" I hereby declare that I have read through this report entitle "PID tuning using a Bat algorithm for coupled tank liquid level system" and found that it has complied the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automation) With Honors "

Signature : ....

Supervisor's Name : Nur Asmiza binti Selamat

Date : ....

PID TUNING USING BAT ALGORITHM FOR COUPLED TANK LIQUID LEVEL SYSTEM

MOHAMAD ARIS IQQHWAN BIN ALIZAN

A thesis submitted

in fulfillment of the requirements for the Degree of Bachelor of Electrical Engineering (Control, Instrumentation & Automation)

With Honours

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2015

DECLARATION

I declare that this report entitle “PID tuning using a Bat algorithm for coupled tank liquid level 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 the candidature of any other degree.

Signature : ....

Name : Mohamad Aris Iqqhwan bin Alizan

Date : ....

DEDICATION

To my beloved mother and father

ACKNOWLEDGEMENT

In the name of Allah, the Most Beneficent and The Most Merciful. It is deepest sense gratitude to the Almighty that gives me strength and ability to complete this final report.

First of all I would like to express my gratitude to my supervisor, Madam Nur Asmiza binti Selamat for his valuable guidance and support throughout this semester until this report completes successfully.

My utmost thanks also go to my family Muhammad Sabri Dani, my beloved father and Zanariah binti Ismail, my lovely mother for their support and love. Not to forget my other family and friends. My fellow postgraduate students should also be recognized for their support. My sincere appreciation also extends to all my colleagues and others who have provided assistance at various occasions. Their views and tips are useful indeed. Unfortunately, it is not possible to list all of them in this limited space. I am grateful to all my family members.

ABSTRACT

This project describes about controlling liquid level for a coupled tank system (CTS). Many industrial processes use the concept of the liquid level control of coupled tank system. The system operated by the liquid pumped into the tank, stored and drained as repeatable process, for example a chemical process that mostly in oil and gas. To maintain the level of the liquid in the tank, a controller needs to be implemented in the system. The level of liquid depends on the set point when the liquid is pumped out. Time by time, the parameter of the system will slightly change due to the disturbance. Therefore, the controller must use optimization technique as the control tuning in order to find the optimal parameter value to overcome the problem for coupled tank liquid level system. In this project, the proportional-integral-derivative (PID) control tuning using a BAT algorithm by using MATLAB and Simulink. The transient system performance will be evaluated and compared with Cuckoo Search (CS) algorithm in terms of overshoot percentage settling time, rise time and steady state error. The error value of the system can be obtained from performance index, integral of time square error (ITSE) and it will be used in optimization technique in order to get the PID parameter of the system. The expected result from this project is BAT algorithm will give a better performance compared to Cuckoo Search (CS) algorithm as BAT algorithm is more flexible in finding the optimal parameter.

ABSTRAK

Projek ini menjelaskan tentang mengawal tahap cecair untuk sistem tangki berpasangan *(CTS).* Banyak proses industri yang menggunakan kawalan aras cecair sistem tangki ditambah. Untuk sistem keseluruhan, cairan ini akan dipam ke dalam tangki, disimpan dan dikeringkan sebagai proses berulang, contohnya proses kimia yang kebanyakannya dalam bidang minyak dan gas. Untuk mengekalkan tahap cecair di dalam tangki , pengawal yang perlu dilaksanakan di dalam sistem. Tahap cecair bergantung kepada titik set apabila cecair dipam keluar . Dari waktu ke waktu, parameter sistem akan sedikit berubah disebabkan gangguan. Oleh itu, pengawal harus menggunakan teknik pengoptimuman tuning kawalan untuk mencari nilai parameter optimum untuk mengatasi masalah untuk tangki ditambah sistem tahap cecair. Dalam projek ini, yang *proportional-integral-derivative (PID)* penalaan kawalan menggunakan algoritma BAT dengan menggunakan *MATLAB* dan Simulink. Prestasi sistem sementara akan dinilai dan dibandingkan dengan Cuckoo Search (CS) algorithm dari segi peratusan terlajak waktu penyelesaian , waktu naik dan ralat keadaan mantap . Nilai ralat sistem boleh diperolehi dari indeks prestasi, yang penting dalam masa kesalahan persegi (ITSE) dan ia akan digunakan dalam teknik pengoptimuman untuk mendapatkan parameter PID bagi sistem ini . Hasil yang diharapkan dari projek ini adalah algoritma BAT akan memberikan prestasi yang lebih baik berbanding dengan CS sebagai algoritma BAT lebih fleksibel dalam mencari parameter yang optimum.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	x
	LIST OF FIGURES	xi
	LIST OF APPENDICES	xiii
1	**INTRODUCTION**	**1**
	1.1 Background of study	1
	1.2 Research Motivation	2
	1.3 Problem Statement	2
	1.4 Objective	3
	1.5 Project Scope	3
	1.6 Report Outline	4
2	**LITERATURE REVIEW**	**5**
	2.1 Coupled tank liquid level system	5
	2.2 Coupled Tank Liquid Level System Controller	6
	2.3 PID Controller	7

	2.4 PID Tuning	8
	2.5 PID Tuning for Coupled Tank liquid Level System	9
	2.6 PID Tuning using optimization technique for Coupled Tank liquid Level System	10
	2.7 Optimization technique	11
	2.8 Bat Algorithm and Cuckoo Search	12
	2.8.1 Bat algorithm	12
	2.8.2 Cuckoo Search	12
	2.5 Summary of previous search	13
3	**METHODOLOGY**	**14**
	3.1 Introduction	14
	3.2 Flow of study	14
	3.3 Coupled Tank System	16
	3.3.1 Mathematical Modelling of Coupled Tank Liquid Level System	16
	3.3.2 Parameter/Constant of Chosen Model of Coupled Tank Liquid Level System	23
	3.4 Parameter/Constant of Chosen Model of Coupled Tank Liquid Level System	24
	3.5 Optimization Technique	24
	3.5.1 Bat Algorithm	25
	3.5.2 Cuckoo Search	27
	3.6 Objective Function	29
	3.7 Simulation	30
	3.8 Disturbance test	31
4	**RESULT AND DISCUSSION**	**34**
	4.1 Introduction	34
	4.2 Open and Closed Loop System	34

	4.3 Parameter Selection	36
	4.4 Bat Algorithm and Cuckoo Search	39
	4.5 PID Controller with Disturbance	47
	4.6 Comparison System with Disturbance	54
5	**CONCLUSION**	**57**
	5.1 Introduction	57
	5.2 Conclusion	57
	5.3 Future Works	58
REFERENCES		**59**
APPENDIX A		**61**

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	The effect of PID controller	8
2.2	Parameter of PID Controller	9
2.3	Performance of Coupled Tank System	10
3.1	Parameter of coupled tank system	23
4.1	System Performance of Open and Closed Loop	35
4.2	Number of Particles Selection	36
4.3	Number of Upper Boundary Selection	38
4.4	Parameter Selection of Implementation Process	39
4.5	Performance Index Cuckoo Search	40
4.6	Performance Index Bat Algorithm	42
4.7	PID tuning parameter	44
4.8	System Performance	45
4.9	Statistic Data Measurement	47
4.10	Performance index of Cuckoo Search with disturbance	48
4.11	Performance index of Bat Algorithm with disturbance	50
4.12	PID tuning parameter with disturbance	51
4.13	System Performance with disturbance	52
4.14	Statistic Data Measurement with disturbance	53
4.15	System Performance for Bat Algorithm	54
4.16	System Performance for Cuckoo Search	56

LIST OF FIGURES

FIGURE	TITLE	PAGE
2.1	Coupled Tank	6
2.2	PID controller block diagram	7
2.3	Metaheuristics Optimization	11
3.1	Flowchart of methodology	15
3.2	Diagram of PID controller with optimization technique	16
3.3	Schematic diagram of coupled tank	16
3.4	Parameter of coupled tank system	22
3.5	PID Control Tuning block diagram	24
3.6	Bat Algorithm Flowchart	26
3.7	CS flowchart	28
3.8	Simulation of whole system flowchart	31
3.9	Disturbance Input	32
3.10	Disturbance Signal Input	32
3.11	System with Disturbance	33
4.1	Step Response Open and Closed Loop System	35
4.2	Number of Particles Selection	37
4.3	Number of Upper Boundary Selection	38
4.4	Performance Index Bat Algorithm	41
4.5	Performance Index Cuckoo Search	43
4.6	Comparison System Performance	45
4.7	Difference of System Performance	46
4.8	Schematic diagram of PID controller with disturbance	48

4.9	Performance index for Bat Algorithm with disturbance	49
4.10	Performance index for Cuckoo Search with disturbance	51
4.11	System Performance with Disturbance	53
4.12	Step Response of PID Bat Algorithm	54
4.13	Step Response of PID Cuckoo Search	55

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Gantt Chart	61

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Control engineering is among the most theoretical and difficult to understand. Application of liquid level control system is widely used especially in chemical industries. Coupled tank water level system is one of example of a liquid level control system which consists of a double tank mounted on a reservoir for water storage. At the center between two tanks, there is a baffle to connect both of the tanks. At the tank output base there is a flow valve connected to the reservoir. Both of the tanks have its own input, which has a water pump connected to it. While capacitance - probe level is used to detect the level of the water for each of the tank.

The liquid level control system is commonly used in process control such as the liquid level control for a tank. The liquid tank system plays an important role for the industrial application. Commonly this system is being controlled by famous controller such as PID, fuzzy logic control and other advanced controllers.

A proportional-integral-derivative (PID) controller uses a feedback controller mechanism which is widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. This controller attempts to reduce the error by modifying the process through the controlled variable.

1.2 Research Motivation

Nowadays, there are many controllers have been designed to achieve desired performance for a coupled tank system liquid level, such as sliding mode controller, fuzzy logic controller, proportional-integral (PI) controller and proportional-integral-derivative (PID) controller. PID control is one of the controllers that can be applied for Single-input Single-output (SISO). In industry, several factors need to be considered in controller design such as time response characteristics, set point tracking and load disturbance to make a system with high productivity. Actually, it is very hard to find the best value for the PID parameters, so optimization technique is required to simplify this problem. For this research, Bat Algorithm will be used as an optimization technique to get the best parameter of PID for this system. Bat algorithm is that the new algorithm that has been discovered by Xin-She Yang but not applied yet into coupled tank system. Based on previous research, Bat algorithm shows the best way of finding parameter of the system. Apart from that, it gives a robust performance for a wide range of operating conditions. Furthermore, it is very familiar and easy to implement using analogue or digital hardware.

1.3 Problem Statement

The designed controller cannot longer suitable to the coupled tank as the parameter of the system is easily changed. The current controller is mostly used trial & error method. This method needs much time to get the desirable value and very hard to handle because it needs an experience person that knows the system handling. In additional, the company needs to pay the person that controls the tuning trial and error method. To overcome the problem, optimization tuning method will be applied as tuning method in order to get the suitable and best PID parameter for the coupled tank liquid system…

1.4 Objectives

The overall objectives of this project are;

i. To implement PID control tuning using swarm intelligence, Bat algorithm for the liquid level system.
ii. To obtain and analyze the system performance and compare it with Cuckoo Search (CS) algorithm.

1.5 Project Scope

The scopes of this project are;

i. To obtain the mathematical modeling equation of Coupled Tank Water Level System based on previous research.
ii. Apply optimization technique to find the PID parameter with optimal system performance in terms of settling time, rise time, overshoot and performance index.
iii. To simulate the system using MATLAB/ Simulink.

1.6 Report Outline

The report is divided into five chapters;

Chapter 1 - Introduction

This section introduces the overall project and explains the objectives and also the scope of the project in order to give a general overview of the coupled tank liquid level system.

Chapter 2 - Literature Review

In this chapter will review on previous research that is related to the current work which concerns to PID controller, coupled tank system, and optimization technique. The literature review is important as guidance to this project.

Chapter 3 – Methodology

In this chapter, it will show the flow study and methodology are used in this project.

Chapter 4 – Results and discussions

This chapter will present the results of the system performance by using PID control tuning using BAT algorithm and Cuckoo Search.

Chapter 5 – Conclusion and Future Works

This chapter consists of conclusions based on the results, including future works that need to do on the next semester in order to complete the study.

CHAPTER 2

LITERATURE REVIEW

2.1 Coupled Tank Liquid Level System

Coupled tank liquid level system is very famous system in the industries. The control of liquid level in tanks and flow between tanks is a basic problem in the process industries [1]. The main purpose of this system is to control the flow rate of the liquid delivered by pump so that the liquid within the tank achieve desired point .The process industries oblige fluids to be pumped, put away in the tanks, and afterward pumped to an alternate tank. Commonly the fluids will be handled by mixing or chemical treatment in the tanks, yet dependably the level of liquid in the tanks must be controlled, and the stream between tanks must be managed. Frequently the tanks are so coupled together that the levels collaborate and this must additionally be controlled. Level and stream control in tanks are at the heart of all chemical engineering systems. Chemical engineering is one of engineering using that is vitally because they need to control the flow and level of the tanks. Examples of chemical engineering are petrochemical industries, water treatment industries and so on.

Many industrial applications of controlling liquid level system are used nowadays. The flow work utilizes solenoid valves as actuators including of two little tanks mounted over a store which works as capacity for the water. Each of both small tanks has independent pumps to pump water into the top of each tank [2]. At the base of each tank, two flow valves connected to the reservoir. There are two types of sensor for sensing the level which is a continuous level sensor and point-level sensor. For the good monitoring level of water in each tank, continuous level sensor has been used which is capacitive-type probe level sensors.

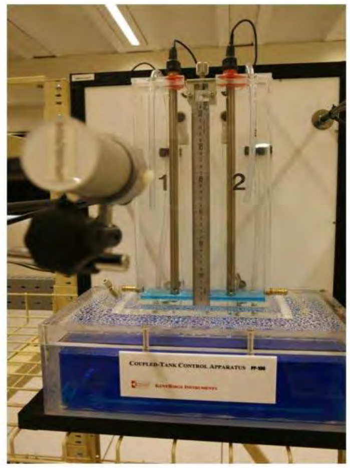

Figure 2.1: Coupled Tank

2.2 Coupled Tank Liquid Level System Controller

Based on the journal [3], the authors established that proportional-integral (PI) controller design for the coupled tank as Single Input Single Output (SISO) process using the Characteristic Ratio Assignment (CRA) method. CRA is an approach to directly control the transient response of linear time invariant control systems. This method is one technique of pole placement based on defined parameter of the characteristic equation. These techniques can adjustment of speed of response and the damping ratios. PI controller can eliminate the steady error but cannot improve transient response.

Another research done features that the liquid tank being maintained by a fuzzy logic controller same as proportional-integral-derivative (PID) controller [4]. Fuzzy logic gives amazing tool that makes the engineer to incorporate human thinking in the control calculation. Fuzzy control is based on fuzzy logic, a logical system which is much closer to human thinking and natural language than traditional logical system [5]. Fuzzy logic control has been effectively utilized within different application ranges going from programmed train operation to flight frameworks. It also enables empowers control engineers to proficiently create, control methods in application ranges marked by low order dynamics. So, fuzzy logic can be used instead of using PID controller.

Next, according to the [6], the authors manage to design a state - feedback controller to implement it at coupled tank system. The State Feedback Controller is designed using an Ackermann's formula based on the pole placement method. This can perform well in servo and regulatory conditions. However, it has limitation in cost for placing all closed-loops and state variables are measurable.

2.3 PID Controller

The proportional-integral-derivatives (PID) controller is a control feedback mechanism, which it is a well-known controller for many decades and virtually of the industries still employ it. This controller will minimize the error by correcting the process control inputs. It will compute the error value as the conflict between a measured process variable and desired set point.

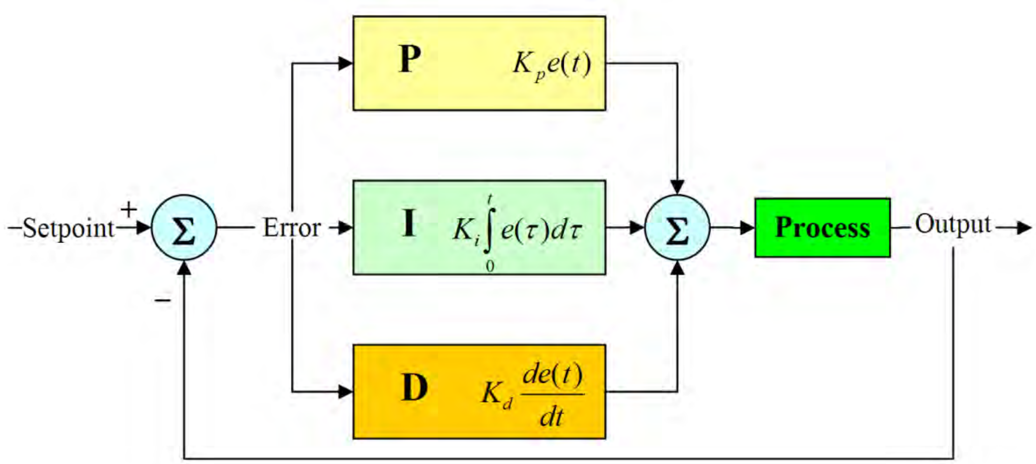

Figure 2.2: PID controller block diagram

Figure 2.2 shows a basic PID controller block diagram. The P stands for proportional control, I for integral control and D for derivative control. This is also what is called a three term controller. The proportional controller is to adjust the amplifier gain for the process stability. It also gives the effect of decreasing the rise time and steady state error. The integral controller is used to eliminate the steady state error of the response characteristic, it is the same as adding a pole to the transfer function of the control system. The purpose of the derivative controller is to fasten up the transient response, as the peak value is obtained earlier than the normal response, just as adding a zero to the transfer function of the control system.

Comparison between $K_p, K_i \; and \; K_d$ for the effect of controller applied on a closed loop system is shown in Table 2.1. Notice that these correlations may not be exactly precise because all controllers are dependent each other.

Table 2.1: The effect of PID controller

Type of controller	**Rise Time, T_r**	**Settling Time, T_s**	**Steady State Error, SSE**	**Overshoot, OS**
Proportional	Decrease	Small Change	Decrease	Increase
Integral	Decrease	Increase	Eliminate	Increase
Derivative	Small Change	Decrease	Small Change	Decrease

2.4 PID Tuning

PID tuning methods for finding proportional gain, integral gain, derivative gain to achieve the optimum values for the desired control response. For the proportional gain, it will effect of reducing rise time and steady state error. Integral gain affects increase or decreasing of rise time while derivative gain varies the transient specification and stability of the system.

There are many types of tuning such as trial and error, auto-tuning and Ziegler-Nichols method.

There are three elements that need to highlight for the PID control tuning which are;

i. The tuning rules should be well motivated and preferably model-based and analytically derived.
ii. It should be simple and easy to memorize.
iii. It should work well on a wide range of processes.

2.5 PID Tuning for Coupled Tank Liquid Level System

From [7],authors are comparing many methods can be used for PID tuning such as trial & error, Ziegler-Nichols, Cohen-Coon, and auto tuning to obtain the performance of the system. The table below shows about the parameter use of PID controller using the method given.

Table 2.2: Parameter of PID Controller

	Parameter		
Method	K_p	K_i	K_d
Trial and error	15.00	1.00	8.00
Auto-tuning	53.40	1.54	-2.98
Ziegler-Nichols	168.00	35.00	201.60
Cohen-Coon	235.88	33.92	203.21

Table 2.3: Performance of Coupled Tank System

Method	T_s**(sec)**	T_r**(sec)**	OS (%)	SSE
Trial and error	84.40	24.00	6.86	0.00
Auto-tuning	53.30	9.14	1.81	0.00
Ziegler-Nichols	32.10	3.29	38.50	0.00
Cohen-Coon	23.59	2.81	33.70	0.00

Settling time is one of transient response specifications which show that the C-C method had the fastest time for the system to reach the stable condition in the system. For the Z-N tuning method, the settling time is second fastest after C-N. However, C-N has high overshoot percentage.

2.6 PID Tuning using Optimization Technique for Coupled Tank Liquid Level System

The authors use particle swarm optimization instead of PID tuning for coupled tank liquid level system. The conventional PID controller shows that it is difficult to reach the desired control response with the aim of high speed with short transition time and small overshoot [8]. So, the particle swarm optimization (PSO) is used to achieve the optimal specifications. The basic principle of the PSO algorithm is it uses a number of particles that constitute a swarm, moving around in the search space looking for the best solution. PSO tuning giving the best performance for coupled tank system compared to other tuning methods.

Next, [9] designs the PID controller tuning using genetic algorithm (GA). GA is a heuristic optimization technique inspired by mechanisms of natural selection. It begins with introductory populace containing various chromosomes where each one represents to a method of the issue in which its execution is assessed focused around fitness function. It has