PARAMETER IDENTIFICATION OF A COUPLED TANK LIQUID (CTS) LEVEL SYSTEM

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DECLARATION

I declare that this thesis entitled "PARAMETER IDENTIFICATION OF A COUPLED TANK LIQUID (CTS) LEVEL SYSTEM" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : MOHAMMAD MUZAFFAR BIN AZIZ

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APPROVAL

I hereby declare that I have checked this report entitled "PARAMETER IDENTIFICATION OF A COUPLED TANK LIQUID (CTS) LEVEL SYSTEM" and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Electrical Engineering with Honours.

Signature : *arfah syahida*

Supervisor Name : ARFAH SYAHIDA MOHD NOR

Date : 6 JULY 2021

DEDICATION

To Madam Arfah Syahida Binti Mohd Nor, my supervisor.

My heartfelt gratitude goes to my adored mum and father.

To my devoted siblings.

To all my acquaintances.

Finally, I would want to thank everyone who has supported me along the way.

I could not have completed this job without your assistance.

Thank you for all your encouragement and kindness.

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ABSTRACT

To prevent buildup in systems or tanks, most industrial facilities use liquid level management as part of inventory control. Pumps are frequently used to move liquid from one system (tank) to another. The pump will cavitate if the liquid level in the tank falls below a certain level, which will harm it and, of course, cause serious difficulties with the plant's functioning. The objective of this study is to develop mathematical models of a connected tank system using system identification. The PID controller is then used to get the connected tank device's output value to what it needs to be. The overall performance of the linked tank system is then assessed by comparing the system's transient response using different PID controller tuning approaches. The empirically created transfer function model is based on the realistic CTS-001 model. When the model is finished, the SI toolbox is used to build a CTS model. The model is then tested to monitor and evaluate the system's transient reaction using open-loop and closed-loop techniques. This performance response is then utilized as a benchmark to build the PID controller and further optimize the overall device response. When the PID controller is put into the system, the outcomes are intended to generate improved overall performance. These findings imply that the system's output response may be fine-tuned to get a superior transient response and overall performance.

ABSTRAK

Pengendalian tahap cecair adalah salah satu strategi kawalan yang paling asas di kebanyakan kilang proses - ia adalah sebahagian daripada kawalan inventori untuk mengelakkan pengumpulan dalam sistem atau tangki. Kita sering memerlukan pam untuk menggerakkan cecair dari satu sistem (tangki) ke sistem yang lain. Pam akan mengalami peronggaan jika paras cecair di dalam tangki jatuh di bawah nilai ambang, yang seterusnya akan merosakkan pam dan tentunya boleh menyebabkan masalah besar pada keseluruhan operasi kilang. Projek ini bertujuan untuk mengembangkan pemodelan matematik sistem tangki berpasangan dengan menggunakan pengenalan sistem. Dari sini, pengawal PID dilaksanakan untuk mendapatkan nilai output yang diperlukan untuk peranti tangki yang digabungkan. Seterusnya, prestasi keseluruhan sistem tangki digabungkan dianalisis dengan membandingkan tindak balas sementara sistem menggunakan kaedah penalaan pengawal PID yang berbeza. Model CTS-001 sebenar digunakan sebagai media untuk menghasilkan model fungsi pemindahan secara eksperimen. Setelah model selesai, kotak alat SI dilaksanakan untuk menghasilkan model CTS. Kemudian model diperiksa untuk memerhatikan dan menganalisis tindak balas sementara sistem melalui gelung terbuka dan gelung tertutup. Respons prestasi ini kemudian digunakan untuk mengembangkan pengawal PID sebagai penanda aras untuk mengoptimumkan lagi tindak balas peranti secara keseluruhan. Hasilnya diharapkan dapat menghasilkan prestasi keseluruhan yang lebih baik apabila pengawal PID dilaksanakan ke dalam sistem. Hasil ini menunjukkan bahawa tindak balas output sistem dapat ditala dengan lebih baik untuk mendapatkan tindak balas sementara yang lebih baik dan prestasi keseluruhan yang baik.

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LIST OF SYMBOLS AND ABBREVIATIONS

PID	Partial-Integral-Derivative
SISO	Single Input Single Output
MATLAB	MATrix LABoratory
MIMO	Multiple Input Multiple Output
TITO	Two Input Two Output
SI	System Identification
USB	Universal Serial Bus
CTS	Coupled Tank System
Z-N	Zeigler-Nichols
C-C	Cohen-Coon

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter explained the project background and the problem statement. The project background briefly explained the application of Liquid Level Control System of Coupled Tank System by using the system identification process. Problem statement, objectives and scopes of the project is also discussed in this chapter.

1.2 Project Background

In various sectors, liquid level management in a tank system is required, such as petrochemical, papermaking, pharmaceutical, and water treatment. Pumping the liquid through the process, storing it in tanks, and pumping it into another tank are all critical steps. The tanks are also interconnected to the point where the levels interact, which must be controlled [1].

The Liquid Level Control System is a system developed specifically for the control of fluid levels in tanks. The primary purpose of these devices is to control the rate at which the pump supplies the tank with liquid so that it can reach the desired amount within the tank. The liquid level system aims to keep within the tank a particular level of fluid. Major applications in manufacturing processes are found in liquid level control systems. We use a system identification method to identify the parameters needed for the liquid level control system.

System Identification is a determination based on input and output of a system with a specified class of systems to which the system under test is equivalent whereas system is a collection of components which are coordinated together to perform a function. A model is needed in system identification technique. Model is a description of the system that should capture the essential information about the system. The principle used in this method is to estimate system from measurement of input, u(t) and output, y(t) [2].

Nonparametric and parametric techniques were used to classify the system using the system identification methodology. Transient response analysis and correlation analysis are two nonparametric approaches employed in this study [3]. The parametric methodology used in this work is the least square method. Six phases were included in the system identification technique approach. Experiment design comes first, followed by data collection and preparation. Following that, an appropriate model structure will be chosen. The model's essential parameters will next be estimated. The model will then be verified [4].

1.3 Motivation

In most process facilities, level control is one of the most fundamental control methods, and it is used in conjunction with inventory control to avoid buildup in systems or tanks. Consider this: we frequently use a pump to transfer liquid from one system to another. If the liquid level within the tank goes below the threshold amount, the pump will cavitate, which will destroy the pump and, of course, cause significant difficulties for the overall plant operation. Another example is that the liquid level in the reactor (tank) or bioreactor has a significant impact on the reactor's or bioreactor's performance; hence, by managing the liquid level, we can guarantee that the reactor or bioreactor in question continues to operate at its best. In short, we frequently need to control liquid levels in tanks, not because we want to maintain constant levels, but because it is a necessary strategy to ensure that the entire system runs smoothly (e.g., no tank will dry up or overflow), smoothly (e.g., no pump will break down due to cavitation), and profitably (e.g., a reactor tank will always perform at its optimum condition).

1.4 Problem Statement

System identification techniques are a flexible tool that may be used to a wide range of scientific and technical challenges. As a result, the approaches are not limited to any one application. Numerous applications in a variety of areas have demonstrated the tool's utility. The approaches do, however, have certain limits.

The application of system identification techniques is limited by the availability of excellent data and suitable model structures. There is not much that can be done without an acceptable data record, and there are numerous reasons why such a record cannot be acquired situations. The first and most apparent reason is that the time scale of the operation is so sluggish that any useful data recordings must be brief. Another reason is that the input may be impervious to manipulation, either by nature or owing to safety and manufacturing constraints.

The signal-to-noise ratio may thus be poor, and identifiability (informative data sets) may not be assured. Longer data recordings can, in principle, compensate for low signal-to-noise ratios. Even if the plant allows for a lengthy period of testing, it may not always be a viable option due to temporal fluctuations in the process, drift, gradual disruptions, and so on.

Finally, even when we can alter the inputs, measure for extended periods of time, and have high signal-to-noise ratios, obtaining a reliable data record may be challenging. The primary reason for this is the occurrence of unmeasurable disturbances that do not fit well into the traditional image of "stationary stochastic processes." However, the reality remains that data quality must be a top priority in system identification applications.

1.5 Objective

The purposes of this project are:

1. To develop mathematical modelling of coupled tank system by using system identification.
2. To design the PID controller for the coupled tank liquid level system.
3. To analyze the stability and the transient response of the coupled tank liquid level system via open loop and by using PID controller.

1.6 Scope

This project mainly focuses on:

1. Obtaining a mathematical equation for a Coupled Tank Liquid Level System with single input and single output (SISO) by using system identification.

2. Using MATLAB software to obtain the output response from the modelling function.

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This chapter focuses on the literature review of the journal, article, book, and other resources. A brief insight of how the coupled tank system works, system identification and type of controller used in this project.

2.2 Coupled Tank System

A single pump and two tanks make up the linked tank system. A pressure sensor is installed in each tank to monitor the water level system. The pump moves water from the bottom basin's reservoir to the top of the system. The water then flows to the right tank, left tank, or both tanks, depending on how the outflow valves are arranged. Outflow orifices of various sizes can also be used to alter the flow rate. Several Single Input Single Output (SISO) combinations are possible thanks to the ability to control water flow and varied outflow orifices.

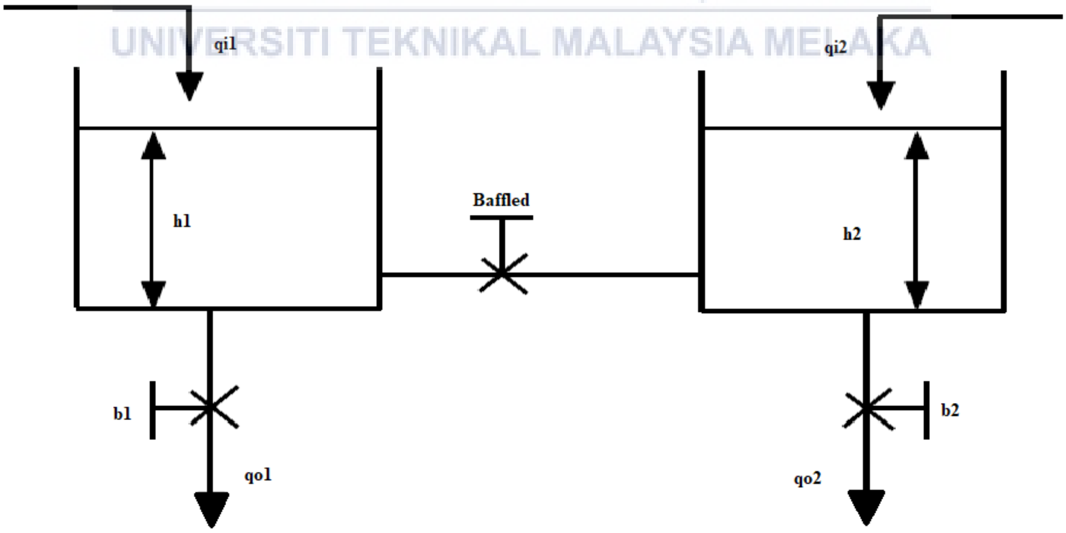

Figure 2.1 – Basic configuration of Coupled Tank System

While many researchers use the same set-up as the figure above, Auwal Shehu et al. [5] take another approach. The coupled tank system still has the same pumping system and reservoir set-up. The only change was how the two tanks were set up, with tank 1 feeding tank 2 and tank 2 feeding the base's water reservoir. Each tank's water drains via a tiny hole at the bottom. A pressure sensor is installed at the bottom of each tank to measure the water level. The flow rate and the pumping rate are considered to be proportionate. Figure 2 shows the schematic for the coupled tank system.

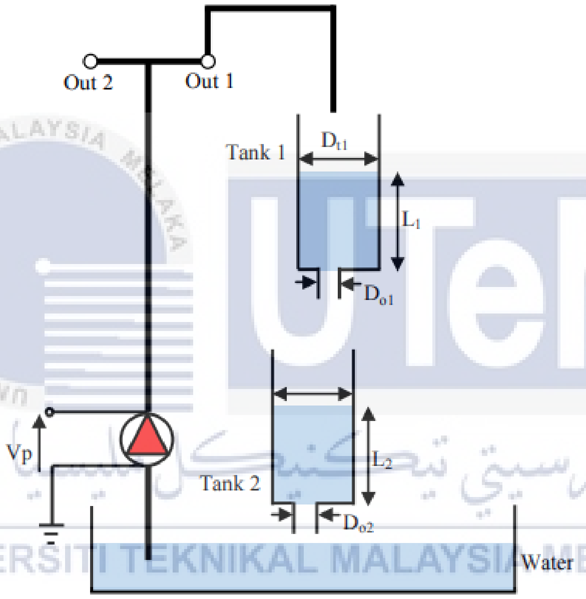

Figure 2.2 – SISO configuration of Coupled Tank System [5]

MIMO (Multiple Input Multiple Output), also known as TITO, is a different arrangement (Two Input Two Output). The coupled tank unit, as illustrated in Figure 3, is made up of four transparent tanks linked by pipes. At the bottom of the setup, a reservoir is put. Water is fed to the higher tanks by two submersible pumps that are installed in the reservoir. A customizable aperture allows water to flow freely from the higher tanks to the lower tanks. The flow routes through the set-up may be arranged in a variety of ways depending on where the valves are positioned. Dynamic connection between the upper two tanks is achieved by opening the valve v1. [6].

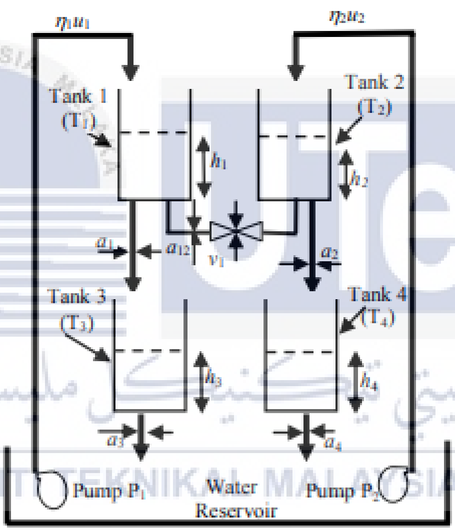

Figure 2.3 – MIMO configuration of Coupled Tank System [6]

2.3 System Identification

System identification is a field of mathematics that uses observable data to construct mathematical models of dynamical systems [7]. Model reduction and the optimal design of experiments for successfully obtaining relevant data for fitting such models are also included in system identification. System identification is a popular method that begins with measurements of the system's behavior and external influences (inputs to the system) and attempts to discover a mathematical connection between them without diving too deeply into what is going on inside the system.

System identification is a broad topic with several approaches based on the nature of the models to be estimated: linear, nonlinear, hybrid, nonparametric, and so on. Simultaneously, the domain may be defined by a small number of guiding concepts, such as the search for sustainable descriptions through correct judgments in the triangle of model complexity, information content in data, and successful validation. There are several techniques and strategies available in this field [8].

There are two types of system identification: linear and nonlinear. Traditional identification methods [9–11] include first creating the system model framework and the error criterion function, and then identifying the model by minimizing the error criteria functions based on the system's input and output data. The least squares approach, gradient correction method, and maximum likelihood method are all examples of traditional identification techniques. The following are some of the benefits of using traditional identifying methods:

- The generalized error criteria function is frequently used as the criterion function, and the influence of system noise is also considered throughout the identification process.
- Although the input signal is theoretically Gaussian white noise, we commonly use the pseudo random signal.
- These techniques are appropriate for online identification.

At the same time, these techniques have the following drawbacks:

• For the least square identification technique, the input signal must be known and must vary relatively and richly, however certain dynamic systems cannot meet this criterion.

• These techniques can produce good identification results for linear systems, but not for nonlinear systems.

• There can be no synchronization between structure identification and parameter identification.

Many modern methods for nonlinear system identification, such as neural networks, fuzzy logic, genetic algorithms, swarm intelligence optimization algorithms, auxiliary model identification algorithms, multi-innovation identification algorithms, and hierarchical identification algorithms, have been developed in recent years [9–11]. Here is a short overview of these techniques:

A. System Identification Method Based on Neural Network

Neural network identification is based on the structure of a nonlinear neural network, can simulate the input-output relationship by using the neural network's ability to infinitely approach any nonlinear mapping, can realize the simple learning algorithm on engineering by using the neural network's ability of self-adaptation and self-learning, and finally obtains the forward or inverse model.

B. System Identification Method Based on Fuzzy Logic Theory

Fuzzy identification must address issues such as input-output space division, determining the input variables and membership function, determining the structure of the output space function, and extracting fuzzy rules.

C. System Identification Based on Genetic Algorithm

A genetic optimization algorithm is a type of bionic optimization method. Genetic algorithms are self-adaptive, heuristic, and global optimization algorithms that are developed by abstracting and simplifying the biological evolution process and are based on natural selection and inheritance.

D. System Identification Method Based on Swarm Intelligence Optimization Algorithms

Swarm intelligence optimization algorithms are a series of optimization algorithms that perform search by stimulating all types of group behavior in creatures of nature and utilizing reciprocal communication and cooperation between individuals in the group. Currently, ant colony optimization algorithm [13], particle swarm optimization algorithm [14], flora optimization algorithm [15], artificial bee colony optimization algorithm [12], and artificial fish swarm optimization algorithm [16] are the most used swarm intelligence optimization methods.

E. Auxiliary Model Identification Method

Auxiliary model identification [17] is a modern identification approach that uses quantifiable system information to build an auxiliary model. The model's output is then utilized to substitute unmeasured variables in the system, and the output of the auxiliary model is closer to the unmeasured variables due to the selection of the auxiliary model parameter. Finally, the system parameters are consistently estimated. Auxiliary model identification has evolved into a type of identification approach that is now employed in the research of adaptive signal processing, adaptive identification, and parameter identification issues in linear and nonlinear models.

F. Multi-innovation Identification Method

The multi-innovation identification technique [18] is a way of identifying that allows us to completely exploit and expand the identification innovation. In other words, this identification theory is founded on innovation by extending identification innovation, transforming scalar innovation into an innovation vector, and transforming the innovation vector into an innovation matrix. Multi-innovation identification has emerged as a new identification area that may be used to the study of parameter estimation, adaptive signal processing, and adaptive identification issues of various models.

G. Hierarchical Identification Method

Hierarchical identification [19] is another important branch of the system identification which is a new identification method based on identifying model decomposition and which is presented to solve the system identification problem of large-scale systems with the complex structure and multi-dimension. Its basic thought is that the identification model is decomposed to make the scale about identification small and to make the original problem relatively simple and the calculation of identification method becomes smaller. Hierarchical identification based on the hierarchical identification theory has become a new identification field it can be applied for studying identification problems of all kinds of multivariable systems with the complex structure and nonlinear systems.

2.3 PID Controller

The most common control method used in industry is proportional-integral-derivative (PID) control, which is well-known in the field of industrial control. The controller compares the collected data to a reference value and uses the difference to generate a new input value with the objective of allowing system data to approach or maintain the reference value [20]. The PID controller changes the input value depending on prior data and the pace at which the difference appears, making the system more accurate and dependable. It consists of a proportional, integral, and derivate controller. A gain amplifier is what a proportional controller is. It can enhance system accuracy and minimize steady-state error, but it will compromise system stability. The adoption of an integrated controller speeds up the system's approach to the target value and eliminates steady-state inaccuracy. The use of a derivative controller can aid in system stabilization and settling.

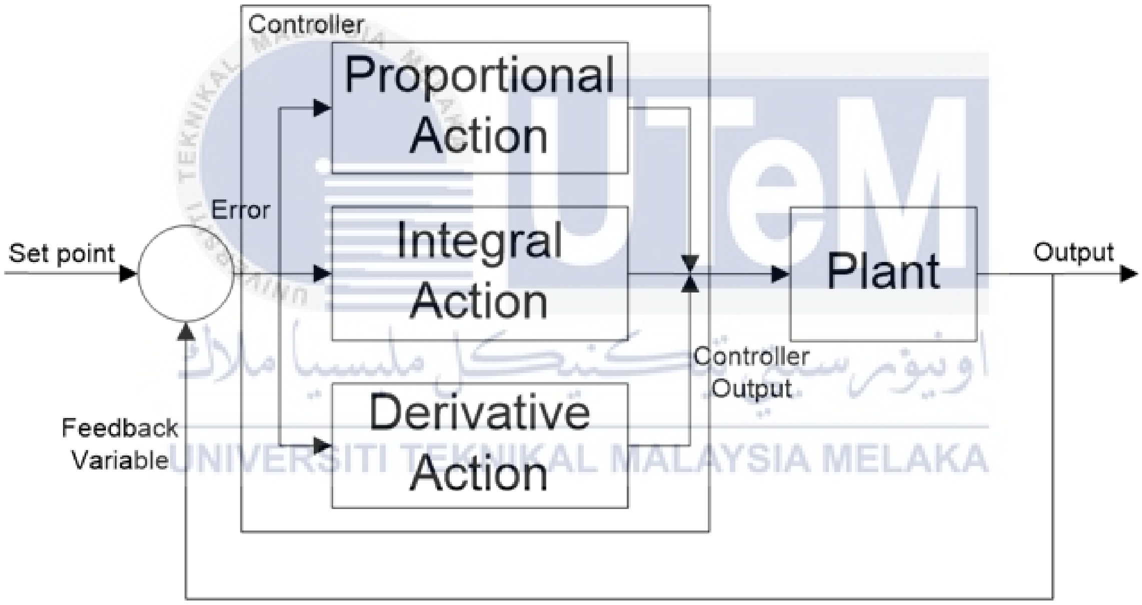

Figure 2.4 – Basic design of PID controller block

Wang and Chang [21] developed their Mobile Robot using a hybrid of a PID controller and a Fuzzy Logic controller, commonly known as a Hybrid Fuzzy PID System. The PID and Fuzzy signal sizes of the hybrid controller may be modified. The hybrid controller's architecture is shown below.