Neural Network Based Level Control in Two Tank Conical Interacting System

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Abstract—*The control of liquid level in tanks form an essential part in many process industries. A level that is too high may upset the reaction equilibrium, cause damage to the equipment or result in spillage of valuable or hazardous material. If the level is too low, it may have bad consequences for the sequential operation. In conical tanks the control of liquid level presents a challenging problem due to its non-linearity and constantly changing cross section. In a two tank conical interacting system it is difficult to control the level in both tanks with a single PID controllers because it can be used only in linear systems. Non-linearity of the system can be controlled by piece wise linearization of the process input-output response curve and dividing the curve into various regions. Separate PID controllers are designed for each linearized regions. The system is tuned and the control parameters are obtained. Though PID controllers are very efficient, it is time consuming and produces damped oscillation. To overcome this problem neural network based controllers are designed.*

Keywords: Neural, Interacting, Gain Scheduling, PID Controllers.

I. Introduction

The control of liquid level in tanks and the flow between tanks is a basic problem in process industries. The process industries require the liquids to be pumped and stores in tanks thereafter pumped to another tank. Many times the liquid will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled. A common control problem in process industries is the control of fluid levels in storage tanks, chemical blending and reaction vessels. The rate of change of flow from one vessel to another as well as the level of fluid is two important operational factors.

Serious difficulties arise in a system when the liquid level in a chosen process varies in process industries like hydrometallurgical industries, food process industries and wastewater treatment industries, conical tanks are widely used. Their shape contributes to better disposal of solids while mixing provides complete drainage, especially for viscous liquids. A level that is too high may upset reaction equilibrium, cause damage to equipment, or result in spillage of valuable or hazardous material. If the level is too low, may have bad consequences for the sequential operations. The level control of liquid in a conical tank presents a challenging problem due to its constantly changing cross section and non-linearity of the tank. Hence, control of liquid level is an important and common tank in process industries.

This paper presents the way of controlling the liquid level of tank in non-linear systems, especially conical tanks. Intelligent controllers like neuro controllers are used for effectively controlling the tank.

II. Process Setup

The schematic diagram of two tank conical interacting system setup is shown in Figure 1. In this setup, Tank 1 and Tank 2 are two identical conical interacting tanks of height (H) 43 cm and Radius(R) 15 cm. These two tanks are interconnected through a valve restriction whose valve coefficient is β_{12}. Fin1 and Fin2 are the two input flows for Tank 1 and Tank 2 respectively. Fout1 and Fout2 are the drains for Tank 1 and Tank 2 respectively .The inflow fin1 is controlled using a control valve.h1 and h2 are the heights of liquid level in Tank1 and Tank2 respectively.

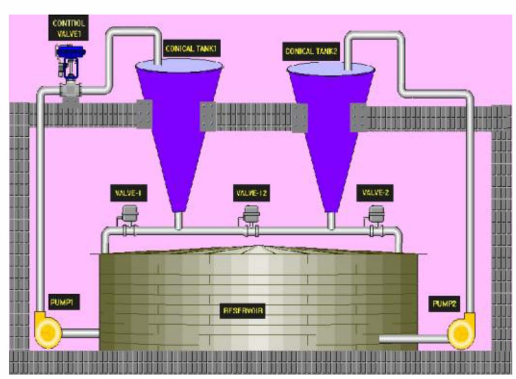

FIG. 1: Schematic Diagram of Two Tank Conical Interacting System

These liquid heights are measured using float type transducer whose output is fed as feedback to control the level.

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The PC interfacing has 8 analog input channel and 2 analog output channel.Pump1 and Pump2 are two pumps used to supply water from the reservoir to tank1 and Tank2 respectively. Here the liquid level h2 in Tank2 will be considered as a process variable. The flow of tank2 (Fin2) is kept constant. The control valve-1 used in this system is the final control element which takes the necessary action to maintain a steady state level in tank2.

III. MATHEMATICAL MODEL

The mathematical model is derived for both the tanks separately as follows.

For Tank 1 the mass balance equation is given by equation,

$$Fin_1 - Fout_1 = 1/3[A_1\left(\frac{dh1}{dt}\right) + h_1\left(\frac{dA1}{dt}\right)] \quad (1)$$

For tank 2 the mass balance equation is given by equation,

$$Fin_2 - Fout_2 = 1/3[A_2\left(\frac{dh2}{dt}\right) + h_2\left(\frac{dA2}{dt}\right)] \quad (2)$$

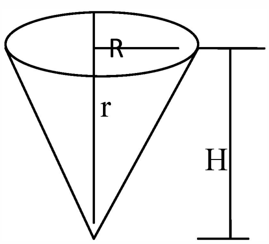

FIG. 2: SINGLE CONICAL TANK

The area of the conical tank is given by

$$A = \pi r^2$$

From the Figure 2,

Tanθ=r/h =R/H

$$Fin_1 - Fout_1 = 1/3[A_1\left(\frac{dh1}{dt}\right) + \frac{h_1\left(\frac{2\pi R^2 h_1 1}{H^5}\right) * dh_1}{dt} \quad (3)$$

The final mathematical model derivation for tank1 is given as follows.

$$\frac{dh_1}{dt} = \{(Fin_1 - \beta_1\sqrt{h_1} - \beta_{12} * \sqrt{h_1} - \sqrt{h_2}) * \frac{1}{A_1}\} \quad (4)$$

The mathematical model equation for tank 2 is

$$\frac{dh_2}{dt} = \{(Fin_2 - \beta_2\sqrt{h_2} - \beta_{12} * \sqrt{h_2} - \sqrt{h_1}) * \frac{1}{A_2}\} \quad (5)$$

IV. HARDWARE IMPLEMENTATION

The process model is implemented in hardware as shown in the Figure 3.

FIG. 3: HARDWARE IMPLEMENTATION

V. OPEN LOOP RESPONSE

LabVIEW AND MATLAB software tools are used in order to implement the mathematical model in simulation and observe the response.

It's found that the flow of tank1 and level of tank2 varies non-linearly. Thus a non-linear curve is reached. Piece wise linearization is performed on the curve and 5 regions are split such that each region is tuned by different PID controllers. The piecewise linearization curve is shown in Figure 4 as follows.

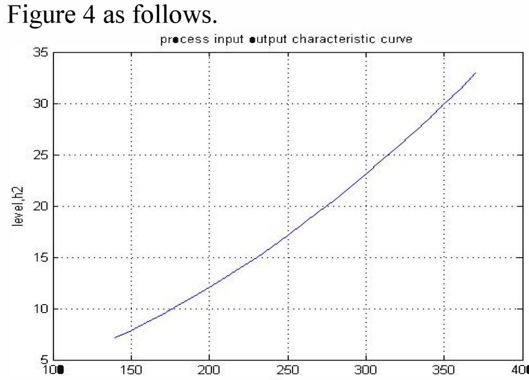

FIG. 4: PIECEWISE LINEARTION

VI. PID CONTROLLER DESIGN

The PID controller attemps to minimize the error by adjusting the process control inputs even if the process subject to disturbance

As there are 5 different regions, 5 PID controllers are used. Each PID controller is tuned separately by finding the controller parameters of each controller. Cohen Coon method of tuning is followed in this process. Table 1 shows the values for different regions split from the piecewise linearization curve.

TABLE 1: TUNING PARAMETERS FOR VARIOUS REGIONS

Regions	Flow Ranges	Kp	Ti	Td
Regions 1	140–187	73.659	2.867	0.448
Region 2	187–234	68.272	2.789	0.585
Region 3	234–270	65.64	0.096	1.74
Region 4	270–320	64.648	2.621	0.976
Region 5	320–370	70.23	1.05	1.245

VII. GAIN SCHEDULING

Gain scheduling is generally an approach to control of non-linear systems that uses a family of linear controllers, each of which provides satisfactory control for a different operating point of the system. Some processes have a degree of non-linearity and so parameters that work well at full-load conditions don't work when the process is starting up from no-load; this can be corrected by gain scheduling (using different parameters in different operating regions). PID controllers often provide acceptable control using default tunings, but performance can generally be improved by careful tuning.

In gain scheduling, the set points for different regions are given and the scheduler block guides the corresponding controller to work on it. The gain scheduler with different regions is shown in the Figure 5.

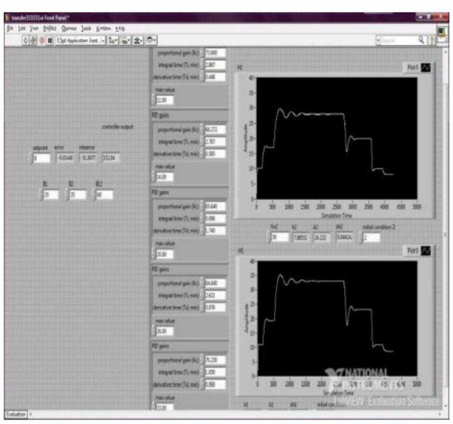

FIG. 5: GAIN SCHEDULING OUTPUT CURVE FOR INCREASING AND DECREASING SET POINTS

VIII. NEURO CONTROLLER

PID controllers have a lot of disadvantages like damped oscillations, process delay and large dead time. These problems can be rectified by using intelligent controllers like neuro controllers.

A neuro controller is designed by training the neural network with the values generated with the gain scheduling PID. Back Propagation Algorithm is used in this case for training the neuro controller.

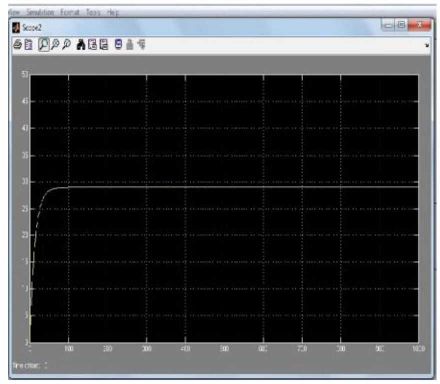

FIG. 6: RESPONSE OF NEURO CONTROLLER, WHEN SET POINT IS EQUAL TO 29

IX. CONCLUSION

In a non-linear system, the two tank interacting conical system whose time constant and gain are functions of process variable is considered for testing the performance of various non-linear intelligent controllers. It is observed that a neuro controller is more efficient in reaching the steady state than PID controller because, in neuro controllers, the network is trained accurately while in PID controllers, they are tuned by trial and error method. Thus, they are not very efficient as neuro controllers. In a two tank conical interacting system it is observed that when PID controllers are used, the time taken to reach the steady state is longer. On the other hand when neuro controllers are used the steady state is reached in a short span of time. Overall, it is observed that a single neuro controller performs the task more efficiently than many conventional controllers (PID) put together for the same process.

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