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FINAL YEAR PROJECT REPORT

OPTIMAL PID CONTROLLER PARAMETER FOR COUPLED TANK SYSTEM USING PRIORITY FITNESS FIREFLY ALGORITHM

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OPTIMAL PID CONTROLLER PARAMETER FOR COUPLED TANK SYSTEM USING PRIORITY FITNESS FIREFLY ALGORITHM

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

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I declare that this report entitle "*Optimal PID Controller Parameter for Coupled Tank System Using Priority Fitness Firefly Algorithm*" 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.

Signature :………………………………………………

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Date :………………………………………………

To my beloved father and mother

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ABSTRACT

In this project, a Coupled Tank System (CTS) is controlled by Proportional-Integrate-Derivative (PID) controller, where the liquid needs to be pumped, stored in the tank and pumped again to the next tank. However, the flow and level of the liquid needs to be controlled and regulated. Thus, the implemented of PID controller is use to control the CTS. Conventionally, there are several tuning methods used to obtain the PID controller parameter which are Trial and Error (T-E), Auto-Tuning (A-T), Ziegler-Nichols (Z-N) and Cohen-Coon (C-C). Then, in order to improve the parameter of PID controller that obtain from conventional method, a new meta-heuristic algorithm namely Firefly Algorithm (FA) is implemented. Priority Fitness Firefly Algorithm (PFFA) is a combination of Priority Fitness and FA. It was designed according to the priority specification that has been set in term of steady state error (SSE), overshoot (OS) and settling time (Ts). Simulation is conducted within the Matlab environment and the results is evaluated and compared with Priority Fitness Particle Swarm Optimization (PFPSO). It shows that PFFA is improved almost 55% and 27 % of the OS and Ts respectively with zero Steady SSE.

ABSTRAK

Di dalam kertas ini, Sistem Tangki Berkembar (*Couple Tank System)* akan dikawal oleh pengawal *Proportional-Integrate-Derivative (PID),*diimana cecair perlu dipam, disimpan di dalam tangki dan dipam semula ke tangki yang seterusnya. Walau bagaimanapun, aliran dan tahap keperluan cecair perlu dikawal dan diselia. Oleh itu, penggunaan pengawal PID digunakan untuk mengawal CTS. Secara konvensional, terdapat beberapa kaedah penalaan untuk pengawal PID iaitu kaedah *Trial and Error (T-E), Auto-Tuning(A-T)* kaedah *Ziegler-Nichols(Z-N)* dan kaedah *Cohen-Coon (C-C)* bagi mendapatkan parameter pengawal PID. Dalam usaha untuk meningkatkan parameter pengawal PID yang diperoleh dari kaedah konvensional, meta-heuristik yang bernama *Firefly Algorithm (FA)* telah digunakan. Gabungan daripada *Priority Fitness* dan FA dikenali sebagai PFFA telah direka mengikut spesifikasi keutamaan yang telah ditetapkan dari segi *steady state error (SSE), overshoot (OS)* dan *settling time (Ts).* Simulasi telah dijalankan menggunakan Matlab dan keputusan telah dinilai dan dibandingkan dengan *Priority Fitness Particle Swarm Optimization (PFPSO).* Ia menunjukkan bahawa PFFA telah meningkatkan prestasi bagi OS dan Ts sebanyak 55% dan 27% masing-masing dan nilai SSE ialah kosong.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	ACKNOWLEDGEMENT	**v**
	ABSTRACT	**vi**
	ABSTRAK	**vii**
	TABLE OF CONTENTS	**viii**
	LIST OF TABLES	**x**
	LIST OF FIGURES	**xi**
	LIST OF APPENDICES	**xiii**
1	**INTRODUCTION**	**1**
	1.1 Introduction	1
	1.2 Coupled Tank System	1
	1.3 Motivation	3
	1.4 Problem Statements	3
	1.5 Objectives	3
	1.6 Scope of Research	3
	1.7 Report Proposal	4
2	**LITERATURE REVIEW**	**5**
	2.1 Introduction	5
	2.2 PID Controller	5
	2.3 Liquid Level Control Technique	7
	2.4 Summary for controller	9
	2.5 Firefly Algorithm	11
	2.6 Optimization method	12

3	**METHODOLOGY**	**15**
	3.1 Introduction	15
	3.2 K-Chart	15
	3.3 Project Flowchart	17
	3.4 Simulation of CTS	20
	3.5 Conventional Tuning Method	21
	3.6 Priority Fitness Firefly Algorithm (PFFA)	27
4	**RESULT AND DISCUSSION**	**30**
	4.1 Introduction	30
	4.2 Tuning Method	30
	4.3 Priority Fitness Firefly Algorithm Method	35
	4.4 Comparison of Tuning Method	36
	4.5 Analysis and Discussion	40
5	**CONCLUSION**	**41**
	5.1 Introduction	41
	5.2 Conclusion	41
	5.3 Recommendation	41
	REFERENCE	**42**
	APPENDIX A	**45**
	APPENDIX B	**48**

LIST OF TABLES

TABLE	TITLE	PAGE
2.1	Closed-loop Z-N method in PID Controller	6
2.2	C-C method in PID Controller	6
2.3	Review Summary for controller	10
2.4	Summary of Optimization	14
3.1	Z-N first method in PID Controller	21
3.2	Characteristic of PFFA	28
3.3	Parameter of PFFA tuning method	29
4.1	Parameter of PID controller that tuned by PFFA	35
4.2	Summary of the parameters of PID controller by using conventional and optimization tuning method	38
4.3	Summary of transient response specification of PID controller by using conventional and optimization tuning method	39

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Coupled Tank System-001	1
3.1	K-Chart of the project	16
3.2	Project's Flowchart for FYP 1	18
3.3	Project's Flowchart for FYP 2	19
3.4	Block diagram of the open loop of the CTS using Simulink	20
3.5	Block diagram of the close-loop of the CTS using Simulink	20
3.6	S-shaped response curve	21
3.7	Step response of open-loop for CTS	22
3.8	Block diagram of the CTS using Simulink	19
3.9	Block diagram of Coupled-Tank system with PID controller	23
3.10	Block diagram of the CTS with PID controller by T-E method	25
3.11	Response by using A-T method	26
3.12	Flowchart of Priority Fitness Firefly Algorithm	27

4.1 Response of closed-loop system with PID controller by using Z-N method 31

4.2 Response of closed-loop system with PID controller by using C-C method 32

4.3 Response of closed - loop system with PID controller by using T-E method 33

4.4 Setting of PID parameter by using A-T method 34

4.5 Response of CTS by using PFFA tuning method 35

4.6 Response of the closed–loop system with PID controller by using conventional tuning methods 36

4.7 Response of the closed–loop system with PID controller by using optimization tuning methods 37

4.8 Response of the closed–loop system with PID controller by using conventional and optimization tuning methods 38

LIST OF APPENDIX

APPENDIX	TITLE	PAGE
A	Turnitin	45
B	Gantt Chart	48

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In this chapter, an introduction about this project is stated. Besides, the problem statement, objectives and scopes of this project is also being discussed.

1.2 Coupled Tank System

The Coupled Tank System (CTS) is widely used in industries especially in chemical industries. The process in CTS required liquid to be pumped, stored in a tank and pumped to another tank [2]. CTS-001 as shown in Figure 1.1 is one of the models for CTS. CTS-001 is an apparatus which is controlled by the computer to control liquid level in the tank. Besides that, the computer also can make the connection between software and hardware. Through the software analysis, the function of oscillation and the input and output response can be carried out. Then, by using the system, it can also verify the model parameter which also can get by using mathematical modeling. To obtain a good response for the systems, make the output response from a modeling function as a benchmark. Then, the performance of the system will be monitored by using MATLAB simulation.

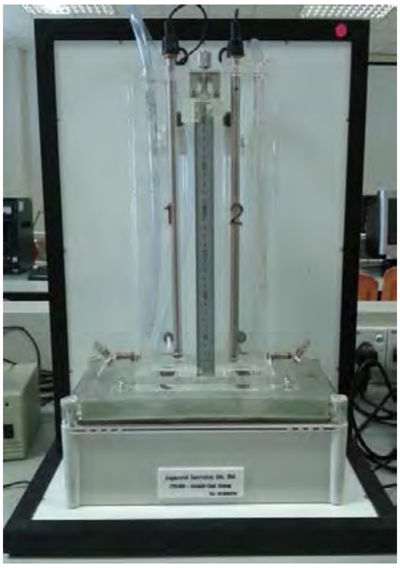

Figure 1.1: Coupled Tank System-001 [1]

1.3 Motivation

In the process industry, there were several problems was facing which is to control the liquid level in the tanks. The liquid needs to go through the process which is pumped, stored in tanks and lastly the liquid will be pumped to another tank [3]. Therefore, a CTS has been chosen to study the behavior and solve this problem. In CTS, it is important to control and regulate the water level in the tank, so, a PID controller has been used to control the water level and the flow between the tank must be regulated. However, by using a PID controller it always gotten an inaccurate result, in terms of poorly tuned in conventional tuning method. So, in order to overcome this issue, a new meta-heuristic called Firefly Algorithm (FA) has been used. This optimization will be combining with Priority Fitness (PF) and will know as Priority Fitness Firefly Algorithm (PFFA) to get a better performance of transient response [4]. Then, the result f the PFFA will be compared with Priority Fitness Particle Swarm Optimization (PFPSO) [1] in order to improve the performance of the transient response.

1.4 Problem Statements

The problem statements of this project are:

i. Hard to achieve a constant desired liquid level that in and out the tank.
ii. Difficulties to gain required control response with short transition time and small overshoot.

1.5 Objectives

The objectives of this project are:

i. To control the water level of CTS and set to 1 cm.
ii. To design and simulate the PID controller by using conventional method which are Trial and Error (T-E), Auto-Tuning (A-T), Ziegler-Nichols (Z-N) and Cohen-Coon (C-C) for the CTS.
iii. To gain an optimal parameters of the PID controller for a CTS by using PFFA as a tuning method.
iv. To validate the performance of CTS between PFFA and PFPSO.

1.6 Scope of Research

The scopes of this project are:

i. Obtain PID controller parameters by using conventional tuning method such as Z-N, C-C, T-E and A-T.
ii. Improve the transient response by applying the PFFA and compared it with PFPSO.
iii. Use MATLAB and Simulink for simulation purpose.
iv. Water level is set to 1 cm as default process.

1.7 Report Outline

In this report, there are 5 Chapters will be discussed. In Chapter 1, an introduction about the system will be discussed. In Chapter 2, it will discuss about the literature review about the project. Later, for Chapter 3 a methodology about the project will be shown. Then, for Chapter 4, a result will be shown and discussion will be explained. Lastly, a conclusion and future work will be stated in Chapter 5.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is brief about the PID controller and FA. Then, the research that have been done before about a few controllers applied to a CTS and about FA also be revised.

2.2 PID Controller

PID controller is one of the controllers that are most commonly used in industry and has been accepted in industrial control. As its name given, PID has three basic coefficient, which are Proportional (P), Integral (I) and Derivative (D) where it used is to obtain optimal response. In PID the process to get the optimal response from a control system are called tuning. There are several tuning methods in PID such as Z-N, C-C, T-E and A-T.

For T-E, once this method is understood it will be easy to obtain each of the gain parameter. At first, the value of PID gain parameter which are K_P, K_I and K_D need to be set to zero, then the K_p is increased until the output of the loop oscillates. The systems will become faster when the proportional gain increased and precaution is needed to avoid the system becoming unstable. When the K_p is set to get a desired fast response, K_I is increased so that it can stop the oscillations.

Then, Z-N method is one of the popular methods tuning of PID controller. Z-N is the tuning method that is widely used by tuning PID controller. It was introduced by John G. Ziegler and Nathaniel B. Nichols in the 1940s [5]. To tune it, first need to set the K_i, K_p and K_d to zero and slowly increase the value of K_p until it obtain the ultimate gain, K_u when the output of the control loop start to oscillate. By using K_u and ultimate peiod,T_u, the value of P, I and D are set as in Table 2.1, but it needs to depend on the type of controller that will be used.

Table 2.1: Closed-loop Z-N method in PID Controller

Controller	K_p	K_i	K_d
P	0.50 K_u	-	-
PI	0.45 K_u	$1.2\frac{Kp}{Pu}$	-
PID	0.60 K_u	$2\frac{Kp}{Pu}$	$KpPu/8$

After the Z-N method, the C-C tuning method is the most popular PID tuning method. This method was introduced by Cohen Coon in 1953 [6]. When there is a large dead time to open loop time constant in Z-N method, the C-C method will be used to correct the slow, steady state response. This method is only suitable for the first order model which has a time delay. This is because controller cannot respond immediately to the disturbance. Then in Table 2.2 below, shows the standard recommended equations to optimize C-C predictions.

Table 2.2: C-C method in PID Controller

Controller	Gain		
	K_C	K_i	K_d
P	(P/NL)*(1+(R/3))	-	-
PI	(P/NL)*(0.9+(R/12))	L*(30+3R)/(9+20R)	-
PID	(P/NL)*(1.33+(R/4))	L*(30+3R)/(9+20R)	4L/(11+2R)

Where: P = percent change of input

N = percent change of output/τ

L = τ_{dead}

R = τ_{dead}/τ

P/NL = K_o

2.3 Liquid Level Control Techniques

The controller is very important in process industry since it is necessary to maintain the liquid level and to transfer liquid to another tank as required. A several techniques of PID controller often used in industries.

In [7,8] a Fuzzy Logic Controller (FLC) was studied. FLC is one of the controllers that believe can replace the PID controller. FLC is used to solve the non-linearity in the system. The process that has in FLC is fuzzication, deffuzzificaton and fuzzy-rule set. In fuzzyffication the control input was produced from the FLC output, which is a change in control input. For a fuzzy rule are known as a conditional statement in the form of IF-THEN rule statement. Then, deffuzzification will sense the error. Lastly, it can be concluded that FLC can be used to replace the PID controller.

Controlling the liquid level of CTS by using hybrid-PI neural network (hybrid PI-NN) was discussed in [9]. In this research the performance of disturbance rejection and control performance of PI-NN was compared with the PID-NN. Optimum setting of a generic tuning rule derives from the Integral Squared Error criterion point of view. From the result also says that the performance of PI-NN is faster than PID-NN and it also has good robustness and small overshoot. Then, after the disturbance was applied PID-NN show a better performance than PI-NN because the robustness of connective weight in PID-NN that used to hold the output response for any external disturbance was introduced.

The research in [10] is about a characteristic ratio assignment (CRA) was applied to the PID controller design for the CTS. Since the PID controller is a high uncertainly non-linear model, the test will be conducted. CRA is fulfilling the requirement of performance for the control system. CRA also efficient in the adjustment of the damping ratio as well as a high speed response. Besides, the CRA only needs one parameter to adjust the speed response and damping ratio. Therefore, this technique is convenient and suitable for designing and tuning the controller.

Research in [11] an Interval type-2 fuzzy control system is introduced. It has been applied to CTS. The purpose of this controller is to improve static error that is formed due to lack of protection from conventional fuzzy control. With a simple design of the controller, it also can reduce the unknown disturbance that came from the real environment. Lastly, as shown in result, it can be concluded that this method has better performance for static and dynamic control with the strongest performance if compared to fuzzy control method.

As in [12] a sliding mode control (SMC) was used. The function of SMC is to determine the robustness of the controller, which is for disturbance in the plant and produced an appropriate control signal for controlling liquid level. Then by comparing SMC with PID controller, which tuning by the Z-N method it can be shown that the Z-N method has a better performance. However, SMC has a better robustness behavior than PID controller. Besides that, PID controller also manages to control a non-linear system that has a particular set point given by time varying commanded input signal.

For the research on [13], a fuzzy controller has been used for double-holding water tank liquid level controller for improving the transient response in the system. In designing a fuzzy, a particular mathematical model also not necessary. Other than that, fuzzy are good for a nonlinear system and higher dead time because it has disturbance and strong robustness. However, fuzzy controller has a better performance than PI controller due to small overshoot, and has faster response speed for the second order large delay controlled object.

Liquid level control of CTS using a Fractional PID controller was discussed in [14]. The fractional control algorithm has been introduced and known as fractional order controller. It seems that fractional order controller has better response than PID controller. Since this controller has five parameters instead of three as in PID controller it gives advantage because controller designs are adjustable. Through this research, a frictional PID controller was simulated without a present of overshoot in response with couple tanks. It also gives better performance than PID controller due to two more tuning parameters.

Then in [15], a PID neural network (PID-NN) was used in the research. In this research it needs to keep the deaerator water level steady by controlling chemical feed water flow and keeping a condenser water level steady by controlling recirculation water flow. The other one is needed to keep the deaerator water level steady by controlling chemical feed water flow. PID has been used widely in the past time to control the water level. However, PID can hardly meet the requirements of control performance and precision because of the strong intercoupling between condenser water level and deaerator water level. Then, the neural network has shown a great interest because it is a good dynamic performance, nonlinear approximation ability, strong robustness and fault-tolerance ability. It has been widely applied in automatic control and some other fields. It can be shown that it has both advantages of PID and neural network. It also proves that PID neural network decoupling strategy can significantly reduce the overshoot and settling time of the condenser water level and deaerator water level, and can make the control process much more stable. It is more effective in decoupling control than PID.

2.4 Summary for Controller

As time flies, there a lot of controllers had been implemented in order to improve the performance of the systems. PID controller is one of the popular controllers that has been used a long time ago after it was being implemented in 1890s. Even though it is used ,widely, but it also has some disadvantage compared to other controllers [7,8]. Therefore, Table 2.3 shows the comparison between PID controllers with other controllers.

Table 2.3: Review Summary for controller

No.	Type of controller used	Year published	Comparison with PID
1	Fuzzy logic controller (FLC)	2005, 2008	Advantages: • Improve the non-linearity system.
2	PID controller (characteristic ratio assignment)	2009	Advantages: • Very fast at adjustment damping ratio. • High speed response.
3.	Hybrid-PI neural network (hybrid PI-NN)	2009	Advantages: • Good robustness • Small overshoot.
4.	Interval Type-2 Fuzzy Controller	2012	Advantage: • Reduce the uncertainty disturbance from the real environment without increase the complexity of the design.
5	Sliding Mode Control (SMC)	2012	Compared to PID (tuning method of Z-N) Advantages: • Improve the non-linearity good robustness.
6	Fuzzy controller	2013	Advantages: • Has strong robustness and the disturbance.
7	Fractional PID controller	2013	Advantages: • No overshoot • Gives better performance due to extra tuning parameter.