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Modeling and Design of Controllers for Interacting Two Tank Hybrid System (ITTHS)

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***Abstract*— This paper presents modeling and control of highly non linear system using manual pid and honeywell pid controller. Interacting two tank hybrid system (ITTHS) is considered as benchmark problem in this paper, where the aim is to control liquid level of tank. Control of liquid level in ITTHS is highly challenging due to variation in the area of cross section. The modeling of such hybrid systems is different from the convention modeling techniques. Modeling and designing controllers for hybrid systems is an upcoming research area. Manual method of tuning pid parameters and Honeywell PID controller has been designed for this process application. Piecewise linearization technique was applied for linearizing non linear system output. For all the five regions, separate Manual and Honeywell PID controller has been designed.**

Index Terms—**Honeywell PID, Piecewise linearization**

I. INTRODUCTION

The control of liquid level in ITTHS is a basic problem in process industries. Generally, non linear problems are difficult to solve and are much less understandable than linear problems. Many industries use conventional tank system for their processing. The major problem in process industries is the control of liquid levels in storage tanks and reaction vessels. Petrochemical industries, paper making industries and water treatment industries need to control level of liquid. Comparing with conventional tanks, conical tanks and spherical tank system ,the hybrid tanks have greater advantages such as inexpensive, improved product quality, wastage of material is reduced and efficient washing. An attempt has been made to develop Manual pid and Honeywell pid for liquid level control in ITTHS. In Section II, the process description and mathematical model are described. In Section III, transfer functions for ITTHS are derived. In Section IV and V, simulation results and performance analysis of Manual and Honeywell PID controller are discussed. Finally, result and conclusion are discussed in Section VI and VII.

II. PROCESS DESCRIPTION

A. *Mathematical Model*

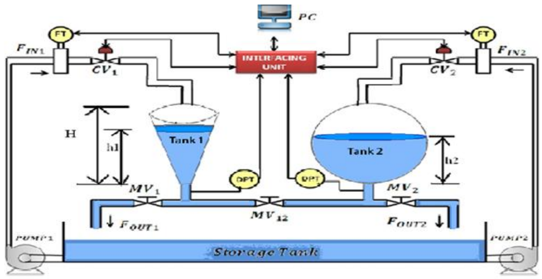

Fig 1. Functional Diagram of ITTHS

The process contains two tanks, TANK1, TANK2 are conical and spherical tanks whose height is H (50 cm) and radius is R (25 cm). These two tanks are interconnected through restriction MV12 as shown in the *Fig. 1.* FIN1 and FIN2 are the two input flows to TANK1 and TANK2 respectively. FOUT2 is the output flow of the TANK2 which flows through restriction R2 to sump h1, h2 are the liquid heights of the TANK1 and TANK2 respectively. These liquid heights are measured by Differential Pressure transmitters and are transmitted in the form of 4-20 mA current signals to interfacing unit of the PC. Here liquid level h2 in TANK2 will be controlled. The input flows FIN1 and FIN2 can be measured by Magnetic Flow transmitters and are transmitted in the form of 4-20 mA current signals to interfacing unit. After implementing the concerned advanced control scheme in the PC, the control signal will be produced in the form of 4 20 mA current signals and are transmitted to respective SMART control valves to produce required flow to the TANK1 and TANK2. In this work ITTHS is considered as SISO process in which level h2 in tank 2 is considered as measured variable FIN1 as manipulated variable. Mathematical Modeling of liquid level system is derived using conservation principle on Total Mass
Balance (George Stephanopoulos, 1990)[6]. According to which;

$$\frac{\text{accumulation of total mass}}{\text{Time}} = \frac{\text{input of total mass}}{\text{time}} - \frac{\text{output of total mass}}{\text{time}}$$

for ITTHS the mathematical model is derived to be

For TANK1: (1)

$$\frac{dh_1}{dt} = \frac{3\{(F_{in1} - \beta_1\sqrt{h_1 - h_2} - \frac{h_1}{3}\frac{dA_1}{dt})\}}{A_1}$$

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For TANK2:

$$\frac{dh2}{dt} = \frac{3/4\{(\beta_1\sqrt{h1-h2}) - \beta_2\sqrt{h2} - (\frac{4}{3}h2\frac{dA2}{dt})\}}{A2} \quad (2)$$

Where

β= density

FIN1 = Volumetric flow rate for TANK1

FOUT = Volumetric flow rate for outlet stream

A1, A2 = Area of the conical and spherical tank with respect to change in flow

h1, h2 = Height of conical and spherical tank 1 and 2

dh/dt = Change in height of liquid level

B .Modeling Parameters

In order to develop simulink model for the process based on equations analytical values are needed and is tabulated as modeling parameters as shown in *Table I* ITTHS has non-linear characteristics, is represented as piecewise linearized models around 5 operating points as shown in *Fig. 2*. Using process reaction curve method, the transfer function are found for all the regions and controller parameters are tuned using Manual PID and Honeywell PID controllers. Thus controller are designed for each region.

Parameters	Description	Value
D	Diameter of spherical and conical tank	50 cm
R	Radius of spherical and conical tank	25 cm
H	Height of conical tank	50 cm
FIN1	Maximum Inflow to tank1	111 cm^3/sec
β_{12}	Valve co-efficient of MV_{12}	78.28
β_2	Valve co-efficient of MV_{12}	20

Table I : Modeling parameters

he simulation results for the step change in set points are shown in *Fig .3 and Fig. 4.*

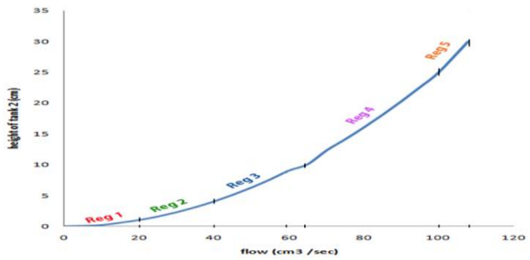

Fig .2: Process Reaction Curve

III. TRANSFER FUNCTION

Transfer function of ITTHS relating h2 and FIN1

$$\frac{\partial h2}{\partial Fin1} = \frac{R2}{\tau1\tau2s^2 + [\tau1 + \tau2 + A(h1)R2]s + 1}$$

Transfer functions are designed for different linearized region using model parameters are shown in *Table II.*

IV. MANUAL PID CONTROLLER

Tuning of a controller refers to the process of determining the parameters proportional gain, integral time and derivative time, so that the desired performances indices are attained.

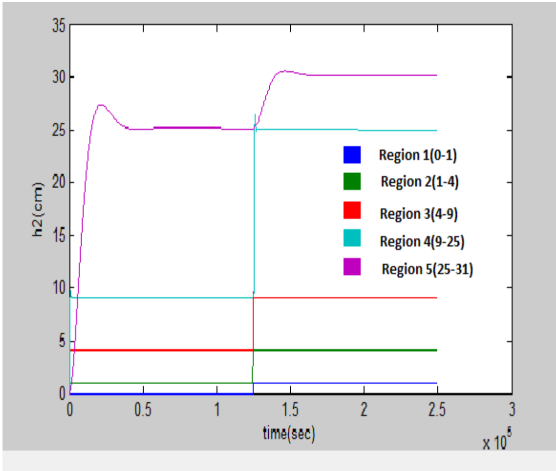

Fig. 3: Response of Manual PID Controller

Tuning of PID controllers is a task requiring considerable knowledge of the process and its dynamics. A properly tuned PID controller has got many advantages like simplicity, robustness, etc.. At the same time, the PID controller is difficult to tune for non-linear and complex systems having no perfect mathematical model. Hence, the non-linear level process system is divided into five second order linear systems and PID controller parameters are obtained for each linear system using manual tuning method. The simulation results and performance analysis are shown in *Fig. 3* and *Table III.*

V. HONEYWELL PID CONTROLLER

The values of proportional gain, integral time and derivative time are calculated by the formula are represented below.

$$k_c = \frac{3}{k_{p(1+\frac{3\theta}{\tau_1+\tau_2})}}$$

$$\tau_I = \tau_1 + \tau_2$$

$$\tau_D = \frac{\tau_1\tau_2}{\tau_1+\tau_2}$$

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The simulation results and performance analysis of Honeywell PID controller are shown in *Fig .4* and *Table III.*

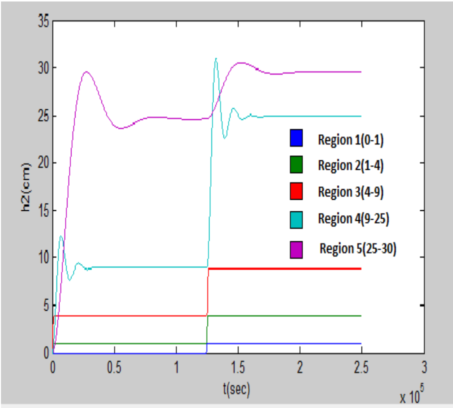

Fig. 4: Response of Honeywell PID Controller

VI. RESULT AND DISCUSSION

A. Comparison of Manual and Honeywell PID Controller

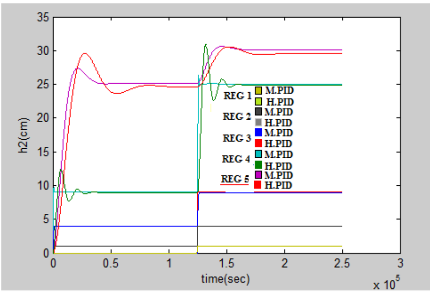

Fig. 5: Response of Manual and Honeywell PID Controller

In Region 1, from performance analysis it is inferred that error is minimum in Honeywell PID Controller.

In Region 2, from simulation result it is inferred that peak overshoot is less in Manual PID Controller and it is shown in *Fig. 5*.

In Region 3, from performance analysis it is inferred that error is minimum in Manual PID Controller.

In Region 4, , from simulation result it is inferred that settling time is fast in Honeywell PID Controller and it is shown in *Fig. 5*.

In Region 5, from performance analysis it is inferred that error and peak overshoot are less in Manual PID Controller.

VII. CONCLUSION

Interacting two tank hybrid system (ITTHS) is considered as non-linear system and designing Manual PID and Honeywell PID controllers for each region. The simulation for ITTHS was tested at different operating regions. The simulation was carried out using MATLAB to ensure that controller perfectly regulates the desired output level as per the requirement.

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APPENDIX

Inflow range	H1(cm)	H2(cm)	$\tau 1$	$\tau 2$	R2	Transfer function
Region 1(0-20)	1.1	1	0.01044	15.393	0.1	$\frac{\partial h_2}{\partial F_{in1}} = \frac{0.1e^{-0.01671s}}{0.096211S^2 + 15.494S + 1}$
Region 2(20-40)	4.4	4	1.3373	462.44	0.2	$\frac{\partial h_2}{\partial F_{in1}} = \frac{0.2e^{-0.004179s}}{368.06S^2 + 475.38S + 1}$
Region 3(40-60)	9.89	9	22.833	3127.485	0.3	$\frac{\partial h_2}{\partial F_{in1}} = \frac{0.3e^{-0.000787s}}{42467.41S^2 + 3351.20S + 1}$
Region 4(60-100)	27.3	25	806.768	24380.98	0.5	$\frac{\partial h_2}{\partial F_{in1}} = \frac{0.5e^{-0.000288s}}{11882117.01S^2 + 32443.86S + 1}$
Region 5(100-111)	33	30	1694.863	31751.720	0.55497	$\frac{\partial h_2}{\partial F_{in1}} = \frac{0.55497e^{-0.00003576s}}{43511213.55S^2 + 50076.629S + 1}$

Table II: Transfer function

Tuning	Setpoint Change	Error	IAE	ISE
Manual PID	0-1	2.26E-05	0.01165	0.0001357
	01-Apr	0.04826	778	6.05E+05
	04-Sep	1.78E-15	0.01072	0.000115
	Sep-25	-0.004368	109.4	1.20E+04
	25-30	-0.1212	1.53E+04	2.33E+08
Honeywell PID	0-1	-1.64E-06	0.5	0.25
	01-Apr	0.4826	78	6084
	04-Sep	0.1259	2689	7.22E+06
	Sep-25	0.09868	4866	2.37E+07
	25-30	0.4317	3.11E+04	9.65E+08

Table III: Performance Indices