# OPTIMIZATION OF PID CONTROLLER PARAMETERS USING ARTIFICIAL FISH SWARM ALGORITHM

By

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FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronic Engineering
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronic Engineering)

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# CERTIFICATION OF APPROVAL

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Approved:

______________________________

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Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

May 2013

# CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Wafa Ali Soomro

# ABSTRACT

This Final Year Project is preceded on the topic named "The Optimization of PID Control Parameters Using Artificial Fish Swarm Algorithm". The background of the topic is presented in the Introduction chapter that describes on PID controllers. The Literature Review chapter thoroughly describes the Idea of Swarm Intelligence and Swarm Optimization. In methodology, the mathematical model of the algorithm is briefly described. For the Analysis and Discussion the PID Pressure Control Plant is used. Its simulation in MATLAB Simulink along with its block diagram is presented in the Results and discussions sections. The results found in the study shows that the optimization is valid and effective.

ACKNOWLEDGEMENTS

I would like to express my gratitude to Allah the Almighty and all those who helped and guided me. Without their support and guidance this dissertation would not have been possible.

First and foremost, my utmost appreciation to Associate Professor Dr Irraivan Elamvazuthi, my supervisor for his time, effort, guidance and the honest encouragement. Dr Irraivan Elamvazuthi has been my inspiration as I overcome all the obstacles in the completion of this work.

Special thanks to the final year project committee for assistance, help and cooperation throughout the entire project duration.

Last but not the least I am indebted to my family for all the support they provide.

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| **PID** | Proportional Integral & Derivative |
| **AFSA** | Artificial Fish Swarm Algorithm |
| **AF** | Artificial Fish |
| **ZN** | Zeigler-Nichols |
| **Kp** | Proportional Gain |
| **Ki** | Integral Gain |
| **Kd** | Derivative Gain |
| **P&ID** | Piping & Instrument Diagram |
| **OS** | Overshoot |
| **Ts** | Settling Time |
| **PSO** | Particle Swarm Optimization |

# CHAPTER 1
# INTRODUCTION

## 1.1 PID Background

A three term Proportional plus Integral plus Derivative (PID) controller, playing a vital role in the field of automation and control, has been counting as reliable component of industry because of its simplicity and satisfactory performance with vast range of processes. Because of its modest structure, it has the ability to be easily understood and implement in practical. Thus their presence is highly appreciated in practical applications [1].

The main goal of the control system is to obtain the desired response for a given system. The control systems are of two types' i-e open loop control system & Close loop control system. In open loop control system the input signal to the process is determined by the controller, where in closed loop control system the input signal to the process is determined by the controller the feedback signal [3].

Feedback control is an essential technique to keep the process variable close to the desired value, and the methodologies developed for feedback control has put marvelous impact in many fields of engineering. These days the components of control system are available at very minute cost, causing implementation of many applications using feedback principle, like in industry, home appliances etc. [3]. Figure 1 describes the overall PID Process.

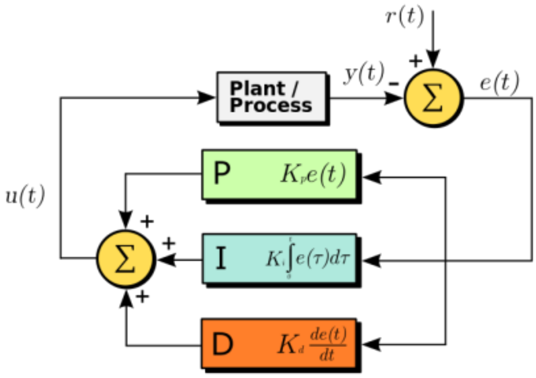


Figure 1 PID Process

There are three separate parameters that are involved in The PID controller calculation; 1) the Proportional, 2) the Integral and 3) The Derivative values. The current error is obtained by Proportional Value; the reaction based on total of the errors is determined by Integral part, while the reaction to the rate at which the error has been changed is obtain by the Derivative part. And the overall process is modified by the summation of all above three actions [4].

## 1.2 Problem Statement

There are two methods of Tuning PID Controllers Conventional method and Intelligent Method. Conventionally the PID parameters are tuned by most commonly used Zeigler-Nichol method. These conventional tuning methods have some drawbacks like;

- Trial and Error Method i.e., much time consuming
- Produce quiet big overshoot
- High Cost
- Less Accurate

Therefore, recently many intelligent approaches are used. In our study we are Optimizing PID Controller parameters (Kp, Ki, Kd), using Artificial Fish Swarm Algorithm.

## 1.3 Objective & Scope of Study

### *1.3.1 Objective*

- To optimize the Parameters of PID Controller using Artificial Fish Swarm Algorithm.
- To validate the results using Matlab.

### *1.3.2 Scope of Study*

This project aims to perform the PID Controller Parameters optimization using AFSA to improve the performance of PID Controller. In this project:

a) The data will be collected through literature.
b) The performance of the algorithm will be tested.

## 1.4 Project Feasibility

This project is feasible in all aspects, since all corresponding facilities in terms of laboratory equipment and software availability is ensured. Based on the proposed architecture of methodology and Gantt chart, the project will be completed within projected time frame.

# CHAPTER 2
# LITERATURE REVIEW

Proportional Integral Derivative Controller as being the oldest and reliable control technique still used in almost every industry, due to their easy implication, tough performance and being simple of being simple physical parameters [7]. To achieve proper closed-loop performance of PID, its three parameters must be tuned [6]. Conventionally the PID parameters are tuned by most commonly used Ziegler-Nichol method. But these conventional tuning methods produce quiet big overshoot. Therefore, recently many intelligent approaches are used. Our studies mainly comprises on Artificial Fish swarm Algorithm.

## 2.1 PID Tuning

Tuning of PID Controller means the assortment of the PID Parameters, it is one of the very crucial issues in overall controller design. A PID is tuned according to the control operation to be performed in any specific task or process in any industry. The main concern in the PID tuning counts The control effort and robustness, as it is related to finalize the cost of the product. There for it should be minimized as much as possible to the least level [3].

To have a clear physical meaning of the parameters is a major advantage of the PID controller. When the proportional gain is increased that would also increase the bandwidth of the system eventually results in the more oscillatory and faster response. Similarly when the integral time is increased that would reduce the integral action and results in a slower but very stable response. And finally when the derivative time is raised, that results in a damping effect. The increase in the derivative time should be avoided, because that delivers an opposite effect causing the system to be unstable [3].

## 2.2 Swarm Techniques

In engineering studies, the terminology of "Swarm" is defined as a group of agents having independent individual dynamics but exhibiting closely coupled behaviors and performing any specific task as a group. Another terminology that relates such system is termed as "multi-agent dynamics system" [5]. In biological perspective the term Swarm relates to some species when they are in certain behavioral modes. Similar to swarm there are also some biological synonyms like, colonies of ants, flocks of birds, schools of fish, etc. from many years, scientists and researchers in biology and engineering are being attracted to this coordinated behaviors of such clusters of species [5].

## 2.3 Swarm Intelligence

A type of Artificial Intelligence (AI), Swarm Intelligence is a study of collective behavior of Reorganized system, usually set of species that communicate locally among themselves as well as with environment.

There are many algorithms that use swarm techniques. Some of them are listed blow

- Artificial fish swarm algorithm (AFSA)
- Ant colony optimization (ACO)
- Particle swarm optimization (PSO)
- Honeybees optimization (HBO)
- Collective intelligence (COIN)

## 2.4 Artificial Swarm Algorithm (ASFA)

A new Algorithm, AFSA that is based and follows the behavior of Swarm techniques and Artificial Intelligence. It is new method proposed based on the behaviors of Animals [8].

In the shallow waters, the fish has the ability to find the area in the water that is more nutritious, and naturally there is a big number of fish gathered at that part of the water. There for an Artificial Fish (AF) practice is proposed that replicate the behaviors like Searching, Swarming and Following [6].

### *2.4.1 Searching Action*

In the water the fish has the natural ability to find the area which is most filled with food. When that area is discovered the fish sense and travel towards that area [6].

### *2.4.2 Swarming Action*

In swarming process, the fish try to avoid congestion with other species and move along in the same direction as the fellow fish [6].

### *2.4.3 Following Action*

If a fish in a group of fishes finds the food, the other companions will immediately follow each other and will find the food [6].

The objective of AFSA is the food consistence in the water, and by all above activities the solution space can be searched [6]. In regard of food searching every fish (In our case AF) moves randomly so being a self-studying process it is an optimization of specific extremum, while the swarming and the following behaviors are processes of AF interaction to neighboring environment [6].

## 2.5 Literature Regarding the Study

Table 1 Research Literature related to project

| No: | Author(s) | Year | Publication | Title | Technique Used | Application | Advantage | Limitations |
|---|---|---|---|---|---|---|---|---|
| 1 | Abolfazl Jalilvand, Ali Kimiyaghalam, Ahmad Ashouri, Meisam Mahdavi | 2008 | Journal Paper | Advanced Particle Swarm Optimization-Based PID Controller Parameters Tuning | Particle Swarm Optimization | Conventional PID Controller | Fitness function calculated more precisely Reduces %OS | -- |
| 2 | Meifeng Zhang, Cheng Shao, Fuchao Li, Yong Gan, and Junman Sun | 2006 | Journal Paper | Evolving Neural Network Classifiers and Feature Subset Using Artificial Fish Swarm | Artificial Fish Swarm Algorithm | Neural Network | Numbers of features are Minimal, *MSE is* minimal and network architecture is simplest. | -- |
| 3 | Wang Yiyue, Liao Hongmei, Hu Hengyang | 2012 | Conference Paper | Wireless Sensor Network Deployment Using an Optimized Artificial Fish Swarm Algorithm | Artificial Fish Swarm Algorithm | Wireless Sensor Network Deployment | fish foraging behavior is Improved, The algorithm can increase network coverage of wireless sensor network | -- |
| 4 | Yi Luo, Juntao Zhang and Xinxin Li | 2007 | Conference Paper | The Optimization of PID Controller Parameters Based on Artificial Fish Swarm Algorithm | Artificial Fish Swarm Algorithm | Single Loop System, cascade control system of Main stream temperature | Good convergence rate, Reduced overshoot Parameters are more simplified | can't demonstrate the validity of AFSA over other algorithm |
| 5 | Yi Luo, Wei Wei and Shuang xin Wang | 2010 | Conference Paper | Optimization of PID Controller Parameters Based on an Improved Artificial Fish Swarm, Algorithm | Improved Artificial Fish Swarm Algorithm | Main steam temperature cascade control system | Swarming behavior increased, More improved convergence rate | -- |

There is a lot of research being carried out regarding the work carried out in our area of study. Following is some literature as per shown in Table 1.

As per Table 1 the literature shows that the swarm optimization has been used in various applications like in Neural Networks, wireless sensor network deployment and different control applications. AFSA actually reduces percent overshoot and the fitness function is calculated more precisely and the convergence rate is improved.

In this study the aim is to optimize the PID Controller parameters using Artificial Fish Swarm Algorithm. AFSA is a new type of Swarm Intelligence; Dr. Li Xiao-lei was the first who proposed this technique back in year 2002.  AFSA actually imitates the behavior of Fish behaviors [6].

# CHAPTER 3
# METHODOLOGY

## 3.1 PID Tuning using Zeigler-Nichols Method

The most popular and reliable tuning methodology for the PID Controller parameters is using Ziegler-Nichols Method, which was offered by Ziegler and Nichols in 1942. There are two approaches for ZN tuning method. 1) Closed loop or ultimate sensitivity method and, 2) Open loop or process reaction curve method. These methods have some drawbacks in terms of insufficient process information for determining tuning parameters causing deprived robustness.

### *3.1.1 Ziegler-Nichols Closed Loop Tuning Method*

Initially before doing Optimization of PID Parameters using AFSA the PID parameters are need to be tuned by conventional Ziegler-Nichols tuning method. The PID parameters that are needed to be tuned in Ziegler-Nichols Method are Proportional Gain, (Kp), Integral gain (Ki) and Derivative gain (Kd). For this method the requirements are Ultimate gain and ultimate period.

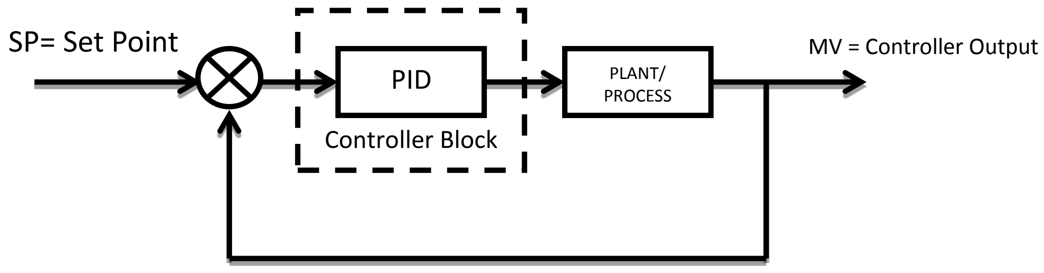


Figure 2 Closed Loop Controller Block Diagram

The tuning rules of closed loop PID tuning, for P, PI & PID are shown in Table 2

Table 2 Z-N PID Parameters Coerrelations

| Controller | Kp | Ki | Kd |
|---|---|---|---|
| P | 0.5 Ku | ∞ | 0 |
| PI | 0.4 Ku | 0.8 Pu | 0 |
| PID | 0.6 Ku | 0.5 Pu | Pu |

## 3.2 The Artificial Fish Swarm Algorithm

A behavior based on artificial fish is created and the model summarizes the behavior of artificial fish. The AFSA iterates once means that individual moves once.

### *3.2.1 The Structure of Algorithm*

$$X=(x_1,x_2,\ldots,x_n),\quad \text{where}\quad x_i(i=1,\cdots,n) \tag{1}$$

The state of Artificial Fish (AF) Individual can be represented as a vector;

The variable Xi is for searching optimum value.

FC=f(X), represents the Present position of AF food Consistence where the objective function is FC.

The total distance between two AF individual is represented by;

$$d_{i,j}=||X_i-X_j|| \tag{2}$$

*Vision:* Distance of Visibility

*Step:* step length (Maximum)

*Delta (δ):* crowded factor

AF model has got the most significance in the overall Optimization process of PID Parameters using AFSA. In the study the parameters that need to be optimized are $K_p$, $K_i$, and $K_d$. The AF vector can be expressed as;

$$X=(K_p, T_i, T_d) \tag{3}$$

And the total distance among two AF individuals can be represented as:

$$d_{i,j} = \sqrt{(K_p{}^i - K_p{}^j)^2 + (T_i^i - T_i^j)^2 + (T_d{}^i - T_d{}^j)^2} \tag{4}$$

At the initial position, the consistence of AF food can be represented as:

### *3.2.2 Behavior Description*

#### *3.2.2.1 Searching Action*

$X_i$ = AF at initial position

$X_j$ = AF in the visibility range

If $FC_i$<$FC_j$, proceed a step within the same direction or else select $X_j$ again.

$$x_{inextk} = x_{ik} + Random(Step)\frac{x_{jk} - x_{ik}}{\|X_j - X_i\|} \quad FC_j > FC_i \tag{5}$$

$$x_{inextk} = x_{ik} + Random(Step) \quad FC_j \le FC_i \tag{6}$$

Where K= 1,2,3…,n, $X_{jk}$, $X_{ik}$ and $X_{inexth}$ represents the k element of state vector $X_j$, $X_i$.

#### *3.2.2.2 Swarming Action*

$X_c$ = AF State at Center, $FC_c$ = Food availability at Center

$n_f$ = number of fishes nearby ($d_{ij}$ ≤ Visual), If $n_f$>=1, the center position of its fellow is discovered by $X_j$.

$$x_{ck} = \left(\sum_{j=1}^{n_f} x_{jk}\right) \Big/ n_f \tag{7}$$

$$x_{inextk} = x_{ik} + Random(Step)\frac{x_{ck} - x_{ik}}{\|X_c - X_i\|} \tag{8}$$

#### *3.2.2.3 Following Action*

$X_i$= AF at initial position

$X_{max}$ = Max state

$FC_{max}$= largest amount of fellow fishes in nearby field ($d_{ij} \leq$ Visual)

If $$FC_{max}/n_f > \delta\, FC_i \tag{10}$$

Fellow $X_i$ has highest consistence of food and if the surrounding is not packed, proceed a step to Max.

$$x_{inextk} = x_{ik} + Random(Step)\frac{x_{\max k} - x_{ik}}{\|X_{\max} - X_i\|} \tag{11}$$

If $n_f = 0$, AF individual performs the action of searching food.

The Algorithm establishes a bulletin board and its purpose it to save the optimal position of AF and food consistence the AF at corresponding position.

### *3.2.3 Behavior Selection*

The AF surroundings is evaluated conferring to the characteristics of the problem that needed to solve and selection of action. Trial method would be the best way for maximum problem. Derive the values using swarming and following behavior and the one with the maximum results would be the choice to implement. Behavior of searching food is the acquiescent behavior.

### *3.2.4 Effect of Parameters While Convergence*

*Visual & Step:* searching and moving behavior is more prominent when the vision scope is smaller but in case of larger scope of vision the behavior of following is prominent. So for the better convergence larger scope of vision would be preferable, while the larger step is good for the convergence.

*2) Crowd factor ($\delta$):* For maximum desired value, the area of crowded factor is $0 < \delta < 1$. And for minimal value $\delta < 1$.

3) The Total of AF Individual (N): ASFA being the part of swarm intelligence. If the number of AF is high the size of local extremum would be strong, leading to a faster convergence speed but the amount of iterations will be more.

## 3.3 PID Parameters Optimization using Artificial Fish Swarm Algorithm

### *3.3.1 Fitness Function Design*

The essence of ASFA optimization searching is the estimation of fitness function. And its design is directly proportional to the performance of ASFA. This study is aimed on the parameters $K_p$, $K_i$, $K_d$. To establish the objective function is a must to do for evaluation of performance index for searching and optimizing in a certain rule.

The gist for designing PID controller is making minimum the system performance of index function J. To assure the strength of system, gain margin and minimum phase condition are satisfied, to compare with literature [2]. Here in our study the ITAE is used as performance index.

$$J(ITAE) = \int_0^\infty t|e(t)|dt \tag{12}$$

The representation of objective function for our study is as follows:

$$J(ITAE) = DT^2 \sum_{k=1}^{LP} k|e(k)| \tag{13}$$

D = Calculation of Step D=DT

LP = number of DOT numbers of Calculation

In this study the searching is aimed maximum, so the fitness functions is fixed accordingly. Hence the reciprocal of system performance index is used as fitness function.

$$FC = 1/J(ITAE) \tag{14}$$

### *3.3.2 Feasible Region of PID Parameter Design*

ASFA creates a group of initialization of Parameters as the fish colony to narrow down the area of PID Parameters that are being optimized. These three parameters ($K_p^*$, $T_i^*$, $T_d^*$) are first tuned by Ziegler-Nichols approach and as the center is expanded to both directions of polarities as follows:

$$\begin{aligned} (1-\lambda)K_p^* &\le K_p \le (1+\lambda)K_p^* \\ (1-\lambda)T_i^* &\le T_i \le (1+\lambda)T_i^* \\ (1-\lambda)T_d^* &\le T_d \le (1+\lambda)T_d^* \end{aligned} \tag{15}$$

Where λ is the value in [1,0].

### *3.3.3 Termination Condition*

In AFSA the convergence is considered and to terminate the algorithm when there is no any higher value of fitness function after a number of iterations of searching.

### *3.3.4 Flow of Algorithm*

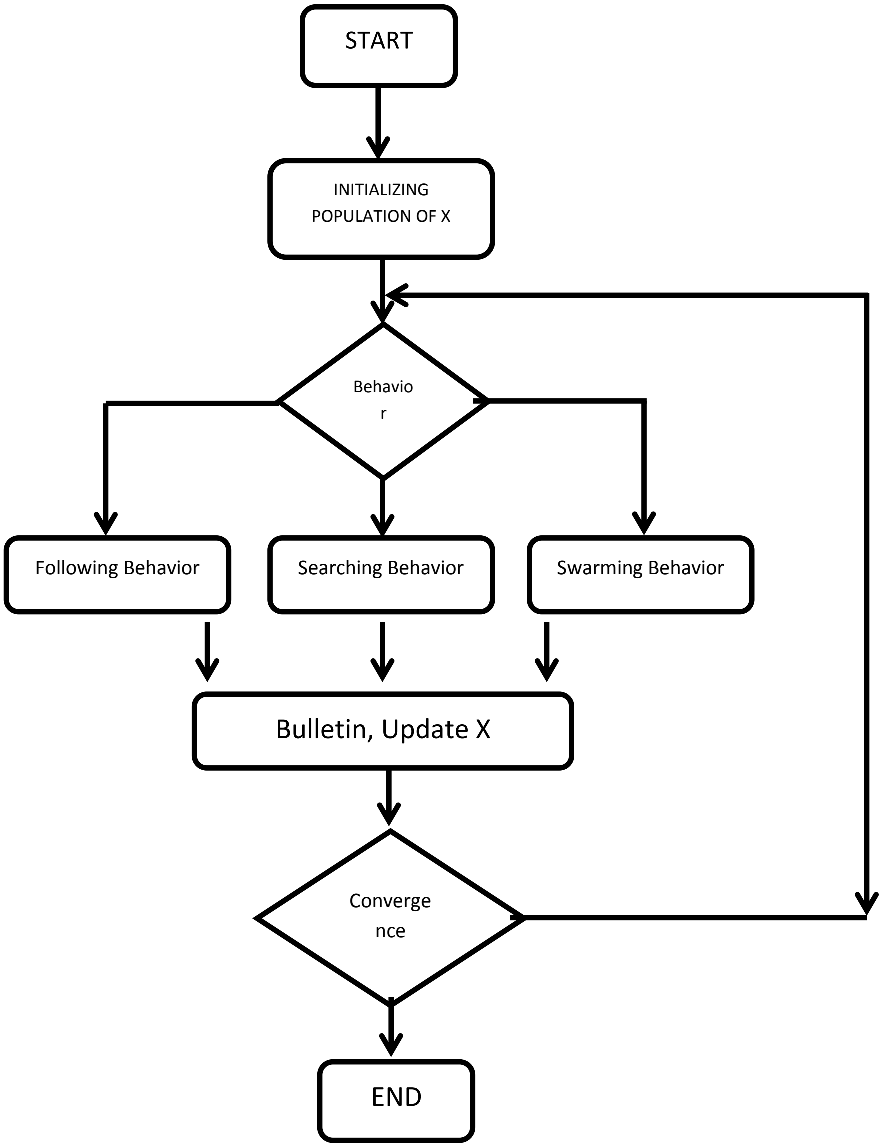

Figure 3 Flow of AFSA

The steps of the algorithm are defined below

Step1: initiate the number of fish, the area of visibility, δ and enter any random position of AF, X=(x1,x2,…,xn).

Step2: Calculate the food contamination of the defined position of AF. Obtain the concentration of food and updated position of Xi. The data must be saved in the bulletin box.

Step3: for every AF, simulation reviews the results of swarming behavior and following behavior. The behavior is chosen by each AF towards higher concentration of food. The Searching behavior is by default behavior of the algorithm.

Step 4: calculate the food contamination of the all AF at initial position as well as at each updated position. And then again the data must be saved in the bulletin box.

Step5: if the iteration is equated to the limit. The optimal concentration of food and corresponding position is the output. Go to step 3 of the output is not desired.

### 3.4 Working with new Parameters

Initially the parameters that are tuned by Ziegler-Nichols Method ($K_p^*$, $K_i^*$, $K_d^*$) as in Figure 4. The new parameters that to be found from the AFSA termed as ($K_p$, $K_i$, $K_d$) would be used as in Figure 5.

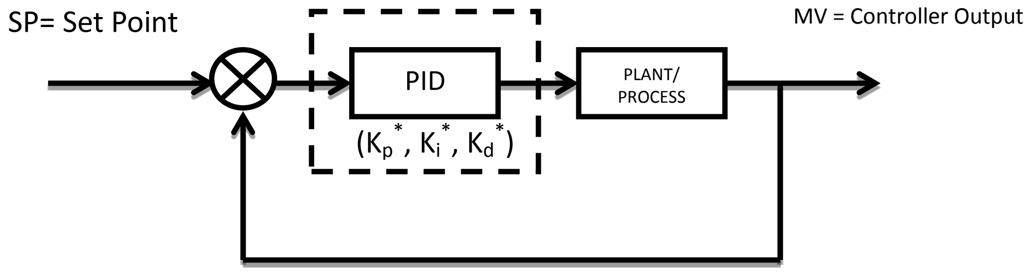


Figure 4 PID Controller block tuned initially with Ziegler-Nichols Method

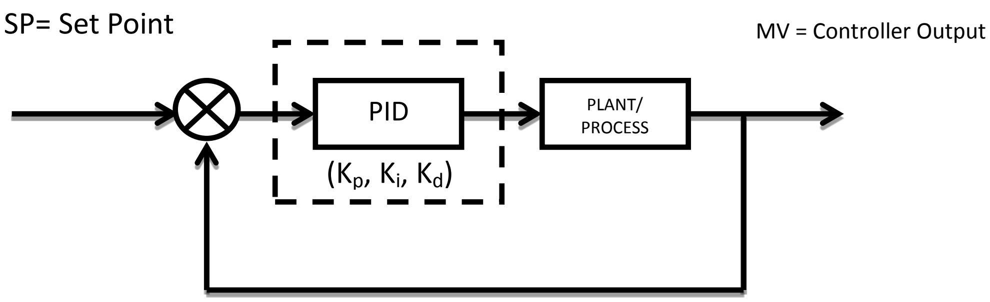


Figure 5 PID Controller block tuned with AFSA with new updated parameters

### 3.5 PID Pressure Control

For the experimental purpose, Flow controller PILOT Plant is used as the Process/Plant in our study. the equivalent block diagram is shown in Figure 6.

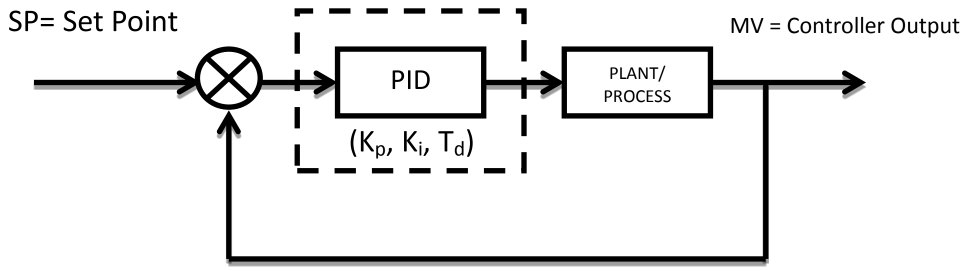


Figure 6 PID Pressure Control

# CHAPTER 4
# RESULTS & DISCUSSIONS

## 4.1 PID Pressure Control

The plant that is being used for the analysis of this study is SIM305-GAMN-FF-BATCH PID Pressure control Pilot Plant [9]. This plant is scaled down vapor-phase Flow, Pressure and Temperature Pilot Plant. It is self-contained unit designed to simulate real flow, pressure and temperature process of compressible fluid and found in industrial plants. Compressed air is used as the medium. The plant consists of two process tanks, VE-210 and VE-220.

The plant consist of two buffer tanks, VE-210 and VE220 that supply regulated, compressed air to the cooling vessel, VE220. As more and more air enters VE-240, the inside pressure builds up. However, the compressed air is vented out at certain rate through the solenoid valve MV-244 to ensure a safe pressure limit inside VE240. The Schematic of the Plant is shown in Figure 7.

Pressure is one of the important conditions to ensure chemical reactions occur at a desired rate. It is also closely related to process temperature and both are closely monitored by the plant operators to ensure safety in operation and maintaining Product Quality. The PID Pressure Control Pilot Plant is Shown in Figure 8.

In order to get the transfer function of the Plant, the process reaction curve is needed. The process reaction curve is shown in Figure 9.

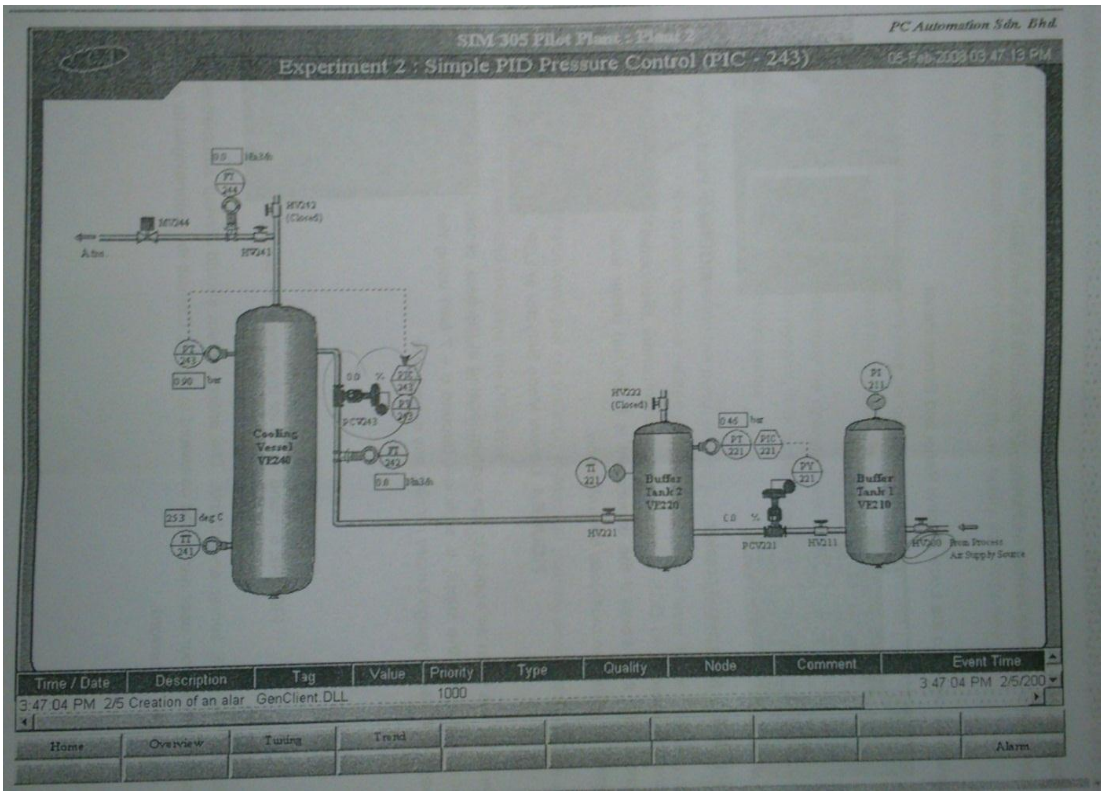


Figure 7 P & ID of PID Pressure Control

Figure 8 PID Pressure Control Pilot Plant

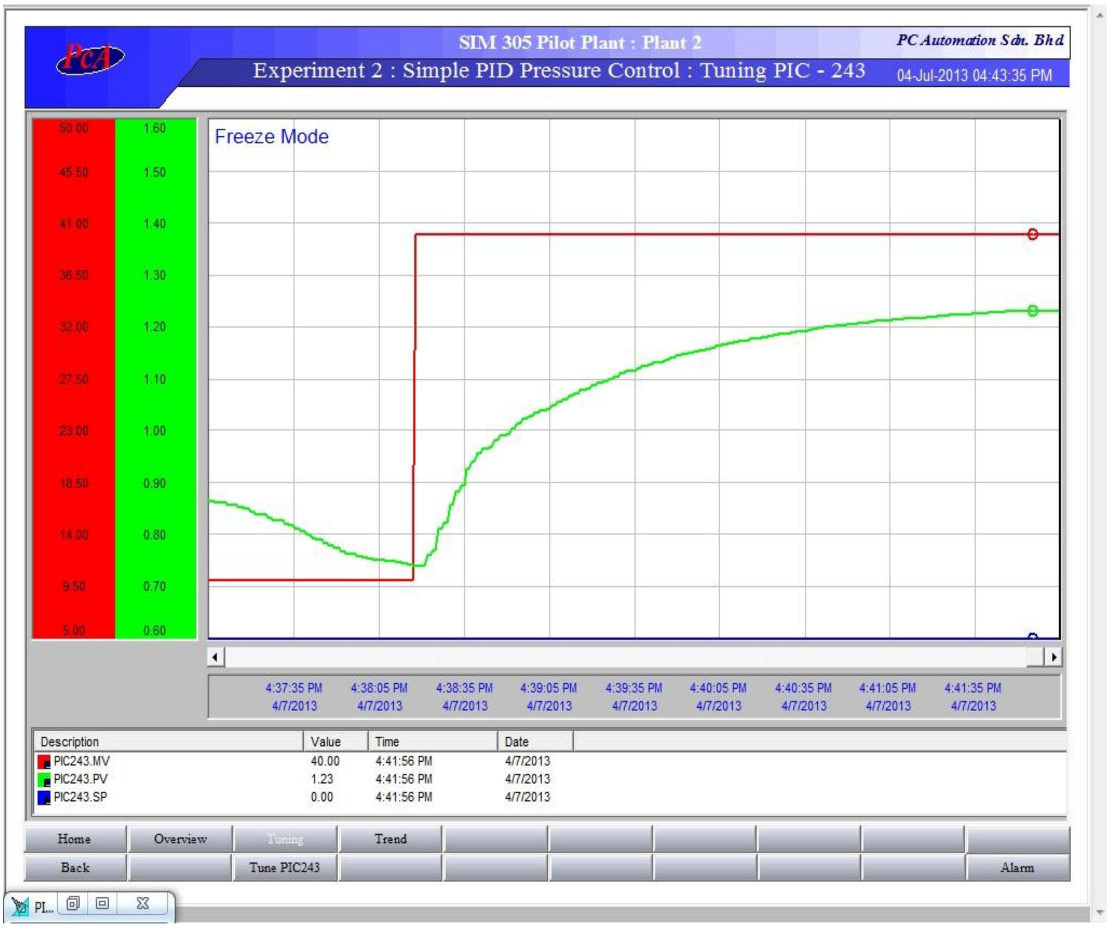


Figure 9 Process Reaction Curve

Table 3 Measurements from the Plant

| **Measurement** | **Value** |
|---|---|
| Change in perturbation / MV, σ | 0.1 |
| Change in output / PV, Δ | 0.21 |
| Maximum Slope, S | 0.015 |
| Apparent dead time, θ | 11 |
| Calculations | Value |
| Apparent time Constant<br>$\tau = 1.5(0.63\ \Delta - 0.28\ \Delta)$ | 140 |

The Table 3 shows the Results obtained from Process reaction curve

The transfer function of the plant can be evaluated as follows:

$$G(s) = \frac{e^{-\theta s}}{\tau s + 1}$$

Substituting the values as per Table 3;

$$G(s) = \frac{e^{-11s}}{140s + 1}$$

### *4.1.1 Closed Loop Tuning of Secondary Loop*

By Ziegler-Nichols closed loop tuning method the parameters of Controller of PID Pressure Plant is tuned, the parameters are shown in Table 4.

Table 4 PID Parameters

| Controller | Kp | Ki | Kd |
|---|---|---|---|
| P | 6.2 | ∞ | 0 |
| PI | 5.4 | 31.4 | 0 |
| PID | 8.19 | 26.208 | 3.943 |

Initially the PID Controller is tuned by Ziegler-Nichol PID Tuning as the results are shown in Table 4. The Simulated effect of Controller is shown in Figure 10.

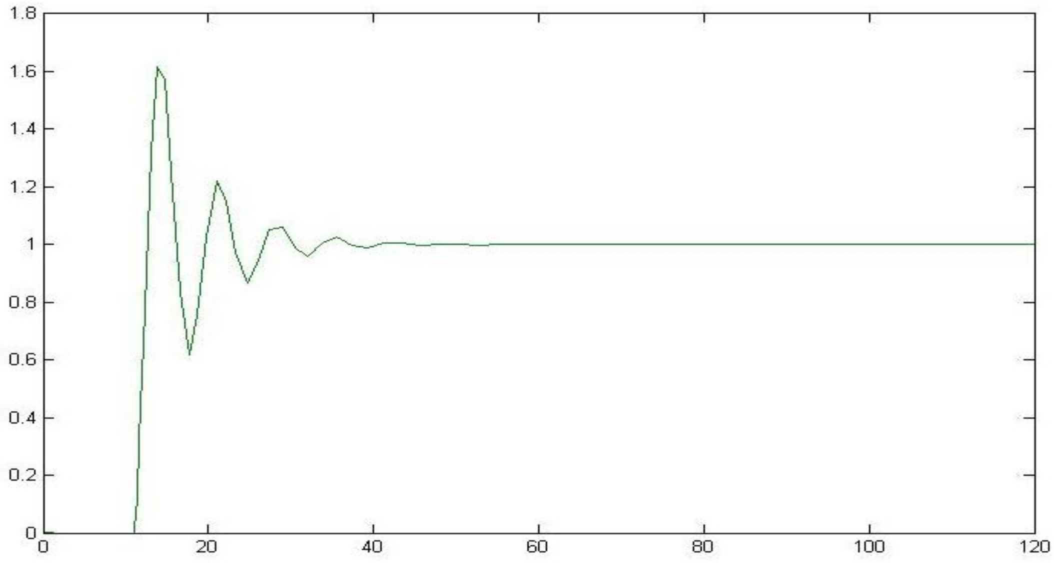


Figure 10 PID Controller response tuned by Zeigler-Nichols Method

### *4.1.2 Optimization of PID Parameters using AFSA*

The plant parameters (Kp, Ki, Kd) are then tuned using Artificial Fish Swarm Algorithm. This research generates the Parameters using this Algorithm. The Matlab Simulink Model is used to initialize the plant model. Follows is the simulation block using Matlab Simulink in Figure 7. The plant model in Simulink model is shown below in Figure 11 & 12.

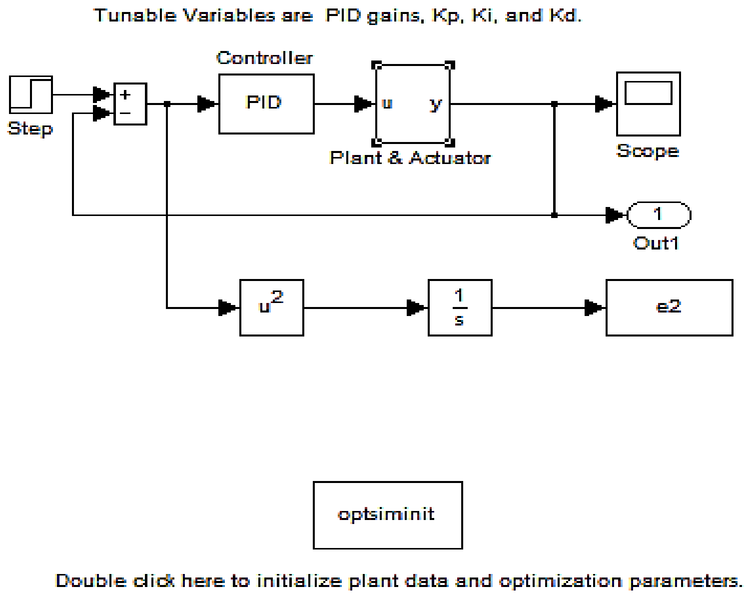


Figure 11 Simulink Block of overall system

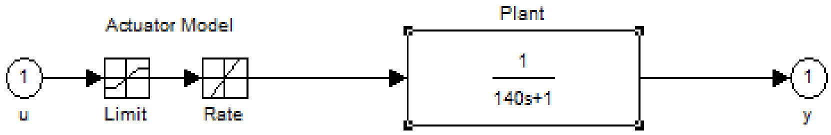


Figure 12 Simulink Block of Plant

Then the PID Parameters are tuned according to intelligent method and the plant is simulated using Artificial Algorithm. Initially all three parameters are initiated ie Kp, Ki, Kd. The result of the simulation is shown in Figure 13.

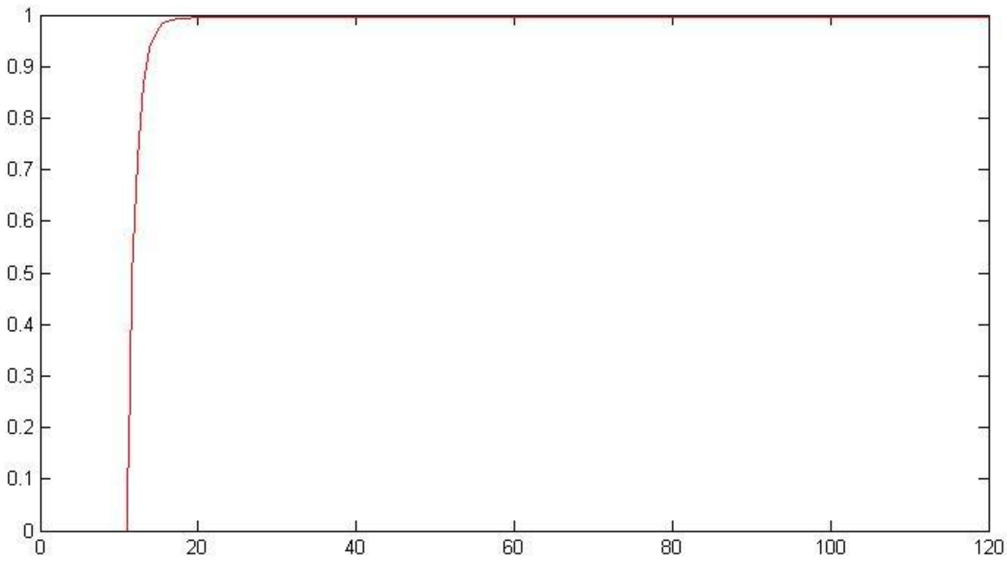


Figure 13 Simulation of new optimized Parameters using AF

With regards to Figure 13, the new optimized parameters using respective method are shown in Table 5.

Table 5 Simulation of new optimized Parameters

| TYPE | Kp | Ki | Kd | %OS | Ts |
|---|---|---|---|---|---|
| AFSA | 36.57 | 0.0022 | 7.8492 | 0 | 20s |

### *4.1.3 Validation of Parameters on PID Pressure Control Pilot Plant*

Apparently the simulation results shows the performance of the PID Parameters is much improved. For the validation of the study on the real world plant the parameters are applied to see the controller response. Initially the plant parameters are tuned using zieglar Nichols PID tuning approach. As per in Table 4, Kp=8.19, Ki=26.208, Kd=3.943 the response of controller is shown in Figure 14.

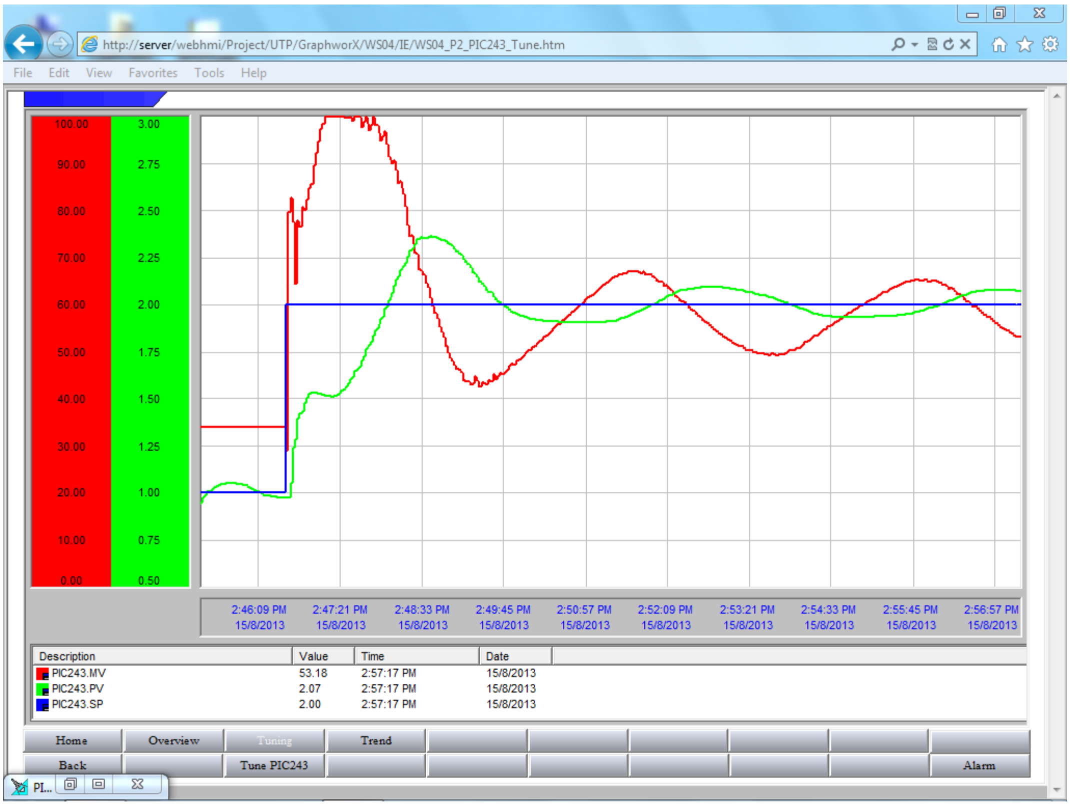


Figure 14 Response of PID Pressure Control Pilot Plant Tuned using ZN Method

After the Plant is tuned using Zeigler-Nichols approach, for the validation of the study, the new tuned parameters as per in Table 5, Kp=36.47, Ki=0.0022, Kd=7.849. Using these parameters the New trend of Controller response is shown in Figure 15.

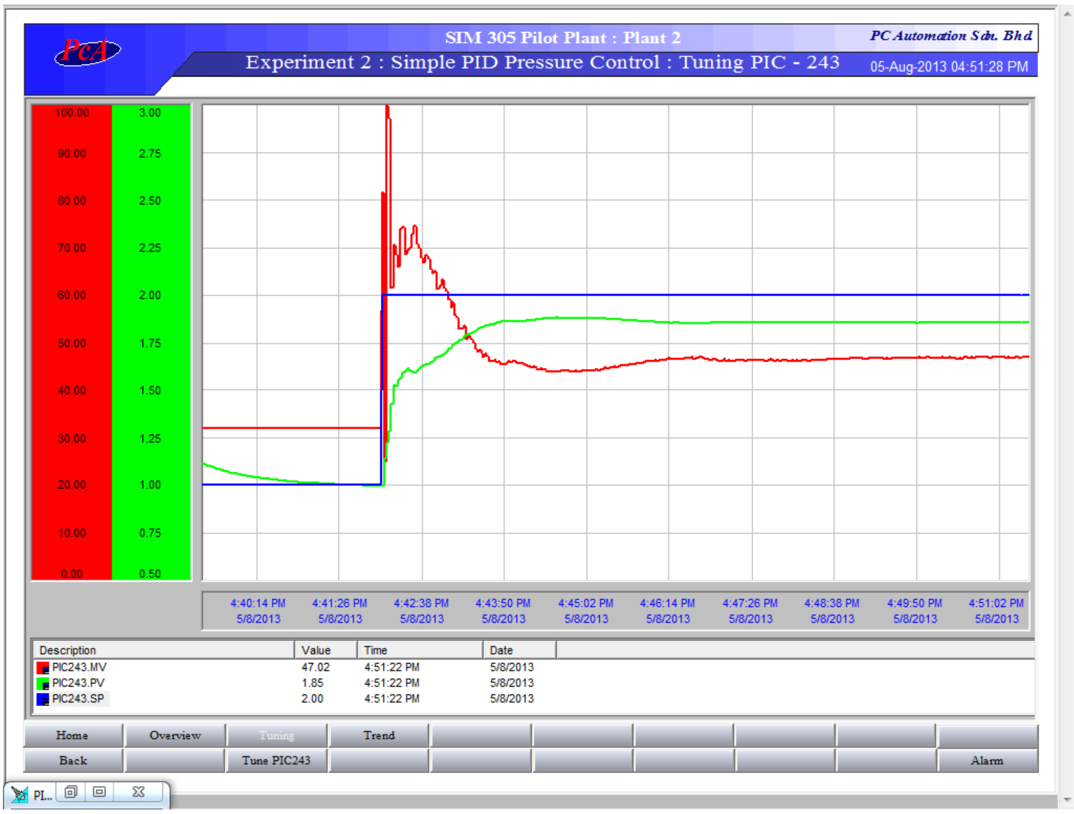


Figure 15 Response of PID Pressure Control Pilot Plant Tuned by AFSA

Since the response in Figure 15 using AFSA is not reaching to set-point, because the SIM305-GAMN-FF-BATCH PID Pressure control Pilot Plant allows only one digit after the decimal point. The integral gain i,e,. Ki=0.0022 is almost equal to zero, as integral part of PID controller improves the system offset [3]. Therefore the controller parameters need to be fine-tuned to reach to the maximum performance. The Controller is Fine-tuned to Kp=36.47, ki=5.65, Kd=7.8 the fine-tuned response of the controller is shown in Figure 16.

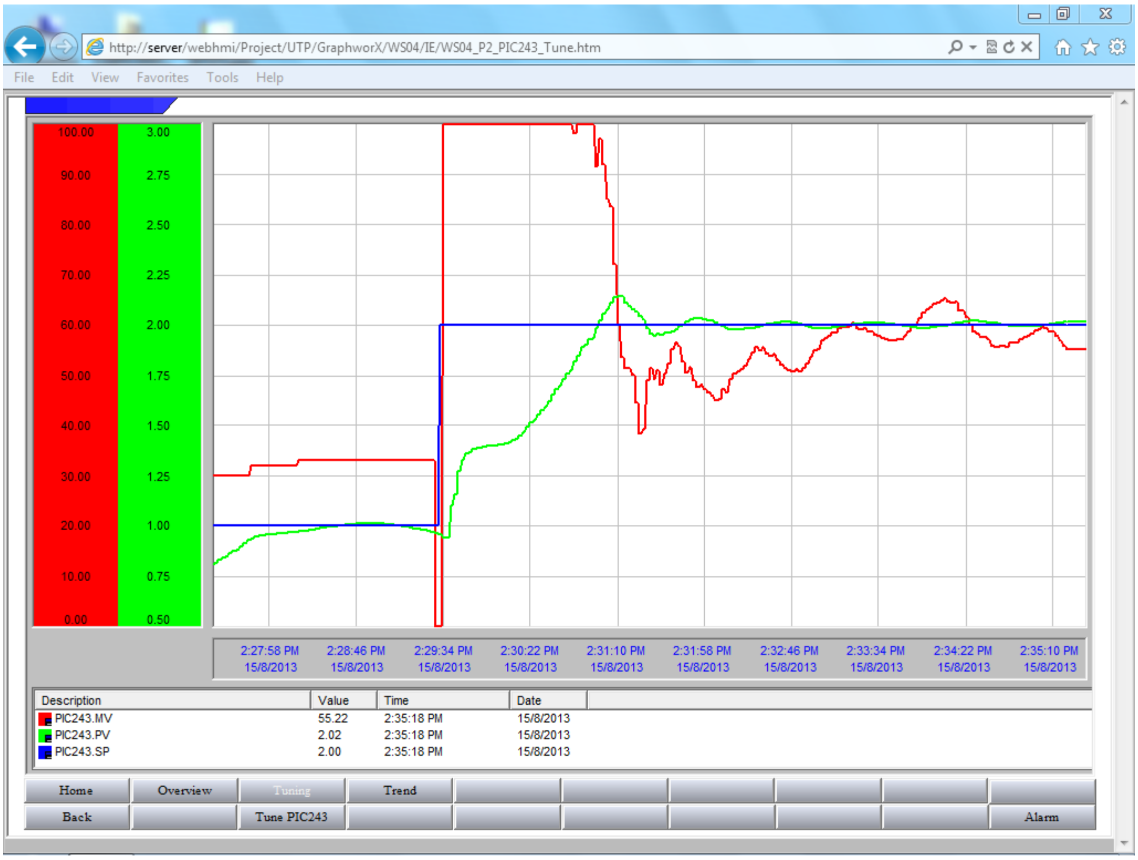


Figure 16 Fine Tuned Response of Controller

### *4.1.4 Observation & Discussion*

Observing the Optimization of PID controller parameters of PID Pressure control plant, From Table 5 the AFSA shows very good performance. The study is compared with other Optimization method to validate and observe the mutual response of different optimization approaches. Figure 16 shows the response of different optimization methods.

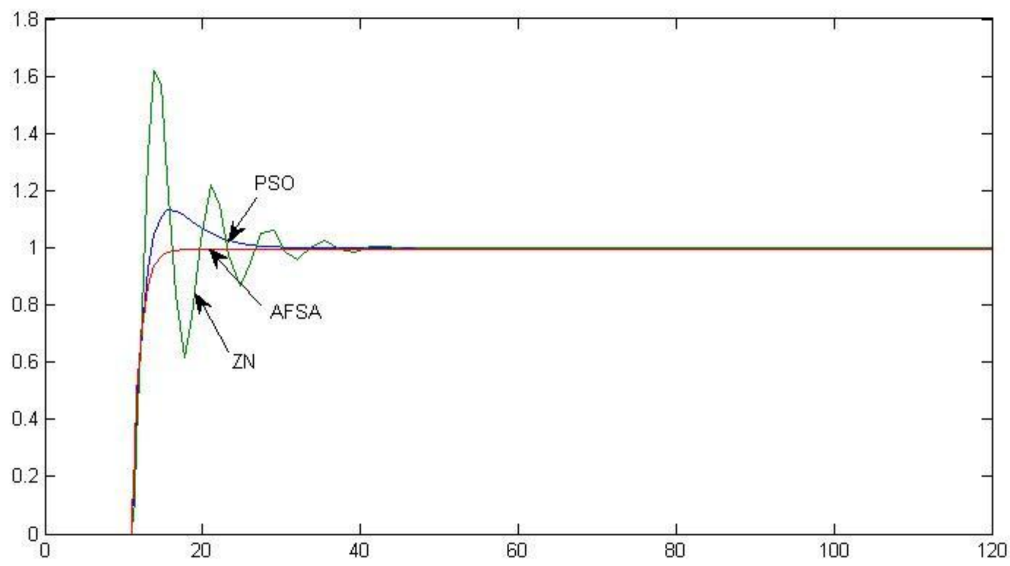


Figure 17 System Responses of different Optimization approaches

With regards to Figure 16 the comparison of Parameters and percent over shoot of respective optimization approaches are illustrated in Table 6.

Table 6 Parameters & Performace Based on Different Optimization Approaches

| TYPE | Kp | Ki | Kd | %OS | Ts |
|---|---|---|---|---|---|
| AFSA | 36.57 | 0.0022 | 7.849 | 0 | 20s |
| PSO | 14.99 | 1772 | 13.872 | 15 | 30s |
| ZN | 8.1969 | 26.208 | 3.943 | 63 | 40s |

Observing the Optimization of PID Parameters using different approaches, Table 6 shows that the intelligent methods present very acceptable results over the conventional methods of PID Tuning. The traditional Zeigler-Nichols gives 63% of overshoot and requires some settling time. While Particle Swarm Optimization is also giving much acceptable results if it is compared with Zeigler-Nichols with the overshoot of only 15% and less settling time. This Study shows the PID Parameters Optimization using Artificial Fish Swarm Algorithm gives very much accurate results if it is compared with both Ziegler-Nichols and Particle Swarm Optimization. The overshoot is almost equal to 0% and the settling time is really fast.

While the validation of the new parameters generated using AFSA on the PID Pressure control Plant, the change in the output, Δ does not reach the set point, because on the Faceplate of the PID Controller accepts only one digit after the decimal point as in Figure 17.

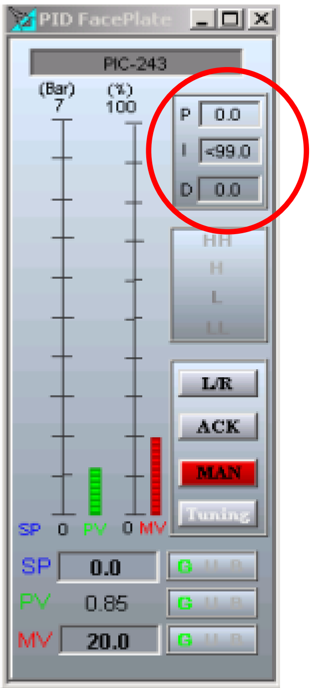


Figure 18 Faceplate of PID Control

Since the Integrator component of PID Controller is Ki=0.002, it is assumed to be Zero by the Controller, the Controller acts like PD Controller. As Integrator part removes the offset and makes the controller reach the set point, the response of AFSA does not reach until the set point.

Since the response in Figure 15 using AFSA is not reaching to set-point, because the SIM305-GAMN-FF-BATCH PID Pressure control Pilot Plant allows only one digit after the decimal point. The integral gain i,e,. Ki=0.0022 is almost equal to zero, as integral part of PID controller improves the system offset [3]. Therefore the controller parameters need to be fine-tuned to reach to the maximum performance. The Controller is Fine-tuned to Kp=36.47, ki=5.65, Kd=7.8 the fine-tuned response of the controller is shown in Figure 16.

## 4.2 Other Examples of Optimization Using AFSA

For the further validation of the study, few more examples of Control Plants are also optimized using AFSA and compared with other optimization approaches. Following are the Plants:

I. $G(s) = \frac{0.5e^{-0.5s}}{1.24s^2+3.5s+1}$

II. $G(s) = \frac{5}{s^4+3s^3+7s^2+5s}$

III. $G(s) = \frac{1}{s^2+0.1s+1}$

IV. $G(s) = \frac{e^{-0.5s}}{(s+1)^2}$

The Optimization results of the all examples are shown as follows:

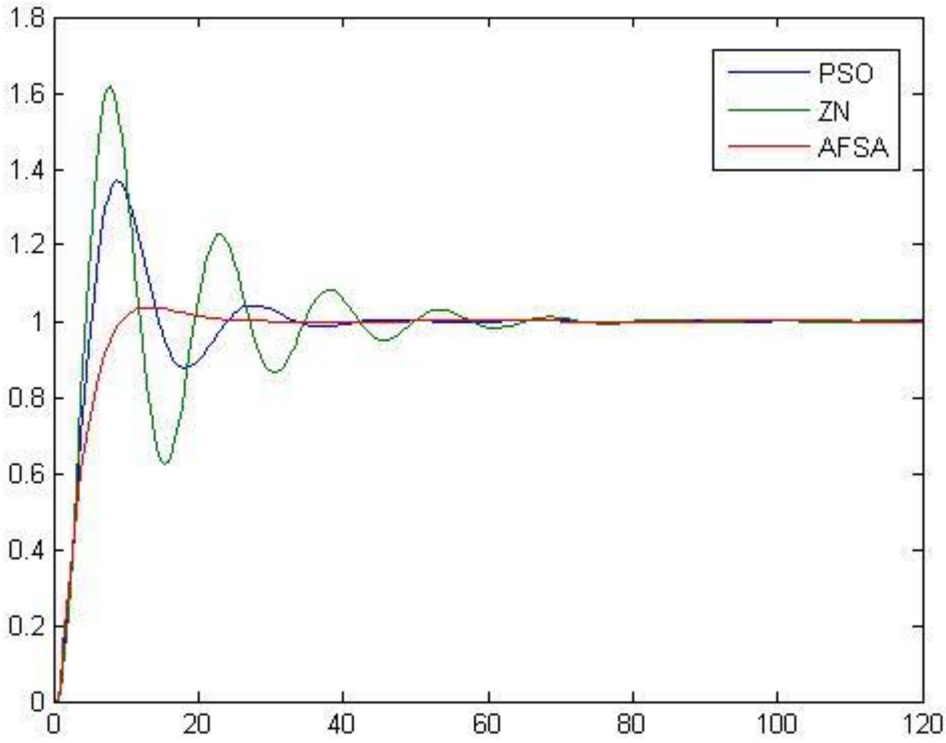


Figure 19 Controller response of Plant I

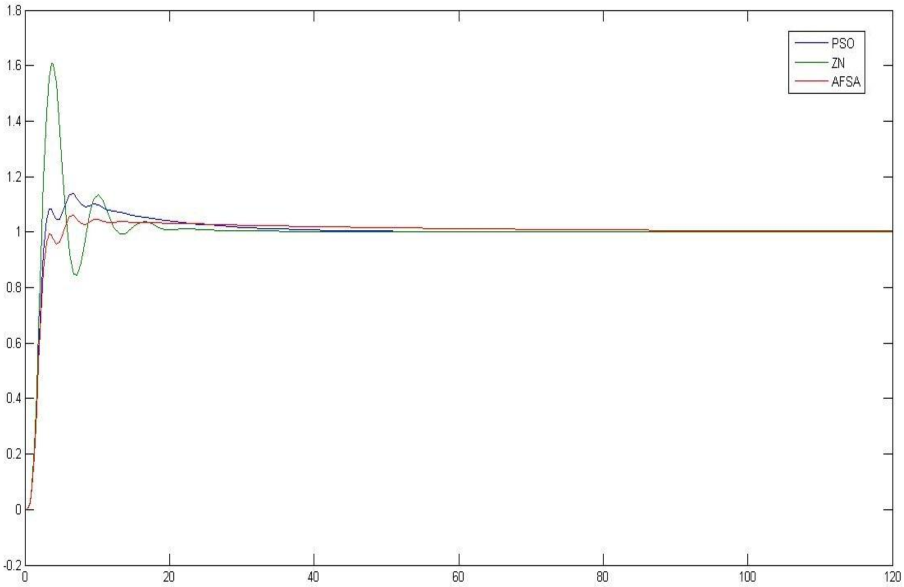


Figure 20 Controller response of Plant II

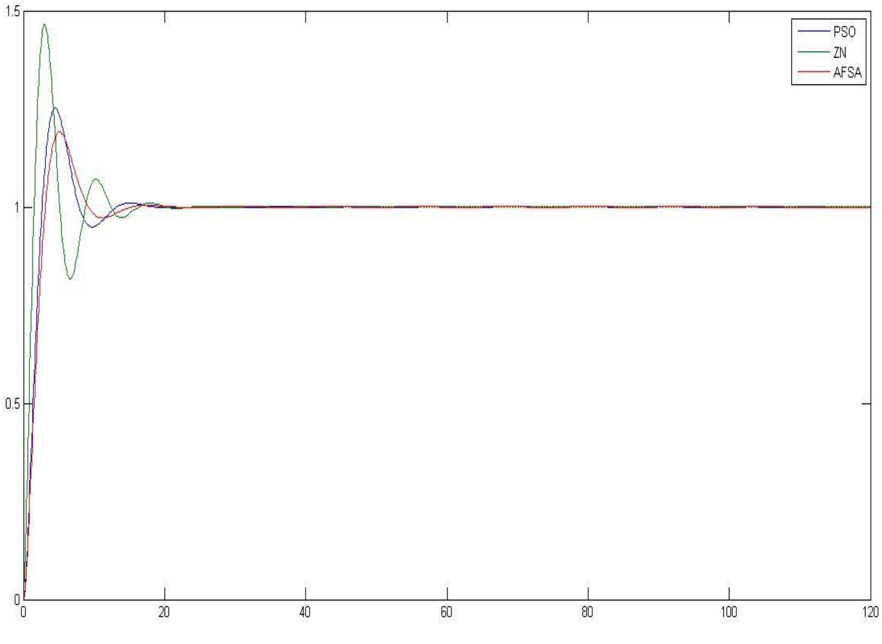


Figure 21 Controller response of Plant III

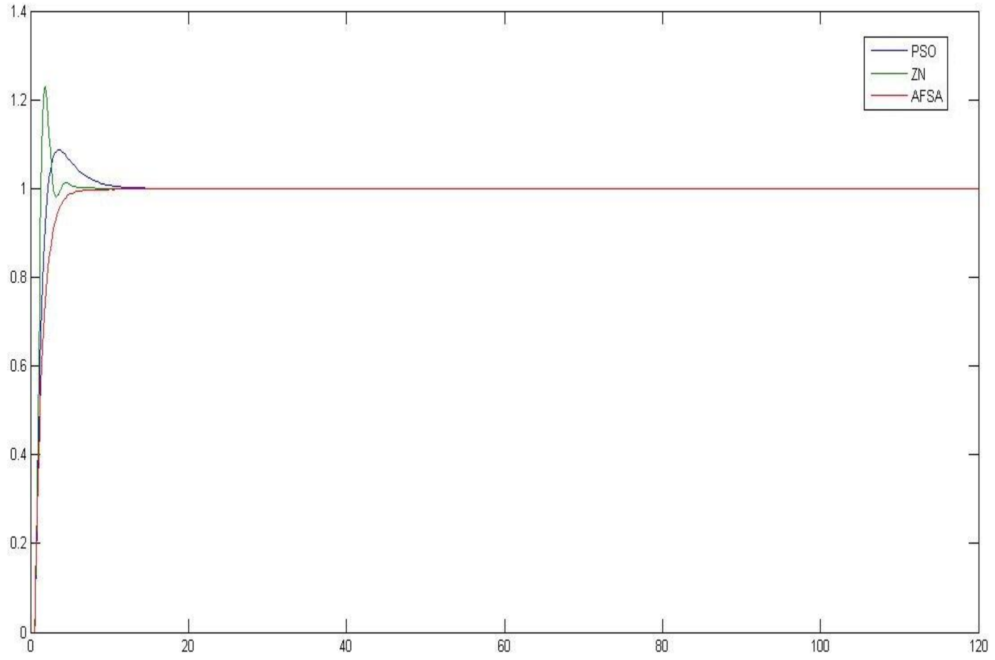


Figure 22 Controller response of Plant III

With regards from Figure 18, 19, 20, & 21, the Parameter estimations and performance of all the plants is elaborated in tables 7, 8, 9 & 10 respectively.

Table 7 Parameters & Performace Based on Different Optimization Methods for Plant I

| TYPE | Kp | Ki | Kd | %OS | Ts |
|---|---|---|---|---|---|
| AFSA | 2.5196 | 0.7260 | 3.7364 | 1.8 | 18s |
| PSO | 2.3808 | 2.2871 | 11.6224 | 38 | 40s |
| ZN | 1.276 | 4.18 | 16.76 | 60 | 62s |

Table 8 Parameters & Performace Based on Different Optimization Methods for Plant II

| TYPE | Kp | Ki | Kd | %OS | Ts |
|---|---|---|---|---|---|
| AFSA | 0.8919 | 0.0199 | 0.7884 | 3 | 9s |
| PSO | 0.9284 | 0.0656 | 0.7873 | 10 | 9s |
| ZN | 0.99 | 0.09 | 0.0988 | 60 | 18s |

Table 9 Parameters & Performace Based on Different Optimization Methods for Plant III

| TYPE | Kp | Ki | Kd | %OS | Ts |
|---|---|---|---|---|---|
| AFSA | 1.1064 | 1.10282 | 3.29 | 20 | 10s |
| PSO | 1.2569 | 1.2680 | 3.5102 | 30 | 11s |
| ZN | 13.22 | 21.98 | 26.187 | 42 | 13s |

Table 10 Parameters & Performace Based on Different Optimization Methods for Plant IV

| TYPE | Kp | Ki | Kd | %OS | Ts |
|---|---|---|---|---|---|
| AFSA | 17.778 | 0.9254 | 15.9425 | 0 | 5s |
| PSO | 8.0570 | 2.8915 | 4.7685 | 6 | 12s |
| ZN | 6.98 | 3.876 | 0.987 | 22 | 6s |

The PID Parameters of all the plants are tuned using Artificial Fish Swarm Algorithm, Particle Swarm Algorithm and Conventional Ziegler-Nichols approaches. The plants that are being tuned using AFSA have comparatively lower overshoots then other approaches and the settling time is also reduced as compere to the other methods. Overall the Results show that the plant tuned with AFSA as much acceptable in terms of Parameters and Percent overshoot.

# CHAPTER 5
# CONCLUSION

The PID parameters are tuned accordingly with Algorithm as stated in the Results section. The results are meeting the criteria and are acceptable. For the analysis and validation of algorithm PID Pressure Control Pilot Plant is used for the Optimization of the PID Parameters along with several other examples. The result is interpreted properly and the system response and performance is better when it is compared with other optimization methods.

There is one limitation in the integral part of PID Parameters when tuned through AFSA, the Parameter is very small and does not match with the input criteria of the PID Control Faceplate in PID Pressure Control Plant. Overall the simulation results are satisfactory. And hence our objective of study that was to "tune the PID Control Parameters" is achieved.

For the future recommendation of the study, the effect of the parameters of Artificial Fish Swarm Algorithm must be taken in to account to see the various aspects of the algorithm.

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# APPENDICES

# APPENDIX A

# FISH SWARM CODE

# APPENDIX B

## MATLAB CODE FOR OPTIMIZATION FOR PID PARAMETERS