Tuning of Classical Controller Using Evolutionary Method for Real Time System

Dr. R. B. Patel
Assistant Professor, Instrumentation & Control Engineering Department,
Sardar Vallabhbhai Patel Institute of Technology, Vasad, Gujarat, India.

***Abstract*— The objective of this paper is to design and comparative analysis of classical controller tuning using traditional and evolutionary methods for real time system. To achieve this objective, the nonlinear water tank control has been selected as real time system. The proposal- integral-derivative control law is used as control algorithm in controller. The tuning parameters as propositional gain, integral gain and derivative gain are tuned using traditional method and evolutionary method. The performance of both methods are compared and discussed with considering hard constraint of real time system.**

***Keywords*— Classical controller, Genetic algorithm, Matlab, Quarc Software, Real time system, PID tuning**

I. INTRODUCTION

Traditionally, a various methods have been applied to tune the PID controller parameters. The prior knowledge regarding plant is required for tuning [1]. Once tuned the controller parameters is tuned for good response but it will not be guaranteed to optimum response in real time system due to nonlinearity and uncertainty of plant dynamics. To assure an environmentally independent good performance, the controller must be able to adapt the changes of the plant dynamic characteristics. For these reasons, it is highly desirable to increase the capabilities of PID controllers by adding new features [2-3].

Several new methods from evolutionary approaches, such as GA, fuzzy logic, the applications of GAs have expanded into various fields of control engineering. With the abilities for global optimization and good robustness, and without knowing anything about the underlying mathematics, GAs are expected to overcome the weakness of traditional PID tuning techniques and to be more acceptable for continuously changing plant dynamics. In this previous work, it has been shown that GAs gives a better performance in tuning the parameters of PID controllers than other methods [4-5]. The SISO plant of coupled tank system supplied by Quanser, Canada is used to analysis of new approach of controller tuning.

This paper is organized as follows. In section II, the classical control is discussed. In section III, a genetic algorithm based tuning method has been discussed. In section IV, described real time water tank control system (Quanser, Canada). In section V & VI are related analysis the result of experiment which was done in laboratory and conclusion.

II. CLASSICAL CONTROL

PID control is a traditional linear control method used commonly in industrial applications. In the parallel form of the PID controller, three simple gains Kp, Ki and Kd, are used in the decoupled branches of the PID controller. The parallel PID control architecture can be given the following equivalent time-domain and Laplace S domain mathematical representations:
Time-domain PID controller formula

$$u_c(t) = k_p e(t) + k_i \int_o^t e(t)d(t) + k_d \frac{de}{dt} \quad (1)$$

Transfer function PID controller formula

$$U_c(s) = \left[k_p + \frac{k_I}{s} + k_D s \right] E(s) \quad (2)$$

The PID controller has been implemented in Simulink and its can be interfaced with real time system with Matlab@ V7.12 and Quarc@ V2.2 software [6-7]. In the industry control, this algorithm is the most commonly used method, because of their intuitiveness, simple structure robust performance and good features. PID parameters tuning method was artificial trial, so it could not achieve the optimal controller performance. So, new methods are required to optimal parameters of controller.

III. GENETIC ALGORITHM BASED TUNING

The basic principles of GA were first proposed by Holland. It uses a direct analogy of such natural evolution to do global optimization in order to solve highly complex problems. It presumes that the potential solution of a problem is an individual and can be represented by a set of parameters. These parameters are regarded as genes of a chromosome and can be structured by a string of concatenated values. In the beginning an initial chromosome is randomly generated. The chromosomes are candidate solutions to the problem. Then, the fitness values of all chromosomes are evaluated by calculating the objective function in decoded form. The genetic operators, crossover and mutation, are applied to this surviving population in order to improve the next generation solution [8]. The process continues until the population converges to the global maximum or another stopping criterion is reached as shown in fig: 1.

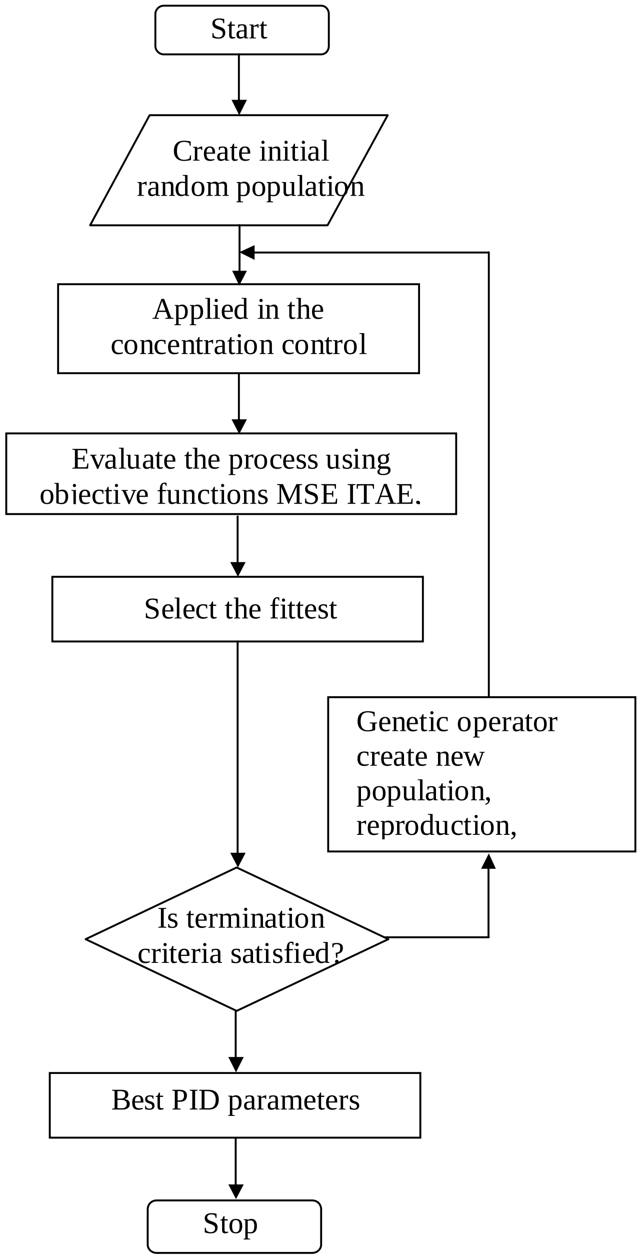

Fig: 1 Flow Chart of Genetic Algorithm

The most crucial step in applying GA is to choose the objective functions that are used to evaluate fitness of each chromosome. The objective functions are mean of the squared error (MSE). Integral of Time multiplied by absolute Error (ITAE), Integral of Absolute Magnitude of the error (IAE) and the Integral of the Squared Error (ISE). Here, ISE is used as follows:

$$\mathrm{I}_{\mathrm{ISE}} = \int_0^T e^2(t)dt \tag{3}$$

The PID controller is used to minimize the error signals to minimize the value of objective function and the fitness value is selected as

$$\text{Fitness value} = \frac{1}{\text{Perfomance Index}}$$

IV. REAL TIME WATER TANK SYSTEM

The real time system "coupled tank" by quanser, Canada is used to check the response of new tuning method.

Fig: 2 Real time water tank system

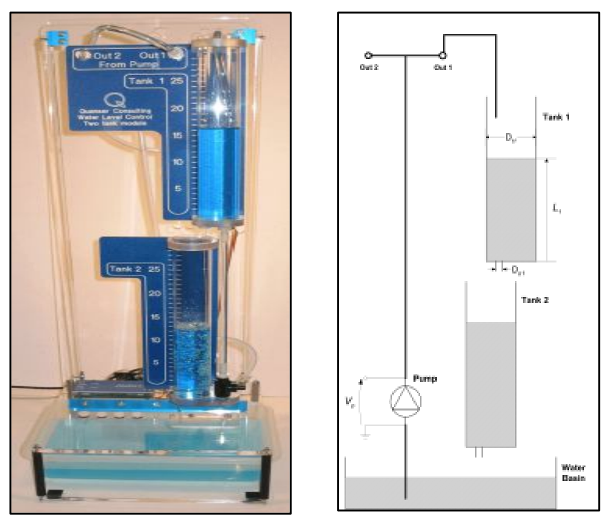

Fig: 3 Experiment kit and its configuration

This single system can be configured into three main types of experiments as Single Input Single Output (SISO) system, State Coupled SISO system, and State-coupled and Input-coupled SISO system. Here, First SISO configuration is used to analysis the response of new tuning algorithm. The actual system and its configuration mode are shown in fig:3. Using mass balance principle for tank, the differential equations [6-7]:

$$A_t\left(\frac{\partial}{\partial t}L\right) = F_i - F_o \tag{5}$$

$$F_i = K_i V_i$$

$$F_o = A_o \sqrt{2}\sqrt{gL}$$

Where At = Area of tank
L = Level of tank;
F_i = Inlet flow;
F_o = Outlet flow;
K_i = Gain of variable drive;
V_i =Voltage of pump;
A_o = Area of outlet;

Applying the Taylor's series approximation, the open loop transfer function is:

$$G(s) = \frac{K_{dc}}{\tau S + 1} \qquad (6)$$

Where

$$K_{dc} = \frac{K_p \sqrt{2}\sqrt{gL}}{A_o g}$$

$$\tau = \frac{\sqrt{gL}\, A_t \sqrt{2}}{A_o g}$$

V. EXPERIMENTAL RESULTS

The PID controller is tuned with two separate methods: traditional and genetic algorithm. The response both methods in real time system are given in the fig: 4.

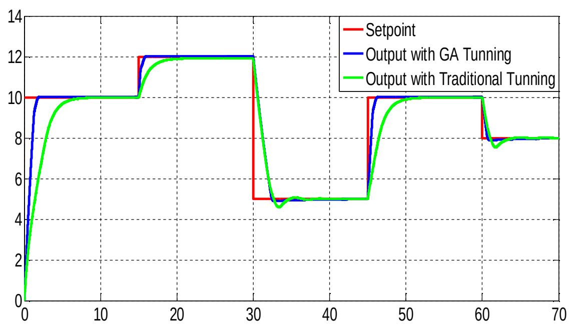

Fig: 4 Controller performances with different tuning algorithm

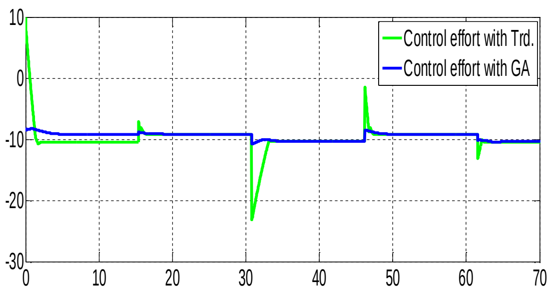

Fig 5 Controller output before plant

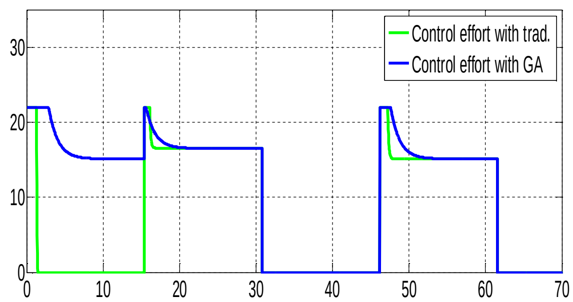

Fig:6 Response of pump on controller output

In simulation, the controller output has not any type of constraint so the response is very fast. But in the real-time system, the output of controller is very high but pump can give only maximum flow of line. So, the response is slow. The response of controller output and pump are given in fig: 5 and fig:6 respectively.

VI. CONCLUSION

This paper proposed two tuning methods of controller. The traditional methods are suitable but it will take more time to tune the plant. Sometimes the plant modeling is difficult so its tuning is also very complex. So, new approach of tuning using genetic algorithm is very good method. The plant model is not mandatory for this approach. In real time system, the process leg and hard constraints have major influence in close loop system. So, tuning with regular method is not satisfactory. From result analysis, the GA based tuning methods is very good response compare then tradition method for real time system.

REFERENCES

[1] Astrom K.J., Taylor H.J., "Non-linear PID auto tuning algorithm", American Control Conference, IEEE, pp.2118-2123.

[2] Satean T., and Santi W, "Level Control in horizontal tank by fuzzy-PID Cascade Controller," World Academy of Science, Engineering and Technology, 2007.

[3] Berk P., Stajnko D., Vindis P. "Synthesis water level control fuzzy logic" journal of achievement in material and manufacturing, International OCSCO world press, April 2011, Issue 2, Vol: 45

[4] T.K. Teng , J.S. Shieh and C.S. Chen , "Genetic algorithms applied in online auto tuning PID parameters of a liquid-level control system", *Transactions of the Institute of Measurement and Control* 25,5 (2003)

[5] H. Ali, I. Ullah, M. Irfan, M. Shahzad, M. Aftab, "Genetic algorithm based PID tuning for controlling paraplegic humanoid walking movement, International journal of computer science issue, Vol.9(4), July 2012.

[6] K.H.Johansson, "The Quadruple Tank process: A multivariable laboratory process with an adjustable zero. IEEE Transactions on control systems Technology, 8(3), Pp 456-465, 2000.

[7] www.quancer.com, Real time system manual

[8] D. E. Goldberg, Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley Publishing Co., Inc., 1989