters on Hydraulic Servo Control System Based on Bacterial Foraging Oriented by Particle Swarm Optimization,” International confrencce on Information Engineering and Computer Science (ICIECS), pp. 1-4, 2009.

[18]. Youxin Luo, Lingfang Li, "Tuning PID Control Parameters on Hydraulic Servo Control System Based on Chaos Quantum-behaved Particle Swarm Optimization Algorithm," International confrence on Logistic Systems and Intelligent Managment, vol. 3, pp. 1861-1864, 2010.

[19]. S. Z. Zhao, M. Willjuice Iruthayarajan, S. Baskar, P. N. Suganthan, "Multiobjective robust PID controller tuning using two lbests multiobjective particle swarm optimization," Information Sciences, Elservier, vol. 181, pp. 3323-3335, April 2011.

[20]. Min Young Kim, Chung Oh Lee, "An experimental study on the optimization of controller gains for an electro-hydraulic servo system using evolution strategies," Control Engineering Practice, vol. 14, pp. 137-147, March 2005.

[21]. Xiaoyi Che, Youxin Luo, Zhaoguo Chen, "Optimization for PID Control Parameters on Hydraulic Servo Control System Based on The Elite Multi-parent Crossover Evolutionary Algorithm," International Conference on Measuring Technology and Mechatronics Automation, vol. 2, pp. 845-848, 2010.

[22]. Youxin Luo, Xiaoyi Che, "Optimization for PID Control Parameters on Hydraulic Servo Control System Based on Evolutionary Cellular Automata Algorithm," vol. 3, pp. 1864-1868, 2010.

[23]. Mohd S. Saad, Hishamuddin Jamaluddin, Intan Z. M. Darus, "PID Controller Tuning Using Evolutionary Algorithms," Wseas Transactions on Systems and Control, Issue 4, vol. 7, pp. 139-149, October 2012.