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FINAL YEAR PROJECT REPORT

TITLE: MODELING AND PSO-BASED LQR CONTROLLER DESIGN FOR COUPLED TANK SYSTEM

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“I hereby declare that I have read through this report entitle “Modeling and PSO-based LQR Controller Design for Coupled Tank System” and found out that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)”

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MODELING AND PSO-BASED LQR CONTROLLER DESIGN FOR COUPLED TANK SYSTEM

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

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle "*Modeling and PSO-based LQR Controller Design for Coupled Tank System*" is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :………………………………………………

Name :………………………………………………

Date :………………………………………………

To my beloved father and mother

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ABSTRACT

Industrial application for liquid level and flow control is used tremendously in a process control industries such as the water treatment industries, paper making industries and petro-chemical industries. Level and flow control is important to ensure the quality and performance of the system can be maintained. This project is related on how to control the water level in the coupled-tank while both tanks is still regulating. It can be classified as Single-Input Single-Output (SISO) system as the process of this system only control one output using one input. Mathematical model can be obtained based on the experimental data collected from the coupled-tank system. The data will be loaded in a process called system identification where the mathematical representation or transfer function of the system can be determined. The validity of the transfer function will be verified before proceeds to controller design. Controller is used as a tool to improve the stability and performance of the transient response of the system. Hence, for this project LQR controller was selected as the controller to control and improve the transient response of the system. The LQR parameter is obtained using the optimization technique called Particle Swarm Optimization (PSO). To validate the result, system performance using LQR controller will be compared with PID controller.

ABSTRAK

Penggunaan industri berkaitan dengan paras cecair dan kawalan aliran adalah amat diperlukan terutamanya dalam industri kawalan proses seperti industri rawatan air, industri membuat kertas dan industri petro-kimia. Pengawalan paras air dan kawalan aliran adalah penting untuk memastikan kualiti dan prestasi sesuatu sistem dapat dikekalkan. Projek ini berkaitan tentang bagaimana untuk mengawal paras air dalam tangki walaupun pengaliran air untuk tangki berkembar ini masih berjalan. Ia boleh diklasifikasikan sebagai sistem satu masukan satu keluaran (SISO) dimana ia hanya mengawal proses yang mempunyai satu keluaran menggunakan satu masukan. Model matematik boleh diperolehi berdasarkan data yang dikumpul daripada perlaksanaan eksperimen terhadap sistem tersebut. Data ini akan dimuatkan di dalam proses yang dipanggil pengenalan sistem di mana perwakilan matematik atau fungsi pindah sistem tersebut boleh ditentukan. Kesahihan fungsi pemindahan akan diperiksa sebelum beralih ke langkah seterusnya yang merupakan reka bentuk pengawal. Pengawal digunakan sebagai alat untuk meningkatkan kestabilan dan prestasi sesebuah sistem. LQR pengawal dipilih untuk mengawal dan meningkatkan prestasi sistem tersebut. Parameter LQR akan diperolehi dengan menggunakan teknik pengoptimuman yang dipanggil PSO. Untuk mensahihkan prestasi sistem, LQR pengawal akan dibandingkan dengan prestasi sistem daripada pengawal PID.

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Coupled tank system plays important role in industrial application such as in petro-chemical industries, paper making industries, medical industries and water treatment industries. The coupled tank system consists of two vertical tanks which are joined together with an orifice and has an inlet liquid pumps and outlet valves. Each tank has its own inlet pump and output valve where the valve will regulate continuously. The coupled tank system can be configured as a Single-Input Single-Output (SISO) or as a Multiple-Input Multiple-Output (MIMO) system via manipulation of pumps input and sectional area of rotary valves. In industries, the liquid in the tank will go through several processes or mixing treatment whereby the level of liquid needs to be controlled and maintained. The flow between tanks must be continuously regulated. The basic control principle of the coupled tank system is to maintain the level of liquid in the tank when there is a process of inflow of liquid into the tank and output of liquid out of the tank.

1.2 Problem Statement

There are differences between real-time control and simulation control. Real-time is related to the surrounding where all of the parameters and condition need to be considered whereas simulation is an imitation of the operation of real process. All of the parameters can be controlled by human. To study the performance of the real-time implementation in a system, the coupled-tank system is chosen. In industries, there are problems faced related to the level of liquid in tank and the flow between the tanks. Most of the time, liquid level in the tanks needs to be controlled while regulating the flow in the tank. Common controller used to control the system is PID controller and Fuzzy Logic Control (FLC) controller. However in several cases, the conventional PID controller is not suitable for a controlled object with variable parameter or when there is existence of external disturbances in the system. One of the solutions to achieve high performance of the system is to apply state feedback controller to the system. There are several controllers that have been applied to control the system of the coupled tank. In this project, Linear Quadratic Regulator (LQR) controller will be selected as the state feedback controller for the system. The LQR controller approach will be tested to verify the improvement related to the performance of the system.

1.3 Objectives

The aim of this project is to obtain the modeling and controller design for coupled tank system. The main objectives of this project are:

1) To obtain transfer function of the coupled tank using system identification method
2) To implement LQR controller on coupled tank system and obtain its parameter using particle swarm optimization (PSO) technique
3) To compare the system performance of LQR and PID controller

1.4 Project Scopes

There are limitations to the completion of this project. The scopes of the project only cover:

1) Interface the coupled tank CTS-001 with DAQ card and use personal computer to stimulate data using software MATLAB
2) The experimental of coupled tank process is using single-input single-output (SISO) control system
3) System Identification used to generate the transfer function of the coupled tank
4) The parameter of LQR controller and PID controller will be determined using PSO optimization technique.

1.5 Project outlines

This report basically divided into five chapters:

CHAPTER 1 Introduction

This chapter allows the readers to visualize the basic aspects of the research done, such as the overview of the coupled tank system, problem statements, objectives and scopes of the project.

CHAPTER 2 Literature Review

This chapter reviews on the basic modeling for a coupled tank, previous controller used for the coupled tank system, several types of optimization techniques use for the system and other reviews that related to this project.

CHAPTER 3 Design Methodology

This chapter consists of the flow related to the study and methodology used for this project. The control principle for coupled tank system, modeling of the coupled tank and the design technique for PSO-based LQR controller will be explained in this chapter. The implementation of system identification to obtain the transfer function will also be included in this chapter.

CHAPTER 4 Result and Discussion

This chapter shows the characteristic of the system, the fitness function of each controller and the result of the transient response performance using the LQR and PID controller to the system.

CHAPTER 5 Conclusion & Future Works

This chapter consists of the conclusion based on the overall works and results. It also includes some future improvement that can be done in the system.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will review on research which focuses on mathematical model, LQR controller, previous controller used for coupled tank, system identification and optimization method used for the system. Coupled tank system is common in process industries as it need to be pumped from one tank to another. Somehow, the liquid needs to be monitored and the flow and level of liquid need to be controlled although the tank need to be continuously regulated. There are many types of controller use to control the coupled tank system such as the LQR, PID, Fuzzy Logic and Slide Control. The controllers have similar objective which are to improve the system performance. System identification is a tool that produces a transfer function from data collected in the coupled tank. From the transfer function obtained using the system identification, the optimization method is applied to find the best value for Q and R matrix in easier way compared to the trial and error method.

2.2 Control Principle of Coupled Tank System

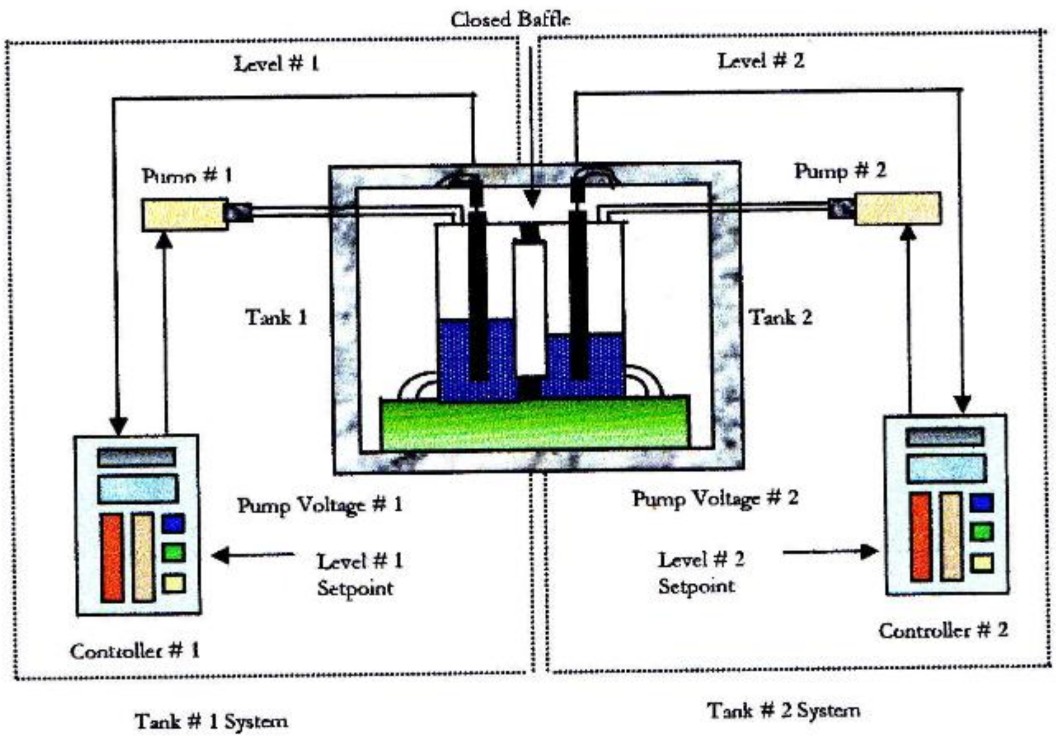

Figure 2.1: Schematic diagram for CTS-001 coupled tank [1]

Figure 2.1 shows the schematic diagram for CTS-001 coupled tank. The basic control principle of the coupled tank system is to maintain the water level in both tanks at a desired point value while the inflow and outflow of water tank keep regulating. Disturbance may be caused by variation in the rate flow from the baffle gap or the changes in the outlet of the tank. When disturbances occur, the water level in the tank will change and settle at a different steady-state level [1].

The control variable involve in the process control of this system is the water level in the coupled tank system. In order to control and maintain the water level at a desired point, the inlet flow rate needs to be adjusted. The pump voltage will become the device to adjust the inlet flow rate. The manipulated variable for this system is the input flow rate because it is the variable needs to maintain the process variable at the desired point.