ISSN: 2348 - 2117

International Journal of Engineering Technology and Computer Research (IJETCR)
Available Online at www.ijetcr.org
Volume 2 Issue 4 Page No. 77-82

Performance tuning of pid controllers using genetic algorithm

Er. Arshpreet Kaur[1], Er. Simran Kaur[2], Dr. B.P.Garg[3], Er. Vikas Gupta[4]

[1] Research Scholar, AIET Faridkot
arshpreet26@gmail.com
[2]Assistant Professor, AIET Faridkot
simrandsandhu@gmail.com
[3]Director Principal, AIET Faridkot
bkgarg2007@gmail.com
[4]Head of Deptt ECE, AIET Faridkot
vikas_gupta81@yahoo.co.in

ABSTRACT

In this paper, determining the optimal proportional-integral-derivative gains of a temperature control system like oven is presented. Certain amount of heat is needed to transfer the heat by conduction and convection inside the oven. This transfer of heat requires a delay or transportation lag. So, this delay or transportation lag is overcome with the help of controller tuning using Genetic Algorithm. Using the conventional tuning methods for PID controller like Zeigler-Nichols, the performance of the plant does improve. But when system parameters are constantly changing, an optimal tuning method like Genetic Algorithm helps. The work has been conducted in MATLAB. A comparison is shown in the step response obtained from tuning by Zeigler Nichols and Genetic Algorithm.

Keywords: *P, I, D, PID, Rise Time, overshoot, settling time, Genetic Algorithm(GA) and Zeigler-Nichols method(Z-N)*

INTRODUCTION:

PID controller is a generic control loop feedback mechanism widely used in industrial control systems. It calculates an error value as the difference between measured process variable and a desired set point. The desired set-point is where the user would like the measurement to be. The variable being adjusted is called the manipulated variable which usually is equal to the output of the controller. The PID controller calculation involves three separate parameters proportional, integral and derivative values. The proportional determines the reaction of the current error, the integral value determines the reaction based on the sum of recent errors, and the derivative values determines the reaction based on the rate at which the error has been changing. The weighted sum of these three actions is used to adjust the process final control element. The transfer function of the PID controller looks like the following:

$$K_p + \frac{K_i}{s} + K_d s = \frac{K_d s^2 + K_p + K_i}{s}$$

K_p = Proportional gain
K_i = Integral gain
K_d = Derivative gain

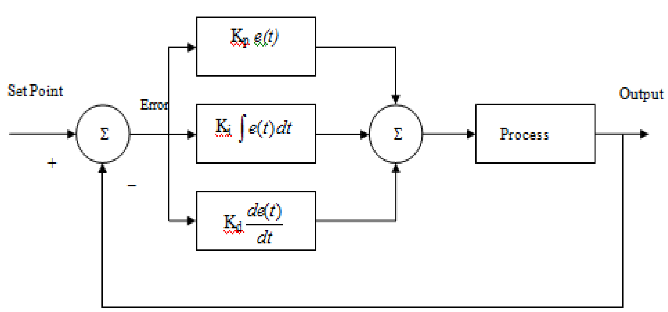

Figure 1: PID Controller in Closed Loop

1.1 SYSTEM DYNAMICS AFFECTED BY PID CONTROLLER

We are most interested in four major characteristics of closed-loop step response. They are:

- **Rise time**: the rise time is the time required for the response to rise from 10% to 90%, 5% to 95% or 0% to 100% of its final value. For under damped second order systems, the 0% to 100% rise time is normally used. For over damped systems, the 10% to 90% rise time is commonly used.
- **Maximum (percent) overshoot, M_p**: the maximum overshoot is the maximum peak value of the response curve measured from unity. If the final steady-state value of the response differs from unity, then it is common to use the maximum percent overshoot. It is defined by:

Maximum percent overshoot $= \frac{c(tp) - c(\infty)}{c(\infty)} X\ 100\%$

- **Settling time**: the settling time is the time required for the response curve to reach and stay within a range about the final value of size specified by absolute percentage of the final value (usually 2% or 5%). The settling time is related to the largest time constant of the control system.
- **Steady-state error**: the difference between the steady-state output and the desired output.

Table 1: The general trend of PID parameters on system dynamics

PID Parameters	Rise Time	Overshoot	Settling time	S-S Error
Kp (Proportional gain)	Decrease	Increase	Small Change	Decrease
Ki (Integral gain)	Decrease	Increase	Increase	Eliminate
Kd (Derivative gain)	Small Change	Decrease	Decrease	Small Change

1.2 CONTROLLER TUNING:

Controller tuning involves the selection of the best values of K_c, K_i and K_d (if a PID algorithm is being used). This is often a subjective procedure and is certainly process dependent. A number of methods have been proposed in the literature over the last 50 years. However, recent surveys indicate,

- 30 % of installed controllers operate in manual.
- 30 % of loops increase variability.
- 25 % of loops use default settings.
- 30 % of loops have equipment problems.

A possible explanation for this is lack of understanding of process dynamics, lack of understanding of the PID algorithm or lack of knowledge regarding effective tuning procedures. This section of the notes concentrates on PID tuning procedures. The suggestion being that if a PID can be properly tuned there is much scope to improve the operational performance of a plant. When tuning a PID algorithm, generally the aim is to match some preconceived 'ideal' response profile for the closed loop system. The following response profiles are typical.

Ziegler-Nichols Tuning Rules:

The Ziegler-Nichols is a PID tuning rule that attempts to produce good values for the three PID gain parameters: proportional, integral and derivative gains.

Ziegler-Nichols First method:

Ziegler-Nichols method applies to the open loop transfer function. It is simpler to calculate because the guess work is taken out as opposed to the closed loop method where the accuracy of 'steady oscillations' becomes estimation at best. The control law settings are then obtained from the table1.1. Here L is delay time and T is time constant.

Ziegler-Nichols Closed Loop method:

The method is straightforward. First, set the controller to P mode only then set the gain of the controller (K_c) to a small value. Make a small set point (or load) change and observe the response of the controlled variable. If k_c is low, the response should be sluggish. Increase k_c by a factor of two and make another small change in the set point or the load. Keep increasing kc by a factor of two until the response becomes oscillatory. Finally, adjust K_c until a response is obtained that produces continuous oscillations. This is known as the ultimate gain (K_u). Note the period of the oscillations (P_u). The control law settings are then obtained from the table 2. It is unwise to force the system into a situation where there are continuous oscillations, as this represents the limit at which the feedback system is stable. Generally, it is a good idea to stop at the point where some oscillation has been obtained. It is then possible to approximate the period (P_u) and the gain at this point is taken as the ultimate gain (K_u), then this will provide a more conservative tuning regime.

Table 2: Tuning parameters for Ziegler Nichols First method

Type of controller	K_p	K_i	K_d
P	$\frac{T}{L}$	∞	0
PI	$0.9\frac{T}{L}$	$\frac{L}{0.3}$	0
PID	$1.2\frac{T}{L}$	$2L$	$0.5L$

Table 3 Tuning parameters for Ziegler Nichols closed loop ultimate gain method

Type of controller	K_c	K_i	K_d
P	$K_u/2$	∞	0
PI	$K_u/2.2$	$P_u/1.2$	0
PID	$K_u/1.7$	$P_u/2$	$P_u/8$

1. LITERATURE SURVEY

The PID controller is the most common form of feedback. It was an essential element of early governors and it became the standard tool when process control emerged in the 1940s. Haglund T. and Astrom K. J. [1991] describe several adaptive techniques based on frequency response analysis, which were used in industrial controllers. The ability of PI and PID controllers to compensate many practical processes has led to their wide acceptance in industrial applications. The requirement to choose two or three controller parameters is most easily done using tuning rules. A discussion of industrial practice (O'Dwyer, 2006), the paper provides a survey of additional tuning rules for continuous-time PI and PID control of time-delayed single-input, single-output (SISO) processes. Matlab-Simulink based real time temperature control of oven designed as an experiment set using different kinds of auto-tuning PID methods (Emine Dogru Bolat 2007). The methods are simulated using Matlab-Simulink to define the controller parameters. A method of designing proportional-integral-derivative (PID) controller based on genetic algorithms (GA) is discussed (Fan et.al. 2009). Ziegler-Nichols tuning formula is used for predicting the range of gain coefficients of GA-PID controller. The use of GA for optimizing the gain coefficients of PID controller has considerably improved the performance of PID controller. Simulation studies on a second-order and a third-order control system demonstrate that the proposed controller provides high performance of dynamic and static characteristics.

In process control today, more than 95% of the control loops are of PID type, most loops are actually PI control. Many tuning technologies are used for the control process. Up to the present time, since the gain of the PID controller has to be manually tuned by trial and error, it is very difficult to achieve an optimal PID gain with no expertise. In this paper an attempt has been made to present a comparison of control system using different PID parameters.

2. PROBLEM FORMULATION:

Plant to be controlled is an electric oven, the temperature of which must adjust itself in accordance with the reference or command. This is a thermal system which basically involves the transfer of heat from one section to another. In the present case, we are interested in the transfer of heat from the heater coil to the oven and leakage of heat from the oven to the atmosphere. There are three modes of heat transfer viz. conduction, convection and radiation. Heat transfer through radiation may be neglected in the present case since the temperature involved is quiet small.

Difficulties are however faced in the system due to following reasons:

(a) The temperature rise in response to the heat input is instantaneous. A certain amount of time is needed to transfer the heat by convection and conduction inside the oven. This requires a delay or transportation lag term, exp (-sT1), to be included in the transfer function, where T1 is the time lag in seconds.

(b) Unlike the equivalent electrical circuit of figure 2. The heat input in the thermal system cannot have negative sign. This means that, although, the rate of temperature rise would depend on the heat input, or the rate of temperature fall would depend on thermal resistance R. The conventional analysis methods then become inapplicable.

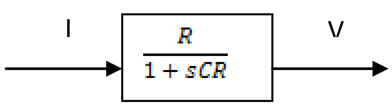

Figure 2: Electrical Analog Representation

(c) Referring to the closed loop oven control system of figure 3, it may be seen that in the steady state the error e_{ss} = lim (Tref-T) = Tref / (1+AR)

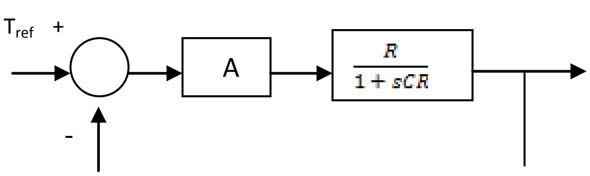

Figure 3: Closed Loop Temperature Control System

In this system, A cannot be increased excessively in an attempt to reduce error, since a large gain is likely to lead to instability due to transportation lag. Also, every time (Tref-T) becomes negative, the heat input is cut off and the oven must cool down slowly. The temperature T therefore oscillates around nominal value.

The objectives that have been realized through the above difficulty are the following:

To identify the oven parameters with the help of plant response.

To determine the transfer function of the oven including its actuator.

To investigate the response of various control tuning methodologies using MATLAB.

To compare the above responses with the controller tuning designed by using GENETIC ALGORITHM.

Genetic Algorithm:

Genetic Algorithms (G.A.s) are stochastic global search method that mimics the natural process of evolution. John Holland introduced this method in United States in the year 1970 at the University of Michigan. The continuing performance improvement of computational systems has made them very attractive for some types of optimization. The genetic algorithm starts with no knowledge of the correct solution and depends entirely on responses from its environment and evolution operators such as reproduction, crossover and mutation to arrive at best solution [1]. By starting at several independent points and searching in parallel, the algorithm avoids local minima and converging to sub optimal solutions.

4.1 Designing of Controller using Genetic Algorithm:

For design of controller for temperature control system, Genetic algorithm based Matlab program is constructed. This program used K_p, K_i, and K_d parameters as three chromosomes of each individual of a population. The parameters are tuned so that the fitness function Integral Square of Error is minimised. Its a simple GA with Roulette wheel selection, one point crossover and simple mutation. For the last iteration a result of step response is checked to determine rise time, peak overshoot, settling time and Nyquist plot. Nyquist plot is used to check relative stability of the system.

Below is the flowchart of GA

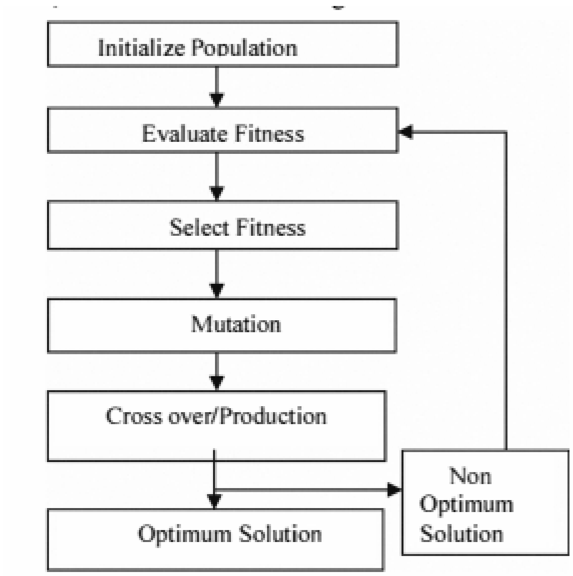

Figure 4: Flowchart of GA

Here are few plant models and their response with and without GA controller.

First order model:

$G_o(s) = \frac{5}{7s+1}$

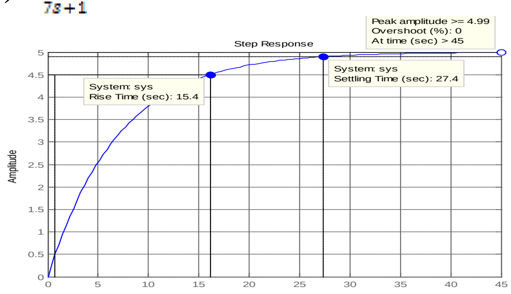

Figure 5: First order Model open loop step response

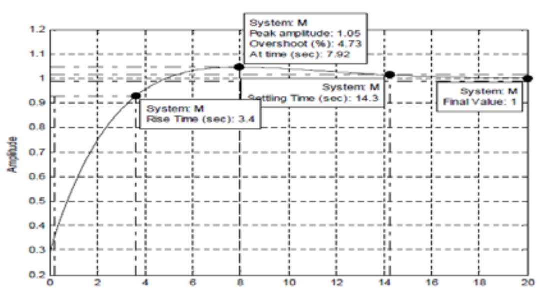

Figure 6: Step response of 1st order plant with GA controller

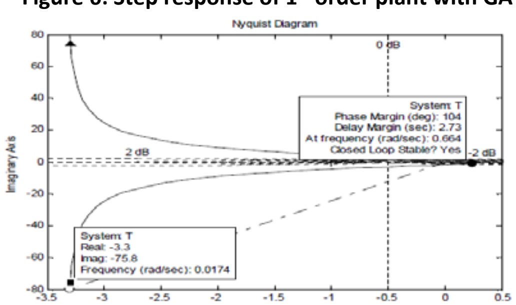

Figure 7: Nyquist Plot of 1st order plant with GA controller

Time delayed 1st order model:

$G_o(s) = \frac{2e^{-0.6s}}{3s+1}$

Using Pade's approximation $G_o(s) = \frac{-1.2s+4}{1.8s^2+6.6s+2}$

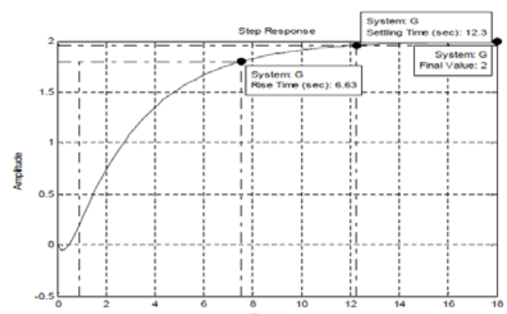

Figure 8: Open Loop Step Response of Time Delayed 1st Order Plant

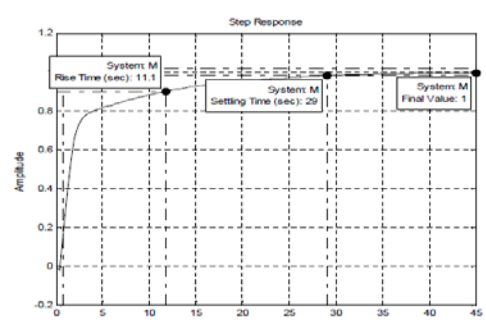

Figure 9: Step response of time delayed 1st order plant with GA

Relative degree 2 resonant model:

$$G_o(s) = \frac{1}{s^2 + 5s + 1}$$

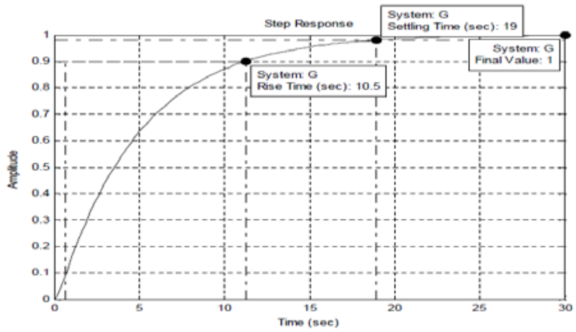

Figure 10: Open loop step response of degree 2 resonant model

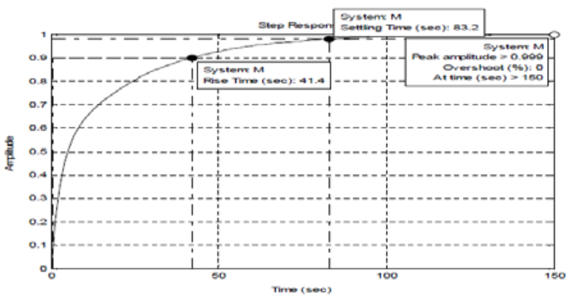

Figure 11: Step response of degree 2 resonant model with GA

Relative Degree 1 Resonant model:

$$G_o(s) = \frac{2(2.5s+1)}{s^2 + 3s + 2}$$

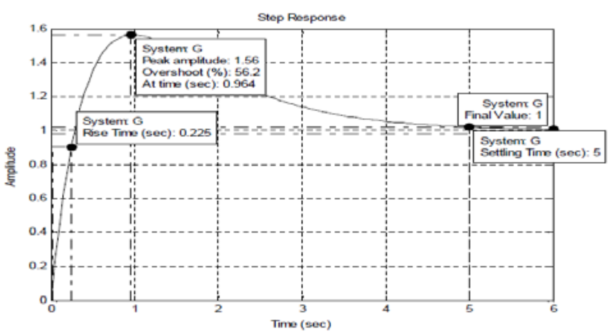

Figure 12: Degree 1 resonant model open loop step response

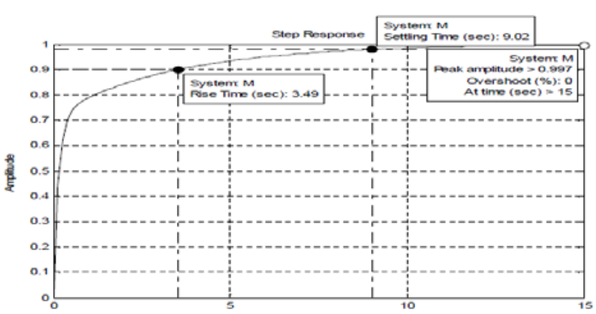

Figure 13: Step response of degree 1 resonant model with GA

3rd order plant model:

$$G_o(s) = \frac{3}{s^3 + 3s^2 + 3s + 1}$$

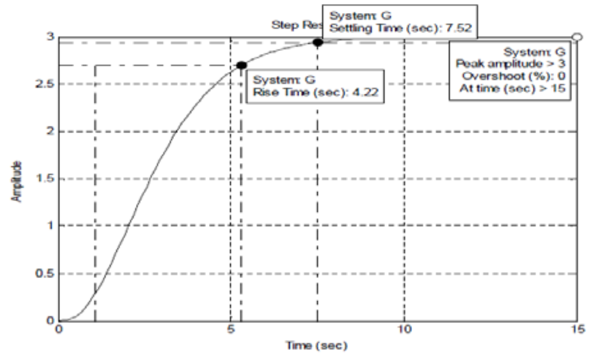

Figure 14: Open Loop response of 3rd order plant

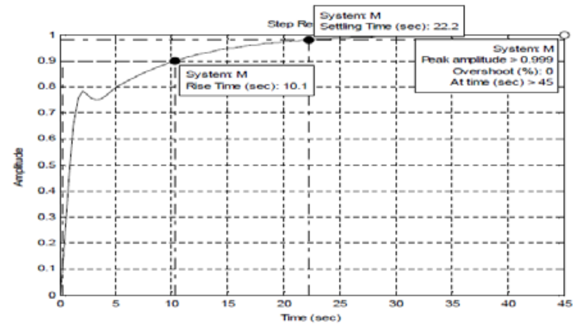

Figure 15: Step response of 3rd order plant with GA

Steam temperature of Thermal Power plant

$$G_o(s) = \frac{2(5s+1)e^{-0.1s}}{(s+1)(4s+1)}$$

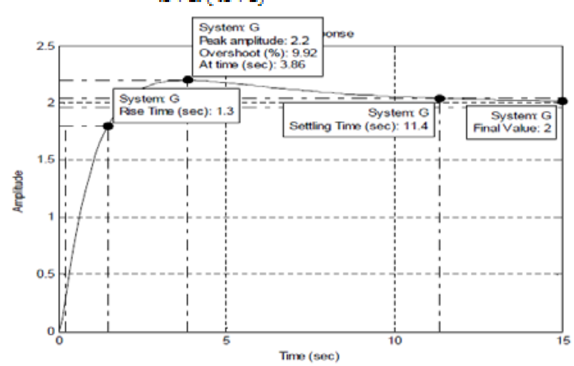

Figure 16: Open Loop step response of steam temperature plant

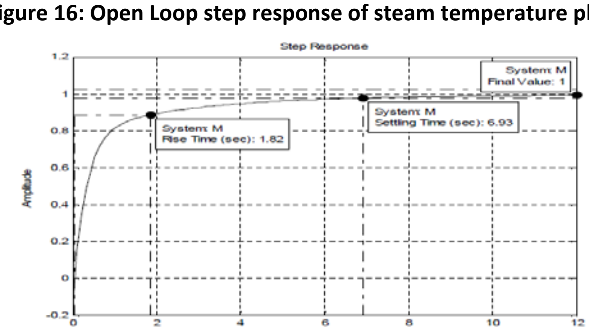

Figure 17: Step response of Steam Temperature plant with GA

Temperature control is one of the most common industrial control systems that are in operation. Oven as temperature control system is chosen.

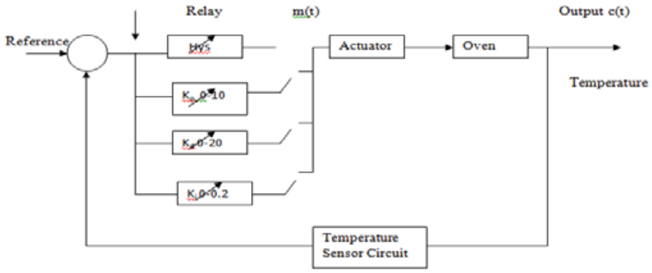

Figure 18: Block diagram of temperature control system

The transfer function identified for the temperature control system i.e. oven [4]:

$K \frac{e^{-0.41s}}{3.3s+1}$

Using Pade's Approximation:

$$G(s) = \frac{2-0.41s}{1.353s^2+7.01s+2}$$

(using K=1)

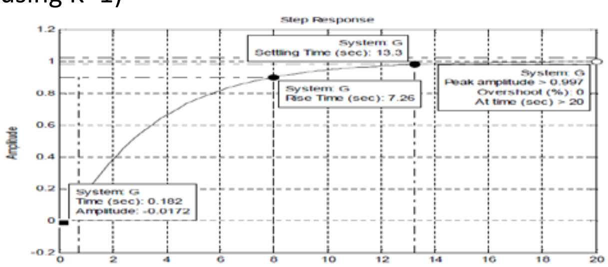

Figure 19: Open Loop Response of Temperature control system

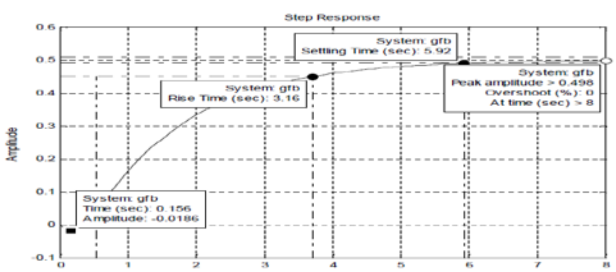

Figure 20: Closed loop response with Unity feedback of Temperature control system

Tuning the PID parameters by Zeigler-Nichols First and Second method [3]. Their step responses are as below.

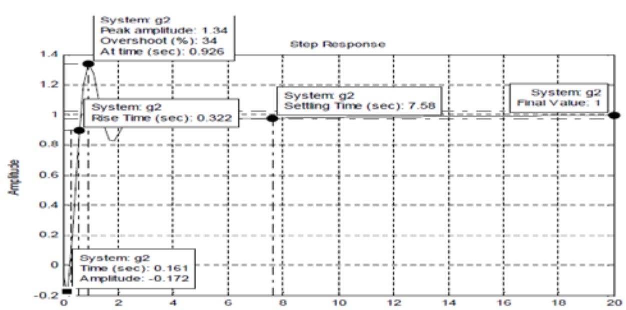

Figure 21: Step response of Zeigler Nichols First method based PID controller Tuning

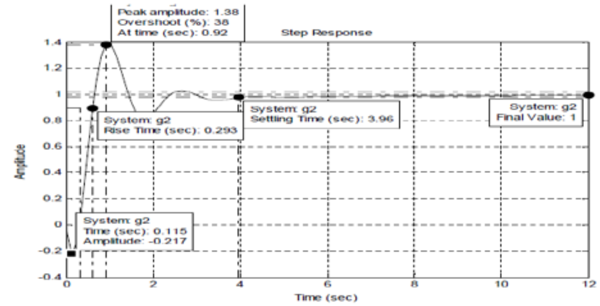

Figure 22: Step response of Zeigler Nichols Second method based PID controller tuning

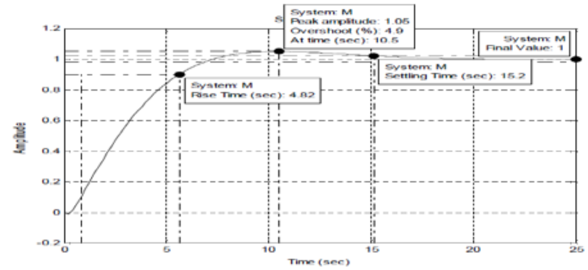

Figure 23: Step response of temperature control system with addition of GA based PID controller

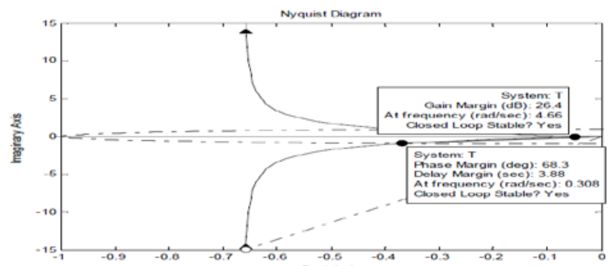

Figure 24: Nyquist plot of temperature control system with addition of GA based PID controller

1.

2. **RESULTS:**

The results obtained from the responses of various controller methods are shown in the table 4.

1. Closed loop response after applying feedback unity

2 Ziegler-Nichols first method

3. Ziegler-Nichols second method

4. Genetic algorithm response

Table 4: Comparison of responses of different methods of controller tuning

S No	Peak response, Overshoot	Settling Time	Rise time	Sag (Amplitude)
1	> 8 sec, 0%	5.92 sec	3.16 sec	Present (-0.0186)
2	0.926 sec, 34%	7.58 sec	0.322 sec	Present (-0.172)
3	0.92 sec, 38%	3.96 sec	0.293 sec	Present (-0.217)
4	10.5sec, 4.9%	15.2 sec	4.82 sec	Negligible

As it is clear from the above table that overshoots are 34% and 38% in Ziegler-Nichols first and Ziegler-Nichols closed loop method and in case of closed loop response overshoot is 0%. As in the case of Genetic Algorithm, overshoot is 4.9%, settling time is 15.2 sec and rise time is 4.82 sec, which are high as compared to Ziegler-Nichols methods but sag or time delay is negligible in the Genetic Algorithm. This shows that rise time and settling time have been increased in Genetic Algorithm response but sag or transportation lag is negligible, which is present in all three responses.

3. CONCLUSIONS & FUTURE SCOPE:

To design an optimal controller that can actually be operated on temperature control system, the thesis focuses on designing of PID controller using Genetic Algorithm, that can reduces the difficulties encountered during operation of plant. The characteristics of the PID controller tuned by genetic algorithm are compared with the results of PID controller based on Ziegler-Nichols first method and Ziegler-Nichols closed loop method for developing tuning technology on the temperature control system .It has been shown in the discussion that Genetic Algorithm based controller proved to be better as compared to other methods. As the main difficulty that came during the operation of plant was delay or transportation lag and that have been removed using the genetic algorithm based controller. In the thesis, a new genetic approach is presented to make control of systems with oscillatory modes and time delay. Optimal tuning of temperature control system is obtained. It is intended that the Genetic PID approach can be connected easily as a backup controller for other adaptive controllers. It is remarkable that the Genetic PID approach can be connected easily as a backup controller for other adaptive controllers.

In my work, Roulette Wheel selection method is used. There are various methods of selection procedure that can be used for designing of controller using Genetic Algorithm are: tournament, rank and truncation selection. One point crossover is used in Genetic Algorithm. Uniform crossover or N-point crossover can be used for designing of Genetic Algorithm. Simple mutation is used in my work. Honey bee crossover mechanism can also be used. So, with different designing technique may lead to achieve Genetic Algorithm with more improved performance.

REFERENCES:

1. Griffin Ian, Bruton Jennifer "On-Line PID Controller tuning using genetic algorithm" URL: http://www. eeng. dcu. ie/~brutonj/Reports/IGriffin_MEng_03.pdf
2. Dorf R.C. and Bishop R.H., (2001) "Modern Control Systems," Prentice–Hall Inc., 9thed., New Jersey-07458, USA, Chapters 1, 5, pp. 1-23, pp. 173-206.
3. Astrom K.J., Hagglund T., (2004) *"Revisiting the Ziegler–Nichols step response method for PID control,"* Journal of Process Control, Volume 14, Issue: 6, pp: 635–650.
4. Emine Dogru Bolat (2007) *"Implementation of Matlab-SIMULINK Based Time Temperature Control for Set Point Changes"* International Journal of Circuits, Systems and Signal Processing, Issue 1, Volume 1.
5. Erriksson L.M. and Johansson M., (2007) *"PID Controller Tuning for Varying Time-Delay Systems,"* Proceedings of 2007 American Control Conference, pp 619-625.
6. Manke B.S., *"Linear Control Systems."* Khanna Publishers, ISBN: 81-7409-107-6, 2002.
7. Nagaraj B. (2010), *"A Comparative study of PID Controller Tuning Using GA, EP, PSO and ACO"* 978-4244-7770-8/10IEEE.
8. Pillai Reshmi P., Jadhav Sharad P., Patil Mukesh D (2013) *"Tuning of PID Controllers using Advanced Genetic Algorithm"* IJACSA Special Issue on Selected

papers from International Conference & Workshop On Advance Computing 2013.

9. Bansal Ruchi and Bhushan Bharat, (2014) *"Optimum Gain Settings of PID Controller using Mutli-Objective Genetic Algorithm"* International Journal of Applied Engineering Research, Volume 9, Number 6, pp: 679-686