UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BINARY PSO - TUNED PID CONTROLLER FOR CONTROLLING DESIRED TEMPERATURE OF A WATER TANK SYSTEM

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A report submitted
in fulfillment of the requirements for the degree of
Bachelor of Electrical Engineering with Honours

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2021

DECLARATION

I declare that this report entitled "BINARY PSO-TUNED PID CONTROLLER FOR CONTROLLING DESIRED TEMPERATURE OF A WATER TANK 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 candidature of any other degree.

.

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APPROVAL

I hereby declare that I have read through this report entitled "BINARY PSO-TUNED PID CONTROLLER FOR CONTROLLING DESIRED TEMPERATURE OF A WATER TANK SYSTEM" and found out that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering.

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Date : 5 JULY 2021

DEDICATION

I wrote this report wholeheartedly for my parents who have been the source of inspiration.

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In the Name of Allah, the Most Gracious, the Most Merciful

First of all, I feel thankful to the Almighty for this opportunity and strength throughout the thick and thin in completing this final year project report. By His blessings, I have completed this report with lots new knowledge and experiences in completing this project.

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ABSTRACT

Water Tank System (WTS) is widely used in many applications especially in industrial sectors. Moreover, the process control method of WTS in controlling desired water temperature really gives impact if the process control does not fulfill the desired specifications. This project studies the variations of PID controller parameters (K_P, K_I. K_D) for WTS using conventional tuning methods such as Auto Tuned (AT), Ziegler Nichols (ZN) and Cohen Coon (CC). In addition, two types of metaheuristic method are used such as Particle Swarm Optimization (PSO) and Binary Particle Swarm Optimization (BPSO) in obtaining the PID controller parameters as well. The controller parameters are then used to observe the output of the system performance response using both conventional and metaheuristic tuning methods. All output performances are analyzed in terms of rise time (Tr), settling time (Ts), percentage of overshoot (%OS) and steady state error (e_{SS}) using MATLAB software. It is envisaged that the BPSO provided the optimal performances responses and can be utilized for efficient temperature control of WTS.

ABSTRAK

Sistem Tangki Air (WTS) digunakan secara meluas dalam banyak aplikasi terutama di sektor industri. Tambahan pula, kaedah pengendalian proses WTS dalam mengawal suhu air yang diingankan benar-benar memberi impak sekiranya kawalan proses tidak memenuhi spesifikasi yang diinginkan. Projek ini mengkaji variasi parameter pengawal PID (K_P, K_I, K_D) untuk WTS dengan menggunakan kaedah penalaan konvensional seperti Auto Tuned (AT), Ziegler Nichols (ZN) dan Cohen Coon (CC). Di samping itu, dua jenis kaedah metaheuristik digunakan seperti Pengoptimuman Kerumunan Zarah (PSO) dan Binari Pengoptimuman Kerumunan Zarah (BPSO) dalam mendapatkan parameter pengawal PID juga. Parameter pengawal kemudiam digunakan untuk memerhatikan keluaran tindak balas prestasi sistem menggunakan kaedah penalaan konvensional dan metaheuristik. Semua prestasi keluaran dianalisis dari segi masa naik (Tr), masa pengenapan (Ts), peratus terlajak (%OS) dan ralat keadaan tetap (e_{SS}) menggunakan perisian MATLAB. Dijangkakan BPSO memberikan respon prestasi yang optimum dan dapat digunakan untuk pengedalian suhu WTS yang efisien.

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LIST OF SYMBOLS AND ABBREVIATIONS

WTS	-	Water Tank System
PID	-	Proportional-Integrate-Derivative
AT	-	Auto Tuned
ZN	-	Ziegler Nichols
CC	-	Cohen Coon
PSO	-	Particle Swarm Optimization
BPSO	-	Binary Particle Swarm Optimization
SSE	-	Sum Square Error
Tr	-	Rise Time
Ts	-	Settling Time
%OS	-	Percentage of overshoot
K_P	-	Proportional constant
K_I	-	Integrate constant
K_D	-	Derivative constant
e_{SS}	-	Steady State Error

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CHAPTER 1

INTRODUCTION

1.1 Background

In such applications as agricultural process, a Water Tank System (WTS) has a role in providing water storage. The overall configuration of the tank and the choice of construction materials provide water tank parameters. There are also different kinds of materials such as plastics, fiberglass, concrete, steel and stones that used to develop a water tank. The WTS offers certain methods of water control that are sufficient for its own application, such as water temperature control, water level indicator and water pH level indicator. This project is more focused on achieving an ideal WTS temperature. Three-term of parameters are included in the PID controller which are Proportional (K_P), Integral (K_I) and Derivative (K_D) values. Based on the current rate of change, each PID value can be interpreted as the current error, past accumulation of errors and future error prediction [1], respectively. The major point of tuning and tuning a control loop while applying a PID controller is related to these three control parameters, which are proportional band, integral and derivatives to obtain ideal control response characteristics.

This project uses several tuning approaches including conventional and metaheuristic via simulation environment for WTS. There are Ziegler-Nichols (ZN), Cohen Coon (CC), Auto Tuned (AT), Particle Swarm Optimization (PSO) and Binary Particle Swarm Optimization (BPSO). In addition, Sum Square Error (SSE) is a type of objective function that is used in finding the best PID parameters in this investigation. In this project, tuning is also important and needed when using the PID controller to ensure that the WTS temperature provides the desired value by modifying and regulating the process control of PID parameters. The parameters of the controller in the process control system, tuned as desired to achieve process optimization and stability, must also be ensured. The WTS architecture is based on the previous study in [2] that illustrates in Figure 1.1.

Figure 1.1: Water Tank System (WTS)

A 240 V supplies with 30 litre water tank is used to build the WTS temperature controller as shown in Figure 1.1. On the top cover of the water tank, a stirrer was installed and it used as a stabilizer that keeps the water in its equilibrium temperature. Based on study in [2], the transfer function for the system is obtained by applying System Identification toolbox via MATLAB software with three different set point values (50°C, 55°C, 60°C). The performance with the best and closest value with over than 80% will be accepted for this model. The best value for WTS is need to perform the desired temperature setting. Thus, the model that provided the best fit value with the set point of 55°C is accepted because it has the best value with 94.12% which is more than 80%.

The transfer function above is used as WTS model and tune the PID controller parameters using the conventional and metaheuristic tuning methods as mentioned previously (AT, ZN, CC). The results and values from both methods are compared in terms of performance response of Rise Time (Tr), Settling Time (Ts), Overshoot (%OS) and Steady State Error (e_{SS}).

1.2 Motivation

When it comes to industrial applications, temperature control is often to be concerned because it will affect the water's physical and chemical properties. In addition, water temperature is critical for some applications, such as agriculture and related industries, in order to achieve and sustain the quality of a product. Therefore, poor condition and temperature of water can lead to inefficiency of the operation. In order to solve this problem, PID tuning methods were introduced as it has a function

to tune the PID controller for WTS to obtain the best response performance of the system. For the implementation of metaheuristic approach, these methods have not much discovered and studied yet especially for WTS. This is also contributing factor in order to study and make more research on implementing the PSO and BPSO for WTS.

1.3 Problem Statement

The problem statement for this project are:

1) Require some experiences and mathematical approaches.
2) Difficult to tune the PID controller that meets the temperature of the WTS.
3) Inefficient operational of WTS affect the quality of the product and unable to achieve the desired specifications.

1.4 Research Objectives

The objectives for this project are:

1) To simulate PID controller parameters based on existing conventional methods for WTS.
2) To implement PSO and BPSO algorithms in tuning the PID controller parameters for WTS.
3) To validate the effectiveness of PSO and BPSO in determining the best performance responses of WTS.

1.5 Scope of Research

1) Simulation executions for WTS using MATLAB (R2019b) software.
2) Three conventional tuning methods are chosen as benchmarking such as AT, ZN and CC.
3) PSO and BPSO tuning methods are used to tune the PID controller parameters.
4) Evaluate in terms of Tr, Ts, %OS and e_{SS}.

CHAPTER 2

LITERATURE REVIEW

2.1 Chapter Overview

This chapter reviews about the theories that are related to this project such as the concept and the system of WTS. Besides, this chapter also reviews and study the theories of PID controller, conventional (AT, ZN and CC) and metaheuristic (PSO and BPSO) tuning methods.

2.2 Tuning using PID controller

PID controller is famously known as one of the conventional controller that functioned as temperature tuner controller that involves Proportional (K_P), Integral (K_I) and Derivative (K_D) parameters in obtaining the best possible control of process control system by using auto-tuned to obtain optimum parameter. As stated in [1], the PID controller has three most basic modes of control that are commonly used in today's era in such different applications, especially in most industries and plantation industries. Each PID value can be read as a present error, past error accumulation and potential error prediction based on the current rate of change, respectively. Applications related to controller such as industry involving temperature regulation, flow rate, strain, chemical composition, speed and more for which controller measurement exists, as previously stated in [1]. Hence, tuning is needed in this process where to ensure that the temperature of water in the tank obtained the values as desired by adjusting and controlling the gain of the process control using PID controller. It is crucial to adjust and control the PID gain in a process because it will produce either the performances are desired or undesired. Steady state error and overshoot should not be too obvious in values if the process control is in stable condition and by ensuring certain parameters of a controller in a process, the control system can be tuned accurately in achieving process optimization and stability. As reviewed in [2], the PID block can be used as auto-tuned by using MATLAB software. By applying PID controller, it is very important since correct tuning will help in

controlling the process response without %OS and e_{SS}. There are some methods for obtaining PID controller parameters, such as trial and error, ZN and CC. In [4], the performance of the system can be influenced by the parameter values themselves, whether good tuning can increase the performance of the system or whether it can be worse because of poor tuning. The PID algorithm as defined by Maria João [3] is:

$$u(t) = MV(t) = K_p e(t) + K_i \int_0^t e(\tau) + K_d \frac{d}{dt} e(t) \tag{2.1}$$

Where;

*P*out: Proportional term of output

Kp: Proportional gain, a tuning parameter

Ki: Integral gain, a tuning parameter

Kd: Derivative gain, a tuning parameter

e: Error = $SP - PV$

t: Time or instantaneous time (the present)

MV: Manipulated variable

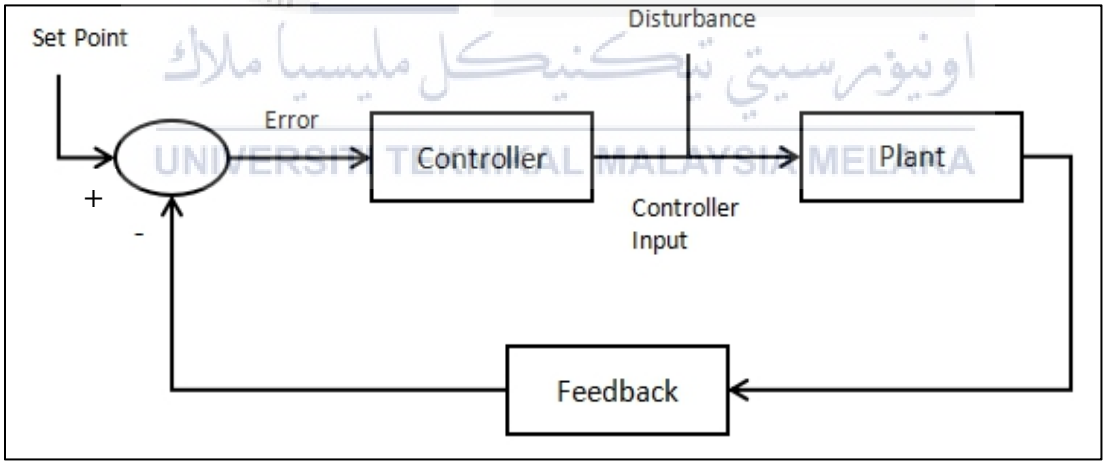

Figure 2.1: PID Controller block diagram [4]

Based on the conclusion in [4], by applying conventional tuning method for PID controller, it has advantages and disadvantages. It takes a long time for the basic trial and error method to achieve good performance. In order to obtain good performance using trial and error method, it needs enough experience to tune and adjust the PID controller as well as it does save time too. To be compared with ZN tuning method, it

needed short period of time to complete and this method also is easy to apply rather than other methods. Although it is easy to apply, it also produce an enormous gain and overshoot value. This was also agreed in [1], where PSO is utilized as the conventional gain tuning PID controller, ZN approach delivers bigger value of overshoot. CC method is similar to ZN method.

2.3 WTS

WTS has the function in storing waters such as in manufacturing industries, agriculture, food processing and more since the previous time. Nowadays, researches and manufacturers attracted in studying and observe the design on WTS for improvements. The improvements and innovations they make is on controlling the temperature and water level of the system. In [5], the control in temperature is one of the most important control in all industrial application. Also, state-of-the-art intelligent controllers are accessible in markets for most industries that still use the simple and trusted PID controller. There are different types of tuning controls that are used to control the desired fixed point value of a device. Most common tuning controller used is PID controller where Jagnade *et. al* [6] has designed a PID controller to control the flow of water that used in single tank system. Besides PID controller, another method known STPID (Self-tuning PID) controller applied by some researcher to control temperature using Genetic Algorithm (GA) approach as a tuning method. Applying GA method, it can obtain and solve optimum controller parameters for a very complex control system problems [8]. In [7], PI controller was used to control the temperature and water level of the water in tank for Multivariable Water Tank (MWT) process and they conclude that the set point change of temperature are too slow.

2.4 PID controller parameter

The PID controller is used to control the performance of a control system. PID controller has been widely used in most industries although it has difficult and complex tuning control but it also has its own advantages where it has fast system response. There are three parameters that has its own behaviour at the output which are proportional constant (K_P), integrate constant (K_I) and derivative constant (K_D) [9]. In [5], the main purpose for tuning method of PID controller is to obtain the optimal