Research Paper

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Design of Auto-Tuning Adaptive Pid Controller For Two Tank Conical System

Engineering

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M. Kandasamy Erode Sengunthar Engineering College, Erode, Tamil Nadu, India

K. Muthukumaran St.Joseph's College of Engineering, Jeppiaar Nagar, Chennai, Tamil Nadu, India

ABSTRACT

In the past few decades, there has been considerable development in the field of adaptive control systems that automatically adjusts controller parameters to compensate for unanticipated changes in process dynamics. In a two tank conical interacting system it is difficult to control the level in both tanks with a single PID controllers because it only suitable for linear systems. In this paper the auto-tuning adoptive control is designed for a Two Tank Conical System and its performance compared with conventional PID control.

INTRODUCTION

Adaptive control systems are being put to productive use in chemical process industries. This is because of the introduction of digital computer for process control, which has widened its applicability. The most of the chemical processes are non-linear and having time-varying characteristics.

If the process is not well-known, the objective function is evaluated (criterion) using the values of controlled output. Then adaptation mechanism will change the controller parameters in such a way that to optimize the values of objective function. Typical examples of this type of control mechanism are: self-tuning regulators (STR) and model referenced adaptive control (MRAC).

The adaptation law of STR uses input signal, output of plant and error between plant and reference model outputs. These three signals are used to adapt the controller parameters. The law attempts to locate a set of parameters which will minimize the error between plant and model outputs. For this, parameters of controller are incrementally adjusted until error becomes zero. Many kinds of adaptation law have been developed and put to use till now. Two important primitive types are gradient method and Lyapunov approach.

Unpredictable changes in process dynamics lead to poor control performances if controller parameters are not properly adapted. Some of these changes arise from nonlinearities, process aging, production strategy changes , raw material property modifications and changes over equipment maintenance cycles. Adaptive control is widely discussed in the literature, and reviews of the evolution of adaptive control algorithms and products have been gained by Astrom(1987), Keyes and Kaya(1989),Chan(1991) and Astrom et al. (1986), Minter and Fisher (1988), Dumnot et al. (1989) , Sorrella (1989), Cao and McAvoy(1990), Hang and Sin(1991) and Isermann et al (1991).

Inspite of increasing number of successful industrial applications of adaptive control, there is room for improvement. Adaptive control compromises with adaptation performances , stability and robustness in order to cope up with industrial environment (De Larminat, 1989; Matko 1990).

MATHEMATICAL MODEL

Mathematical model is obtained by writing mass-balance equation for the system under study. The two tank conical interacting system is a TITO (Two Input Two Output) process in which h_1 and h_2 are controlled variables and f_{in1} and f_{in2} are manipulated variables.

Using mass-balance equation,
Rate of inflow - rate of outflow = rate of change of accumulation i.e., change in volume

$$\frac{dh1}{dt} = \left\{ fin1 - \beta 1\sqrt{h1} - sign(h1-h2)\beta 12\sqrt{|h1-h2|} - \frac{1}{3}h1\frac{dA(h1)}{dt} \right\} \div \frac{1}{3}\pi R^2 \left(\frac{h1^2}{H^2}\right)$$

$$\frac{dh2}{dt} = \left\{ fin2 - \beta 2\sqrt{h2} + sign(h1-h2)\beta 12\sqrt{|h1-h2|} - \frac{1}{3}h2\frac{dA(h2)}{dt} \right\} \div \frac{1}{3}\pi R^2 \left(\frac{h2^2}{H^2}\right)$$

Where,

fin1 = inflow to tank 1

fin2 = inflow to tank 2

β1 and β2 = control valve coefficients of outlet valves of tank 1 & tank 2

β12 = control valve coefficient of MV12

h1 = height of tank 1

h2 = height of tank 2

A(h1) = area of tank 1

A(h2) = area of tank 2

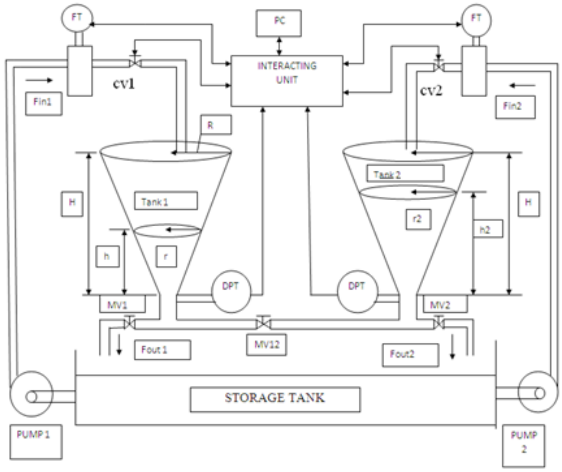

Figure 1: Experiment set up of Two Tank Conical System

Maximum height of tank 1 & tank 2 , H = 73cm

Top radius of conical tank, R =19.25cm

Maximum inflow to tank 1 & tank 2, fin1 & fin2 = 500lph

Valve co-efficient of MV1, β1 = 50.00 cm2/s

Valve co-efficient of MV2, β2 = 50.00 cm2/s

Valve co-efficient of MV12, β12 = 35.00 cm2/s

RESULTS AND DISCUSSION

Open Loop System

The experimental setup was operated at 240 lph and the open loop response was obtained as follows:

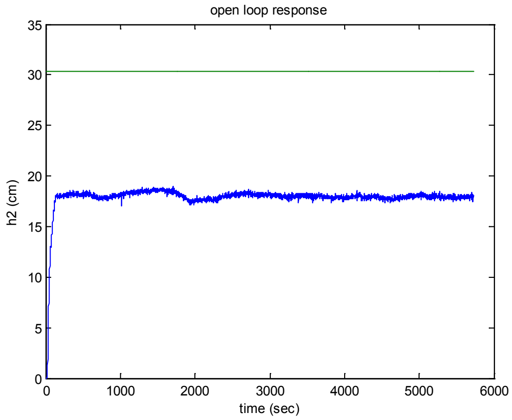

Figure 2: Open Loop Responses

The open loop transfer function is obtained with help of open loop response, which is

$$\frac{c(s)}{r(s)} = \frac{1.0720e^{-25s}}{563.6s+1}$$

Feedback Control System

The close loop system is constructed with help of obtained open loop transfer function.

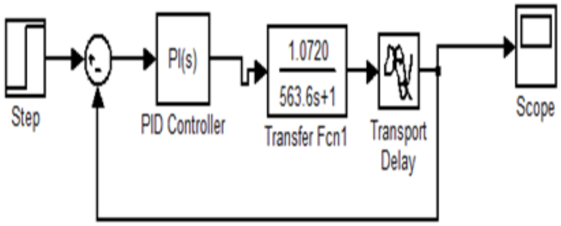

Figure 3: Feedback Control System

The below closed loop response is obtained using PI controller , for the level control process.

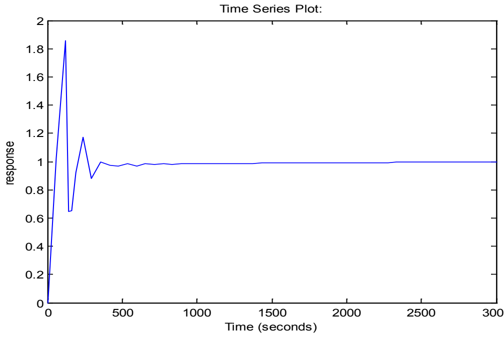

Figure 4 : Closed Loop Response

Auto-Tuning Adaptive PID Controller

The response of the conical tank system using Adaptive PID Controllers is shown in below.

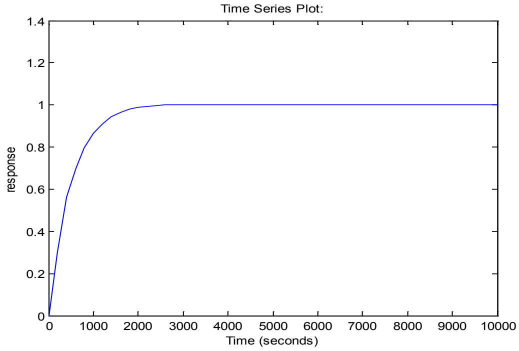

Figure 5: Response of Adaptive PID Controller

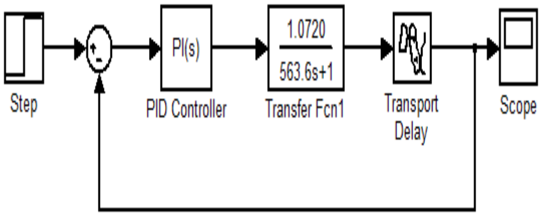

Figure 2 Adaptive Control block diagram

The response conical tank is obtained using the values calculated by case 1 formula where, P = 0.8932 and I =0.00177.

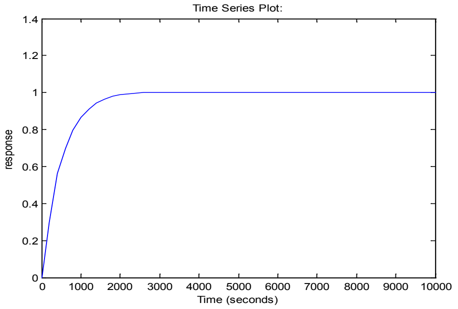

Figure 3 Response of conical tank

Integral Squared Error (ISE), Integral Absolute Error (IAE) are calculated for both Feedback controller and Auto Tuning Adaptive Controller, which is shown below.

TABLE – 1
ISE and IAE for Conical Tank

PROCESS	ISE	IAE
Feed Back	1375	60.56
Auto-Tuning Adaptive PID	282.7	527

The table indicates that Auto-Tuning Adaptive PID is better method compared with conventional PID control system.

CONCLUSIONS

The design procedure and responses obtained for the two tank conical systems is analyzed using Feedback (Zeigler Nichols) and Auto-tuning adaptive method.

From the analysis, it may be concluded that response of the auto-tuning adaptive method is comparatively smooth and settled without any oscillations unlike the feedback technique. Also comparison of ISE and IAE values are obtained for the tank under different circumstances and it indicates that Auto-tuning adaptive method performance is better than Feedback (Zeigler Nichols)

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