Abstract

Background/Objectives: The objective of this paper is to design a centralised controller for liquid level in the two interacting conical tank system. Methods/Statistical analysis: Two centralised Proportional and Integral (PI) controller tuning methods (Davison method and Tanttu and Liestehto method) are used for simulation and implemented in real time process. Findings: Centralised PI controller reduces the interaction between the two interacting conical tank and improves the system performance. The performances are compared in terms of Integral Square Error (ISE) and Peak Overshoot. It is observed that Tanttu and Liestehto method produces better response than Davison method. Applications/Improvements: Level control in two interacting conical tank is used in chemical industries and water treatment plants.

Keywords: Centralised Controller, Multivariable System, Two Interacting Conical Tank System

1. Introduction

Most of process industries are multivariable processes and highly interactive between the input and output variables. These interactions will disturb the process variable of other loops and it is very difficult to design a controller for multivariable systems. Decentralized controller can be designed for that kind of processes. But decentralized controller not producing better performance for highly interactive processes. So centralized controller method is needed for controlling the multivariable system effectively. Centralized controller has nxn PID controller for multivariable system having nxn transfer function. This centralized controller method reduces the interaction between the processes. A dynamic matrix controller is implemented for two interacting conical tank system. Decoupling controller also can be used for multivariable system. The centralized controller can be used for non-square also. For tuning centralized PID controller, various tuning methods are used. The methods include the Davison method, the Macijowski method and the Tanttu and Liestehto method. The designed controllers are tested for servo and regulatory operations and their performances are compared. The controllers are compared based on Integral Square Error (ISE) and Maximum Peak Overshoot (MP) value. ANFIS method is used in distillation column. Setpoint filter is used to reduce the peak overshoot. Bacterial Foraging Algorithm also used to tune PID controller. Decentralized PID Controller is designed for 3x3 Multivariable System using Heuristic Algorithms. Skogestad method is used for designing PID controller for interacting Spherical tank. Gain scheduled PI controller is used for nonlinear system. Multivariable controllers are designed for unstable and four tank system.

Two Interacting Conical Tank (TICT) systems are considered in this paper for implementation of the above said controller. It is an example for 2x2 nonlinear systems. When the height of liquid level in the tank increases the area of the tank also increases. When two conical tanks are connected, then it gives more complexity in controlling the system due to the interaction between the tanks.
2. Real Time Experimental Setup

The experimental setup of the two interacting conical tank system are shown in Figure 1. It consists of two conical tanks connected in interacting manner. Two pumps which delivers liquid flow to the two tanks individually. Two control valves connected between the motor pumps and the conical tanks which act as a final control element. Two differential pressure transmitter measure the water level in conical tanks. The entire setup is connected to a PC through a USB based data acquisition card. The objective is to control the levels of the two conical tank system (h1 and h2) by varying the inflow to the tanks.

The mathematical model of the Two Interaction Conical Tank (TICT) system is given by

\[
\frac{dh_1}{dt} = \frac{f_{in1} - h_1 \frac{dA(h_1)}{dt} - \beta_1 \sqrt{h_1} - \text{sign}(h_1 - h_2) \beta_2 \sqrt{h_1 - h_2}}{\frac{\pi R^2 h_1^2}{3 H^2}}
\]

(1)

\[
\frac{dh_2}{dt} = \frac{f_{in2} - h_2 \frac{dA(h_2)}{dt} - \beta_1 \sqrt{h_2} + \text{sign}(h_1 - h_2) \beta_2 \sqrt{h_1 - h_2}}{\frac{\pi R^2 h_2^2}{3 H^2}}
\]

(2)

The Table 1 provides a complete technical specification about the real time experimental setup of the two interacting conical tank system.

The generalized transfer function matrix of a 2-by-2 system is represented as below.

\[
\begin{bmatrix}
    h_1(s) \\
    h_2(s)
\end{bmatrix} =
\begin{bmatrix}
    G_{11}(s) & G_{12}(s) \\
    G_{21}(s) & G_{22}(s)
\end{bmatrix}
\begin{bmatrix}
    u_1(s) \\
    u_2(s)
\end{bmatrix}
\]

(3)

Where, \(h_1\) and \(h_2\) are outputs (level of the tanks), \(u_1\) and \(u_2\) are the inputs (water flow rate).

The transfer function \(G_{11}(s), G_{12}(s), G_{21}(s)\) and \(G_{22}(s)\) are obtained by conducting step test. By keeping constant inflow rate to the tank, the steady state responses of open loop systems are obtained. From the open loop responses of two interacting conical tank system, the transfer functions are obtained as follows.

\[
G_p(s) = \begin{bmatrix}
    2.7 & 3.1 \\
    4.166s + 1 & 6.583s + 1 \\
    1.6 & 2.4 \\
    2.833s + 1 & 9.4167s + 1
\end{bmatrix}
\]

(4)

Relative gain (RGA) matrix is computed for the transfer function is given by

\[
\text{RGA} = \begin{bmatrix}
    4.4022 & -3.4022 \\
    -3.4022 & 4.4022
\end{bmatrix}
\]

(5)

From the above matrix, the input-output pairing is identified as Fin1-h1 and Fin2-h2. Here, Fin1 and h1 are the input flow rate and water level of the conical tank1. Similarly, Fin2 and h2 are the input flow rate and water level of the conical tank2.

![Figure 1. Two Interacting Conical Tank System.](image)
3. Design Of Controller

3.1 Davison Method

Davison has proposed a multivariable PI controller where the matrices $K_c$ and $K_i$ are given by

$$K_c = \delta \left[ G(s=0) \right]^{-1}$$

$$K_i = \varepsilon \left[ G(s=0) \right]^{-1}$$

Here $\delta$ and $\varepsilon$ are the fine tuning parameters. The fine tuning parameters range is from 0 to 1. The recommended values are 0.1-0.3.

3.2 Tanttu and Liesleh to Method

Tanttu and Liesleh to are based on IMC controller. In which controller for the individual transfer function has to be designed.

The transfer function is a first order system with dead time, the PI controller by IMC is given by

$$k_{cij} = \left( \frac{1}{\sqrt{k_{p_{ij}}}} \right) \left( \frac{\tau_{ij}}{\tau_{c,ij}} \right)$$

$$\tau_{lij} = \tau_{ij}$$

where $\tau_{ij}$ is the desired closed loop time constant. Let us assume that $\tau_{cij} = \alpha \tau_{ij}$, where $\alpha$ is a single tuning factor. Hence the matrix $K_c$, is given by

$$K_c = \left( \frac{1}{\alpha} \right) \left[ K_{p_{11}} \ K_{p_{12}} \right]^{-1}$$

$$K_i = \left( \frac{1}{\alpha} \right) \left[ K_{i,11} \ K_{i,12} \ K_{i,21} \ K_{i,22} \right]^{-1}$$

4. Result and Discussion of Real Time Process

For TICT, three tuning methods (Davison method and Tanttu and Liesleh to method) are used. The ISE and Peak overshoot values of both methods are compared which shown in Figure 2, Figure 3 and Table 2. In this

![Figure 2. Servo Response of Tank 1.](image)

![Figure 3. Servo Response of Tank 2.](image)

| Method     | MP in % | Integral Square Error (ISE) h1 | Integral Square Error (ISE) h2 |
|------------|---------|--------------------------------|--------------------------------|
| DAVIDSON   | 15.72   | 7.60e+06                       | 6.04e+06                       |
| TANTTU     | 14.00   | 7.48e+06                       | 5.52e+06                       |

Table 2. The comparisons of different method’s ISE values of TICT
comparison, Tanttu and Liesleh to method has the least 
ISE value compared to Davison methods.

5. Conclusion

Transfer function model of two interacting conical tanks 
are obtained. Two different Centralized PI Controller 
is designed and implemented in real time process. The 
designed controllers are tested for servo and regulatory 
operations and their performances are compared in terms 
of Integral Square Error and Maximum Peak over Shoot. 
From the analysis the simulation and Real time results, 
Tanttu and Liesteh to method controller gives improved 
performance when compared to the Davison method.

6. References

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