Designing Optimal PID controller with Genetic Algorithm In view of controller location in the plant

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Abstract- In this paper an optimal PID controller in view of controller location in the plant is proposed. To adjust the parameters of the controller a fitness function in terms of transient and steady state parts of response and control energy of characteristics of system which are function of controller location, is introduced. A genetic algorithm is employed to minimize the fitness function to achieve a satisfactory response for system. The results are validated by some simulations.

Key words: PID controller, Optimal control, Genetic algorithm, Controller placement

1. Introduction

Genetic algorithms (GA) are one of the efficient tools that are employed in solving optimization problems[1]. The basic idea of genetic algorithm is as follow[2][3]: the genetic pool of a given population potentially contains the solution, or a better solution, to a given optimization problem. This solution is not active because the genetic combination on which it relies is split between several subjects. Only the association of different genomes can lead to the solution. Optimization in genetic algorithm is based on optimization of a fitness function which is a function of environment individuals or genes. Each new generation is generated by applying Crossover and Mutation operand on old generation. Then in new generation good genes that lead to better fitness function have more chance to survive. So, after some generations the optimal solution will be attained. Because of the simplicity and robustness, PID controllers are frequently used controllers in industries[4][5]. Parameter adjustment of PID controllers is an old challenge in the field of control system design. Some of methods have been proposed to select the PID coefficients, but they are not completely systematic methods and result in a poorly tuned controller that needs some trial and error[6]. So far, finding new methods to automatically select PID parameters was interest of researches[7]. On the other hand, controller placement is not noted enough but although controller location has important affect on system controlling. In this paper, we will introduce a new method to select location and coefficients of an optimal PID controller. In next section the problem discussed in this paper is defined then in section III previous related works is viewed. In forth section the idea of designing Optimal PID controller with Genetic Algorithm In view of controller location in the plant is proposed and then the idea is verified by simulation results in section V. The last section contains conclusions and future works.

2. Problem definition

The common control model in previous works is illustrated in Fig. 1. The controller is a PID controller and we have:

$$u(t) = K_p e(t) + K_D \dot{e}(t) + K_I \int e(t)dt \qquad (1)$$

where K_p, K_I, K_D are parameters of controller and $e(t)$ is error (see Fig.1). The aim of optimal control problem is to select control parameters such that a good output response is attained as well as minimum energy is spent. Maximum overshot and steady state error corresponding to step response parameterize the

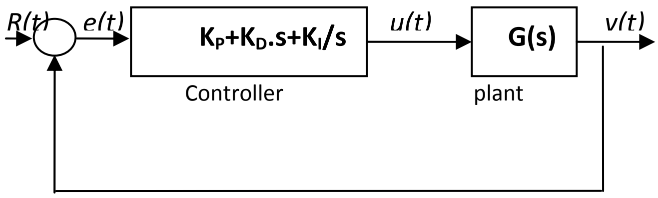

Fig.1. A schematic PID control system

concept of "good response" and time integral of control signal parameterizes the concept of "energy". But in some cases controller adding causes system unstability and optimal system design even with GA using is very hard work but controller replacement can solve this problem. The problem that we will deal in this paper is to propose a genetic algorithm approach to suitable controller placement. In this new algorithm to aims optimal control in addition to selecting adapted control parameters is considered to the location of PID controller.

3. Related works

Some earlier works that have used evolutionary algorithms to parameter adjustment of controllers, have been utilized one of the following fitness functions [8][9][10][11]:

$$f(K_P, K_I, K_d) = A(1-e_{ss}) + B(1-O_{\max}) \quad (2)$$

$$f(K_P, K_I, K_d) = X(1-e_{ss}) + Y(1-O_{\max}) + Z(1-E_u) \quad (3)$$

$$f(K_P, K_I, K_d) = A(e_{ss}) + B(O_{\max}) \quad (4)$$

$$f(K_P, K_I, K_d) = X(e_{ss}) + Y(O_{\max}) + Z(E_u) \quad (5)$$

where E_u denotes the energy of control signal and $O_{\max}$ denotes the maximum overshoot and $e_{ss} = \lim_{t\to\infty} e(t)$ denotes the steady state error of response. The fitness functions (2,3) should be maximized and the fitness functions (4,5) should be minimized during optimization algorithm. *A* and *B* and *X* and *Y* and *Z* are the parameters (*A*+*B*=*1*), (*X*+*Y*+*Z*=*1*) that should be manually tuned according to the understudy plant. But in all above cases doesn't attention to controller location have a bad affect on optimization.

4. Optimal PID controller

To obtain an optimal controller, the controller location in plant of system should be taken in account. For this purpose the fitness function and algorithm of optimization mechanism must be modified. In order to modify fitness function, we consider $e_{ss}, O_{\max}, E_u$ as functions of controller location so new fitness function is:

$$f(K_P, K_I, K_d, P) = A(e_{ss}(P)) + B(O_{\max}(P)) + C(E_u(P))$$
$$A + B + C = 1 \quad (6)$$

Where P denotes the location of controller. Parameters A, B, C should be manually tuned according to the understudy plant and importance priority of response characteristics. Now, if optimization procedure is executed to minimize (6), an optimal PID controller will be expected. The optimization algorithm that we employ is a common version of genetic algorithm. We can introduce the following computing procedure based on genetic algorithm for optimal selection of the controller location and parameters of controller:

Algorithm:

1. Put the controller in P_{th} location then calculate fitness function
2. Randomly choose the genetic pool of parameters K_p, K_I, K_D
3. Compute the finesses of all genetic strings, taking (6) as fitness function.
4. Choose the best subset of the population of the parameters: K_p, K_I, K_D
5. Generate new strings using the subset chosen in step 4 as parents and the "single point crossover" and "mutation" as operators.
6. Verify the fitness of the new population members.
7. Repeat the steps 4 to 6 for the 20 times
8. Save data in table and sort them
9. Repeat the steps 1 to 8 until P = number of controller location
10. Select the fitness function of minimum block of table

11. Randomly choose the genetic pool of parameters K_p, K_I, K_D

12. Compute the finesses of all genetic strings, taking (step10) as fitness function.

13. Choose the best subset of the population of the parameters: K_p, K_I, K_D

14. Generate new strings using the subset chosen in step 13 as parents and the "single point crossover" and "mutation" as operators.

15. Verify the fitness of the new population members.

16. Repeat the steps 13 to 15 until the fixed amount of fitness is attained.

This algorithm is illustrated in Fig. 2. For details the reader can refer to the texts about genetic algorithm such as [2][3],[8],[12][13] and also HELP documents of MATLAB.

5. Simulation Results

A numerical simulation was implemented using MATLAB. We selected system is illustrated in Fig. 3. :

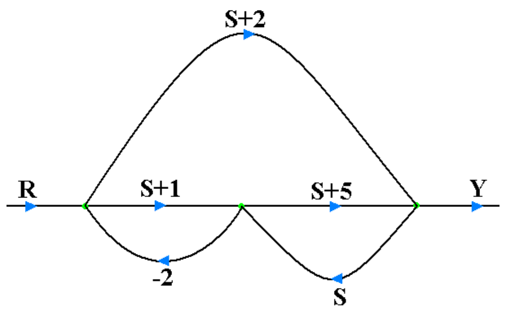

Fig.3. Suppositional system for a numerical simulation

And performed the forth section s algorithm to design Optimal PID controller in view of controller location. The characteristics of applied GA were as follow:

Population = 20
Scaling function = Rank
Creation function = Uniform
Selection = Stochastic Uniform
Crossover = 0.80
Elite Count = 2
Generation = 100
Mutation function = Gaussian
Crossover function = Scattered
Scale = 1
Shrink = 1.5
Migration Direction = Forward

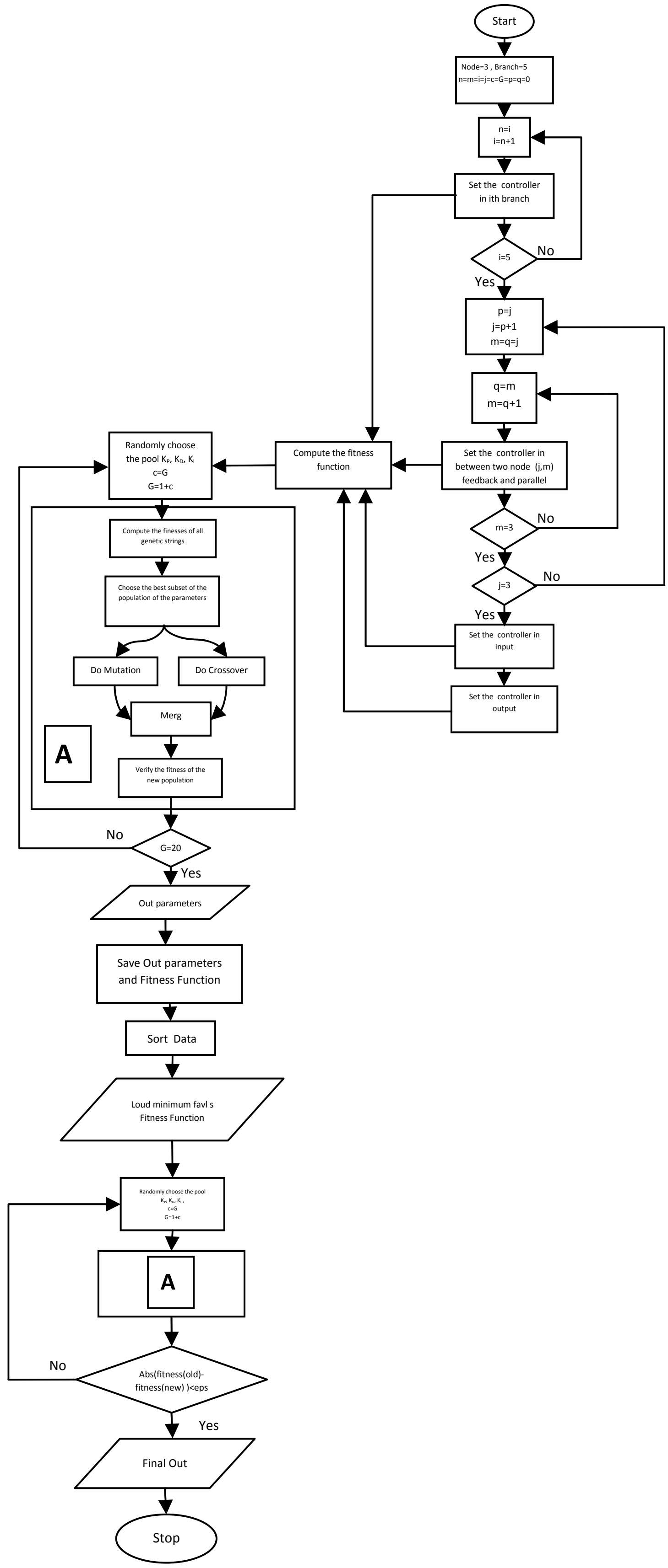

Fig.2. Genetic algorithm employed for selection of location and parameter adjustment of PID controller

Fraction = 0.2
Interval = 20
Iteration = 32

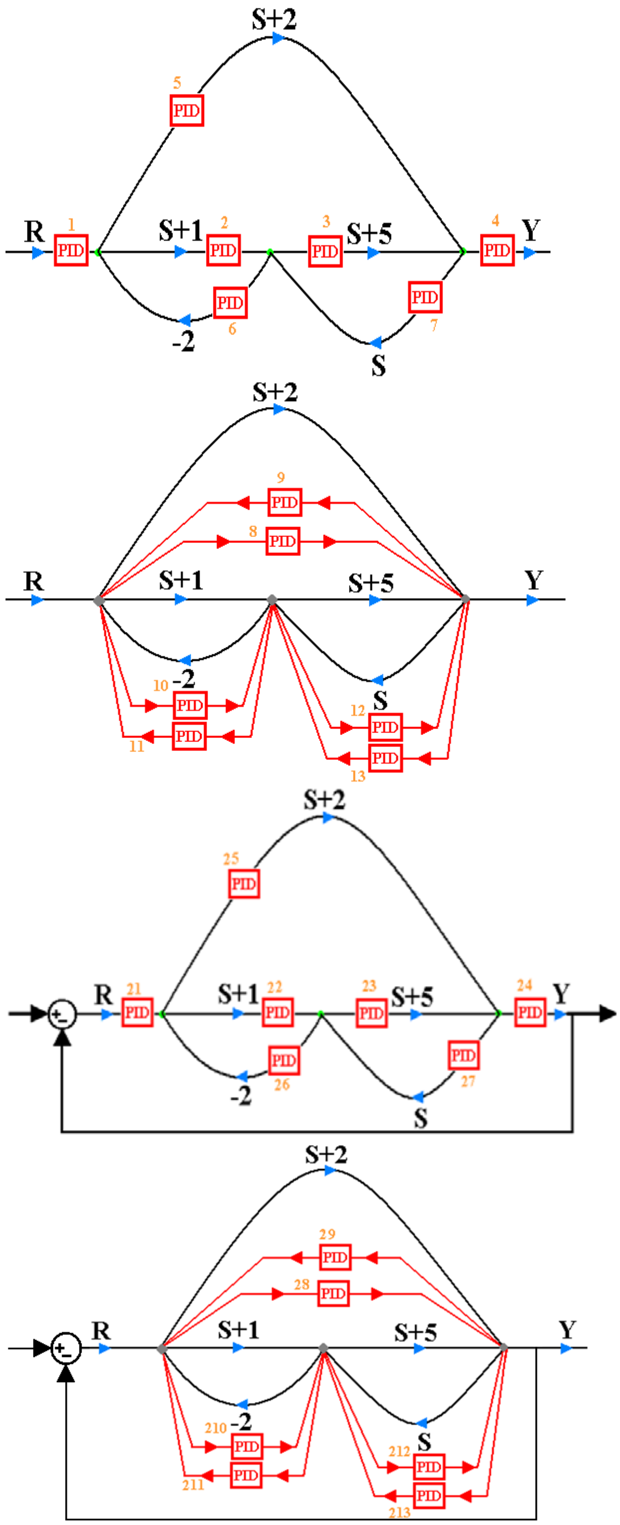

Fig.4. All possible PID controller situations in Suppositional system

Algorithm offers situation 7 for controller location so feedback is eliminated and we know feedback elimination has some advantages such as device number and system complication decrement (sensor is the most costly device in control system and maybe causes noise entrance) also feedback maybe causes system unstability .

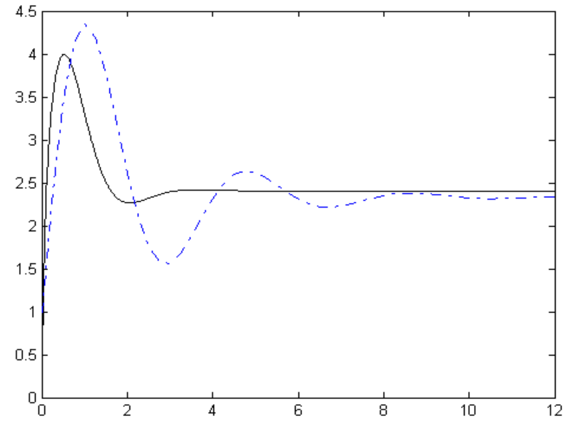

Fig.5. Output response of simulated system:
Dashed-Blue: Output response of simulated system without controller
Solid-Black: An optimal PID controller selected according to fitness function (6)- Proposed method and located at situation 7

$K_p = 0.5435, K_I = 0.0919, K_D = 0.0252$

6. Conclusions

The aim of this paper was controller location selection and parameter tuning of an optimal PID controller using genetic algorithms. To reach that goal a fitness function in terms of transient, steady state and control energy characteristics of system which are function of controller location, is introduced. Minimization of such a fitness function by genetic algorithm causes a satisfactory steady state error and maximum over shoot as well as less control energy in comparison with the similar fitness functions.

In the proposed method some parameters of fitness function (i.e. *A, B, C* in (6)) should be tuned manually. Proposition of some algorithms to automatically tune these parameters will be accomplished in future works.

References

[1]B. Thomas, F. Hoffmeister, "*Global optimization by mans of evolutionary alghorithms*" in Random Search as Method for Adaptation and Optimization of Complex Systems, edited by: A. N. Anamoshkin, Kras-Nojarsk Space Technology University, pp. 17-21, 1996

[2]Goldberg D., *Genetic Algorithms,* Addison Wesley, 1988.

[3] Holland J.H., *Adaptation in natural and artificial system,* Ann Arbor, The University of Michigan Press, 1975.

[4] R.C. Dorf, R.H. Bishop, *Modern Control Systems*, Prentice Hall, 2001

[5] K. J. Astrom, T Haagglund, "*PID Controller: Theory, Design and Tuning*", Research Triangle Park, NC, USA, 2nd Edition, 1995

[6] S. Skogestad, "*Simple analytic rules for model reduction and PID controller tuning*", Journal of Elsevier Process Control 13, pp. 291–309, 2003

[7] A. O'Dwyer, *Handbook of Pi and Pid Controller Tuning Rules*, Imperial College Press, 2003

[8] M.Seyedkazemi,A.Akbarimajd,A.Baghbanpourasl, *"A Genetically Tuned Optimal PID controller"* WSEAS Transaction On System And Control Issue 3, Volume 2, March 2007 ISSN : 1991-8763

[9] M.Seyedkazemi, F.Sedaghati *" Genetic Algorithm Application to Control of STATCOM for Damping of Sub Synchronous Resonance "* Proc of the 7th WSEAS International Conf on POWER SYSTEMS (PE '07) Beijing, China, Sep, 2007

[10] B. Porter, A. H. Jones, " *Genetic Tuning of Digital PID Controllers*" IEEE Electronics Letters, Vol. 28, pp. 843-844, Apr 1992

[11] C. L. Lin, H. Y. Jan, T. S. Hwang, "*Structure Variable PID Control Design Based on DNA Coding Method*" Proc. IEEE Int. Conf. Control Applications, 2004

[12] A. Akbarimajd M. J. Yazdanpanah, G. KarimianKhosrowshahi, "*Tracking Control of A Mobile Robot Using A Genetically Tuned Mixed H_2/H_{inf} Adaptive Technique*", Proc. of the 2004 IEEE Conf. on Robotics, Automation and Mechatronics, Singapore, 2004

[13] B.Laguance, J.C.M-Grecia, A.S.Lopez and G.F.Anaya ,"*Mixed H_2/H_{inf} Based PID Control Via Genetic Algorithms: An Experimental Evaluation*", Proc. On European control conference, Cambridge, UK., Sep. 2003

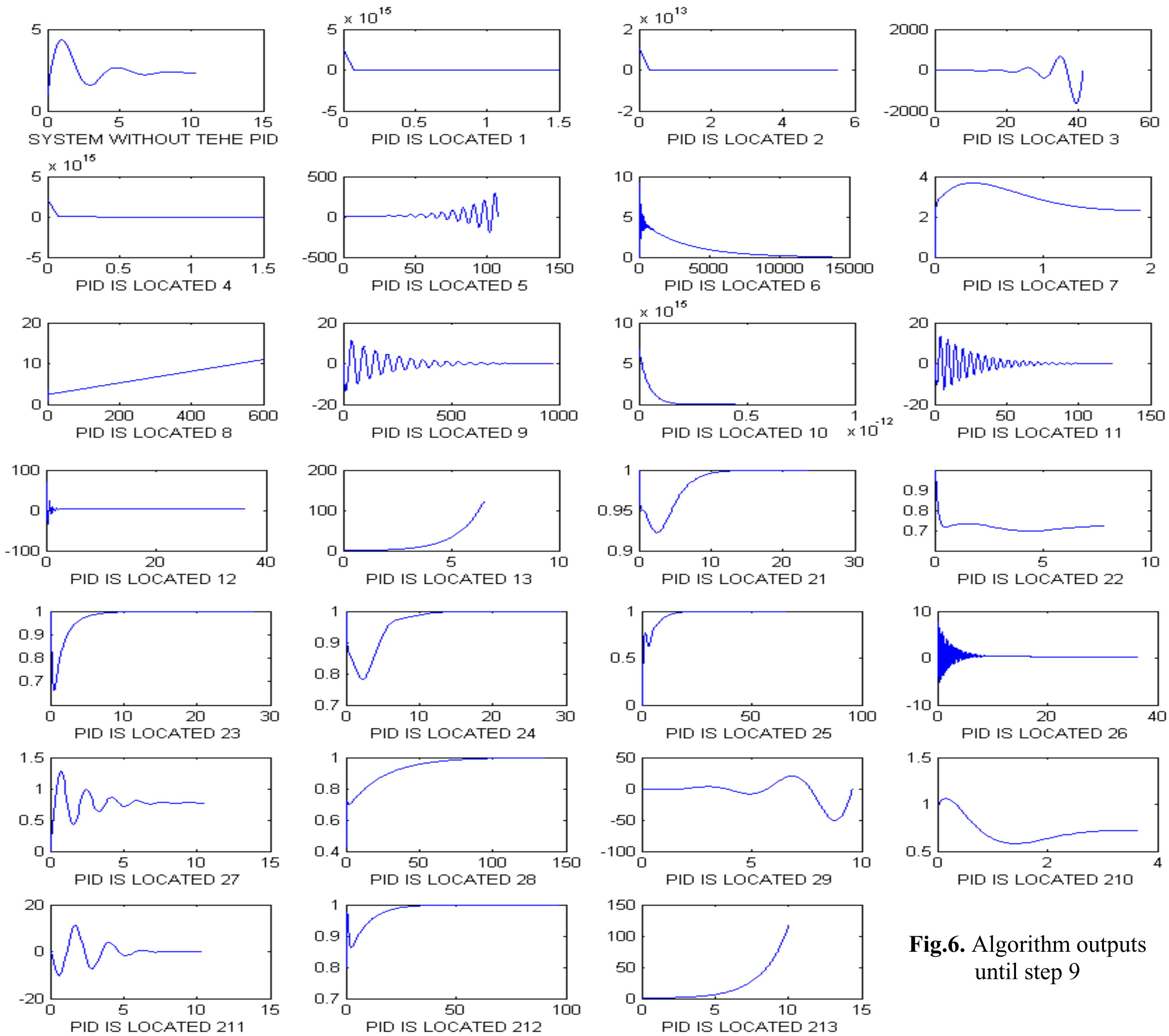

Fig.6. Algorithm outputs until step 9