Journal of Basic and Applied Engineering Research
Print ISSN: 2350-0077; Online ISSN: 2350-0255; Volume 2, Number 16; April-June, 2015 pp. 1402-1404

http://www.krishisanskriti.org/jbaer.html

PID Controller Design with FMINCON & GA

Abhishek Tripathi[1] and Rameshwar Singh[2]

[1,2]Department of Electrical Engineering, Nagaji Institute of Technology and Management, Gwalior, India
E-mail: [1]abhishektripathi90@gmail.com, [2]rameshwar.gwalior@gmail.com

Abstract—*PID controller is best controller available which can control present past and future states of any plant. PID controller take care of all transient response parameters. Best utilization of PID controller can be done by choosing the three gains of PID controller. The optimal gain can be selected by many different methods like ZN tuning. The other evolutionary methods also in trend for PID controller tuning. Genetic algorithm is trending for optimization of this kind of problem. Genetic algorithm is used for the single objective and multi objective problem however we are introducing multi-objective Genetic algorithm and MATLAB's constrained optimization tool 'FMINCON'. We complain both optimization techniques with respect to the optimum value and time for both algorithm.*

Keywords*: PID controller, Genetic Algorithm, Optimization, FMINCON, Control system*

1. INTRODUCTION

In control system the performance of the system is measured in terms of the transient response. Transient response parameter includes Raise Time, Peak Time, Settling Time and Overshoot. These parameters also responsible for the stability of the system. A control system designer design tune the PID controller by taking these parameter as objective function. PID controller can be tuned by many methods, ZN tuning is one of those famous techniques. PID controllers developing very fast and approaching to the saturation level. Now PID controller not just a simple PID controller which have three gains but instead it becomes smart controller who have capability to tune itself for different control applications.

From last decade the PID controller's gain is optimized with the soft computing methods. The Genetic Algorithm, Particle swarm optimization, Neural Network, Fuzzy Controllers are now trending. Genetic algorithm is a search techniques which finds global minima or maxima with the principle which is inspired from the genes. There are lots of techniques available which is inspired by the nature. For example Particle Swarm Optimization is follows the principle of swarm how the horde is created by the birds and other available nature creatures. Another famous techniques is ABC (Ant bee Colony Optimization), this optimization technique is inspired by the Ants. When Ant finds some food its left his saliva in her path so that other member of its tribe follow this path by smelling the saliva of previous ant. So in that way all ant follow the same path and looks they are walking in line.

In this paper we are proposing the use of genetic algorithm with a unique objective function. This paper follows the concept of minimization of ITSE and MSE together which ultimately minimize settling time and overshoot directly. The same objective function also minimized by the 'FMINCON' optimization tool. We will also compare the previous objective functions which use above error minimization technique.

We used single objective and multi-objective optimization concepts of optimization. The multi objective function is actually converted into the single objective problem. And then we can use any optimization technique for that objective function.

2. PROBLEM FORMULATION AND THE OBJECTIVE FUNCTION

Designing of PID controller consist three variable which are proportional gain, derivative gain and integral gain. By changing these value we can control any plant. Not only the plant will be stable but also it will work at its best possible performance. Latest PID controllers are designed with the soft computing. The controllers available today are not only the PID controller in fact we can call them the smart controller because the PID controllers are now integrated with artificial intelligence like neural networks, fuzzy logic and etc. For getting the optimum value of that gain the evolutionary techniques are now trending like Genetic algorithm, Particle swarm Optimization, Ant bee colony optimization and etc.

Matlab 2014 version comes with the optimization toolbox. Matlab optimization tool box contains many optimization functions and for using those optimization technique one required to provide an objective function and constraints. The objective function is the function which is to be minimized and constraints are those parameter which is to be satisfied while minimizing. If programmer want to maximize the objective function he/she should convert his/her problem as minimization problem by taking inverse of original problem or by multiplying negative one to the function.

In this paper we choose ITSE and MSE as the objective function and the limitation of the gain and stability as

constraints. The two separate objective functions are given as following.

$$f_1(kp, ki, kd) = \int_0^T te^2(t)dt \quad (1)$$

$$f_2(kp, ki, kd) = \frac{1}{N}\sum e^2(k) \quad (2)$$

Where: kp,ki,kd= PID controller gain;

t= Time;

e= Erorr;

k= Samples;

N= Total number of samples

The first function represents the ITAE and second function represents MSE both functions are used for find out the optimum response in optimization problems. In this paper we used both function in a single new function with some weight so that we can use both function's benefits. The propose function is given in the equation 3.

$$J(kp, ki, kd) = \alpha f_1 + (1 - \alpha) f_2 \quad (3)$$

Where: J= Objective function

J is the performance index which is to be optimized. The same objective function will be shared by Genetic algorithm and MATLAB's FMINCON optimization function.

3. RESULTS & DISCUSION

We have tested the both optimization technique on three different type of system and result will be as follows

Example 1: Let's consider the following open loop type zero transfer function;

$$G(s) = \frac{1}{s^2+0.8s+0.3} \quad (4)$$

Step response of uncompensated system is given in fig. 1.

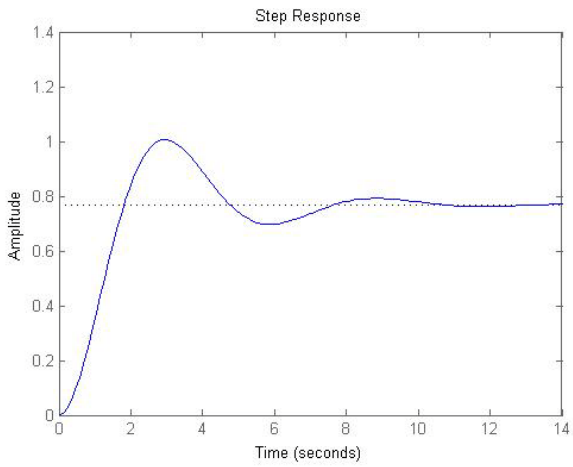

Fig. 1: Uncompensated System for Example-1

After choosing the proper fitness function as given in equation 3. We apply optimization technique on the designed transfer function and we have following step response and tabulated result is given in Table 1.

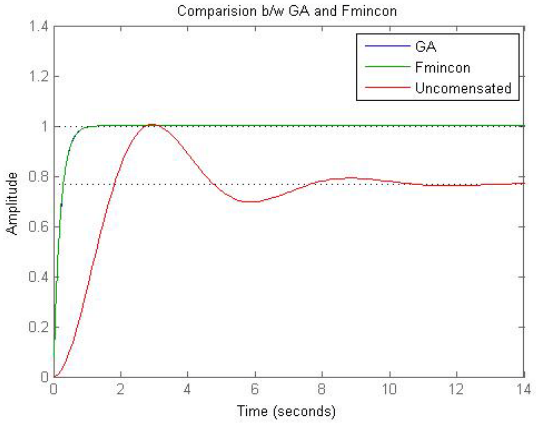

Fig. 2: Compensated system with FMINCON and GA for Example-1

Table 1: Comparisoin of Output Response between GA & FMINCON for Example-1

	PID GAIN			Raise Time	Setting Time	Overshoot	Undershoot
	Kp	Ki	Kd				
Uncompensated	1	0	0	1.2228	9.6247	30.7704	0
FMINCON	4.03232	1.5098	4.9657	0.4395	0.7710	0.0374	0
GA	4.0591	1.5200	4.9918	0.4370	0.7655	0.0510	0

Example 2: Let's consider following type one Plant equation.

$$G(s) = \frac{100}{s(s^2+15s+52)} \quad (5)$$

The response of uncompensated system is given in fig. 3.

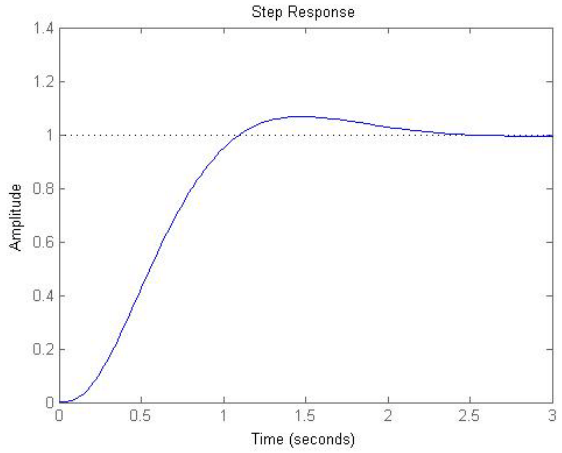

Fig. 3: Uncompensated System for Example-2

After optimization with FMINCON and GA we have following stepresponse:

Its looks like FMINCON and GA gives same response in example one and in example 2 GA looks better. On the performance bases if we compare both response we will see that GA give optimum response than the FMINCON but this difference is not very large in above cases but on the algorithm speed performance FMINCON is very fast as compared to GA.

GA takes 30 sec to 1 min or even more sometimes but FMINCON function optimise above two objective function with the minimum time consumption it took about 5 to 15 sec to optimize the same objective function.

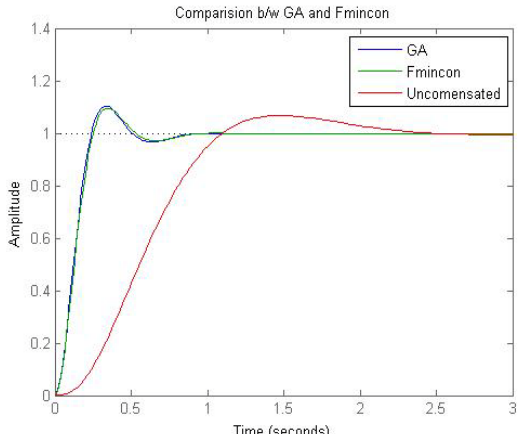

Fig. 3: Compensated system with Fmincon and GA for Example-2

The detail of parameter and output comparison is given in table-1. The FMINCON and GA Parameter are as following.

GA Parameters: All setting of GA are consider as default as used in MATLAB. The following setting we changed;

Lower Bound=[0 0 0];

Upper Bound=[5 5 5];

Population Size=20;

No. of variable=3;

FMINCON Parameters: The FMINCON parameters are same as default used in MATLAB we only set lower bound and upper bound same as GA. The starting point is set to the [0 0 0].

Table 2: Comparisoin of Output Response between GA & FMINCON for Example-2

	PID GAIN			Raise Time	Settling Time	Overshoot	Undershoot
	Kp	Ki	Kd				
Uncompensated	1	0	0	0.6855	2.0987	6.7626	0
FMINCON	4.3229	0.0164	1.094	0.1678	0.7655	9.5523	0
GA	4.5198	0.0016	1.1642	0.1601	0.7550	10.3464	0

4. CONCLUSION

Genetic algorithm gives optimum result for control system problem as compared to the ZN tuning and FMINCON. FMINCON function also gives satisfactory response with very less time as compared to the Genetic algorithm. GA is called evolutionary technique which can be used with the other intelligent technique like fuzzy and ANN. Controllers with this kind of technique capable of learning by itself and called intelligent controllers.

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