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DISSERTATION REPORT

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System Identification and Control for Scrubber Unit at MLNG

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Electrical and Electronic Engineering

CERTIFICATION OF APPROVAL

System Identification and Control for Scrubber Unit at MLNG

by

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Approved by,

(Ir Dr Idris Bin Ismail)

UNIVERSITI TEKNOLOGI PETRONAS

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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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(MOHD FARID IZZAT BIN IKWHAN)

ABSTRACT

Nowadays, there are a lot of research that focus on plant improvement; especially in Malaysia Liquefied Natural Gas (MLNG). Without these improvement, the outstanding cost for the plant operation could not be reduced; these improvement is needed to reduce the cost operation so that more revenue will be gained. Thus, optimization are needed to develop profit in any methods available; for this case is to reduce cost of plant operation. Before the project can proceed, research on System Identification and the process are needed. In this paper, the first approach for optimization is to model the plant step test data. Step test data was done in MLNG. Then, obtained data was identified by using System Identification Toolbox in MATLAB. The data was modeled by using the System Identification methods available such as Auto Regression eXogenous (ARX), Box Jenkins (BJ), and also State Space Analysis. The model will be estimate and validate, hence the best model method will be determined by Best Fit Analysis. Then, the model will be control by using pole-placement method and projected output will be compared with the plant data. The outcome of this project proven that the plant can be more optimized with deeper research and analysis of the plant. The more optimized the plant will be, the more profit gain the plant will be.

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LIST OF ABBREVIATIONS

SI	System Identification
MLNG	Malaysia Liquefied Natural Gas
ARX	Auto Regression eXogenous
BJ	Box Jenkins
SISO	Single Output Single Input
PBRS	Pseudo Binary-Random Sequence
CV	Controlled Variable
MV	Manipulated Variable
FODT	First Order Dead Time
SODT	Second Order Dead Time
APC	Advance Process Control
MPC	Model Predictive Control

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Natural Gas (NG) is one of the natural resources that the whole world used for many purposes such as fuel. Therefore, the demand for it increase year by year as we depend on it. Make matters worse, it increases exponentially same with the population growth.

As this project focus on the scrubber unit in MLNG, this particular unit is the part that given to be optimized for increase the production, reduce the operation costs and increase the quality of the end product. Before optimization can be done, the plant or the process should be modelled to represent it into mathematical data that can be simulated later. These estimation is known as System Identification (SI).

SI also divided by two main categories that are linear and non-linear method. Each of them is best to be used according to the process itself. For instances, the number of degrees of freedom and constraints are determined before choosing the method for SI besides the linearity of the process itself [1,2]. Method that can be used such as Auto Regression eXogenous (ARX), Box-Jenkins (BJ) modelling and State-Space analysis [3-8].

As scrubber is used to separate unwanted particles [9] and in this case this particular unit operates with Single Input Single Output (SISO), linear method used to model this unit [3-6].

1.2 PROBLEM STATEMENT

Scrubber Unit in MLNG (U1400)

This unit main process is to remove IC_5 (Iso-Penthane) from the feed towards the end product. Hence, there are certain acceptance value of IC_5 in the pipeline and were monitored and controlled by the reflux part of a knock-out column. Here, the accepted value will be controlled; if the IC_5 value more than the accepted value, the reflux valve will manipulated so that the value will be decrease. Thus, modelling specifically on where these unit will optimize the end product.

This process (as shown in Figure 1) itself located between the Dehydration Unit (U1300) and the Liquefaction Unit (U1400), thus the feed (314_FRC009) will become more exposed of disturbance that could be occur anytime. To prevent the product from become off-spec and faster respond of the Scrubber Unit MV, the temperature (314_TI001_43) will be monitored together with the composition. Temperature was assumed that it will change if the composition change as their properties varies (heat capacity and many more). Thus, before the product become off-spec due to late respond of the analyzer, the temperature sensor will indicates increase in temperature and quickly react according to the controller that were set earlier. Control will be on direct relation of the temperature and the flow that will be found out throughout the project end .

Hence, the operation cost can be reduced when these plant optimized. Nevertheless, the problem needed to solve is how to optimize the plant.

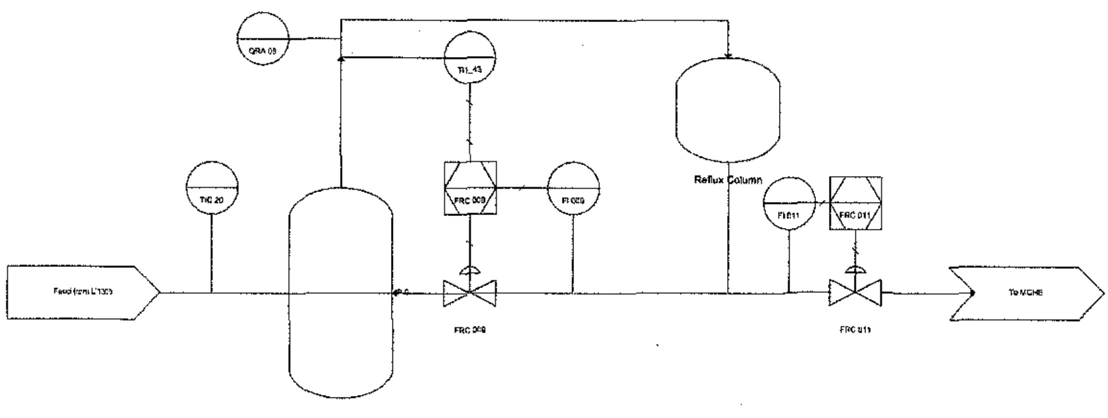

Figure 1 : Scrubber Unit in MLNG

1.3 OBJECTIVES

- To reduce the cost of the plant operation
- To obtain the dynamical models for the plant (System Identification) for better improvement of the plant
- Finding suitable technique in acquiring data for System Identification in online plant – best technique is the best representation the plant
- Design a controller to control the Scrubber unit

1.4 SCOPE OF STUDY

The scope of study for this research project is about the most efficient method to do an optimization of a certain fragment of the plant. Thus, the research must be includes all relevant steps for optimization process; in this case firstly system identification and later on is the appropriate control approaches to be implemented at the controller.

There are many system identification methods available nowadays. Anyhow, several reliable and matching criteria identification methods are used for SISO such as ARX, BJ and state space representation [3-6]. Different process uses different methods because each process has its requirement such as suitable for first order or second order process besides how many output or input applicable for the process. Before that, these base data was formed that is estimation and validation data. All of them compared to get the best fit result [10-13].

Before that, we must study on the standard system identification technique on how to data were acquired in an online plant. Here, research on how online plant was undergo to achieved the best model suited for the plant representation before more further steps in the optimization [14]. The example of techniques is step test, and Pseudo-Binary Random Sequence (PBRS) [15].

Besides, the relevant control approaches for the chosen model used for representing the plant is also needed to look on. Without the right control approach, the output for the model if given the signal would not turn out to be as expected; thus giving bad results. By using PID control with Pole-placement method, the author managed to get the model to react as wanted.

1.5 RELEVANCY OF PROJECT

In terms of the relevancy of this project, it poses a great deal of significance to the production site. Demand for NG increases as there are many usages for it nowadays such as alternative for petrol. As the demand for it increases after a lot of customers wanted to have this resources, gas companies are striving towards the hard way to enhance their production.

The ability to optimize efficiently is the primary condition for business decisions. There were allocated budgets and department to undergo study on optimization. With the optimization, the production will boost up thus more profit will be added to the revenue; the effort and costs finally pays off.

Therefore, before the optimization can be done, we suppose to model the plant for the analysis of the process can be done. The major problem is on how to identify the system of the online plant by using system identification.

Firstly, we can wait for the identified constraints to become constant. Here, we can ensure the stability of the process thus good model can be found for this system. Better model gives out better data representation of the plant.

Besides, we also can do the PBRS (Pseudo-Binary Random Sequence) for the step test instead of normal step test [12]. Here, the system will ensured the product will not damage due to the step test as the CV will be set higher than average. It is because to prevent the CV will not exceed the accepted value for the product. If the value exceeds, the product will become off-spec.

The modelling part also plays part in this project. The nearest model for the plant can give out almost exact reaction with the real plant react. These modelling characteristic differs with the process and the types of the model itself. It varies between the system input and output besides the concept for the model itself.

1.6 FEASIBILITY OF PROJECT

All of the objectives stated earlier are achievable and feasible in term of project duration and time frame. Researches and simulations for this whole project will not take more than the whole allocated time if planned wisely.

Step test were done earlier at MLNG and data was acquired from them. By that data, modeling can be done after selection of range and some manipulations were done with it. After that, model were estimate and validate before accept by best fit analysis.

In these eight months, a lot of simulations were done. By using trial and error approach, majority of the time were spent in determining the best modeling method in the System Identification Toolbox. Even though there are a lot of available modeling methods, some of them gives out bad results thus the author remove the method from the list.

More over, the appropriate controller for the model before arranged in the function block need to be find out because not all of the controllers gives out good reaction. Besides, to enhance the reaction, all of the controllers needed to manually tune to get better output results.

Nevertheless, by countless of simulations and trials, the best results will be produced and it still within the time constraints given. Even though there sometimes the author was having the difficulties to proceed, the author managed to overcome it within the time given.

CHAPTER 2

LITERATURE REVIEW AND THEORY

2.1 LITERATURE REVIEW

This paper will be discussing about the system identification available to indentify the process curve. Thus, best system identification is needed to get the best model for the data. As mentioned earlier, the evolution of technology gives a big impact to our life as technology expands by time. Therefore, throughout the year 80's, 90's and past over the millennium, technology benefits production site of the plant; increases production by optimization. In the 1980's, Box Jenkins modelling are not an option because of the current technology limit. It is shown by Ljung books on System Identification first edition during the 1980's did not have the option for Box Jenkins Method as it was not yet discovered during that time [3]. Thus, by having more modeling method, there are more options for SI thus more multivariable types of process can be modeled for further analysis such as optimization.

As for the step test, journal on Mixed-Signal Circuit Classification in a Pseudo-Random Testing Scheme indicated that the linear process usually have some Gaussian white noise. To reduce the effect of the noise, the most appropriate standard System Identification test is Pseudo Binary Random Sequence (PBRS). Besides, it can increase in accuracy and reliability of the step test [3, 15].

The PRBS is also advantageous as the signal varies between only two values that are practically in most industrial process. However, the range for the PRBS to take place is still limited within the allowed range to prevent the product of the process to be off-spec. Besides, the signal can be focused in a frequency range that corresponds with the process dynamic and its span will not exceed beyond the bandwidth of the plant [5].

According to Jensen and Skogestad (2006) in Optimization Operation of a Simple LNG Process, the Optimization needed to undergo several steps and procedure to do so. Firstly, modeling was done to determine the equation of state for the plant. Then, their manipulated inputs were determined and also the constraints that need to highlight for. After that then the degrees of freedom can be determined. For this process, the optimization method used is finding the optimal design for the plant. Thus, it was proven that by optimizing the design can optimize the operation [1,2,16-17].

To add on, a lot of Skogestad has suggested on self-optimizing control structure has the same pattern where the optimizing implementation depends on the control layer of the plant; whereas the lowest layer is the Control Variable (CV) and Manipulated Variable (MV). Start from the lowest to the highest are selection of controlled variable, selection of manipulated variable, selection of measurements, selection of control configuration and selection of controller type. However, the most crucial part is determining the constraints as it determine whether the implementation will be difficult or easy [1,2]. Then finally the project can enter the next phase of optimization.

For the best method to model an industrial process such as scrubber is to obtain from on-line plant. As for the process itself, we must determine what the constraints are and the assumed constant variable for the CV and MV can varies without changing any other variables. This was emphasized by McDonald (1997) in his discussion about On-Line Control of A Chemical Process Plant for the Exxon Chemical Patents Inc [18].

Control is one of the essential aspect for further optimization. The control approach chosen for the model is pole placement method [5, 19-21]. These controls are usually used for control loop feedback mechanism where there are feedback at the end of the process. Better control approaches provide better results and control for the process.

The presence of noises can affect the analysis of the data. Unwanted noise can be eliminated by filtering the data. In this paper, moving average filtering method is used to eliminate the noise thus give better results to the experiment [22]. Moreover, it is proven that when the noise was removed, data analysis will be more accurate [23].

The scrubber unit itself need to be considered. To optimized something, knowledge about the operation of process at that need to be enhanced. This was done through 7 months Industrial Internship at MLNG and close discussion with engineers and operation personnel. Thus it is proven in Kaiser's writings (2000), the plant process should be familiarized first before modeling can takes place to achieved the best model for the plant [24].

2.2 REVIEW OF SYSTEM IDENTIFICATION TECHNIQUE

There are many system identification technique used in modeling a process. In general, it can be segregated in linear system and non-linear system. The forms is more towards linear technique such as ARX, Box Jenkins and State Space.

2.2.1 Auto Regression eXogeneous (ARX) Modeling

It stands for linear regression modeling. It is one of the simplest system identification used because the disturbance does not have any gain in the model [8,17]. The model is represented in discrete form and normally used for discrete process. Besides, it has good signal-to-noise ratio where disturbance affect less to the model. Figure 2 shows ARX representation in block diagram where *u* is the input, *e* is disturbance and *y* is output.

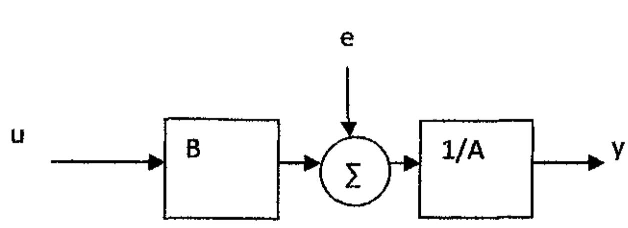

Figure 2 : ARX representation in block diagram

And it can mathematically prove by equation (2.1) where d is time delay, n_a is number of poles, n_a is number of zeros and *u(k)* is input:

$$A(z^{-1})y(k) = B(z^{-1})u(k-d) + e(k) \quad (2.1)$$
$$A(z^{-1}) = 1 + a_1 z^{-1} + \cdots + a_{n_a} z^{-n_a}$$
$$B(z^{-1}) = b_1 + b_2 z^{-1} + \cdots + b_{n_b} z^{-n_b+1}$$

2.2.2 Box Jenkins Modeling-

This modeling method was introduced in 20th century and a little bit late compared with ARX modeling. The flexibility is one of the best advantages of this Box Jenkins method. Despite having more polynomial than ARX modeling, this modeling assumes no common characteristic between noise and input-output behavior. This method also suitable with this process as the disturbance has no relationship with the input and the output of the process [8-9,17]. Figure 3 shows BJ representation in block diagram where *u* is input, *e* is disturbance and *y* is output.

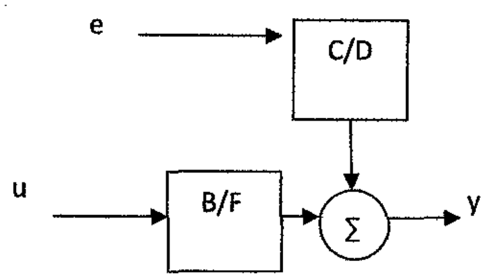

Figure 3 : BJ representation in block diagram

And it can mathematically prove by equation (2.2) where *d* is time delay, *na* is number of poles, *nb* is number of zeros and *u(k)* is the input:

$$y(k) = \frac{B(z^{-1})}{F(z^{-1})}u(k-d) + \frac{C(z^{-1})}{D(z^{-1})}e(k) \quad (2.2)$$
$$D(z^{-1}) = 1 + d_1 z^{-1} + \cdots + d_{n_a} z^{-n_a}$$

2.2.3 State-space Representation

By using state-space method, state variables are used to describe a system by set of first order differential or different equations [3]. It provides a convenient and compact way of modeling [25]. It can be used for both SISO and Multiple Input Multiple Output (MIMO). It can mathematically proved by equation (2.3) where $\dot{x}(t)$ is the derivated input from *x(t)*, *y(t)* is the output and *A*, *B*, *C*, and *D* all are their gains.

$$\dot{x}(t) = Ax(t) + Bu(t) \qquad (2.3)$$
$$y(t) = Cx(t) + Du(t)$$

2.2.4 Best Fit Analysis -

Best fit is used to evaluate and compare various SI technique. By undergo model estimation and validation throughout the system identification, the estimation modeling that satisfy with the validation modeling by best fit with the actual data is the best choice of system identification for the process[17]. The norm for output is over norm of the input. The best fit analysis can be determined by equation (2.4):

$$fit = 100\ x\ \left|1 - \frac{norm(\hat{y}-y)}{norm(y-\bar{y})}\right| \% \qquad (2.4)$$

where y = true value, $\hat{y}$ = Approximate value, $\bar{y}$ = Mean value

2.2.5 Filtering

Filtering is a common technique to remove unwanted measurement or noises. Filtering noises from the graph could increase the effectiveness of the model. Thus, by smoothing the graph (as shown in Figure 4) using moving average filter technique, the noises from the graph will be reduce thus improve the data to be estimated or modeled later on [22,26-27].

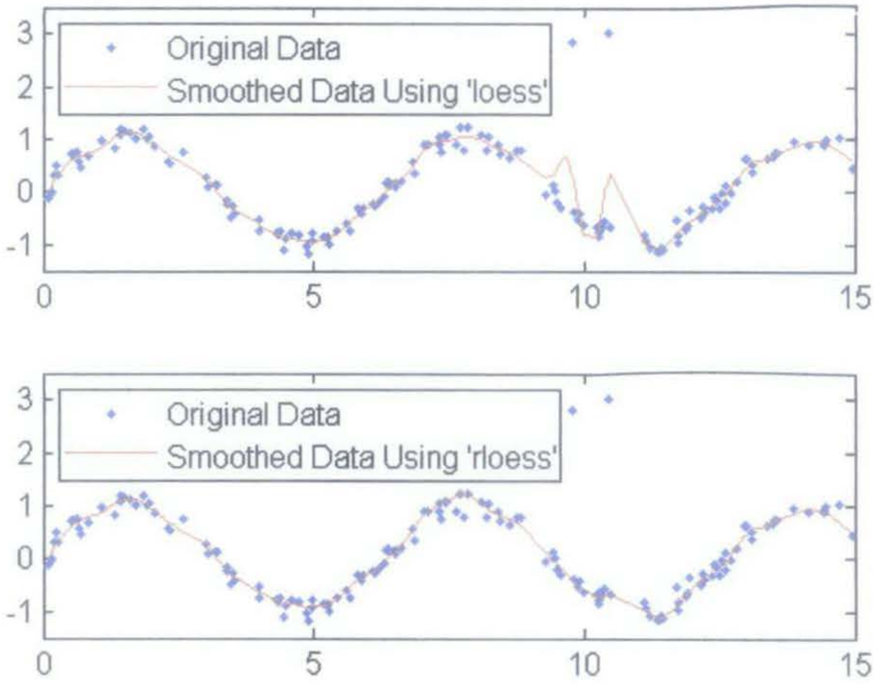

Figure 4 : Example of smoothing data in MATLAB

2.3 PID Controller

PID is widely used in industry. Thus, selection of PID controller would meet the industrial needs. In MLNG, more than 90% of the controller uses PID. Many of the MLNG operators are familiar with PID tuning thus selection of PID controller would be appropriate for this study.

PID Control Pole-placement Method

Same concept with the ordinary PID control, this method is used as a controller to control the plant and the user specifically choose the pole location in this closed loop feedback system [5,28-29]. Besides, this type of control is also used in decentralized control because of its self-tuning attribute [30]. Figure 5 shows Pole-placement method representation in block diagram where w is input, u is the feed to the plant and y is output where it is proven more in equation (2.5).

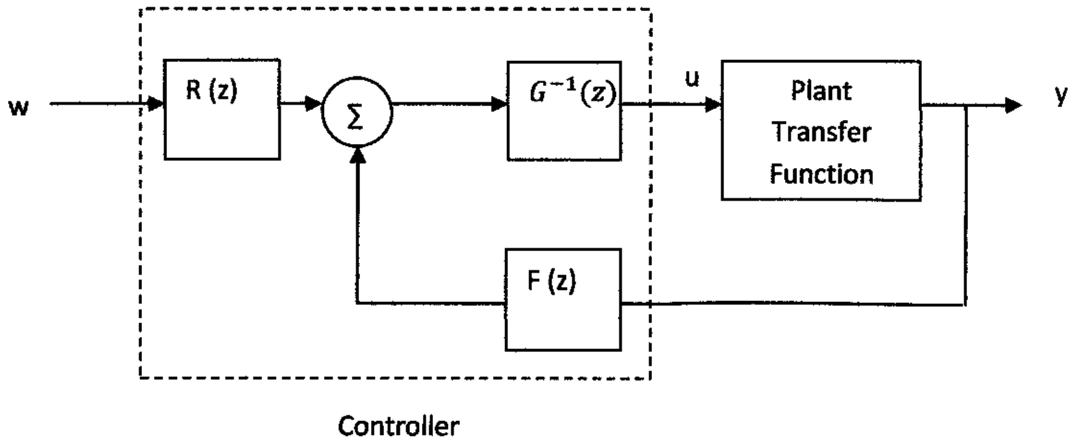

Figure 5 : Pole-Placement Control in block diagram

Control law defines that,

$$R(z)W(z) - F(z)Y(z) = G(z)U(z) \quad (2.5)$$

$$\text{Plant Transfer Function} = \frac{Y(z)}{U(z)} = \frac{B(z)z^{-k}}{A(z)}$$

$$\text{Overall function} = \frac{Y(z)}{W(z)} = \frac{R(z)B(z)z^{-k}}{G(z)A(z)+z^{-k}F(z)B(z)}$$

Where *w* is the input, *R(z)*, *F(z)* and $G^{-1}(z)$ is the controller gain, *u* is the input for plant transfer function and *y* is the final output.

CHAPTER 3
METHODOLOGY

3.1 RESEARCH PROJECT METHODOLOGY

Basically, there are eight strategic approaches involved in this project research methodology. Those approaches are shown in Figure 6.

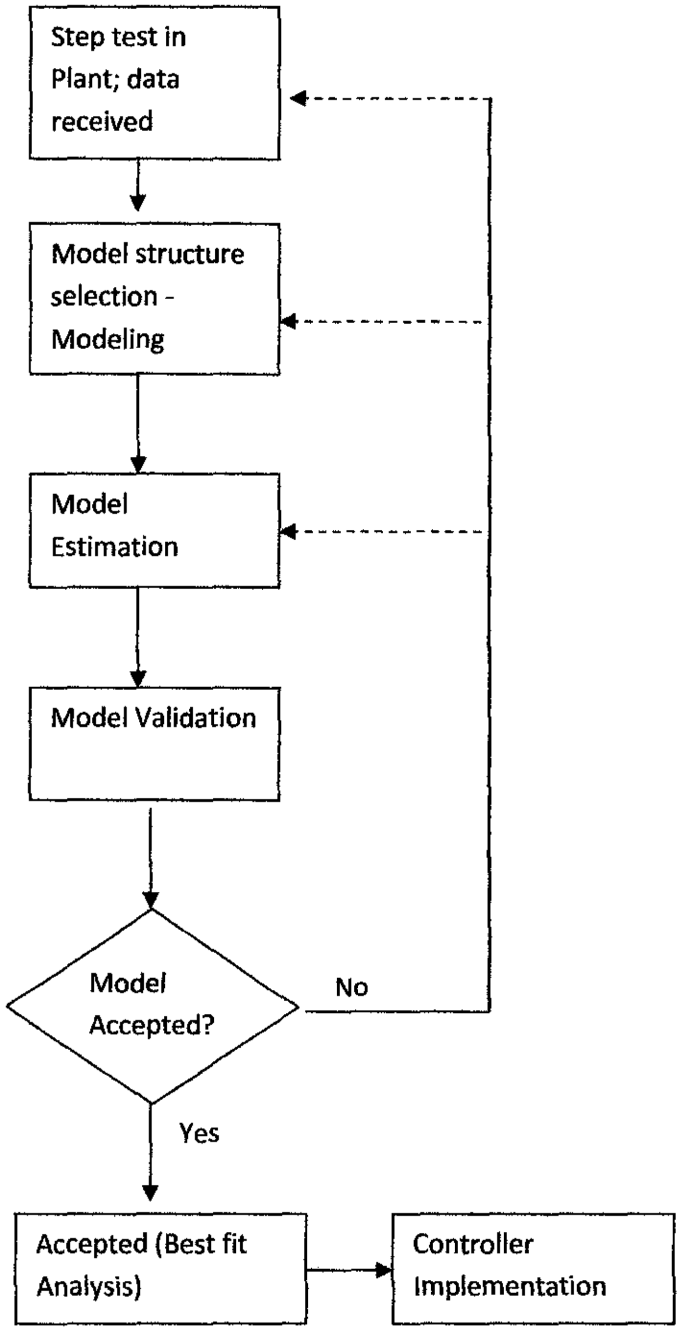

Figure 6 : Research Methodology

Figure 6 shows the general approaches taken to extend of the project. Before that, the problem statement or the concern of the project is production is possible to be increased. Thus, by research for the best way to optimize the plant we can determine which method suits the best. Hence, we can increase the production and in the same time increase the profit for the company. But before that, a good system identification is needed.

The objective for the project is to:-

- To reduce the cost of the plant operation
- To obtain the dynamical models for the plant (System Identification) for better improvement of the plant
- Finding suitable technique in acquiring data for System Identification in online plant – best technique is the best representation the plant
- Design a controller to control the Scrubber unit

3.1.1 Data Acquisition

Upon after receiving the project title, the first step the author of this paper need to do is to acquire data. Step test are the best data for modeling and the author managed to obtained the step test data from MLNG. The step tests are prepared by the operators in MLNG. For obtaining better step test, a near PBRS was done as shown in Figure 10 [15]. The data was acquired based on the actual plant condition. As there are noises in it, the data was filterized by using moving average filtering method to remove the unwanted portion of the data [16]. The span is set at 3% from the actual line to eliminate any unwanted noise that later on can affect the whole result [17-18].

3.1.2 Experiment Assumption

One of the assumption the author emphasize is the system is error free. The plant for the system is a closed loop feedback column that rarely having disturbance occur. Besides that, the system is assumed to be First-Order Dead Time (FODT) system or Second-Order Dead Time (SODT) system.

The difference between FODT and SODT is the complexity of the system where the transient respond varies between the two. SODT has a wide range of response that can varies from undamped, underdamped, overdamped, or critically damped [31-33].

3.1.3 Model Estimation and Validation

By using the MATLAB's System Identification (SI) Graphic User Interface (GUI), several types of modeling are tested such as ARX system identification modeling, BJ system identification modeling and state space system identification modeling [34]. The first part of data is used for model estimation meanwhile the second part is used for model validation. Besides for every method, every possible system orders are tested and compared with the best-fit analysis [10-13]. Besides, during this phase the range of the data used for both estimation and validation was determined by the author to get the best result. The process was repeated until the author satisfied with the results before proceed with the next step.

3.1.4 Control Architecture

As for the control architecture, the author has implemented Pole-Placement Controller which the user define the position of the pole for controlling the feedback of the system plant [23-24,30]. The configuration is shown by figure below. Discrete PID (as shown in Figure 7) is used to show and analyse the digital control technique as implemented in typical distribution control system.

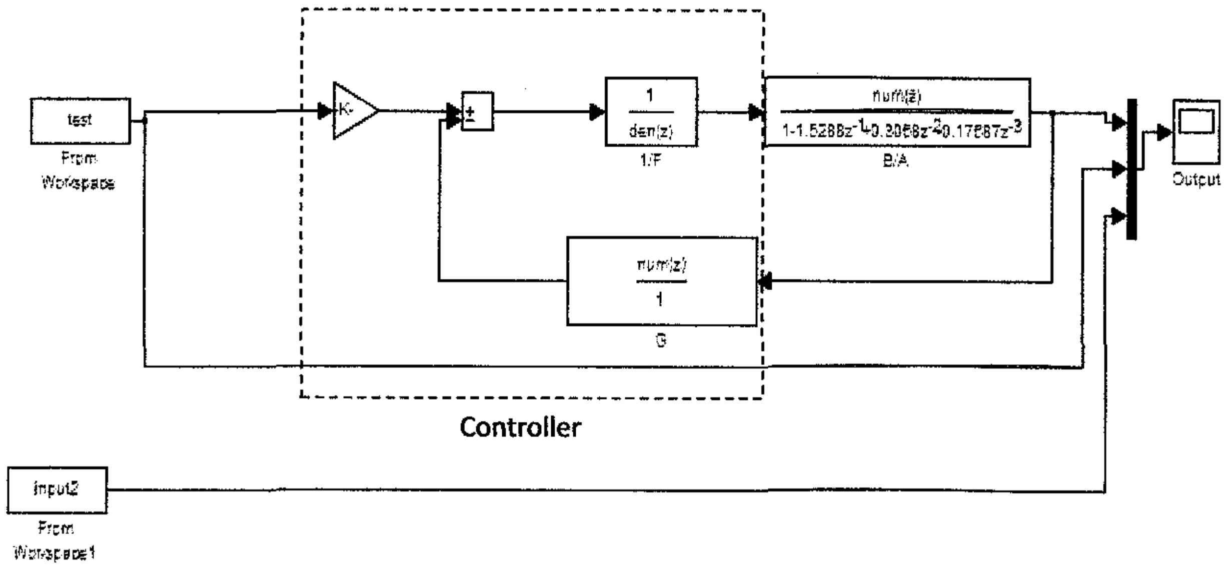

Figure 7 : Function Blocks in Simulink

3.1.5 Tuning Controller

The controller later on will be tuned by either Cohen-Coon or Ziegler Nicholas tuning method [30,35-36]. Basically, the tuning parameter is almost the same for all types of controller because eventually to get the best control for the system the controller needs to undergo manual tuning. Then, these fined tuning will help to achieve best reaction curve for the designated system.

3.2 Software and Tools

There are several tools the author used throughout this project. All of them is available in MATLAB such as System Identification Toolbox. Besides, there are a lot of functions available in MATLAB that can be used in this project as long as the syntax is right. For instance, the data filtering and measuring the area under curve function were all already available in MATLAB. The combination of all these function used to run the project throughout the progress.

3.3 Gantt Chart Semester 1

No	Detail/Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Selection of Project Topic								Mid-semester break							
2	Preliminary Research Work															
3	Literature Review															
4	Preliminary Report Submission							√								
5	Proposal Defense							√								
6	Software and Equipment Familiarization															
7	Simulation Using Software															
8	Submission of Interim Report															√

√	Milestone
	Process

Figure 8 : Gantt Chart for FYP 1

3.4 Gantt Chart Semester 2

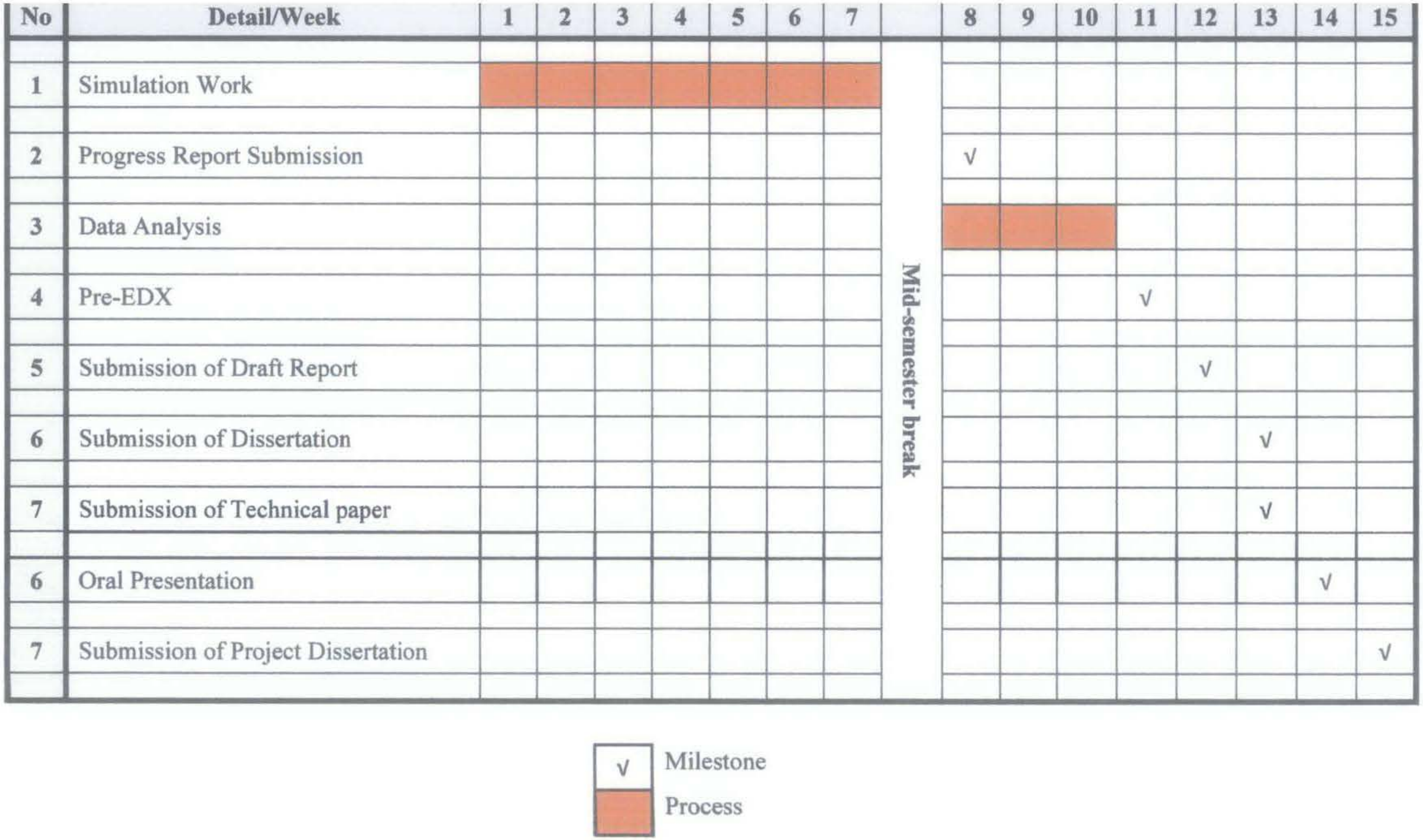

Figure 9 : Gantt Chart for FYP 2

CHAPTER 4

RESULTS AND DISCUSSION

4.0 INTRODUCTION

The prospected was started with discussion with MLNG personnel. After several discussion, best available data was send and used for analysis. The data consists of 400 minute, taken approximately June 2011.

In general, three run of experiment are carried out. First run was each data of estimation and validation uses the 200 minute each. For second run, each of data consists of 80 minutes each. The last run is the same with the second one but the data was filtered before analyse.

4.1 FIRST RUN

System Identification need some specific series of data to produce the model for the data. As in the MLNG itself there are a lot of data that being saved for analysis purpose, the appropriate series of data needed for optimization purpose. Hence, the step test data was chosen and the whole period of step test data commissioning was obtained. These data later is on plotted in MATLAB System Identification Toolbox for further progress. First run is the first data obtained from MLNG. The data is used based on the best available data that closely show changes similar to PBRS. Figure 10 shows set of data for header temperature and feedback flow back to the scrubber.

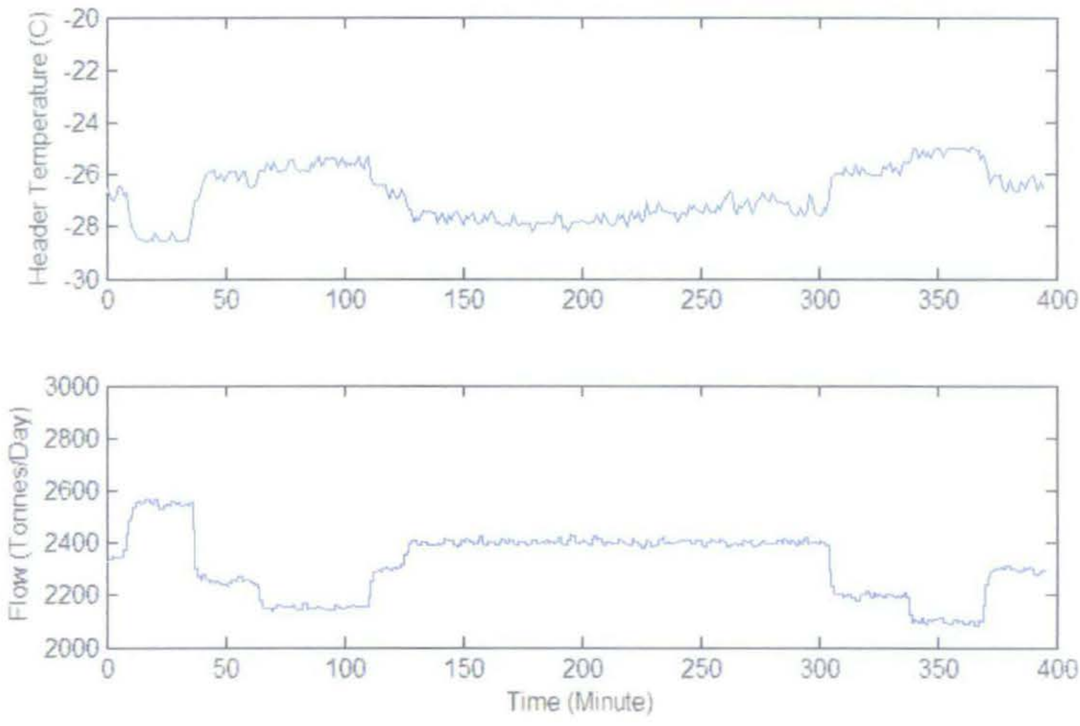

Figure 10 : Data Obtained from Plant

Then, the data were split into two; one for estimation and one for validation purpose as shown in Figure 11 and 12. Two sets of data are selected for modelling purpose; one for estimation and one for validation. These two set are chosen from the range that tried by trial and error and will be compared by best-fit analysis to find the best model for the system. The range chosen for this first run is 200 minutes for both estimation and validation data.

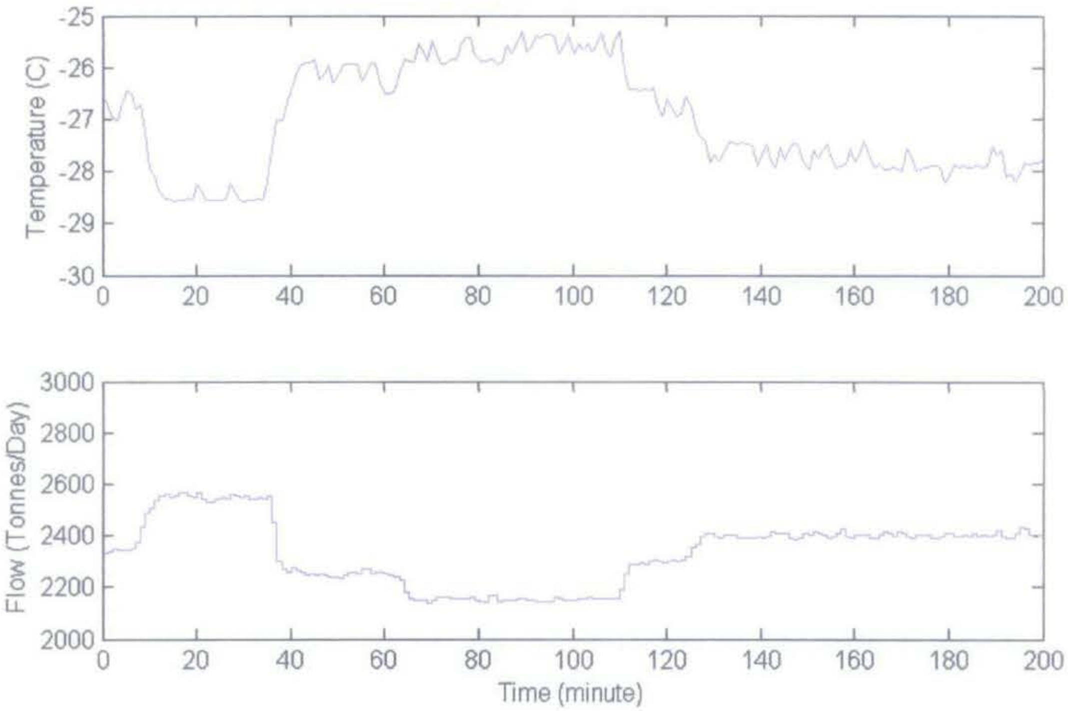

Figure 11 : Data estimation for first trial

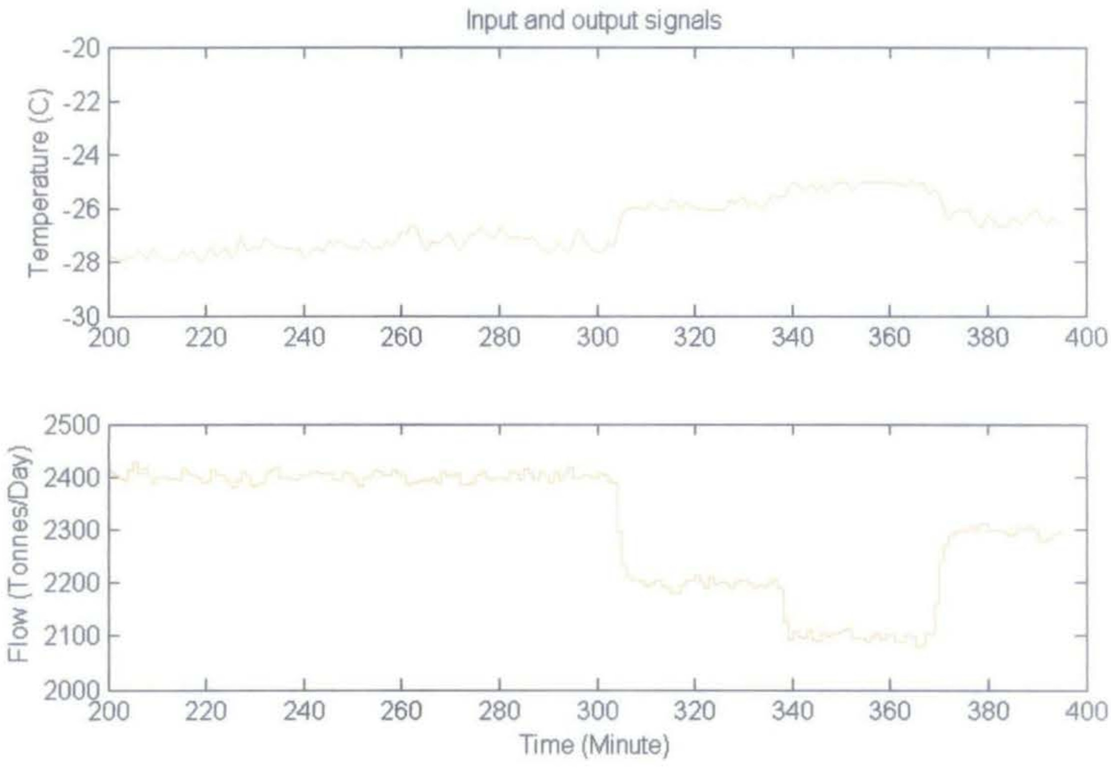

Figure 12 : Data validation for first trial

Thus, the best fit analysis was done and the best fit graph and table is shown below where the black line is the process model itself (shown in Figure 11 and Table 1). Because of there are a lot of modeling type that had been tried, the author shortlisted a few to be shown.

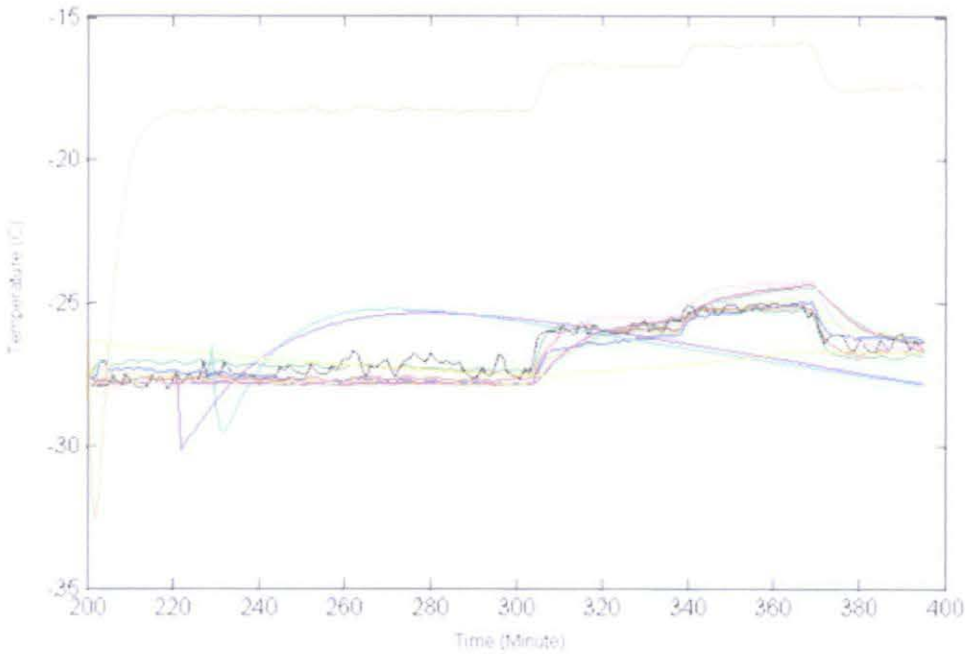

Figure 13 : Best fit analysis for first trial

Model	Best Fit (%)
3rd Order Non-linear ARX	61.35
2nd Order ARMAX	59.2
3rd Order ARX	45.08
1-pole Process Model	18.15
1st Order BJ	41.43

Table 1 : Best fit Analysis for methods in first trial

The requirement for the model was not achieved as the best fit for the analysis should be more than 70%. Thus, the author needs to repeat the modeling step again.

4.2 SECOND RUN

The range of data was manipulated to find the better results in term of best fit analysis. 120 samples were chosen for each type of validation and estimation data (as shown in Figure 14 and Figure 15). Besides, these are the period where the step test is done. Hence, the result for the best fit analysis would be higher than before.

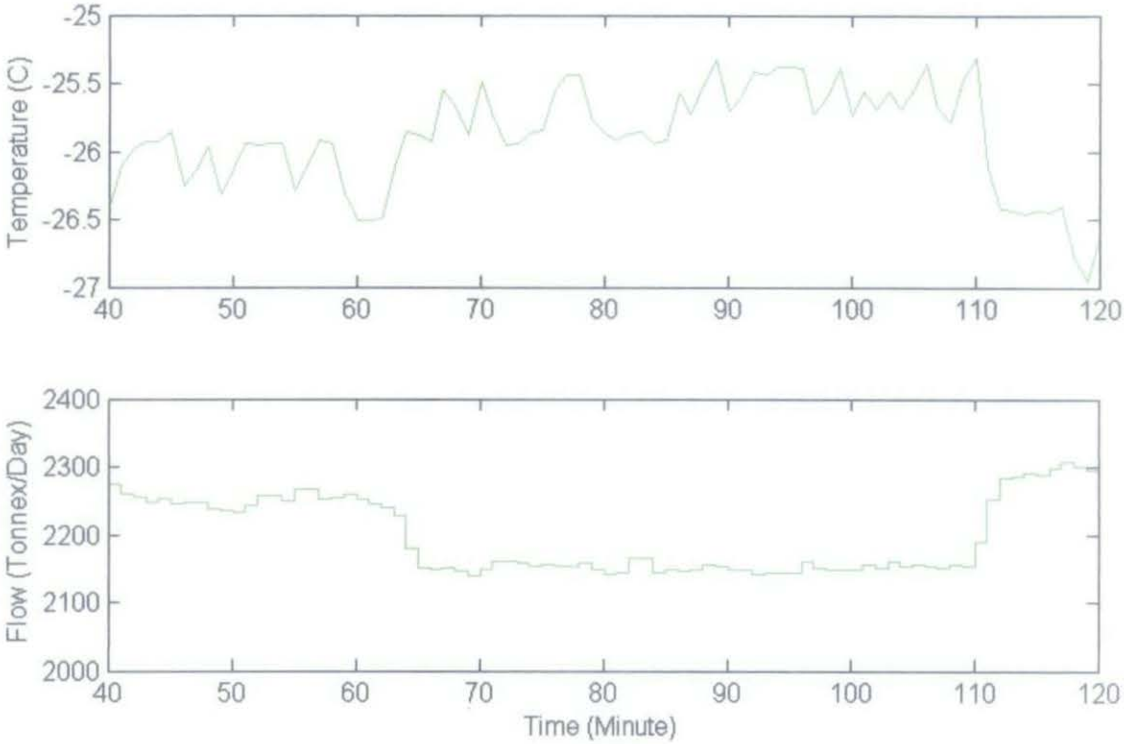

Figure 14 : Data estimation for second trial

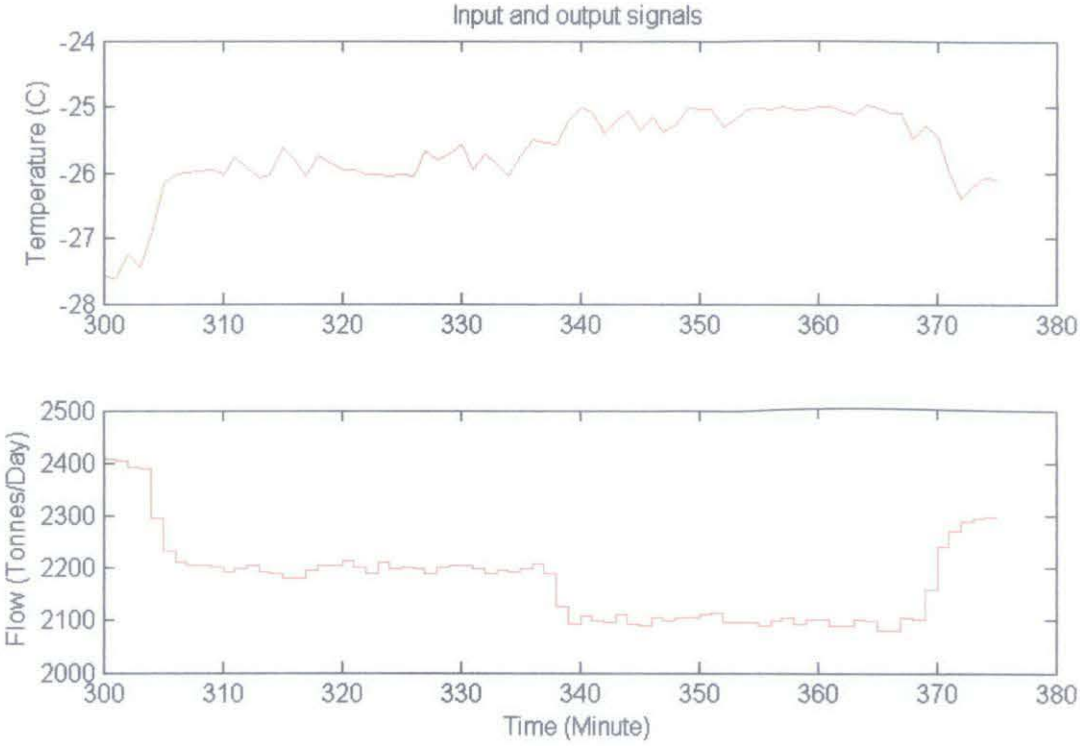

Figure 15 : Data validation for second trial

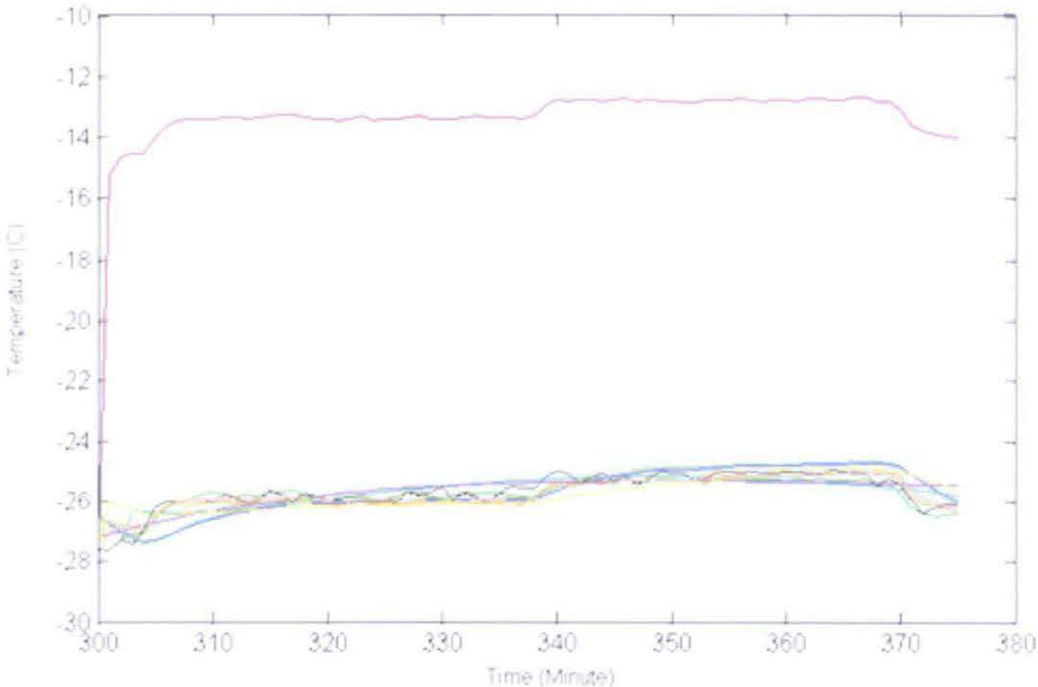

Figure 16 : Best fit analysis for second trial

Model	Best Fit (%)
Non-linear ARX	64.17
2nd Order ARMAX	60.45
3rd Order ARX	59.95
3-poles Process Model	47.33
1st Order BJ	49.2

Table 2 : Best fit Analysis for methods in second trial

The requirement for the model was still not achieved as the best fit for the analysis should be more than 70% (shown in Figure 16 and Table 2). However, the increased best fit results indicates that the author was in the right track, Thus, the author need to repeat the modeling step as in the methodology try to solve the issue. It is proven that noise from the measurement could affect the accuracy of the model. Thus, It is suggested that noise from the measurement to be filter to evaluate whether this could increase the best fit values.

4.3 THIRD RUN

To enhance the modeling results, the unwanted noises should be removed from the data. As the data obtained has a lot of noise and needed to be filtered, these data are filtered by using **smooth** function in MATLAB. For instance, moving average is a filter method that uses unweighted mean to smooth out the curve of data. Thus, the author has introduced a few types of filter to be used and the results were manually compared later on. The span initially was set to 10% from the actual data. The filtered data that consists of local regression filter, savitzky-golay filter and moving average filter are shown in Figure 17, 18, 19.

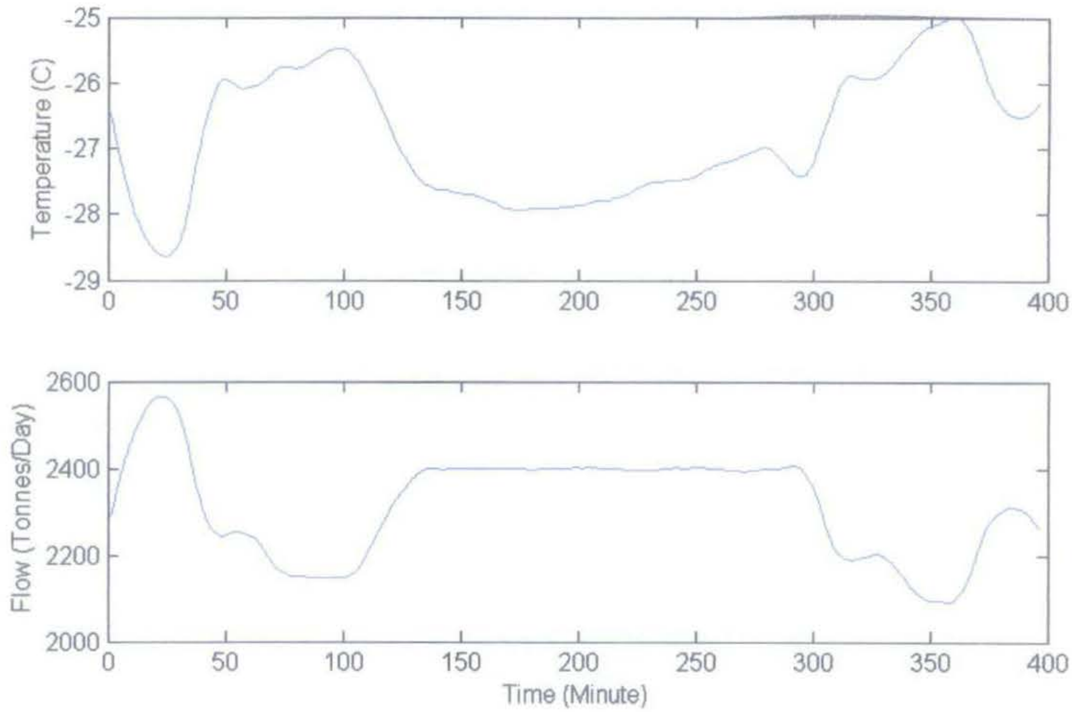

Figure 17 : Data filtered with local regression filter

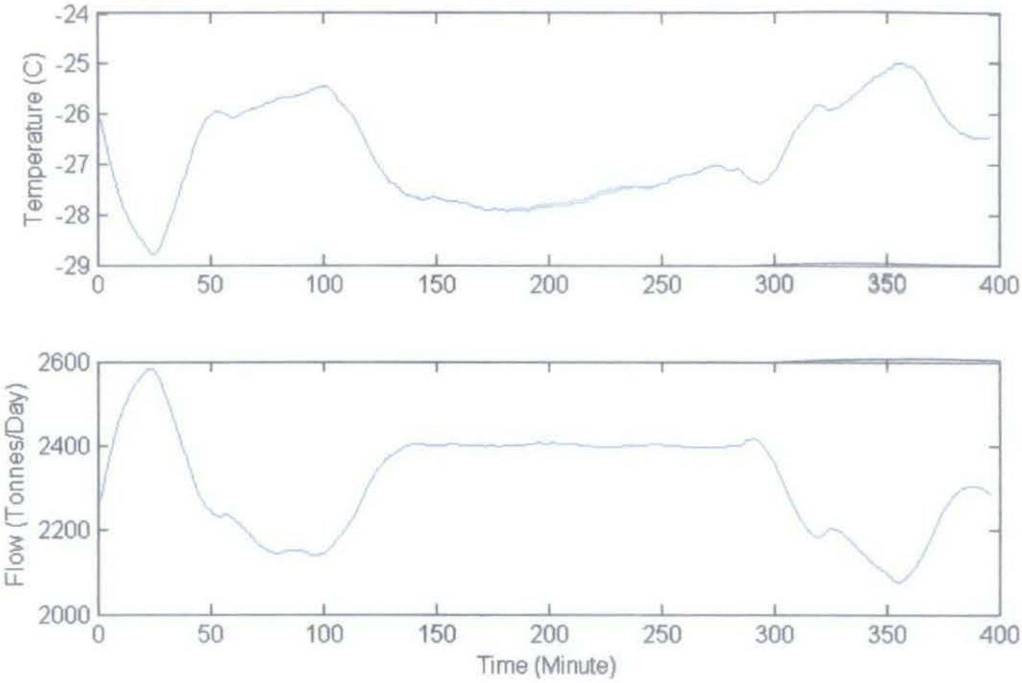

Figure 18 : Data filtered with savitzky-golay filter

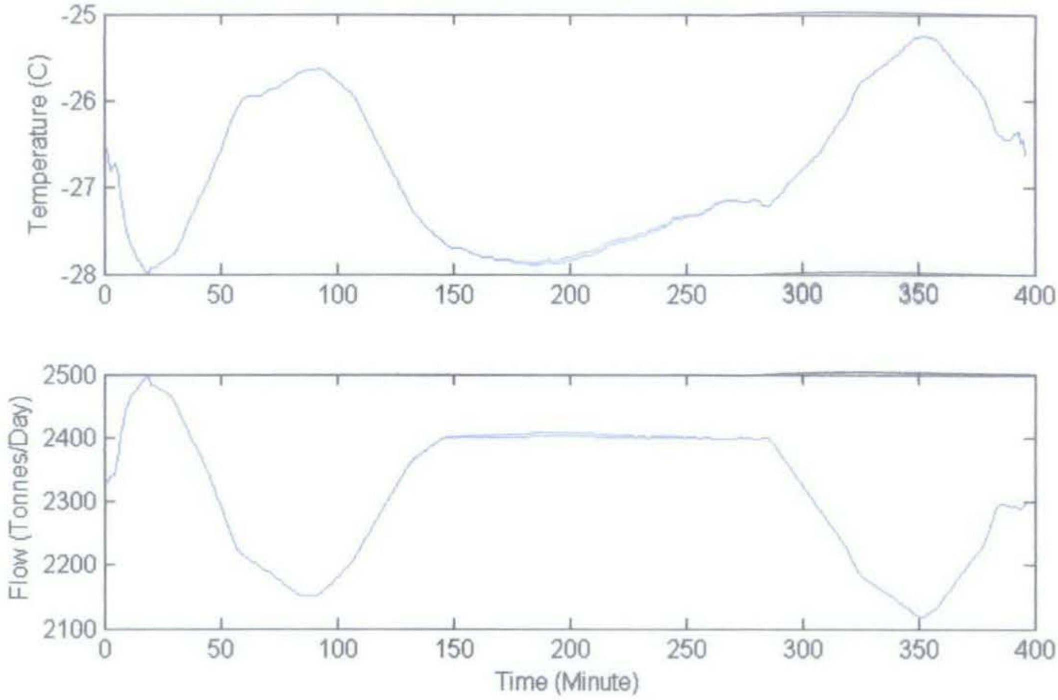

Figure 19 : Data filtered with moving average filter

The step was repeated with span value of 5% and 3%. Hence, the chosen filtered data that compared manually with each other is used for the next part of the project.

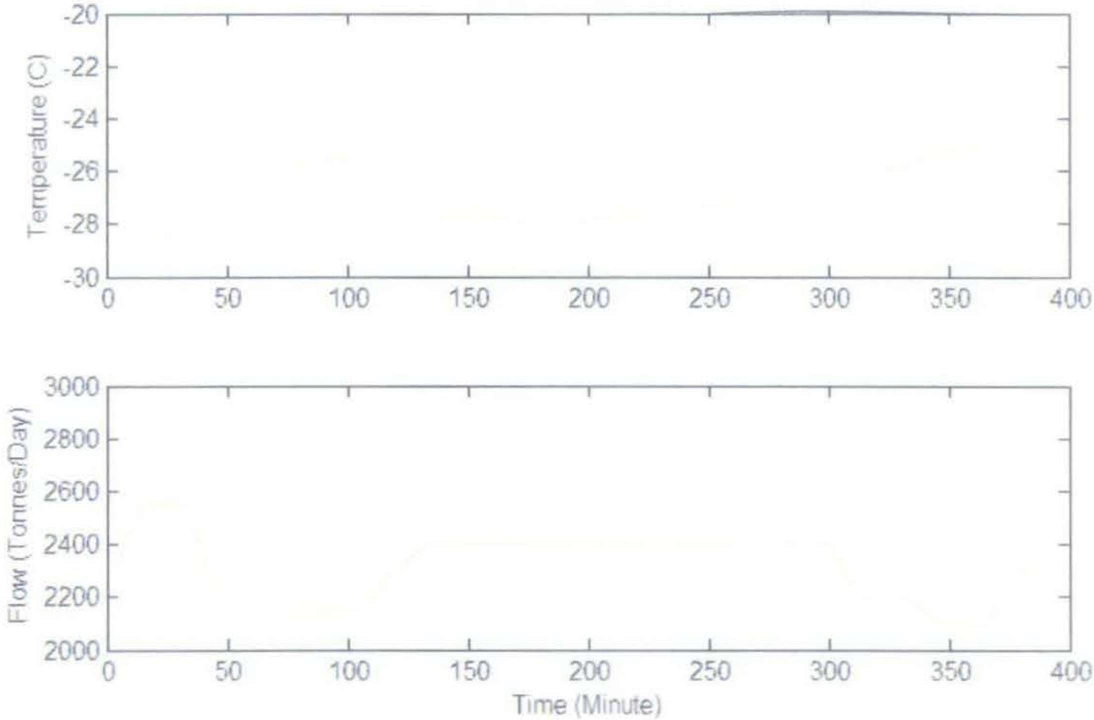

Figure 20 : Final Data After Filter

Two sets of data are selected for modelling purpose; one for estimation and one for validation. These two set are chosen from the range that tried by trial and error like before (as done in second run and shown in Figure 21 and Figure 22) and will be compared by best-fit analysis to find the best model for the system.

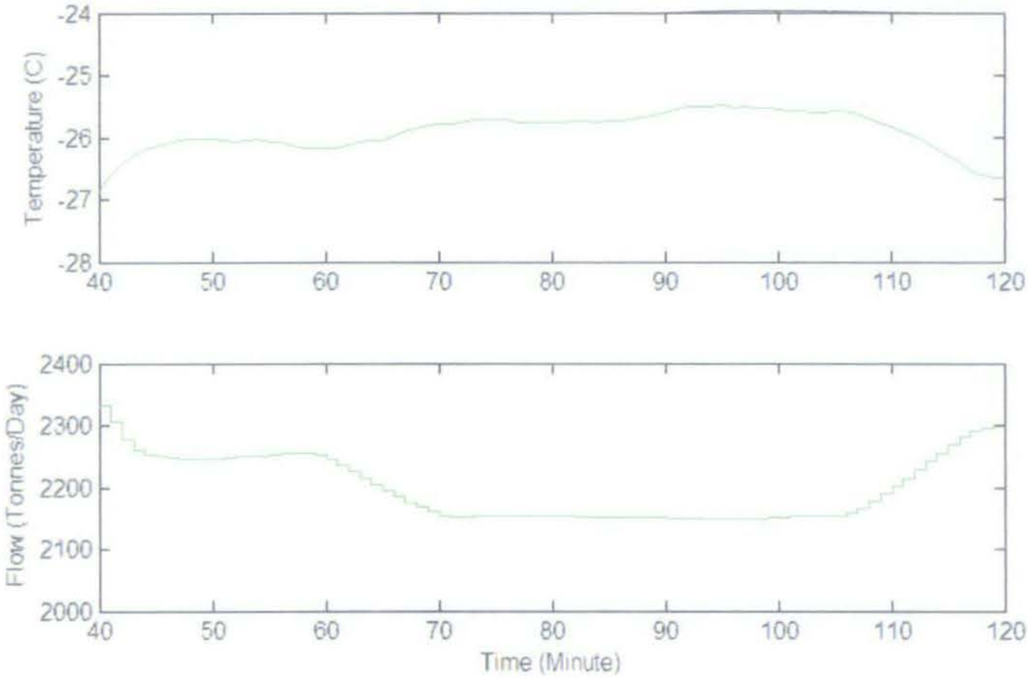

Figure 21 : Data estimation for third trial

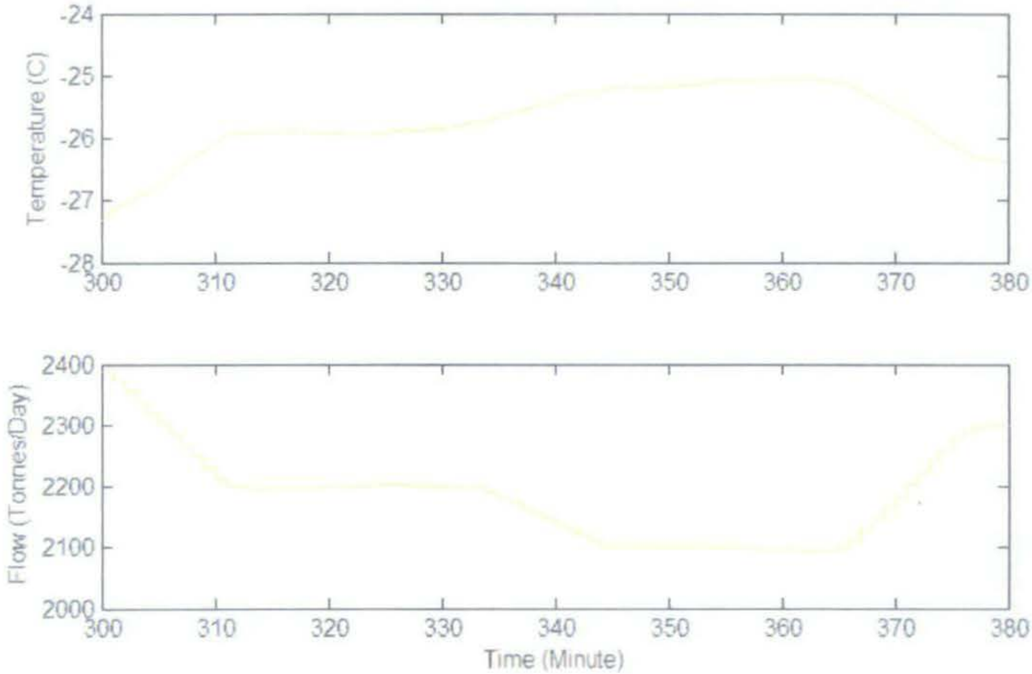

Figure 22 : Data validation for third trial

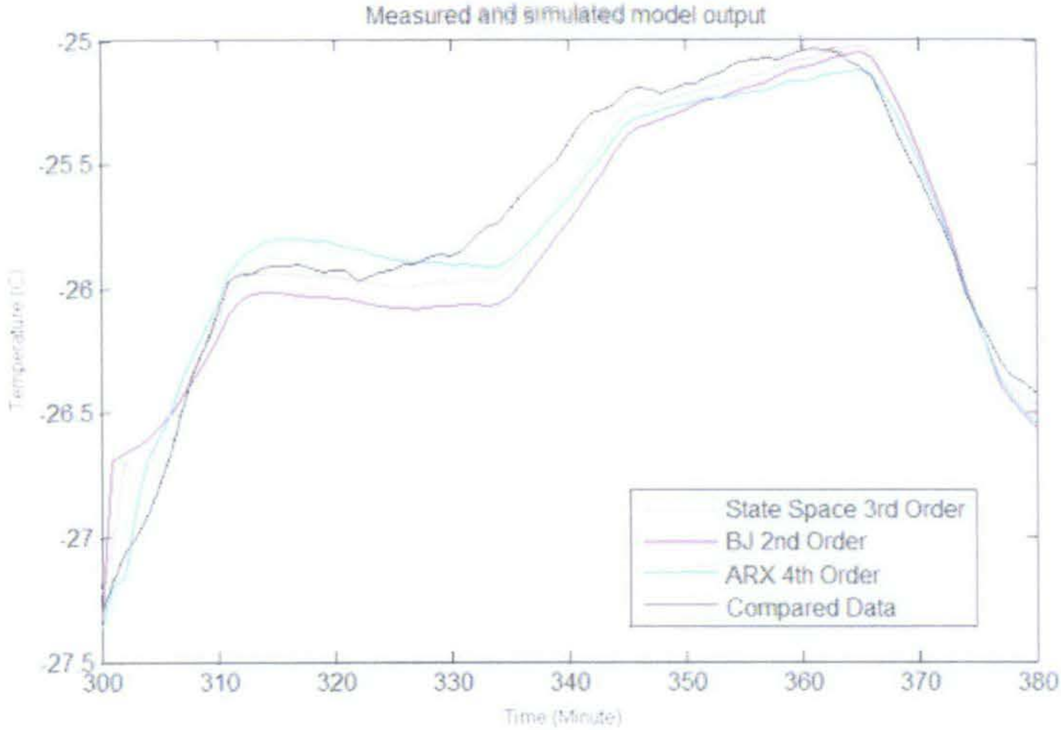

Figure 23 : Best fit Analysis for third trial

Results for this model is:-

Model	Best Fit (%)
3rd Order ARX	74.32
2nd Order ARMAX	73.74
Nonlinear ARX	70.09
2-poles Process Model	68.7
2nd Order BJ	67.12

Table 3 : Best fit Analysis for Method in third trial

As shown in Figure 23 and Table 3 for this model, the best results is the 3rd Order ARX Modeling as it shows 74.32% best fit analysis with the actual data. By then, the parameters of this particular model are shown as below. Also given the loss function of the model is 0.000393645 and the Final Prediction Error (FPE) given is 0.000456629. The accepted range of best fit analysis is more than 70% from the best fit analysis.

Thus, from the parameter obtained, the transfer function obtained is:-

$$\frac{-0.004634z^{-1}+0.000577z^{-2}+0.0009414z^{-3}}{1-1.5288\,z^{-1}+0.3068z^{-2}-0.17687z} \tag{4.1}$$

Then, the plant will be implemented with a controller by using pole-placement approach. The model of the plant is configured is shown in Figure 24.

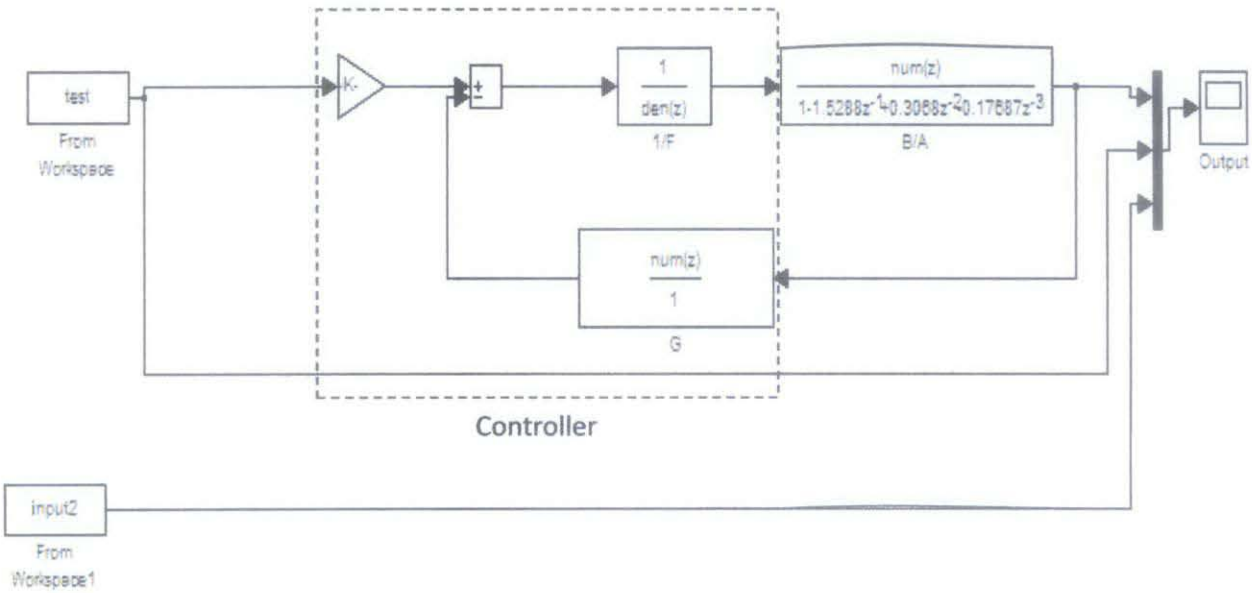

Figure 24 : Plant Model with Plant Transfer Function and Designated Controller

The output of the plant is compared with the model output by selecting the range of the output data with the model output when given a step test referring the plant output. After done a lot of manual tuning, the data was plotted and compared with Area Under Curve (AUC) analysis.

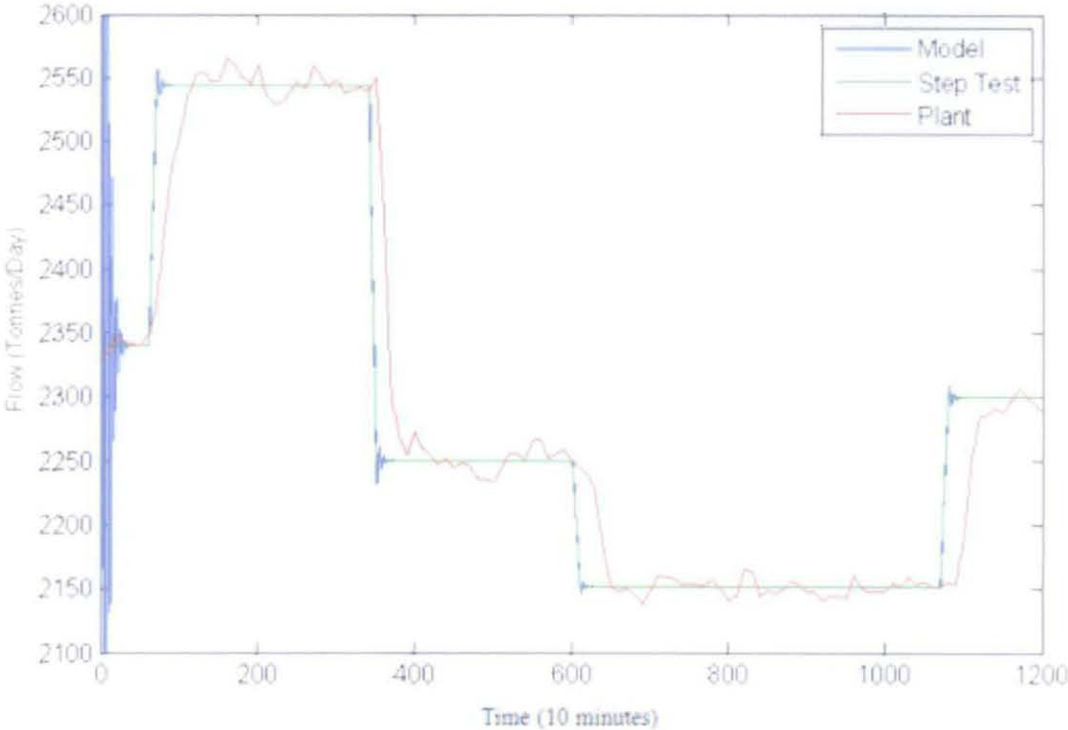

Figure 25 : Output of Plant Model

Figure 25 shows the output of plant model compare to step test and plant data. It can be seen that the output can be control effectively. It also can be observed that it also follow the actual plant changes based on the PBRS change. Figure 26 shows the error achieves in third run model.

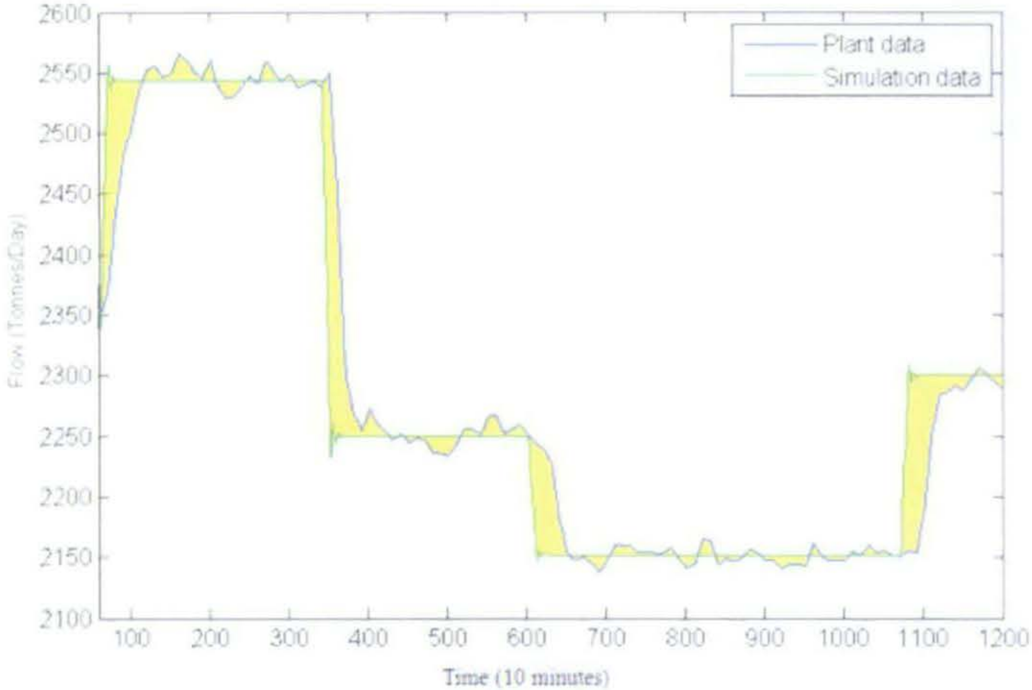

Figure 26 : Area Under Curve (AUC) for Plant Data and Model Output

Subject	Value
Area Under Curve of Plant Data	2608000
Difference of Area Under Curve of Plant Data with Model Data	48.6908
Percentage of Differences	0.05%

Table 4 : Area Under Curve Difference

Nevertheless, we can conclude that the model has small percentage of difference besides the model reaction curve also did not drift far from the step test. Thus, the model is valid to be used in the designated plant.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

Throughout the project, it is proven that there is always room for improvement. Hence, this further improvement helps to optimized the plant. The highlight of this project is achieving the best model with the best control approach to control the plant process hence improve the productivity of the plant.

The main objective of this project is to reduce the operation cost of the process. By lowering the margin of acceptable concentration of IC_5 within the acceptable range (0.05% mol), the feedback flow can be reduced thus less time needed for the process to reach the end product; indirectly lowering the operation cost for the process. Besides, higher value of IC_5 can cause lover Gas Heating Value (GHV) of the end product. In addition, the objectives of the project are satisfied and all of them were managed to be completed within the time allocated.

Moreover, the project can be more enhanced if the data acquisition is limited only in one shift to minimize human error on it. Besides, the project used PID control rather than any other control to meet industrial standard.

In the nutshell, there is always space for improvement that we can implement in any aspect if appropriate research and analysis were done to it. However, we need to carefully take into consideration of all the limits and constraints before trying to implement the improvement to it.

5.2 RECOMMENDATION

This project still can be improved in the future. By that time, a lot of new modeling technique will be found thus gives out more accurate model than what the author can find nowadays. Not only that, the control approach also takes place to help produced better reaction for the process.

By using this method to improve the other portion of the plant, the whole plant can be improved more. Besides, the Advance Process Control (APC) for the plant can also be optimized by integrating all of the controllers into a Model Predictive Controller (MPC) that can predict the output and react before any part of the process drift off badly.

For future usage, it would be better if more data acquired. This can enhanced the analysis with more series or conditions of simulation. Besides, more intelligent controller can be used such as fuzzy logic, neural network, and many more to explore the reaction of the model.

This project also can be presented on its findings to MLNG. Besides presenting the near similarities of the model with the plant, the effectiveness of the controller tuning also can be emphasize during the presentation. Even slightest improvement can increase the overall profit of the plant.

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