

Comparison of Ziegler-Nichols, Cohen-Coon and Fuzzy Logic Controllers for Heat Exchanger Model: A Review

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Abstract

First-Order plus Delay-Time (FOPDT) model approximation can be carried out through either a kind of model reduction approach or a kind of system identification approach. In industrial applications heat exchanger plays a very vital role. In heat exchanger model controlling temperature range and achieving a desired temperature is a very complicated process. We can use different controlling techniques to achieve desired temperature. In this paper comparison of step response of Ziegler-Nichols PID controller (Method II), Cohen-Coon Method and Fuzzy logic controller has been developed for a heat exchanger model. A First-Order plus time delay system is very common in modern industry. For this particular model MATLAB simulations are carried out and responses are obtained for PID and Fuzzy Logic Controller.

Keywords: Cohen-Coon, Fuzzy Logic Controller, PID Controller, Ziegler-Nichols Technique.

Many industrial processes have the time delay effect introduced due to measurement delay. This delay causes unnecessary instability in whole system. There are a number of ways through which nonlinearity can be present in the system. 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. PID controllers [1] are very commonly used in control industry. There are a number of controlling techniques used to enhance the performance of controllers. In this paper the first part comprises of heat exchanger model and its First-Order plus Delay-time (FOPDT) approximation. The middle part consists of simulation of various techniques Ziegler-Nichols (oscillations method), Cohen-Coon Method Fuzzy logic controller. In the end part various results are compared qualitatively.

I. Introduction

Any control system when involves the movement of material or information it encounters time delay.

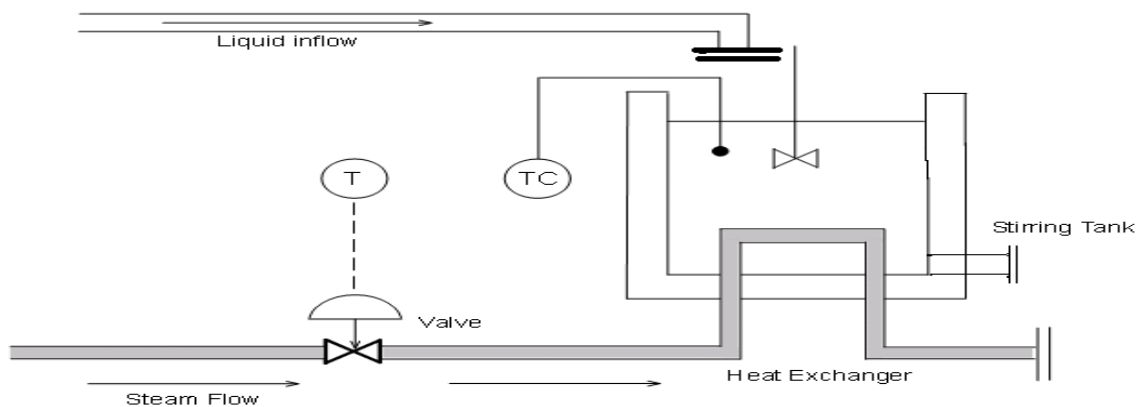


Figure 1: Heat Exchanger Model

II. System Modeling

A chemical process for heating consists of chemical reactors and a heat exchanger system. The heat exchanger [4] heats up the fluid to a desired value by using superheated steam. Different assumptions have been considered regarding this process. First assumption is that, fluid level remains constant. The second assumption is that, heat storage capacity of the insulating wall is negligible.

The above model can be expressed as First Order plus Time Delay (FOPDT) System. The first order plus time delay system has the following form of mathematical model:

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

Where τ is time delay, T is Time constant and K is represents gain of the system. From the experimental data the transfer function [4] of the process model [4] is given by

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

III. Controller Design

Different types of controller tuning techniques that can be applied to temperature control process are listed below:

- A. Ziegler-Nichols (method II) PID tuning
- B. Cohen-Coon Method
- C. Fuzzy Logic controller

A. Ziegler-Nichols (method II) PID Tuning

PID controllers are integral part of the control industry. Earlier trial and error tuning was used to tune these PID controllers until Ziegler and Nichols published a paper in 1942 where they described two methods for tuning the parameters of P-, PI- and PID controllers. These two methods are the Ziegler-Nichols' closed loop method [5] [6] and the Ziegler-Nichols' open loop method. 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 Z-N PID gives following values

$K_u=2.9521$, $P_u=48.2$

Therefore, by calculation using above table we get

$K_p=1.77$, $K_i=0.0735$, $K_d=10.672$

Since, we know that

PID controller is represented by

$K_p + K_p/T_i + K_p * T_d$

Where

$K_p/T_i = K_i$ and $K_p * T_d = K_d$

B. Cohen-Coon Method

A decade after Ziegler-Nichols published a paper based upon PID tuning Cohen-coon developed another tuning method. The Cohen-Coon method [7] is a more complex version of the Ziegler-Nichols method. The method is similar to the Ziegler- Nichols method but the difference comes with the fact that Cohen-Coon provides the faster rise time.

Table 2: Cohen-Coon Parameters

Type	K_p	T_i	T_d
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

$K_p=2.207$

$K_i=0.0757$,

$K_d=10.672$

C. Fuzzy Logic Controller

The concept of Fuzzy Logic was conceived by Lotfi Zadeh, a professor at the University of California at Berkley, and presented not as a control methodology, but as a way of processing data by allowing partial set membership rather than crisp set membership or non-membership. This approach to set theory was not applied to control systems until the 70's due to insufficient small-computer capability prior to that time. Usually fuzzy logic controller performs better

than PID controllers [10] for system exhibiting time delays in thermal models [11]. Fuzzy logic controllers based on human approach. This method is very frequent in European countries. A rule-based system [8] [9] is characterized by a set of rules that were defined by antecedents and consequents. Inference rules were made by a simple logic.

A fuzzy logic controller has four main components as shown in Figure:

- a) Fuzzification
- b) Inference engine
- c) Rule base
- d) Defuzzification

E→	NL	NM	NS	Z	PS	PM	PL
CE↓							
NL	VL	VL	VL	VL	VL	VL	L
NM	VL	VL	VL	VL	VL	L	L
NS	VL	VL	MED	L	L	VL	VL
Z	VL	L	L	MOD	MED	MED	MOD
PS	MED	MED	MOD	MOD	H	H	VH
PM	H	H	H	VH	VH	F	F
PL	VH	VH	F	F	F	F	F

Figure 2: Rule base for Fuzzy Logic Controller

E represents error and CE represents change in error in the rule base table. In the above table NL- Negative Large, NM- Negative Medium, NS- Negative Small, Z- Zero, PS- Positive Small, PM- Positive Medium, PL- Positive Large. Further VL stands for Very Low, L- Low, MED- Medium, MOD- Moderate, H- High, VH- Very High, F- Full. Fuzzification [12] is a process in which, crisp

variables are converted into linguistic variables. The membership functions are divided into a range. Rule base plays a very important role. They are in form of IF-THEN statements. Consider a rule If (temperature is “cold”) then (heater is “high”) Defuzzification generates a crisp numeric value. The defuzzified output is fed to the plant.

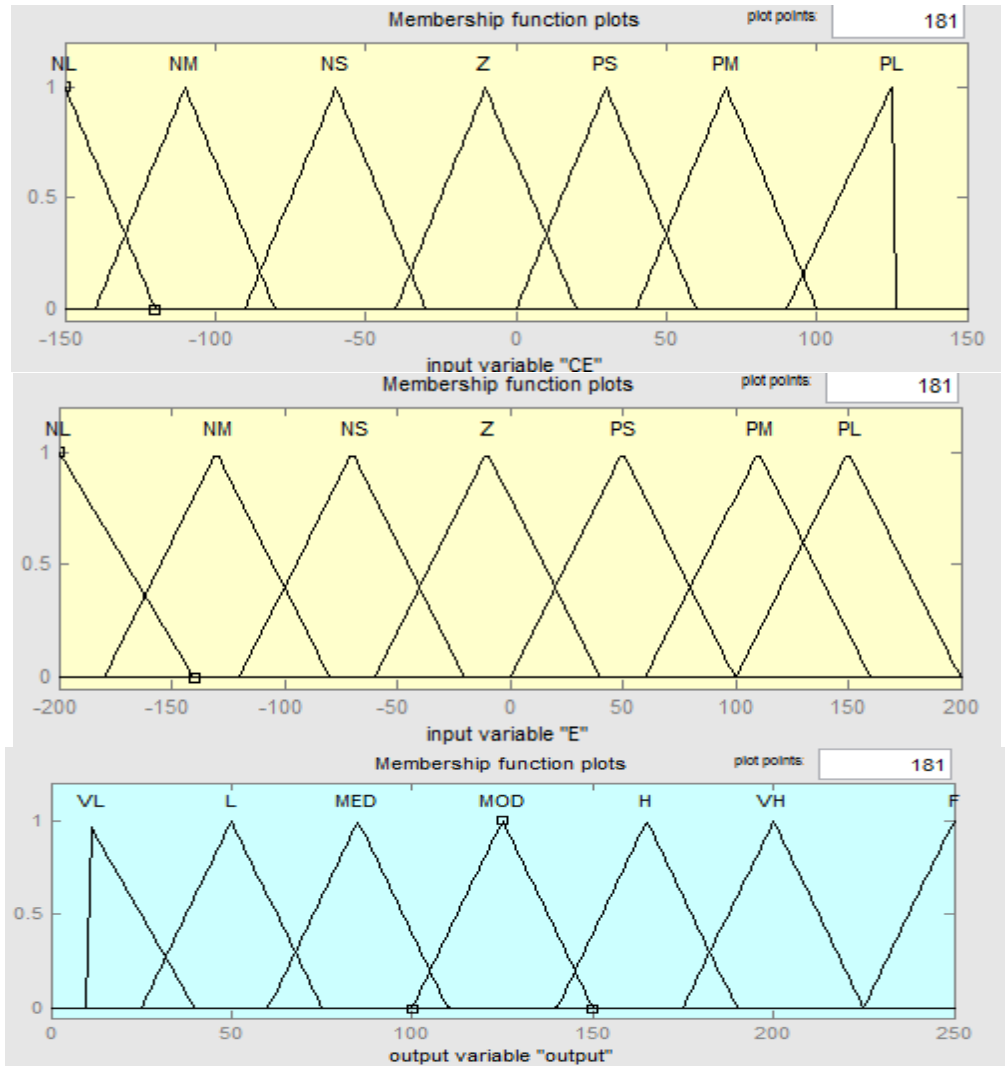


Figure 3: Membership Function Plots

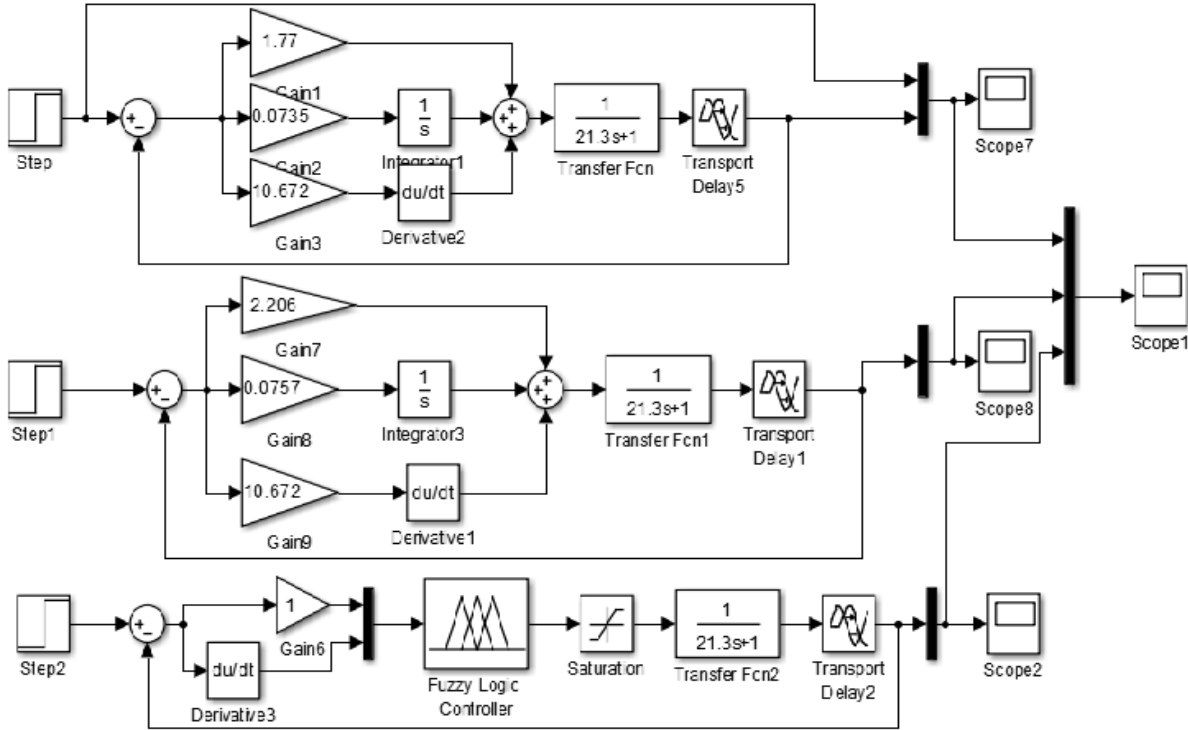


Figure 4: Comparison diagram of Ziegler-Nichols, Cohen-Coon and Fuzzy Logic Controller

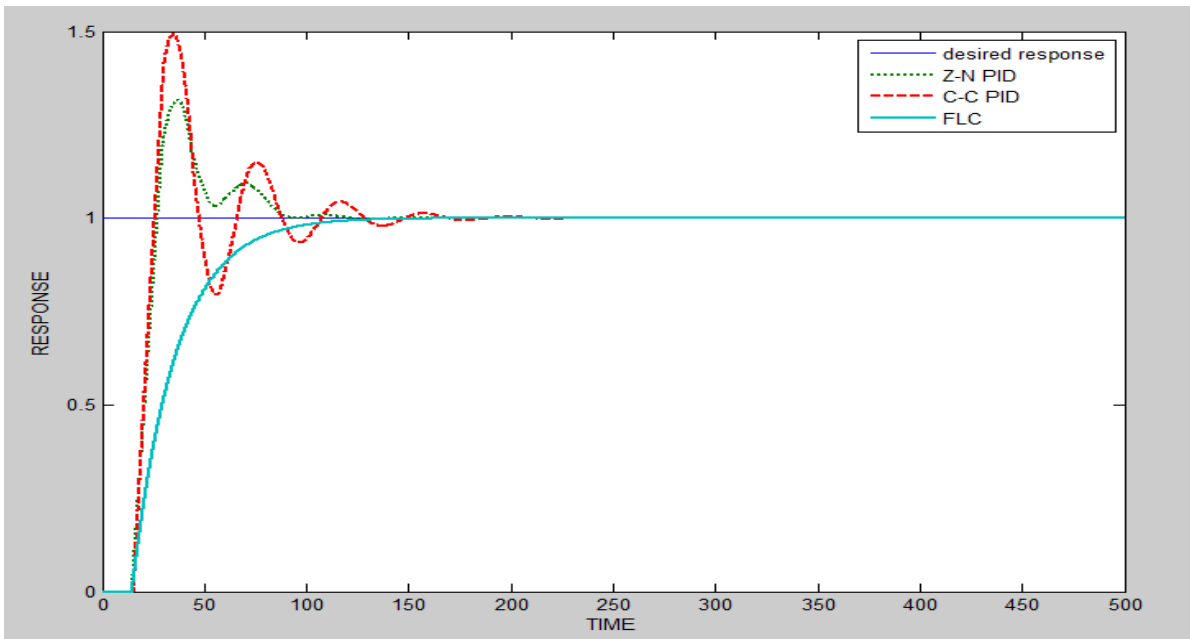


Figure 5: Comparison of Z-N, C-C and Fuzzy Logic Controller

Table 3: Comparison of Various Parameters for Different Controllers

	Z-N	C-C	FLC
PEAK AMPLITUDE	1.31	1.49	1
OVERSHOOT	31.6%	49.9%	0
SETTLING TIME	85.32	139	98
RISE TIME	9.91	5.52	46.81

IV. Conclusion

In this paper the response of First-order plus Time-delay (FOPTD) process is compared using Ziegler-Nichols (method II), Cohen-Coon Method and fuzzy logic controller. According to the calculations, if system requires faster transient response Cohen-Coon method is better ,and in case of Ziegler-Nichols response is faster but there is an overshoot of slightly more than 30 percent, but if system is sensitive to any kind of overshoot than fuzzy logic gives better response.

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