PID CONTROLLER OPTIMIZATION FOR AVOIDING OVERSHOOT AND REDUCE RISE TIME IN TEMPERATURE ON BARREL HEATING SYSTEM USING BAT ALGORITHM

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DECLARATION

I declare that this report entitle "***PID Controller Optimization For Avoiding Overshoot And Reduce Rise Time In Temperature Of Barrel Heating System Using Bat 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.

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Date : ....

DEDICATION

Special word dedicated to my lovely mother Masiah bte Mohd. Husain who always give me supports, faith and constant encouragement while completing my Degree.

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ABSTRAK

Sistem Pemanasan di dalam tangki adalah sistem yang mengawal suhu mesin seperti mesin pengacuan plastik. Pelet mentah dikekalkan daripada bekas ke dalam ruang laras. Kemudian, laras dihangatkan dengan band-band pemanas rintangan di dalam zon yang berbeza. Jumlah zon pemanasan bervariasi dari mesin ke mesin tertumpu produk akhir. Akhir sekali, leburan dikekang ke angkasa cetakan, di mana ia akan dimantapkan lagi dengan pendinginan. Hal ini penting untuk menjaga suhu leburan pada nilai yang dikehendaki, untuk mengelakkan barang yang tidak siap. Oleh itu, pengawal PID adalah salah satu pengawal yang terbaik yang dapat meningkatkan sistem. Ziegler Nichols, Root Lokus, pelaras automatik dan lain-lain boleh digunakan untuk mendapatkan hasil yang terbaik di antara pelaras yang lain. Tambahan pula, terdapat penyelidik-penyelidik mula untuk menggunakan "metaheristic algorithm" untuk penambahbaikkan sesuatu sistem. Di dalam projek ini, "Bat Algorithm" telah terpilih untuk digunakan di dalam sistem pemanasan. Projek ini bermula dengan melaras pengawal PID untuk mendapatkan nilai dari pengawal bagi sistem pemanasan barel dan diikuti dengan simulasi perisian MATLAB dengan pengawal PID dan tanpa pengawal PID. Akhirnya, hasil daripada model ini telah dianalisis.

ABSTRACT

Barrel Heating System is a system that control the temperature of the machine such as plastic molding machine. The raw pellets are sustained from the container into the barrel chamber. Then, the barrel is warmed with resistive heater bands in different type of zones. The quantity of heating zones varies from machine to machine focused around the end product. Lastly, the melt is constrained into the mold space, where it gets solidify by cooling. It is important to keep up the temperature of the melt at a desired value, in order to avoid unfinished items. Therefore, the PID controller is one of the finest controller that can improve the system. Ziegler Nichols, root-locus, auto tuning and others can be used in order to get the best result among the tuning. In addition, there are many researcher turn to metaheuristic algorithm in order to improve the system. In this paper, Bat Algorithm was selected to be used in Barrel Heating System. The project started with tuning PID controller to get the value of the controller for the barrel heating system and followed by simulation of MATLAB software with and without PID controller. Finally, the result of this model was analyzed.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURE

LIST OF ABBREVIATIONS

ABC-BP	-	Artificial Bee Colony using BPNN
BA	-	Bat Algorithm
Bat-BP	-	Bat Algorithm based Back-Propagation
BMI	-	Body Mass Index
BPNN	-	Back-Propagation Neural Network
CPU	-	Central Processing Unit
DCS	-	Distributed Control Systems
DE	-	Differential Evolution
DG	-	Distributed Generation
DOSH	-	Department of Occupation Safety and Health
FIS	-	Fuzzy inference system
FC	-	Fuel Cell
FYP	-	Final year project
GA	-	Genetic Algorithm
HBA	-	Hybrid Bat Algorithm
HBARF	-	Hybrid Bat Algorithm Random Forests
HSA	-	Harmony Search Algorithm
HSABA	-	Hybrid Self-Adaptive Bat Algorithm
IBACH	-	Improved Bat Algorithm with CHaos

Kp	-	Gain proportional
Ki	-	Gain integral
Kd	-	Gain derivative
LF	-	Levy Flight
MT	-	Micro Turbine
NIHL	-	Noise-Induced Hearing Loss
NiMH	-	Nickel–Metal Hydride
PID	-	Proportional, integral and derivative
PD	-	Proportional derivative
PLC	-	Programmable Logic Controllers
PSO	-	Particle Swarm Optimization
SABA	-	Self-Adaptive Bat Algorithm
Ti	-	Time integral
Td	-	Time derivative
WT	-	Wind Turbine
ZN	-	Ziegler Nichols

LIST OF SYMBOLS

A	-	Alpha
^0C	-	Degree
Γ	-	Gamma
Ni	-	Number of Agent
Nt	-	Number of Iteration
ρ_α	-	Probability
%	-	Percentage
Sec	-	Seconds
L	-	Time delay
T	-	Time constant

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

Temperature control is an important part in many industrial process and heating barrel for various chemical and metallic products. The desired shape, structure and quality are attained with proper temperature control in barrel heating system for plastic injection molding industries. Overheating or under heating of plastic pellets affects the quality of product. The barrel temperature of the process directly influences the viscosity of polymer and need to be control effectively. This is one of the challenging task in plastic molding process.

The ON/OFF controller used in industries for control of the barrel heating system which are not giving satisfactory performance. While using ON/OFF controller, the power consumption is high and the heater lifetime decreases because of the continuous chattering which leads to wear out of the relay quickly. The varying temperature happen because of the quality of the product is not even at all the area. To reduce the power consumption, eliminate the temperature swings, and also to improve the product quality, the PID control algorithm can be selected. PID controllers give satisfactory performance with undershoot. Therefore, a model based PID controller can overcome these problems [1].

The bat-inspired metaheuristic algorithm, to be specific the bat algorithm, was as of late proposed by Xin-She Yang [2], referred on the echolocation of microbats [3]. In this present reality, echolocation can have just a couple of thousandths of a second (up to around

8–10 ms) with a shifting frequency in the district of 25–150 kHz, comparing to the wavelengths of 2–14 mm in the air. In the standard bat algorithm, the echolocation characteristics of microbats can be idealized as the accompanying three rules:

i. All bats use echolocation to sense separation or distance, and they likewise 'know' the contrast between food/prey and foundation obstructions in some supernatural way;

ii. Bats fly haphazardly with velocity v_i at position x_i with a settled frequency fmin, fluctuating wavelength and commotion A0 to look for prey. They can naturally alter the wavelength (or frequency) of their discharged pulses and change the rate of pulse emission $r \in [0, 1]$, contingent upon the proximity of their target;

iii. In spite of the fact that the clamour can fluctuate from various perspectives, we expect that the commotion differs from a huge (positive) A0 to a base constant value Amin. The main purpose to develop this metaheuristic algorithm is to solve problem faster, solve large complex problem and also obtain robust solution. [4]

1.2 Problem Statement

The toughest job in the plastic molding procedure is control of machine procedure parameters because of their inter-relations. The barrel temperature of the procedure specifically impacts the polymer thickness and it has to be controlled successfully which requires a quick rise time and avoid overshoot [1]. Temperature process usually have slow time constants and long delay, causing difficulties and limitation to control the system design. The PID controller computes an error esteem as the distinction between a deliberate procedure variable and a desired set point. The controller endeavours to minimize the error by modifying the procedure through the uses of a controlled variable. Basic PID Controller does not comprehensive enough in order to improve optimal solution of the system. Therefore, PID Controller optimization was used and analysed to reduce the error of barrel heating system by using different tuning. Then, the algorithm is applied in order to improve the performance on the system. Bat Algorithm had been selected for this research to studies and analyse its capability on this system.

1.3 Objective

Objective of the project need more specific and can be measurable. The main objective is to propose a model of Bat Algorithm (BA) to optimize the PID controller for avoiding overshoot in temperature and rise time of barrel heating system.

1. To design the PID controller for barrel heating system in order to avoid overshoot and produce quick rise time.
2. To optimize the PID controller by using Bat Algorithm.
3. To analyse and compare the performance of conventional controller with Bat Algorithm (BA) in terms of rise time and overshoot.

1.4 Scope of Research

A barrel heating system is design to control and maintain the temperature in different zones to get the desired value without damaging the product. There are a lot of controllers that can be used likes PD controller, PID controller and others This project focuses on the PID controller optimization for **avoiding overshoot** and also **reduce rise time** in temperature of barrel heating system and was test by using Bat Algorithm (BA) and Harmony Search Algorithm (HSA) method. The controller was model in SIMULINK in MATLAB software. In addition, this project **does not required of hardware** on build barrel heating system.

Table 1.0: The requirement value of the project

Overshoot (%)	0 – 10
Rise Time (sec)	1 – 5

1.5 Motivation

The motivation for this research is to improve barrel heating system by using PID Controller. The function of the barrel heating system is to control and maintain on the desired temperature of the product. It is not easy to maintain the temperature of the system. The varying temperature happen because of the quality of the product is not even at all the area. To reduce the power consumption, eliminate the temperature swings, and also to improve the product quality, the PID controller was selected. PID Controller was used by using Root Locus, Ziegler Nichols and Tuning technique to optimize the controller. The changes is based on rise time, percent overshoot and stability. Besides that, Bat Algorithm (BA) is used to optimize PID controller shown signs of better result.

1.6 Report Structure

This report includes of five chapters which Chapter 1 for Introduction, Chapter 2 for Literature Review, Chapter 3 for Methodology, Chapter 4 for Result and lastly Chapter 5 for discussion on whole research.

Chapter 1 was included for introduction, discussed more about project background, objectives on the research, problem statement and also scope of the project.

For Chapter 2, this chapter is included about Literature review which is highlight the previous work and also all material principle and mathematical theory use in this research.

Then, Chapter 3 is more about methodology to use flowchart of the process and software with clear explanation to present the research. Gantt chart and flow chart also included in Chapter 3 to show the progress of whole Final Year Project.

For chapter 4 which is the final result gained from this project which included graph, diagram and table. The result of the best technique of tuning with PID Controller and link with coding for Bat Algorithm for Barrel Heating System also inserted in this chapter. This chapter also provide analysis and discussion on the result of the research, stressing the significant and implication of the finding on this system.

Lastly, Chapter 5 included a conclusion for a whole project referred on simulation in Matlab and explain the achievement from the objective. Recommendations for future work may also be included together with contributions of project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter discusses the literature review of previous research on temperature of barrel heating system. Beforehand, a few controllers were utilized as a part of this project. There were Proportional Derivative (PD), Fuzzy Logic controller and others. This project focuses on using PID controller only. The concept of Bat Algorithm (BA) was used to optimize the usage of PID controller. This algorithm has been actualized much of the time in many cases in engineering and software engineering study. Most of the paper specified that the BA is very efficient and prove to be superior for almost all the test problems and also in many application depends on different application and terms.

2.2 Plastic molding machine and Barrel Heating System

The usage of plastic molding machine is to manufacture plastic like bottle caps, chairs, tiny containers, toys and others. The crude pellets are sustained from the hopper into the barrel. The barrel is warmed with resistive heater bands in diverse zones. The quantity of heating zones varies from machine to machine focused around the final item. The responding screw show inside the barrel chamber pivots to push the melt towards the mold end. The melt is constrained into the mold space, where it gets solidify by cooling.

Besides, it is essential to sustain the temperature of the melt at a desired value, in order avoid uncompleted items [5, 6]. The proposed PI-PD controller was provided in this part of process in order to keep the temperature of the melt at 200 degree.

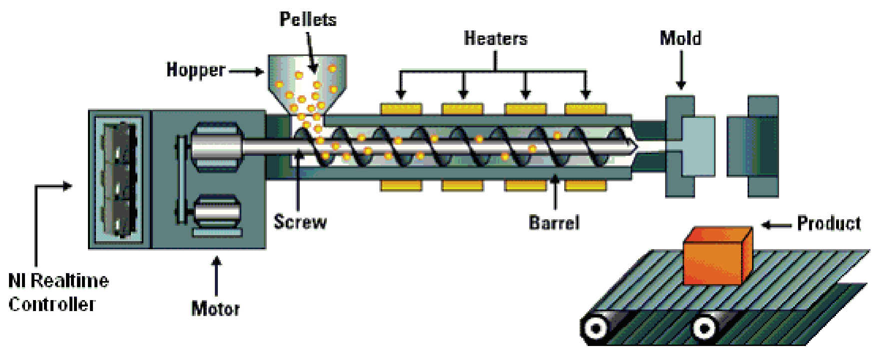

Figure 2.0: Plastic Molding Machine

2.2.1 Auto tuning of temperature control system with application to injection molding

Temperature control is essential issue in numerous industrial process, for examples are electric-resistance furnaces, crystal ovens, and heater boilers/tanks/barrels for different synthetic and metallic items. Such a thermal process usually express the integrating response characteristic throughout the heating stage, and after increasing to the set-point temperature, it have a tendency to act in a stable manner given a certain heating range due to the air convection or radiation loss into the environment. The key control challenges for such methods are to avoid overheating for an example is temperature overshoot in the heating stage and to firmly keep up the set-point temperature against load disturbance also flow of process/environment varieties [1].

Besides, thermal processes commonly have slow time constants and long-time deferral, bringing on challenges to control-system design [7]. In addition, there is an injection molding machine in the heating barrel, as indicated in Figure 2.0, the raw materials (plastic resin) fed from the hopper need to be warmed and dissolved to a temperature over $200\,^{0}c$ before injection molding. To guarantee consistency in item quality, the front three zones (i.e., 1–3) of the heating barrel are needed to be heated up with insignificant temperature overshoot as fast as it would and then, keep up the melting temperature, for an example 200^0C, for injection molding. Based from the earlier information of the barrel thermal inertia, previous literature created an optimal time exchanging method for heating up with a small temperature overshoot [8]. A few model-prediction control technique have been lately reported for successfully sustain the barrel temperature [9]–[11].

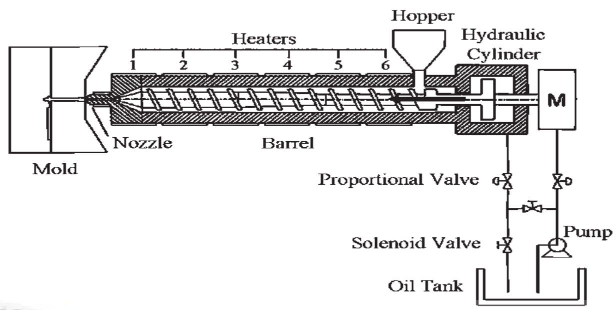

Figure 2.1: Injection Molding

2.3 PID Controller

This controller has the capacity to give an extensive variety of processes and additionally has been connected with an advancement of innovation and technology that actualized in digital form instead of pneumatic and hydraulic parts. This control component as a standalone controller and was added to functional block, for example, Programmable Logic Controllers (PLC) and Distributed Control Systems (DCS). In the PID controller, the new viable apparatuses have been included for enhancing the analysis and design systems in the fundamental of algorithm with a specific end goal to build the execution.

The PID controller calculation includes three different parameters, which are called three-term control: the proportional, the integral and derivative meant P, I, and D. Basically, these values can be translated in terms time: P relies on upon the present error, I on the accumulation of past errors, and D is an expectation of future error, referred on current rate of change [12].

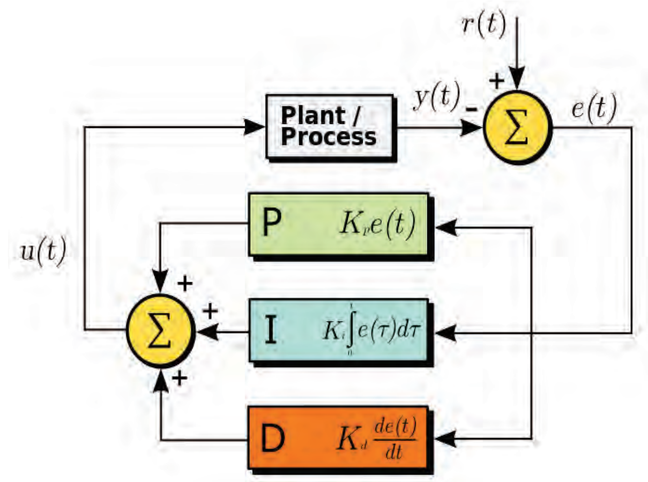

Figure 2.2: The PID Controller in the block diagram

2.3.1 Proportional Controller

The first term in PID controller is proportional controller. The usage of this proportional controller is to control the error according to the equation of Kp. The equation of Kp is shown below:

$$u(t) = Kpe\ (t) = Kp\ (r(t) - y(t)) \quad (2.1)$$

Providing a small control variable when the control error is small and also to avoid excessive control efforts is one of the advantages of the proportional controller. The reason using the proportional controller are to produce a steady-state error. The figure below shows the proportional controller in terms of a closed loop system.

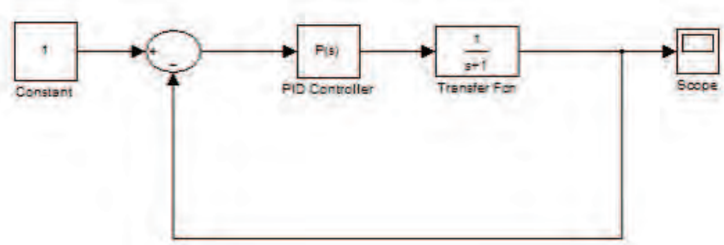

Figure 2.3: The proportional controller in a closed loop system

2.3.2 Integral Controller

The integral controller is used to proportional to the integral of the control error. The value of Ki is the integral gain. This integral activity is identified related to the past value of the control error. The transfer function for the Ki is shown below:

$$u(t) = Ki \int_0^t e(\tau)d\tau, \qquad (2.2)$$

At the beginning, the vicinity of a post in the complex plane permits the decrease to a zero of the steady-state error. This system happens when apply a step reference sign and if the step load disturbance.

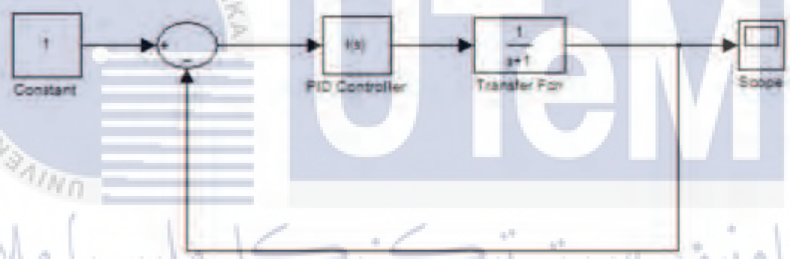

Figure 2.4: The integral controller in a closed loop

2.3.3 Derivative Controller

The derivative controller is focused around the future value focused around expectations of the control error. The slope of the error over time and multiplying this rate of change need to be determined to calculate the derivative of the process error by the derivative gain K_d. The magnitude of the contribution of the derivative term to the overall control action is termed the derivative gain, K_d. The derivative term is given by:

$$u(t) = Kd\frac{de(t)}{dt} \qquad (2.3)$$

The derivative controller has an incredible great potential in enhancing the control performances. This controller also counteracts an incorrect pattern of the control error. On a few issues, this derivative controller not very frequently adopted.

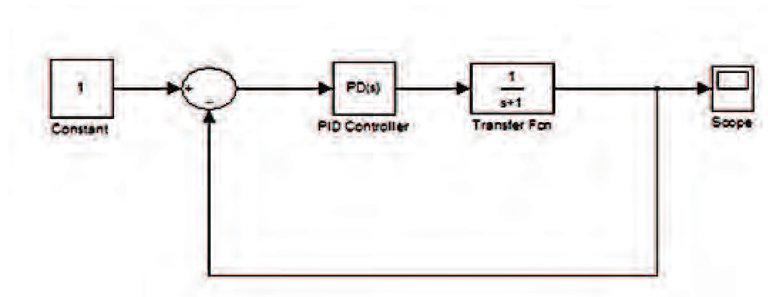

Figure 2.5: The derivative controller in a closed loop

2.3.3 Controller Parameter

In the PID controller, the certain value that is added to a controller parameter will changes the output of the transfer function. There are four noteworthy qualities of the closed loop system that will influence the system:

i. Rise time
ii. Overshoot
iii. Settling time
iv. Steady-state error

Firstly, the rise time is the time that takes for the plant output rise past 90% of the desired level surprisingly. At that point, the overshoot is to discover the values at the crest level and analyse if the values at the top level is higher than the steady state then again typical against the steady state. The settling time is the time that takes for the framework gather to its steady state. At long last the steady-state error is to characterize the distinction between the steady-state output and the wanted output. The Table 2.0 demonstrated underneath the setup for the parameter controller [12].

Table 2.0: Controller Parameter of each response.

Response	Rise Time	Overshoot	Settling Time	Steady-state Error
Kp	Decrease	Increase	No definite Trend	Decrease
Ki	Decrease	Increase	Increase	Eliminate
Kd	No definite Trend	Decrease	Decrease	No definite Trend

2.4 Optimization Design

Design optimization frames an essential piece of any design issue in engineering and industry. Structural design optimization concentrates on discovering the optimal and practical answers for complex structural design issues under dynamic complex stacking pattern with complex nonlinear constraints. These constraints regularly include a great many and even a huge number of individuals with stringent limitations on stress, geometry and in addition loading and service necessities. The point is not just to minimize the expense and materials use, additionally to augment their execution and lifetime service. Every one of these designs are of scientific and practical significance [13, 14].

However, most structural design optimization issues are exceedingly nonlinear and multimodal with commotion, and consequently they are frequently NP-hard. Discovering the privilege and practically proficient calculations are normally troublesome, if not unthinkable. In reasonable, the decision of a calculation obliges extensive experience and learning of the issue of interest. Indeed, even thus, there is no ensure that an optimal or even suboptimal arrangement can be found.

2.4.1 Metaheuristic Algorithm

A metaheuristic is a higher-level strategy or heuristic designed to discover, produce, or select a heuristic (fractional search algorithm) that may give an adequately good answer for an optimization issue, particularly with inadequate or imperfect data or restricted computation capacity [29]. Metaheuristics test a set of solution which is too huge to be totally tested. Metaheuristics may make couple of presumptions about the optimization issue being explained, thus they may be usable for an assortment of problems [15].

Contrasted with optimization algorithm and iterative methods, metaheuristics do not promise that a comprehensively optimal solution can be found on some class of problems.[16] Many metaheuristics actualize some type of stochastic optimization, so that the solution found is dependent on the set of random variables generated.[17] By looking more than a huge set of feasible solutions, metaheuristics can regularly discover great answer with less computational exertion than algorithm, iterative techniques, or basic heuristics.[18] As such, they are valuable methodologies for optimization problems.[19]

Metaheuristic algorithms involving evolutionary and swarm intelligence algorithms are now becoming greatest technique for solving many of difficult problems and especially real-world engineering problems [20]. The vast majority of heuristic and metaheuristic algorithms have been derived from the behavior of biological systems and/or physical systems in nature. For example, particle swarm optimization was build based on the swarm behavior of birds and fish or charged system search inspired from physical processes [21].

New algorithms are also developed recently, including harmony search, the firefly algorithm and also Bat Algorithm. Each of these algorithms has certain advantages and disadvantages. A natural question is whether it is possible to combine major advantages of these algorithms and try to develop a successful better and good algorithm?

2.5 Bat Algorithm (BA)

Bat calculation (BA) is the new development based metaheuristic calculation established on the chasing behaviour of Microbats. The algorithm has been develop based on the supposition that the bat has capability to find its prey in complete obscurity [2]. The bat position represent to a conceivable answer of the issue. The best position of a bat to its prey shows the element of the solution Here, obstructions are abstained from using echolocation. In such a case, different frequencies are returned. For the most part, the BA has three fundamental presumptions [22]:

• All bats are using echolocation to cleverly calculate distance. They know the distinction between food/prey and the encompassing environment foundation in supernatural way.

• Bats are flying randomly using velocity v_i at position x_i. They consequently change transmitted pulses and modify the rate of pulse emission $r \in [0, 1]$, of their echolocation frequency.

• Although the din could be distinctive in a few ways. Here, it is expected that the loudness change from a huge (positive) A_0 to a minimum value of A_{min}.

2.5.1 Behaviour of microbats

. Bat are fascinating animals. They are only mammals with wings and they also provide advanced capability echolocation. Microbats actually use a type of sonar which called echolocation to detect prey, avoid obstacle and locate their roosting crevices in dark places. These bats produce a very loud sound pulse and listen for the echo that bounces back from the surrounding objects. Their pulse vary in properties and can be correlated with their hunting strategies, depending on the species. The increase of the frequency, namely frequency tuning, together with the speedup of pulse emission will shorten the wavelength of echolocation and thus increase accuracy of the detection. Most bats usually use short, frequency-modulated signals to sweep through about an octave, while others more often use constant-frequency signals for echolocation. Their signal, bendwidth varies depends on the species, and often increased by using more harmonics [23].

2.5.2 Bat Motion

Each bat is relate with a velocity v^t_i and a location x^t_i, at iteration t, in a d- dimensional search or answer space. Among all the bats, there occur a current best solution x. Therefore, the above three guidelines can be translated into the updating equations for x^t_i and velocities v^t_i:

$$f_i = \frac{V_i}{\lambda_i} \tag{2.4}$$

$$f_i = f_{min} + (f_{max} - f_{min})\delta \tag{2.5}$$

$$V_i^t = V_i^{t-1}(x_i^t - x_{gbest}^t)f_i \tag{2.6}$$

$$x_i^t = x_i^{t-1} + V_i^t \tag{2.7}$$

where β ∈ [0,1] is a random vector drawn from a uniform distribution.

Here x^t_{gbest} is the current worldwide best area (arrangement) which is situated subsequent to looking at all the solutions among all the n bats. As the item λi fi is the velocity increment, we can utilize either fi (or λi) to modify the velocity change while altering the other factor λi (or fi), depending upon the type of the issue of interest. In our usage, we will use fmin = 0 and fmax = 100, depending the domain size of the issue of interest [24]. At first, every bat is haphazardly appointed a frequency that is drawn consistently from [fmin, fmax]. The flow chart of Bat Algorithm was shown below:

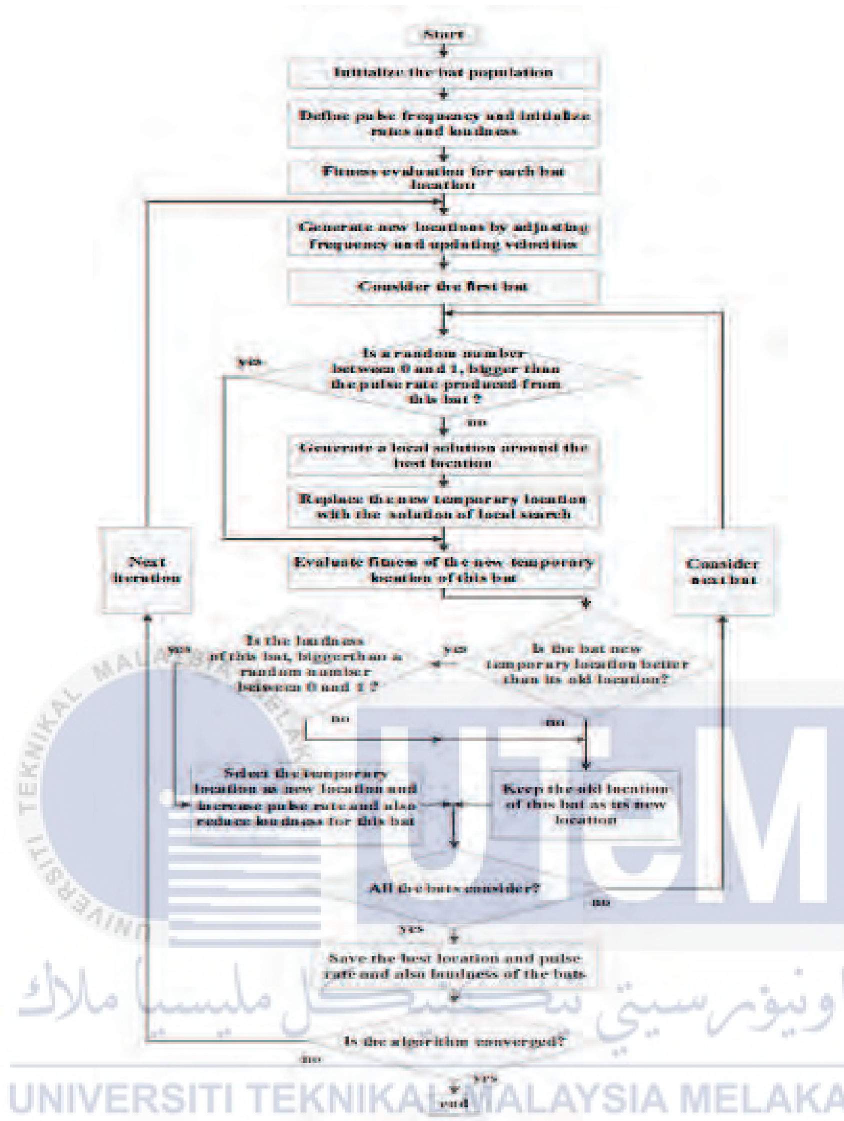

Figure 2.6: Flowchart of Bat Algorithm.

2.6 Previous Study on Barrel Heating System

The previous study on control temperature using other methods and optimization algorithms is also discussed in this section. The researchers have been studied and proposed an algorithms and controllers in other to find the optimal results for controlling temperature in Barrel Heating system.

2.6.1 Fuzzy PI-ID methods

In the previous research, the project is using fuzzy PI-ID controller to enhance the performance of the temperature in barrel heating system. Fuzzy controller is a fuzzy logic based controller which involves three steps to be specific fuzzification, deduction and defuzzification. Fuzzification changes over the real time crisp quantity into fuzzy value. Taking into account the guidelines of Fuzzy Inference System (FIS), choices are made. Defuzzification changes over the fuzzy decisions into system acknowledged crisp quantity. Fluffy controller has two inputs, which is viz error and change in error, and control output.

In PI-PD controller, the PI action is on the error (steady state error) and the PD react on the process variable (temperature). In the late research, in view of this PI-PD controller-a modified structure of PID controller has been considered [25]. The controller is tuned using Fuzzy logic technique which can improves the performance of the system [26].The project also used other tuning such as Ziegler-Nichols (ZN) tuning. ZN tuning method is the widely used method of controller tuning [27]. The controller are simulated by MATLAB/SIMULINK represents the block diagram of barrel heating system. From the simulation results, it is observed that the fuzzy tuned PI-PD controller beat the other controllers namely Ziegler-Nichols tuned PID controller, Fuzzy Logic controller and Fuzzy tuned PID controller [28].

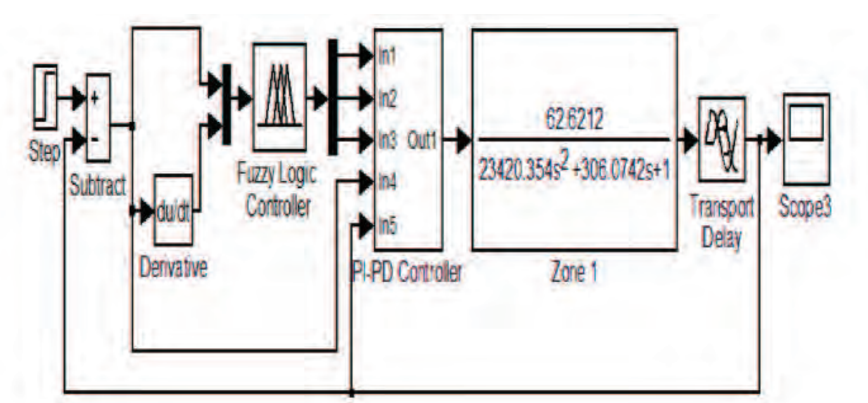

Figure 2.7: The block diagram of fuzzy PI-PD Controller in Zone 1 barrel heating system

2.6.2 Genetic Algorithm

In 1975, Genetic Algorithm (GA) was first introduced by John Holland [29]. In Genetic Algorithm, answer of an optimization problem is coded as a chromosome. A population of chromosome is generated initially. Each chromosome will be evaluated its fitness value through iteration. This number corresponds to the target function of the problem. The best chromosomes will be chosen as parents based on the fitness number. These parents will mate in order to result in new better offspring in the crossover and mutation operation.

In this research, GA-based PID parameters optimization is designed. To produce an optimal PID controller for controlling the output temperature of an air heater is the goal of this research. The design of PID controller is done offline using a process model resulted by system identification of air heater. Heuristic tuning system known as Ziegler-Nichols tuning is generally picked as a technique to focus the estimation of Kp, Ki, and Kd[30]. Genetic Algorithm (GA) is used to enhance the performance of the step response resulted by Ziegler-Nichols tuning which has high overshoot and long settling time. In this mode, a chromosome are decoded as the PID controller parameters numbers immediately, namely Kp, Ki, and Kd, without using the number obtained by Ziegler-Nichols tuning. These parameters then are set to PID controller in SIMULINK model.

On the other hand, these qualities still need to be re-tuned manually of the fact that its execution has not full fill the prerequisite. Truth be told, starting outline of PID controller acquire by all means, needs to be re-tuned over and over through computer simulation until the closed loop system execution is as wanted. This drives the advancement of intelligent tool that can help engineers to accomplish the best execution of PID controller for all operation focuses.

Table 2.1: Summary of previous research on Barrel Heating System.

TITLE	AUTHOR / YEARS	DESCRIPTION	FINDINGS	CITATION
Modified PID controller for Avoiding Overshoot in Temperature of Barrel Heating system	M. Anbarasan, S. J. Suji Prasad, R. Meenakumare, P. A. Balakrishnan/ 2013	To proposed of using PI-PD controller-a modified structure of PID controller for controlling the temperature of the melt in the barrel.	Fuzzy tuned PI-PD controller reduces the overshoot and settling time and thus it is found that there is significant reduction in Proportional Kick (Kp) and Derivative kick (Kd).	[28]
Genetic Algorithm-based PID Parameters Optimization for Air Heater Temperature Control	Dwi Ana Ratna Wati, Rakhmat Hidayat/ 2013	To applies Genetics Algorithms (GA) for tuning PID controller of an air heater.	The response of GA-based PID controller has superior performance than its using Ziegler Nichols tuning which is improve on step response characteristics of output temperature is achieved using proposed method.	[31]

2.7 Previous study on Bat Algorithm

The bat algorithm involve to a class of Swarm Intelligence (SI) [32-34]. This algorithm increased in the year 2010,when Yang build a new optimization algorithm inspired by the behaviour of micro- bats that use unique mechanism called echolocation [35].Echolocation is used by bats for orientation and to find prey/food. The original bat algorithm was used to various benchmark functions, where have achieved solid answers. The primary reason is that BA uses a great combination of major advantages of these algorithms in some reason. Moreover, PSO and HS are the unique cases of BA under appropriate simplifications [36]. However, one can revert to for obtaining more details specification [37].

The reason to enhance this metaheuristic algorithm is to solve the problem more fast and large complex problem and obtain robust solution. There are many cases solve by using Bat Algorithm. Subsequently, BA is applied to some benchmark engineering problems including pressure vessel design, welded beam design, spring design, control load frequency for interconnected power system, optimization nuclear energy, enhance for data structure, topology optimization, mechanics and materials applied (e.g solve Uninhabited Combat Air Vehicles) .etc. The convergence rate of this algorithm was enhance in the study [38], where the authors hybridized the original bat algorithm with differential evolution strategies (HBA). In the research, the same authors dealt with hybridizing the bat algorithm using many of differential evolution strategies and a random forests machine learning technique (HBARF) [39, 40].The complete survey regarding bat algorithm can be found in [1]. From previous studies, there is no research about controlling temperature in any machine for Bat Algorithm from 2009 until 2014. Actually, the choice of the optimization algorithms largely depends on the type of the problem of interest and also the expected quality of answer. For a detail category of problems, certain algorithms may produce good results faster and more efficiently. Therefore, this research is a new stages for Bat Algorithm to be analyse for controlling temperature in this Barrel Heating System.

From previous studies on novel Bat Algorithm based on Differential Operator and Levy Flights trajectory, a differential operator is presented to increase the convergence velocity of proposed algorithm, which is same to mutation strategy "DE/best/2" in differential algorithm. L'evy flights direction can guarantee the diversity of the population in contrast to early convergence and make the algorithm adequately jump out of local minima. The purpose to put forward an improved bat algorithm with differential operator and Levy flights trajectory (DLBA) is to upgrade the convergence rate and accuracy of Bat Algorithm. Bat's position variation is affected by the pulse emission rate and loudness also. Firstly, pulse emission rate reasons upgrade of position, and more new position can be investigated, consequently, expanding the diversity of population. Furthermore, loudness is intended to fortify local pursuit and to guide bats discover better arrangements. 14 typical benchmark capacities and an occasion of nonlinear equations are verified; the simulation comes about not just show that the proposed algorithm is achievable and fascinating, additionally show that this proposed algorithm has superior estimate abilities in high-dimensional space [41].

On other research is about a novel based algorithm based on re-tuning of PI Controller of coal gasifier for optimum response. This algorithm is simulate to retune the parameter of pressure loop PI controller of coal gasifier, which is extremely nonlinear multivariable process owning five controllable input, four outputs and tough interactions between the control loops. The problem of this system is working of coal gasifier includes numerous constraints to be fulfilled on inputs and outputs. The current controller along with its tuned parameters does not ready to fulfil the constraints at 0% load for sinusoidal pressure aggravation and gives better response at 100% and 50% load conditions. The parameter of pressure loop PI controller is re-tuned utilizing Lévy Flight (LF) guided BAT calculation and implementation tests which incorporates, pressure disturbance test, load change test and coal quality test are led. Test outcomes shows that the re-tuned controller gives better response, assembly all the constraints at 0%, 50% and 100% load conditions [42].

Next, on the other earlier research about novel self-adaptive modification approach based on Bat Algorithm. This research used Bat Algorithm to resolve the optimal energy administration of MG involving a few RESs with the back-up of Fuel Cell (FC), Wind Turbine (WT), Photovoltaic (PV), Micro Turbine (MT) and storage devices to meet the energy intersect. The problem is formulated as a nonlinear constraint optimization problem to minimize the total expense of the grid and RESs, at the same time. Also, the problem considers the interactive effects of MG and utility in a 24-hour time interval which would rise the difficulty of the problem from the optimization perspective more extremely. The proposed optimization method is included of a self-adaptive modification technique compromised of two modification technique referred on bat algorithm to investigate the total search space comprehensively. The superiority of the proposed strategy over the other well-known algorithms is shown through a typical renewable MG as the test system. The simulation results presented the achievability and superiority of the proposed technique over the other well-known methods in the zone. On other way, the positive role of NiMH-Battery to decrease the total rate of the MG was shown. Referring to the simulation results, the suggested technique has proper ability from both convergence speed and global searching ability points of view [43].

Another previous paper of optimization of Bat Algorithm is exhibited an enhanced variance of a Bat Meta-heuristic Algorithm, (IBACH), for solving integer programming issues. In real world optimization issues are frequently exceptionally difficult to solve, and numerous applications need to manage NP-hard problems. To take care of such issues, optimization tools must be utilized despite the fact that there is no ensure that the optimal solution can be gotten. Actually, for NP problems, there are no proficient algorithms at all. As a result of this, numerous issues must be unravelled by trial and errors using different optimization methods. The proposed algorithm utilizes chaotic behaviour to produce a candidate solution in behaviour like acoustic monophony. Numerical results demonstrate that the IBACH has the capacity get the optimal results in examination to traditional technique (branch and bound), particle swarm optimization algorithm (PSO), standard Bat algorithm and other harmony search algorithm algorithms. In any case, the advantages of this proposed algorithm is in its ability to acquire the optimal solution inside less computation, which spare time in comparison with the branch and bound algorithm (exact solution technique). This shows that IBACH is potentially more greatful in solving NP-hard problems [44].

Table 2.2: Literature Review on Optimization of Bat Algorithm.

Author	Technique	Modification/Problem	Result	Ref.
Jian Xie, Yongquan Zhou, and Huan Chen	Novel Bat Algorithm	Modification: Proposing a novel bat algorithm based on differential operator and Levy flights trajectory. Problem: Introducing differential operator to accelerate the convergence speed of proposed algorithm, which is similar to mutation strategy "DE/best/2" in differential algorithm.	The simulation results not only show that the proposed algorithm is feasible and effective, but also demonstrate that this proposed algorithm has superior approximation capabilities in high-dimensional space.	[41]
Rangasamy Kotteeswaran and Lingappan Sivakumar	Novel Bat Algorithm	Modification: Retune the parameters of pressure loop PI controller of coal gasifier. Problem: Satisfying many constraints of functioning of coal gasifier on inputs and outputs.	The re-tune controller provides better response, meeting all the constraints at 0%. 50%, and 100% load conditions.	[42]
Aliasghar Baziar, Abdollah	Novel Self Adaptive	Modification: solve the optimal energy management of MG including several RESs with the back-up of Fuel Cell	The simulation results showed the feasibility and superiority of	[43]

Kavoosi-Fard, Jafar Zare	Modification Approach Based on Bat Algorithm	(FC), Wind Turbine (WT), Photovoltaic (PV), Micro Turbine (MT) as well as storage devices to meet the energy mismatch Problem: The problem is formulated as a nonlinear constraint optimization problem to minimize the total cost of the grid and RESs, simultaneously	the proposed method over the other well-known methods in the area	
Osama Abdel-Raouf, Mohamed Abdel-Baset, Ibrahim El-henawy	Improved Chaotic Bat Algorithm (IBACH)	Modification: Use chaotic behaviour to generate a candidate solution in behaviours similar to acoustic monophony Problem: Solving integer programming problems.	IBACH algorithm is superior to both HS and IHS in terms of both efficiency and success rate. This implies that IBACH is potentially more powerful in solving NP hard problems.	[44]

Besides, there is many case for the research on hybridation of Bat Algorithm too. Hybridation happen between another algorithms in order to optimize the system depending on the problem of the research.

On this previous hybridation paper, Bat Algorithm hybrid with Differential Evolution. The objective of the research was to demonstrate that HBA significantly enhances the results of the first BA. For this reason, two BAs were executed by basic Bat Algorithm and Hyrid Bat Algorithm so that a well-selected set of test functions in the writing are utilized for optimization benchmarks. The parameters of the two BAs were the same. The dimension of the problem significantly affects the outcomes optimization. As the conclusion, BA was improved by developing new hybrid algorithm, HBA. HBA is a hybrid of BA with DE strategies. As shown with our experiments, HBA enhance signicantly the original variant of BA. In future project, HBA will be verified on a large-scale global optimization [45].

In addition, Bat algorithm in combination with Back-propagation neural network (BPNN) algorithm also will be presented in this previous paper. This hybridation algorithm was used in order to solve the local minima issues in gradient descent trajectory and to rise the convergence rate. The presentation of the suggested Bat based Back-Propagation (Bat-BP) algorithm is compared with Artificial Bee Colony using BPNN algorithm (ABC-BP) and also simple BPNN algorithm. The presentation of the proposed Bat-BP is confirmed by method simulations on 2-bit, 3-bit XOR and 4-bit OR datasets. The simulation outcomes demonstrate that the proposed Bat-BP unites with 0 MSE and 100 percent precision for 2-bit XOR and 4-bit OR datasets. Additionally, the CPU time is little when compared with ABC-BP and conventional BPNN. Further work is needed to remove oscillation in the gradient descent way by presenting momentum coefficient [12] in Bat-BP algorithm. It is expected that by presenting momentum, the CPU time, convergence rate and precision will become vastly improved in Bat-BP algorithm [46].

Hybridation between Bat Algorithm and Self-adaptive also was presented by algorithm using different DE strategies and applied these as a local search heuristics for improving the current best solution directing the swarm of a solution towards the better regions within a search space. A hybridization of the SABA algorithm is generally discussed which acquires a hybridized SABA algorithm called the HSABA. Despite the fact that the SABA algorithm essentially beat the result of the original BA algorithm, it suffers from the merged domain-specific information of the issue to be solved. This paper concentrates on hybridizing the SABA usign a novel local search heuristics that better exploits the self-adaption mechanism of this algorithm. The standard "rand/1/container" DE method and three other DE techniques concentrating on the current best answer were utilized for this reason, where the alteration of the local search in a hybrid self-adaptive BA algorithm (HSABA). The results of this previous research showed that the HSABA significantly outperformed the results of all the other algorithms in the experiments. Therefore, it shows that self-adaptation and hybridization are suitable mechanisms can improves the results of population-based algorithms [47].

There are some hybridation of Bat Algorithm applied in Mechatronic and Material section. Bat Algorithm based metaheuristic optimization was hybrid with back-propagation neural network, and fuzzy logic called Hybrid Bat-BP. The major problem happened was to diagnose Noise-Induced Hearing loss (NIHL) in Malaysian industrial worker. The presented Hybrid Bat-BP will use heat, body Mass index (BMI), diabetes, and smoking along with the century old audiometric variables (i.e. age, frequency, and time of exposure) to enhance predict NIHL in Malaysian workers. The outcomes got through Hybrid Bat-BP will be able to help by recognize and decrease the NIHL rate in the labourers with high precision. The study results will also help deputies (i.e.; Department of Occupation Safety and health, Malaysia- DOSH) to strengthen law requirement inside the industries with a specific end goal to guarantee safe environment for the workers [48].

Table 2.3: Summary on Hybridation of Bat Algorithm

Author	Technique/ Hybridization	Problem	Result	Ref.
Iztok Fister Jr, Dusan Fister, and Xin-She Yang	Technique: BA and Differential Evolution (DE) Hybridization: Hybridizing the original BA using DE Strategies.	Solving lower dimensional optimization problem.	HBA significantly improves the original bat algorithm.	[45]
Nazri Mohd. Nawi, M. Z. Rehman, Abdullah Khan	Technique: BA and Back-Propagation Neural Network Hybridization: Combination of BA and Back Propagation Neural Network	Solving local minima problem in gradient descent trajectory and increase the convergence rate.	The simulation results show that the computational efficiency of BPNN training process is highly enhanced when combined with BAT algorithm	[46]
Iztok Fister Jr, Simon Fong, Janez Brest, and Iztok Fister	Technique: BA and DE Hybridization: Hybrid BA using different DE strategies.	Improving the current best solution directing the swarm of a solution towards the better regions within a search space.	The results of exhaustive experiments were promising and have encouraged us to invest more efforts into developing in this direction.	[47]
Nazri Mohd Nawi, M. Z. Rehman, M. I. Ghazali, M. N. Yahya	Technique: BAT based metaheuristic optimization, back-propagation neural network, and fuzzy logic. Hybridization: Combination of BAT based metaheuristic optimization, back-propagation neural network, and fuzzy logic.	Predicting Noise-Induced Hearing Loss (NIHL) in Malaysian workers.	The results obtained through Hybrid Bat-BP will be able to help us identify and reduce the NIHL rate in the workers with high accuracy.	[48]

2.8 Summary

All the previous study and search that related to this project is defined in this chapter. There are many algorithm and controller from previous works and research to improve the system of temperature. All of the research can be as a guidance and reference for a further project. The function and the working principle of the temperature system is explained to improving with other tuning and controllers such as fuzzy controller with PI-PD controller, Genetic algorithm and others. For Bat Algorithm previous research, there are modification section that applied with another system and hybridation section. Hybridation of Bat Algorithm with other algorithm such as Differential Evolution (DE), Back-Propagation Neural Network, fuzzy logic and others were included in this part too.

CHAPTER 3

METHODOLOGY

3.1 Introduction

In this chapter of methodology, it discussed on how to carry out this study that is focused on how to identify the desired objectives through the selected tools. This chapter is to cover the methodology from the project planning, project flow chart, product case study and design the flow chart that to achieve the objectives.

The Limits of Barrel Heating System is used as the transfer function of Barrel Heating System model from the previous research. Firstly, transfer function is used for testing to make sure that the model is fit with the limitation. After that, a flow chart of the process is presented to make sure all the process flow is running well. Lastly, MATLAB was used to run the transfer function. The model is tested by comparing the result without and with PID controller in MATLAB. The result shown different because the controller gave a different response.

FYP 2 was begun with designing BA model in Barrel Heating System. Once the model is simulated, BA is used to optimize the Barrel Heating System to develop the outcome when using PID controller. After that, analysis will start to determine how BA affects the model. The purpose of Bat algorithm is to get the response of the presentation of BA in Barrel Heating System.

3.2 Problem Analysis

The problem analysis is to characterize the issues that give the idea that ought to comprehend in this project. The reasons of this task are to illuminate the error on the system by utilizing the trial undertaking experimental. This undertaking needs to recognized, break down and concentrate on the decisive word that has distinguished, for example,

i. MATLAB & SIMULINK
ii. Transfer function
iii. PID Controller
iv. Coding on Bat Algorithm
v. Coding on Harmony Search Algorithm

The flow of problem analysis is utilized to discover the problem that expressed previously. That keyword is related to the objective that has identified.

3.3 Flow Chart

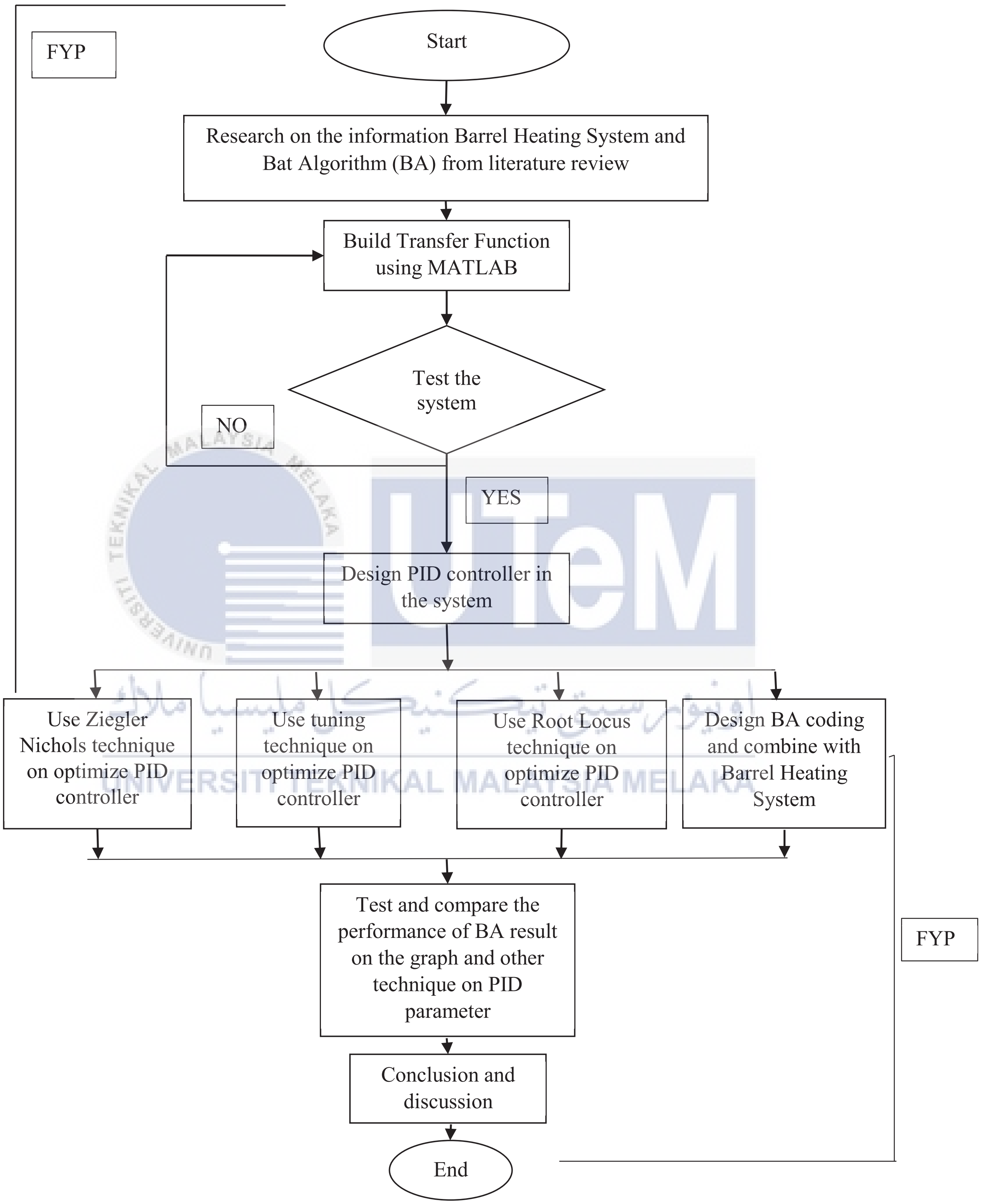

Figure 3.0: Flow chart of the research.

3.4 Project Flow Chart

The project flow outline was to portray the flow of the activities include in the research from the earliest starting point till the end project. The project flowchart was demonstrated in Figure 3.1 below.

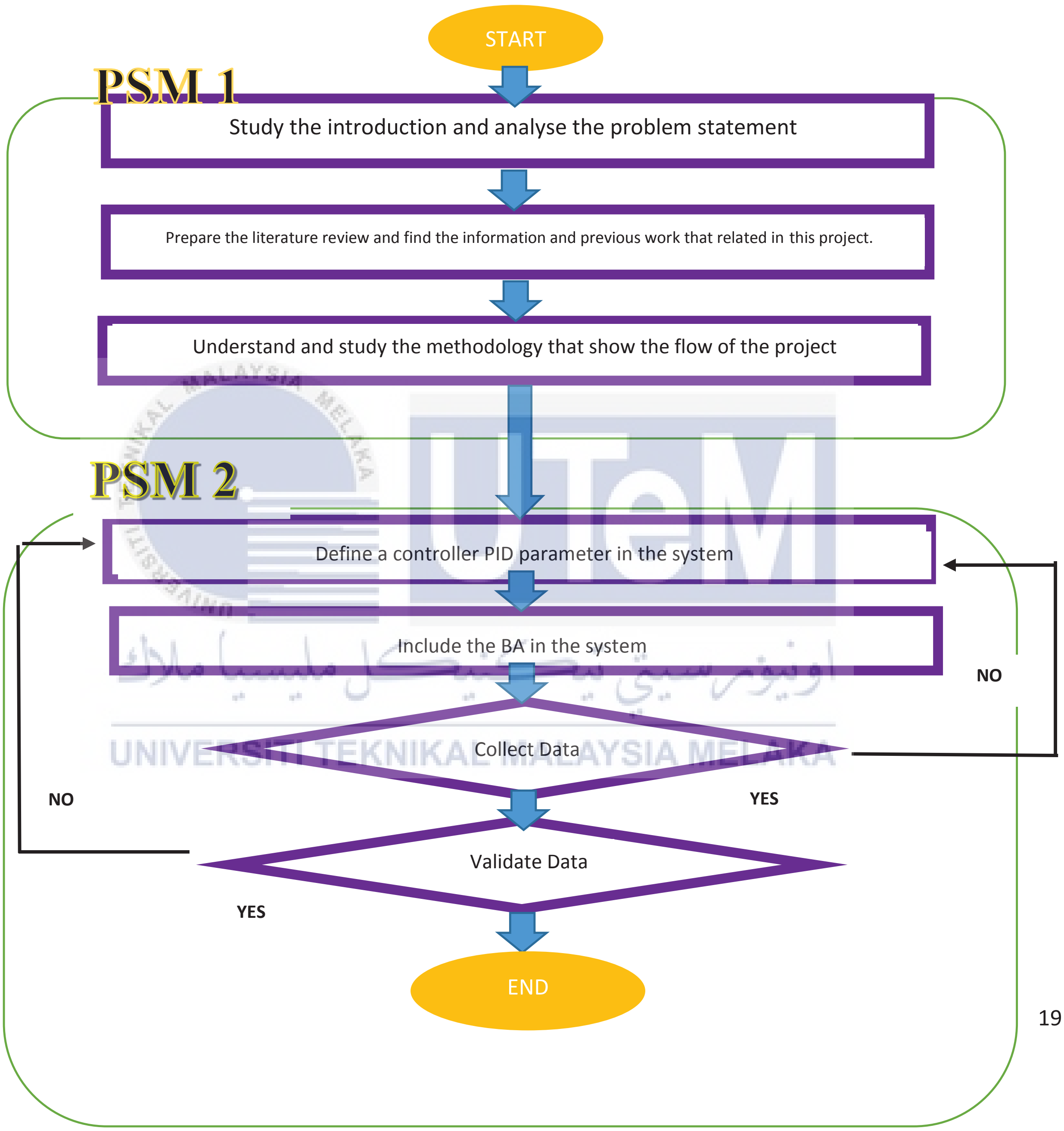

Figure 3.1: The flow of the FYP 1 and FYP 2

3.4.1 Final Year Project 1

At the starting of the project that shows in the Figure 3.2 above, this research focus to and analyse the importance and basic of the project that explained the problem statement and the target of the research. To optimize the PID Controller for avoiding overshoot and reduce rise time in Barrel Heating system is the main objective of the research. This stage was one of the most important phase in determining the scope and the significance of the studies towards attaining exceptionally anticipated results. The objective and the scope must be analyse clearly and obviously make a point to get greatest and an acceptable seeing about the subject.

The literature review or on the other named as writing survey is a complete study of productions in the particular field of study or identified with a specific line of research generally as a rundown of references or in depth review of key work. The source and references that characterize in the writing survey were getting from journals, books, articles and site. This part likewise knows as rules from the earliest starting point until this task has completed. This rule was vital on the grounds that this part see the advancement of this research.

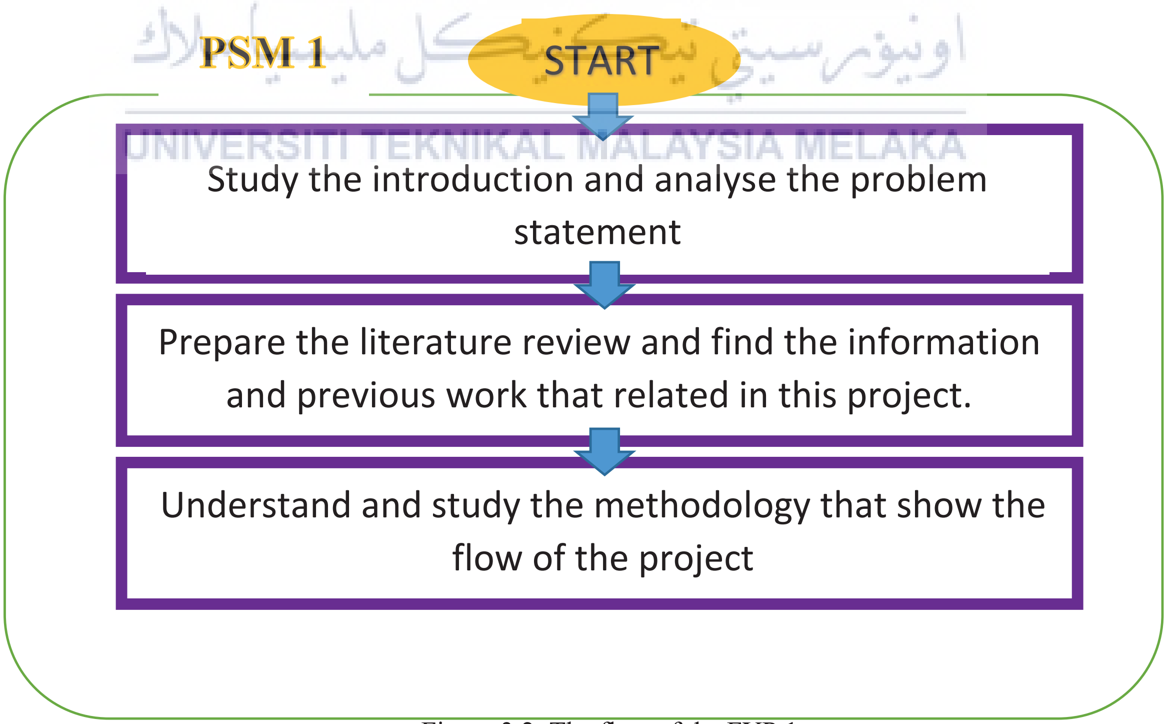

Figure 3.2: The flow of the FYP 1

3.4.2 Final Year Project 2

In this phase of research that shows in Figure 3.3 below, there is the vital stage that should clearly characterize and comprehend the result of this research. The programming is the stage that outline to give the guideline and correspond with the system. At that point, the programming will exchange to the true application to demonstrate the objective. The reasons that assemble a system on PID controller are to control the displacement of the experimental research.

The troubleshoot framework is dependably at the programming stage. It implies the project is completely achievement if the project can runs perfectly and also get the good simulation of the experimental research. Lastly, the final step is to test run the experimental project using the Bat Algorithm. If the Simulink can run smoothly and the combination on BA and PID Controller can get better result on overshoot and rise time, this mean that the project is successful and effective.

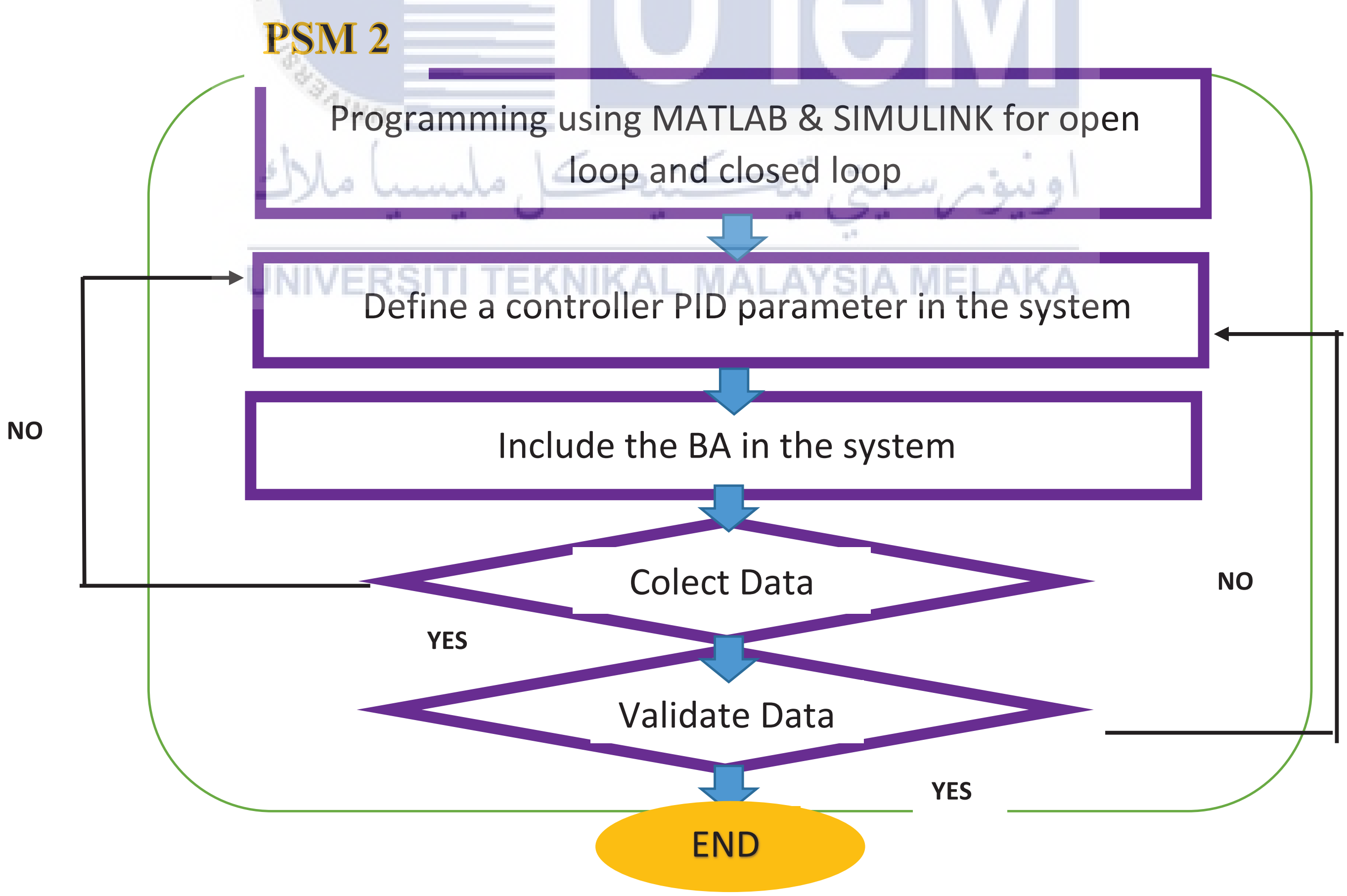

Figure 3.3: The flow of FYP 2

3.5 Project Planning

The project planning is built to explain and enhance this report project. In final year project 1, that semester 1 clarified more about the introduction, literature review, previous work result, methodology and conclusion. While in final project 2, during semester 2 it analyse about the result and discussion from the experimental project.

The introduction is more focused and zoom on the background of study, objectives, scope and also problem statement. The literature review was concentrated about previous work or research that related to this project. The source and information will get from the journal, conference meeting report, books, and articles. For methodology section, it is more detail on the flow of project, the planning of the project, the flow on developing using MATLAB software into SIMULINK. From simulation on MATLAB, the parameter like Kp, Ki and Kd can be determined. Then, the system included with PID Controller was used with different technique which are Root Locus, Ziegler Nichols and auto tuning. The result was analyse to get the best stability, overshoot and rise time. After that, the result then continued for Bat Algorithm.

In the FYP 2, the simulation and programming was done in this project. The actual result and discussion will get analyse on the graph in the MATLAB based the overshoot and rise time from the system. The temperature that produces barrel heating system will be control by PID controller and one of the best technique will be continued for bat algorithm to enhance the system.

3.6 Programming Flow Chart

The research of this project proceeds with the programming stage. This stage is to teach and do the simulation from the m.file and SISO tool. Create the programming using MATLAB on the grounds that this software is manufactured to characterize the open loop and closed loop transfer function. The parameter of the controller that gets from the SISO tool will difference with the error method and determined the better values. This must be synchronized well to make the task run smoothly. The Figure 3.4 demonstrates the programming flow chart.

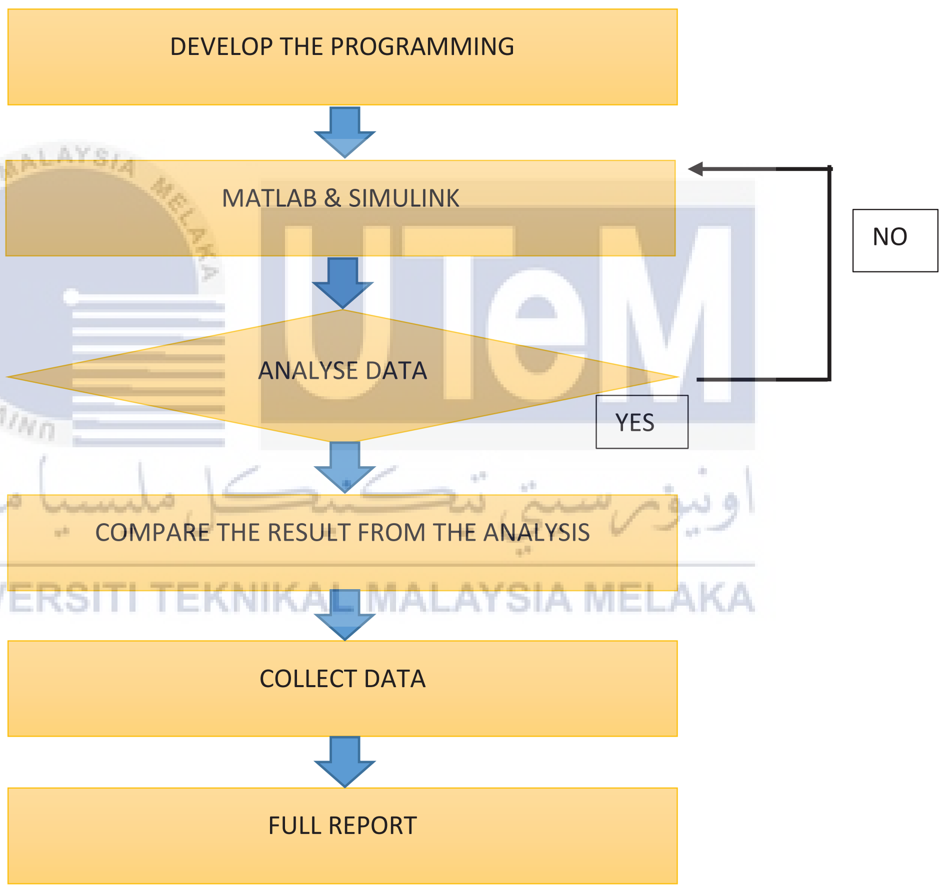

Figure 3.4: The programming flow chart

3.6 Project Schedule

Table 3.0: Gantt chart for Overall Project

Project Planning													
List of major activities involved in the proposed project. Indicate duration of each activity to the related months.													
	Weeks												
Project Activities	1	2	3	4	5	6	7	8	9	10	11	12	13
FYP 1													
Find supervisor and Decide the Title													
Gather the information required of the research													
Research about Optimization in Barrel Heating System													
Research on the Bat Algorithm													
Write Progress Report													
Simulate Transfer Function of Cruise Control													
Analysis on response of Barrel Heating System													
Design PID Controller on Barrel Heating System													
Analysis Response when using PID Controller													
Presentation of the Project Proposal and Seminar 1													
FYP 2													
Simulation using Bat Algorithm on Matlab													
Collecting Data													
Compare, Analysis & Discussion													
Report													

Table 3.1: Project Milestone

TASK	DATE
Find Supervisor and Decide Title for Final Year Project	08/09/2014 – 19/09/2014
Simulate Transfer Function of Barrel Heating System	27/10/2014
Simulate PID Controller for Barrel Heating System	4/11/2014
Seminar and Presentation Project Proposal 1	27/11/2014
Design Bat Algorithm in Barrel Heating System	24/02/2015
Due Date for Submit Complete Report	01/06/2015
Presentation of Project	09/06/2015

3.7 Method of Controller

The PID controller setup is to depict about the methods for the starting to use the PID controller. The technique in controller setup will demonstrate to regulate step by step to gain parameter in Kp, Ki and Kd in PID controller.

There are a few methods in the closed loop system to get expected estimation of Kp, Ki and Kd. The method that normally used as a part of MATLAB to plan a PID controller is error methods, SIMLULINK and also SISO tool kit. The research include the requirement value as a guideline on the project.

3.7.1 Command window methods and SIMULINK

In MATLAB programming, a few routines are used to outline a PID controller. The trial and error method generally use in MATLAB to make a coding in the command window. This strategy is the essential method to outline any coding that identified with the PID controller and also any calculation in mathematics. To simplicity being used this command window to make coding, used the editor as a part of MATLAB that can settle the error of the coding. The error, for example, missing any command can be effectively settled.

For command window, the numerator and denominator are included in order to model the transfer function. The numerator is the value or expression given above the fraction line while the denominator is the value or expression given below the fraction line. The equation of transfer function will appears when combining the numerator and denominator given.

For a SIMULINK, it is a block diagram environment for multi domain simulation and Model-Based Design. It supports simulation, automatic code generation, and continuous test and verification of embedded systems. The capabilities of the SIMULINK is can build the model with predefined library blocks and the simulating the dynamic behaviour of the system given and view results as the simulation runs. After that, the simulation result is analysed results and debug the simulation. The SIMULINK can managing project perfectly because can store large amount of data for the project.

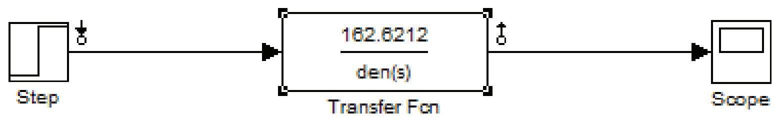

Figure 3.5: Example of the block diagram on SIMULINK

3.8 Design PID Controller technique

In this section, there are some methods for tuning of controller parameters in PID controllers which are the method for finding appropriate number of Kp, Ti and Td are shown. Auto tuning is one of the tuning used for this project.

3.8.1 Design for PID Auto Tuning Method

The PID controller number is set as Kp = 1, Ki = 1, Kd = 0. Then, the tune button is pressed and the response is tune until it achieves require desired value. The settling time and percentage overshoot required is below 5 seconds and 10% for this system. So, to adjust until it meets the requirement in this project, the tuned value is needed. The value that obtained in this system is shown in Figure 3.6 below.

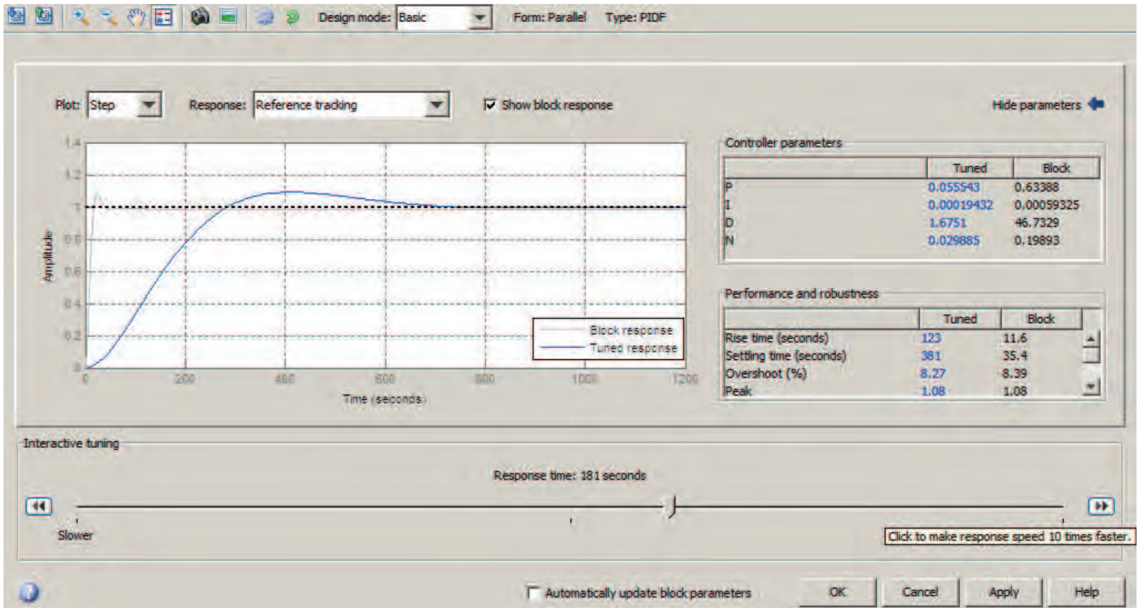

Figure 3.6: The example graph from the auto tuning

3.8.2 Design for PID Ziegler- Nichols Method

The second technique is by using a Ziegler – Nichols to design PID controller. This method will produces the proportional gain (Kp), integral time (Ti), and derivative time, (Td). The original Ziegler-Nichols method moves the critical point into a point with fixed coordinates according to the chosen type of the controller.

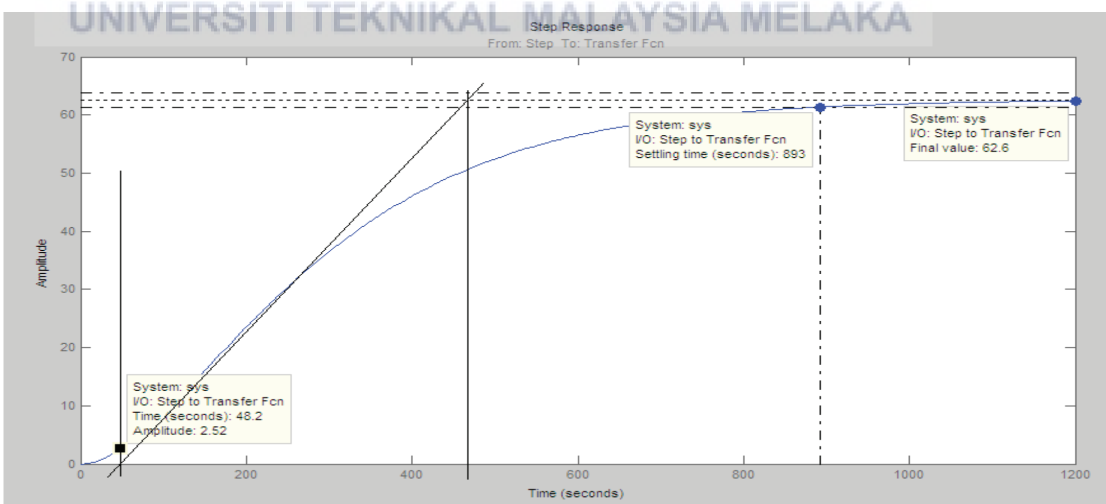

Figure 3.7: The example of starting graph from the Ziegler Nichols method

The step used in this method are:

1. To define experiment on the response of system to a unit step.
2. To such a unit step response curve to look the S-shaped curved.
3. From S-shaped curve has two constant, time delay, L and and time constant, T.
4. Take the value L and T from drawing tangent line at the inflection point of the S-shaped curve and determining the intersection of the tangent line with the time axis and line c(t)=K. as show at figure below. The equation on T is defined by the upper part of graph to the lower part of the graph which is shown with the triangle figure.
5. From response, the value gain will calculate to inset in PID table:

$$Kp = 1/2(T/L) \quad (3.1)$$

$$Ki = Kp/Ti \quad (3.2)$$

$$Kd = KpTd \quad (3.3)$$

3.8.3 Design for PID Root Locus Method

To improve the PID controller or phase Lag-Lead, this Root Locus technique can be used. For barrel heating system, this tuning is chosen for design optimize PID controller. This technique can be used to desire operating points for the system dominant poles which can fulfil the transient response requirements respect to the original root locus

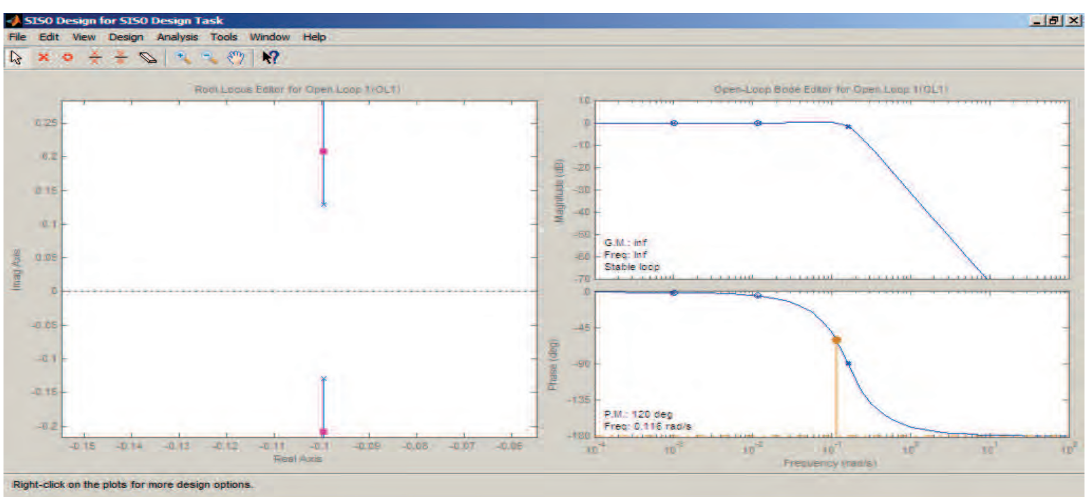

Figure 3.8: The example on analysis graph of the system using root locus

3.9 Simulation technique in the research

3.9.1 Simulation on Barrel Heating System without Controller

The simulation on Barrel Heating System without controller has been done in FYP 1. In this simulation, this system show to analyse the flow of the Barrel Heating System. PID controller is not added in this block diagram. The block diagram has been built before run the SIMULINK as shown in Figure 3.9 below.

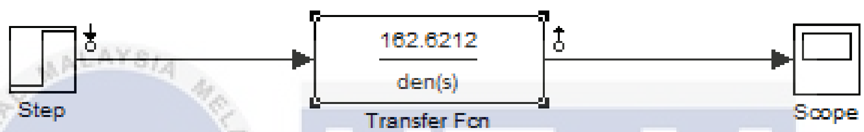

Figure 3.9: Transfer function system without PID controller.

3.9.2 Simulation on Barrel Heating System with PID Controller

Figure 3.10 below shows the Barrel heating system with PID controller. The PID controller was included in the block diagram and set the number of proportional, integral and derivative controller.

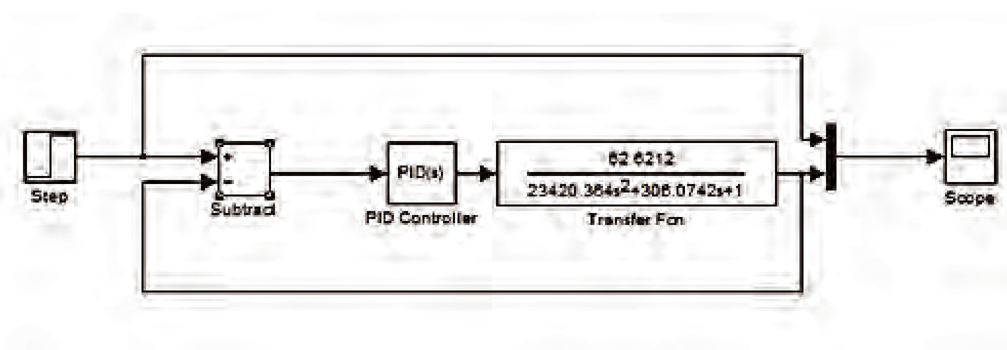

Figure 3.10: Transfer function system with PID controller

3.10 Method on Bat Algorithm

For this project, Bat Algorithm was used in order to analyse the performance with Barrel Heating System. In this research, optimization is carried out using BA for defining best value of Kp, Ki, & Kd by reducing the objective function. The best solution is mentioning to the best output gained that meet the requirement. The procedure for Bat Algorithm is set up in the coding. The basic coding was analyse to do for a new coding which is compatible with the barrel heating system. The basic steps of BA can be summarized as the pseudo code shown below:

```
1    init_bat();
2     eval =  evaluate_the _new_population;
3      Fmin = find_the_best_solution(Xbest);(initialization)
4       While termination_condition_not_meet do
5         For i = 1 to Np do
6           Z = generate_new_solution(Xi);
7            If rand (0,1) > ri then
8              Z = inprove_the_best_solution(Xbest)
9               End if {local search step}
10              fnew = evaluate_the_new_solution(z);
11            Eval = eval + 1;
12           If fnew ≤ fi and N (0,1) < Ai then
13          Xi = z;fi = fnew;
14        End if {save the best solution conditionally}
15      fmin = find_the_best_solution (Xbest);
16    end for
17   end while
```


Figure 3.11: Pseudo code of Bat Algorithm

The original Bat Algorithm involve the following component:

- Initialization (lines 1-3); initializing the algorithm parameters, generating the initial population, evaluating this, and finally, determining the best solution Xbest in the population

- Generate_the_new_solution (line 6); moving the virtual bats in the search space according to the physical rules of the bat echolocation.
- Local_search_step (lines 7-9); improving the best solution using random walk heuristic.
- Evaluate_the_new_solution (line 10); evaluating the new solution
- Save_the_best_solution_conditionally (lines 12-14); saving the new best solution under some probability Ai similar to simulated annealing.
- Find_the_best_solution (line 15); finding the current best solution

For displaying BA to the Barrel Heating System, there are few parameters that are important when taking the result. The parameters are alpha, gamma, number of iteration (Nt), number of dimension (Np), number of agent (Nd) and boundary. The number of dimension are fixed to three from the beginning until the end of simulation of BA.The coding include the range of upper limit (uB = [20 10 300]) and lower limit (lB = [0 -10 0]) on previous best result in FYP 1 for Kp,Ki and Kd. Sample time is a period of time that set during the experiment. The sample time use is 50 seconds. After the coding is done, barrel heating system was link to the coding and run the system. . After these two parameters are set, the arrangement of alpha and gamma are simulate. First step to use the coding in this system is by rearrange the changes of the value on alpha and gamma. The series of both value are between $0.1 \leq \alpha / \beta \leq 1.0$. The PID controller was tuned and set the value of proportional, integrator and derivative controller value to Para1, Para2 and Para3. The procedure to get the best result for this part is running in two times for each table. The best value of the error, Kp, Ki, Kd and the stability of the graph in this table will be used on the next step.

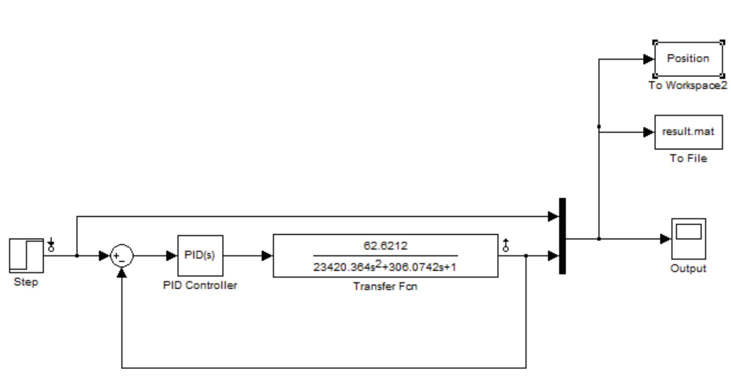

Figure 3.12: Block Diagram for Bat Algorithm

From the block diagram that link to BA coding, the simulation started to run and analyse the best result of error, Kp, Ki and Kd referred from the requirement of upper boundary, lower boundary and others.

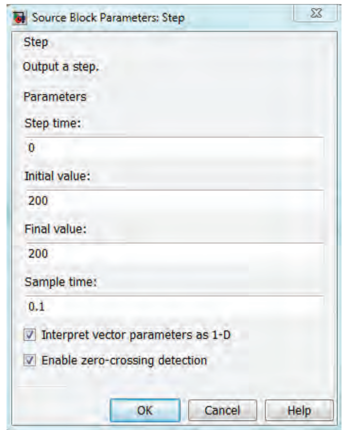

Figure 3.13: Source Block parameter for Bat Algorithm

Source block parameter was the placed to include the information on sample time in order to set the input of the system and showed in output graph. The initial value used is 200^0c referred from the previous research [5, 6].

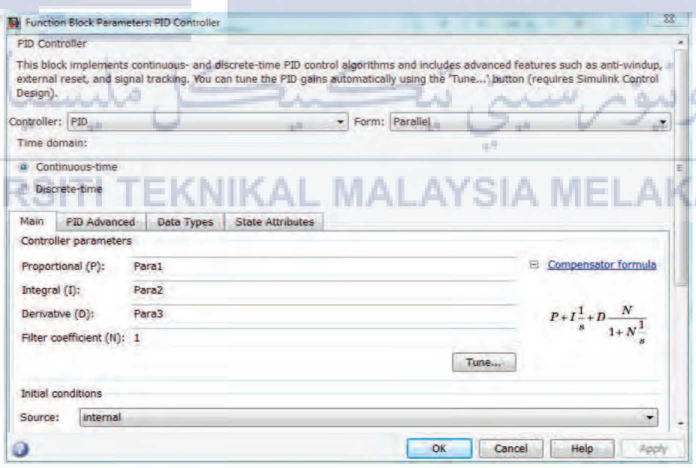

Figure 3.14: Function Block Parameter for Bat Algorithm

In PID Controller of function block parameter Kp, Ki and Kd was initially set to Para1, Para2 and Para3 in order to simulate to new parameter of the system. The result of new parameter was shown at Matlab window command and workspace.

Secondly, the procedure was continued by rearrange the changes in number of agent (Ni) and number of iteration (Nt). The range for number of agent (Ni) used is between 10≤ Ni≤50 while the range for number of iteration (Nt) is between 50≤Nt≤300. To get the best result, the table was run for two times. Then, the best graph is analyse. The example for table Ni versus Nt shown below:

3.11 Summary

In this chapter, all the procedure was being included for FYP 1 and FYP 2. From developing barrel heating system using SIMULINK until producing coding for BA. For the first semester, the methodology involve Simulink on the system, upgrade the system with PID Controller, then enhance it with different type of technique of tuning for a better result. For the second semester, the project will start with designed BA and HSA coding compatible with the system, then analyse both of algorithm on different methods of table and finally compare both result of Bat Algorithm. For the chapter 4 which is Result will explain more on result of PID controller with different type of tuning on Barrel Heating system after SIMULINK in MATLAB software which is completed in FYP 1 in the semester 1 and also final result after optimize PID Controller with BA.

CHAPTER 4

RESULT, ANALYSIS AND DISCUSSION

4.1 Introduction

This chapter present the simulation of the result for barrel heating system using controller and without using controller. After that, PID controller which is obtained in the previous chapter is inserts into the model to simulate the model which is with controller. Then, the result of the system with PID Controller will be included using different tuning such as Ziegler- Nichols, Root Locus and Auto tuning. Each response gained is analysed and to know which optimization PID give the best result. After complete simulation of PID controller, Bat Algorithm will be improved it. The BA method include of four parameters and was verified with diverse values of α, γ, Ni and Nt as mention in earlier chapter. The selected value of α and γ are starting from 0.1 to 0.9 while Ni and Nt is set as constant. Once the value of α and γ are set up, it will be applied to Ni and Nt to find the best result for the system.

4.2 System without PID Controller

A barrel heating system without PID controller is simulated in SIMULINK. The transfer function was included into the system which is close-loop system and the result was been observed and analysed. The output graph can been seen on the scope as in Figure 4.0.

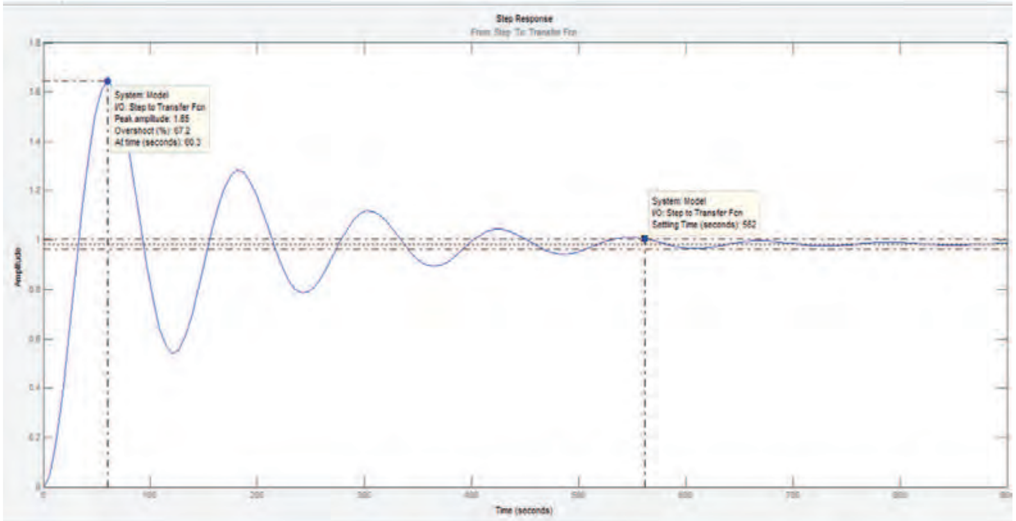

Figure 4.0: The graph of the barrel heating system without PID Controller

From the graph above, it shows that the overshoot value is 67.2% while the settling time is 582 seconds. The value of PID was set Kp=Ki=Kd=0. The transfer function was used is second order system.

4.3 System with PID Controller

The barrel heating system then included PID Controller. After SIMULINK the block diagram in Matlab software, the output is in shown below as in Figure 4.1.

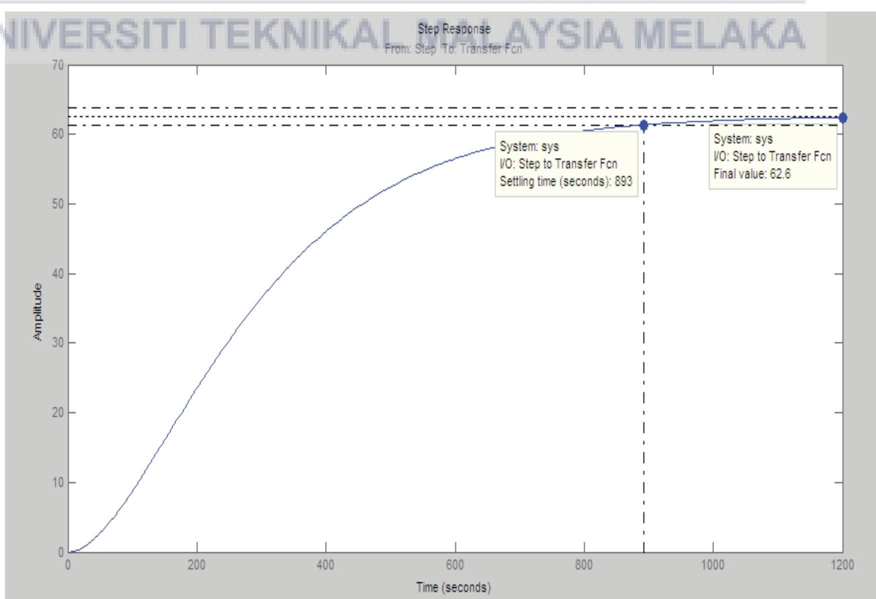

Figure 4.1: The graph of the barrel heating system using PID Controller

Figure 4.5 show the response of PID controller. The settling time 893 seconds, and the final value is 62.6. PID controller has almost no overshoot while the system without PID Controller is higher than that. It shown the system is better when using the controller.

4.4 Simulation with PID Controller using different tuning

In this part, it will discuss about the techniques that was used to design PID controller. PID controller was getting will put in Simulink model. The techniques are use:

i. Ziegler-Nichols Method
ii. Root Locus Method
iii. Auto Tuning Method

4.4.1 Ziegler Nichols

To utilize this tuning, the response curve need in for S shaped curve. For transfer function of barrel heating system, the response was shown in form S shaped curve based on Figure 4.2 below. From the reaction, build the line tangent to get answer of L and T.

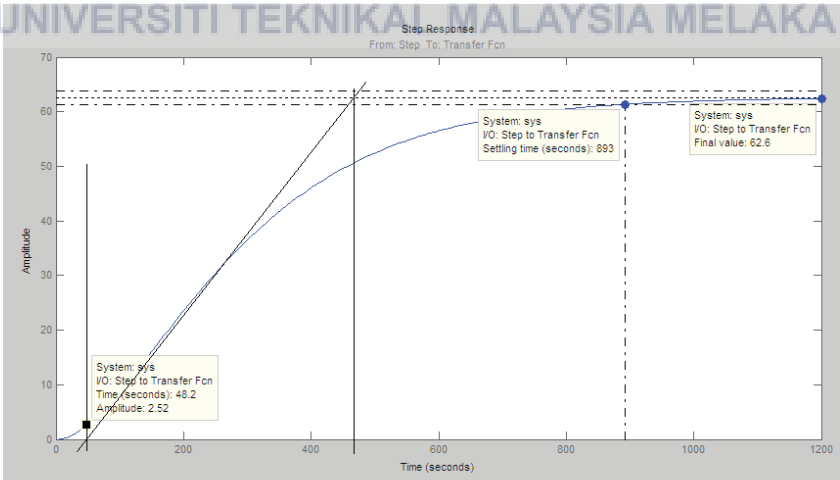

Figure 4.2: The starting graph on using Ziegler-Nichols

From the response above, the value of L and T will insert to the table for design PID controller:

T = t2-t1
= 466-48.2
=417.8 sec
L = t1
= 48.2 sec

From the equation Ti, Td, Kp, Ki, Kd, the value is verify

Ti=2L Td=0.5L Kp=1.2(T/L) Ki=Kp/Ti Kd=Kp* Td

Table 4.0: The result of calculation in Ziegler Nichols equation

	Kp	Ti	Td	Ki	Kd
PID	10.40	96.4	24.1	0.108	250.64

The gain value of Kp, Ki, and Kd that was calculated will be insert into the PID function block at SIMULINK model.

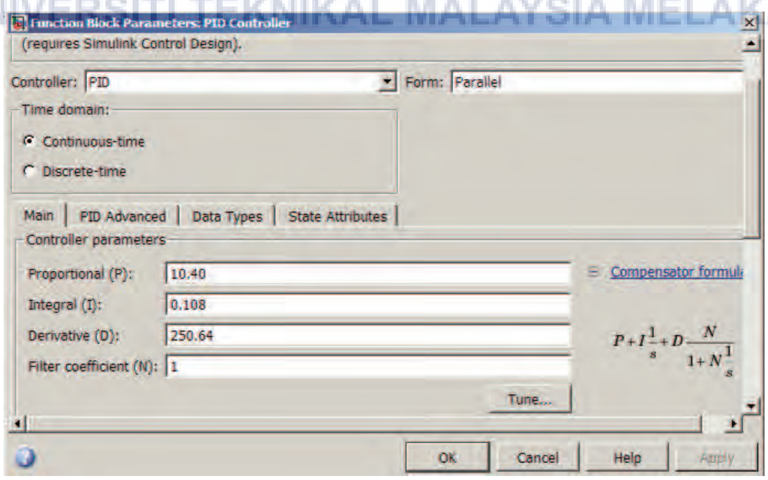

Figure 4.3: Adding the P, I and D value in the function block parameter

After new parameter Kp, Ki and Kd on Ziegler Nichols method was determined. The values was inserted into function block parameter in order to shown new output graph.

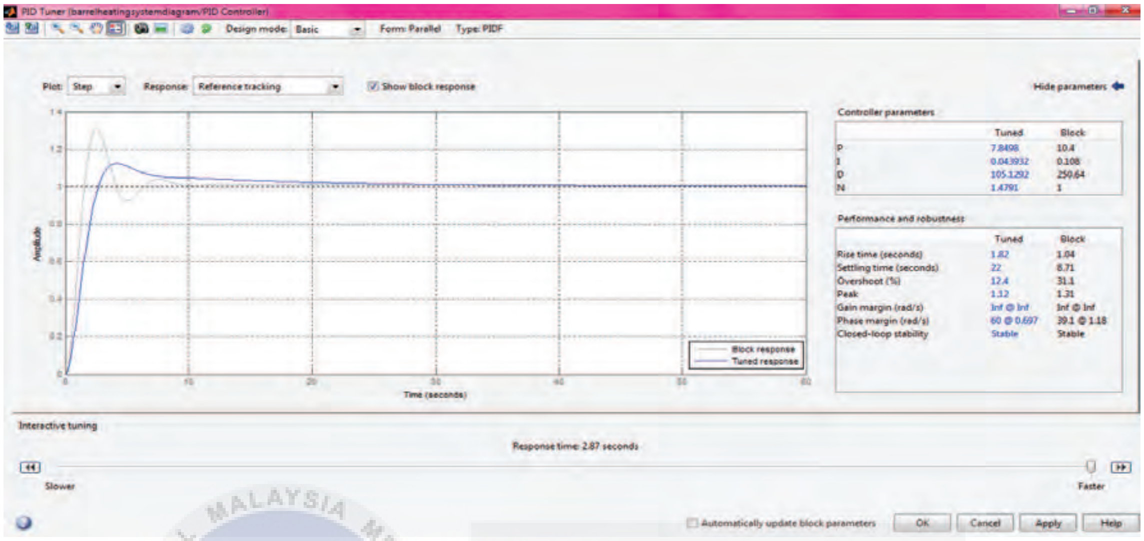

Figure 4.4: The graph of the system using Ziegler Nichols tuning

Based on the figure 4.4 above, the rise time is 1.04 seconds, the settling time is 8.71 seconds while the overshoot is 31.1 % and lastly the value of peak time is 1.31.

Table 4.1: The new value of parameter and performance of the system using Ziegler Nichols methods

Parameter	
Kp	10.4
Ki	0.104
Kd	250.64
Performance	
Rise time (sec)	1.04
Settling time (sec)	8.71
Overshoot (%)	31.1
Peak	1.31

4.4.2 Root Locus

For this technique, the transfer function was design in common window to produces root locus graph response. The root locus response was shown in the Figure 4.5 below.

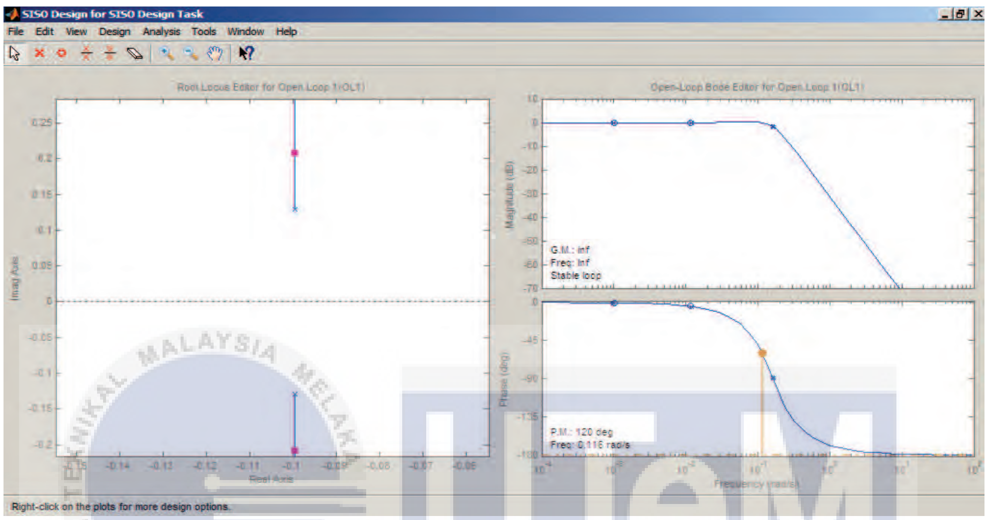

Figure 4.5: The Root Locus before tuning the root locus

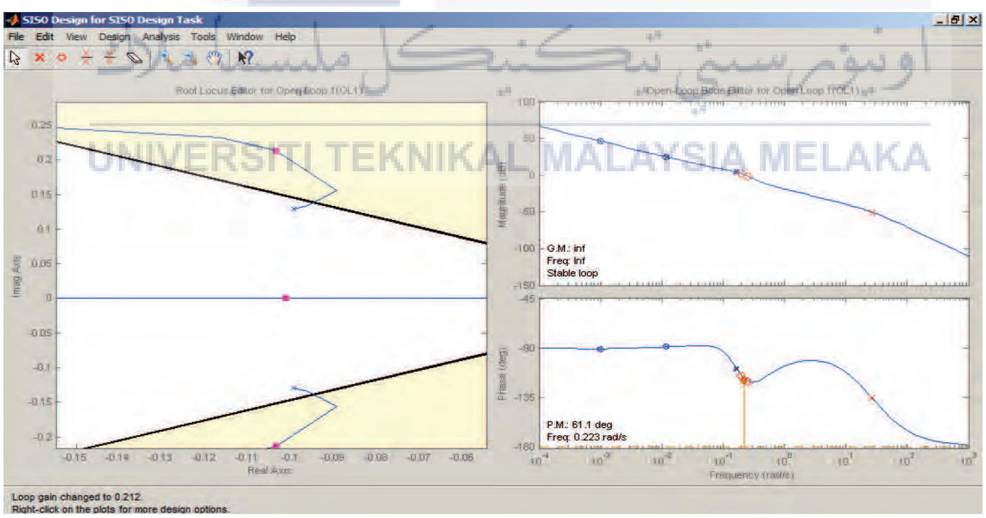

Figure 4.6: The Root locus response

Based on the Figure 4.6 above, this is the root locus response without PID. From root locus will design requirement with percent overshoot approximately to zero. The figure below show root locus after adding a new percent overshoot.

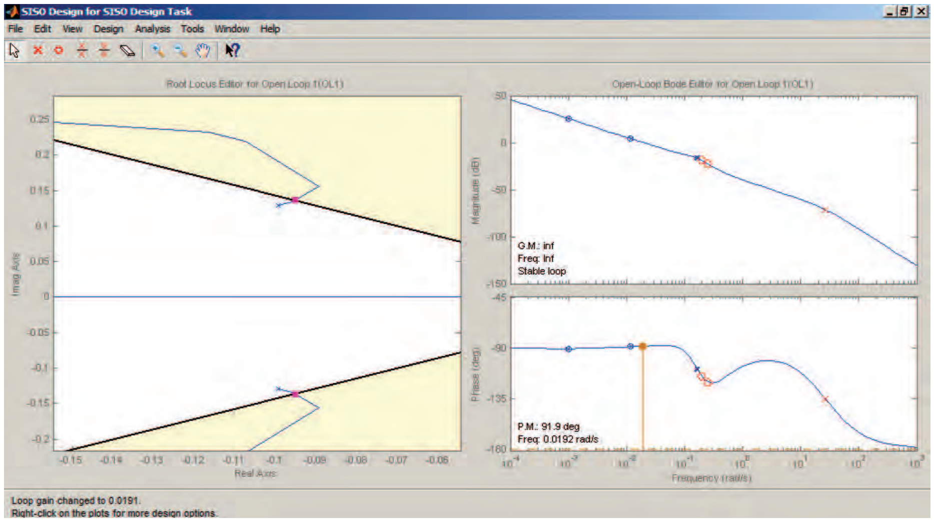

Figure 4.7: The root locus after adding the tuning

From the overshoot will get number of damping ratio. The line of zero percent overshoot was intercept with root locus that has pink dotted based on the Figure 4.7 above. Then, try to tune the root locus to use compensator editor. The value of gain will show after tuned.

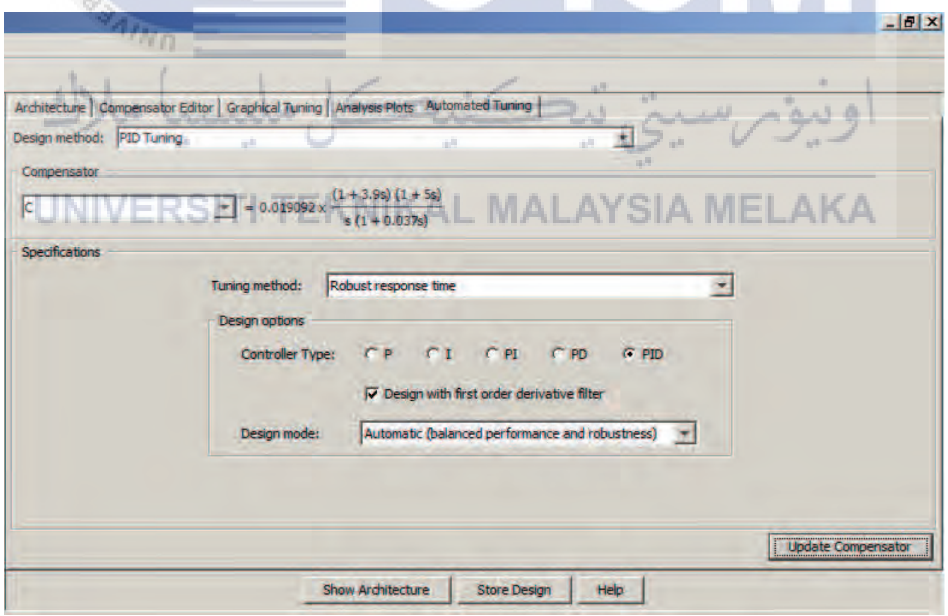

Figure 4.8: Tuning root locus and PID controller

In Figure 4.8 shows that root locus method was set into PID Controller in order to update compensator. Tuning of method used was robust response time.

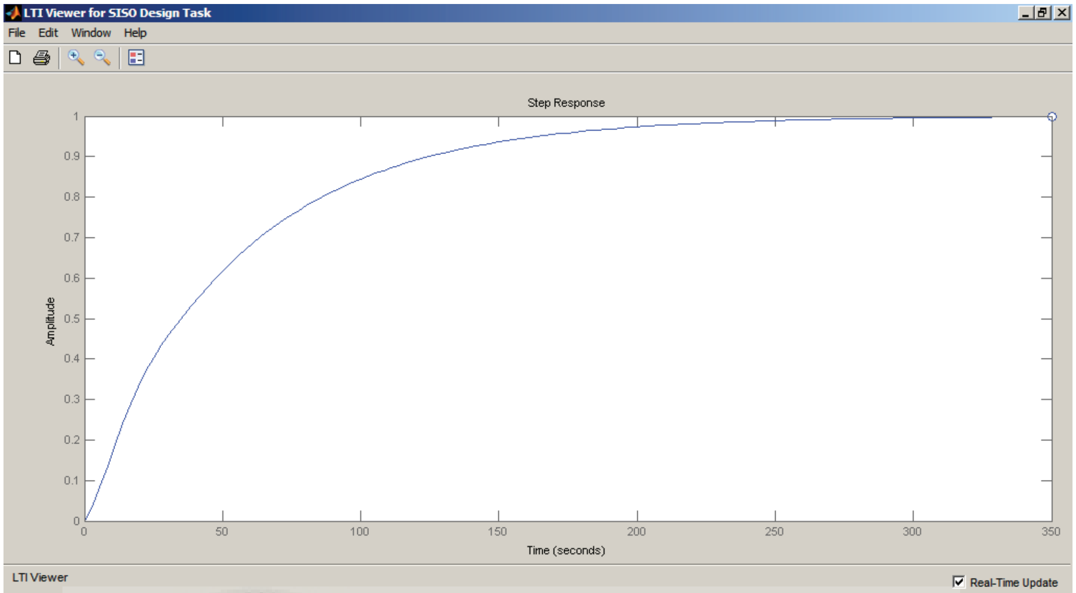

Figure 4.9: The graph after adding the tuning

From the graph of Figure 4.9 above, the overshoot is zero and achieve the requirement while the rise time not rise quickly as the task given. Ziegler Nichols tuning was different from others because it is use manually design and calculation. As the result, it will conclude that the PID controller still have weakness to design an optimization. For the root locus tuning with PID, improve the overshoot only.

Table 4.2: The new value of parameter and performance of the system using Root Locus methods

Parameter	
Kp	0.0361
Ki	0.00013521
Kd	2.22965
Performance	
Rise time (sec)	50
Settling time (sec)	270
Overshoot (%)	0
Peak	1

From Table 4.2 shows that the new parameter of Kp = 0.0361, Ki = 0.00013521 and Kd = 2.22965 while rise time is 50 seconds and overshoot is zero. Rise time value was too far from the requirement needed in this research while overshoot value fulfil the requirement given.

4.4.3 Auto tuning

Auto tuning is continues from the Ziegler Nichols but the way to get the value from auto tuning is way more simple than that. For the auto tuning, the way to get the graph is by tuning the response time on the below at interactive time manually. The graph will change when moving the response time.

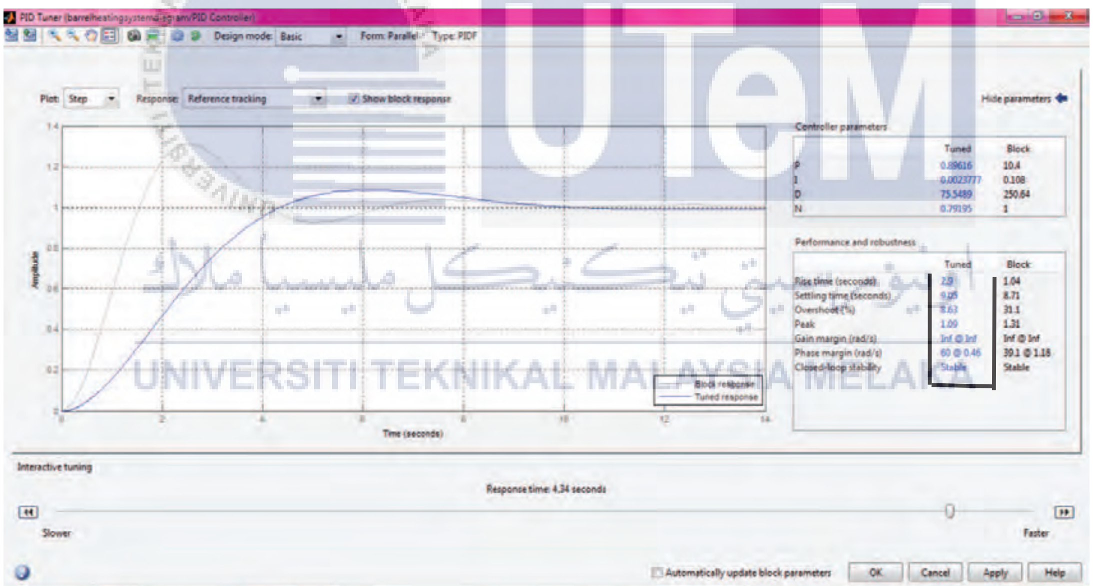

Figure 4.10: The graph of the system using auto tuning

Figure 4.10 shows that the least value that can get for overshoot value of the graph is 8.63 % when stop at the response time 4.34 seconds. The rise time is 2.9 seconds, settling time is 9.05 seconds and lastly, the peak is 1.09. The auto tuning is more than to tune the graph manually to achieve the requirement.

Table 4.3: The new value of parameter and performance of the system using Auto tuning methods

Parameter	
Kp	0.89616
Ki	0.0023777
Kd	75.5489
Performance	
Rise time (sec)	2.9
Settling time (sec)	9.05
Overshoot (%)	8.63
Peak	1.09

4.5 Result of Bat Algorithm

First of all, basic coding was analyse to improve into new coding which compatible with Barrel Heating System. Each of the equation in this coding have their own function. Started with initialize BA parameter, initialize bat population, define pulse frequency, initialization pulse rates and loudness of the echo and others. After that, this coding was link to the SIMULINK. There are, four parameter that used in order to optimize PID Controller which are α versus γ and Ni versus Nt.

4.5.1 Alpha versus gamma

On the first stages, value of alpha and gamma in this algorithm was carried out. The purpose for this stages is to initialize the finest combination of the Bat parameter to enhance the Barrel Heating System. At this part, sample time was fixed in 50 seconds. Value alpha and gamma was utilized in order to get optimal performance on the graph. The value of alpha and gamma was changed manually. The table between alpha and gamma was shown in Table 4.4, 4.5 below:

Table 4.4: Result of α versus γ

β \ α	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0.0	6.412e+003 Kp=2.1595 Ki=0.0336 Kd=239.8344	6.8250e+003 Kp=15.4179 Ki=-0.2073 Kd=290.8423	7.3222e+003 Kp=23.8077 Ki=-0.3215 Kd=271.4001	1.0633e+003 Kp=15.8403 Ki=-0.1878 Kd=130.6869	6.1175e+003 Kp=2.5137 Ki=0.0421 Kd=288.0020	6.9574e+003 Kp=11.5115 Ki=-0.1507 Kd=261.3178	6.2168e+003 Kp=5.5823 Ki=-0.0277 Kd=280.6704	7.0715e+003 Kp=15.8247 Ki=-0.2159 Kd=271.9766	8.2143e+003 Kp=23.8077 Ki=-0.3215 Kd=288.0020	7.4580e+003 Kp=17.9708 Ki=-0.2471 Kd=250.4412
0.1	6.1928e+003 Kp=4.7257 Ki=-0.0122 Kd=273.1851	1.1164e+004 Kp=12.0699 Ki=-0.1495 Kd=111.2988	7.0190e+003 Kp=11.3200 Ki=-0.1479 Kd=255.7460	6.8695e+003 Kp=11.4070 Ki=-0.1465 Kd=267.5161	7.5558e+003 Kp=9.3626 Ki=-0.1251 Kd=212.1874	7.0782e+003 Kp=10.6502 Ki=-0.1374 Kd=247.8310	6.1342e+003 Kp=4.5996 Ki=-0.0077 Kd=279.9434	8.4385e+003 Kp=11.1951 Ki=-0.1558 Kd=181.6326	6.8413e+003 Kp=11.4070 Ki=-0.1496 Kd=271.6766	8.6054e+003 Kp=15.9940 Ki=-0.2168 Kd=186.6413
0.2	6.5356e+003 Kp=2.7813 Ki=0.0096 Kd=212.1495	6.1160e+003 Kp=2.5271 Ki=0.0471 Kd=288.0214	6.6849e+003 Kp=10.9990 Ki=-0.1358 Kd=280.3279	1.0193e+004 Kp=14.3042 Ki=-0.1825 Kd=135.6504	8.9566e+003 Kp=11.9878 Ki=-0.1698 Kd=166.0182	6.1176e+003 Kp=2.5137 Ki=0.0429 Kd=288.0151	6.1175e+003 Kp=5.5182 Ki=-0.0222 Kd=294.3623	7.8354e+003 Kp=0.8545 Ki=0.0921 Kd=185.4013	7.6595e+003 Kp=13.8040 Ki=-0.1914 Kd=226.0523	6.8566e+003 Kp=-3.0304 Ki=-0.1884 Kd=295.3097
0.3	7.2596e+003 Kp=10.7147 Ki=-0.1409 Kd=236.3213	8.8976e+003 Kp=15.0467 Ki=-0.2041 Kd=174.0643	1.7162e+004 Kp=9.3686 Ki=-0.1417 Kd=57.4822	8.3288e+003 Kp=15.8585 Ki=-0.2169 Kd=198.1071	7.5452e+003 Kp=11.0928 Ki=-0.1514 Kd=221.5644	6.9639e+003 Kp=2.7917 Ki=-0.0011 Kd=183.1684	6.6960e+003 Kp=8.5163 Ki=-0.0944 Kd=261.6700	6.1176e+003 Kp=2.5118 Ki=-0.0418 Kd=288.0151	6.9022e+003 Kp=13.0015 Ki=-0.1740 Kd=273.3768	7.8042e+003 Kp=11.8257 Ki=-0.1612 Kd=211.2309
0.4	7.5941e+003 Kp=13.0689 Ki=-0.1799 Kd=227.0812	6.6595e+003 Kp=4.0764 Ki=-0.0179 Kd=218.9017	8.0597e+003 Kp=15.0601 Ki=-0.2089 Kd=208.8849	6.3566e+003 Kp=2.8690 Ki=-0.0155 Kd=235.0111	6.2961e+003 Kp=8.4823 Ki=-0.0808 Kd=301.0208	9.4202e+003 Kp=8.9554 Ki=-0.1289 Kd=144.4170	6.1174e+003 Kp=2.5148 Ki=0.0424 Kd=287.9955	8.544e+003 Kp=2.5118 Ki=-0.1988 Kd=185.3609	7.0291e+003 Kp=3.6676 Ki=-0.0172 Kd=191.5011	6.1267e+003 Kp=4.2728 Ki=-0.0014 Kd=276.6382
0.5	6.7798e+003 Kp=13.2544 Ki=-0.1742 Kd=284.8295	6.6978e+003 Kp=2.8826 Ki=0.0032 Kd=200.2376	7.3004e+003 Kp=11.9054 Ki=-0.1599 Kd=239.7013	8.3213e+003 Kp=13.1866 Ki=-0.1862 Kd=192.2604	6.9660e+003 Kp=11.9333 Ki=-0.1572 Kd=262.9176	1.1039e+003 Kp=11.9878 Ki=-0.1730 Kd=121.8640	6.8713e+003 Kp=15.1956 Ki=-0.2043 Kd=285.9351	7.6030e+003 Kp=11.0067 Ki=-0.3498 Kd=218.0558	9.7183e+003 Kp=18.9275 Ki=-0.2235 Kd=149.9731	7.9804e+003 Kp=10.8360 Ki=-0.1490 Kd=198.9806
0.6	6.8631e+003 Kp=10.9666	7.3163e+003 Kp=9.3197	1.0928e+004 Kp=-0.0542	7.8434e+004 Kp=18.7008	8.2539e+003 Kp=-3.4636	7.0550e+003 Kp=-0.8963	6.9737e+003 Kp=15.7963	6.5865e+003 Kp=2.2751	1.1712e+004 Kp=18.8508	8.3073e+003 Kp=7..0663

	Ki=-0.1372 Kd=265.3758	Ki=-0.1207 Kd=225.0142	Ki=-0.0447 Kd=104.9022	Ki=-0.2556 Kd=227.9789	Ki=0.1795 Kd=214.8331	Ki=0.1088 Kd=232.5236	Ki=-0.2164 Kd=379.6672	Ki=0.0224 Kd=214.5071	Ki=-0.1431 Kd=103.4036	Ki=-0.0936 Kd=167.1257
0.7	1.3810e+004 Kp=18.6056 Ki=-0.1785 Kd=79.8558	7.2117e+003 Kp=20.4338 Ki=-0.2826 Kd=274.1472	7.2267e+003 Kp=20.4943 Ki=-0.2808 Kd=273.0987	9.4372e+003 Kp=13.4385 Ki=-0.1833 Kd=154.3539	8.1068e+003 Kp=2.3308 Ki=-0.0050 Kd=141.4611	6.636e+003 Kp=11.0484 Ki=-0.1363 Kd=284.9805	6.1532e+003 Kp=2.6650 Ki=-0.0346 Kd=276.6658	7.2880e+003 Kp=-1.0206 Ki=0.1076 Kd=217.5275	7.9439e+003 Kp=7.7747 Ki=-0.1018 Kd=185.4069	8.3073e+003 Kp=20.2299 Ki=-0.2681 Kd=205.3517
0.8	2.1638e+004 Kp=11.6623 Ki=-0.2141 Kd=37.9798	7.0643e+003 Kp=18.7486 Ki=-0.2586 Kd=281.8326	7.7914e+003 Kp=13.8067 Ki=-0.1917 Kd=218.6309	7.6583e+003 Kp=14.5713 Ki=-0.2005 Kd=228.6309	6.0682e+003 Kp=2.9826 Ki=-0.0315 Kd=288.7945	8.8946e+003 Kp=15.1891 Ki=-0.2071 Kd=174.3884	6.3754e+003 Kp=4.2257 Ki=-0.0110 Kd=244.9742	8.1519e+003 Kp=13.5248 Ki=-0.1907 Kd=200.5472	7.1837e+003 Kp=8.4703 Ki=-0.1089 Kd=227.3718	7.2005e+003 Kp=8.5386 Ki=-0.1061 Kd=226.8299
0.9	6.1162e+003 Kp=2.5251 Ki=0.0421 Kd=288.0303	7.4310e+003 Kp=13.4148 Ki=-0.1844 Kd=238.0393	6.4667e+003 Kp=1.4633 Ki=0.0532 Kd=247.2296	6.6953e+003 Kp=8.5954 Ki=0.0969 Kd=262.3786	6.1195e+003 Kp=2.4946 Ki=-0.0428 Kd=287.9913	7.4293e+003 Kp=13.3650 Ki=-0.1845 Kd=237.9508	6.4657e+003 Kp=1.4741 Ki=0.0533 Kd=247.2184	7.0846e+003 Kp=14.8873 Ki=-0.2046 Kd=267.4067	6.8916e+003 Kp=6.4746 Ki=-0.0653 Kd=229.8465	7.5780e+003 Kp=8.9072 Ki=-0.1170 Kd=208.4642

For this stages, it takes a longer time to get the solution. On the sample time, the bigger the number, the time to achieve the result. Each of the block of table have a graph that will illustrate on the scope. From the result, it shows that the finest graph for first phases on alpha and gamma range is while alpha=0.7 and gamma=0.7 compare to the others. This combination produce 4 parameters to be measured which error=7.2880e+003, Kp=-1.0206, Ki=0.1076 and Kd=217.5275. The response of this combination are shown in Figure. Based on this result, α = 0.7 and γ = 0.7 then applied to the next parameter in Ni versus Nt.

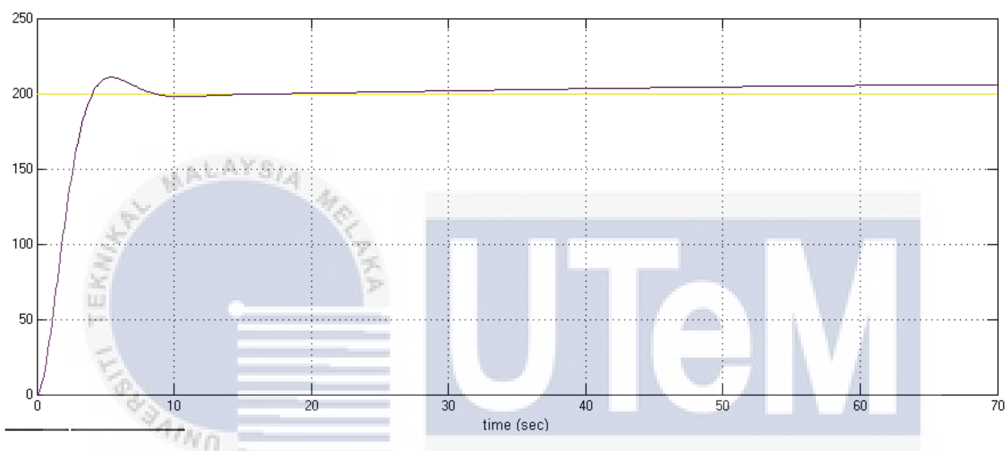

Figure 4.11: graph when alpha=0.7 and gamma=0.7

The result shows that the error is7.2880e + 003, Kp= -1.0206,Ki= 0.1076 and Kd= 217.5275. Even though, the error is pretty large but the graph run smoothly.

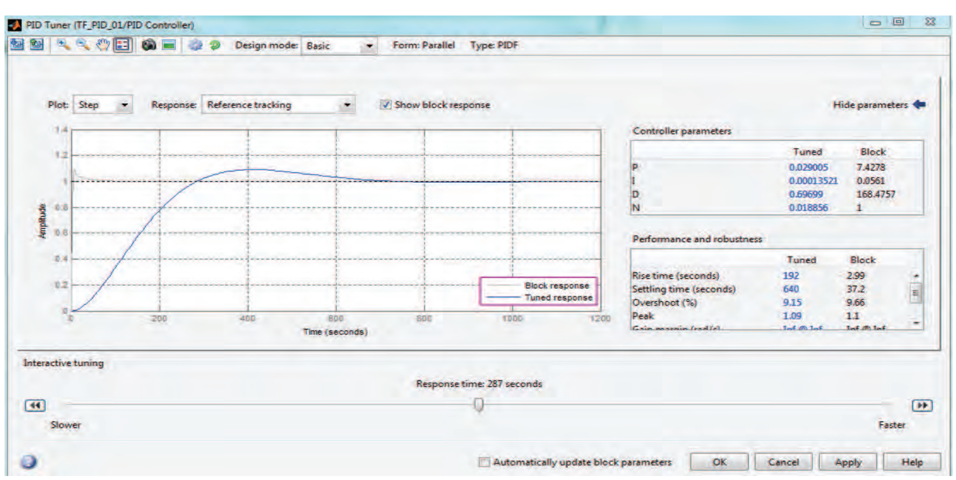

Figure 4.12: PID Tuner on the result of alpha versus gamma

From block response referred on figure 4.12, overshoot (%) of this graph is 9.66% while the rise time is 2.09 seconds. However, the graph not steady state enough when adding Bat Algorithm.

4.5.2 Ni versus Nt

In this part, the coding was develop by shifting the value on Ni (no of agent) and Nt (no of iteration). The best value of alpha and gamma which is α=0.7 and β=0.7 from previous table will be used in this section. The sample time, lower boundary and upper boundary was used from previous stages. Value of Ni which is number of agent were set into 5 different value which are 10, 20, 30, 40 and 50 while Nt which is the number of iteration were set into 6 different value which are 50, 100, 150, 200, 250 and 300. Each combination will be simulated and the best response will be analysed to the next step. This table below takes longer than first stages because the greater number of agent, the longer time taken to get the result of error, Kp, Ki, Kd and graph. Each of every combination on the number of agent and number of iteration shown the value for "Best", "Mean", "Worst". "Best" is the defined as the best error or minimum fitness which selected from 3 number of trial. "Mean" is known as the average error of 3 values that obtained the same combination of Ni and Nt while "Worst" is shows that the worst fitness of all 3 values of trial. The table of value on Ni (no of agent) and Nt (no of iteration) was presented in Table 4.6 below:

Table 4.5: Ni versus Nt

Nt \ Ni		10		20		30		40		50
50	Best Mean Worst	9.7418e+003 9.7570e+003 9.7731e+003	Best Mean Worst	8.5262e+003 8.7419e+003 8.9577e+003	Best Mean Worst	8.9164e+003 8.5248e+003 8.0333e+003	Best Mean Worst	7.9437e+003 7.5767e+003 8.0097e+003	Best Mean Worst	8.7415e+003 9.0761e+003
100	Best Mean Worst	6.9750e+003 7.0331e+003 7.3579e+003	Best Mean Worst	6.7973e+003 6.7999e+003 6.8001e+003	Best Mean Worst	7.7667e+003 8.0331e+003 8.3241e+003	Best Mean Worst	1.1130e+003 2.5441e+003 3.7651e+003	Best Mean Worst	7.0001e+003 7.8225e+003 8.4785e+003
150	Best Mean Worst	8.5724e+003 8.5999e+003 8.6046e+003	Best Mean Worst	7.3506e+003 7.5000e+003 7.6567e+003	Best Mean Worst	8.0798e+003 8.5543e+003 9.0743e+003	Best Mean Worst	7.0196e+003 7.5888e+003 8.0312e+003	Best Mean Worst	6.0665e+003 6.3211e+003 6.5041e+003
200	Best Mean Worst	7.0198e+003 7.4567e+003 7.9488e+003	Best Mean Worst	9.8514e+003 9.8996e+003 9.9071e+003	Best Mean Worst	6.7218e+003 6.8456e+003 7.0554e+003	Best Mean Worst	6.7678e+003 6.8945e+003 7.0427e+003	Best Mean Worst	5.3518e+003 5.5543e+003 5.9764e+003
250	Best Mean Worst	8.1655e+003 8.5489e+003 8.7568e+003	Best Mean Worst	9.8514e+003 9.8921e+003 9.9654e+003	Best Mean Worst	6.2118e+003 6.3211e+003 6.4007e+003	Best Mean Worst	5.7418e+003 5.7719e+003 5.8593e+003	Best Mean Worst	4.4418e+003 4.7090e+003 4.9002e+003
300	Best Mean Worst	5.7725e+003 6.0761e+003 8.5486e+003	Best Mean Worst	5.1908e+003 5.3879e+003 5.7983e+003	Best Mean Worst	6.4428e+003 6.6329e+003 7.0588e+003	Best Mean Worst	3.7228e+003 3.8119e+003 4.0441e+003	Best Mean Worst	3.7121e+003 3.7917e+003 3.8791e+003

After analysis of the Table 4.5, for the best graph on the value Ni (no of agent) and Nt (no of iteration) is when Ni=10 and Nt=200 which is when the error is 7.0198e+003 marked in colour orange. Even though, the error is quite high but the graph shows the best stability among others. The best error among the rest is 1.1130e+003 while the worst mean was 3.7651e+003 when Ni=40 and Nt=100. When combination Ni=30 and Nt=200, the best fitness that shown is 5.1908e+003 while for the worst error is 5.7983e+003. Lastly for the worst mean, it includes of the best fitness is 9.8514e+003 and the worst fitness is 9.9071e+003 when Ni=20 combine with Nt=200.

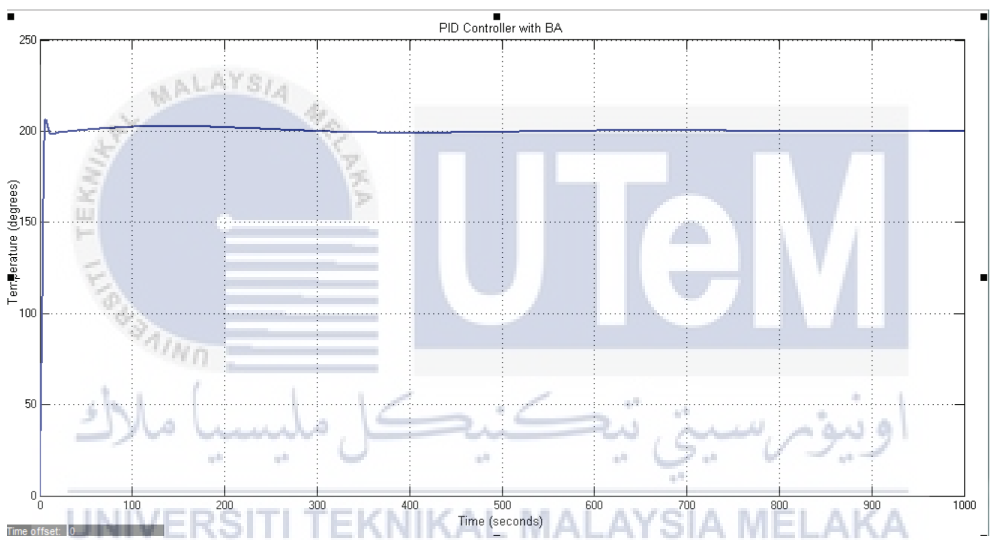

Figure 4.13: Graph when Ni=10 and Nt=200

After analysis on the SIMULINK in block PID Controller, the error is 7.0198e+003, Kp=1.5223, Ki=0.0302 and Kd=186.0974. Even though the error is huge but the graph shows stability in this system. From both graph in first stages and second stages, the graph in second stages more smoothly than the first ones.

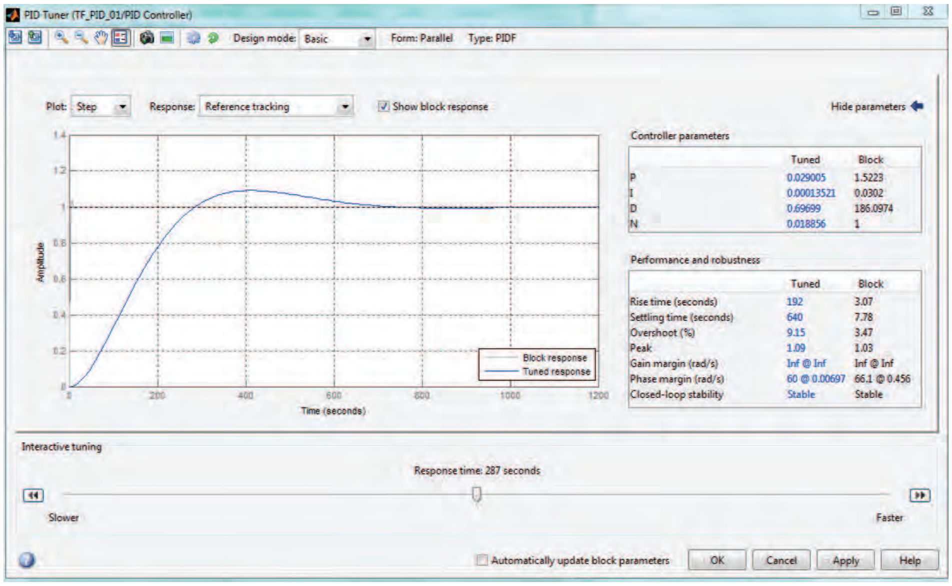

Figure 4.14: PID Tuner with the result when Ni=10 and Nt=200

From block response in PID Controller, the overshoot (%os) is 3.47% while the rise time is 3.07 seconds. The graph is nearly to stability.

Table 4.6: The new value of parameter and performance of the system using BA methods

Parameter	
Kp	1.5223
Ki	0.0302
Kd	186.0974
Performance	
Rise time (sec)	3.07
Settling time (sec)	7.78
Overshoot (%)	3.47
Peak	1.03

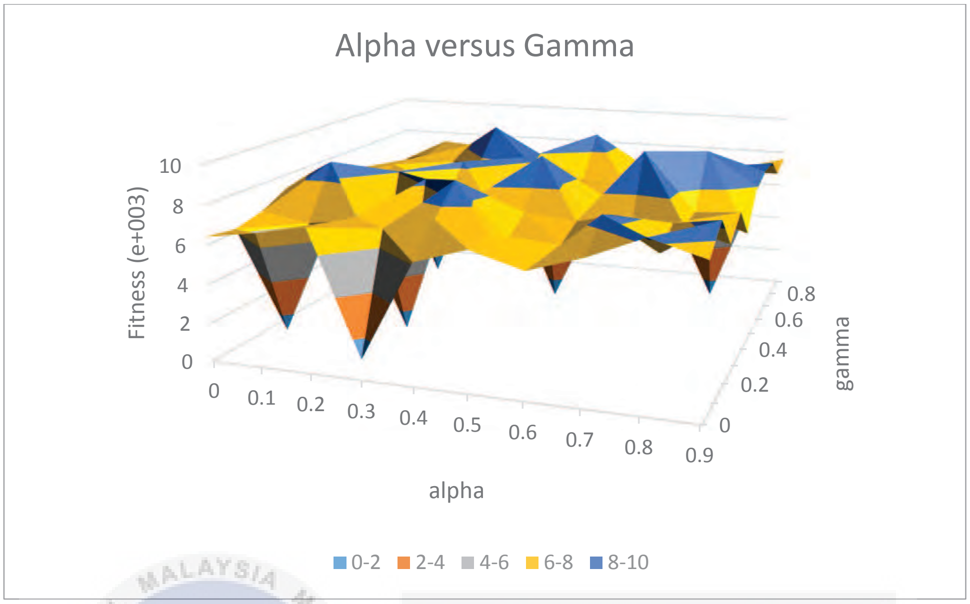

Figure 4.15: alpha versus gamma versus fitness

Based on Figure 4.14, which is summarized in surface structure on Table 4.6 shows that the fitness changes corresponding to alpha and gamma. Therefore, in order to get stability on output graph, the combination of alpha and gamma need to be simulate to 3 trial to get the best fitness. There showed some fluctuation of fitness happened when combination on alpha and gamma.

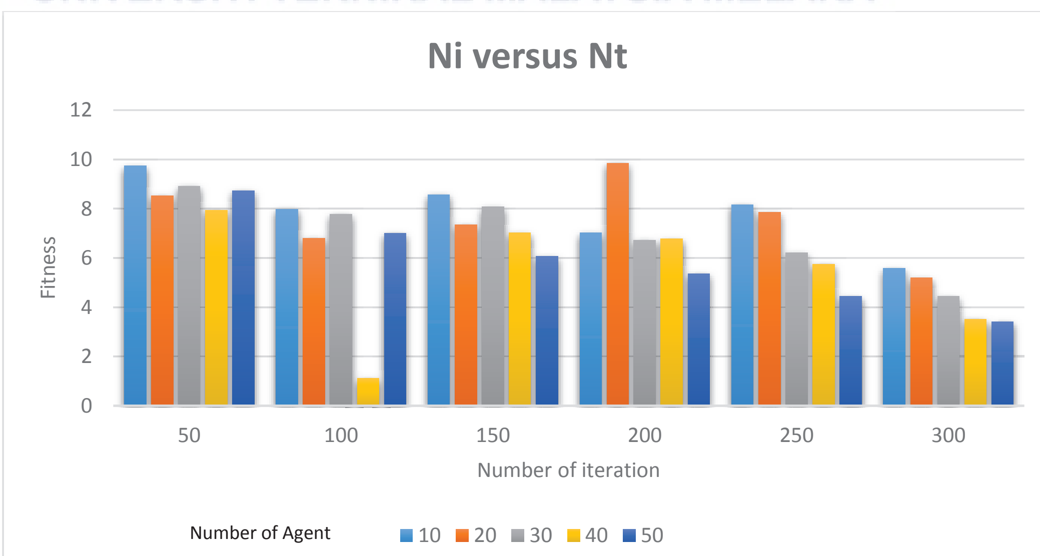

Figure 4.16: Ni versus Nt versus Fitness.

In Figure 4.16, it is showed that the optimal solution is improved when number of iteration increase. This bar graph illustrate when the number of iteration from 50 to 300, the pattern of fitness value decrease. Same goes when Ni=10, Ni=20, Ni=30, Ni=40 and Ni=50 combine with Nt=300, the value of fitness decrease linearly. Furthermore, for number of agent (Ni) also have the same situation as nest that when number of agent decrease, the number of error also decline and thhe optimal solution is improved. It shows that when the Ni=50, the pattern from Nt=50 to Nt=300, the number of fitness reduce linearly. Unfortunately, in order to obtain the result, the increase of agent and iteration leads to a longer time. Therefore, the number of agent and iteration need to have a limited duration to a certain range to collect data.

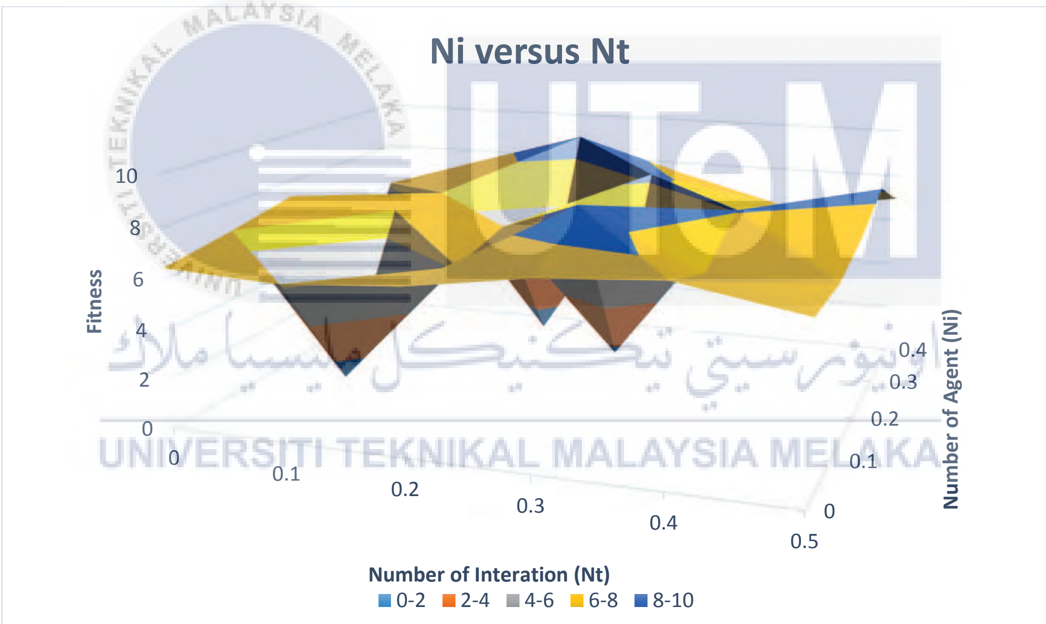

Figure 4.17: Pattern Ni versus Nt versus fitness

Referred on Figure 4.16, it showed the pattern on number of agent versus number of iteration and fitness. There are many fluctuation happened but related to bar graph on Figure 4.15 above, the arrangement on the number of agent and iteration decrease, then the fitness decrease. Therefore, the optimal solution is capable to be improved.

4.6 The final result

As the result, the comparison between all the tuning is verify to show the best graph that full the requirement given in order to enhance the barrel heating system. Table 4.5 was divided into the response on the value without PID Controller, PID Controller with Auto tuning, PID Controller with Root-Locus, PID Controller with Ziegler Nichols and last but not least, PID Controller with Bat Algorithm.

Table 4.7: The comparison on the system without, with PID controller on different tuning

Response	**Without PID Controller**	**With PID Controller**			
		Auto Tuning	**Root-Locus**	**Ziegler-Nichols**	**Bat Algorihm**
Rise Time (sec)	25	2.9	50	1.04	3.07
Settling Time (sec)	582	9.05	270	8.71	7.78
Overshoot	67.2	8.63	0	31.1	3.47
Peak Time	1.65	1.09	1	1.31	1.03

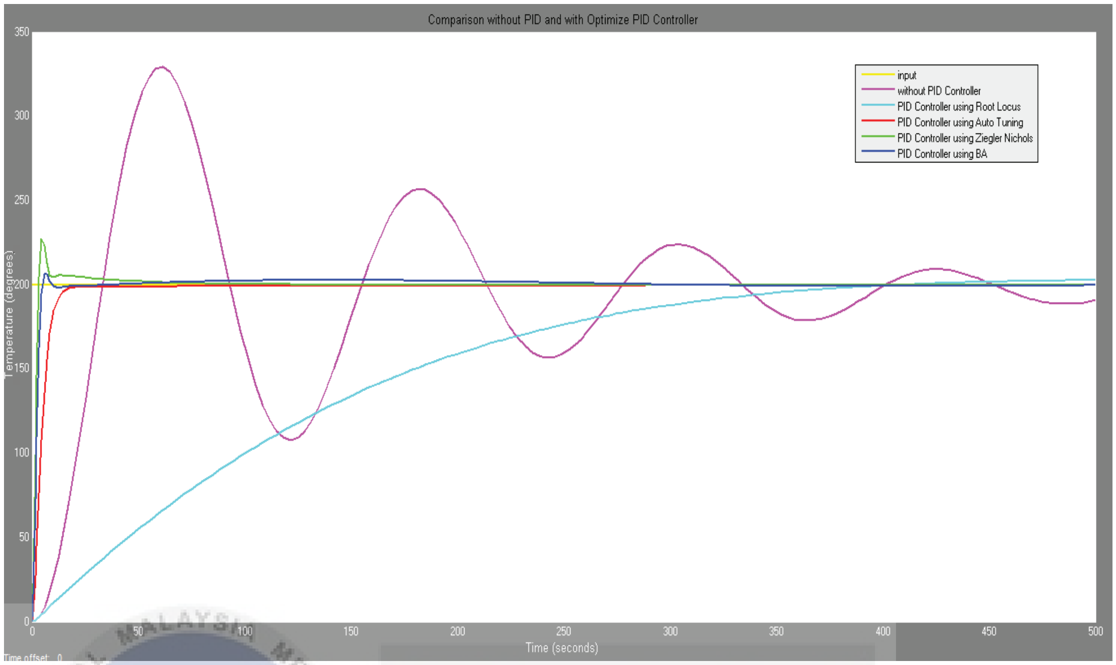

Figure 4.18: The comparison of all different tuning

From the Table 4.5, when using the system with PID controller is way to better to improvise the graph output on the system. The tuning that achieve the requirement of overshoot on Barrel Heating System is root locus which achieve about zero percent while for the requirement that achieve on least number of rise time is Ziegler Nichols tuning which about 1.09 seconds. Overall, the best tuning of all the tuning used in this system is Bat Algorithm. All the requirement on the response of using Bat Algorithm is lower than others and fulfil the requirement on rise time and overshoot. The value on rise time 3.09 seconds which third lowest while the settling time is 7.78 seconds which is lowest number than other tuning. For overshoot, the ranking of Bat Algorithm is 3.07 % which is the second lowest and lastly same with the number peak about 1.03 on the second ranking after Root Locus tuning. It show that PID Controller optimize with BA can optimal the solution on Barrel Heating System.

CHAPTER 5

CONCLUSION

5.1 Conclusion

As a conclusion, PID Controller optimization had been successfully designed to control Barrel Heating System using simulation on the MATLAB. The comparison of the tuning has been made and simulation techniques show a better result of the system. The simulation technique by using simple block diagram which is easier to run and execute the program is one of the advantage of simulation technique. When designing PID using root locus, Ziegler Nichols and auto tuning there is still have a weakness in order to achieve the requirement of the system but there still can be improve in some part to comparison to show the output response. After that, Bat Algorithm was used in this research in order to identify the effectiveness on Barrel Heating System which is these technique using mathematically design for implement into MATLAB software.

From the result and comparison above, it shows that PID Controller optimization using BA is the best among other which achieving the requirement given. The parameter in BA coding which are α, γ, Ni and Nt cause the performance of the system better than basic PID Controller. The higher the number of agent and iteration, the lower the number of fitness will be which is improved the optimal solution in this system. In this paper shows that BA had potential on Barrel Heating System in order to control temperature of reducing rise time and avoid overshoot.

5.2 Recommendation

For future research in order to improve Barrel Heating System, other metaheuristic algorithm can be analyzed. For example Cuckoo Search Algorithm (CSA), Particle Swarm Algorithm (PSO), Genetic Algorithm (GA), Harmony Search Algorithm (HSA) and other algorithm. By analyzed the system with other algorithm, the optimal solution will be found by compare with each other.

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APPENDICES B

Nt \ Ni	10	20	30	40	50
50	8.7418e+003 Kp=7.4278 Ki=-0.0561 Kd=168.4757	7.5262e+003 Kp=19.2867 Ki=-0.1471 Kd=265.1600	6.9164e+003 Kp=13.9748 Ki=-0.1057 Kd=295.9736	7.1437e+003 Kp=16.9213 Ki=-0.1302 Kd=288.5936	6.7415e+003 Kp=11.6290 Ki=-0.0832 Kd=297.9986
100	6.9750e+003 Kp=11.4910 Ki=-0.0833 Kd=277.8434	6.7973e+003 Kp=11.7174 Ki=-0.0835 Kd=293.7217	7.7667e+003 Kp=9.7711 Ki=-0.0730 Kd=219.0113	1.1130e+003 Kp=15.4904 Ki=0.0726 Kd=116.9723	7.5001e+003 Kp=22.1814 Ki=-0.1224 Kd=257.7295
150	7.9724e+003 Kp=20.8819 Ki=-0.1498 Kd=237.5391	6.9506e+003 Kp=14.7599 Ki=-0.2002 Kd=277.4476	6.0798e+003 Kp=2.8963 Ki=0.0331 Kd=288.0101	7.0198e+003 Kp=1.5223 Ki=0.0302 Kd=186.0974	6.0665e+003 Kp=3.0348 Ki=0.0297 Kd=288.0489
200	7.2465e+003 Kp=3.0134 Ki=-0.0029 Kd=178.4597	9.8514e+003 Kp=10.9752 Ki=-0.1552 Kd=139.3432	8.7218e+003 Kp=7.4278 Ki=-0.0521 Kd=158.2347	7.7678e+003 Kp=5.4231 Ki=-0.0541 Kd=238.4007	9.4518e+003 Kp=8.4311 Ki=0.0211 Kd=140.4117
250	9.1655e+003 Kp=14.6378 Ki=-0.1076 Kd=175.4238	9.8514e+003 Kp=10.1552 Ki=-0.1095 Kd=288.1200	8.2118e+003 Kp=5.4128 Ki=-0.161 Kd=218.4757	8.7418e+003 Kp=6.5687 Ki=-0.0211 Kd=171.4757	8.7418e+003 Kp=7.1543 Ki=-0.0331 Kd=199.4237
300	8.7725e+003 Kp=12.7241 Ki=-0.0969 Kd=186.6472	7.1908e+003 Kp=17.4910 Ki=-0.2415 Kd=208.2250	6.7428e+003 Kp=7.4278 Ki=-0.0641 Kd=168.3347	5.7228e+003 Kp=7.4278 Ki=-0.2341 Kd=117.4657	5.7121e+003 Kp=7.4278 Ki=-0.6931 Kd=188.4711

A Brief Review of Bat Algorithm (BA) Research Progression from 2010 to 2014

First A. Author, *Fellow, IEEE*, Second B. Author, and Third C. Author, Jr., *Member, IEEE*

Abstract*— Bat Algorithm is one of the example of Metaheuristic algorithms besides Particle Swarm Optimization (PSO), Firefly Algorithm and Harmony Search Algorithm (HSA). The Bat Algorithm is based on the echolocation behavior of bats that can fascinate the prey's attention. This paper gives a brief insight of the advancement of the Bat Algorithm from 2010 until 2014. Toward the starting, this paper is clarified the inclining of production from 2010 until 2014. At that point, it is clarify the commitment of the individual distribution identified with Bat Algorithm based on three categories: modifications, hybridizations and applications. It is accepted that this paper will extraordinarily advantage to the user who needs understanding about the trends of Bat Algorithm's publications.

***Index Terms*--- Bat Algorithm, Metaheuristic Algorithm,**

I. Introduction

Metaheuristic algorithms, for example, particle swam optimization (PSO) and simulated annealing is currently getting to be most effective systems for tackling an optimization problems. The greater part of heuristic and metaheuristic optimization has been gotten from the conduct of natural and physical framework in nature.

Bat Algorithm (BA) is another example of metaheuristic method that based on the echolocation behaviour of bats. The capacity of echolocation of microbats is interesting as these bats can discover their prey and discriminate algorithm by idealizing the echolocation behaviour of bats.

The publication papers include journals and conference proceedings are accumulated from well-established online databases like IEEE Explore, Scopus, ScienceDirect, Elsevier, and Scientific.Net. The keyword "Bat Algorithm" is utilized to inquiry the papers. In the wake of gathering papers from the online databases, the procedure of disposal is done to dispose of undesirable and irrelevant papers. In conclusion, it just left with 80 papers identified with BA. In light of years 2010 until 2014, there are 48 papers brief about the modifications and 16 of hybridization of BA and the rest are applications of original BA. From these 80 papers, there are 54 papers classes under journal and the remaining is under classifications of conference proceedings.

II. Format of Manuscript

II.1. Publication by Year

Fig. 1 demonstrates the quantity of production of BA on yearly start from year 2010 to 2014. It is seen that there are marginally diminish on 2011 preceding it abruptly expand the quantity of production until 2013. On the other hand, the distribution demonstrates a little bit difference on the 2014.

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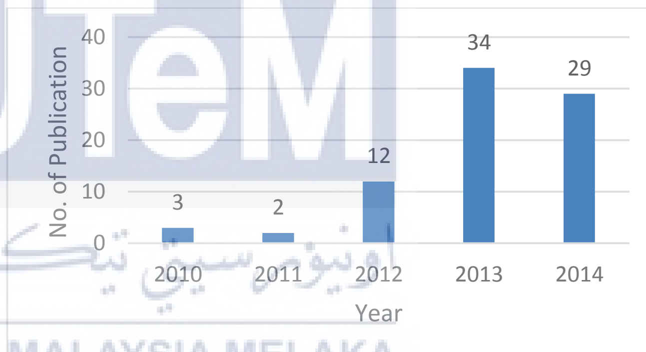

Fig. 1. Number of publications by year

II.2. Publication by Type of Publication

There are 54 journals out of totals 80 papers reviewing on this paper. The remaining papers are based on conference proceedings. Table 1 shows the contribution of journals towards BA publications. These are the few scientific journals that contributed the most; journal of applied mechanics and materials, electrical power and energy system, and advanced material research.

II.3. Publication by Country

Analyses through the publications of nation are additionally essential on the grounds that from the recorded data it will demonstrate the most contributed nation in exploration of BA. From the discoveries, the most noteworthy rate is originates from India. It is the most striking contrasted with others with 27%. At that point it took after by China and Iran with rates of 11% and 10% individually. United Kingdom and Malaysia imparting same number of rates of 8% while Turkey is contributed 5%. Other than that, 4% of rates are contributed by Taiwan, Slovenia and Brazil other than 3% of rates are contributed by Mexico, Bosnia and Herzegovina, Egypt, Canada and USA. The remaining nation: Trinidad and Tobago, Romania and Switzerland are individually contributed 1%.

D. Publication by Type of Contribution

From this paper, the BA publication was isolated into 3 main area of contributions: BA alteration, BA hybridization and BA application. In light of our discoveries, there are 48 papers clarify about the improving of BA, 16 papers is about the hybridization of BA by converging with others algorithms, and the offset papers is basically clarifying about the utilizations of BA.

TABLE I
JOURNALS/PROCEEDINGS

No	Journal/Proceedings	No. of Paper
1.	ICTACT Journal On Soft Computing	1
2.	4th International Conference, SEMCCO Swarm, Evolutionary, and Memetic Computing	1
3.	IFIP Advances in Information and Communication Technology	1
4.	International Conference for the Information Community	1
5.	Neural Computing & Application	1
6.	Computers and Structures	1
7.	Journal of Computer and Information Technology	1
8.	International Journal Of Intelligent Systems And Applications	1
9.	Elektrotehniski vestnik	1
10.	Springer-Verlag Berlin Heidelberg	1
11.	Nature Inspired Cooperative Strategies for Optimization	1
12.	Computational Intelligence and Neuroscience	1
13.	International Conference on Mining Intelligence and Knowledge Exploration	1
14.	The Scientific World Journal	1
15.	Journal of Intelligent Learning Systems and Applications	1
16.	I.J. Modern Education and Computer Science	1
17.	International Journal of Electrical and Electronic Engineering & Telecommunication	1
18.	International Journal of Computer Applications	1
19.	Journal of Computers	1
20.	Recent Researches in Telecommunications, Informatics, Electronics and Signal Processing	1
21.	Engineering Computations	1
22.	International Journal of Computer Science & Engineering Technology	1
23.	International Journal of Bio-Inspired Computation	1
24.	IEEE Int. Conference on Future Generation Communication Technology	1
25.	Nature and Biologically Inspired Computing	1
26.	Conference on Graphics, Patterns and Images	1
27.	Annual Conference Companion on Genetic and Evolutionary Computation	1
28.	Asian Journal Of Civil Engineering	1
29.	Lecture Notes on Software Engineering	1
30.	The Scientific World Journal	1
31.	International Journal of Applied Information Systems	1
32.	Telkomnika	1
33.	Elektronika Ir Elektrotechnika	1
34.	International Journal Of Engineering And Computer Science	1
35.	Advances in Engineering Software	1
36.	Applied Mechanics and Materials	1
37.	IEEE Transactions On Magnetics	1
38.	IEEE International Power Engineering And Optimization Conference	1
39.	Conference On Computer And Robot Vision	1
40.	IEEE Congress On Evolutionary Computation	1
41.	Iranian Conference On Intelligent Systems	1
42.	Software Engineering, Artificial Intelligence, Networking And Parallel/Distributed Computing	1
43.	Second International Conference On Robot, Vision And Signal Processing	1
44.	IEEE International Conference On Systems, Man, And Cybernetics	1
45.	International Conference On Machine Intelligence And Research Advancement	1
46.	International Conference On System Theory, Control And Computing	1
47.	International Conference On Computer And Knowledge Engineering	1
48.	International Conference On Communication And Signal Processing	1
49.	International Journal Of Bio-Inspired Computation	1
50.	International Conference On Mechatronic Sciences, Electric Engineering And Computer (MEC)	1
51.	8th Malaysian Software Engineering Conference	1
52.	IEEE SYSTEMS JOURNAL	1
53.	Power Electronics, Drive Systems And Technologies Conference	1
54.	International Conference On Advances In Engineering, Science And Management	1
55.	International Conference On Advances In Computing, Communications And Informatics	1
56.	Advances In Computing, Communications And Informatics (ICACCI, 2014 International Conference	1
57.	IEEE Student Conference On Research And Development	1
58.	Advances In Computing, Communications And Informatics (ICACCI, 2014 International Conference	1
59.	International Conference On Hybrid Intelligent Systems (HIS)	1
60.	International Conference On Circuits, Power And Computing Technologies	1
61.	Canadian Conference On Electrical And Computer Engineering	1
62.	IEEE Student Conference On Research And Development	1
63.	IEEE PES General Meeting | Conference & Exposition	1
64.	IEEE Systems Journal	1
65.	International Conference On Computation Of Power, Energy, Information And Communication	1
66.	IEEE Colloquium On Humanities, Science And Engineering Research	1
67.	International Journal Of Optimization In Civil Engineering	1
68.	IOSR Journal Of Engineering	1
69.	International Electrical Engineering Journal	1
70.	International Conference On Energy Efficient Technologies For Sustainability	1
71.	World Congress On Structural And Multidisciplinary Optimization	1
72.	Applied Mathematics and Computation	1
73.	Applied Mechanics and Materials	2
74.	Electrical Power and Energy Systems	2
75.	Neurocomputing	1
76.	Advanced Materials Research	2

77.	International Conference on Management and Artificial Intelligence	1

TABLE II
COUNTRY OF ORIGINS

No	Country	Number of Publication	Percentage
1	India	21	26%
2	China	8	10%
3	Iran	7	9%
4	United Kingdom	6	8%
5	Malaysia	6	8%
6	Switzerland	5	6%
7	Turkey	4	5%
8	Slovenia	4	5%
9	Taiwan	3	4%
10	Brazil	3	4%
11	USA	3	4%
12	Egypt	2	3%
13	Bosnia and Herzegovina	2	3%
14	Canada	2	3%
15	Singapore	1	1%
16	Mexico	1	1%
17	Trinidad and Tobago	1	1%
18	Romania	1	1%

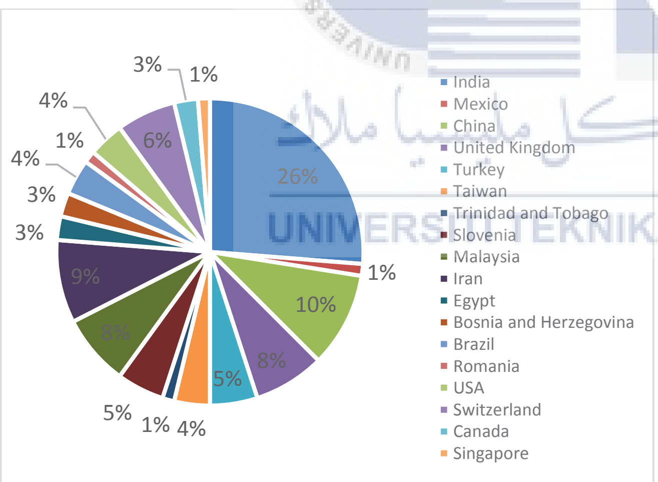

Fig 2. Country of Publications

II.4. Publication by Type of Contribution

Modifications of BA

The improvement of BA has been growing from 2010. There are various enhancement done on BA performance and Table III states the modification of BA.

Hybridizations of BA

The merging of two or more optimization technique between BA and others into a single algorithm is called hybridization. Basically, these combinations would give the best solution especially in term of performance: better fitness value or faster convergence rate, which outperforms BA table IV shows the hybridization of BA along the 5 years review.

Applications of BA

The interests in exploiting BA capabilities lead to the increase of application of BA in various areas. The main areas are computer science, Mathematics, Energy Engineering, etc. Table V shows the areas and applications of BA.

III. Conclusion

In this paper, the development of BA has been reviewed from 2010 to 2014. BA is still considered as a new algorithm, but its growth is remarkable during this five year.

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TABLE III
BA MODIFICATIONS

Author	Technique	Modification /Problem	Result	Ref.
Xingjuan Cai, Lei Wang, Zhihua Cui, Qi Kang	Bat Algorithm	Modification : Three variants of bat algorithms are employed Problem: Solving numerical optimization problem.	MBA is superior to other algorithms.	[3]
Xiaowei Wang, Wen Wang, Yong Wang	Adaptive Bat Algorithm (ABA)	Modification : Proposed an improved bat algorithm called adaptive bat algorithm (ABA) Problem: Improving the phenomenon of the premature convergence problem.	ABA not only has marked advantage of global convergence property but can also effectively avoid the premature convergence problem.	[4]
Xin-She Yang and Amir H. Gandomi,	Novel Approach Bat Algorithm	Modification : BA has been carefully implemented and carried out optimization for eight well-known optimization tasks. Then, a comparison has been made between the proposed algorithm and other	BA performs superior to many different existing algorithms used to solve these seven benchmark problems.	[21]

		existing algorithms. Problem: Solving engineering optimization tasks.		
O. Hasançebi T. Teke, O. Pekcan	Bat Inspired Algorithm (BIA)	Modification : using one benchmark as well as three practical truss structures that are sized for minimum weight subject to stress, stability and displacement constraints Problem: Solving the way bats use to navigate their surroundings .	The numerical results demonstrate efficiency of the proposed algorithm in practical structural optimization.	[6]
Jiann-Horng Lin, Chao-Wei Chou, Chorng-Horng Yang, Hsien-Leing Tsai	Bat Algorithm	Modification : Chaotic sequence and a chaotic Levy flight are incorporated in the metaheuristic search for efficiently generating new solutions Problem: Solving parameter estimation (model calibration) in nonlinear dynamic models of biological systems.	The parameters of the secondary system are adaptively optimized by the proposed chaotic Levy flight bat algorithm to make it follow the dynamics of the primary system.	[7]
Xin-She Yang	Bat-Inspired Algorithm	Modification : Proposing the Bat Algorithm based on the echolocation behaviour of bats. Problem: Combining the advantages of existing algorithms into the new bat algorithm.	Bat-Inspired Algorithm seems much superior to other algorithms,	[11]
Jian Xie, Yongquan Zhou, and Huan Chen	Novel Bat Algorithm	Modification : Proposing a novel bat algorithm based on differential operator and Levy flights trajectory. Problem: Introducing differential operator to accelerate the convergence speed of proposed algorithm, which is similar to mutation strategy “DE/best/2” in differential algorithm.	The simulation results not only show that the proposed algorithm is feasible and effective, but also demonstrate that this proposed algorithm has superior approximation capabilities in high-dimensional space.	[12]
Rangasamy Kotteeswaran and Lingappan Sivakumar	Novel Bat Algorithm	Modification : Retune the parameters of pressure loop PI controller of coal gasifier. Problem: Satisfying many constraints of functioning of coal gasifier on inputs and outputs.	The re-tune controller provides better response, meeting all the constraints at 0%. 50%, and 100% load conditions.	[13]
Aliasghar Baziar, Abdollah Kavoosi-Fard, Jafar Zare	Novel Self Adaptive Modification Approach Based on Bat Algorithm	Modification : solve the optimal energy management of MG including several RESs with the back-up of Fuel Cell (FC), Wind Turbine (WT), Photovoltaic (PV), Micro Turbine (MT) as well as storage devices to	The simulation results showed the feasibility and superiority of the proposed method over the other well-known methods in the area	[15]

		meet the energy mismatch Problem: The problem is formulated as a nonlinear constraint optimization problem to minimize the total cost of the grid and RESs, simultaneously		
Osama Abdel-Raouf, Mohamed Abdel-Baset, Ibrahim El-henawy	Improved Chaotic Bat Algorithm (IBACH)	Modification: Use chaotic behaviour to generate a candidate solution in behaviours similar to acoustic monophony Problem: Solving integer programming problems.	IBACH algorithm is superior to both HS and IHS in terms of both efficiency and success rate. This implies that IBACH is potentially more powerful in solving NP hard problems.	[16]
S.Sakthivel, R.Natarajan, P. Gurusamy	Bio-Inspired Bat Optimization Algorithm	Modification: Properly setting the real power generation from the generators in a power system Problem: Solving ELD problem which is to minimize the fuel cost and this is the most common form of optimal power flow (OPF) problems	The numerical results clearly show that the proposed algorithm gives better results. The strength of the algorithm is proved with two different objective functions, both smooth and non-smooth functions.	[18]
Gang Li, Jinliang An, Chunchua Chen	Bat Model	Modification: Proposing a fully new model which was called bat model for determining the initial tracking position and tracking direction automatically, we proposed a fully new model, Problem: Solving the two difficulties of automatic approaches of road extraction which is the first one is how to identify initial tracking position and direction automatically, and the second one is how to complete the tracking process correctly with the disturbing influence.	The proposed method can determine initial tracking position correctly, and complete the tracking process automatically even if the road represents a shape of ribbon with a big bending and the disturbing influence.	[19]
Xin She Yang	Multi-objective bat algorithm	Modification: Validated against a sub-set of test functions and then applied to solve multi-objective design problem. Problem: Solving multi-objective design problem such as welded beam design.	Simulation results suggest that the proposed algorithm works efficiently	[23]
R.Y. M. Nakamura, L.A. M. Pereira, K.A.Costa, D. Rodrigues, J.P. Papa, X.S.Yang	Binary Bat Algorithm (BBA)	Modification: Associating or each bat a set of binary coordinates that denote whether a feature will belong to the final set of features or not. Problem: Finding the set of features that maximizes the accuracy in a	The proposed algorithm has outperformed the Compared techniques in 3 out of 5 datasets, being the second best in the remaining two datasets.	[26]

		validating set.		
A.Kaveh, P. Zakian	Enhanced Bat Algorithm (EBA)	Modification : Associating with different constraints and loadings such as stress, displacement and frequency constraints, static and time history dynamic loadings. Problem: Solving sizing optimization of skeletal structures consisting of truss and frame structures.	Results show the suitability and efficiency of the present algorithm for optimal design of skeletal structures.	[28]
Selim Yilmaz and Ecir U. Kucuksill e	Improved Bat Algorithm (IBA)	Modification : Exploration and exploitation mechanisms of BA are improved by three modification s which is Inertia Weigh Factor Modification , Adaptive Frequency Modification and Scout Bee Modification . Problem: Solving the problem that BA can easily get trapped in local minimum on most of the multimodal test functions.	Results indicate that proposed version is better than standard version in terms of solution quality.	[29]
Adis Alihodzic and Milan Tuba	Improved Bat Algorithm (IBA)	Modification : Add some elements from the differential evolution and from the artificial bee colony algorithm. Problem: Overcoming the existing conventional methods are being hindered by an exhaustive search when the number of thresholds is increased for the optimal multilevel thresholding.	Improved bat algorithm proved to be better than five other state-of-the-art algorithms, improving quality of results in all cases and significantly improving convergence speed.	[30]
Mo Yuanbin, Zhao Xinquan, Xiang Shujian	Local Memory Search Bat Algorithm (LMSBA)	Modification : Introducing local extreme search in BA local search, and the time complexity of LMSBA is same to BA. Problem: As economy grows, economic system becomes more complex with increasingly harsher requirements for mathematical methods; on the other hand, our understandin g of information has been deepened from simple certain information to complex uncertain information.	The result of the case study showed that the proposed algorithm was efficient, then the proposed algorithm was used to solve the grey economic dynamic system, and the results further showed that the method was valid for solving economic control problems.	[32]
S. Yılmaz, E. Ugur Kucuksill e, Y. Cengiz	Modified Bat Algorithm (MBA)	Modification : Modifying the equation of pulse emission rate and loudness of bats. Problem: Solving the number of problem dimension.	The results of MBA are superior in terms of solution quality on optimization problems compared to BA.	[33]
S. Subi, P. Thangam	Modified Bat	Modification : Creating a	MBAT takes and less error	[34]

	Algorithm (MBA)	flexible and effective method that uses Data Mining algorithms Problem: Shorten the time taking task for record deduplication.	rate when comparing to the GP	
O. Hasancebi, S. Carbas	Bat Inspired Algorithm (BI)	Modification: Using three real-size large steel frames under actual load and design considerations. Problem: Solve minimum weight design problems of steel frames	The results obtained provide a sufficient evidence for successful performance of the BI algorithm in comparison to other metaheuristics employed in structural optimization.	[35]
Teodoro C. Bora, Leandro dos S. Coelho, and Luiz Lebensztajn	Mono and Multi-Objective BA	Modification: It has 5 design parameters and 6 constraints for the mono-objective problem and 2 objectives, 5 design parameters, and 5 constraints for multiobjective version. Problem: Solving BLDC motor problem.	The results show a good trend for the mono-objective BA: the efficiency is always close to 95.23% when solving the BLDC motor problem.	[37]
S. Akhtar, A.R Ahmad, E. M. Abdel-Rahman	Bat Inspired Algorithm	Modification: Bat Algorithm is employed in this work for full human body pose estimation. Problem: Problem in full body articulated human motion tracking	The performance of BA is compared with Particle Filter (PF), Annealed Particle Filter (APF) and PSO using a standard data set. The qualitative and quantitative evaluation of performance of full body	[38]

			human tracking demonstrates that BA performs better then PF, APF and PSO.	
A.Chowdhury, P. Rakshit, A. Konar	Modified Bat Algorithm	Modification: Modified using BA to predict the Protein-Protein Interaction (PPI) network. Problem: Protein regulate every process in the cell and do not function in isolation.	The result reveals that the proposed method outperforms its competitors in predicting PPIs with respect to ten performance metrics.	[39]
Afrabandpey.H, Ghaffari. M, Mirzaei.A, Safayani. M	Novel Bat Algorithm	Modification: An improved version of Bat algorithm with chaos is represented. Problem: Difficulties of tackling real-world problems with growing complexities.	Simulation results on some mathematical benchmark functions demonstrate the validity of the proposed algorithm, in which the Chaotic Bat Algorithm (CBA) outperforms the classical BA.	[40]
G.Kalantzis, Y.Lei	Self-tuned Bat Algorithm	Modification: Minimizes the number of iterations required for optimization to reach the sub-optimal solution. Problem: A novel self-tuned metaheuristic algorithm is presented for optimization in radiation therapy treatment planning.	The studies indicated that upon the hyper-optimization the performance of the Bat algorithm can be increased by up to ~62%.	[41]
C.Sur, A.Shukla	Discrete Bat Algorithm	Modification: In bat algorithm, they also utilize their Echolocation	The result show that the algorithm has potential for better results and been compared	[42]

		property for further investigation of the search space for prey. Problem: Discrete domain problems.	with the converging rate of Ant Colony Optimization (ACO) & Intelligent Water Drops (IWD) algorithms.	
Yi-Ting Chen, Tsair-Fwu Lee, Mong-Fong Horng, Jeng Shyang Pan and Shu Chuan Chu	Echo-Aided Bat Algorithm	Modification: In EABA, the velocity of each bat not only considers the frequency of ultrasound but takes the echo time into account to suitably adjust the movement steps of bats. Problem: To employ the echo time. To measure the distance from bats and objective.	The experimental numeric result shows that Echo-Aided Bat Algorithm (EABA) has better ability of search to improve the quality of the best solution than BA.	[43]
Y.T. Chen, B.Y.Liao, C.F.Lee, W.D.Tsay, M.C.Lai	Adjustable Frequency Bat Algorithm	Modification: Adjustable frequency was determined by flight direction of bats to adapt the velocity toward the correct direction. Problem: To improve solution accuracy for optimization problem.	The experiment numeric result shows that AFBA has better ability of search to improve the quality of the global optimal solution than BA.	[44]
G.Kumaravel, C.Kumar	Novel Bats Echolocation Algorithm	Modification: Design of self-tuning PI controller for STATCOM Problem: To improve the voltage profile and transient stability in power system.	The dynamic responses were better than the fixed gain PI controller and PSO based self-tuning PI controller.	[50]
Amr Rekaby	Directed Artificial Bat Algorithm (DABA)	Modification: Introduce a new innovative algorithm Directed Artificial Bat Algorithm (DABA). Problem: The importance of these algorithms is increased by time due to the complex scientific applications, and other optimization problems demand.	DABA achieves better results than ABC with efficiency enhancements between 5% and 10%.	[51]
C.Yammani, S.Maheswarapu, S.Kumari Matam	Shuffled Bat Algorithm	Modification: 84-bus distribution system was tested with proposed algorithm. Problem: For optimal planning of the Distributed generation (DG's) with renewable bus available limit constraint.	The new planned shuffled bat algorithm is tested and compared with other optimization technique like GA and BA. This work is tested on 84-bus distribution systems and results are found to be satisfactory.	[55]
N.Niamul Islam, M A Hannan, H.Shareef and A.Mohamed	Bat Optimization Algorithm	Modification: Optimize BOTOA for optimal design of Power System Stabilizer (PSS). Problem: To minimize the value of objective function.	The comparison of both algorithm reveals the effectiveness of BOTOA over PSO in tuning of PSS parameters for multi machine power system.	[56]
P.Li, Z.Zhou, R.Shi	Improve Bat Algorithm	Modification: Improved bat algorithm along with point estimate method to optimize the operation of microgrid.	The results of numerical examples verified that the proposed method can find optimal operating cost distribution under uncertain environment.	[57]

		Problem: Optimize the operation of MG under uncertain environments.		
T.Nikman, R.Rasoul Azizipanah-Abarghooee, M.Zare and B.Bahmani-Firouzi	Multi-objective Self-Adaptive Learning Bat Algorithm	Modification: Developed a new multi-objective SALBA solution technique to solve the RCDEED problem. Problem: A complex nonlinear non-smooth and non-convex multi-objective optimization problem.	Numerical results evaluate the performances of the framework for real-size test-system.	[58]
R.Kheirollahi, F.Namdari	Modified Bat Optimization Algorithm	Modification: A modified Bat Optimization Algorithm (BOA) has been applied. Problem: The optimal coordination of over current relays problem.	Results show the proposed method has significantly reduced the execution time of the algorithm while improving the accuracy of the output results.	[61]
S.Carbas, O.Hasancebt	Bat Inspired Optimization (BIO) Algorithm	Modification: Sized the steel space frame Problem: Cost of structures	BIO produced improved results with respect to other methods of meta heuristics.	[63]

TABLE IV
BA HYBRIDIZATIONS

Author	Technique/ Hybridization	Problem	Result	Ref.
Iztok Fister Jr, Dusan Fister, and Xin-She Yang	Technique: BA and Differential Evolution (DE) Hybridization: Hybridizing the original BA using DE Strategies.	Solving lower dimensional optimization problem.	HBA significantly improves the original bat algorithm.	[9]
Nazri Mohd. Nawi, M. Z. Rehman, Abdullah Khan	Technique: BA and Back-Propagation Neural Network Hybridization: Combination of BA and Back Propagation Neural Network	Solving local minima problem in gradient descent trajectory and increase the convergence rate.	The simulation results show that the computational efficiency of BPNN training process is highly enhanced when combined with BAT algorithm	[10]
Iztok Fister Jr, Simon Fong, Janez Brest, and Iztok Fister	Technique: BA and DE Hybridization: Hybrid BA using different DE strategies.	Improving the current best solution directing the swarm of a solution towards the better regions within a search space.	The results of exhaustive experiments were promising and have encouraged us to invest more efforts into developing in this direction.	[14]
Adis Alihodzic, Milan Tuba	Technique: BA and Kapur's Method Hybridization: BA combine with Kapur's Method	Searching for the multilevel thresholds using the maximum entropy based criterion.	The computational times show that the BA algorithm outperformed CS algorithm.	[20]
Xing Shi He, Wen Jing Ding, Xin She Yang	Technique: BA, simulated annealing and Gaussian Perturbations Hybridization: BA based on simulated annealing and Gaussian Perturbations	Enhancing bat algorithm performance.	SAGBA is superior to the other two algorithms in terms of convergence and accuracy.	[5]
Iztok Fister Jr., Dusan Fister, Uztik Fister	Technique: Differential Evolution, Bat Algorithm and Random Forest Regression Hybridization:	Balancing an exploration and exploitation by a large scale function optimization.	Hybridized algorithms improved the original bat algorithm significantly.	[27]

	Hybridization of the bat algorithm with differential evolution strategies and a random forests machine learning method.			
Monica Sood, Shilpi Bansal	Technique: K-Medoid Clustering Algorithm and Bat Algorithm Hybridization: K-Medoids Clustering Technique using Bat Algorithm	Knowing the initial value based on the echolation behaviour of bats and overcoming the K-Medoids issues.	The use of this hybrid approach for the clustering as well as achieving better efficiency.	[31]
Nazri Mohd Nawi, M. Z. Rehman, M. I. Ghazali, M. N. Yahya	Technique: BAT based metaheuristic optimization, back-propagation neural network, and fuzzy logic. Hybridization: Combination of BAT based metaheuristic optimization, back-propagation neural network, and fuzzy logic.	Predicting Noise-Induced Hearing Loss (NIHL) in Malaysian workers.	The results obtained through Hybrid Bat-BP will be able to help us identify and reduce the NIHL rate in the workers with high accuracy.	[36]
M.K. Ramawan, Z. Othman, S.I. Sulaiman, I. Musirin, N.Othman	Technique: BA and ANN Hybridization: Combination of BA and ANN	To predict the output power in photovoltaic system	The result for BA-ANN had performed more than EP-ANN in term of producing lower root mean square error (RMSE.)	[64]
H.Li, J.Xing	Technique: BP Neural Network and BA Hybridization:: Optimize the BP neural network weights and threshold by the BA.	To apply the BP neural network to combat effectiveness evaluation, propose the thought of make the photoelectric defence system combat effectiveness value to different "classification".	The weakness of the expert decision-making system not easy was overcome.	[65]
Yazan A.Alsariera, Hammoudeh S.Alamri, Abdullah M.Nasser, Mazlina A.Majid, Kamal Z.Zamli	Technique: Bacteria Fpraging Optimization (BFO) and BA Hybridization: BFO and BA have been adopted for comparison using 12 selected benchmark functions.	To finding the best solution from all feasible solutions.	BFO gives more accurate solution as compared to BA. However, BA exhibits faster convergence rate.	[66]
P.Savsani, R.L.Jhala, V.J.Savsani	Technique: Artificial Bee Colony (ABC), biogeography-based optimization, gravitational search algorithm, cuckoo search algorithm (CSA), firefly algorithm, bat algorithm, and teaching-learning-based optimization (TLBO). Hybridization: Seven different metaheuristic optimization algorithms developed between 2005 and 2012 are applied are applied on robot arm.	To plan a trajectory which can minimize joint travelling time, joint travelling distance, and total joint Cartesian lengths.	The significance of TLBO, ABC, and CS for the robot trajectory optimization problems.	[67]
A.Garg, P.K.Mahapatra, A.Kumar	Technique: Bat and PSO algorithm.	To optimize the lathe tool positional error in a	Both metaheuristic algorithms were tested on	[68]

	Hybridization: Using two algorithm methods to optimize the lathe tool positional error in a developed machine vision system for determination of lathe tool position and verification.	developed machine vision system for determination of lathe tool position and verification.	the lathe tool movement ranging from 0.020mm to 7mm. BA resulted outperforms than PSO algorithm.	
N.Din Mustafa, A.Athif Mohd Faudzi, A.Faiz Zainal Abidin, K.Osman, K.Suzumori.	Technique: Reaction Curve Method (RCM) and Bat Algorithm (BA) Hybridization: Two methods are proposed to obtain the plan models. The plant models from both methods were used to access position control of the actuator using GPC algorithm.	To control strategy for a double acting pneumatic cylinder.	The results show that by using BA, the overshoot is eliminated and steady state error is reduced compared to RCM.	[69]
T.Alemu Lemma, F.Mohd Hashim	Technique: Fuzzy System and Bat Algorithm Hybridization: The fuzzy models are trained applying locally linear model tree algorithm followed by a meta-heuristic nature inspired algorithm	Capture variation of exergy destruction in a Gas Turbine Generate (GTG).	The result is a demonstration of how powerful BA is in nonlinear model identification.	[70]

	called Bat Algorithm.			
Mrs. V.Usha Reddy, A.Manoj	Technique: Fuzzy Logic and Bat Algorithm Hybridization: Fuzzy Logic is used to find optimal capacitor locations while Bat Algorithm is used to find optimal capacitor sizes.	Loss reduction in distribution system	By installing capacitors at all potential locations, the rel power loss has been reduced significantly.	[71]
P.Li, Z.Zhou, R.Shi	Technique: Improved Bat Algorithm & Point Estimate Method Hybridization: Proposing Improved Bat Algorithm along Point Estimate Method	Optimizing the operation of microgrid.	The results of numerical examples verified that the proposed method can find optimal operating cost distribution under uncertain environment.	[57]
Lemma Tamiru Alemu, Fakhruldin Mohd Hashim,	Technique: Normalized Radial Basis Function and Bat Algorithm Hybridization: Demonstrate the use of normalized radial basis function (NRBF) network and Bat Algorithm (BA) for size optimization of a mechanical part under static loading.	Problem: Developing the NRBF model is generated simulating a parameterized CAD model.	NRBF-BA model is indeed effective in providing a reasonable solution for a moderately complex problem.	[77]

TABLE V

BA APPLICATIONS

Area	Applications	Authors	Year	Ref
Energy	Optimal operation management of Microgrid (MG) using Point estimate method (PEM) and Bat algorithm (BA)	P.Li, Z.Zhou, R.Shi	2014	[57]
	Optimal partial-returning of decentralised PI controller of coal gasifier using Bat Algorithm	Rangasamy Kotteswaran, Linggappan Sivakumar	2013	[2]
	Re-tuning of PI Controller of Coal Gasifier for Optimum Response.	Rangasamy Kotteswaran, and Lingappan Sivakumar	2013	[13]
	Novel Self Adaptive Modification Approach Based on Bat Algorithm for Optimal Management of Renewable MG	Aliasghar Baziar, Abdollah Kavoosi-Fard, Jafar Zare	2013	[15]
	Application of bat algorithm for Combined economic load and emission	Bandi Ramesh, V Chandra Jagan Mohan and V C Veera Reddy	2013	[17]
	Application of bat optimization algorithm for economic load dispatch considering valve point effects	S.Sakthivel, R.Natarajan, P. Gurusamy	2013	[18]
	Thyristor controlled series capacitor placement and sizing	G.Manikanta, Dr.G.V.Nagesh Kumar	2014	[59]
	Exergy modelling in a Gas Turbine Generator (GTG)	T.Alemu Lemma, F.Mohd Hashim	2011	[70]
	Optimal capacitor placement for loss reduction in distribution systems.	Mrs. V.Usha Reddy, A.Manoj	2012	[71]
	Optimal coordination of over current relays	R.Kheirollahi, F.Namdari	2014	[61]
	Grid-connected photovoltaic system output prediction	M.K. Ramawan, Z. Othman, S.I. Sulaiman, I. Musirin, N.Othman	2014	[64]
	Optimal spot pricing in electricity market with inelastic load	M. Murali, M. Sailaja Kumari, M. Sydulu	2014	[73]
	Robust tuning of power system stabilizer for small signal stability enhancement	D.K. Sambariya, R. Prasad	2014	[76]
Engineering	Use for structural optimization.	O. Hasançebi T. Teke, O. Pekcan	2013	[6]
	Bat algorithm is proposed to train BPNN to achieve fast convergence rate and accuracy	Nazri Mohd. Nawi, M. Z. Rehman, Abdullah Khan	2013	[10]
	Automatic road extraction from high resolution remote sensing image based on bat model and mutual information matching	Gang Li, Jinliang An, Chunchua Chen	2011	[19]
	Bat Algorithm (BA) for Image Thresholding	Adis Alihodzic, Milan Tuba	2010	[20]
	Global Engineering Optimization	Xin-She Yang and Amir H. Gandomi,	2012	[21]
	Solving topology optimization problems in microelectronic applications.	Xin She Yang, Mehmet Karamanoglu, Simon Fong	2012	[24]
	Utilized for size optimization of skeletal structures consisting of truss and frame structures.	A.Kaveh, P. Zakian	2014	[28]
	To solve minimum weight design problems of steel frames is outlined in the paper.	O. Hasancebi, S. Carbas	2014	[35]
	Solving BLDC motor problem.	Teodoro C. Bora, Leandro dos S. Coelho, and Luiz Lebensztajn	2012	[37]
	Adjustable frequency bat algorithm based on flight direction	Y.T. Chen, B.Y.Liao, C.F.Lee, W.D.Tsay, M.C.Lai	2013	[44]
	Full body human pose estimation	S. Akhtar, A.R Ahmad, E. M. Abdel-Rahman	2012	[38]
	Optimization Intrusions Detection Systems (IDS)	A.C.Enache, V.Sgarciu	2014	[45]
	Comparative study of different meta heuristics	P.Savsani, R.L.Jhala,	2014	[67]

	for the trajectory planning of a robotic arm.	V.J.Savsani		
	Design of self-tuning PI controller for STATCOM.	G.Kumaravel, C.Kumar	2012	[50]
	Optimize the lathe tool positional error in a developed machine vision system	A.Garg, P.K.Mahapatra, A.Kumar	2014	[68]
	Generalized predictive controller using BA for double acting pneumatic cylinder.	N.Din Mustafa, A.Athif Mohd Faudzi, A.Faiz Zainal Abidin, K.Osman, K.Suzumori.	2013	[69]
	Improved solution based on Bat Algorithm to vehicle routing problem in a Caravan range community.	A.Ochoa, L. Margain, J.Arreola, A.De luna, G.Garcfa, E.Soto. S.Gonzalez, K.Haltaufoerhyd and V.Scarandangotti	2013	[53]
	Optimal placement and sizing of DER's with Load models using Bat Algorithm.	C.Yammani, S.Maheswarapu, S.Kumari Matam	2013	[54]
	Optimal placement and sizing of multi distributed generation with renewable bus available limits using shuffled Bat Algorithm.	C.Yammani, S.Maheswarapu, S.Kumari Matam	2014	[55]
	Power system stabilizer design using BOTOA in multi machine power system	N.Niamul Islam, M A Hannan, H.Shareef and A.Mohamed	2013	[56]
	Optimum design of reinforced concrete frames	S.Gholizadeh and V.Aligholizadeh	2013	[60]
	Optimum Design of Steel Space Frames	S.Carbas, O.Hasancebt	2013	[63]
	Size optimization	Lemma Tamiru Alemu, Fakhruldin Mohd Hashim,	2014	[77]
Medical	Perceiving hairline bone fracture in medical X-ray images	Goutam Das	2013	[22]
Physics and Astronomy	Optimizing parameter estimation in nonlinear	Jiann-Horng	2010	[7]

Multi-disciplinary	dynamic biological systems	Lin, Chao-Wei Chou, Chorng-Horng Yang, Hsien-Leing Tsai		
	Protein-protein interaction network	A.Chowdhury, P. Rakshit, A. Konar	2014	[39]
	Improving a financial trust forest	Alberto Ochoa, Lourdes Margain, Alberto Hernandez, Julio Ponce, Alejandro De Luna, Arturo Hernandez & Oscar Castillo	2013	[25]
	Optimization in Radiation Therapy Treatment Planning.	G.Kalantzis, Y.Lei	2014	[41]
	An Echo-Aided bat algorithm to support measurable.	Yi-Ting Chen, Tsair-Fwu Lee, Mong-Fong Horng, Jeng Shyang Pan and Shu Chuan Chu	2013	[43]
	Optimization in cascade H-bridge multilevel inverters.	R.Khamooshi, J.SH. Moghani	2014	[49]
	Multi-user detection	Xiaozhi Liu, Jing Li	2013	[74]
Computer Science	Optimizing HFS scheduling problem to minimize makespan and mean flow time.	M.K. Marichelvam and T. Prabaharan	2012	[1]
	A Novel Bat Algorithm Based on Differential Operator and Lévy Flights Trajectory	Jian Xie, Yongquan Zhou, and Huan Chen	2013	[12]
	Comparing the proposed algorithm with other existing algorithms, including genetic algorithms and particle swarm optimization.	Xin-She Yang	2010	[11]
	A novel Hybrid Self-Adaptive Bat Algorithm	Iztok Fister Jr., Simon Fong, Janez Brest, and	2014	[14]

		Iztok Fister		
	Solve integer programming problems.	Osama Abdel-Raouf, Mohamed Abdel-Baset, Ibrahim El-henawy	2014	[16]
	Using Bat Algorithm with Levy Walk to solve directing orbits of chaotic systems	Xingjuan Cai, Lei Wang, Zhihua Cui, Qi Kang	2014	[3]
	Adaptive Bat Algorithm	Xiaowei Wnag, Wen Wang and Yong Wang	2013	[4]
	Enhancing bat algorithm performance	Xing Shi He, Wen Jing	2013	[5]
	Hybridization Bat Algorithm	Iztok Fister Jr., Dusan Fister, and Xin-She Yang	2013	[9]
	Solving multiobjective optimisation problems with MOBA.	Xin-She Yang	2011	[23]
	Binary bat algorithm for feature selection	R.Y. M. Nakamura, L.A. M. Pereira, K.A.Costa, D. Rodrigues, J.P. Papa, X.S.Yang	2012	[26]
	Differential evolution strategies with random forest regression in the bat algorithm	Iztok Fister Jr., Dusan Fister, Uztik Fister	2013	[27]
	Investigate the performance of proposed approach (IBA) on unimodal and multimodal benchmark functions.	Selim Yilmaz and Ecir U. Kucuksille	2013	[29]
	Improve quality of results in all cases and significantly in convergence speed.	Adis Alihodzic and Milan Tuba	2014	[30]
	Using bat algorithm for K-Medoids clustering technique	Monica Sood, Shilpi Bansal	2013	[31]
	Modifying the equation of pulse emission rate and loudness of bats.	S. Yılmaz, E. Ugur Kucuksille, Y. Cengiz	2014	[33]
	Optimization record deduplication using MBA.	S. Subi, P. Thangam	2013	[34]
	Predicting NIHL in Malaysian workers	Nazri Mohd Nawi, M. Z. Rehman, M. I. Ghazali, M. N. Yahya	2014	[36]
	Optimization tasks on chaos	Afraband pey.H, Ghaffari. M, Mirzaei.A, Safayani. M	2014	[40]
	Adaptive & discrete real bat algorithms for Route search optimization of graph.	C.Sur, A.Shukla	2013	[42]
	Application of an improved SVR based bat algorithm for short-term price forecasting in the Iranian pay-as-bid electricity market.	H.Taherian, I.N.Kakhki	2013	[46]
	Application of bat algorithm in dual Channel speech enhancement.	K.Prajna, G.Sasibhushana Rao, K.V.V.S. Reddy, R. Uma Maheswari	2014	[47]
	Topology optimization	X.S.Yang, M.Karamanoglu, S.Fong	2012	[48]
	Photoelectric Defense system-BP neural network optimized by BA	H.Li, J.Xing	2013	[65]
	Directed Artificial Bat Algorithm	Amr Rekaby	2013	[51]
	Hybrid model to improve BA performance	R.Gupta, N.Chaudhary, Saibal K.PAl	2014	[52]
	Planning the sports training sessions	Iztok Fister, Samo Rauter, Xin-She Yang, Karin Ljubic, Iztok Fister Jr	2014	[75]
	Stock price prediction	Xiaoyan Lv, Silong Sun, Hong Liu	2014	[78]
	Comparative study of global-best harmony search (GHSA) and Bat Algorithm (BA)	Pasura Aungkulanon	2014	[79]
	Solving multi-stage multi-machine multi-	Ponnapa Musikapu	2012	[80]

	product scheduling problems	n and Pupong Pongcharoen		
Education	Training feed forward neural networks in e-learning context	Koffka Khan, Ashok Sahai	2012	[8]
	Solve the grey economic dynamic system	Mo Yuanbin, Zhao Xinquan, Xiang Shujian	2013	[32]
Mathematics	Comparative performance analysis of BA and BFO algorithm using standard benchmark functions.	Yazan A.Alsariera, Hammoudeh S.Alamri, Abdullah M.Nasser, Mazlina A.Majid, Kamal Z.Zamli	2014	[66]
	Reserve constrained dynamic environment/economic dispatch.	T.Nikman, R.Rasoul Azizipanah-Abarghooee, M.Zare and B.Bahmani-Firouzi	2013	[58]
	Optimal power dispatch	S.Biswal, A.K.Barisal, A.Bahera and T.Prakash	2013	[62]
	ML estimation problems	V.P.Thafasal Ijyas, S.M. Sameer	2014	[72]

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APPENDICES D

Coding Bat Algorithm

```
% Terms
% x          - Position
% v          - Velocity
% t          - Iteration
% d          - Dimension (Parameters)
% N          - Number Of
% i          - Agent
% min        - Minimum
% max        - Maximum
% gamma      - Gamma
% alpha      - Alpha
% A          - Loudness
% bheta      - Bheta
% epsilon    - Epsilon
% f          - Frequency
% fit        - Fitness
% g          - Global Best
% u          - Upper Boundary
% l          - Lowwer Boundary

% Clear Workspace

clc;
clear;

% Initialize Problem Parameters

SampleTime = 50;

% Initialize Bat Algorithm Parameters

Nd = 3;
Nt = 300;
Ni = 50;

x = zeros(Nt,Ni,Nd);
xg = zeros(Nt,Nd);
fitg = zeros(Nt,1);
v = zeros(Nt,Ni,Nd);
f = zeros(Nt,Ni);
r = zeros(Nt,Ni);
A = zeros(Nt,Ni);
fit = zeros(Nt,Ni);

fmin = 0;
fmax = 100;

Amin = 1;
Amax = 2;
```

```
alpha = 0.7
gamma = 0.7;

fitg(1) = 9999999999999999;

ux = [20 10 300];
lx = [0 -10 0];

for i = 1:Ni

    for d = 1:Nd

        % Initialize The Bat Population
        x(1,i,d) = lx(d) + (ux(d) - lx(d)) * rand();

    end

    % Define Pulse Frequency
    bheta = 1/(1 + exp(-10 * (0.5 - rand())));
    f(1,i) = fmin + (fmax - fmin) * bheta;

    % Initialize Pulse Rates And Loudness
    r(1,i) = rand();
    A(1,i) = Amin + (Amax - Amin) * rand();

end

for t = 1:Nt

    t

    for i = 1:Ni

        Para1 = x(t,i,1);
        Para2 = x(t,i,2);
        Para3 = x(t,i,3);

        %Perform simulation on 'PSOpid'
        sim('TF_PID_01');

        result = open('result.mat');

        FF = 0;

        [sizeRow sizeCol] = size(result.ans);

        %Calculate error according to least square error
        for CounterTime = 1:sizeCol  %Diubah
            FF = FF + abs(result.ans(2, CounterTime) - result.ans(3,
CounterTime)); %Diubah
        end

        % Evaluate Fitness Of New Solution
```

```
        fit(t,i) = FF;

        % Update Global Best
        if fit(t,i) < fitg(t)
            fitg(t) = fit(t,i);
            xg(t,:) = x(t,i,:);
        end

        % Generate New Solution According Equation (2) and (4)
        bheta = 1/(1 + exp(-10 * (0.5 - rand())));

        for d = 1:Nd

            f(t,i) = fmin + (fmax - fmin) * bheta;
            v(t,i,d) = v(t,i,d) + (x(t,i,d) - xg(t,d)) * f(t,i);
            x(t,i,d) = x(t,i,d) + v(t,i,d);
        end

        for d = 1:Nd

            % Check for Boundary
            if x(t,i,d) > ux(d)
                x(t,i,d) = ux(d);
            end
            if x(t,i,d) < lx(d)
                x(t,i,d) = lx(d);
            end

        end

        Para1 = x(t,i,1);
        Para2 = x(t,i,2);
        Para3 = x(t,i,3);

        %Perform simulation on 'PSOpid'
        sim('TF_PID_01');

        result = open('result.mat');

        FF = 0;

        [sizeRow sizeCol] = size(result.ans);

        %Calculate error according to least square error
        for CounterTime = 1:sizeCol  %Diubah
            FF = FF + abs(result.ans(2, CounterTime) - result.ans(3,
CounterTime)); %Diubah
        end

        % Evaluate Fitness Of New Solution
        fit(t,i) = FF;

        % Generate A Local Solution Around The Selected Best Solution
        if rand() > r(t,i)
```

```
            x(t,i,:) = xg(t,:) + 0.001 * randn(1,Nd);
        end

        for d = 1:Nd

            % Check for Boundary
            if x(t,i,d) > ux(d)
                x(t,i,d) = ux(d);
            end
            if x(t,i,d) < lx(d)
                x(t,i,d) = lx(d);
            end

        end

        Para1 = x(t,i,1);
        Para2 = x(t,i,2);
        Para3 = x(t,i,3);

        %Perform simulation on 'PSOpid'
        sim('TF_PID_01');

        result = open('result.mat');

        FF = 0;

        [sizeRow sizeCol] = size(result.ans);

        %Calculate error according to least square error
        for CounterTime = 1:sizeCol  %Diubah
            FF = FF + abs(result.ans(2, CounterTime) - result.ans(3,
CounterTime)); %Diubah
        end

        % Evaluate Fitness Of New Solution
        fit(t,i) = FF;

        % Update Global Best
        if fit(t,i) < fitg(t)
            fitg(t) = fit(t,i);
            xg(t,:) = x(t,i,:);
        end

        % Generate A New Solution By Flying Randomly
        for d = 1:Nd

            x(t,i,:)= x(t,i,:) + 2 * (0.5 - rand()) * mean(A(t,:));

            % Check for Boundary
            if x(t,i,d) > ux(d)
                x(t,i,d) = ux(d);
            end
            if x(t,i,d) < lx(d)
                x(t,i,d) = lx(d);
```

```
            end


        end

        Para1 = x(t,i,1);
        Para2 = x(t,i,2);
        Para3 = x(t,i,3);

        %Perform simulation on 'PSOpid'
        sim('TF_PID_01');

        result = open('result.mat');

        FF = 0;

        [sizeRow sizeCol] = size(result.ans);

        %Calculate error according to least square error
         for CounterTime = 1:sizeCol   %Diubah
            FF = FF + abs(result.ans(2, CounterTime) - result.ans(3,
CounterTime)); %Diubah
        end

        % Evaluate Fitness Of New Solution
        fit(t,i) = FF;

        % Update If The Solution Improves, Or Not Too Loud
        if (fit(t,i) < fitg(t)) && (rand() < A(t,i))
            fitg(t) = fit(t,i);
            xg(t,:) = x(t,i,:);

            r(t,i) = r(1,i) * (1 - exp(-1 * gamma * t));
            A(t,i) = alpha * A(t,i);
        end

    end

    % Bring Current Iteration Information To Next Iteration
    x(t+1,:,:) = x(t,:,:);
    xg(t+1,:) = xg(t,:);
    fitg(t+1) = fitg(t);
    v(t+1,:,:) = v(t,:,:);
    f(t+1,:) = f(t,:);
    r(t+1,:) = r(t,:);
    A(t+1,:) = A(t,:);
    fit(t+1,:) = fit(t,:);

end

plot(1:Nt,fitg(1:Nt))
fitg(Nt)
xg(Nt,:)
```

```
Para1 = xg(t,1);
Para2 = xg(t,2);
Para3 = xg(t,3);

sim('TF_PID_01');
```