

**IMPLEMENTATION OF PID CONTROLLER FOR CONTROLLING THE  
LIQUID LEVEL OF THE COUPLED TANK SYSTEM**

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## ABSTRACT

The PID controllers have found wide acceptance and applications in the industries for the past few decades. In spite of their simple structures, PID controllers are proven to be sufficient for many practical control problems. This project presents the PID controller design for controlling liquid level of coupled tank system. These coupled tank liquid level systems are in second order system. The PID Controller will be designed to control the liquid level at tank 1 and design techniques of the PID Controller are then conducted based on developed model. MATLAB has been used to simulate and verified the mathematical model of the controller. Visual Basic 6 has been used to implement the graphical user interface (GUI) and implementation issues for the controller's algorithms will also be discussed. The DAQ card is used for interfacing between hardware and software. The simulated result will be compared with the implemented result.

## ABSTRAK

Pengawal PID telah diperakui penerimaan dan penggunaan yang luas dalam industri untuk beberapa dekad sebelum ini. Walaupun mempunyai struktur yang ringkas, pengawal PID telah membuktikan bahawa ia boleh menyelesaikan banyak masalah dalam kemahiran pengawalan. Projek ini memaparkan pengawal PID direka untuk mengawal paras air pada tangki berkambar. Pengawal PID dicipta untuk mengawal paras air pada tangki pertama dan teknik penciptaan bagi pengawal PID direka berdasarkan model yang dihasilkan. MATLAB digunakan untuk simulasi dan mengesahkan model matematik pengawal. Visual Basic 6 digunakan untuk mencipta GUI dan isu penciptaan kawalan masa nyata bagi pengawal juga dibincangkan. Kad DAQ digunakan sebagai penghubung antara perkakasan dan perisian. Akhirnya, keputusan bagi simulasi akan dibandingkan dengan keputusan eksperimen.

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**LIST OF ABBREVIATIONS**

PID	-	Proportional-Integral-Derivative
DAQ	-	Data acquisition
GUI	-	Graphic User Interface
CTS-001	-	Coupled Tank Liquid Level System
SISO	-	Single Input Single Output
PV	-	Process Variable
MV	-	Manipulative Variable
SP	-	Set Point
V	-	Voltage
USB	-	Universal Serial Bus
$K_p$	-	Proportional Gain
$K_i$	-	Integral Gain
$K_d$	-	Derivative Gain
RC	-	Resistor-Capacitor Circuit

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## CHAPTER 1

## INTRODUCTION

## 1.1 Overview

Industrial application of liquid level control abound, such as in food processing, nuclear power generation plant, industrial chemical processing and pharmaceutical industries. The typical actuators used in coupled tank liquid level system include of two small tanks mounted above a reservoir which functions as storage for the water [4]. Each of both small tanks has independent pumps to pump water into the top of each tank [4]. At the base of each tank have a flow valve connected to reservoir. In addition, level sensors such as capacitive-type probe to monitor the level of water in each tank, displacement float and pressure sensor provide liquid level measurement [4].

The PID Controller usually used for temperature, motion and flow controllers. It's available in analog and digital forms. PID Controller will control the water pump so that water in both tank in level as required. The DAQ card is used as the interface to connect the system and equipment. Software such as MATLAB will be used to get the simulation result of the system performance and Microsoft Visual Basic 6 to implement the designed controller by developing Graphical User Interface (GUI). Figure 1.1 shows the block diagram of the coupled tank control apparatus with controller.

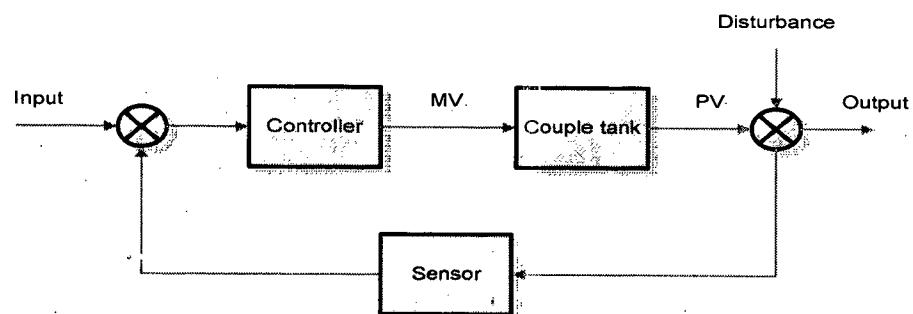


Figure 1.1: Block diagram of the couple-tank control apparatus.

## 1.2 Problem Statement

The Proportional-plus-Integral-plus-Derivative (PID) controllers have found wide acceptance and applications in the industries for the past few decades. It has a simple control structure which was understood by plant operators and which they found relatively easy to tune. In spite of the simple structures, PID controllers are proven to be sufficient for many practical control problems and hence are particularly appealing to practicing engineers. An abundant amount of research work has been reported in the past on the tuning of PID controllers. Ziegler Nichols step response, Ziegler Nichols ultimate cycling, Cohen Coon, Internal model control, and error-integral criteria tuning formulae are to mention only a few [7]. "PID" means Proportional-Integral-Derivative, referring to the three terms operating on the error signal to produce a control signal. Since many control systems using PID control have proved satisfactory, it still has a wide range of applications in industrial control.

In this project, several useful PID Controller design techniques will be presented, and implementation issues for the algorithms will also be discussed. The PID Controller will be designed to control the liquid level at tank 1. In this project, the simulation of proportional, integral and derivative actions are explained in detail, and variations of the basic PID structure are also introduced. A graphical user interface (GUI) implementing of PID Controller tuning formulae will also be present at this project.

Finally, we need continuous data from the plant as the feedback, so to overcome this problem an Advantech DAQ card have been used as the interfacing device between the hardware and software.

### 1.3 Objective

There are several objectives that must be achieved in order to make this project successful;

- i. To develop a PID Controller for controlling the liquid level of tank one of coupled tank system.
- ii. To validate the result from simulation (using MATLAB) through experimental set up (implementation using Microsoft Visual Basic 6).

### 1.4 Scope of project

This project is all about how to designed the controller and simulate it using MATLAB. Then, implement PID Controller by developing GUI using Microsoft Visual Basic 6 software on coupled tank liquid level system. After that, both results are compared.

There are several software will be used, first software is MATLAB 7.1 that been used to simulate and verified the mathematical model of the controller. Second software that will be us is Microsoft Visual Basic 6 that been used to implement the graphical user interface for PID Controller.

The communication between DAQ card, Visual Basic 6 and Coupled tank liquid level system will be determined, in term of address to give or receive analog or digital signal.

### 1.5 Summary

This chapter is about the explanation for overall project. The objective and the scope of the project will be given in order to give an insight about the idea of the project. On the next chapter, the literature review for this controller but use at different system and same system but with different controller will be discussed.

## CHAPTER 2

### LITERATURE REVIEW

#### 2.1 Overview

This chapter will discuss about the article that referred for this controller but applied at different plant or different method to designing and also for different controller but applied at same plant or same method of designing.

#### 2.2 Article

- [1] Jutarut Chaorai-ngern, Arjin Numsomran, Taweepol Suesut, Thanit Trisuwannawat and Vittaya Tipsuwanporn., " PID Controller Design using Characteristic Ratio Assignment Method for Coupled-Tank Process", Faculty of Engineering, King Mongkuts Institute of Technology Ladkrabang, Bangkok 10520, Thailand

This paper presents the PID controller design for coupled tank process using characteristic ratio assignment (CRA).The simulation results can be illustrated the validity of their approach by MATLAB

- [2] Mohd Fua'ad Rahmat and Mariam MD Ghazaly.," Performance Comparison between PID and Fuzzy Logic Controller in Position Control System of DC Servomotor", Jurnal Teknologi, 45 (D) Dis. 2006: 1-17

This paper presents the comparison between PID controller and Fuzzy Logic Controller about their time specification performance in position control system of a DC motor. This paper included design and development of a GUI software using Microsoft Visual Basic 6 to programming real time software.



- [3] Muhammad Rehan, Fatima Tahir, Naeem Iqbal and Ghulam., ” Modelling, Simulation and Decentralized Control of a Nonlinear Coupled Tank System”, Department of Electrical Engineering, PIEAS, Second International Conference on Electrical Engineering 25-26 March 2008 University of Engineering and Technology, Lahore (Pakistan)

This paper presents a coupled three tank system is taken as a plant and will be modeled mathematically using Bernoulli's law, simulate with Matlab/Simulink and decentralized using control and estimation tool manager from simulink model and mathematical model

### 2.3 Summary

This chapter is about the explanation for some article that will refer to gets the information or some knowledge that will apply to make the project run successfully. They are several articles that explain about same controller that will use in this project but applied at different plant or different method of designing, and also different controller but applied at same plant.

## CHAPTER 3

### METHODOLOGY

#### 3.1 Overview

This chapter will discuss about the method that has been used to complete this project. The coupled tank liquid level system CTS-001 will be used in this project as a plant. In this project, several useful PID Controller design techniques will be presented. The PID Controller will be designed to control the liquid level at tank one to obtain the desired level. In this project, Advantech DAQ card have been used as the interfacing between the hardware and software.

## 3.2 Project Flow Chart

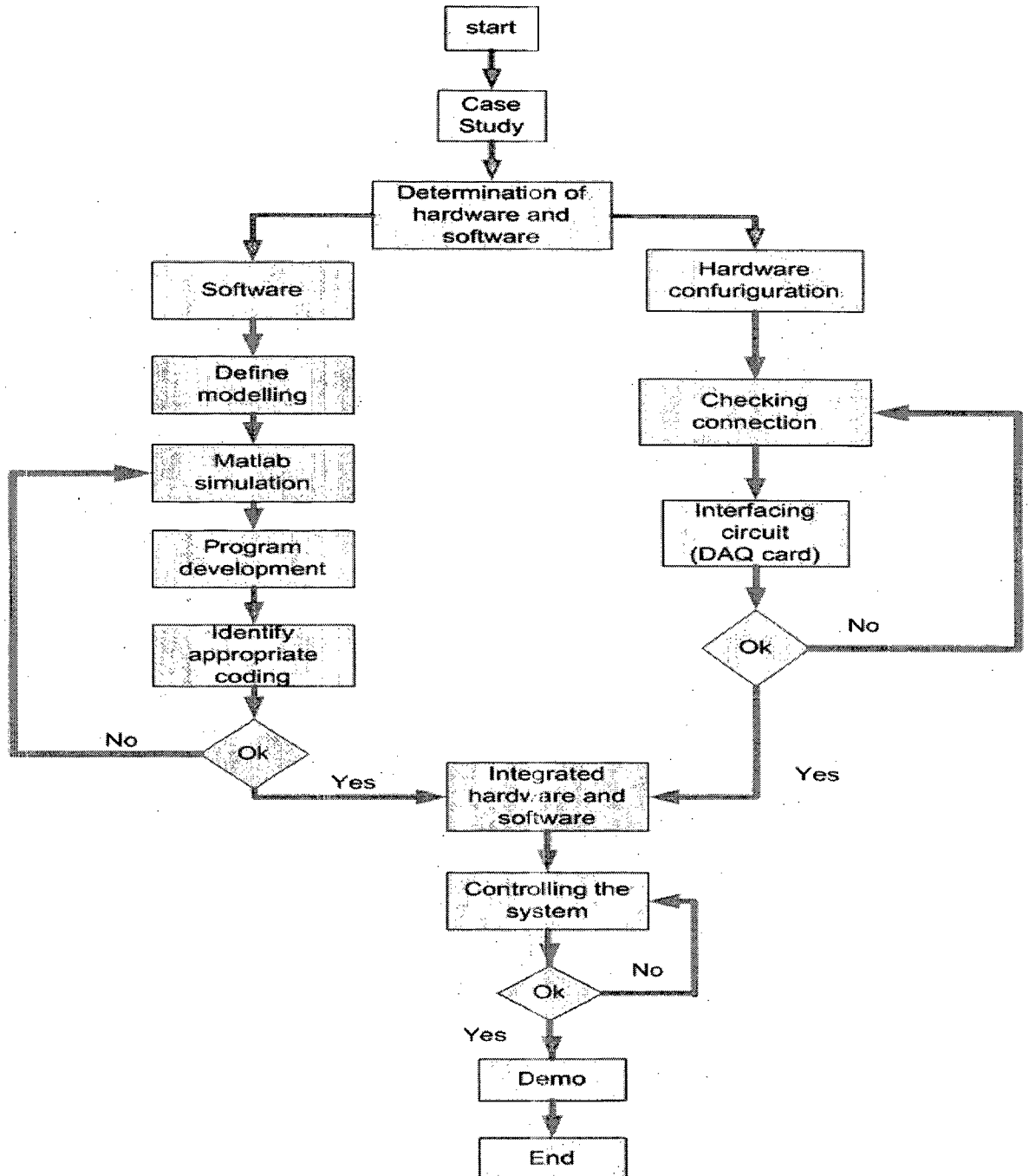


Figure 3.1: Flow chart for software and hardware development

Figure 3.1 shows about the overall progress for both software and hardware development that will discuss later. This project will be divided to two parts to make sure this project run smoothly. The first part is a software part, which will cover modeling the controller. The controller must be designed and simulated using MATLAB and then implemented in Visual Basic 6 as GUI. The second part will cover for the hardware part. In this part, the coupled tank liquid level system will be assembled to make sure it will run properly. Then, a communication between plant and controller must be done using DAQ card. The DAQ card must be analyzed and these operations need to refer the manual, to make the interfacing between plant and controller.

After that, both parts must be integrated to test the whole system. At this part, the real time result that implemented using Visual Basic 6 must be compared with the experiment result that simulated using MATLAB. Troubleshooting will be performed if some errors occurred to obtain better result.

### 3.3 Mathematical Modeling of Coupled Tank System

Before the process of designing controller begin, it is vital to understand the mathematics of how the coupled tank system behaves. In this system, nonlinear dynamic model are observed. Four steps are taken to derive each of the corresponding linearised perturbation models from the nonlinear model [4]. These steps will be generally discussed in this topic. Figure 3.2 shows the schematic diagram of coupled tank system that been used.

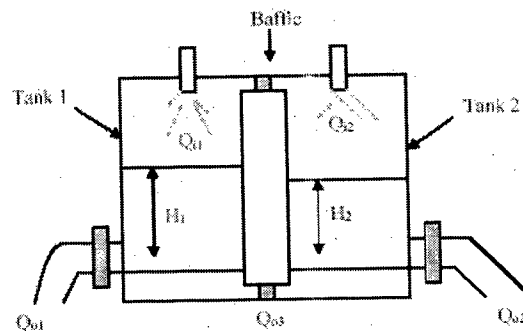


Figure 3.2: Schematic Diagram of Coupled Tank System

#### 3.3.1 A Simple Nonlinear Model of Coupled Tank System

A simple nonlinear model is derived based on figure 3.2. Let  $H_1$  and  $H_2$  be the fluid level in each tank, measured with respect to the corresponding outlet. Considering a simple mass balance, the rate of change of fluid volume in each tank equals the net flow of fluid into the tank. Thus for each of tank 1 and tank 2, the dynamic equation is developed as follows.

$$A_1 = \frac{dH_1}{dt} Q_{i1} - Q_{o1} - Q_{o3} \quad \dots (3.3.1.2)$$

$$A_2 = \frac{dH_2}{dt} Q_{i2} - Q_{o2} - Q_{o3} \quad \dots (3.3.1.3)$$

Where

$H_1, H_2$  = height of fluid in tank 1 and tank 2 respectively

$A_1, A_2$  = cross sectional area of tank 1 and tank 2 respectively

$Q_{o3}$  = flow rate of fluid between tanks

$Q_{i1}, Q_{i2}$  = pump flow rate into tank 1 and tank 2 respectively

$Q_{o1}, Q_{o2}$  = flow rate of fluid out of tank 1 and tank 2 respectively

Each outlet drain can be modeled as a simple orifice. Bernoulli's equation for steady, non viscous, incompressible shows that the outlet flows in each tank is proportional to the square root of the head of water in the tank. Similarly, the flow between the two tanks is proportional to the square root of the head differential.

$$Q_{o1} = \alpha_1 \sqrt{H_1} \quad \dots (3.3.1.4)$$

$$Q_{o2} = \alpha_2 \sqrt{H_2} \quad \dots (3.3.1.5)$$

$$Q_{o3} = \alpha_3 \sqrt{H_1 - H_2} \quad \dots (3.3.1.6)$$

Where  $\alpha_1, \alpha_2, \alpha_3$  are proportional constants which depend on the coefficients of discharge, the cross sectional area of each orifice and the gravitational constant.

Combining equation (3.3.1.4), (3.3.1.5) and (3.3.1.6) into both equation (3.3.1.2) and (3.3.1.3), a set of nonlinear state equations which describe the system dynamics of the coupled tank are derived

$$A_1 \frac{dH_1}{dt} = Q_{i1} - \alpha_1 \sqrt{H_1} - \alpha_3 \sqrt{H_1 - H_2} \quad \dots (3.3.1.7)$$

$$A_2 \frac{dH_2}{dt} = Q_{i2} - \alpha_2 \sqrt{H_2} - \alpha_3 \sqrt{H_1 - H_2} \quad \dots (3.3.1.8)$$

### 3.3.2 A Linearised Perturbation Model

Suppose that for a set of inflows  $Q_{i1}$  and  $Q_{i2}$ , the fluid level in the tanks is at some steady state level  $H_1$  and  $H_2$ . Consider a small variation in each inflow,  $q_1$  in  $Q_{i1}$  and  $q_2$  in  $Q_{i2}$ . Let the resulting perturbation in level be  $h_1$  and  $h_2$  respectively. From equations (3.3.1.7) and (3.3.1.8), the equation will become:

For Tank 1

$$A_1 \frac{d(H_1 + h_1)}{dt} = (Q_{i1} + q_1) - \alpha_1 \sqrt{(H_1 + h_1)} - \alpha_3 \sqrt{H_1 - H_2 + h_1 - h_2} \quad \dots (3.3.2.1)$$

For Tank 2

$$A_2 \frac{d(H_2 + h_2)}{dt} = (Q_{i2} + q_2) - \alpha_2 \sqrt{(H_2 + h_2)} + \alpha_3 \sqrt{H_1 - H_2 + h_1 - h_2} \quad \dots (3.3.2.2)$$

Subtracting equations (3.3.1.7) and (3.3.1.8) from equation (3.3.2.1) and (3.3.2.2), the equations that will be obtained are,

$$A_1 \frac{dh_1}{dt} = q_1 - \alpha_1 (\sqrt{H_1 + h_1} - \sqrt{H_1}) - \alpha_3 (\sqrt{H_1 - H_2 + h_1 - h_2} - \sqrt{H_1 - H_2}) \quad \dots (3.3.2.3)$$

$$A_2 \frac{dh_2}{dt} = q_2 - \alpha_2 (\sqrt{H_2 + h_2} - \sqrt{H_2}) + \alpha_3 (\sqrt{H_1 - H_2 + h_1 - h_2} - \sqrt{H_1 - H_2}) \quad \dots (3.3.2.4)$$

For small perturbations,

$$\sqrt{H_1 + h_1} = \sqrt{H_1} \left(1 + \frac{h_1}{2H_1}\right) \quad \dots (3.3.2.5)$$

Therefore,

$$\sqrt{H_1 + h_1} - \sqrt{H_1} \approx \frac{h_1}{2\sqrt{H_1}}$$

Similarly,

$$\sqrt{H_2 + h_2} - \sqrt{H_2} \approx \frac{h_2}{2\sqrt{H_2}}$$

And

$$\sqrt{H_2 - H_1 + h_2 - h_1} - \sqrt{H_2 - H_1} \approx \frac{h_2 - h_1}{2\sqrt{H_2 - H_1}}$$

Simplify equation (3.3.2.3) and (3.3.2.4) with these approximations will become,

$$A_1 \frac{dh_1}{dt} = q_1 - \frac{\alpha_1}{2\sqrt{H_1}} h_1 - \frac{\alpha_3}{2\sqrt{H_1 - H_2}} (h_1 - h_2) \quad \dots (3.3.2.6)$$

$$A_2 \frac{dh_2}{dt} = q_2 - \frac{\alpha_2}{2\sqrt{H_2}} h_2 + \frac{\alpha_3}{2\sqrt{H_1 - H_2}} (h_1 - h_2) \quad \dots (3.3.2.7)$$