Research paper on Comparison of various PID Controllers Tuning Methodologies for Heat Exchanger Model

Sumit[1], Ms. Kajal[2]

[1]Student, Department of Electrical Engineering, R.N College of Engineering, Rohtak, India
[2]Assistant Professor, Department of Electrical Engineering, R.N College of Engineering, Rohtak

ABSTRACT

In the past decades, control system has played a very important role in the development and advancement of modern civilization. In present scenario almost every aspect of our day-to-day activities is affected by some type of control systems. This paper compares the step response of a heat exchanger model using various techniques viz. Ziegler- Nichols PID controller (Method II), Cohen-Coon Method, Tyreus-Luyben and Approximated M-constrained Integral Gain (AMIGO) methods. A First-Order plus time delay (FOPTD) system is very common in modern day technology. MATLAB simulations are carried out and responses are obtained for PID and Fuzzy Logic Controller.

Key Words: PID controller, Ziegler-Nichols technique, Cohen-Coon, Tyreus-Luyben, AMIGO.

I. INTRODUCTION

Proportional Integral Derivative controllers (PID) [1] play a vital role in control and automation industry. Even after hundreds of years PIDs are not replaced, but their tuning has been always remaining a contradictory part. Since almost every process exhibit time delay therefore tuning of the PIDs was never an easy task. We know that any control system when involves the movement of material or information it encounters time delay [2]. The presence of time-delay thus complicates the whole system. Since most physical, chemical, mechanical systems are affected by temperature, so it is most often measured quantity. There are a number of controlling techniques used to enhance the performance of controllers. In this paper various techniques viz. Ziegler-Nichols (oscillations method), Tyreus-Luyben, Cohen-Coon Method and Approximated M-constrained Integral Gain (AMIGO) methods are compared using MATLAB simulation . In the end part various results are compared qualitatively. Heat exchanger model of a chemical reactor is considered for simulation of various techniques.

II. SYSTEM MODELING

A chemical process for heating consists of a chemical reactors and a heat exchanger system. The heat exchanger [3] heats up the fluid to a desired value by using superheated steam. Different assumptions have been considered regarding this process. The first assumption is that fluid level remains constant. The second assumption is that heat storage capacity of the insulating wall is negligible.

The First Order plus Time Delay (FOPTD) System of the above model is described below.
The first order plus time delay system has the following form of mathematical model [4] and it is described using figure 2 which is a part of system identification using a step change in valve voltage [4]:

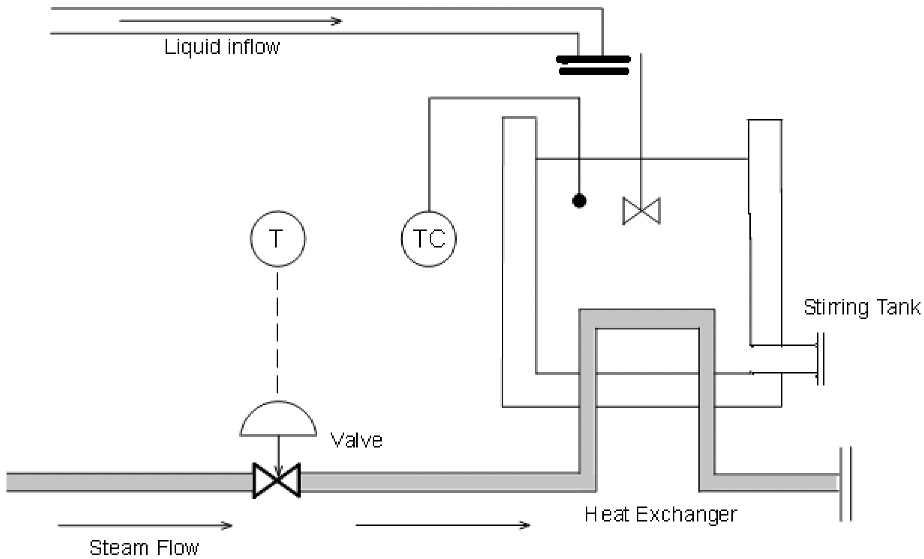

Fig. 1: Heat Exchanger Model

$$G(s) = \frac{K}{(Ts + 1)} e^{-\tau s}$$

From fig 2
t1 = 21.8; t2 =36.0;
Time constant (T) = 3/2*(t2 - t1)
Time delay = t2 – T
Time constant (T) = 21.3
Time Delay (L) = 14.7

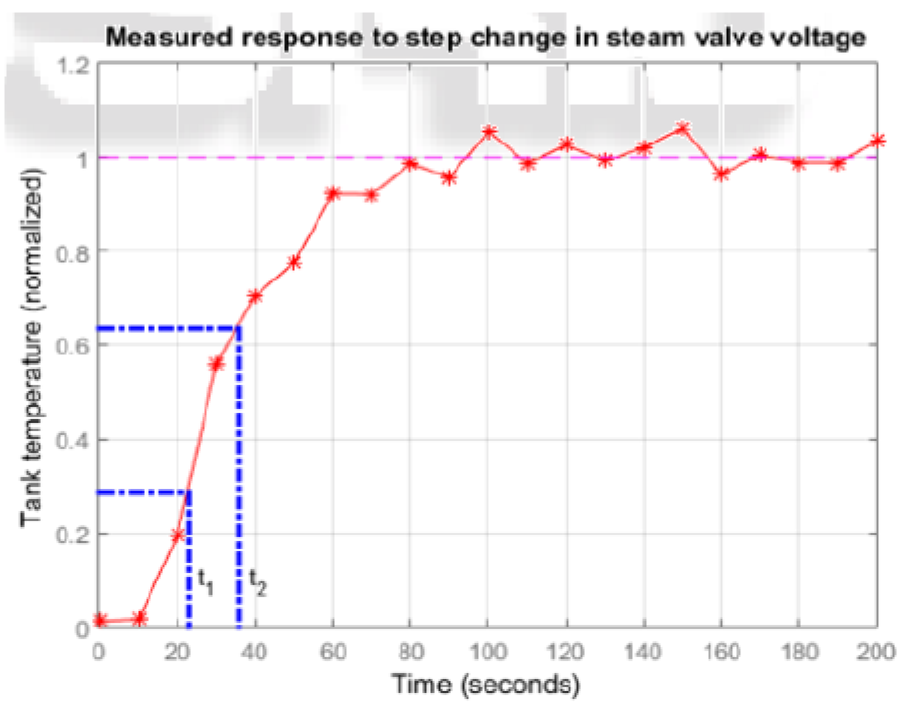

Fig. 2: step change in steam valve voltage (Heat exchanger model

Where, t is time delay

T - Time constant and
K- gain

From the experimental data the transfer function [4] of the process model is

$$M(s) = \frac{e^{-14.7s}}{(21.3s + 1)}$$

III. CONTROLLER DESIGN

Different types of controller which can be applied to temperature control process are listed below:

- Ziegler-Nichols (method II) PID tuning
- Tyreus-Luyben method
- Cohen-Coon Method
- AMIGO method

A. Ziegler-Nichols (method II) PID tuning

Ziegler and Nichols published in 1942 a paper where they described two methods for tuning the parameters of P-, PI- and PID controllers. These two methods are the Ziegler-Nichols' open loop method and the Ziegler-Nichols' closed loop method [5] [6]. The present paper describes the closed-loop method.

The tuning procedure is as follows:

Step I: Find out the sign of process gain.

Step II: Introduce proportional control.

Step III: Raise proportional gain until sustained periodic oscillation occurs.

Step IV: Note down ultimate gain Ku (gain at which oscillation occurs) and ultimate period Pu (distance between two consecutive crests)

Step V: Calculate control parameters as prescribed by Ziegler and Nichols

Table 1: Ziegler Nichols parameter for PID controller

	Kc	Ti	Td
P	Ku/2		
PI	Ku/2.2	Pu/1.2	
PID	Ku/1.7	Pu/2	Pu/8

On simulation we get

Ku=2.9521, Pu=48.2

Therefore, by calculation using above table we get

Kp=1.77, Ki=0.0735 ,Kd=10.672

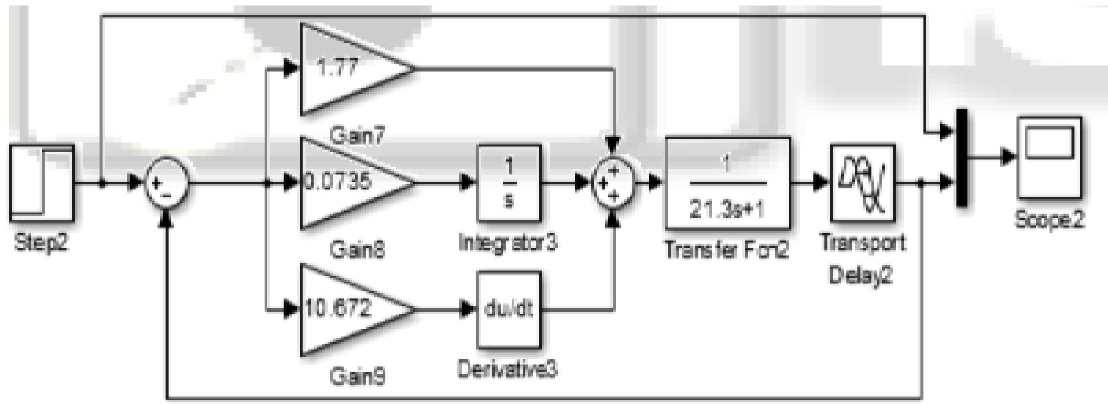

Fig. 3: Ziegler-Nichols SIMULINK model

B. Tyreus-Luyben Method

This method was proposed byB.DTyrus and W.I Luyben in 1997. Tyreus-Luyben method [8] is similar to the Ziegler-Nichols closed loop method as discussed above. The procedure to determine ultimate gain Ku and ultimate period Pu is same until step IV. Table for calculation of parameters is given below.

Table 2 Tyreus-Luyben parameter for PID controller

	Kp	Ti	Td
PI	Ku/3.2	2.2 Pu	
PID	Ku/2.2	2.2 Pu	Pu/6.3

On calculation Tyreus-Luyben PID

Kp=1.342
Ki= 0.0557
Kd=8.086

Since PID term is given by :Kp + Kp/Ti + Kp*Td

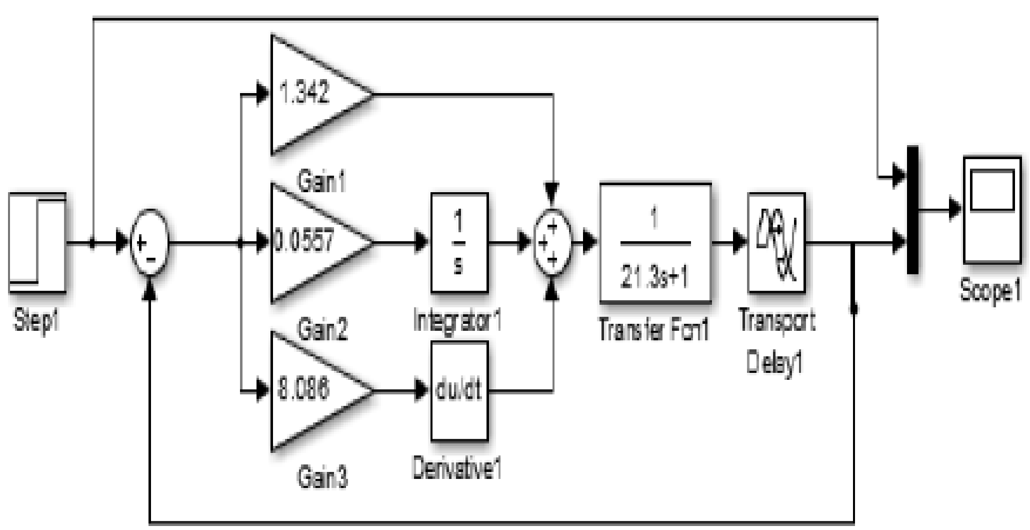

Fig 4- Tyreus-Luyben SIMULINK model

C. Cohen-Coon Method

The Cohen-Coon method [7] is a more complex version of the Ziegler-Nichols method. This method is more sensitive than the Ziegler-Nichols as it gives quicker response than Ziegler- Nichols method. It was developed almost a decade later than Ziegler-Nichols method in 1953. The table for calculation of various parameters is given below.

Table 3- Cohen-Coon parameters

Type	Kp	Ti	Td
P	$\frac{1}{K}\frac{T}{\tau}\left(1+\frac{\tau}{3T}\right)$		
PI	$\frac{1}{K}\frac{T}{\tau}\left(0.9+\frac{\tau}{12T}\right)$	$\tau\frac{(30+3\tau/T)}{(9+20\tau/T)}$	
PID	$\frac{1}{K}\frac{T}{\tau}\left(\frac{4}{3}+\frac{\tau}{4T}\right)$	$\tau\frac{(32+6\tau/T)}{(13+8\tau/T)}$	$\tau\frac{4}{(11+2\tau/T)}$

On calculation C-C PID gives following values
Kp=2.207, Ki=0.0757, Kd=10.672

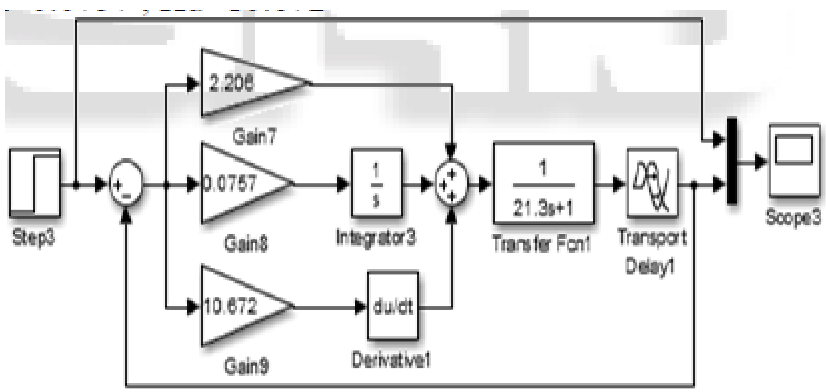

Fig. 5: Cohen-coon SIMULINK model

D. Approximated M-Constrained Integral Gain Optimization (AMIGO) Tuning Method:

Approximated M-constrained Integral Gain Optimization (AMIGO) [9] tuning method was developed by K.J Astrom and T. Hagglund in 2004. The various parameters of the method are shown in table.

Table 4 AMIGO parameter for PID controller

	Kp	Ti	Td
PID	$\frac{1}{K}\left(0.2+0.45\frac{T}{L}\right)$	$L\frac{(0.4L+0.8T)}{(L+0.1T)}$	$\frac{(0.5LT)}{(0.3L+T)}$

On calculation we get

Kp = 0.852
Ki = 0.0426
Kd = 5.187

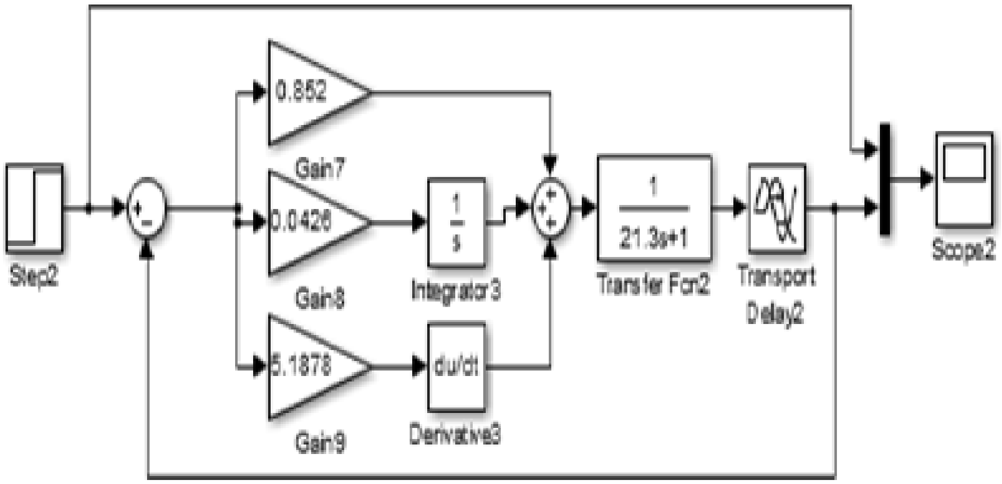

Fig 6: AMIGO SIMULINK MODEL

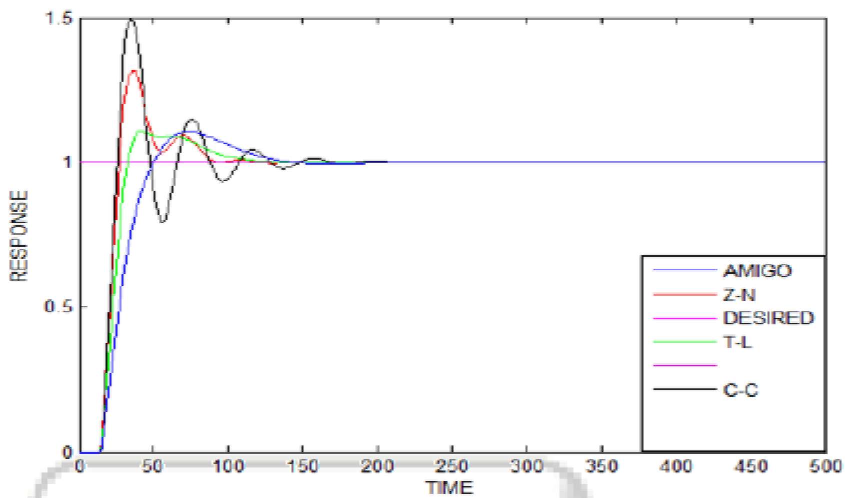

Fig 7: Comparison of Z-N, C-C, T-L and AMIGO methodologies

Table 5: Comparison Of Various Parameters For Different Controllers

	Z-N	T-L	C-C	AMIGO
PEAK AMPLITUDE	1.31	1.11	1.495	1.10
OVERSHOOT	31.6%	11.2%	49.09%	10.4%
SETTLING TIME	85.32	100	139	121.98
RISE TIME	9.91	13.21	5.52	24.88

CONCLUSION

In this paper the response of First-order plus Time-delay (FOPTD) process is compared using Ziegler-Nichols (method II),Cohen-Coon, Tyreus-Luyben and Approximated M-constrained Integral Gain Optimization (AMIGO) method. According to the calculations if system requires faster transient response Cohen-Coon method is better amongst all but it also gives a large overshoot. AMIGO method gives minimum overshoot in this case but it's settling time is very high. Therefore finally Tyreus-Luyben method gives tolerable overshoot and its settling time is also not very large comparatively.

REFERENCES

[1]. Yingjian Xu, Dept. of Automation, Shanghai Jiao Tong Univ., Shanghai, China; A simple PID controller tuning strategy for first order plus dead time model electronics, Communications and Control(ICECC), 2011.

[2]. AndriMirzal, “Stability Analysis and Compensation of Time Delays in Analog Control Systems” International Journal of Control and Automation Vol. 5, No. 4, December, 2012

[3]. Xinye Wang, Generalized exergy for finite-time heat transfer Processes, Transportation, Mechanical, and Electrical Engineering (TMEE), 2011 International Conference on 16-18 Dec. 2011, Page(s):1036 – 1039

[4]. Matlab: Control System Toolbox / Temperature Control in a Heat Exchanger.

[5]. Susmita Das, Ayan Chakraborty, Jayanta Kumar Ray, “Study on Different Tuning Approach with Incorporation of Simulation Aspect for Z-N (Ziegler-Nichols) Rules”, International Journal of Scientific and Research Publications, Volume 2, Issue 8, August 2012 1 ISSN 2250-31537.

[6]. Bhaskar Lodh Simulink Based Model for Analysing the Ziegler – Nichols Tuning Algorithm as applied on Speed Control of DC Motor International Journal of Advanced Research in Electrical, Electronics and Instrumentation

[7]. N. Gireesh, Dr. G. Sreenivasulu, “Comparison of PI Controller Performances for a Conical Tank Process using different tuning” Published in: Advances in Electrical Engineering (ICAEE), 2014 International Conference on Date of Conference: 9-11 Jan. 2014 Page(s):1 – 4 INSPEC Accession Number: 14384490 DOI:10.1109/ICAEE.2014.6838426 Publisher:IEEE

[8]. Tyreus B D W I Luyben, Tuning of PI controllers for integrator/dead time processes, ind.eng.chem. Res., 31, 2625-2628(1992).

[9]. K.J. _Astrom, T. Hagglund , “Revisiting the Ziegler–Nichols step response method for PID control” Journal of Process Control 14 (2004) 635–650.

[10]. Vila Nova, PID Controller Tuning Rules for Robust step response of First-Order-Plus-Dead-Time models, American Control Conference, 2006 on 14-16 June 2006, Minneapolis, MN

[11]. Khan, S. (2014). Modelling and temperature control of heat exchanger process. International Journal for Research in applied science and engineering technology.