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Enhancement of PID Controller Performance for a Quadruple Tank Process with Minimum and Non-Minimum Phase Behaviors

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Abstract

This paper analyses the Proportional-Integral-Derivative (PID) controller's performance for quadruple tank process. The selection of controlling the flow ratios in quadruple tank process act as Minimum and Non-minimum phase system. Its performance can be affected when system is shifted from minimum to non-minimum phase configuration and vice versa. This paper mainly focuses on searching the optimal controller structure by increasing the controllers' performance criteria. A comparative study on different controllers' structures responses are in the presence of peak overshoot. A simulation study of PID controller and Modified PID controller structures have been designed and to analyzed the different controllers' performance for the minimum and non-minimum phase system. The simulation results show that the PI-PD controller structure is provides enhanced performance for the set point tracking with nonappearance of peak overshoot.

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Keywords: Quadruple tank process, PID controller and structure, Multivariable controller, Minimum and Non-minimum system

1. Introduction

Chemical process industries are strongly integrated process, that exhibit nonlinear behavior and complex dynamic properties. Many industrial controlled problems have more number of manipulated and controlled variables. It is common for industrial processes to have significant uncertainties, strong interaction of minimum and non-minimum phase behavior. The four tank multi variable system exhibits characteristics of interest in both control and research motivation. The quadruple-tank introduced by Johansson [1] has received a great attention because it presents interesting properties in the controller design and implementation. In this process, it can be shifted from minimum to non-minimum phase configuration and vice versa simply by changing a valve controlling the flow ratios γ_1 and γ_2 between lower and upper tanks. The linearized dynamics of the minimum and non-minimum phase system has a multivariable zero that is possible to move along the real axis either in left half-plane or right half plane by simply changing the valve controlling the flow ratios. The changing valve flow ration in quadruple tank process exhibits a sophisticated and simple way complex dynamics. Such dynamic characteristics include interactions; minimum and non-minimum phase systems require optimum controller operation.

Ali Abdullah and Mohamed Zribi [2] proposed that input-output feedback linearization controller for level control of a quadruple tank process. This proposed result indicated that the developed control schemes work well and are able to regulate the output of the process to its desired value and gave the best performance. Danica Rosinov and Matus Markech [3], reported that robust decentralized PID controller was designed for a nonlinear model of quadruple tank system with both minimum phase and non-minimum phase system configuration. This method has been proposed for LMI approach to the linearized state space model with polytopic uncertainties and both the approaches are compared and simulation results are presented. Kenichi Tamura and Hiromitsu Ohmori [4] discuss the auto-tuning of the expanded PID control for multi input and multi output (MIMO) linear system. The auto tuning is to give an adaptive law of time-varying PID parameter matrices and the closed-loop regulation system is asymptotically stabilized using the expanded PID control. In this paper a multivariable process is considered four interconnected water tanks with configuration of minimum phase and non-minimum phase system.

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Nomenclature

A	Cross-section of tank
a	Cross-section of the outlet hole of tank
h	Water level in tank
g	Acceleration of gravity
k	Flow corresponding to pump
F_{in}	Input flow of tank
F_{out}	Output flow of tank
A	Area of the tank
R	Output flow of tank
h_1	Liquid level inside tank 1
h_2	Liquid level inside tank 2
h_3	Liquid level inside tank 3
h_4	Liquid level inside tank 4
V	Volume of the tank
T_d	Dead time of input flow
g	gravitational constant
K_p	Proportional gain constant
K_i	Integral gain constant
K_d	Derivative gain constant
T_i	Integral time constant
T_d	Derivative time constant
u	Controller output
e	Error signal
y	Actual liquid level inside the tank
G	Process transfer function matrix

Greek Symbols

γ_1	Divides flow from pump 1 to the tanks 1 and 4
γ_2	Divides flow from pump 2 to the tanks 2 and 3

Abbreviations

PI	Proportional-Integral
PID	Proportional-Integral-Derivative
ZN	Ziegler-Nichols
FOPDT	First order plus dead time
MIMO	Multi-input and Multi-output

K Yamada [5] discussed that a designing method for modified PID control for minimum phase systems using the parameterization of all proper stabilizing controllers for linear minimum phase systems. The adequate controller structure is used system presents of minimum and non-minimum phase behavior that arises due to the multivariable nature of the problem. For this reason the quadruple tank has been used with different PID controller structure and to analyze the performance of the control techniques. Takaaki Hagiwara and Kou Yamada [6], this paper reported that a design method of modified PID controllers for MIMO plants. This paper deals that PID controller structure is the most widely used one in industrial applications. This method has been to guarantee the stability of PID control system in MIMO plants and the admissible sets of proportional, integrator and derivative parameters are used to guarantee the stability of PID control system.

The objective of the work is to design and implement a different form of PID controller structure and robust control analysis for a multivariable four tank level control process. The designs are demonstrated on a quadruple tank level control process with two inputs and two outputs. The aim of this work is to analyze some different PID controller structure of multivariable control systems. The control methodologies are PI, PID,PI-D, I-PD and PI-PD controllers. The five control algorithms are comparatively

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