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IMPLEMENTATION OF PID CONTROLLER USING CONVENTIONAL METHOD FOR MIMO SYSTEMS

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ABSTRACT

PID controllers used in most of the process industries. This is normally because PID controller has the advantage of simple structure, good stability, and high reliability. The main issue regarding the PID controller is the accurate and efficient tuning of parameters. Due to higher order, time delay etc, and difficulties may arise to tune the PID controller for a complex system. To overcome these difficulties, optimization techniques are used. Generally, most industrial processes are multivariable systems. Many industrial plants are often burdened with problems like high order, time delays, damped poorly, nonlinearities, and time-varying dynamics etc, so it is difficult to tune the gains of PID controller. That means, the proper design of multi-loop PID control for multivariable process is a challenging task. In this paper, PID controller is designed using conventional tuning method for multi-input multi-output system. To evaluate the performance of proposed PID control design, binary Wood-Berry distillation column which is a multivariable process with strong interactions with input and output pairs is taken.

KEYWORDS: PID tuning, MIMO, Optimization, Differential Evolution (DE)

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INTRODUCTION

PID controller is the most widely used controller in industry. More than 90% of control loops are PID, with a wide range of applications [1] since PID controllers have simple structure and the meaning of three parameters, which can be easily understood by process operators. There are many tuning methodologies of PID controllers have been proposed earlier. But it is difficult to tune the PID controller parameters because many industrial plants are burdened with higher order, time delays, damped poorly and nonlinearities. That means, the design of multi-loop PID control for multivariable process is a challenging task.

For the best performance of the system, optimal tuning of PID control parameters is needed. Conventional tuning methods such as Ziegler / Nichols [2], Cohen / Coon [3], gain phase margin methods were used. These conventional methods are based on trial and error and process reaction curve. However, PID controller tuning difficulties may arise when the system is complex. Hence, many evolutionary algorithms such as genetic algorithm (GA) [4], Differential Evolution (DE) algorithm and Particle Swarm Optimization (PSO) Algorithm [5] were used for tuning. To validate the performance of proposed PID control design, binary Wood-Berry distillation column which is a highly nonlinear, multivariable process with strong interactions with input and output pairs is taken.

This paper is structured as follows. In section 2, a description of binary distillation column is given. Section 3 presents the fundamentals of PID controller. Section 4 explains conventional tuning method. Simulation results are presented and discussed in section 5. Finally, section 6 outlines a brief conclusion about this study.

CASE STUDY: A DISTILLATION COLUMN MODEL

Distillation is defined as a process in which a liquid or vapour mixture of two or more substances is separated into its component fractions of desired purity, by the application and removal of heat. To get this separation efficiently, distillation columns are used. Distillation can contribute to more than 50% of plant operating costs. The way of reducing operating costs of existing units is to improve their efficiency and operation via process optimization and control. The Wood

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and Berry distillation column process is chosen for study.

In the distillation column, vapour moves up the column, and as it exits the top of the unit, it is cooled by a condenser. The condensed liquid is stored in a holding vessel known as the reflux drum. Some of this liquid is recycled back to the top of the column and this is called the reflux. The condensed liquid that is removed from the system is known as the top product or distillate. The feed flows down the column where it is collected at the bottom in the reboiler. The vapour raised in the reboiler is re-introduced into the unit at the bottom of the column. The liquid removed from the reboiler is known as the bottoms product

Wood and Berry model is a 2×2 process (2 inputs and 2 outputs) that separates methanol and water [6]. It's a binary column with feed contains only two components. It 's tray column consist of 8 trays where trays of various designs are used to hold up the liquid to provide better contact between vapour and liquid, hence better separation.

The controlled variables are the composition of the top and bottom products expressed in weight percentage of methanol. The manipulated inputs are reflux and reboiler steam flow rates expressed in lb/min. The transfer function of distillation column has first order dynamics with time delays. The transfer function model of this process is given by

$$\begin{bmatrix} y_1(s) \\ y_2(s) \end{bmatrix} = \begin{bmatrix} \dfrac{12.8e^{-s}}{16.7s+1} & \dfrac{-18.9e^{-3s}}{21.0s+1} \\ \dfrac{6.6e^{-7s}}{10.9s+1} & \dfrac{-19.4e^{-3s}}{14.4s+1} \end{bmatrix} \cdot \begin{bmatrix} u_1(s) \\ u_2(s) \end{bmatrix} + \begin{bmatrix} \dfrac{3.8e^{-8.1s}}{10.9s+1} \\ \dfrac{4.9e^{-3.4s}}{13.2s+1} \end{bmatrix} \cdot [D(s)]$$

Where input signals are the reflux flow rate u_1 and steam flow rate u_2, the output signals are the top product composition y_1 and bottom product composition y_2 in mole fraction. The feed flow rate D is act as process disturbance. The linear model is valid around the set point $y_1 = 0.96$ and $y_2 = 0.02$ [7]. The time sampling is 1 min.

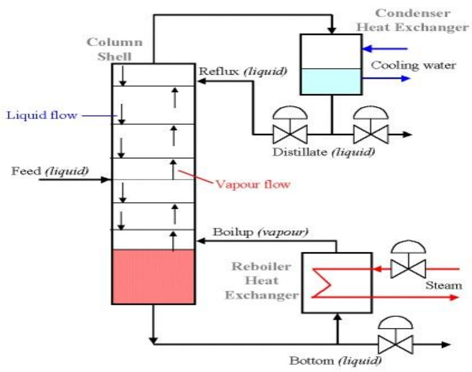

Figure 1. Block diagram of distillation column

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In the Wood-Berry distillation column with n= 2, the following objective function is used:

$$F = \sum_{k=1}^{N} k.|e1(k)| + k.|e2(k)|$$

Where k is the number of sample in the time domain, N is the total number of sampling, $e_i(k)$ is the error signal given by the difference between the setpoint signal and the output signal.

PID CONTROLLER

PID controller parameters consist of three separate terms: proportional, integral and derivative values denoted by k_p, k_i, k_d. The appropriate setting of these parameters will improve the dynamic response of a system, reduce overshoot, eliminate steady state error and increase the stability of the system [8]. The transfer function of a PID controller is

$$C(s) = \frac{U(s)}{E(s)} = k_p + {k_i}/_{s} + k_d s$$

The fundamental structure of PID controller is shown in figure 3.1. Once the set point has been changed, error will be computed between the set point and actual output. The error signal E(s), is used to generate the proportional, integral and derivative control actions, with the resulting signals weighted and summed to form the control signal U(s) applied to the plant model M. New control signal, U(s), will be sent to the plant M. This process will run continuously until steady state [9].

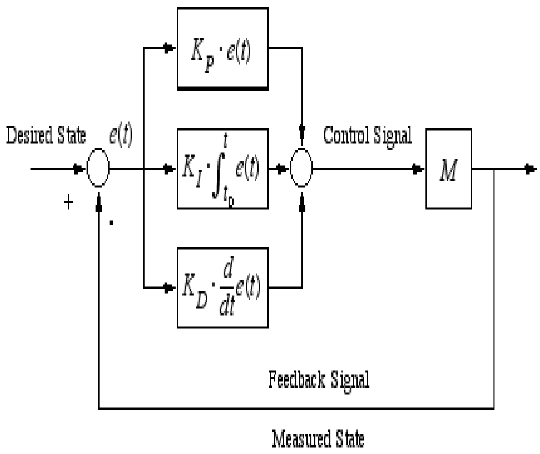

Figure 2. Block diagram of PID controller

CONVENTIONAL TUNING METHOD

The block diagram of conventional tuning method consists of error detector, PID controller, plant (distillation column) and optimization method. The error signal generated by the error detector is the difference between input signal and feedback signal. The controller modifies and amplifies error signal to produce better control action. This optimization method is applied to the PID controller and provides signal is fed to the plant (distillation column) to correct its output.

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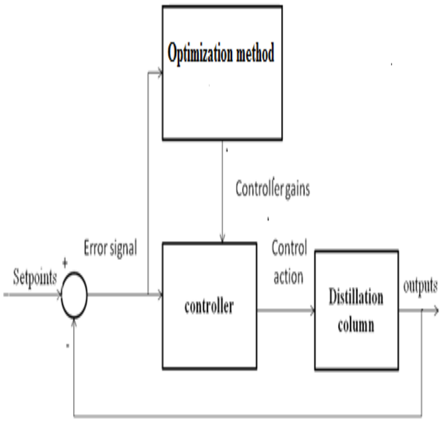

Figure 4. Diagram of multivariable controller design

Table 1: Data for multivariable PID controller parameters using DE [10]

Parameters	Differential Evolution (DE)
$K_{p,1}$	1.9866
$K_{i,1}$	0.4643
$K_{d,1}$	1.0242
$K_{p,2}$	-0.2254
$K_{i,2}$	-0.1008
$K_{d,2}$	-0.4123

SIMULATION RESULTS

Conventional block diagram for PID tuning consists of step input, PID controller, distillation column. In the conventional PID tuning, PID controller parameters such as K_p, K_i, K_d are obtained using one of the conventional method called differential evolution algorithm [10].

DE is a population based stochastic function minimiser (or maximize), whose simple and straight forward feature make it attractive for numerical optimization. DE algorithms use a floating point encoding EA for global optimization over continuous spaces. DE exhibits an overall excellent performance for a wide range of benchmark functions. DE combines simple arithmetic operators with the operators of recombination, mutation and selection to evolve from a randomly generated starting population to a final solution [10].

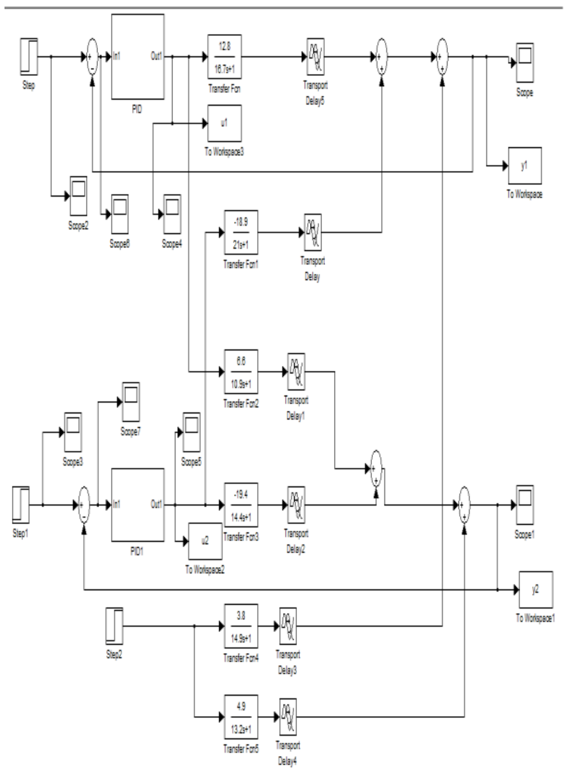

Figure 5. Block diagram for conventional PID tuning

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Table 2 : Controller performance analysis

Controller		Settling time (sec)	Rise time (sec)	Peak
Conventional PID	Top	40	7.18	1.074
	Bottom	173	7.96	0.4852

OUTPUT RESPONSE

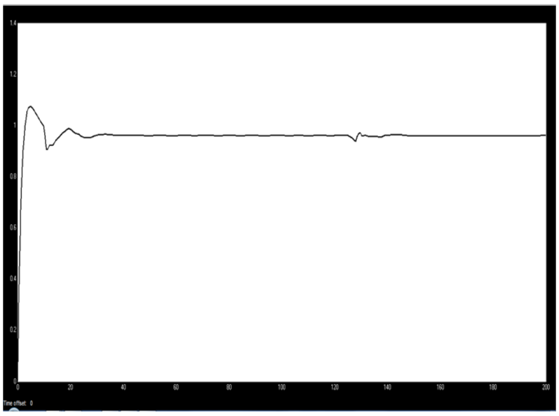

Figure 6. Response of output 1 for conventional tuning

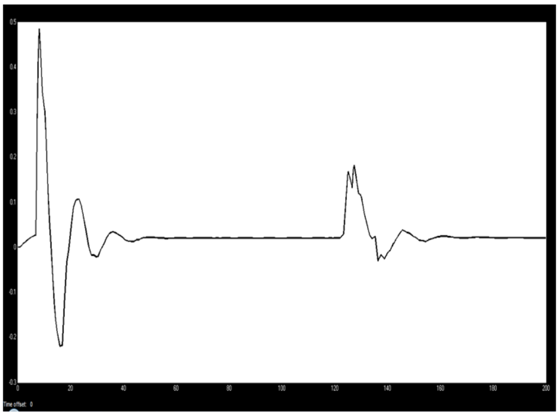

Figure 7. Response of output 2 for conventional tuning

From Table 4.2, it was inferred that the settling time for the top tray of the distillation column was 40 seconds, rise time for the top tray of the distillation column was 7.18 seconds, and peak value for the top tray of the distillation column is 1.074. Similarly for the bottom tray, the settling time is 173 seconds, rise time is 7.96 seconds, and peak value is 0.485.

CONCLUSION

The conventional circuit diagram for PID controller is simulated and the performance of conventional PID controller is analysed. Here PID controller parameters are obtained from differential evolution algorithm [10]. For conventional PID, the top tray and bottom tray values of Wood Berry distillation column is obtained. The obtained values for the top tray are settling time 40 seconds, rise time 7.18 seconds, peak value is 1.074 and for the bottom tray, settling time is 173 seconds, rise time is 7.96 seconds, and peak value is 0.485.

FUTURE WORK

`The main disadvantage of the conventional PID controller is poor performance. To improve the performance various optimization methods such as particle swarm optimization and firefly algorithm will be used to implement PID controller for distillation column.

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