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FINAL YEAR PROJECT REPORT

PSO-TUNED PID CONTROLLER FOR COUPLED-TANK SYSTEM (CTS) VIA PRIORITY-BASED FITNESS SCHEME

SHARIFAH YUSLINDA BINTI SYED HUSSIEN

B011110227

BACHELOR OF ELECTRICAL ENGINEERING

(CONTROL, INSTRUMENTATION AND AUTOMATION)

“I hereby declare that I have read through this report entitle “PSO-Tuned PID Controller for Coupled-Tank System (CTS) via Priority-based Fitness Scheme” and found out that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)”

Signature :…………………………………………

Supervisor’s Name :…………………………………………

Date :…………………………………………

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SHARIFAH YUSLINDA BINTI SYED HUSSIEN

A report submitted in partial fulfillment of the requirements for the degree of

Bachelor of Electrical Engineering (Control, Instrumentation and Automation)

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2014

I declare that this report entitle "*PSO-Tuned PID Controller for Coupled-Tank System(CTS) via Priority-based Fitness Scheme*" 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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Name :………………………………………………

Date :………………………………………………

To my beloved father and mother

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ABSTRACT

The industrial applications of coupled-tank system (CTS) are widely used especially in chemical process industries. The overall process is require liquids to be pumped, stored in the tank and pumped again to another tank. Nevertheless, the level of liquid in tank need to be controlled and flow between two tanks must be regulated. This project presents development of an optimal Proportional-Integrate-Derivative (PID) controller for controlling the desired liquid level of the CTS. Priority-based Fitness Scheme in Particle Swarm Optimization (PFPSO) will be tested in optimizing the PID controller parameters. Simulation is conducted within MATLAB environment to verify the performance of the system in terms of rise time (Ts), settling time (Ts), steady state error (SSE) and overshoot (OS). The performance will be compared to the conventional tuning methods which are trial and error method, auto-tuning method, Ziegler-Nichols (Z-N) method and Cohen-Coon (C-C) method. It has been demonstrated that implementation of PSO via Priority-based Fitness Scheme (PFPSO) for this system is potential technique to control the desired liquid level and improve the system performances compared with conventional tuning methods.

ABSTRAK

Penggunaan sistem tangki berkembar (CTS) dalam industri banyak diaplikasikan terutamanya dalam industri proses kimia. Keseluruhan proses tersebut adalah cecair di pam, di simpan di dalam tangki and dipam semula ketangki yang lain. Cecair tersebut haruslah dikawal dan aliran di antara kedua-dua tangki perlu dikawal. Projek ini membentangkan pelaksanaan optimum bagi pegawal kesempurnaan terbitan berkadar terus (PID) bagi mengawal paras cecair yang dikehendaki dalam sistem tangki berkembar. Keutamaan beradasarkan kecergasan dalam pengoptimunan kerumunan zarah (PFPSO) akan diuji dalam pengawal PID. Simulasi akan dilaksanakan menggunakan MATLAB bagi mengesahkan prestasi sistem dalam konteks masa naik (Tr), takat stabil (Ts), ralat keadaan mantap (SSE) dan lajakan isyarat (OS). Prestasi ini akan dibandingkan dengan kaedah penalaan tradisional iaitu kaedah percubaan dan kesilapan, kaedah auto-tuning, kaedah Ziegler-Nichols (Z-N) and kaedah Cohen-Coon (C-C). Ia telah menunjukkan bahawa pelaksanaan PFPSO bagi sistem ini adalah teknik yang berpotensi untuk mengawal paras cecair yang dikehendaki dan meningkatkan prestasi sistem tersebut berbanding dengan kaedah penalaan konvensional.

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CHAPTER 1

INTRODUCTION

1.1 Coupled-Tank System (CTS)

Figure 1.1: Coupled-tank apparatus CTS-001

The coupled-tank apparatus CTS-001 as shown in Figure 1 is a computer-controlled CTS used for liquid level control. The concept of virtual instrumentation is introduced in CTS-001. The need for conventional dedicated user interfaces on individual instrumentations can be eliminate by using virtual instrumentation techniques [1]. Besides, the computer can be used as the tool of communications between the hardware and software. Through the software analysis, it enables to carry out the function of oscillation and display the input and output response. From the system, it also can verify the parameter of the model which can be derived from the mathematical modeling. This output response from the modeling function can be taken as the bench mark to achieve good response after implemented it in the CTS. The performance can easily be monitored in MATLAB simulation.

1.2 Problem Statement

Real time control involves algorithms to control a certain processes. In order to study the performance in terms of implementation in real-time and each control features, control of level of CTS is chosen. This application is widely used in the process industries especially in chemical industries. It is often essential that the liquid to be supplied in tanks. It is maybe be stored up in tanks and transferred it to the other tank as per requirement. The liquid must be maintained at a specific height or in a certain level. If the level cannot be maintained at the specific height as requirement, it can bring losses to the company or industries. In this project, PID controller will be implemented to the system in order to control the level process. A common control problem in process industries is the control of fluids level in storage tanks and chemical blending. The flow of the liquid into and out the tank must be regulated as to achieve a constant desired liquid level as fluid to be supplied at a constant rate. Many control algorithms have been implemented using various types of technique to compensate with the control requirement. The most commonly techniques have been used are Genetic Algorithm (GA), Simulated Annealing (SA), Characteristic Ratio Assignment (CRA) and many more to obtain the optimal gain or parameter of PID controller which are K_p, K_i and K_d. Each of the performance is verifying in terms of rise time (Tr), settling time (Ts), steady-state error (SSE) and overshoot (OS).

1.3 Objectives

The objectives of this project are:

i. To model and simulate PID controller tuned by conventional method which are trial and error, auto-tuning, Ziegler-Nichols (Z-N) and Cohen-Coon (C-C) for CTS.
ii. To obtain optimal parameters of the PID controller for CTS using Priority-Fitness based Particle Swarm Optimization (PFPSO) as the tuning method.
iii. To compare the performance of CTS in terms of transient response specifications (settling time, overshoot, rise time and steady-state error) and validate it with PSO.

1.4 Scopes

The scopes of this project are:

i. Implemented PID controller in order to control the performance in terms of settling time of CTS.
ii. Apply PFPSO as the tuning method in finding the optimal parameters of PID controller of CTS.
iii. Use MATLAB and Simulink in writing PFPSO code and simulation.

CHAPTER 2

LITERATURE REVIEW

2.1 Theory and Basic Principle

The industrial CTS are widely used in consumer liquid proceeding and chemical processing industry. In order to control the level of the liquid, a conventional PID controller had been implemented. There are several methods to find the parameters for PID controllers such as trial and error method, Z-N method and C-C method.

2.1.1 PID Controller

PID controller is a control feedback mechanism controller which is widely used in industrial control system. PID controller involves three-term control which are the proportional (P), the integral (I) and the derivative (D). PID controller is used to calculate an error value as the difference between a measured process variable and a desired set point. It also used to minimize the error by adjusting the process control inputs.

$$u(t) = K_p e(t) + K_i \int e(t)dt + K_d \frac{de}{dt}(t)$$
$$u(t) = K_p \left[e(t) + \frac{1}{T_i} \int e(t)dt + T_d \frac{de}{dt}(t) \right] \quad (2.1)$$

Where $K_i = \frac{K_p}{T_i}$; $K_d = K_p T_d$

In the PID controller, there are three parameters which needed to be tuned. One of the parameter was proportional gain, K_p in the proportional controller. This controller has the effect of reducing the rise time and steady-state error but the percentage of the overshoot in the system is high. In the integral controller, K_i as the integral gain, also decrease the rise time but it will eliminate the steady-state error of the system. Even though it eliminates the error but the percentage of the overshoot is increase and it will affect the settling time as well. In order to improve the performance of the system, derivative gain, K_d in the derivative controller is introduced. This controller will take action to improve the transient specification and stability of the system. The effects of the each of the controller on a closed-loop system are summarized in Table 2.1 shown below.

Table 2.1: PID controller properties

Controller	**Effect of Performance**			
	Rise Time, Tr	**Steady-state Error, SSE**	**Overshoot, OS**	**Settling Time, Ts**
Proportional, P	Decrease	Decrease	Increase	Small Change
Integral, I	Decrease	Eliminate	Increase	Increase
Derivative, D	Small Change	Small Change	Decrease	Decrease

In order to gain the high stability and short transient response of the system, the correct gain value must be obtained from the PID tuning. Even though it is only three control parameters, but to adjust the parameter referred to the Table 2.1 are difficult. Therefore, an optimization tuning method of PID controller is used to determine the value of the gains.

2.1.2 Conventional Tuning Method of PID Controller

Tuning method is very important in control system. The values of the parameters in the controller can affect the performance of the system. The performance of the system can be generally improved by careful tuning but it also can be worst performance with poor tuning. In PID, there is several tuning method that can be used to find the desired control response.

2.1.2.1 Manual Tuning

Manual tuning is the easiest way to get the value of the parameter because no mathematical is required. However, the value of the parameter is not guaranteed as the best value because it is obtained by trial and error method. For a PID controller, the K_i and K_d values must be set first to zero before increasing the K_p. This will takes a lot of time to obtain the good result. The time can only be shortened with the experienced personnel.

2.1.2.2 Ziegler Nichols (Z-N)

Z-N is the tuning method that is widely used in the industry. It is developed by John G. Ziegler and Nanthaniel B. Nichols in 1940s. In this tuning method, K_i and K_d gain are also need to be set first to zero and then increase K_p until it reaches the ultimate gain, K_u at which the output of the loop starts to oscillate in the oscillation period, P_u in PID controller. The set gain is shown in Table 2.2 and Table 2.3. The advantage of this tuning rule is that it gives the PID loops best disturbance rejection but it yields an aggressive gain and overshoot in the system.

Table 2.2: Closed-loop Ziegler-Nichols method in PID Controller

Controller	**Parameter**		
	K_p	**K_i**	**K_d**
Proportional, P	$0.50K_u$	-	-
Proportional-integral, PI	$0.45K_u$	$1.2K_p/P_u$	-
Proportional-integral-derivative, PID	$0.60K_u$	$2K_p/P_u$	$K_pP_u/8$

Table 2.3: Open-loop Ziegler-Nichols method in PID Controller

Controller	**Parameter**		
	K_c	**T_i**	**T_d**
Proportional, P	K_o	-	-
Proportional-integral, PI	$0.9K_o$	$3.3\ \tau_{dead}$	-
Proportional-integral-derivative, PID	$1.2K_o$	$2\ \tau_{dead}$	$0.5\ \tau_{dead}$

where: $K_o = (X_o/M_u)(\tau/\ \tau_{dead})$