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Design of Optimum PID Controller for Heat Exchanger System Using Different Tuning Algorithm

A.Sathis Edwin[1], M.Prasanna[2], R.Ramya[3], S.Vigneshwaran[4], S.Ramachandran[5]

UG Student, Dept. of ICE, Saranathan College of Engineering, Trichy, Tamilnadu, India[1,2,3,4]

Assistant Professor, Dept. of ICE, Saranathan College of Engineering, Trichy, Tamilnadu, India[5]

ABSTRACT: The importance of a heat Exchanger system is to transferring heat from hot fluid to cold fluid, so temperature of the outgoing fluid is to be controlled in the desire manner. The heat exchanger widely used in industrial applications such as pasteurization, digester heating, heat recovery, pre-heating and effluent cooling. The proposed paper examines a PID controller design for Heat Exchanger system. Heat exchanger system commonly used in process industries, it handle the high range of temperature and pressure. In industrial aspect the process settling time should be less, the PID controller gives the faster settling time. Based on the empirical model, CHIEN-HRONES-RESWICH(C-H-R), closed loop Ziegler-Nichols(Z-N), and TYREUS-LUYBEN algorithms is implemented .The different algorithms output response is compared and the best among the three is validated , with the help of performance index measurement such as IAE,ISE,ITAE and simulation results are shown.

KEYWORDS: Heat Exchanger, C-H-R, Z –N, PID Controller, TYREUS.

I.INTRODUCTION

The proportional-Integral-Derivative control scheme was discovered in the 1940s, and being used in the process industries to control process difficulties. The Ziegler-Nichols is the straight forwarding tuning scheme in 1942[1], the usage of PID control has grown extremely good. The proportion- integral-derivative controller is a control loop feedback mechanism widely used in industrial control system. Model based identification of PID controller parameter setting increase the process constancy and quality. In the process control area, there has been some work along these lines, including the IMC Proportional-Integral (PI)/PID tuning by Rivera et al[2] and Korari and Zafiriou introduced the IMC for process control system[3]. This is based on the predictive output of the process mode. This Empirical model identified by step change method [4].

PID controller calculates an error value as the difference between a measured variable and a desired set point. The controller attempts to minimize error by adjusting the process through use of a manipulated variable. A best summary on PID tuning described in [5], [6] and [7]. In order for control loops to work properly, the PID loop must be exactly tuned. Designing and tuning the PID controller demands flexible algorithm, if multiple and incompatible objective is to be achieve [8]. There is variety of heat exchanger used in the process industries but the operation is same for all the cases [9].

All chemical industries generate or absorb the energy in the form of heat. The PID type controller were commonly used, because of its three term control gives the solution for both transient and steady state response.PID Control scheme offer the easiest and efficient results to many real time control problems. PID controller is mostly preferable for temperature control process to get immediate response. This experiment is based on real time based temperature control for heat exchanger. The distinctive standard for good control is that the response of the system to a step change in set point should have a least overshoot, bare minimum rise time and settling time. To accomplish the efficient control standard, design of PID Based control method is proposed in this work to maintain a temperature of the liquid at desired value. The empirical model is experimentally obtained from step response analysis. The PID controller algorithm of closed loop Z-N, C-H-R, TYREUS-LUYBEN algorithms response are compared, depends on performance index measurement like IAE, ISE and ITAE. The optimum PID controller scheme was selected.

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II. SYSTEM IDENTIFICATION

A. EMPIRICAL MODEL: To identify the behaviour of a system, an empirical modelling of the physical system taking place. Transfer function of the model = $\frac{1.9789}{1.3785+1}e^{-0.34s}$

B. MODEL DESCRIPTION: The schematic diagram of temperature control of a heat exchanger is shown in Figure 1. Input cold water is supplied from the overheat tank to the heat exchanger. Steam is supplied to the top side of the heat exchanger. The 2-wire RTD is used to determine the output temperature of the heat exchanger and is connected to the transmitter. The 2-wire RTD transmitter produces the standard 4-20mA output, which is directly proportional to the temperature. Separate power source are supplied to the transmitter device. The data from the transmitter are updated in the PC based controller using the data acquisition (DAQ) device. The ADC and DAC are used for analogue and digital conversion. The PC based controller process the error Signal and computes the suitable control signal. The controller unit sends the equivalent control signal to current to pressure converter through another DAQ device. The current to pressure converter is used for converting the current signal [4-20mA] to pneumatic signal [3-15psi], so that the steam valve can be actuate in desired fashion.

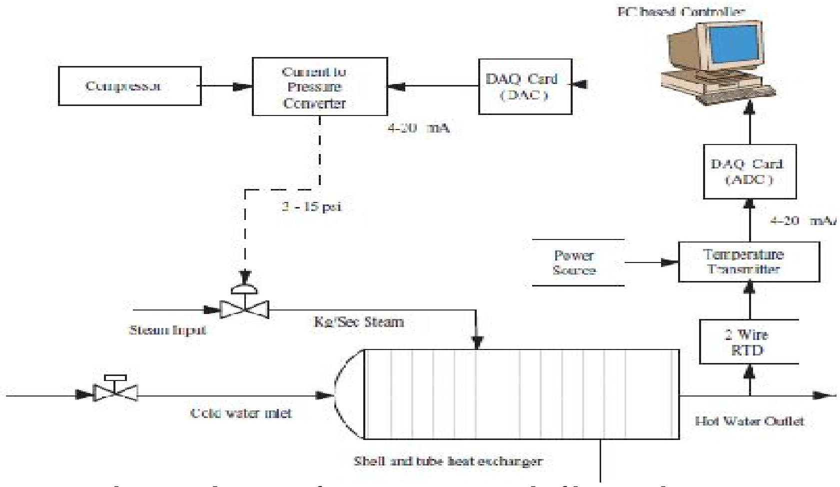

Figure 1: Schematic diagram of temperature control of heat exchanger

III.CONTROLLER DESIGN

A.CLOSED LOOP ZIEGLER-NICHOLS (Z-N) CONTROLLER: This scheme is a trial and error tuning method based on sustained oscillations that was first developed by Ziegler and Nicholas .A quarter decay ratio is consider as design criterion for this method. It is not valid for processes that are open loop unstable and time consuming because a trial and error procedure must be performed.

Table 1
Tuning Formula

Type of control	K_c	T_i	T_d
proportional-Integral-Derivative(PID)	0.6kcu	Pu /2	Pu/8

B.CHIEN-HRONES-RESWICH CONTROLLER (LOAD REJECTION): This method that has invented by CHIEN, HRONES and RESWICH [2] is a modification of open loop Ziegler and Nichols method. They proposed to use quickest response without overshoot or quickest response with 20% overshoot as design criterion.

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Table 2
Tuning Formula

Type of control	K_c	T_i	T_d
proportional-Integral-Derivative(PID) (20% over shoot)	$\frac{1.2}{Km}\frac{\tau_m}{d}$	2d	0.42d

C.TYREUS- LUYBEN CONTROLLER: The TYREUS-LUYBEN procedure is quite similar to the Ziegler-Nichols scheme but the final controller settings are dissimilar. Also this scheme only proposes settings for PI and PID controllers.

Table 3
Tuning Formula

Type of control	K_c	T_i	T_d
Proportional-Integral-Derivative(PID)	kcu/3.2	2.2Pu	Pu/6.3

IV. RESULT AND COMPARISON

The controller parameters are calculated (table 4) closed loop Z-N, TYREUS-LUYBEN and C-H-R controllers were tuned using them.

Table 4
Obtained controller parameters

controller	K_c	T_i	T_d
Closed loop Z-N	3.102	0.464	0.116
C-H-R(20% over shoot)	2.570	0.68	0.142
TYREUS-LUYBEN	1.615	2.043	0.417

The graph (time vs. overshoot) was plot for heat exchanger system. It clearly sights the curves of three controllers (Z-N, C-H-R, and TYREUS-LUYBEN). The comparison between three curves is done.

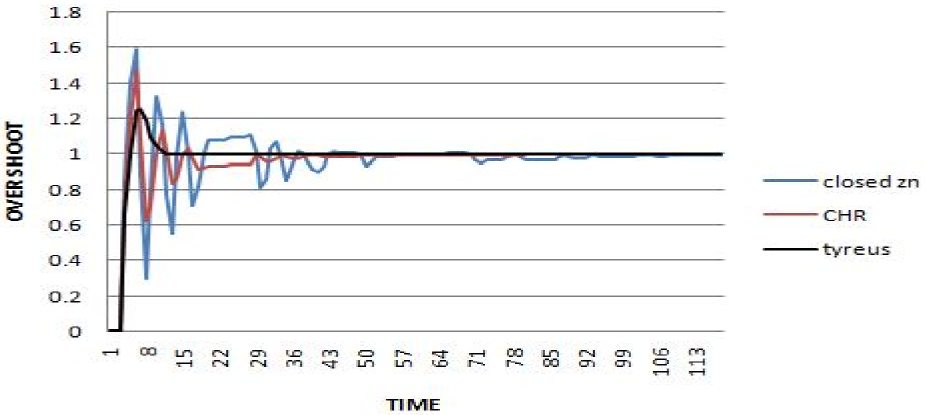

Figure 2: Comparison between closed loop Z-N, C-H-R, and TYREUS-LUYBEN method

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The performance index of three controllers (Z-N, C-H-R, and TYREUS-LUYBEN) is summarized in Table 5, it is observed that the error index (IAE, ISE, and ITAE) decreases as the overshoot and settling time also decreases.

Table 5
Comparison of performance index

specification	Closed loop Z-N	C-H-R(20% over shoot)	TYREUS-LUYBEN
IAE(Integral of Absolute magnitude of the Error)	2.169	1.259	0.7348
ISE(Integral Square Error)	0.9526	0.6119	0.4677
ITAE(Integral Time Absolute Error)	9.54	1.259	1.22

VI.CONCLUSION

The proposed paper examines a case study of heater exchanger system and evaluates three different methods to control the outlet fluid temperature. The obtained results validated that the TYREUS-LUYBEN based PID controller provide satisfactory performance index then closed loop Ziegler-Nichols and C-H-R method. Hence from the above result, TYREUS-LUYBEN based PID seems to be an effective choice for the temperature control of the heat exchanger than conventional PID technique.

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