CONTROL OF TEMPERATURE PROCESS USING PID CONTRLLER TUNED USING OPTIMIZATION TECHNIQUE

TAN GEOK SEONG

B011210153

Faculty of Electrical Engineering

Universiti Teknikal Malaysia Melaka

JUNE 2016

CONTROL OF TEMPERATURE PROCESS USING PID CONTRLLER TUNED USING OPTIMIZATION TECHNIQUE

TAN GEOK SEONG

A report submitted in partial fulfillment of the requirements for the degree of Bachelor in Electrical Engineering (Control, Instrumentation and Automation)

Faculty of Electrical Engineering
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2016

"I hereby declare that I have read this project entitle "Control of Temperature Process Using PID Controller Tuned Using Optimization Technique" and that is has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentation and Automation)"

Signature : ……...
Supervisor's Name : Puan Nur Asmiza Binti Selamat
Date : ……...

I declare that this report entitle “Control of Temperature Process Using PID Controller Tuned Using Optimization Technique” 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 : ……..
Name : Tan Geok Seong
Date : ……..

ACKNOWLEDGEMENT

In preparing this report, I was in contact with many people, researchers and academicians. They have contributed towards my understanding and thought. In particular, I wish to express my sincere appreciation to my project supervisor, Madam Nur Asmiza Binti Selamat, for encouragement and guidance critics. Without her continued support and interest, this project would not have been same as presented here.

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. I also would like to thankful to my beloved parents for their support provided for the whole duration time in the process of completing this project. Unfortunately, it is not possible to list all of them in this limited space.

`

ABSTRACT

Temperature process control system is widely used in every sector of industrial process. Proportional Integral Derivative controller (PID) is used to tune the parameter of the temperature process. The system performance using conventional method of trial and error in tuning the control parameter is not efficient and time consuming. PID controller as a conventional controller still being used in industrial and it has weakness in performance. The objective of this project is to analyze the system performance between Cuckoo Search and Particle Swarm Optimization technique with applying PID controller. The parameters of the PID controller that have been tuned from the both optimization techniques of ITSE is used as the performance index or criteria of comparison for optimization technique between Cuckoo Search (CS) and Particle Swarm Optimization (PSO) will be applied to temperature process control system of stirred heated liquid tank. The comparison between both optimization techniques performance will be made and observed such as settling time (Ts), rise time (Tr), overshoot percentage (OS), standard deviation and disturbance rejection. This project is only involving simulation at MATLAB and Simulink. From the results of comparison between Cuckoo Search and Particle Swarm Optimization, it showed Cuckoo Search has the better performance in overall terms of rise time, settling time, standard deviation and also disturbance rejection.

ABSTRAK

Sistem kawalan proses suhu adalah satu system yang diguna di setiap sector dalam industry secara meluas. Pengawal PID adalah satu pengawal digunakan untuk mengawal parameter dalam proses kawalan suhu. Prestasi system yang menggunakan cara konvensional daripada kaedeh 'trial and error' sebagai penala mengawal parameter adalah tidak cekap dan mengambil masa lama. Pengawal PID sebagai pengawal konvensional masih digunakan dalam industry walaupun prestasi PID mempunyai kelemahan. Objektif melaksanakan projek ini adalah untuk membandingkan perbezaan prestasi sistem antara Cuckoo Search (CS) dan Particle Swarm Optimization (PSO) teknik pengoptimuman dengan mengaplikasikan pengawal PID. Hasil parameter ITSE sebagai kriteria atau prestasi indeks akan dibandingkan antara proses pengoptimuman Cuckoo Search (CS) dan Particle Swarm Optimization (PSO) daripada pengawalan selepas proses pengoptimuman akan diapplikasikan dalam system kawalan proses suhu. Hasil perbandingan antara two teknik pengoptimuman (CS) dan (PSO) yang telah mengaplikasi dalam pengawal PID akan dibincangkan seperti rise time, settling time, overshoot, standard deviation dan disturbance rejection. Projet ini akan melibatkan MATLAB dan Simulink simulasi sahaja. Keputusan simulasi perbandingan antara Cuckoo Search dan Particle Swarm Optimization menunjukkan bahawa Cuckoo Search lebih baik daripada Particle Swarm Optimization dalam keseluruhan prestasi keputusan seperti dalam jangka masa naik, masa stabil, sisihan piawai dan juga gangguan penolakan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

This chapter will comprise the overall concept and idea of the project based on the title for applying a controller on a temperature process using optimization technique. Firstly, background and objectives of the final year project would be discussed. Then, problem statement, motivation and scope of the project would also be stated. Lastly, a brief summary of the report structure is done at the end of the chapter.

1.1 Background of the project

Temperature is one of the most critical parameters in process control as it may cause failure in quality products or break down the system or system performance affected become non optimal such as reactor temperature control failed caused the chemical mixing ratio of product unable to reach the desired condition. Thus, such a dynamic process is needed to be applying a controller in order to maintain and control the outlet temperature within a specific desired range. However due to the highly unstable and non-linearity characteristics of the temperature process, designing of controllers is a challenge. PID controller is been widely used in many of the process control systems, but there is a problem in tuning the parameters since the PID controller parameters give a big influence in the system performance. Therefore, optimization technique is introduced to implement to controllers as the parameter tuning. In this project will discuss about optimization technique implement into controller tuning of a temperature process and the performance of the system with controllers implemented optimization technique are analyzed.

1.2 Problem Statement

Temperature process control system is one of the common systems which widely used in industries application such as industrial food processing and heat treating. Temperature process control system is a liquid tank with a heater and with two temperature sensors. The temperature sensor used in this process is type RTD, Pt 100. The liquid's temperature inside the process tank needs to be controlled. The PID controller will be applying to the temperature process control system. The parameter of PID controller need to be tune effective so as the performance of the temperature process control system can be improved. However, there is still having significant weakness in their performance and capabilities when dealing with complex processes [5]. Trial and error method which the conventional method that commonly apply to determine the parameter of PID controller but the results from this method is not always correct and it need to spend a lot of time in getting the best performance result. Optimization techniques used to perform tuning of PID controller parameter instead of using trial and error method because trial and error method will be time consuming [13]. The optimization techniques used in this study to perform parameter tuning.

1.3 Motivation

Temperature is one of the most important parameter in every sector of manufacturing industries like chemical, food processing, pharmaceutical etc. In these kinds of industries some product need the required temperature to be maintained at highest priority the product will fail. There is some temperature process control failures such as reactor temperature control failed caused the chemical mixing ratio of product unable to reach the desired condition, ionizer of the temperature control failed in food manufacturing causing the beans or food products are not fully bacteria free. Temperature process control system is important in industry control mechanism especially in food processing because poor temperature control will cause food poisoning. Bacteria require a certain warmth temperature of environment to live, if the temperature failed in under control, bacteria will multiply on the food which will cause food poisoning and affect the consumers' health.

1.4 Project Objectives

The main two objectives of this study are:

1. To apply PID controller on temperature process control system and tune using Cuckoo Search and Particle Swarm Optimization techniques.
2. To analyze and compare system performance (steady-state error, rise time, peak time, overshoot percentage, settling time and fitness function) of PID controller with Cuckoo Search (CS) and Particle Swarm Optimization (PSO).

1.5 Scope of Project

In this study will focus on the PID controller in temperature process control system. The temperature process transfer function will be taken from the reference of previous research [17]. The controller parameter will be tuned using optimization technique of Cuckoo Search (CS) and Particle Swarm Optimization (PSO). The simulation will be done in using MATLAB and Simulink. Integral of Time Square Error (ITSE) is applied to obtain the error of the system. The analysis will be done based on system performance in terms of rise time, settling time, overshoot percentage, performance index and standard deviation. The fixed disturbance of sine signal input and step signal input are applied to observe the system behaviour of temperature process control system.

1.6 Report Structure

This report will be contained five chapters and each of the chapter stated as below.

This chapter 1 of introduction will cover the overview of the project such as project background, problem statement, objective and scope of this report. In chapter 2 of project background will discuss about background theory of temperature process, PID controller, Fuzzy controller, optimization technique and other past researches which related to this project. Next is about chapter 3 of methodology. This chapter will show the flowchart of the whole research implementation. Besides, this chapter will discuss about the steps and technique being used in this project. For the chapter 4 of results will show the performance

of the system which applied of PID controller with Cuckoo Search and Particle Swarm Optimization on temperature process will be analyse and discuss in this chapter. At the end of the chapter 5 will make a conclusion for the project and recommendation for the future plan which related to the project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter presented about background theories and previous researches on the title of temperature process control system, controllers tuning and optimization technique application that related to this project. This chapter will describe about the literature review.

2.2 Temperature Process

Temperature process is a process to control and maintain the temperature at a desired state as temperature is one of the important parameters of control in many process industries. [1] Temperature process can be applying to other industries process such as plastic injection molding process, food processing, plastic extrusion process, air conditioning system and heat exchanger system because involving temperature and needed to be under or over control condition. Unfortunately, it will be regulated to achieve a desired system temperature but refinement can be employed to enhance the control accuracy by designing a temperature controller. Control the temperature is a difficult task because temperature process is highly non-linear process and multi variables process. Figure 2.1 show the block diagram of temperature process.

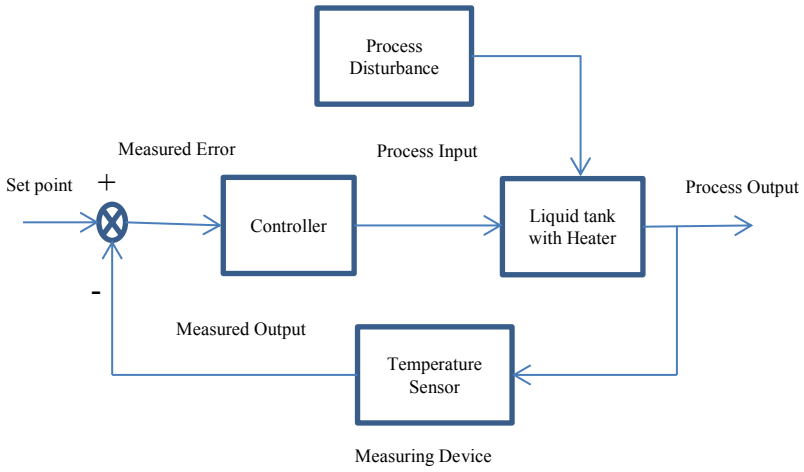

Figure 2.1: Block Diagram of Temperature Process

2.3 Operation of Temperature Process

Basically, a temperature process consists of a temperature input unit (temperature sensors and ADC converter), controller with control output unit (program and control element). The temperature of the objects that need to be measured is sensed using a temperature sensor whose output is converted into resistance by using signal conditioning circuit and amplified using operational amplifier to increase the accuracy and sensitivity of the system. The voltage from the sensor is then digitized through the ADC converter and input to program controller. From the controller, the converted input data to temperature is compared with the desired state or set-point and computed the error. The controller will compensate the changes in the system and tuned to the specification needed using trial and error or tuning methods such as optimization technique. The program will converted the temperature back to voltage or current and fed to the DAC converter. The analog data of voltage is input to the control element such as heater or fan. Based on the signal input, the voltage signal is controlled the current passing to the heater circuit response and the heater is response to heating or cooling the temperature. This process will continue flow until the temperature achieved the specification needed [1].

2.4 Application of Temperature Process Control

Temperature process is one of the major processes that must be apply into many applications whether in industries or home such as plastic extrusion process, plastic thermoforming process, shell and tube heat exchanger system.

The plastic extrusion process [2] is the technique which used in the polymerization industry. The polymer is fed into the hooper in solid pellet heated and melted. The melted polymer material is pushed forward by a powerful screw and passes through the molding mechanism to form the die. The plastic extrusion process consists of several temperature zones controlled by electrical heaters where each represents heating stages with appropriate power specifications. Controller is apply in order to control the temperature stability precisely so to maintain the quality of the product.

Plastic thermoforming process [3] consists of three phases- heating, forming, and solidification. Heating is the first and most important as it will influence the continuous phases and products. At the beginning, the plastic sheet is fed into the oven and gets heated. The heated sheet is then transferred to the molding section as a new sheet enters the oven to be heated and keep repeating it until reach the specification of the required temperature profile over the whole sheet is achieved.

Shell and tube heat exchanger system [4] is one of the common systems which used in the many industries process which it function as transfer heat from hot fluid to colder. Generally, the process fluid from the supply tank flow into the exchanger system and heats up to a desired degree by fluid or steam from the boiler. The process fluid is heated up by receiving the heat energy through a solid wall without any contact. Controller is applying to control the outlet fluid in the heat exchanger system.

2.5 Sensors

There are many temperature sensors in the market such as thermocouples, thermistors, resistance temperature detectors (RTD) and infrared sensors which function as sense and measure the changes in temperature. RTD has linear positive change (LPC) characteristic and can convert the temperature which sensed from environment converted into resistance. Most of the industries are using platinum RTD (PT-100) in the process due to the accuracy, repeatability, stability over time and temperature. PT-100 is requiring an electrical current to produce a voltage drop across the sensor because it is a passive transducer [8].

2.6 PID Controller

Proportional-integral-derivative controller (PID controller) is the most common conventional controller which widely used in industrial control systems due to its simplicity, robustness and successful practical application [9]. PID contains three term of parameter control as shown in equation 2.1 which is proportional gain (K_P),integral gain (K_I) ,and derivatives gain (K_D). Proportional gain use to minimize the error, integral gain use to eliminate the steady state error while derivative gain uses to improve the transient responses. The overall function of PID controller is to calculate the difference error between the measured value and the desired value, throughout the three control parameter terms. It can improve the system performance in reducing the error and speed up the responses [10]. In order to achieve the desired system response, tuning methods are applied to find the proportional gain (Kp), integral gain (Ki) and derivative gain (Kd). There are many methods of tuning such as auto tuning, trial and error, Ziegler Nicholas (ZN) in method 1 and method 2, and also optimization technique that proposed in this project. Figure 2.2 shows the PID control of block diagram.

$$\mathrm{u(t)} = K_p[\mathrm{e(t)}) + \frac{1}{T_i}\int e(t)dt + T_d\frac{d}{dt}\mathrm{e(t)}] \qquad (2.1)$$

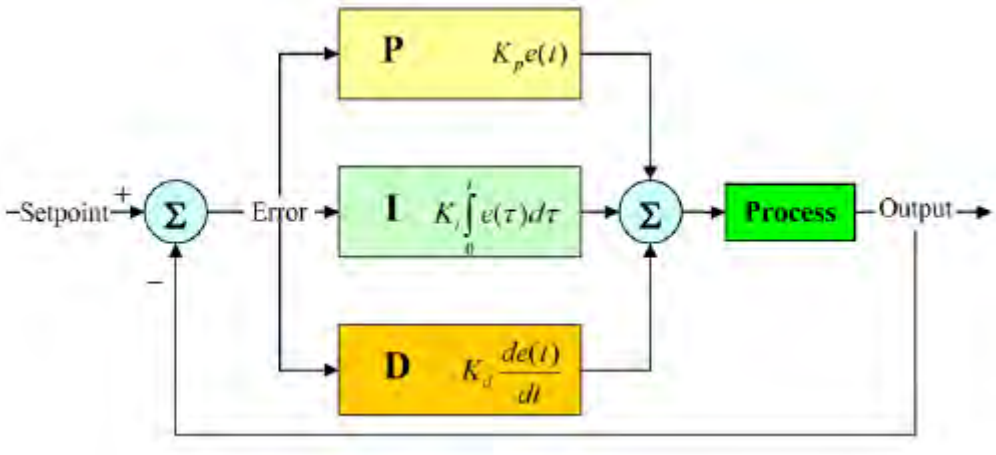

Figure 2.2: PID Block Diagram

2.7 PID Tuning Method

PID tuning methods are applied to find the controller parameter of proportional gain (Kp), integral gain (Ki) and derivative gain (Kd) in order to achieve the desired system response. There are many types of tuning methods such as auto tuning, Ziegler Nicholas (ZN), trial and error method, Cohen-Coon.

2.7.1 Ziegler-Nicholas Method

The Ziegler Nicholas tuning method or known as close loop tuning method was inspired by Ziegler and Nicholas in 1942. There are two methods in Ziegler Nicholas which is Z-N method 1 which open loop and Z-N method 2 with closed loop. This method consists of two steps which are determining the dynamic characteristics of the control system which are the ultimate gain (Kc) and ultimate period (Pu) and estimate the controller tuned parameter of Proportional gain (Kp), integral gain (Ki) and derivative gain (Kd). The Ziegler Nicholas method only consider with proportional gain element while the integral and derivative gain will be ignored by determining the ultimate gain and period. the sustained oscillation period is achieved,by adjusting the proportional gain. The ultimate gain is use to sustain the oscillation so as the loop can oscillate with constant amplitude. The smaller adjustment in gain can be made to prevent the loop unstable when the ultimate gain is achieved. Calculation of controller parameter made from the ultimate gain and

period obtained by using the table 2.1. Below the table 2.1 shows the controller settings based on the Ziegler Nicholas Method to apply in controller tuning [19].

Table 2.1: Controller Settings Based On the Ziegler Nicholas Method

	P	PI	PID
Kc	0.5Kc	0.45Kc	0.6Kc
τI	-	Pu/1.2	Pu/2
τD	-	-	Pu/8

2.7.2 Cohen-Coon Method

Cohen-Coon tuning method is the second common used beside of Ziegler Nicholas method. This method was proposed in 1953 which eleven years after Ziegler and Nicholas had published their tuning method. This method is similar with the Z-N method and it has the advantages that this method provides a faster rise time though it is more complex than the Z-N method [18]. Cohen-Coon is only suitable used for the first order models with time delay as the slow response of the controller to disturbance. Below the table 2.2 shows the controller settings based on the Cohen-Coon Method to apply in controller tuning [19].

Table 2.2: Controller Settings Based On the Cohen-Coon Method

Type	Kp	τI	τD
P	$\frac{1}{K}\times\frac{T}{\tau}(1+\frac{\tau}{3T})$	-	-
PI	$\frac{1}{K}\times\frac{T}{\tau}(0.9+\frac{\tau}{12T})$	$\tau\frac{(30+3\tau/T)}{(9+20\tau/T)}$	-
PID	$\frac{1}{K}\times\frac{T}{\tau}(4/3+\frac{\tau}{4T})$	$\tau\frac{(32+6\tau/T)}{(13+8\tau/T)}$	$\tau\frac{4}{(11+2\tau/T)}$

2.7.3 Fuzzy Logic

The concept of Fuzzy Logic was started from Lotfi Zadeh 1965's of fuzzy set theory. Fuzzy logic (FL) is a form of many respected logic where it is a problem solving control system methodology that gives itself to application in system ranging from simple and small controller to bulky control system. With traditional logic theory, binary input have two valued logic either true or false (1 or 0) while FL has developed to handle the concept of partial truth. FL will determine the true and exact value might range between completely true or false where can get the result faster and more precise. There are four main parts in FL controller which are fuzzification, fuzzy rule, inference and defuzzification [16]. Fuzzification is to choose the input parameters and converted into linguistic fuzzy variables. Fuzzy rules are a bunch of rules of 'IF-THEN' which constructed related between input and output parameters. Inference is to make decision on firing the the fuzzy relation based on the rule base. Defuzzification is a mapping from a space of fuzzy control actions defined over an output universe of discourse into a space of non-fuzzy control action. Figure 2.3 shows the block diagram of the fuzzy logic control system.

2.8 Related Previous Research

Several researches have been done in previous researches which involve the application of temperature process control system. One of them is Controlling of Temperature Process Using IMC-PID and PSO. The purpose of this research is to make a comparison tune of PID parameter in controlling the stirred heated liquid tank system between IMC, ZN and PSO. The system performance of the three tuning methods was investigated when applying PID controller to control the temperature process control system of stirred heated liquid tank. From the result shown PSO gives the best performances compared to ZN and IMC due to transient response improved and effectiveness in term of time domain specifications [2].

The authors use genetic algorithm (GA) to tune the PID controller for temperature process [18]. From the results showed that the PID controller tuned with Z-N method has difficulty in achieve the desired response than GA which gives better performance in