LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Project background

In many industries process such as petro chemical industries, paper making industries and water treatment industries are using the tank system to control the liquid level. The liquid level 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. The conventional proportional- integral- derivative (PID) is commonly utilized in controlling the level. On the other hand, the fuzzy logic controller (FLC) is also popularly implemented in many practical industries application.

The CE 105 Couple Tank System which is available in Instrumentation and Measurement Laboratory, FKEE, UTHM. CE 105 will be used as model to implement the PID and FLC. In order to control the liquid level in the couple tank, there are five controllers that will be considered in this part which are proportional controller (P), proportional plus integral controller (PI), proportional plus derivative controller (PD), proportional plus integral plus derivative controller and fuzzy logic controller.

1.2 Problem Statement

The control of liquid level in tanks and flow between tanks is a basic problem in the process industries. The process industries require liquids to be pumped, stored in tanks, then pump to another tank. Many times the liquids will be processed by chemical or mixing treatment in the tanks, but always the level of liquid in the tanks must be controlled, and the flow of the tank must be regulated.

Level and flow control in tanks are at the heart of all chemical engineering systems. But chemical engineering system are also at the heart of our economies. Vital industries where liquid and flow control are essential include petro chemical industries, paper making industries and water treatment industries.

Our lives are governed by level and flow control system. The water closet (WC) toilet in our house is also a liquid level control system. The swinging arm attached to the input valve of the WC water tank allows water to flow into tank until the float rises to a point that closes the valve.

There are many alternative controller design theories that can be used to control the level of liquid on tanks. Proportional integral derivative control is one of a kind of control strategies that uses to control the level and flow of liquid. Proportional control, PI control, PD control and PID control will be investigate to determine which controller is the best for liquid level control.

Even though the PID controller is widely used in industrial process, the tuning of PID parameter is a crucial issue in particular for the system's characteristic which has large time delay and high order system [Underwood, 2000]. Commonly in industrial process, only an expert or experience workers are able to monitor and tune the PID parameters based on their experience.

Therefore, in certain cases where there is deficient of experience with the process, it is sometimes quite impossible to achieve a satisfactory performance. For this reason, it is desirable to introduce other type of controller such as artificial conventional fuzzy logic controller.

1.3 Objectives

The objectives of the project are as followings:

1. To develop the real time control (PID and FLC) on the Tank Apparatus (CE 105) by graphical environment using Laboratory Virtual Instrument Engineering Work bench (LabVIEW) language.
2. To investigate the performance of P, PI, PD and PID controller in control of tank system.
3. To propose the Fuzzy Logic Controller in control of tank system.

1.4 Scope of the project

The scopes of the project are as followings:

1. Study the characteristic of Tank Apparatus (CE 105).
2. Hardware setup between Couple Tank, Data Acquisition Card and personal computer.
3. Study on Fuzzy Logic controller toolbox.
4. Design the graphical programming for PID Controller and Fuzzy Logic Controller.

1.5 Thesis outline

This thesis is organized in six chapters. The first chapter gives an overview of the project that gives the introduction of control system. It consists of project background, objective, and scope.

Chapter two covers literature review which included the controller used to control of pump running. Some brief explanation on the results obtained.

Chapter three covers the flow of methodology and description of each procedure. The details of the implementation of software and hardware are discussed. It also consists of theory of controller implementation.

Chapter four focus on the result, analysis and discussion of this project.

Chapter five includes the conclusion and recommendation of the thesis.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter will review previous research which focuses on PID, Fuzzy Logic and liquid level control of couple tank system. There are a group of control method in controlling the liquid level in the couple tank system which had been implemented will be discussed.

2.2 Related Works

In the previous years, there are many control strategy approaches for controllers design of liquid level control system such as robus PID controller [Masato Kahara et. Al, 2001], Fuzzy-PD control, Cascade control, Multiple Model Predictive Control [Ming He et. Al, 2005] and advance PID auto tuner [Qiang Bi et. Al, 2000]. For example, [Satean Tunyasrirut et. Al, 2007] proposed a Fuzzy Logic Controller and Cascade Controller which can control the liquid level in horizontal tank. Another example is a Generalized Predictive Control for control the level water in couple tank developed by Ahmad ‘Athif bin Mohd Faudzi [Ahmad ‘Athif et. Al, 2006].

In some cases, an artificial intelligent approach such as Fuzzy Logic Control (FLC) has gain interest in control system design. For example, [Pornjit Pratumsuwan et. Al, 2009] proposed a Fuzzy Logic Control to control the electro hydraulic system. This hardware was used as a equipment in laboratory for student experiment tasks. This project also used PID controller. Finally, student will see the different between PID and FLC performance. For PID tuned, they used Ziegler Nichols method and trial and error. Fuzzy Logic Control has superior performance compared to a PID controller.

2.3 Fuzzy based using SCADA

Zafer Aydogmus proposed concept of fuzzy based controller for level control using SCADA. This research presents a SCADA (supervisory control and data acquisition) control via PLC (programmable logic control). Sugeno type of fuzzy algorithm has been used in this study and to achieved the parameters of the membership function in the MATLAB/Simulink program has been used.

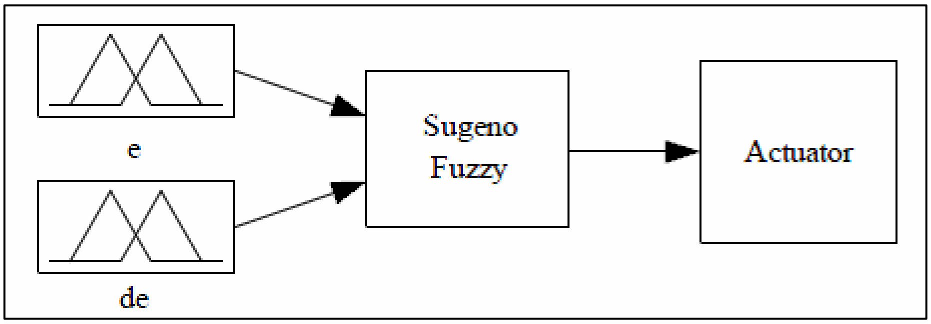

Figure 2.1: Sugeno type fuzzy controller

As shown in figure 2.1, this fuzzy logic controller has two input variables; e(t) is the error which is the difference between set value and process value and de(t)dt is the differential of e(t) and an output variable which is the control signal of the actuator. Linear type output membership functions have been used in fuzzy rule base which has four fuzzy rules.

The function of the SCADA in this research is for monitoring element. A SCADA system has been composed for monitoring the liquid level in the tank and position of the actuator valve. It is possible to observe the time variations of the level water and position of the actuator valve.

This researcher has been done the comparison between simulation and implementation result and similar results were obtained. However, the actual model of the system has not been simulated completely, some negligible differences have been observed between the experimental and simulation results of the actuator position.

2.4 PID, fuzzy and cascade controller

Satean Tunyasarirut and Santi Wangnippranto proposed concept of PID, fuzzy logic and cascade controller to control the liquid level in horizontal tank. The user can control the liquid level using three types of controller. The cylindrical horizontal tank has diameter 300 mm and 480 mm long. The interface card module PCI 6024E and LabVIEW software program is used for build the cascade controller.

Cascade control can be used for improved disturbance rejection when there are several measurement signals and one control variable. Cascade control is build up by two controller loop. The inner loop is called the secondary loop that using the PID controller. The outer loop is called the primary loop that using the fuzzy logic controller. This research consists of computer, interface card, level transmitter, and linear control valve.

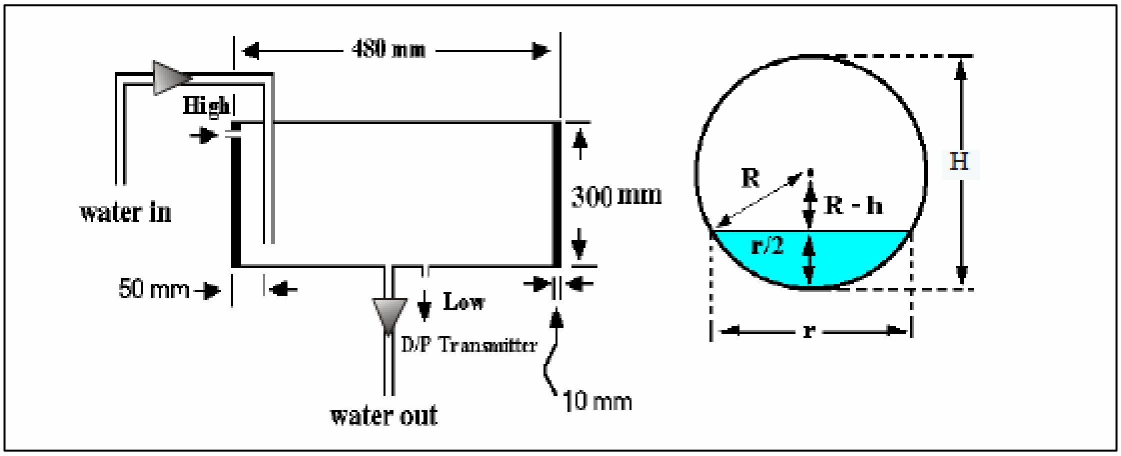

Figure2.2: The horizontal tank model

Figure 2.2 shows the structure of the liquid volume in the horizontal tank. The high of the horizontal tank is 300 mm and length is 480 mm. This horizontal tank is selected as the model to implementation of Fuzzy-PID cascade control.

The fuzzy logic controller was builds in the LabVIEW program. The input of fuzzy logic controller is the level error between the actual level and target level of the level in horizontal tank. Fuzzy logic controller part consists of fuzzification, control rule and defuzzification. Membership function editor is used for expressing input and output variables.

From this research, the conclusion has been made which is the response time of the cascade controller less than single loop or fuzzy logic control. Both of controllers give the smallest state error and also can see that the interrupt load can effect all the controller.

2.5 Neuro- fuzzy controller by genetic algorithms

The title of this research is tuning of a neuro- fuzzy controller by genetic algorithms (NFCGA) with an application to a couple tank liquid level control system was finished by Seng Teo Lian, Khalid Marzuki and Yusof Rubiah. This paper has proposed a method for a automatic tuning of a fuzzy logic controller which is based on the RBF neural network using genetic algorithm (GA). It is named NFCGA. The NFCGA is then applied to a noisy couple tank liquid level.

A linear mapping method is used in this project to encode the GA chromosome, which consists of the width and center of the membership function, and also the weights of the controller. Dynamic crossover and mutation probabilistic rates are also applied for faster convergence of the GA evolution.

The performance of the NFCGA has been compared with those of a conventional FLC and a PID controller in terms of step response, load disturbance and change in plant dynamic.

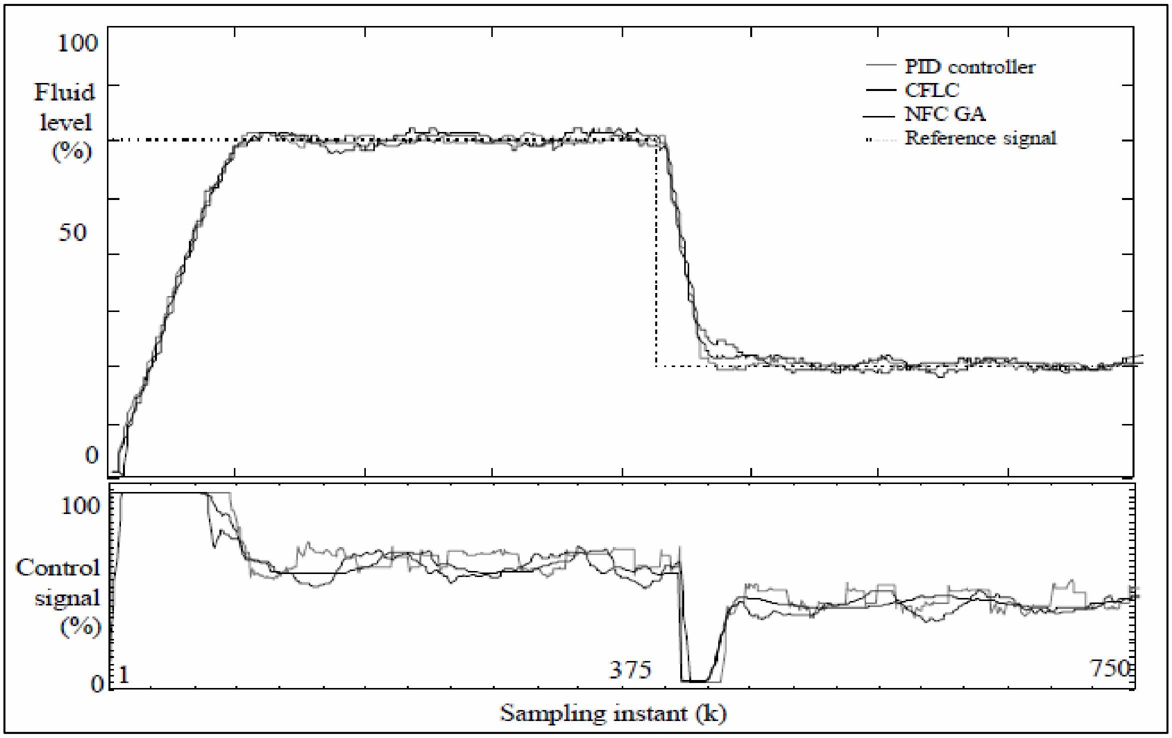

Figure 2.3: Step responses and control signals of the three controllers

Figure 2.3 shows the step responses of all three controllers which are conventional FLC, PID and NFCGA. Generally, it can be seen that the transient response of all controller are good, and their performance are very similar. However, it can be observed that the control signal from the NFCGA is smoother than those of other two control schemes.

2.6 Summary

The controller of controlling the liquid level in the tank system can be generalized in many ways. Zafer Aydogmus have shown that the SCADA control via PLC is designed for monitoring and control the liquid level and valve position. The sugeno fuzzy type has been selected as the best algorithm for this research. While, Satean Tunyasarirut and Santi Wangnippranto using PID, FLC and cascade controller. As a result cascade controller produces the less response time compared to others. Last but not least, neuro fuzzy controller by genetic algorithm proposed by Seng Teo Lian from Universiti Teknologi Malaysia. This research activated the plant using three types of controller which is PID, Fuzzy and NFLGA. As a result the control signal from the NFLGA is smoother than others.

From all of previous presented paper various method and controller were used to activate the pump in stable condition. Most of the researchers try to obtain the best controller base on control signal response.

CHAPTER 3

METHODOLOGY

3.1 Overview

The focus of this chapter is to provide further details of methodology and approaches to completing this research. The CE 105 Couple Tank System which is available in Instrumentation and Measurement Laboratory, FKEE, UTHM. CE 105 will be use as model to implement the PID and FLC. The process plant, data acquisition card and the LabVIEW software will be discuses for its implementation.

In this research, there are a few steps need to be considered which can be illustrated graphically in the figure 3.1. After completed the controller design, the whole hardware will be testing to make sure it achieved the limitation voltage of pump and transducer.

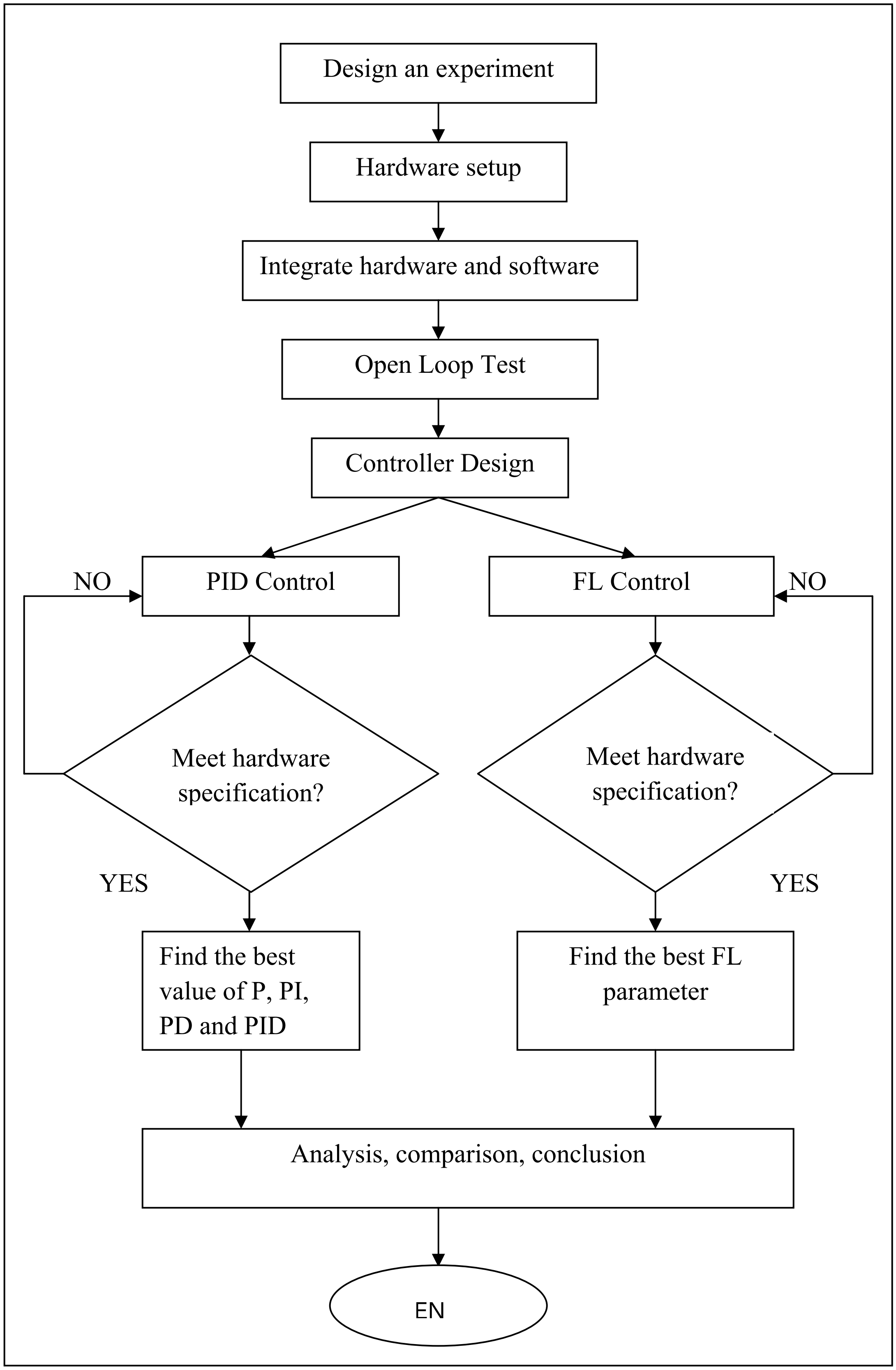

Figure 3.1: Sequences of PID and FL Controller Implementation on the Couple Tank System

3.2 Modeling the Single Tank System

Initially, consider the couple tanks with valve A closed and valve B open. This system is a single tank process that can be drawn as shown in figure 3.2.

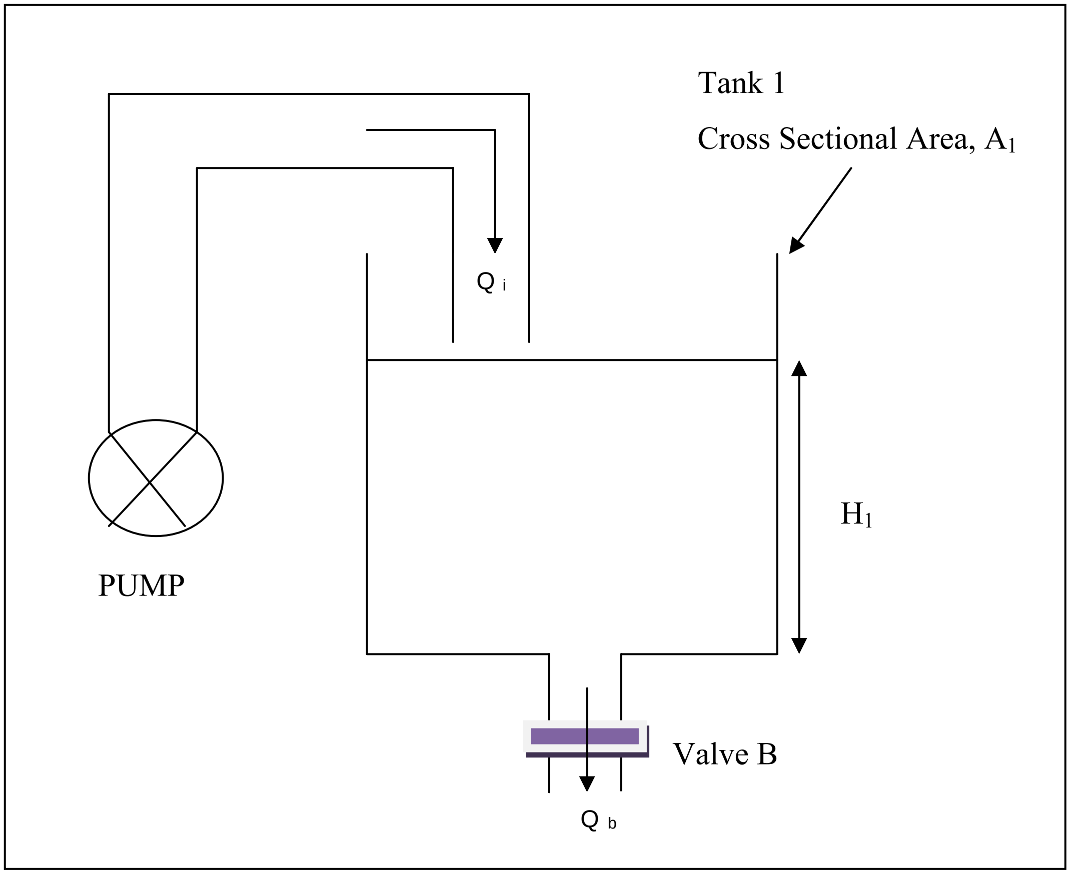

Figure 3.2: Single Tank System

The system model is determined by relating the flow into the tank to that leaving via valve B [Couple tank system CE 105 manual].

Hence,

$Q_i - Q_b$ = rate of change of liquid level volume

$$Q_i - Q_b = \frac{dV_1}{dt} = A\frac{dH_1}{dt} \qquad (3.1)$$

Where,

A = cross sectional area of tank 1

V_1= volume of liquid in tank 1 ($V_1 = A.H_1$)

Q_i = pump flow rate

Q_b = flow rate out of valve B

If valve B is assumed to behave like a standard sharp edged orifice, then the flow through valve B will be related to the fluid level in the tank, H_1, by the expression,

$$Q_b = C_{db}.a_b.\sqrt{2g.H_1} \qquad (3.2)$$

Where,

a_b= cross sectional area of the orifice. Represents the dimensions of valve B and the flow channel in which it is mounted. Because this dimension changes along the length of the channel, a_b would have to be taken to be the mean value.

c_{db}= discharge coefficient of valve B. This coefficient takes into account all liquid characteristics, losses and irregularities in the system such that two sides of the equation balance.

g= gravitational constant = 0.98 m/sec^2

The orifice relationship (3.2) assumes C_{db} is a constant and, therefore, that Q_b is proportional to the square root of the level H_1 for all possible operating condition. In a practical valve the flow rate Q_b will be some general non linear function of level H_1.

$$Q_b= f(H_1) \qquad (3.3)$$

Combining equation 3.1 and 3.3 gives,

$$A.\frac{dH_1}{dt} + f(H_1) = Q_i \qquad (3.4)$$

Equation 3.4 is the mathematical model that describes the system behaviour.

The system model, equation 3.4 is a first order differential equation relating input flow rate Qi, to the output water level, H_1. In order to make it useful for control systems purposes it must be linear equation by considering small variations about a desired operating level of liquid in the tank.

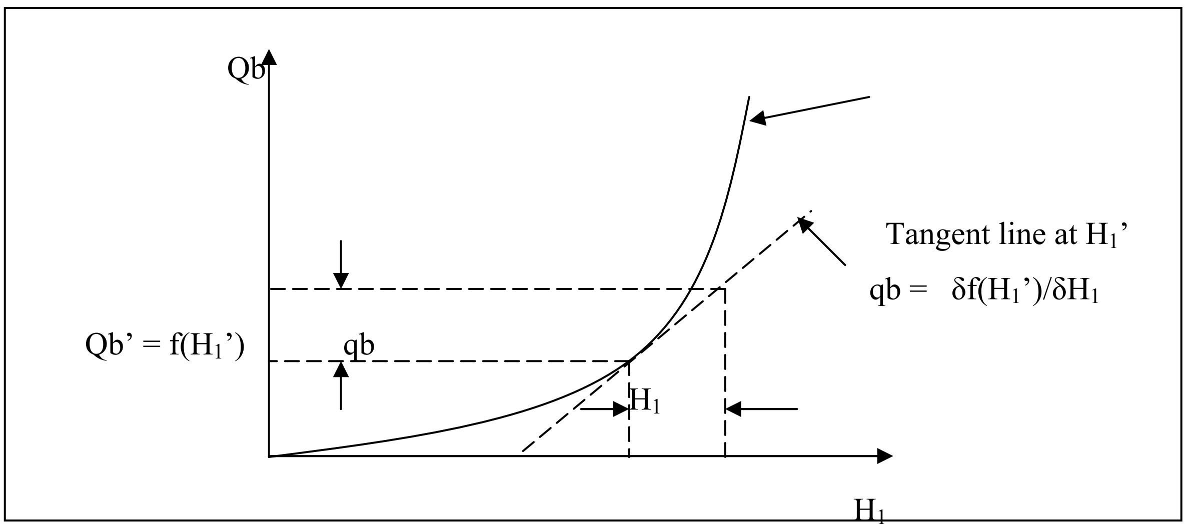

Figure 3.3: Linearization of the liquid level operating system

$$\text{Let,} \quad H_1 = H_1' + h_1$$

From the figure 3.3, H_1' is the normal operating level and is a constant H_1 is a small change about that level. Then, for small variations of h_1 about H_1', can approximate the function $f(H_1)$ by the straight line tangent at H_1'.

Let the inflow Q_i consist of a steady component Q_i' plus a small change q_i, then if Q_b' is the steady state outflow corresponding to h_1, then we can rewrite equation 3.4 as:

$$A.\frac{dh_i}{dt} + Q'_b + q_b = Q'_i + q_i \qquad (3.5)$$

Which can be rewritten, with reference to figure 3.3 as,

$$A.\frac{dh_1}{dt} + f(H'_1) + h_1.D = Q'_i + q_i \qquad (3.6)$$

Where the coefficient is the slope of the valve characteristics at the level H_1'

$$D = \frac{\delta f(H'_1)}{\delta H_1} \qquad (3.7)$$

When the level is constant, with q_i=0 and h_1=0, then equation 3.5(b) gives the steady state relation for flow and level,

$$f(H_1') = Q_i' \qquad (3.8)$$

Subtracting equation 3.8 from equation 3.5 and then rearranging gives the linear, first order differential equation for the single tank system,

$$A.\frac{dh_1}{dt} + h_1.D = q_i \qquad (3.9)$$

Given,

$k_b = D^{-1} = 1/D$

$D = 1/k_b$

Time constant, T = A/D; A= T.D

$$(T.D\frac{dh_1}{dt}) + h_1.\frac{1}{k_b} = q_i \tag{3.10}$$

$$(T.\frac{1}{kb}\frac{dh_1}{dt}) + h_1.\frac{1}{k_b} = q_i \tag{3.11}$$

$$\frac{1}{kb}[(T.\frac{dh_1}{dt}) + h_1] = q_i \tag{3.12}$$

$$T.\frac{dh_1}{dt} + h_1. = k_b q_i \tag{3.13}$$

Taking Laplace transforms gives the single tank system transfer function,

$$[T.sh_1] + h_1 = k_b.q_i$$

$$h_1 [Ts + 1] = k_b.q_i$$

$$\boxed{h_1(s) = \frac{k_b}{Ts+1}.q_i(s)} \tag{3.14}$$

where, T is the Time Constant of the system given by,

$$T = A/D$$

and k_b is given by,

$$K_b = D^{-1}$$

Where;

A = cross sectional area of tank A

D=slope at the normal operating level

T = time constant

3.2.1 System Description of Couple Tank System

In this research, couple tank apparatus CE105 is used as a plant system. This plant developed by the TQ Education and Training Ltd, 2001. The schematic diagram of the couple tank system is shown in figure 3.4. This system has two types of transducers which are pressure sensing liquid level and flow transducer. The specifications of the couple tank system as shown in table 3.1.

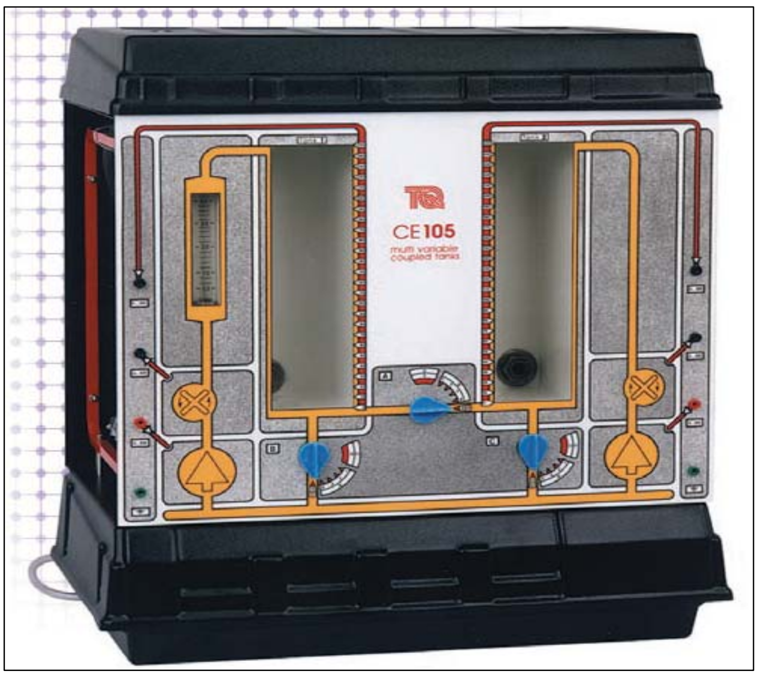

Figure 3.4: Schematic diagram of the Couple Tank System

This plant also equipped by Digital Controller Box (CE 122) to control the liquid level using PID controller. However, in this research, the Digital Controller Box (CE122) is not use as the interface block.

Table 3.1: Specification of Couple Tank System

Tank 1	Cross Sectional Area = 9350 mm^2
Tank 2	Cross Sectional Area = 9350 mm^2
Valve A,B,C	10 mm Valve Orifice Cross Sectional Area = 78.5 mm^2
Liquid Level Sensors	0 to 10 V DC Output Corresponding to 0 to 250 mm As indicated on the front panel water level scales
Pump Flow Sensors	0 to 10 VDC Output Corresponding to 0 to 4400 mm As indicated on the front panel flow meter

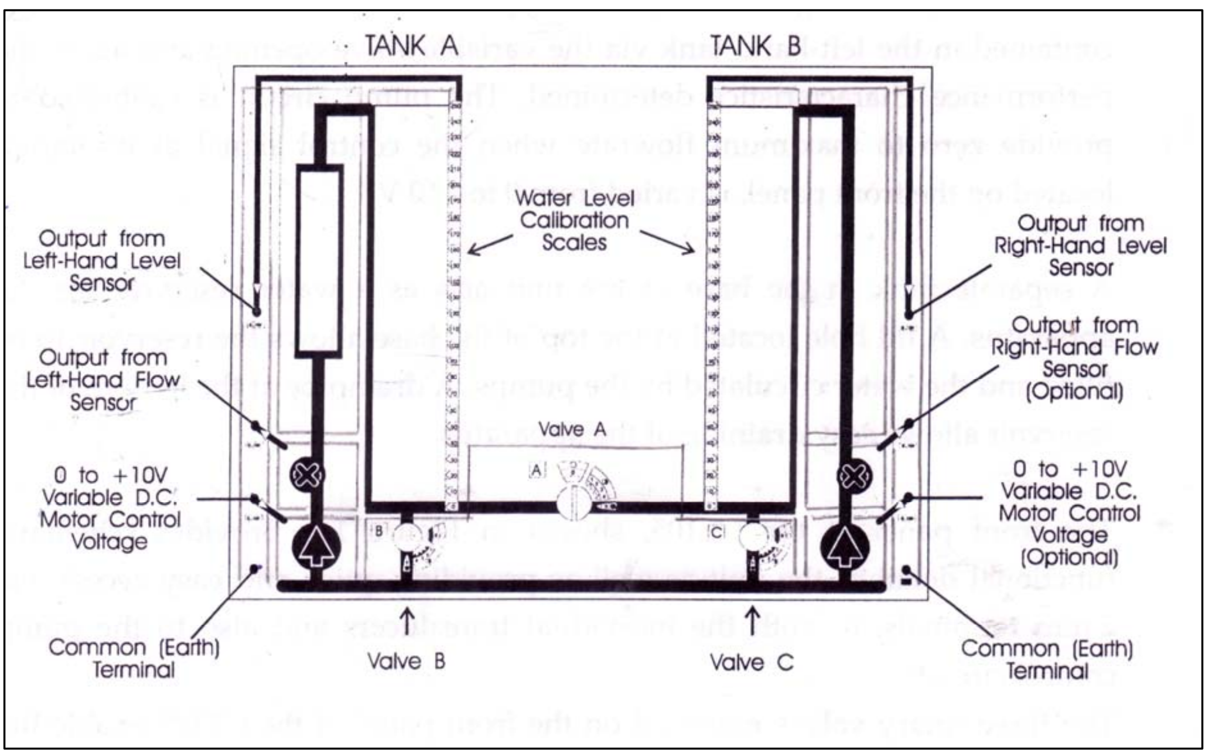

Figure 3.5: The schematic functional detail of CE 105

Figure 3.5 shows the schematic functional detail of the unit as well as providing quick and easy access. The three rotary valves mounted on the front panel of the CE 105 enable the flow characteristic of the system to be varies as required. Valve B and C provide direct discharge into the reservoir below from the left and right hand tanks respectively. Valve A may be used to vary the coupling between the two tanks. In all cases, the scales adjacent to each valve indicate the relative discharge rate. (0 being closed and 5 being open).

An overflow channel is included at the top of each tank. Each tank is fitted with a pressure sensing liquid level transducer. The output from the pump is sensed by an in line flow transducer of the variable reluctance type.

The top unit of the CE 105 contains the mains supply unit connector and the AC to DC rectification circuit. These are mounted in a sealed die-cast box designed to prevent water from entering. This ensures that, the user isolated from potentially dangerous voltage levels.

The motor drive and transducer signal conditioning circuit (flow and level) are also located in the top unit of the CE 105. Electrical connections between the individual transducers, the pump drive circuit and the top unit are made with the relevant plugs and sockets being correctly fitted at the time of installation.

The manipulated input can be set manually to simulate the PC from 0 to 10 Volt output. If the manipulated variable (level transducer) is connect to the manipulated input (pump voltage), the feedback signal will acquire the output from the pressure sensing liquid level transducer.

The NI cDAQ 9178, NI 9253 and NI 9201 will be as an interface between the Couple Tank System and the LabVIEW and Matlab software on the computer. Couple tank apparatus is calibrated using LabVIEW software. After the calibration, the relationship for pump sensitivity, level transducer sensitivity and flow transducer sensitivity is obtained.

3.2.2 Transfer Function of the CE 105 System: Single Tank System

The couple tank is used as a control system, the input flowrate (q_i) is controlled by adjusting the applied voltage to the pump motor amplifier (v_i). The liquid level is sensed by a pressure transducer that produces an output voltage (y_1), which is proportional to the liquid level (h_1). The overall system represent schematically in figure 3.6.

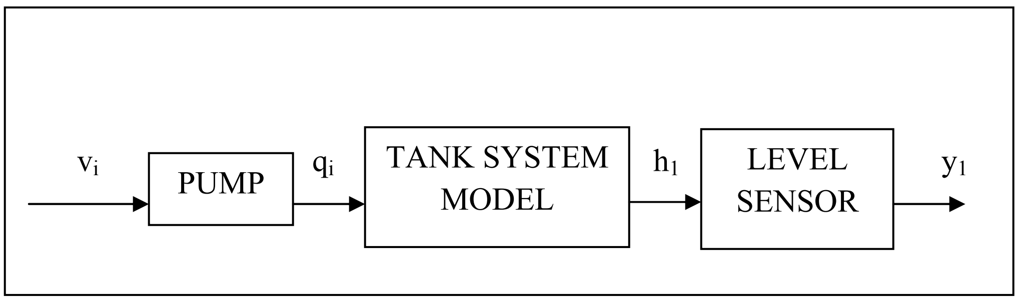

Figure 3.6: Schematic Diagram of the overall system

Where;

v_i = applied voltage to the pump motor amplifier
q_i= input flow rate
h_1= liquid level
y_1=output voltage

The pump flow rate, q_i and the input voltage, v_i, are related by an actuator characteristic that is assumed to be linear as shown in figure. The same is true of the level sensor characteristic.

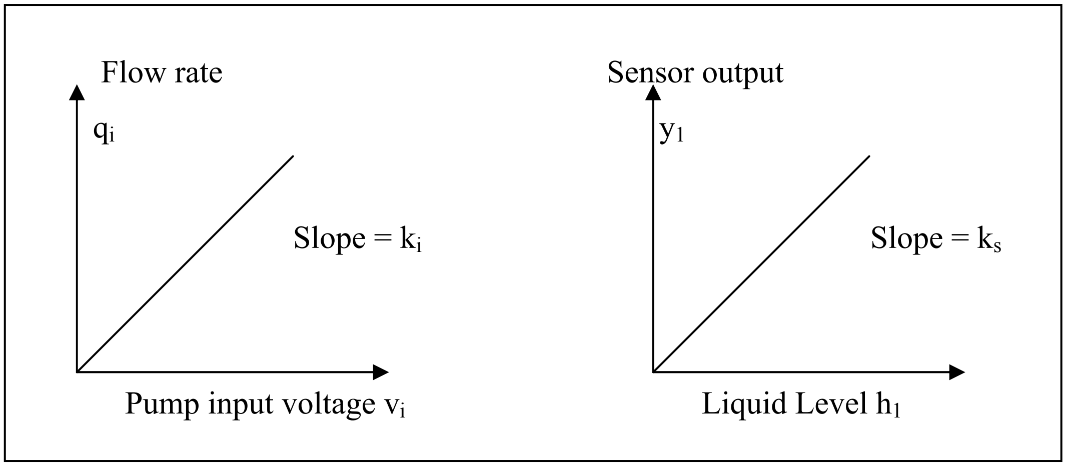

Figure 3.7: Pump and Level Sensor Characteristic

If K_i and K_s are the pump and sensor gain constants respectively, then,

$$q_i = k_i \,.\, v_i \tag{3.15}$$

$$y_1 = k_s \,.\, h_1 \tag{3.16}$$

$$h_1(s) = \frac{k_b}{Ts+1} \,.\, q_i(s) \tag{3.17}$$

Equation 3.17 can takes from the modeling of tank system.Combined these with the system transfer function equation gives the standard first order system transfer function,

$$\frac{Y_1}{V_i} = \frac{G}{Ts+1} \tag{3.18}$$

$$G = k_i.k_s.k_b \tag{3.19}$$

Where,

G = the system gain

T = the system time constant

k_i = pump characteristic

k_s= sensor characteristic

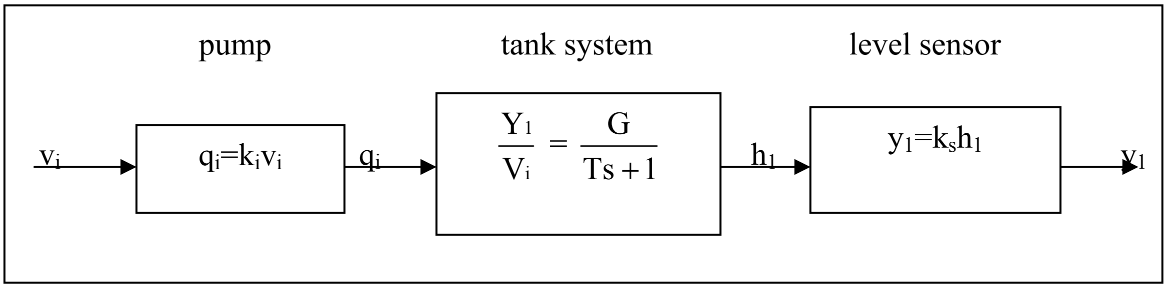

Figure 3.8: Schematic Diagram of the overall system

Figure 3.8 shows the overall diagram of the tank system. Finally, the experimental result of open loop test will be use to obtain transfer function of the single tank system. The gain and time constant can be taken from the output response of the open loop result.

3.2.3 Experimental Setup

The plant CE 105, data acquisition hardware and personal computer are connected as shown in figure 3.19 and evaluated as t o whether everything is in working condition. The experiment consists of a pump inside the couple tank, with pressure sensing liquid level and flow meter. The range of the pump is 0 to 10 V and also same with level sensor and flow rate sensor. Pressure sensing liquid level is located in the tank.

The NI 9263 and NI 9201 developed by National Instrument is used to read and write data to and from the CE 105. From figure 3.9, both analog input and analog output will directly connect to the CE 105 plant using Compact Data Acquisition.