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Online Tuning of Two Conical Tank Interacting Level Process

S.Vadivazhagi [1], Dr.N.Jaya [2]

Research Scholar, Dept. of E&I, Annamalai University, Chidambaram, Tamilnadu, India [1]

Associate Professor, Dept. of E&I, Annamalai University, Chidambaram, Tamilnadu, India [2]

ABSTRACT: J.G. Ziegler and N.B. Nichols, after carrying out extensive experiments with different types of processes proposed certain tuning rules, that were readily accepted and till now are used as basic guidelines for tuning of PID controllers. This paper presents the online tuning of Two Tank Conical Interacting Level Process(TTCILP). This online tuning is based on simple experimental tests and is often required because the process models used to calculate the preliminary controller settings are not exact. There are different methods for online controller tuning. In this paper, the tuning method used for the process under study is Ziegler-Nichols (Z-N) tuning algorithm. The objective of this paper is to show that by employing the Z-N tuning, an optimization can be achieved. The performance of the PI controller based on Z-N tuning is verified by taking servo and regulatory responses in MATLAB/SIMULINK software environment. The controller provides satisfactory performance in both the cases.

KEYWORDS: Two Tank Conical Interacting Level Process, PI controller, Z-N method, MATLAB/SIMULINK, ISE.

I.INTRODUCTION

The control systems used for modern industrial plants typically include thousands of individual control loops as discussed by Dale Seborg et al (2004). Most of the industrial plants present many challenging problems due to their non linear dynamic behavior. Because of inherent non linearity, most of the chemical process industries are in need of traditional control techniques. One such non linear process taken up for study is Two Tank Conical Interacting Level Process. To achieve a satisfactory performance using conical tanks, its controller design becomes a challenging task because of its nonlinearity. Conventional controllers are widely used in industries since they are simple, robust and familiar to the field operator. It is well known that the Ziegler-Nichols continuous cycling tuning is the most popular method to tune the parameter settings of conventional PI controller.

The PI and PID controllers are widely used in many industrial control systems for several decades. Over 60 years ago, Ziegler and Nichols (1942) published a classic paper that introduced the continuous cycling method for controller tuning. D.Marshiana et al (2012) presented a paper on the design of Ziegler Nichols tuning controller for the non linear system such as conical tank. A simulink based model for analyzing the Z-N tuning algorithm for speed control of DC motor is presented by Bhaskar Lodh (2014). Chan Wooei Shyan et al (2013) discussed about different controller tuning rules for a hopper tank which has a non linear behavior. A comparison of PID controller tuning techniques is done by Anusha et al (2014) for the non linear conical tank process.

The paper is organized with following main headings. The mathematical modelling of conical interacting level process is described along with its operating parameters. Next, implementation of Z-N controller tuning is presented followed by the simulation studies which covers the servo and regulatory responses. Finally the paper ends with a conclusion which confirms that the controller designed offers satisfactory performance for a given set point.

II. MATHEMATICAL MODELLING

The two tank conical interacting system consists of two identical conical tanks (Tank 1 and Tank 2), two identical pumps that deliver the liquid flows F_{in1} and F_{in2} to Tank 1 and Tank 2 through the two control valves C_{V1} and C_{V2} respectively as shown in Fig. 1. These two tanks are interconnected at the bottom through a manually controlled valve,

MV_{12} with a valve coefficient β_{12}. F_{out1} and $F_{out\ 2}$ are the two output flows from Tank 1 and Tank 2 through manual control values M_{V1} andM_{V2} with valve coefficients β_1 and β_2 respectively.

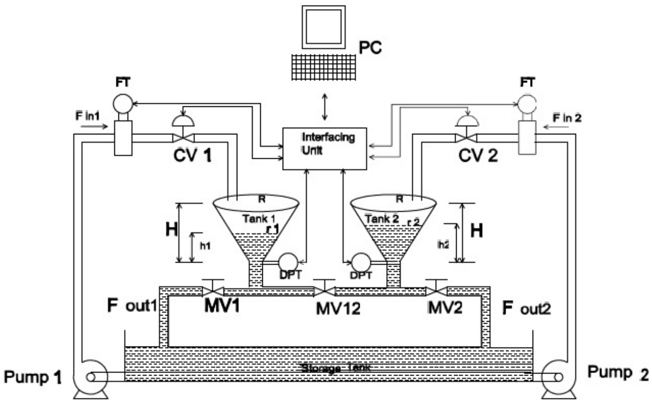

Fig. 1. Schematic of TTCILP

The operating parameters of the interacting conical tank process is shown in Table.I

Table I Operating parameters of TTCILP

Parameter	Description	Nominal values
R	Top radius of conical tank	19.25cm
H	Maximum height of Tank1&Tank2	73cm
F_{in1}& F_{in2}	Maximum inflow toTank1&Tank2	400 cm^3/sec
β_1	Valve coefficient of MV_1	35 cm^2/sec
β_{12}	Valve coefficient of MV_{12}	78.28 cm^2/sec
β_2	Valve coefficient of MV_2	19.69 cm^2/secs

In this work, TTCILP is considered as two inputs two output processes in which level h_1 in Tank 1 and level h_2 in Tank 2 are considered as output variables and F_{in1} and F_{in2} are considered as manipulated variables. The mathematical model of two tank conical interacting system is given below as discussed by Ravi and Thyagarajan (2011).

$$\frac{dh_1}{dt} = \left[\frac{F_{in1} - h_1 \dfrac{dA(h_1)}{dt} - \beta_1\sqrt{h_1} - sign(h_1 - h_2)\beta_{12}\sqrt{|h_1 - h_2|}}{\dfrac{1}{3}\pi R^2 \dfrac{h_1^2}{H^2}} \right] \quad (1)$$

$$\frac{dh_2}{dt} = \left[\frac{F_{in2} - \beta_2\sqrt{h_2} + sign(h_1 - h_2)\beta_{12}\sqrt{|h_1 - h_2|} - h_2 d\dfrac{A(h_2)}{dt}}{\dfrac{1}{3}\pi R^2 \dfrac{h_2^2}{H^2}} \right] \quad (2)$$

where
$A(h_1)$ = Area of Tank 1 at $h_1(cm^2)$
$A(h_2)$ = Area of Tank 2 at $h_2(cm^2)$
h_1= Liquid level in Tank 1 (cm)
h_2= Liquid level in Tank 2 (cm)

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III. ZIEGLER NICHOLS ONLINE TUNING ALGORITHM

Ziegler and Nichols presented a simple method for adjusting the controller when it is installed on an application, making use of the ultimate gain and period. For tuning the controller when the process is under closed loop operation, continuous cycling method can be opted. The ultimate gain (K_u) and ultimate period (T_u) of oscillation must be determined from the actual process by the following procedure as given by Carlos Smith and Armando Corripio in the Principles and Practice of Automatic Process Control (1997).

1. Switch off the integral and derivative modes of the feedback controller so as to have a proportional controller.
2. With the controller in closed loop, increase the proportional gain until the loop oscillates with constant amplitude. Record the value of gain that produces sustained oscillation as K_u , the ultimate gain.
3. From the time recording of the controlled variable, the period of oscillation is measured and recorded as T_u.

The recommended optimum settings are:

P control: $K_p = 0.5\ K_u$

PI control: $K_p = 0.45\ K_u$, $T_i = T_u / 1.2$

PID control: $K_p = 0.6\ K_u$, $T_i = T_u / 2$, $T_d = T_u/8$

The controller settings obtained are tabulated below as shown in Table II.

Table II Controller settings for PI controller

Type of controller	**K_p**	**T_i**	**T_d**
PI	1.95	1217	-

IV. SIMULATION STUDIES

An on-line tuning controller is designed for conical interacting level process and the performance is evaluated through MATLAB/SIMULINK software. The simulation is carried out by considering the nominal values of h_1 and h_2. (h_1 = 28cm and h_2 = 26cm). Servo and Regulatory responses are taken for tank1 and tank2.

Servo Performance

In servo operation the designed controller tracks the set point in a satisfactory manner. Figure 2 and 3 shows how the controller takes the operation for the given set point with respect to h_1 and h_2.

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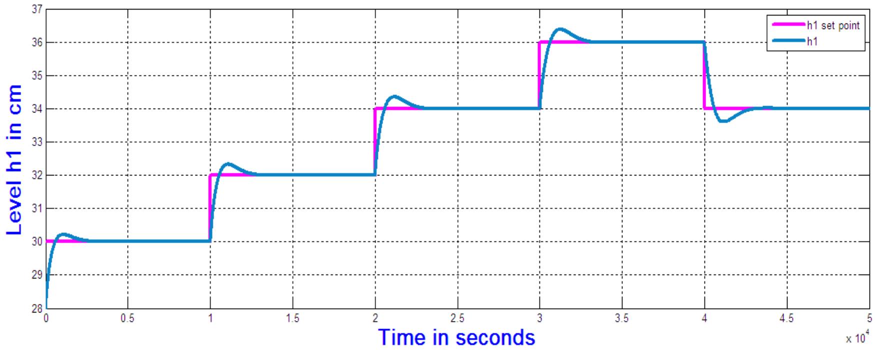

Fig.2 Servo response of h_1

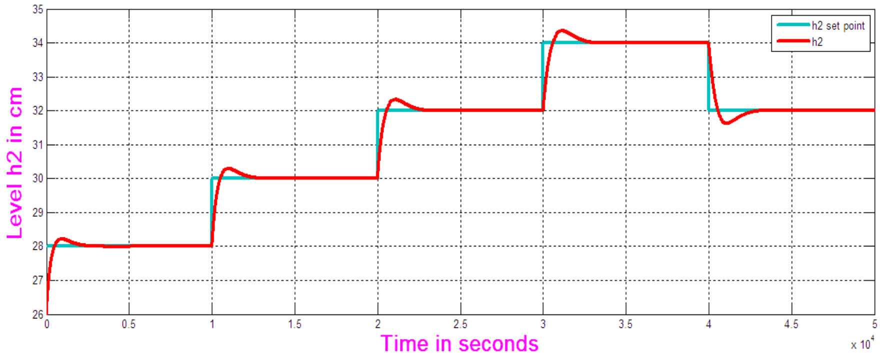

Fig.3 Servo response of h_2

From the responses, it is inferred that the online tuning controller is able to maintain the tank levels h_1 and h_2 at the respective set points. The integral square error (ISE) obtained is tabulated in Table III.

Table III Integral Square Error (ISE)

Operating points of h_1 in cm	ISE	Operating points of h_2 in cm	ISE
28-30	0.05219	26-28	0.04272
30-32	0.1102	28-30	0.0934
32-34	0.176	30-32	0.1514
34-36	0.2502	32-34	0.2173
36-34	0.3272	34-32	0.2858

Regulatory performance

In the regulatory operation, the disturbances are corrected automatically and the controller brings back the output to the desired level. Disturbances are introduced at output levels of h_1 = 30cm and h_2 = 30 cm. Figure 4 and 5 shows the regulatory response of conical interacting level process using Z-N tuned PI controller.

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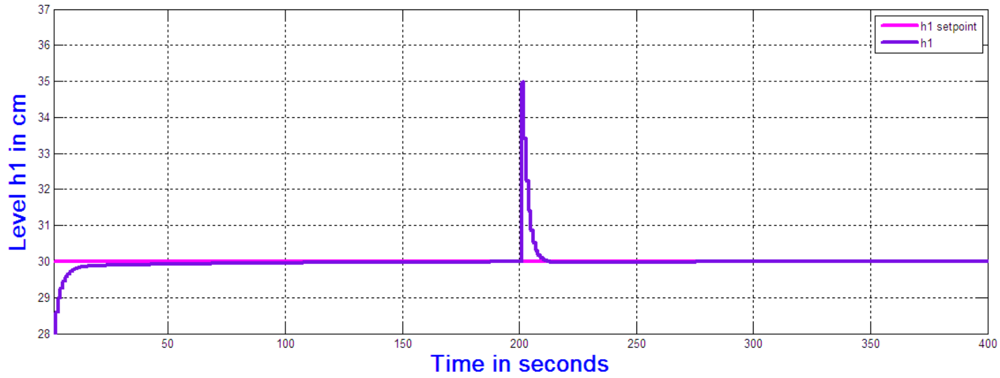

Fig.4 Regulatory response of h_1

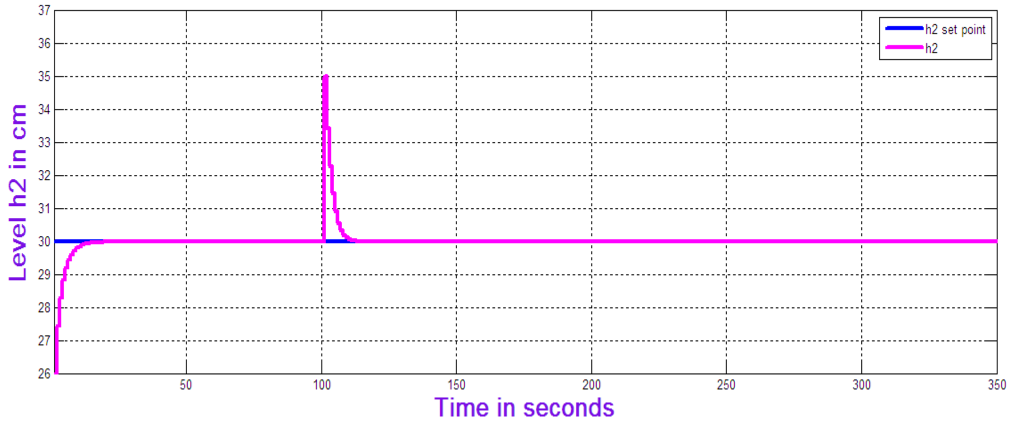

Fig.5 Regulatory response of h_2

Simulation results show how the controller rejects the disturbance and brings back the plant back to the desired level.

V. CONCLUSION

The strength of the ZN method is that it does not require a mathematical model, but controller parameters can simply be chosen by experimentation. Ziegler-Nichols method provides initial settings that will give satisfactory result, but it is always advisable to fine-tune the controller further for the particular process and better performance is expected to be achieved.

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