Industrial Science
Vol.1,Issue.3/Feb. 2014 **ISSN** : 2347-5420

Research Papers

IMPLEMENTATION OF GENETIC ALGORITHM TO TEMPERATURE CONTROL SYSTEM

Pooja Khatri and Manjeet Dalal

Assistant Professor,EEE Deptt.Department of Electrical & Electronics Engineering H.C.T.M. Kaithal Haryana
Assistant Professor,EEE Deptt Department of Electrical & Electronics Engineering H.C.T.M. Kaithal Haryana

Abstract

During the last years the use of intelligent strategies for tuning of controller has been growing. The evolutionary strategies have won an important place, thanks to their flexibility. The first attempt to automate the tuning of controllers was based on the time response of a process, but this approach had the drawback of requiring a lot of user interaction. A very important advancement was made when it was decided to use the frequency response of a process instead of its time response, in this way a bigger degree of automation was obtained. Optimal tuning plays on important role in operations or tuning in the complex process such as the temperature of an oven used in many industrial applications. Transfer of heat inside an oven requires a delay or transportation lag. So, this delay or transportation lag is overcome with the help of controller tuning using Genetic Algorithm. A comparison approach is also made with the other methods of tuning like Ziegler-Nicholas. Genetic algorithm is powerful software tool for obtaining accurate results. It works same as the combination of genes in biological processes. Any temperature control system like oven take certain time to heat up initially, But with the help of genetic algorithm this time taken to heat up can be reduced. And the oven can be made to start instantly without wasting time. It is very difficult to achieve an optimal gain like this as up to the present time the gain of the controller has to be manually tuned by hit and trial. Thus this paper describes the Genetic algorithm approach that would certainly reduce manual effort and give accurate result.

KEYWORDS:
Genetic Algorithm , intelligent strategies , evolutionary strategies .

I.INTRODUCTION

Plant

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

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 1. 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.

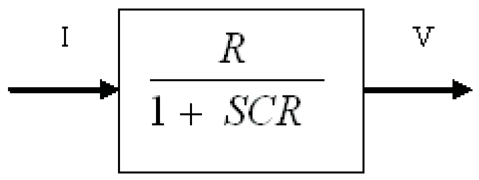

Figure 1 Electrical Analog Representation

(C) Referring to the closed loop oven control system of figure 2, it may be seen that in the steady state the error $e_{ss} = \lim_{t\to\infty} (T_{ref} - T) = T_{ref} / (1+AR)$

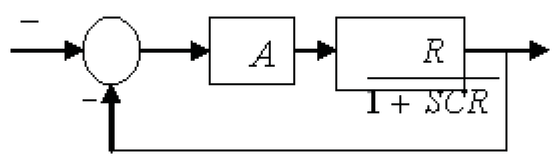

Figure 2 Closed Loop

Problem Formulation

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

1.To identify the oven parameters with the help of plant response.
2.To determine the transfer function of the oven including its actuator.
3.To investigate the response of various control tuning methodologies using MATLAB.
4.To compare the above responses with the controller tuning designed by using GENETIC ALGORITHM.

2.Temperature Control System

Temperature control is one of the most common industrial control systems that are in operation. This equipment is designed to expose the learner to the intricacies of such a system in the friendly environment of a laboratory, free from disturbances and uncertainties of plant prevalent in an actual process. The temperature data may be obtained manually, thus avoiding expensive equipment like an X-Y recorder. A solid state temperature sensor converts the absolute temperature information to a proportional electric signal. The reference and actual temperatures are indicated in degree Celsius on a switch selectable digital display. In the analysis of any control system is to derive its mathematical model. The various blocks are shown in figure.

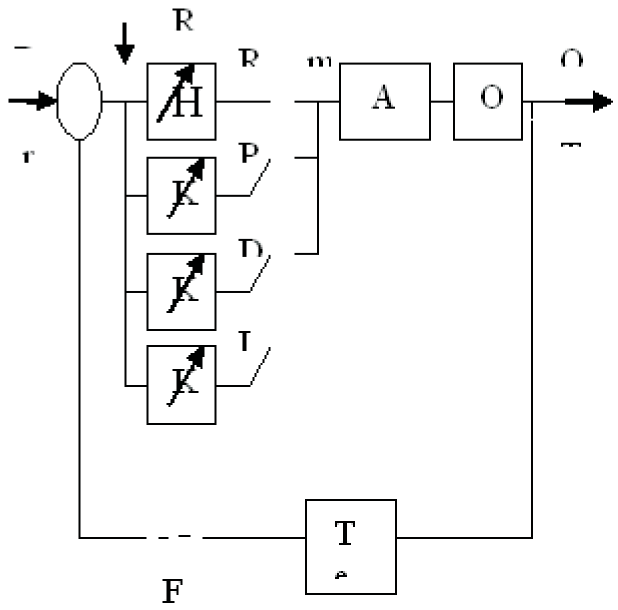

Figure3 Block Diagram of the Temperature Controller

3.Experimental Work

Identification of Oven Parameters

Plant identification is the first step before an attempt can be made to control it. In the present case, the oven equations are obtained experimentally from its step response. In the open loop testing, the oven is driven through the P-amplifier set to its maximum gain10. The input to the amplifier is adjusted through reference potentiometer.

The constant for oven plus controller is given by

K= Oven temperature at steady state/ Input (volt)

Hence, $K = \frac{49}{50} = 0.99 \approx 1$

T_1, T_2 as measured from the open-loop graph is:

$T_1 = 3.3$ sec; $T_2 = 0.41$ sec

Transfer function can be written as:

$$\text{Transfer Function} = \frac{Ke^{\;T_2 s}}{T_1 s \quad 1}$$

So, transfer function = $K\frac{e^{\;0.41s}}{3.3s \quad 1}$

Using Pades' Approximation $e^{\;0.41s} \quad \frac{2 \quad 0.41s}{2 \quad 0.41s}$

$$\text{Hence } G(s) = \frac{K\ 2 \quad 0.41s}{2 \quad 0.41s \quad 3.3s \quad 1}$$

Here K = 1

$$\text{So, } G(s) = \frac{2 \quad 0.41s}{1.353s^2 \quad 7.01s \quad 2}$$

Open Loop Response

Open loop response of the plant transfer function is shown in figure 4.

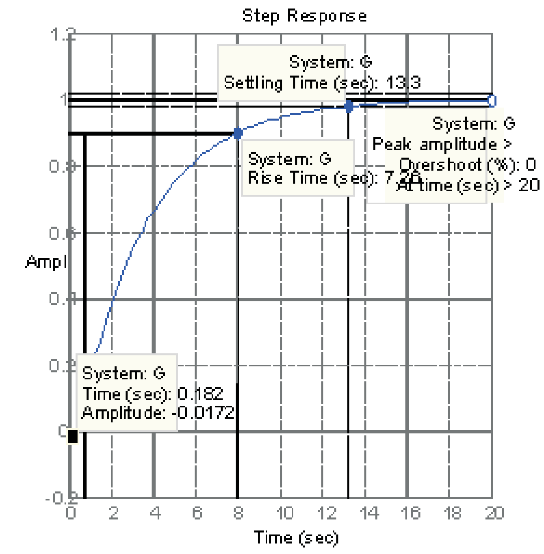

Figure 4 Open Loop Response of Temperature Control System

Closed Loop Response

Closed loop response of the plant with unity feedback is as shown in figure 5.Rise time, settling time, peak overshoot are also shown in the figure.

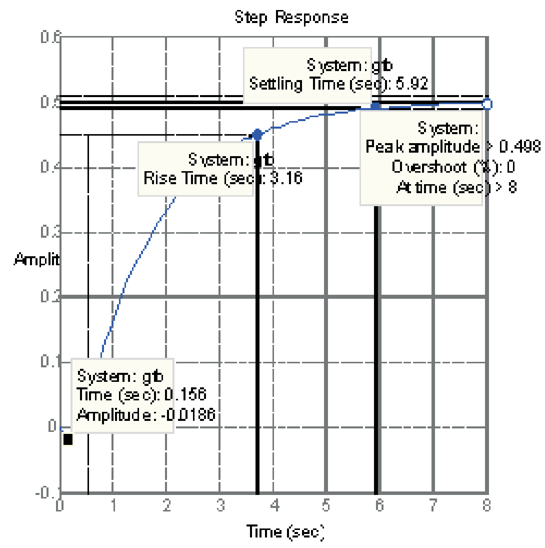

Figure 5 Closed Loop Response with Unity Feedback of Temperature Control System

Zeigler-Nichols First Method

The results of PID tuning using Ziegler-Nichols method are as shown in figure 6. Here the values of Kp, Ki and Kd acc. to Ziegler-Nichols first method are as:

$K_p = 9.65$
$K_i = 1.2195$
$K_d = 0.205$

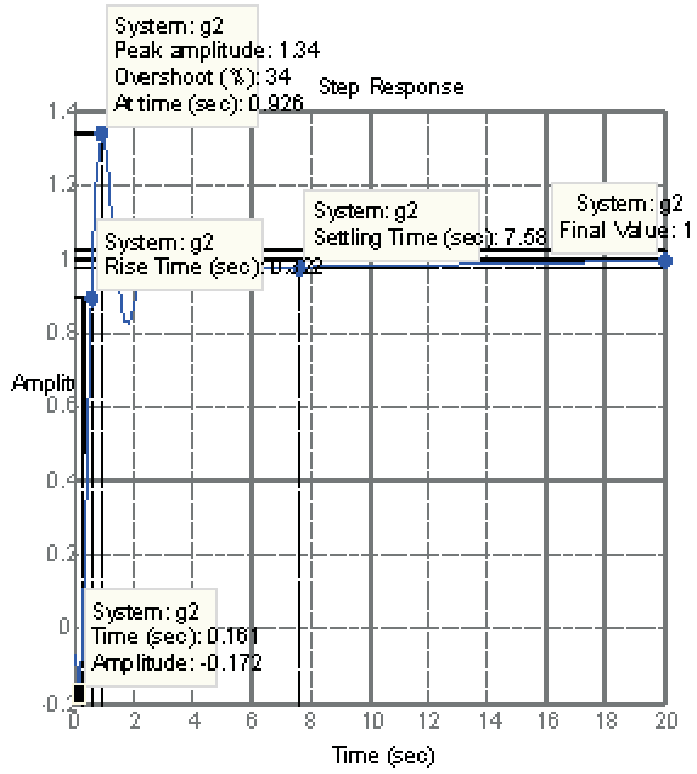

Figure 6 Step Response of Ziegler-Nichols based PID Controller Tuning

Ziegler Nichols Second Method

The results of PID tuning using Ziegler-Nichols method are as shown below in figure 7. Here the values of Kp, Ki and Kd acc. to Ziegler-Nichols second method are as:

$K_p = 9.6585$
$K_i = 1.666$
$K_d = 0.15$

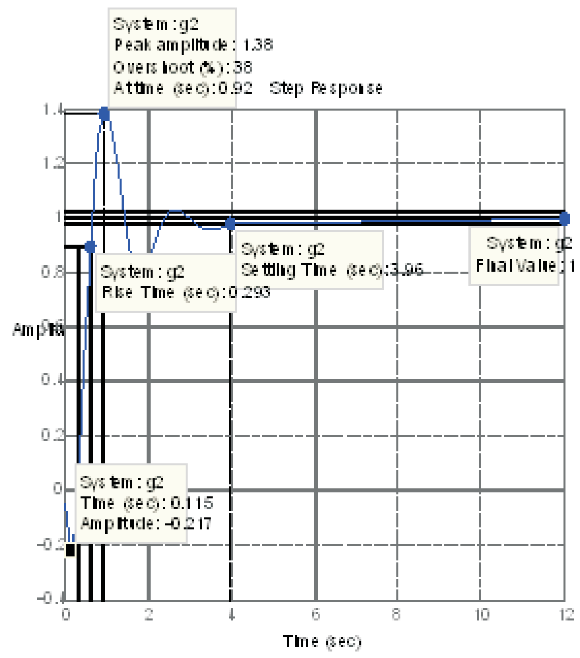

Figure 7 Step Response of Ziegler-Nichols Closed Loop based PID Controller Tuning

Genetic Algorithm Response

The step response for a time delay model is as shown above in figure 8, due to the exponential factor a dip is observed in the response. When a GA tuned PID controller is used then the step response of the closed loop system is as given in figure 4.31.

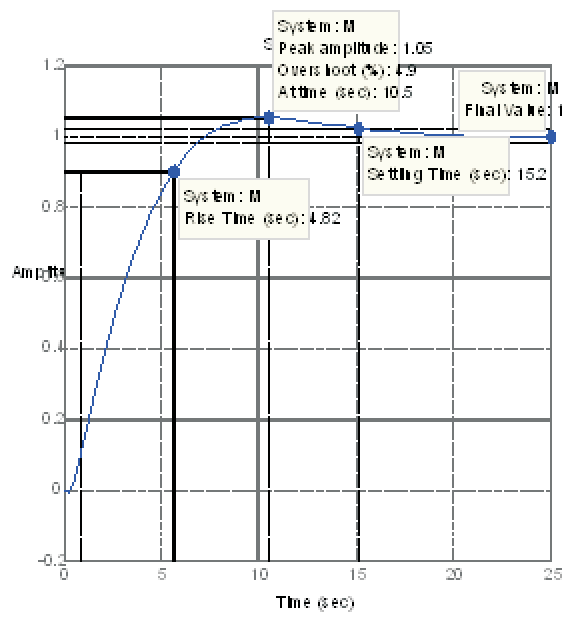

Figure 8 Step Response of Temperature Control plant with the addition of GA based PID Controller

Nyquist Plot

Nyquist plot of the transfer function with addition of controller is shown in figure 9.It shows the relative stability of the plant. Points mentioned in the graph shows the stability in that region.

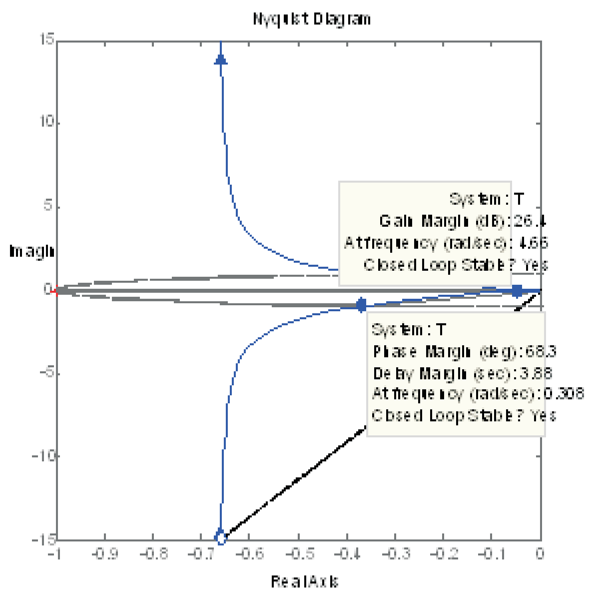

Figure 9 Nyquist Plot of Temperature Control Plant with addition of GA based PID Controller

4.RESULT

The results obtained from the responses of various controller methods are shown in the table as given below:

Method	Peak response, overshoot	Settling time	Rise time	Sag(Amplitude)
Closed loop response	> 8 sec,0%	5.92 sec	3.16 sec	Present(-0.0186)
Ziegler Nicho first method	0.926 sec,34%	7.58 sec	0.322 sec	Present(-0.172)
Ziegler-Nichols second method	0.92 sec ,38%	3.96sec	0.293 sec	Present(-0.217)
Genetic algorithm response	**10.5,4.9 %**	**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.

5.CONCLUSION

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.

6. REFRENCES

1.Aldo Balestrino, et al., (2005), "Performance Indices and Tuning in Process Control".
2.Brian D.O., Anderson, (1992), "Controller Design: Moving from Theory to Practice."IEEE Control systems, pp 16-25
3.C.Goodwin, et al., "Control system design." Prentice Hall, ISBN: 8120321197.
4.Dong Hwa Kim, (2003), "Comparison of PID Controller Tuning of Power Plant using Immune and Genetic Algorithm."CIMSA 2003 Integrated Symposium on Computational Intelligence for Measurements and Applications, Switzerland, 29-31 July 2003, pp169-174
5.Goldberg D., (1989), "Genetic Algorithms in Search, Optimization and Machine Learning." Addison Wesley, ISBN: 0201157675.
6.Hagglund T, and. Astrom K.J., (2000), "Supervision of Adaptive Control algorithms", Automatica.Vol. 36, (2000) 1171-1180.
7.I.J.Nagrath and M.Gopal, "Control System Engineering." New Age international, ISBN: 8122411924.
8.J.C.Basilio and S.R.Matos (2002), "Design of PI and PID Controllers with Transient Performance Specification." IEEE Transaction on Education, Vol.45, No.4, 364-370
9.Jen-Yeng Chen (1999), "An Integration Design Approach in PID Controller."NSC-87-2218-E-157-004 National Science Council, Republic of China, Under Construct NSC, pp901-907
10.Katusuhiko Ogata, "Modern Control Engineering." Prentice Hall, ISBN: 812032045X.pp 682-686
11.Lasse M Erriksson and Mikael Johansson (2007), "PID Controller Tuning for Varying Time-Delay Systems." Proceedings of 2007 American Control Conference, New York City USA, pp 619-625
12.Mandal A.K., "Introduction to Control Engg. Modelling, Analysis and Design." New Age International Publisher 2006,ISBN:81-224-1821-X
13.Manke B.S., "Linear Control Systems." Khanna Publishers, 2002 ISBN: 81-7409-107-6.
14.Marco Antonio Paz-Ramos, et al., (2007), "Proportional -Integral –Derivative controllers tuning for unstable and integral processes using GA.",pp532-539
15.Paul H.lewis and Chang Yang, "Basic control system engineering." Prentice Hall, ISBN: 0137444346.