

IMPLEMENTATION OF PROPORTIONAL INTEGRAL DERIVATIVE (PID)
CONTROLLER ON COUPLED TANK LIQUID LEVEL SYSTEM

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**Dedicated to my beloved parents, sibling and friends
For giving a constant source of support and encouragement**

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ABSTRACT

Nowadays, the liquid level control is one most important element in industrial field especially in chemical industry. The basic concept of how the coupled tanks system work in this project is by using computer as the main control where user can control the level of liquid in one tank or both tanks. The purpose of this project is to implement PID controller on coupled tank liquid level system by using visual basic software. The visual basic software are used because it easy to interface with hardware. PID controller was used due to widely acceptance applicability in process industry. The mathematical model of PID controller was used implement as such to produces suitable output so that the liquid level can be controlled at desired set point. Meanwhile, the mathematical model of coupled tank liquid level system was derived to obtain the transfer function of the plant and later be used to simulate the plant performance in MATLAB program.

ABSTRAK

Pada masa sekarang, kawalan aras cecair adalah satu unsur penting dalam industri terutama industry kimia. Konsep asas bagaimana untuk tangki berkembar berfungsi dalam projek ini ialah, dengan menggunakan komputer sebagai pengawal utama, pengguna boleh mengawal ketinggian cecair di dalam satu tangki atau untuk kedua-dua tangki. Tesis ini menerangkan tentang cara yang digunakan untuk mengawal aras air pada ketinggian yang dikehendaki. Tujuan projek ini adalah untuk melaksanakan pengawal PID pada tangki cecair ketinggian berkembar menggunakan perisian visual basic (VB-6). Perisian visual basic (VB-6) digunakan kerana ia mudah untuk kemunikasi dengan tangki cecair ketinggian berkembar. Pengawal PID digunakan kerana ia telah digunakan secara meluas dalam industry proses. Formula matematik dalam pengawal PID telah digunakan untuk menghasilkan keluaran yang bersesuaian dengan system dikehndaki. Formula matematik untuk tangki cecair ketinggian berkembar dalam buku manual digunakan sebagai perkara rumus bagi system tangki cecair ketinggian berkembar

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LIST OF SYMBOLS

DAQ- Data Acquisition

GUI- Graphical User Interface

LQR- Linear Quadratic Regulator

SISO- Single Input Single Output

MIMO- Multi Input and Multi Output

CHAPTER ONE

INTRODUCTION

1.1. Overview

In the process of industrial there are various parameters need to be controlled such as temperature, level, and etc. Some process needs to keep the liquid level in the horizontal tank such as oil, chemical liquid in its. The level control is a type of control method for common in process system. The level control system must be controlled by the proper controller. The objective of the controller in the level control is to maintain a level set point at a given value and be able to accept new set point values dynamically.

PID controller is widely used in industrial application such as in temperature, motion and level control. By using PID controller the output will obtain in a short time, minimal steady state error and can control the overshoot. The proportional component (K_p) provides an overall control action proportional to the error through the all pass gain factor. The integral component (K_i) was used to minimize steady state error through low frequency compensation. The derivative component used to reduce overshoot and improve transient response through high frequency compensation.

Water level control is a process of controlling the water level to desired set point by controlling the pump that used to inject the water to the tank and measured it by sensor. The important parts of control water level are to the situation that requires fluid to be supplied to a chemical reactor at a constant rate and to maintain

the water at desired level. People generally switch on the pump when their taps go dry and switch off the pump when the overhead tank starts overflowing. This results in the unnecessary wastage and sometimes non-availability of water in the case of emergency. There are some other problem that might occur when level of water is not control such as when water need to be at constant rate and it used for cooling system, the system will breakdown because of high temperature.

1.2. Objective

In this project there are several objective should be archived, they are:

1. To implement PID controller for controlling coupled tank liquid level sensor
2. To simulate PID controller for controlling water level sensor in coupled tank system.
3. To see the effect of tuning proportional (K_p), Integral (K_i) and derivative (K_d) on the system response.

1.3. Scope Of Project

To make this easier to handle this project was divided, into two difference part, for hardware and software.

1.3.1 Hardware

The hardware that we used was named by coupled tank liquid level system. It consists of two small tower-type tanks mounted above a reservoir which functions as storage for the water. Water is pumped into the top of each tank by two independent pumps. The head of water in each tank is clearly visible on the attached scale at the front of the tanks. Each tank is fitted with an outlet, at the side near the base. Data

acquisition needs to be used to communicate between hardware and software. There are several data acquisition cards for input output that can be used such as from National Instrument, Advantech and others.

1.3.2 Software

The software parts are most difficult, because of needed to study MATLAB and Visual Basic (Vb-6) software to implement PID controller to the system.

- I. MATLAB are used as a simulation for PID controller and coupled tank liquid level system.
- II. To create GUI using Visual Basic 6. Need to understand algorithm for PID controller for implement to the coupled tank system.

1.5 Problem statement

As real-time control involves algorithms to control a certain processes, and used complex algorithm. In order to study its performance in terms of implementation in real-time and simulation at each control features, control of level of a coupled tank is chosen. This application is widely used in the process industry especially in chemical industries. In this project, controlling liquid level process will be done in real-time by applying Proportional-Integral-Derivative (PID) algorithm and compare with simulation.

Other issues in real-time such as rapid testing, nonlinearity and computational problem have led researchers in recent years to do intensive work on development methodologies to enhance control in real-time. Therefore software's such as Visual Basic (VB), MATLAB, and other simulation software would reduce the effort for implementation especially in algorithm to imply.

The main interest in this research is to implement a real-time predictive control algorithm to a coupled tank for level control process using PID controller and its control performance will be benchmarked against MATLAB simulation using same controller.

1.6 Thesis Organization

This thesis consists of six chapters including this chapter. The content of each chapter are outline as follow:

Chapter 1: is about introduction to the thesis. This chapter introducing the overview of project including objective and the scope of the project.

Chapter 2: is an article review. This chapter provides review about background of Coupled Tank liquid system, PID controller, PID application and about how Direct digital control (DDC) is implement.

Chapter 3: Include the project methodology. This will explain about how the project was organized and the flow of the process in completing this project.

Chapter 4: is about PID controller. This chapter review about how to implement PID controller for the project.

Chapter 5: is about the result of the MATLAB simulation and real time result in visual basic will discuss. The output response for each result will analyzed. All the case studies will analysis in this chapter. Lastly, Chapter 6: is about result based on this project and the suggestion to improve the system in future.

CHAPTER TWO

LITERATURE REVIEW

2.1 Overview

This chapter will review previous research which concern to PID controller, liquid level control of coupled-tank system and how digital direct control DDC work. The history about PID controller and their application as well as the usage of couple tank Liquid level system will be discussed.

2.2 Couple tank Liquid level system

Coupled-Tank Control Apparatus is a low-cost pilot plant designed for laboratory teaching of both introductory and advanced control systems theory. This apparatus can be used for teaching system modeling using static and transient measurements; steady state error analysis; transient response studies; and for evaluating the design, operation and application of common controllers as well as controller tuning methods. [1]

2.3 PID controller

PID controllers are used in more than 95% of closed-loop industrial processes. It can be tuned by operators without extensive background in Controls, unlike many other modern controllers that are much more complex but often provide only marginal improvement. In fact, most PID controllers are tuned on-site. Although we are learning all the theories to design the controller, the lengthy calculations for an initial guess of PID parameters can often be circumvented if we know a few useful tuning rules.[2] This is especially useful when the system is unknown.

PID controllers are dominant and popular and, have been widely used since the 1940's because one can obtain the desired system responses and it can control a wide class of systems. A PID controller attempts to correct the error between a measured process variable and a desired set point [3].

PID controllers have a simple control structure, inexpensive cost, many proposed systematic tuning methods, and have been used for more than half a century [4]. PID controller consist of three separated element that are Proportional(P) which as the proportional value (K_p), Integral (I) consist of proportional error and the duration of error (K_i) and Derivative (D) determine the rate of change of the process error (K_d).

There are several method for tuning PID such as Ziegler-Nicholas, Bode's integrals, disturbance rejection magnitude optimum, pole placement and optimization methods. However in this project the Ziegler-Nicholas tuning method was use.

The first tuning method was developed in 1942 by Ziegler and Nichols and is known as Quarter-Amplitude-Damping (QAD) [5]. For this tuning method, first we must set proportional value ($K_p=0$), integrated value ($K_i=0$) and derivative value ($K_d=0$) then increase proportional value (K_p) until the output starts overshooting and ringing significantly. After that Increase K_D until the overshoot is reduced to an acceptable level then lastly Increase K_I until the final error is equal to zero.

2.4 Direct digital control (DDC)

DDC control consists of computer-based controllers with the control logic performed by software. Analog-to-Digital (A/D) converters transform analog values into digital signals that a microprocessor can use [6].

DDC used to collect the data and process the data. The DDC system will monitor the system by selected time and analyze [7]. The benefits of using DDC are increase control efficiency, energy efficiency, operation efficiency and DDC systems are capable of collecting and processing large streams of data [6,7].

Direct Digital Control, known as "DDC", logs electronic temperature measurements and compares them to the desired settings (set-points), then calculates an appropriate response if the two aren't equal, and finally sends out new signals to correct for any difference. Start/stop control and alarm reporting are also incorporated into DDC. [8].

2.5 Summary

In this chapter, the reason for choosing PID controller and the basic operation of DDC is mention. Basically the PID controller was choosing because it's simple and normally used in control system. Besides that the couple tank liquid level for case study also was discuss in details. The most important is how to tune the PID controller. So based on several tuning method the Zeigler-Nicholas will be used as tuning method.

CHAPTER THREE

METHODOLOGY

3.1 Overview

The scope of this chapter is to provide further details on methodology and approach upon completing this project. Level control is one of the control system variables which are very important in the industries. A simplified version mock-up of one of the system like the interacting tanks in such industries is essential in order to understand its dynamic behavior (Bennett, 1994). Therefore, AISB Coupled-Tank Control Apparatus CT-001 which is available in UMP's lab serves as a low-cost pilot plant that represents the interacting tanks in the actual industries. The CTS-001 will be used as test bed for real-time implementation of PID controller implementation. Thus system identification of non parametric model is involved in modeling the system in Visual Basic (VB-6). The model obtained is specialized to both tanks system (second order single input single output). The process plant, data acquisition card and the Visual Basic (VB-6) and MATLAB software will be discussed for its implementation throughout the project in this chapter.

3.2 Project Structure

There are few steps taken to initiate this project. These steps are implemented to assure that the project can be running smoothly and the objective can be achieved.

The basic of the methodology consist of three main tasks. They are:

1. Design phase
2. Development phase
3. verification phase

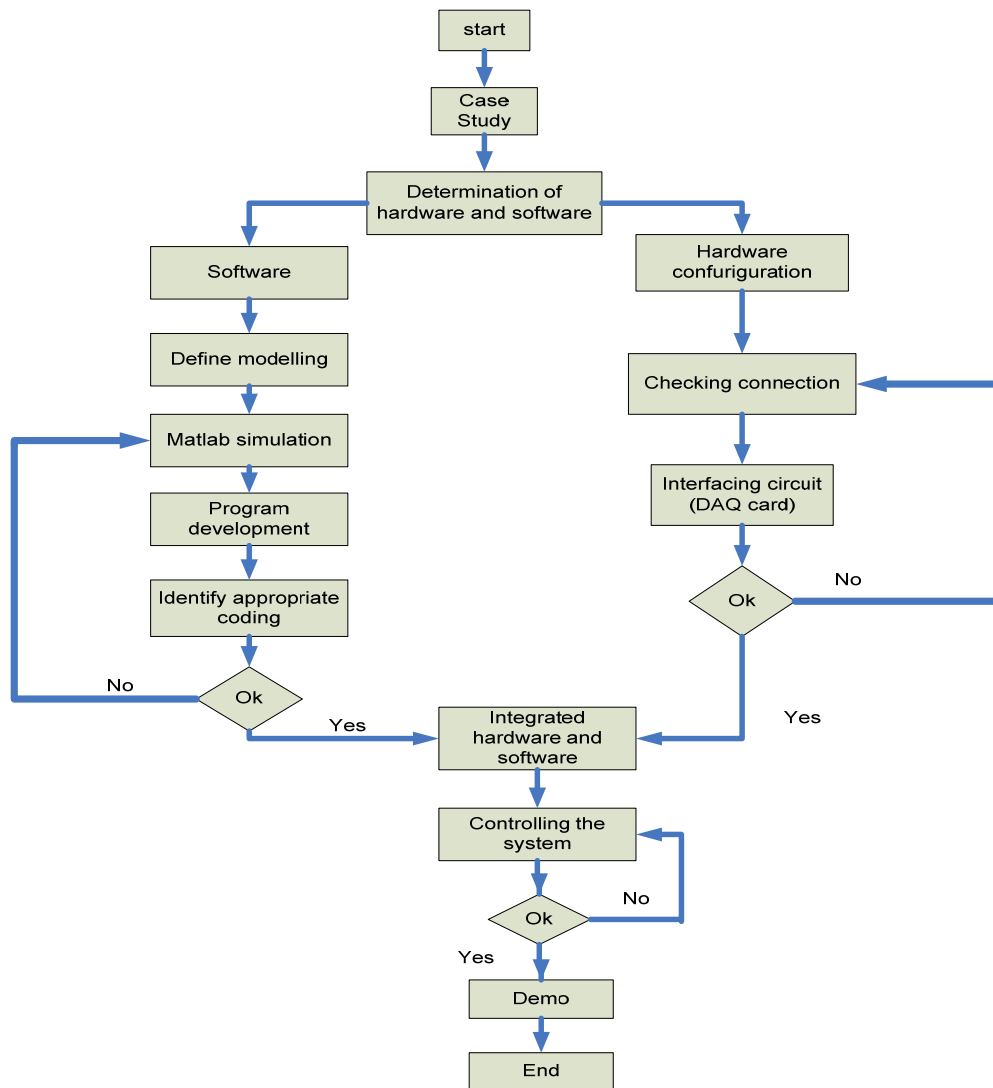


Figure 3.1: Flow chart Project

The figure 3.1 above show the how the flow chart project that has been done. The project was divided into two parts, to make it easy to handle. The first part is software design and the second part is hardware design. In hardware design part flow, the main target is to create appropriate system for the process control. The plant that is coupled tank liquid level will be assembling, all the connection must be check correctly and able to work properly. After finish with the plant, a simple communication must be done between plant and computer using DAQ card, the DAQ card itself must be analyzed to make the interfacing easier. The input and output need to be test.