UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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TITLE: PID CONTROL TUNING USING CUCKOO SEARCH ALGORITHM FOR COUPLED TANK LIQUID LEVEL SYSTEM

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"I hereby declare that I have read through this report entitle "*PID Control Tuning using Cuckoo Search Algorithm for Coupled Tank Liquid Level System*" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

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PID CONTROL TUNING USING CUCKOO SEARCH ALGORITHM FOR COUPLED TANK LIQUID LEVEL SYSTEM

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A report submitted in partial fulfillment of the requirements for the degree of Bachelor in Electrical Engineering (Control, Instrumentations and Instrumentations)

Faculty of Electrical Engineering

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“In the name of Allah the Most Gracious, the Compassionate Merciful”

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ABSTRACT

This project describes a liquid level control for a Coupled Tank System (CTS). Coupled tank is common equipment that is used in the industry. In this particular system, the liquid will be pumped into the tank, stored and having a process for example a chemical process. The liquid will be then transferred to another tank depending on the requirement of the system. A controller need to be added in the liquid level system in order to maintain the level of the liquid as desired. As the time pass by, the parameter of the system will slightly change due to the condition of the system for example disturbance. Thus, the existing controller parameter will no longer valid. Therefore, optimization technique will be used as the tuning to find the controller parameter, which will lead the system to give optimal performance. In this study, the Proportional-Iintegral-Derivative (PID) control tuning using Cuckoo Search (CS) is designed by using MATLAB and Simulink. The transient system performance (overshoot, settling time, rise time and steady state error) will be evaluated and compared with Particle Swarm Optimization (PSO). Performance index, Integral of Time Square Error (ITSE) will be used in this study as the comparator for both PSO and CS. The performance index also will be as reference that indicates the performance of the CTS. Based on this study, the result shows that tuning with CS algorithm outperforms the tuning using PSO algorithm in term of both fitness and transient response.

ABSTRAK

Projek ini menerangkan kawalan tahap cecair untuk sistem tangki ditambah, *Coupled Tank System (CTS).* Tangki ditambah adalah peralatan biasa yang digunakan dalam industri. Dalam sistem tertentu, cecair akan dipam ke dalam tangki, disimpan dan mempunyai proses sebagai contoh proses kimia. Cecair tersebut akan kemudian dipindahkan ke tangki lain bergantung kepada keperluan sistem. Pengawal perlu ditambah dalam sistem tahap cecair untuk mengekalkan tahap cecair seperti yang dikehendaki. Sebagai masa berlalu, parameter sistem sedikit akan berubah disebabkan oleh keadaan sistem contohnya gangguan. Oleh itu, parameter pengawal yang sedia ada tidak lagi sah. Oleh itu, teknik pengoptimuman akan digunakan sebagai penalaan untuk mencari parameter pengawal, yang akan membawa sistem untuk memberikan prestasi optimum. Dalam kajian ini, yang *Proportional-Integral-Derivatif (PID)* penalaan kawalan menggunakan algoritma *Cuckoo Search* (CS) direka dengan menggunakan MATLAB dan Simulink. Prestasi sementara sistem (lanjakan, masa penetapan, masa naik dan ralat keadaan mantap) akan dinilai dan dibandingkan dengan *Particle Swarm Optimization* (PSO). Indeks prestasi, *Integral Time Square Error (ITSE)* akan digunakan dalam kajian ini sebagai pembanding untuk kedua-dua PSO dan CS. Indeks prestasi juga akan menjadi rujukan yang menunjukkan prestasi CTS. Berdasarkan kajian ini, keputusan menunjukkan bahawa penalaan dengan algoritma CS melebihi pertasi penalaan menggunakan algoritma PSO dari segi kedua-dua kecergasan dan prestasi keluaran sistem.

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CHAPTER 1

INTRODUCTION

1.1 Background of study

Liquid level control system is commonly used in many process control applications, for example the level of liquid in a tank. Liquid tank system plays an important role in industrial application, such as in food processing, filtration and water purification system. In process industries, the water will be pumped into the tank and having a liquid process for example chemicals and mixing treatments. Afterwards, the liquid is transfered to other tanks as per requirement. The requirement in this system is to control the flow rate of the liquid delivered by the pump so that the liquid within the tank is as per desired. Vital industries where liquid level flow control is essential include petrochemical industries, papermaking industries and water treatment industries. In order to achieve this requirement of the process, the fluid supplied to the tanks must be controlled. An effective and proper tuning of PID tuning will be improved the performance of coupled tank liquid level system. Optimization technique will be used to obtain the tuning parameter of the controller.

The liquid level control is widely used in industrial application especially in chemical process industries. In mixing the reactant process, level control is important. The accuracy of the level according to the desired determines the quality of the overall product. Food process industries commonly used mixing reactants process such as sugar refining industries. The level of the tank preparing sugar syrup and the acid have to be mixed together in order to coagulate the syrup. This is to control the quality of the sugar is reserved. Evaporation is one of the applications that is applied in liquid level control. Evaporators are used in many chemical process for the purpose of separating chemicals products. Fertilizer process plant is one of the examples that used evaporator to transform a weak solution of chemicals to more concentrated solution.

1.2 Problem statement

Many controllers have been designed by other researchers in order to find the preferred performance of coupled tank liquid level system for example Fuzzy Logic Controller (FLC), Sliding Mode Controller (SMC) and Proportional Integral Derivative (PID) controller. PID controller is the most commonly used control algorithm in the system. PID controller popularity can be attributed due to its effectiveness in a wide range of operation conditions, its functional simplicity and the ease with which engineers can implement it using current computer technology. The designed controller will be no longer suitable to the couple tank liquid level system as the parameter of the system is changed. Due to the durability of the system is getting weakear, value of the parameter will be changed and the controller is no longer suitable to be implemented. Thus, optimization technique will be used as the tuning to obtain the optimal PID parameter. By using this method, it gives easiness in tuning regardless the change in system condition. Optimization technique has been applied to the in this system with different controller for example PID tuning using Genetic Algorithm (GA) and Fuzzy Logic with Particle Swarm Optimization (PSO). The controller with optimization technique gives better performance in overshoot percentage, settling time, rise time and steady state error. The new algorithm that was introduced by Xin-She Yang [5], Cuckoo Search (CS) algorithm has not been applied yet as a PID tuning method in coupled tank liquid level system. CS algorithm is one of the swarm intelligence based of the optimization tuning method. The algorithm will be used to find an optimal value PID parameter of coupled tank liquid level system.

1.3 Objectives

In order to obtain the parameter tuning based in optimization technique, hence objectives of this study are:

i. To obtain PID control tuning using swarm intelligence, Cuckoo Search for coupled tank liquid level system
ii. To evaluate the transient system performance using Cuckoo Search and compare with Particle Swarm Optimization

1.4 Project scope

Four scopes are listed in order the project is conducted within the boundary.

i. Apply performance index, Integral of Time Square Error (ITSE) to obtain the error of the system and as the indicator of system performance.

ii. Apply the optimization technique, Particle Swarm Optimization and Cuckoo Search algorithm in finding PID parameter with optimal system performances (overshoot, settling time, rise time and steady state error)

iii. Use MATLAB and Simulink for simulation and develop Particle Swarm Optimization and cuckoo search algorithm.

iv. Apply disturbance to the coupled tank liquid level system to test the robustness of the optimization controller.

1.5 Report Outline

The report is divided into five chapters;

Chapter 1 – Introduction

This chapter provides readers a first glimpse at the basic aspects of the research undertaken, which are overview coupled tank liquid level system, problem statement, objectives and scopes of this report.

Chapter 2 – Literature Review

This chapter reviews the basic principle of the system, related previous work and other reviews related to this project.

Chapter 3 – Methodology

This chapter will show the flow of the study and methodology being used in this study. The concept and characteristics of both algorithms will be shown in this section.

Chapter 4 – Results and Discussions

This chapter will present the results of the system performance by using PID control tuning using Particle Swarm Optimization (PSO) and Cuckoo Search (CS). Both of the optimization controllers will be tested with disturbance.

Chapter 5 – Conclusion and Future Works

This chapter consists of conclusion based on the result of the algorithm. It includes some of the advantages of using optimization of controller (PIDCS and PIDPSO) in the Coupled Tank System (CTS).

CHAPTER 2

LITERATURE REVIEW

2.1 Basic Principles

2.1.1 Coupled tank liquid level system

In this system, the liquid level in the coupled tank system is the controlled variable or process variable. It needs to be controlled or maintained at some desired liquid level. The input flow rate needs to be adjusted using pump voltage in order to control or maintain the liquid level. In the process control, the input flow rate is known as the manipulated variable in order to maintain the height of second tank at its set point. The basic principle of this system is to maintain the liquid level in the tank when there is an inflow of liquid into the tank and outflow of liquid out of the tank. The system is in a steady state condition when the liquid level is at a constant level. The water flow into the tank must be equal to the water flow out of the tank. This condition is same with the flow rate of inflow and outflow of liquid in the tank. If the rates remain unchanged, the liquid level of the coupled tank system will be maintained.

Despite that, the liquid level in the coupled tank system will change and settle at a different steady-state level when there is disturbance occurs in the system. The disturbance will change either the inflow or the outflow rate of the system. In order to maintain the liquid level at the previous condition, the input flow rate needs to be adjusted. The inflow rate needs to be increased when the outflow rate is greater than the inflow rate. Hence, the liquid level in the tank is increased. When the outflow rate is lower than the inflow rate, the liquid level will be settled at a higher level than before, assuming that a steady state is achieved before the tank overflows.

2.1.2 PID Controller

The Proportional-Integral-Derivatives, PID controller is a control feedback mechanism, which it is a well-known controller for many decades and almost most of the industries still use it. This controller will minimize the error by adjusting the process control inputs. It will calculate the error value as the difference between a measured process variable and desired set point.

$$u(t) = K_p \left[e(t) + \frac{1}{T_i} \int e(t)dt + T_d \frac{d}{dt} e(t) \right] \quad (2.1)$$

Where K_i is equal to the ratio of K_d and T_i and K_d is equal to the product of K_p and T_d.

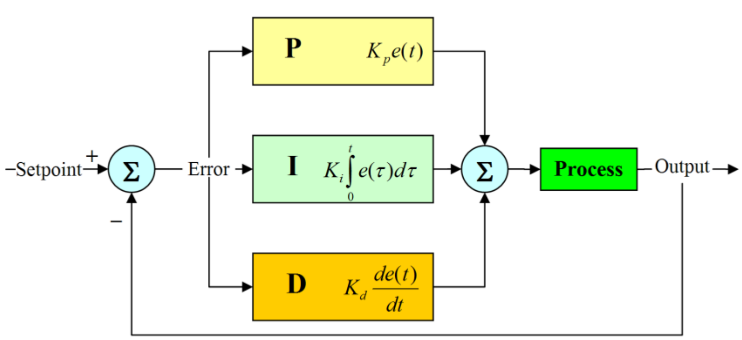

Figure 2.1: PID controller block diagram

Figure 2.1 shows a basic PID controller in the block diagram form. The PID controller consists of three term control which are Proportional (P), Integral (I) and Derivative (D). Each of the term control gives the different performance of the system (overshoot, settling time, rise time and steady state error). Proportional controller, Kp is an adjustable amplifier to be responsible for process stability. It will give an effect of reducing the rise time and steady state error will decrease. The steady state error needs to be eliminated. Thus, by using an integral controller, Ki will reduce the error and lastly eliminate the steady state error. However, it will give a high oscillation and overshoot percentage, as well the effect of the settling time of the performance will increase. In order to improve the whole performance of the system, derivative controller, Kd will be added to the system. It will give an effect of reducing overshoot percentage, increasing the stability of the system as well as improving transient response.

Table 2.1 is the comparison of the effect controller, Kp, Kd and Ki applied on a closed loop response. The table is used as a reference in trial and error method or traditional tuning. By varying of these variables, it may change the effect of the other two. It is because Kp, Kd and Ki are depending on each other.

Table 2.1: The effect of performance based on PID controller properties

	Settling Time, Ts	**Rise Time, Tr**	**Steady State Error, SSE**	**Overshoot, OS**
Proportional, P	Small Change	Decrease	Decrease	Increase
Integral, I	Increase	Decrease	Eliminate	Increase
Derivative, D	Decrease	Small Change	Small Change	Decrease

2.1.3 PID tuning

The process of obtaining the parameter of proportional gain, Kp, integral gain, Ki and derivative gain, Kd are called PID tuning. Difference control process may have different performance criteria. Therefore, different tuning parameters would be required. There are several techniques available for PID tuning, for example self-tuning PID, auto-tuning PID and optimization technique can be applied to the coupled tank system.

In this study, PID tuning that will be used is optimization technique. Optimization is a process that finds a best or optimal, solution for a problem. The optimization problem can be defined as finding the values of the variables that minimize or maximize the objective function while satisfying the constraints. The optimization problems are centered on three factors, which are;

i. Objective function, which is to be minimized or maximized
ii. A set of unknown or variables that affect the objective function
iii. A set of constraints that allow the unknown to take on certain values but exclude others

Optimization is one of the simplest ways to give a better value of the parameters of a system under specified conditions. The function of the optimization in a system is to obtain the relevant parameter values, which enable performance index (also known as objective function) to produce minimum and maximum value. Optimization methods classified into five classes, which are Linear Programming, Integer Programming, Quadratic Programming, Combination Optimization and Metaheuristic.

As the Metaheuristic algorithm recursively develops the pattern matrix at every iteration, the attribute variables of the pattern matrix decrease with the progressing iteration steps [1]. Two