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Development Of GA Based PID Controller For Three Tank Interacting System

Manikandan P [#1], Naveen R [#2], Geetha M [*3],

[#] *UG Scholar, PSG College of Technology,*
Coimbatore, Tamilnadu, India.

[*] *Assistant Professor*
PSG College of Technology, India.

Abstract

The aim of this paper is to simulate a flexible and fast tuning method based on Genetic Algorithm to determine the optimal parameters of the PID controller for the desired system specifications. The parameter tuning of the Three Tank Interacting System is done by both the proposed Genetic Algorithm method and the conventional Zeigler Nichols method. Simulation results of both these methods are compared. A third order system is considered here and it can be applied to higher order systems also.

Index Terms – Interacting system, PID Controller, Genetic Algorithm, Zeigler Nichols tuning method

1. Introduction

The economic constraints place increasingly higher requirements on control systems. New generations of equipments must have higher performance parameters such as better efficiency and system flexibility. In various industrial processes the need for higher productivity is placing new demands on mechanisms connected with process control. In industrial applications and robotics, a smooth transition of the system from one fixed point to another is desirable than an abrupt transition. So, precision control of the system becomes important. Proportional Integral and Derivative (PID) controllers have been used for this purpose to improve the transient response and stability of the system. This paper endeavours to design a level control system using Genetic Algorithm. By employing the GA method of tuning a system, an optimization can be achieved.

2. SYSTEM MODEL

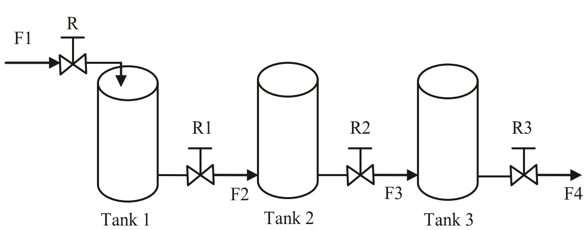

Fig. 1 Three Tank Interacting System

Tank1, Tank2 and Tank3 are connected in series in Fig. 4. The basic model equations of the interacting system is given by:

The overall transfer function of the interacting three tank system is given by

Tank 2:

$$F_1(t) - F_2(t) = A_1 dh_1 / dt \quad (1)$$

Tank 3:

$$F_2(t) - F_3(t) = A_2 dh_2 / dt \quad (2)$$

$$F_3(t) - F_4(t) = A_3 dh_3 / dt \quad (3)$$

$$F_2(t) = (h_1 - h_2) / R_1 \quad (4)$$

$$F_3(t) = (h_2 - h_3) / R_2 \quad (5)$$

$$F_4(t) = h_3 / R_3 \quad (6)$$

$$H_3(s) / F_1(s) = RR_{1\,2}R_3 / [(ARs_{1\,1}+1)(A_2RR_{1\,2}s + R_2 + R_1) - R_2] \cdot (A_2R_2R_3s + R_2 + R_3) - RR_{1\,3}(ARs_{1\,1}+1) \quad (7)$$

Substituting these values in the general form of the transfer function we get,

$$H_3(s) / F_1(s) = \frac{1.2}{0.00077\,s^3 + 0.053s^2 + 1.441\,s}$$

3. SIMULATION ENVIRONMENT

A. Block diagram

The plant is tuned by the GA based PID controller to obtain the desired system specifications. The output from the plant is again fed back to the controller so that the error is reduced. The general block diagram of a Genetic Algorithm based PID controller is shown in fig.2.

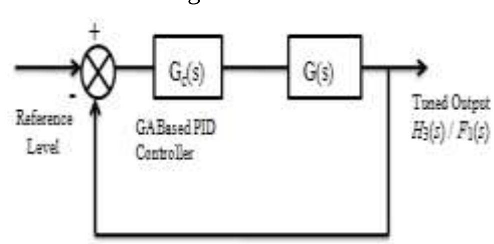

Fig.2 General Block Diagram

B. Zeigler Nichols closed loop tuning method

This method is also called as ultimate gain method. The ultimate gain is the minimum value of gain for which the system continuously oscillates at constant amplitude. The ultimate period is the period of response with the gain set to its ultimate value. To determine the ultimate gain of the controller (with all integral and derivative action turned off) the proportional action is gradually varied until the process cycles continuously. The process is placed in the closed loop with a proportional controller; the gain is decreased until the process goes to sustained oscillations. The corresponding value of gain is called as ultimate gain or K_{cr} and the period of oscillation is called the ultimate period $P_{cr.}$

Table 1 ZN Tuning parameters

Type	K_p	T_i	T_d
P mode	$K_{cr}/2$	-	-
PI mode	$K_{cr}/2.2$	$P_{cr}/1.2$	-
PID mode	$K_{cr}/1.7$	$P_{cr}/2$	$P_{cr}/8$

The values of the PID tuning parameters are obtained from the control law settings of Zeigler Nichols method. The value of critical gain is obtained from the root locus plot. A simulink model for the considered system is constructed and simulated for the obtained critical gain for sustained oscillations. From the simulink output, the period of oscillation at the critical gain is found.

a) Root locus of the system

The ultimate gain or critical gain of the system is usually found by trial and error method if the mathematical model of the system is not known. As the transfer function of the system is well known, root locus was plotted to find the accurate value of gain for which sustained oscillations is obtained.

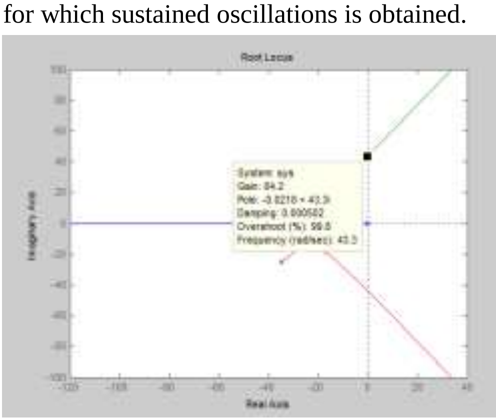

Fig.3 Root locus of the system

b) Simulink model

The system model was constructed using matlab-simulink. A step input and the obtained gain 84.2(from root locus method) is given to the system.

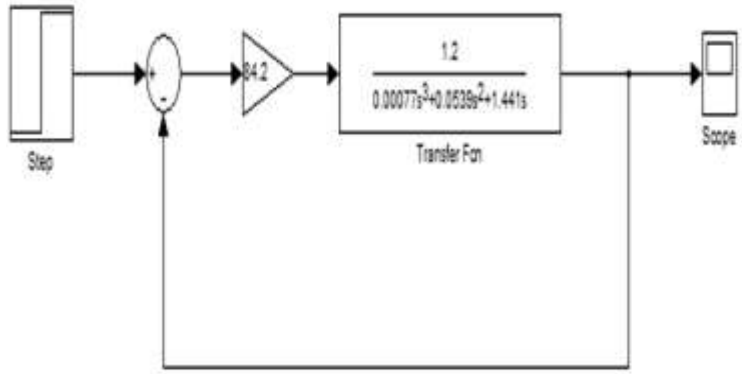

Fig.4 Simulink model of the system

The output is obtained as in the fig.5

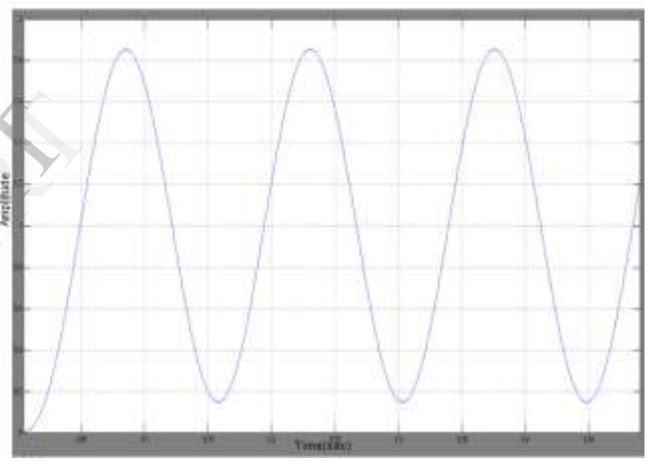

Fig.5 Simulink output

From the simulink output the values required are obtained as,

$K_{cr} = 84.2$
$P_{cr} = 0.1449$ s

The values of critical gain and period of oscillations are substituted in the table of control law settings to obtain the ZN tuned gain parameters.

Table 2 ZN tuned gain parameters

Gain parameters	K_p	T_i	T_d
Gain values	49	0.0549	0.018245

c) PID simulink model

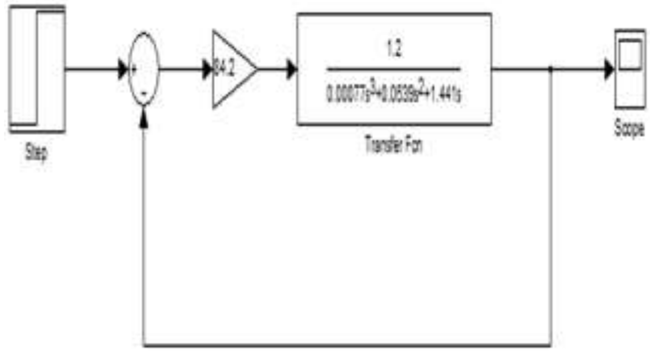

Fig.6 PID Simulink model

The gain block in the simulink model is replaced by a PID controller as shown in the figure 1.6 and the tuned controller output for the above gain parameters is obtained.

C. Genetic Algorithm

GA works on a collection of several alternative solutions called population. Each solution or individual in the population is called chromosome and individual character in this is called gene. To obtain better solutions (population) from existing one, a new generation is evolved in each iteration.

The generation gap is the fraction of individuals in the population that are replaced from one generation to the next. Based on this, there are two basic GA approaches, called simple GA and steady state algorithm. Generation gap is equal to one in the simple GA and is less than one for the other approach.

a) PID tuning by GA

The major objective of the GA is to determine the optimal values of the PID controller parameters to improve the transient response of the system. To achieve this, the algorithm considers the maximization of an objective function. This objective function provides a means for evaluating the performance of the PID controller with the determined gain parameters, so that an optimized controller would be developed by the best individual.

When applied to the PID controller design problem, the genes are the gain values of the controller K_P, K_I, and K_D which are to be determined. Each chromosome contains a complete set of the genes needed to define uniquely a trial solution.

The fitness of each chromosome is evaluated using the error criterion, which is used as the basis of selection for the chromosomes in the next generation.

b) Optimisation Tool

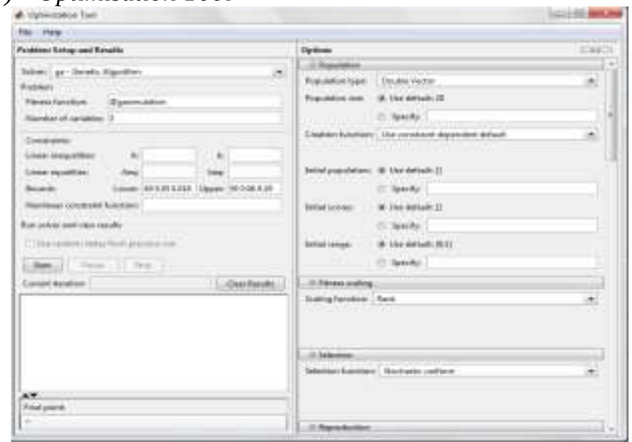

Fig.7 Optim tool in matlab

Matlab has an in-built optimisation tool which is used for optimisation purposes. This optim tool opens the Optimisation tool, a graphical user interface (GUI) for selecting a solver, the optimization options, and running problems. A problem structure can be created or modified in optim tool by exporting the problem information to the MATLAB workspace.

c) Optimisation result

During the optimization process, the required poles and the actual closed loop poles are used by the genetic algorithm. In each generation, according to the controller parameters, closed loop poles are determined. The tuning algorithm searches the optimal parameters for the PID controller with the help of these closed loop poles. The optimised control parameters for the desired system specifications tuned by Optim tool of matlab using GA solver is shown in the fig. 8.

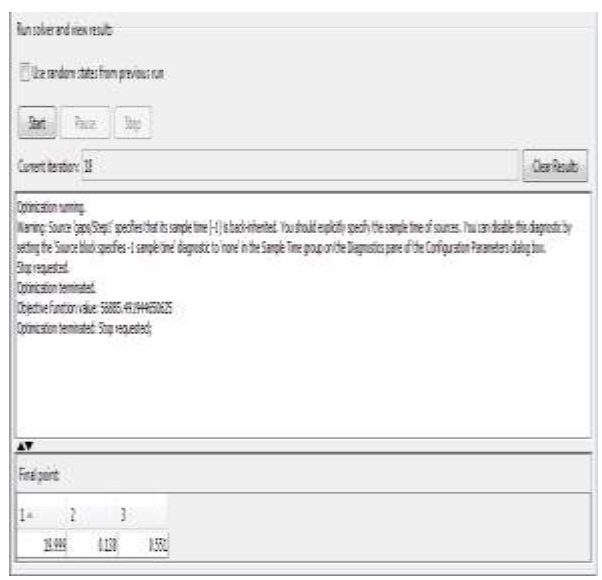

Fig.8 Output of GA tuning

The optimised gain parameters obtained by Genetic Algorithm method of tuning are shown in the table 3.

Table 3 GA tuned gain parameters

Gain parameters	K_p	T_i	T_d
Gain values	19.999	0.138	0.551

4. SIMULATION RESULTS

A. Zeigler Nichols method

The PID model constructed using simulink was simulated for the gain parameters obtained using Zeigler Nichols tuning method and the output is obtained as shown in the fig.9

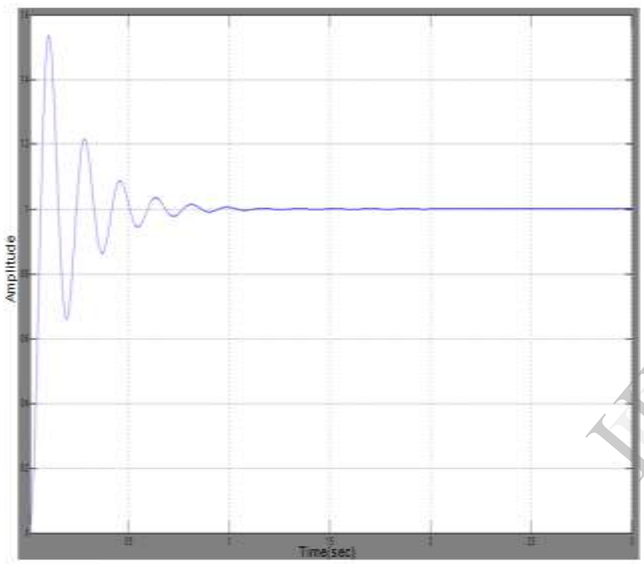

Fig.9 Tuned controller output

B. Genetic Algorithm

The PID simulink model is simulated for the optimised tuning parameters obtained using Genetic Algorithm tuning method.

GA based tuning method shows better results in case of rise time, settling time and peak overshoot as shown in the fig.10.

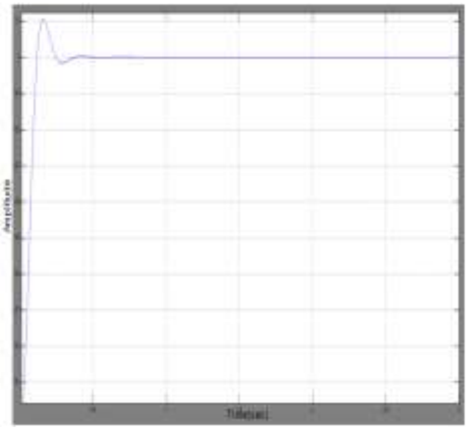

Fig.10 Tuned controller output

C. Comparison between ZN and GA

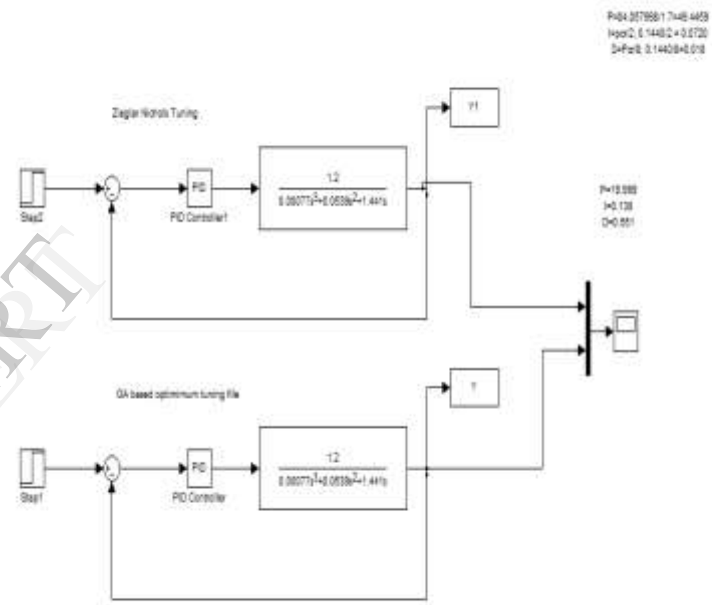

Fig.11 ZN and GA tuning method

a) Simulation result

The output of conventional Zeigler Nichols method is compared with the Genetic Algorithm based tuning method based on the simulation results obtained from both the tuning methods as shown in the fig.12

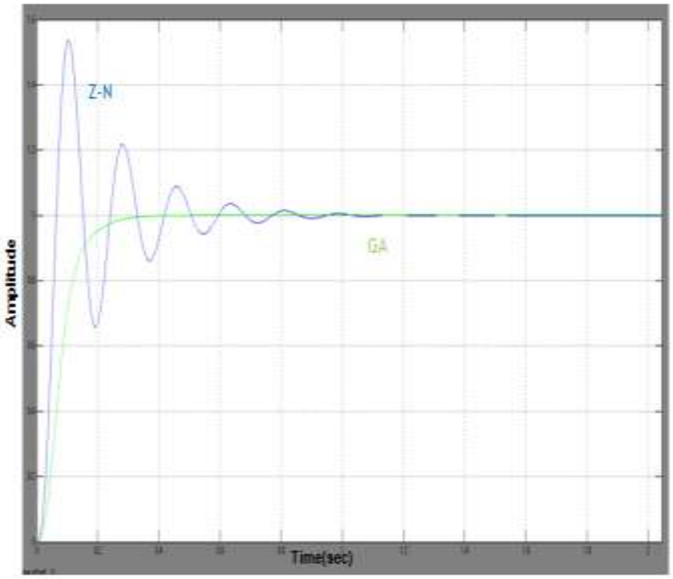

Fig.13 Comparison of GA and ZN tuning results

b) Analysis of result

1. The designed PID with GA has much faster response than the conventional method i.e., in GA, offset is minimum and settles faster resulting in better tuning than ZN method
2. In Zeigler Nichols tuning, the oscillations and peak overshoot is more when compared to GA tuning
3. The conventional method is good for getting the initial values of the PID tuning which needs to be modified
4. GA based tuning method also shows better results in case of rise time and settling time

5. CONCLUSION

The genetic algorithm based PID tuning provides much better results compared to the conventional methods. In the designed PID controller tuning with GA, the actual response is found to be satisfying the required value. PID controller gain values depend upon the range selected for the initial population. The range of requirement can be widened by increasing the range of initial population but the number of generations required to converge to optimal value may increase. In this paper, implementation of the genetic algorithm based PID controller for the tank level control system is covered. The simulation results also show that matlab paired with simulink is an efficient and user friendly tool for modelling and analysis of tank level control system using PID controller.

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