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Design of an Adaptive Controller for Non Linear System

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ABSTRACT: This paper investigates the idea about the adaptive PI controller for conical tank system. In this paper Z-N tuning method is proposed for tuning the PI controller for various operating region of the process. The model was identified for the every region using open loop reaction curve method. The relation between the controller parameter and process parameter is obtained by curve fitting tool which is abbreviated by CF. The normal PI and Adaptive controller performance are compared in terms of setting time, overshoot and the rise time.

I. INTRODUCTION

Anandanatarajan et al.[1] have demonstrated the performance of PI controller at various operating regions in the Conical tank. His paper proposed the limitations of PI controller for the first order plus Dead time process. In this paper, the normal PI controller fails to stabilize the system because the non linearity takes vital role in conical tank. The authors also presented the servo and regulatory performance analysis for the various operating point in conical tank to study the behaviour of PI controller. Kesavan et al [2] have mentioned the features of conical tank such as time variant, non linear and time delay. He proposed the difficulties in obtaining the mathematical model for non linear system and introduced the . on line estimation of gain and time constant to obtain the exact model. Dinesh kumar et al [3] have highlighted importance

of adaptive PI controller in non linear system like spherical tank and conical tank. The authors also developed a simple adaptive technique to improve the performance of controller. Bhuvaneshwari et al [4] have discussed about Ziegler Nichols tuning methodology of PI controller in various operating region and highlighted the nonlinearity of the conical tank process. The writers also discussed the process characteristics of conical tank for various operating region with the process parameters such as level and Inflow to the process. Nafiz Aydin HZAL et al [5] and R.Vilanova et al [10] have Highlighted that the PID controllers provides unsatisfactory performance for the large dead time processes and integrating process. The PID controllers cannot able to control the process effectively for the disturbance in the process and set point changes. K.tan et al [6] and Tor steiner schei et al [8] have mentioned the limitations of PID controller for the non linear process. Te proposed the various techniques to overcome these limitations in order to have a good control action. Astrom et al [7] have discussed about the gain scheduled controller design for non linear process without dead time.

II. DESCRIPTION

The conical tank liquid is maintained at a desired level by controlling the inlet flow of the process. The conical tank is a simple system which is having single input and single output. The given system is very simple and has high nonlinearity due to the variation of process gain and time constant with respect to height of the tank [9].

The mathematical model can be obtain using the mass balance equation is given by

$$\frac{Total\ mass\ of\ accumulation}{time} = \frac{Total\ mass\ of\ input}{time} - \frac{Total\ mass\ of\ output}{time} \tag{1}$$

The relationship between inlet flow rate and outlet flow rate of the tank is

$$\frac{dV}{dt} = F_{in}(t - t_d) - K_v\sqrt{h} \tag{2}$$

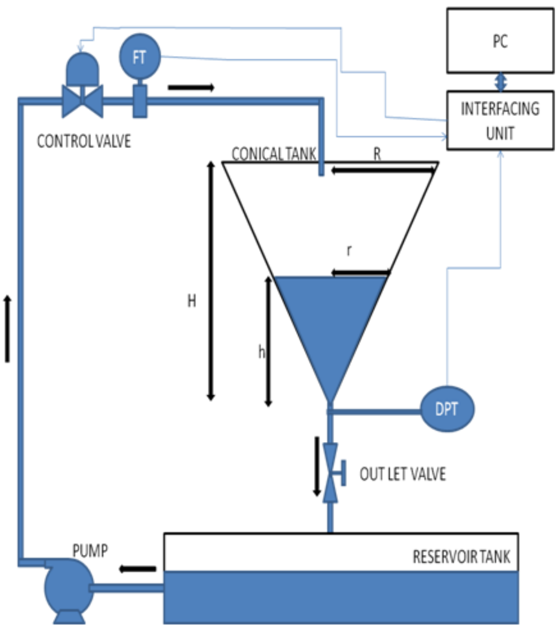

Fig.1 Layout diagram of conical tank process

R/H=r/h
r=(R/H)h
The relation between inlet flow rate and height is

$$\frac{dh^3}{dt} = \frac{f_{in}(t-t_d) - k_v\sqrt{h}}{\pi(\frac{R^2}{H^2})} \quad (3)$$

The transport delay t_d is defines as the time taken for change in height for corresponding change in inflow.

$$t_d = \frac{(H-h)+r}{g}$$

Here the dead time is negligible due to less value than others. So the equation (3) becomes

$$\frac{dh^3}{dt} = \frac{f_{in}(t) - k_v\sqrt{h}}{\pi(\frac{R^2}{H^2})} \quad (4)$$

Where,
f_{in} - Inlet flow rate
k_v - Outlet valve coefficient
h - Height at liquid level of the conical tank
H - Maximum height of the conical tank conical tank
R - Maximum radius of the conical tank
g - Acceleration due to gravity
t_d - Dead time

III. OPEN LOOP RESPONSE OF THE PROCESS

The maximum height and radius of the conical tank is 10cm and 7 cm respectively. The time constant and gain of the process increases as the level increases. The simulation model of the conical tank is shown in figure. The response of the system obtained from the simulation diagram for the various magnitude of input signal. The time constant of the system varies from 6s to 530s and the gain varies from 25 to 62 for different height of the tank. The gain and time

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constant of the process changes for different magnitude of input changes. The model parameters are obtained for the different region of the conical tank.

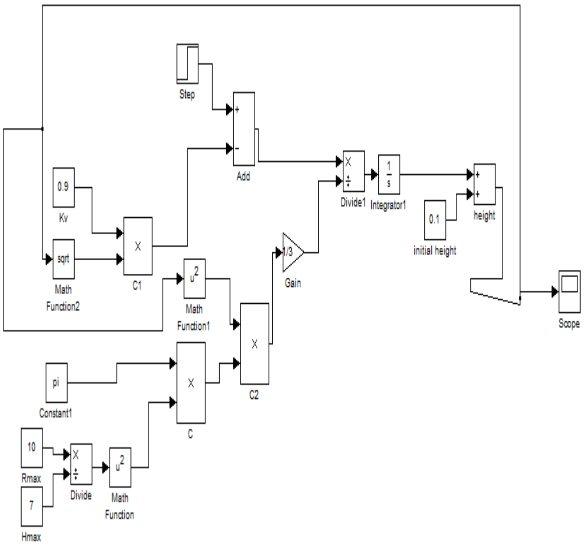

Fig. 2.Simulink diagram of conical tank process

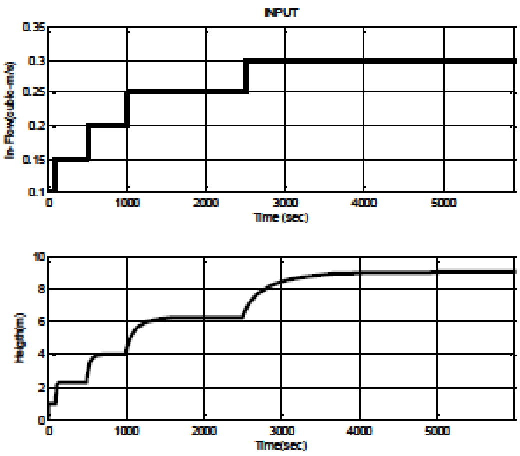

Fig.3. Open loop response of the conical tank

Table1. Model parameters with various operating region

SI.No	Height	Process gain	Time constant in seconds
1	1cm	25	6
2	2.25cm	34.99	26.7
3	3.9cm	44	103.5
4	4.5cm	49.6	170
5	6.25cm	54.78	270.8
6	8.98cm	62	530

The transfer function for various regions of conical tank is given by $G(s)=\frac{Ke^{-t_d s}}{\tau s+1}$ (5)

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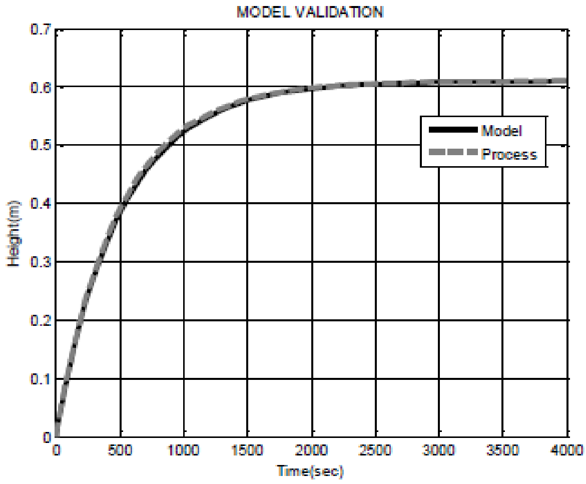

Fig.4 .Model validation

IV. TUNING OF PI CONTROLLER

The Proportional plus integral controller is tuned using ZN method for particular region which is at 5cm. The tuned value of PI controller gives the efficient controlling action for appropriate region. If the conical tank height varies from top to bottom, the controller fails to track the set point with optimal time. The response of the PI controller for the various regions obtained from the simulation using MATLAB. For Different region a PI controller is designed using Z-N open-loop tuning methods shown in the table 2. The closed loop process was simulated with controller using controller parameter for different height of the conical tank.

Table2. Model parameters with various operating region

Sno	Operating point(m)	Propositional Gain (Kc)	Integral Gain (Ki)
1	1	0.0250	0.0030
2	2.1	0.113	0.0129
3	3.2	0.200	0.0149
4	4.5	0.325	0.0187
5	6	0.5017	0.0301
7	8.1	0.681	0.443

The PI controller parameters obtained from the different region are used to calculate exact controller parameters for all regions by using linear polynomial equation obtained from curve fitting tool. The least

$$Kc(h)=(-5.82*h^3+88.9*h^2+240*h+45.47)*10^{-4} \quad (6)$$

$$Ki(h)=(0.4920*h^3-9.045*h^2+68.47*h-0.189)*10^{-4} \quad (7)$$

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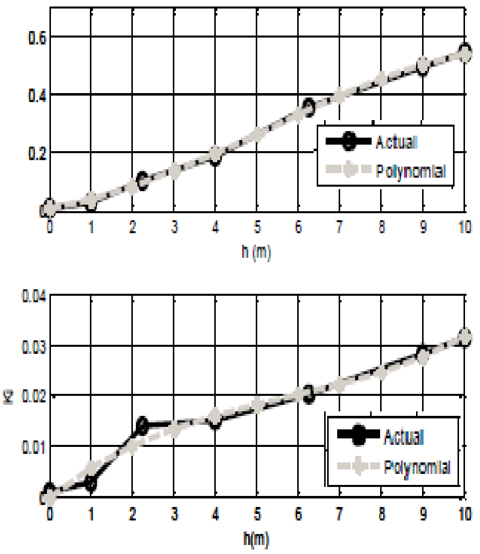

Fig.5. Model validation

V. RESULT AND DISCUSSION

The adaptive PID controller performance compared with conventional PID controller. The normal PID controller gives the good performance with in the operating region. The conventional PID controller fails to stabilize the system if the set point goes beyond the operating region. The adaptive PI controller will be the good controller for disturbance rejection and set point tracking. The adaptive PI controller has less overshoot, settling time and rise time than Normal PID controller. The +50% and -50% of disturbance from the set point given to the process variable. A comparison was made between the two controllers are Conventional PID controller and adaptive controller for given disturbance.

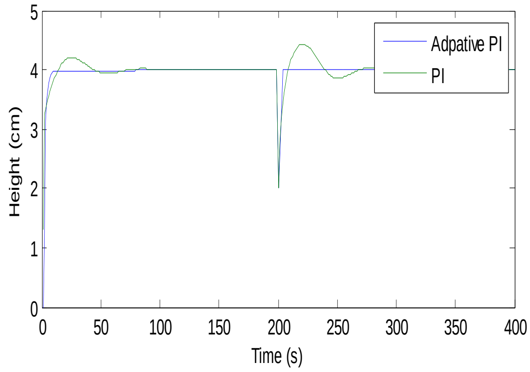

Fig.6. Negative disturbance rejection by PI and adaptive PI controller

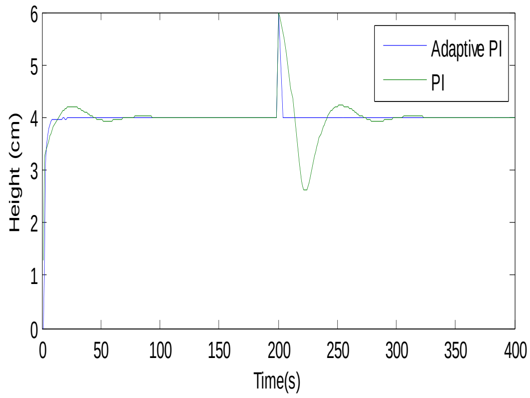

Fig.7. Positive disturbance rejection by PI and adaptive PI controller

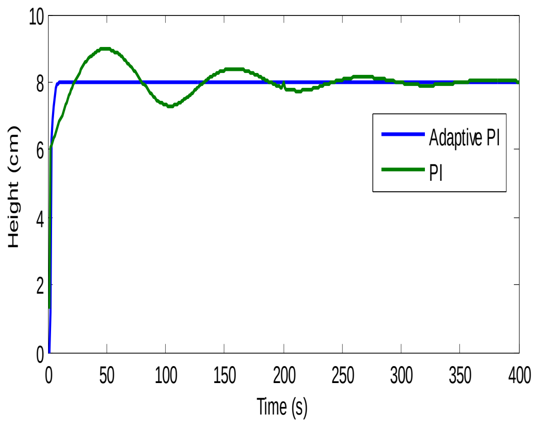

Fig.8. Response of PI and adaptive PI controller for set point of 8cm

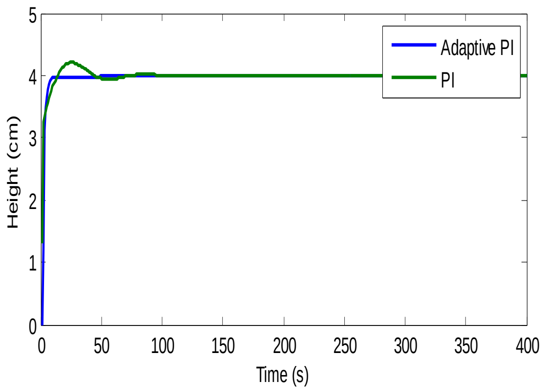

Fig.9. Response of PI and adaptive PI controller for set point of 4cm

VI. CONCLUSION

The incompetence of the PI controller and competence of the adaptive PI controller is illustrated. In servo performance, the adaptive PI controller provides the best performance than PI controller in terms of rise time, settling time and peak overshoot. The adaptive controller is the effective controller for regulatory problem than conventional controller. The less value of rise time, peak time and settling time ensure that adaptive PI controller is effective than other.

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