PROCESS CONTROL SYSTEM IDENTIFICATION

By

CHE MUHAIZILAWATI CHE HAS

A project dissertation submitted to the
Electrical & Electronics Engineering Programme
in Partial Fulfillment of the Requirements
for the Degree
BACHELOR OF ENGINEERING (Hons)
(ELECTRICAL & ELECTRONICS ENGINEERING)

UNIVERSITI TEKNOLOGI PETRONAS
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DECEMBER 2004

CERTIFICATION OF APPROVAL

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Approved by:

(Assoc. Prof. Dr. Mohd Noh Karsiti)

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 acknowledgment, and that the original work contained herein have not been undertaken or done by unspecified sources or person.

CHE MUHAIZILAWATI CHE HAS

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ABBREVIATIONS AND NOMENCLATURES

The list contains symbols that have some global use. Some of the symbols may have another local meaning.

AR	=	Auto Regressive
ARX	=	Auto Regressive with eXternal input
ARMAX	=	Auto Regressive Moving Average with eXternal input
SISO	=	Single Input Single Output
$e(t)$	=	disturbance at time t.
$u(t)$	=	input variable at time t
$y(t)$	=	output variable at time t

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بسم الله الرحمن الرحيم

In the Name of Allah, the Beneficent, the Merciful

ACKNOWLEDGEMENT

Many people have contributed guidance, supervises, supports and technical helps during the accomplishment of this whole project entitled 'Process Control System Identification'.

The author would like to express my deepest thank to all the people as listed below:

1. Associate Professor Dr. Mohd Noh Karsiti, supervisor of the project, who vigorously helps in many aspects until the project is completed as successful as it is.
2. Mr Rosdiazli Ibrahim, whom had contributed some ideas especially on handling the data acquired from the pilot plant process.
3. Mr Azhar Zainal Abidin, Lab Technologist of Process Control Lab, whom had helped a lot regarding the process control handling.
4. My beloved family, whose has been supportive from the beginning of the project.
5. And all other people whom are though not listed here. Without their helps, this project will not be completed as it is.

Thank You

ABSTRACT

System Identification is an art of dealing with a problem of generating workable model of dynamic response based on the observed dataset from the actual system. The modelling process is based on the observed input and output data of a system.

The objective of this project is to design and implement System Identification for Liquid System Pilot Plant in UTP by applying both the conventional System Identification technique known as empirical modeling and the intelligent techniques, a computer based method named System Identification Toolbox. Then, the comparison study between intelligent techniques and conventional modelling technique is conducted for a better performance determination.

System Identification procedure involves the construction of a model from actual data and the model validation process. The construction of a model engages with three basic entities that are data record, model structure and determination of the best model. By following the System Identification procedure, the four steps taken in accomplishing this project were: (1) experimental design, (2) modelling via empirical modelling, (3) simulation of System Identification via MATLAB-Simulink and (4) investigate performance Comparison between empirical modelling and model predictor using System Identification Toolbox.

Empirical modelling is a simple graphical and calculation technique. A linear transfer function that is obtained from this method is adequate for the project implementations. The second method is intelligent method which is carried out with the aid of MATLAB software. All the selected best models are capable to reproduce the observed data with minimum predicted error.

At the end of the project, based on some comparison and analysis, the author concludes that an intelligent technique gives a better performance compared to the conventional technique.

CHAPTER 1
INTRODUCTION

1.1 BACKGROUND OF STUDY

System Identification is a process of generating workable model of dynamic response based on observed dataset from the actual system[1]. It is used to give the input-output relationship of the dynamic response. The behaviour of these input and output data of a system will be used to design and implement open loop control.

There are a few methods available in modelling the systems. Some of them are Transient Response, Least Square Method, System Identification Toolbox[2] (by using Model Predictor), Process Reaction Curve Method, Frequency Response, Stochastic Steady State and Psedorandom Noise (PRBS). Each of the methods has its advantages and disadvantages. Therefore, this project is mainly to analyse the behaviour some of them.

In general, the project requires the author to study on the theory of the System Identification and familiarization MATLAB's command function to be used in the command window. Before proceeding to simulation part, the author must really understand the System Identification Loop that includes the data record, the model structure, the determination of the best model and the model validation.

Since System Identification is based on observed input and output data of a system, an actual dataset become a crucial part. For simplicity, a dataset that consists of single input and single output (SISO) is being used.

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[1] Refer to reference 1
[2] Refer to reference 2

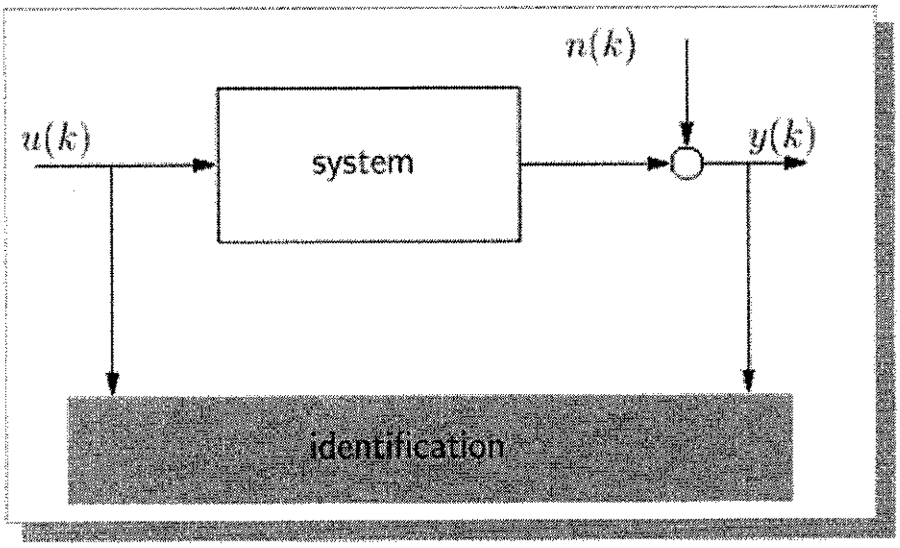

Figure 1.1: The System Identification Process

1.2 PROBLEM STATEMENT

1.2.1 Problem Identification

The objective of this project is to design and implement System Identification for a selected process control system from existing pilot plants. The Liquid System Pilot Plant has been chosen as the project implementation of the System Identification. The main task is to gather a real time data and apply the conventional techniques of System Identification known as empirical modelling. Nevertheless, the performance result of the conventional technique could be further improved by means of an intelligent method. Thus, the intelligent computer based technique known as System Identification Toolbox is simulated for further comparison. It consists of several model predictors such as AR (Auto Regressive) Model, ARX (Auto Regressive with eXternal input) Model and ARMAX (Auto Regressive Moving Average with eXternal input) Model.

1.2.2 Significance of the Project

In real industrial application, variables in a chemical process exhibit strong correlations created by the process itself as well as feedback controllers. The correlations are typically dynamic and nonlinear. Conducting a study on System Identification will help the author to appreciate the art of building a mathematical model to represent a particular system. Having the knowledge of deducing a mathematical model by studying the behaviour of the input and output data will be much helpful in a process control system.

A good model will be able to estimate responses that are quite identical to the existing dynamical system. A model that accurately captures the correlations can be useful in many applications including process monitoring, software sensor integration and predictive control. Thus, this project has a very wide application area.

1.3 OBJECTIVE AND SCOPE OF STUDY

1.3.1 Objectives of Study

1. To gather real time data and apply the conventional System Identification technique for the Liquid System Pilot Plant.
2. To simulate the estimated model constructed on MATLAB.
3. Analyzed the comparison between intelligent techniques using System Identification Toolbox with conventional modelling for a better performance determination.

1.3.2 Scope of Study

The scope of this Process Plant System Identification project is narrowed down to a single loop of Flow Control, FIC 664 for a product of heat exchanger at Universiti Teknologi PETRONAS (UTP) pilot plant.

1.3.3 The Relevancy of the Project

A lot of research has been done on the application of System Identification in the process plants throughout the past few years. The outcomes were very promising in which some are already tried in the real process plant. As Universiti Teknologi PETRONAS (UTP) had designed several pilot plants for modelling and experiment purposes, thus this project has met the relevancy through the implementation of System Identification.

1.3.3 Feasibility of the Project within the Scope and Time Frame

The author has outlined a time management to cater the project schedule. The time management is important to get equal attention to each task. In the other hand, it is essentially to ensure that the project is feasible and could be completed within the allocated time frame. Basically, for the whole project, 10% of the time is spent on literature review, 20% for setting-up the experiment, 60% or modelling purposes including the analysis and 10% for compiling all the findings.

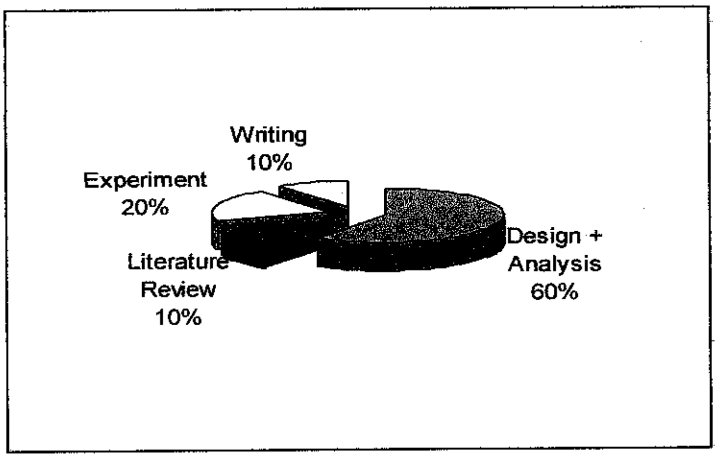

Figure 1.2: Time Management

1.4 SUMMARY

System Identification is a process of generating workable model of dynamic response based on the observed dataset from the actual system. It is used to give the input-output relationship of the dynamic response. The behaviour of these input and output data of a system will be used to design and implement open loop control.

In general, the objective of this project is to design and implement System Identification for Liquid System Pilot Plant in UTP. The scope of the project is narrowed down to the single loop Flow Control FIC-664. To be more specific, the project is about to gather the real data and apply the conventional System Identification technique known as empirical modelling. Nevertheless, the performance result of conventional technique could be further improved by means of an intelligent method. Thus, the intelligent computer based technique known as System Identification Toolbox is simulated for further improvement. It consists of several model predictors such as AR Model, ARX Model and ARMAX Model. Then, comparison study between intelligent techniques and conventional modelling technique is conducted for a better performance determination.

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CHAPTER 2
LITERATURE REVIEW

2.1 CONTROL SYSTEM[3]

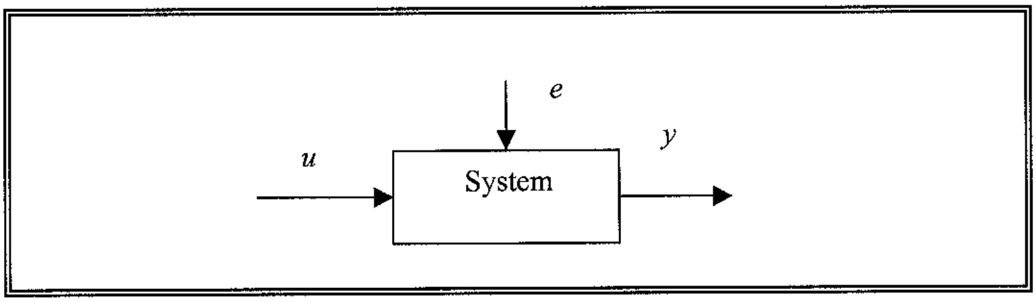

Figure 2.1: General Input-Output System Configuration with Noise

Basically, figure 2.1 shows that a dynamic system with three basic elements which are the input *(u)*, the output *(y)* and the noise *(e)* that also known as disturbance for the system.

A control system provides an output or response for a given input or stimulus. The input represents a desired response; the output is the actual response. There are two control system configurations that are open and closed loop systems.

Open loop system consists of a subsystem called an input transducer that converts the form of the input to that used by the controller. Then the controller drives the process or plant. The input is sometimes called the reference while the output can be called the controlled output. The distinguishing characteristic of an open loop system is that it cannot compensate for any disturbances that add to the controller's driving signal. As a result, the output will be corrupted by the effect of noise. The system cannot correct for the disturbances.

The disadvantages of an open loop system can be overcome in closed loop system. The input transducer converts the form of the input to the form used by the controller. An output transducer, or also known as sensor, measures the output

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[3] Refer to reference 3

response and converts it into the form used by the controller. The closed loop system compensates for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction. If there is any difference between the two responses, system drives the plant, via actuating signal to make a correction. If there is no difference, the system does not drive the plant, since the plant's response is already in desired form.

An example of open loop system is a timer that can be used to switch a building's lights on at nights and off in the morning. However, if a particular day is very dark, the system will not give adequate performance. If a light level sensor is added to the controller, it becomes a closed-loop system.

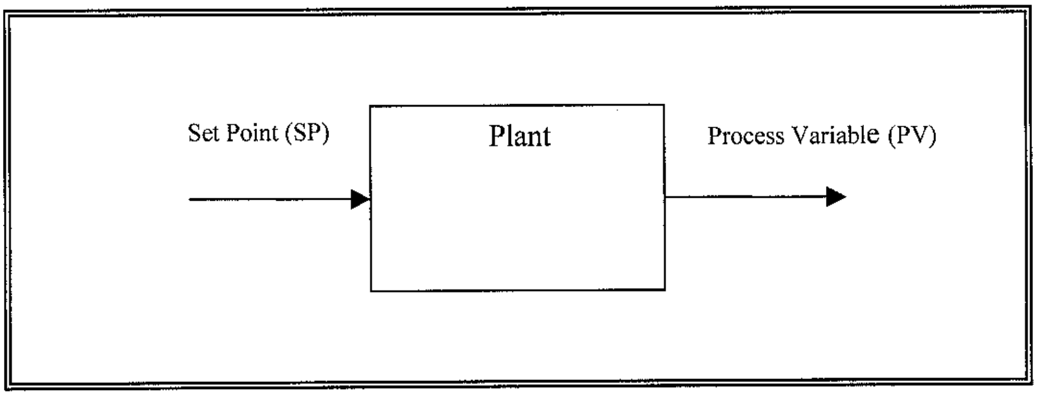

Figure 2.2: An Open Loop System

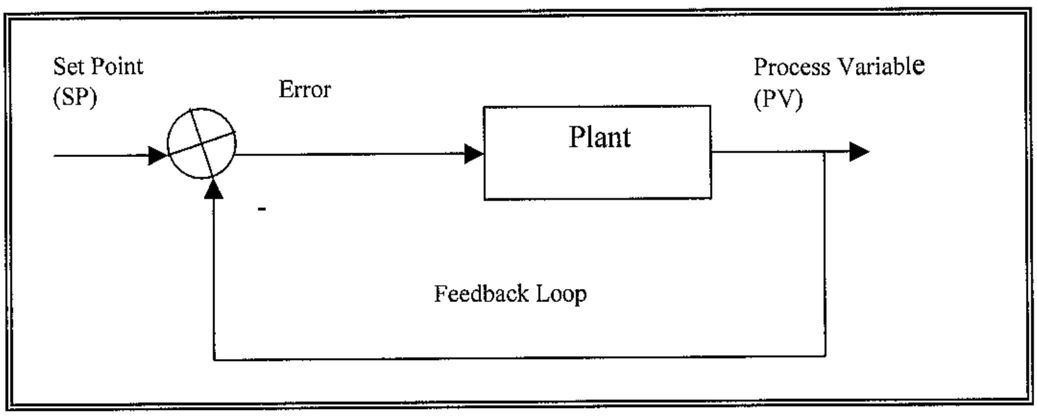

Figure 2.3: A Closed Loop System

2.2 SYSTEM IDENTIFICATION

System Identification allows one to build mathematical models of a dynamic system based on measured input and the output of the system and it is able to act like the actual system. It is done by manipulating the parameters of the particular model until the output value is close as possible with the actual measured outputs. There are several methods or model available in System Identification. Each of the methods has its own approach in trying to get the output the same as the actual measured outputs. A good model is a model that can represent a small error when compared to the actual or real system.

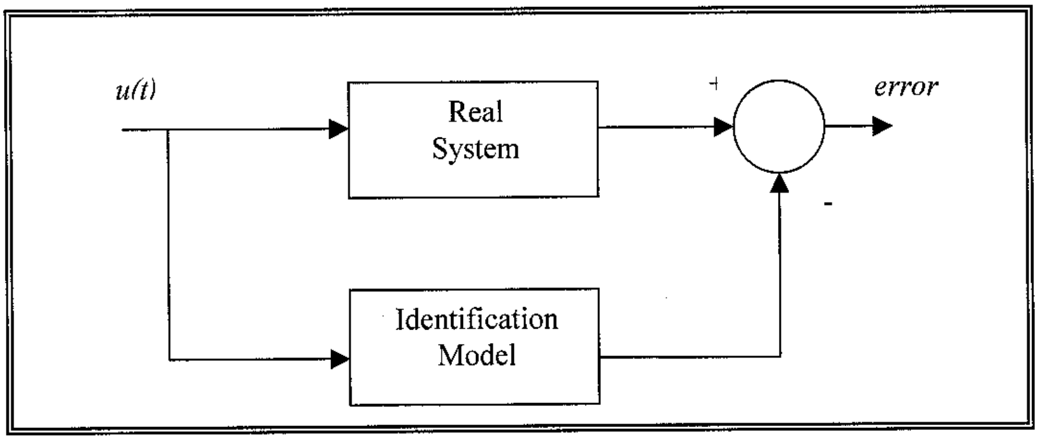

Figure 2.4: General System Identification Model

2.3 BASIC ELEMENTS FOR PLANT CONTROL LOOP

The basic elements for control loop are as shown in figure 2.5. It contains the sensor stage, transducer stage, signal conditioning, measured parameters and controller.

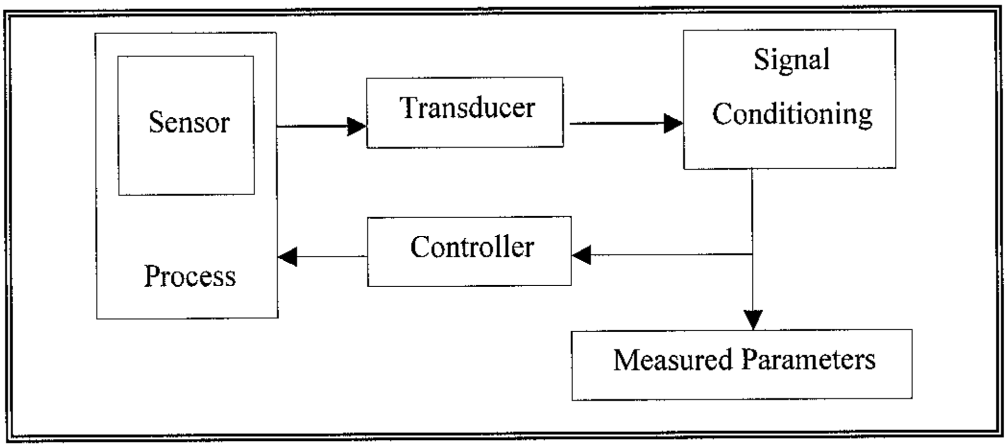

Figure 2.5: The Basic Elements for Plant Control Loop

The Sensor Stage is a part where a sensor is used as physical element that operates due to some natural phenomenon to sense variable being measured. The selection, placement and installation of the sensor are important because input to the feedback control system is the information or the data that sensed by the sensor. The interpretation of all information assessed through and indicated by the system depends on that which actually sensed by the sensor.

For Transducer Stage, a transducer or transmitter converts the sensed information into detectable signal form such as mechanical, electrical or optical signal. It converts the sensed information into a form that easily quantify.

Signal Conditioning play an important role by taking a signal from transducer and modifies it into desired form by any of these two actions. The first one is by increasing the magnitude of the signal through amplification or by removing some portions of signal through filtering. Signal conditioning stage also provides mechanical or optical linkage between transducer and output stage.

While for the Output Stage, it provides an indication of the value of the measurement either by simple readout display or a marked scale. It contains a device that can record the signal for later analysis that is useful for plant supervisor or engineer.

The most critical part in the system is Control Stage. It interprets the measured signal and compare to the desired one. Then, controller will make a decision regarding the control of process. Controller's role is to ensure the measured and desired output is as close as possible. There are three types of controller that are widely used in industry. The three of them are known as P Controller (Proportional Mode), PI (Proportional-Integral Mode) Controller and PID (Proportional-Integral-Derivative Mode) Controller. Each of them exhibits different characteristics although the main goal for using them are the same, to maintain the process variable close to its desired value.

2.4 EMPIRICAL MODELLING[4]

The purpose of plant modelling is to establish the relationships between parameters in the physical systems and the transient behaviour of the systems. There are two ways in modelling a plant, which are the mathematical approach or empirical (experimental) approach.

The mathematical approach is based on fundamental theories or laws, such as conservation of mass, energy and momentum. This approach is of favour because small number of principles can be used to explain a wide range of physical systems. In other words, this particular approach simplifies the view of nature. Apart from that, this approach has a broad range of applicability, which enables the task of evaluating potential changes in operating conditions and equipment and also to design new plants.

However, mathematical approach has limitations, which generally results from the complexity of mathematical models. Thus, modelling most realistic processes requires a large engineering effort to formulate the equations, determine all parameter values and solve the equations, usually through numerical methods. Thus,

[4] Refer to reference 4

an alternative modelling method, termed as empirical modelling, specifically designed for plant process control.

Empirical modelling provides the dynamic relationship between selected input and output variables. Models are determined by making small changes in the input variable about nominal operating condition. The resulting dynamic response is used to determine the model. A linear transfer function developed using empirical methods is adequate for many process control designs and implementations.

In subsequent, only one method is presented. It is termed the process reaction curve and employs simple, graphical procedures for model fitting. This method is chosen by interpreting the graphical reaction curve rather than employing a tedious statistical method.

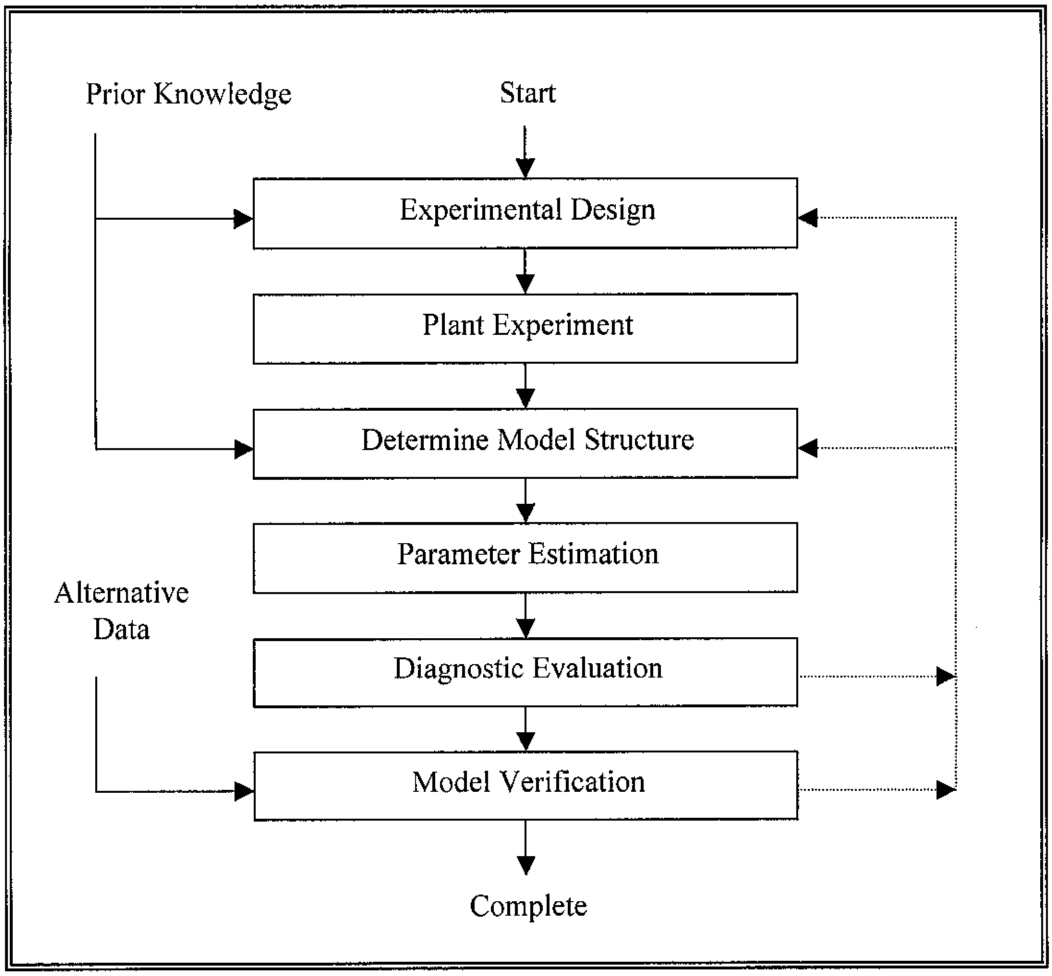

Figure 2.6: Procedures for Empirical Transfer Function Model Identification

2.5 SUMMARY

This chapter can be divided into four main parts: (1) control system, (2) System Identification, (3) basic elements for plant control loop and (4) empirical modelling.

Control systems have widespread applications in science and industry. It has three basic elements that are the input *(u)*, the output *(y)* and the noise *(e)* or better known as disturbance. There are two control system configurations that are open and closed loop systems.

Part 1: Open loop system consists of a subsystem called an input transducer that converts the form of the input to that used by the controller, which then drives the process. Open loop system cannot compensate for any disturbances that add to the controller's driving signal. As a result, the output will be corrupted by the effect of noise. The disadvantages of an open loop system can be overcome in closed loop system. By adding one element known as sensor, closed loop system can measure the output response and converts it into the form used by the controller. The closed loop system compensates for disturbances by measuring the output response, feeding that measurement back through a feedback path, and comparing that response to the input at the summing junction. If there is any difference between the two responses, system drives the plant, via actuating signal to make a correction. If there is no difference, the system does not drive the plant, since the plant's response is already in desired form.

Part 2: System Identification allows one to build mathematical models of a dynamic system based on measured data. It is done essentially by adjusting parameters within a given model until its output coincides as well as possible with the measured output. There are several models available in System Identification. A good model is a model that can represent a small error when compared to the actual or real system.

Part 3: The basic elements for control loop are sensor, transducer, signal conditioning, output and controller. Sensor is a physical element that operates due to some natural phenomenon to sense variable being measured. The selection, placement and installation of the sensor are important because input to the feedback control system is the information or the data that sensed by the sensor. A transducer or transmitter converts the sensed information into detectable signal form such as mechanical, electrical or optical signal. Signal Conditioning play an important role by taking a signal from transducer and modifies it into desired form by any of these actions; (1) increasing the magnitude of the signal through amplification, (2) removing some portions of signal through filtering and (3) providing mechanical or optical linkage between transducer and output stage. Output stage provides an indication of the value of the measurement either by simple readout display or a marked scale. It contains a device that can record the signal for later analysis that is useful for plant supervisor or engineer. The most critical part in the system is control stage. It interprets the measured signal and compare to the desired one. Then, controller will make a decision regarding the control of process. Controller's role is to ensure the measured and desired output is as close as possible. The three types of controller that are widely used in industry are P Controller (Proportional Mode), PI (Proportional-Integral Mode) Controller and PID (Proportional-Integral-Derivative Mode) Controller.

Part 4 : The purpose of plant modelling is to establish the relationships between parameters in the physical systems and the transient behaviour of the systems. There are two ways in modelling a plant, which are the mathematical approach or empirical (experimental) approach. The mathematical approach is based on fundamental theories or laws, such as conservation of mass, energy and momentum. This approach is of favour because small number of principles can be used to explain a wide range of physical systems. Apart from that, this approach has a broad range of applicability, which enables the task of evaluating potential changes in operating conditions and equipment and also to design new plants.

Empirical Modelling provides the dynamic relationship between selected input and output variables. Models are determined by making small changes in the input variable about nominal operating condition. The resulting dynamic response is used to determine the model. A linear transfer function developed using empirical methods is adequate for many process control designs and implementations. In subsequent, only one method is presented that is termed the process reaction curve and employs simple, graphical procedures for model fitting. This method is chosen by interpreting the graphical reaction curve rather than employing a tedious statistical method.

CHAPTER 3

PILOT PLANT

The model SIM305-FF-BATCH is a scaled down Liquid-phase Flow and Temperature Process Pilot Plant. It is a self-contained unit designed to simulate real processes found in industrial plants. The simulation can be used for the study of the measurement and control of various Flow and Temperature processes.

It shall also serve as a teaching and for the study and application of the latest internationally adopted Foundation Field-bus Distributed Control (Field Control) technology. The field-bus is a digital, two-way multi-drop communication link among intelligent measurement and control devices, and automation and display systems.

Due to its unique design considerations, this pilot plant may be used for Batch or Continuous Operations. A comprehensive set of industrial grade process instruments and a Local Control Panel (LCP) are included as a standard feature. All process wetted parts are made from Galvanized Steel or Galvanized Iron to withstand corrosion and to ensure durability.

The process loop for this project is the FIC-664 loop which involves the Flow Transmitter (FT 664), Flow Controller (FIC 664) and Flow Control Valve (FY 664). This loop[5] controls the flow in the Product Tank (VE660). For better understanding of the plant especially the FIC 664 loop, the loop drawing is drawn. The loop drawing provides information on equipment, piping, valves and instrumentation concerned. All items are identified using a standard numbering system, which complies with the PETRONAS Technical Standards.

[5] Refer to appendix A

3.1 LOOP DRAWING

Loop drawing shows all the details of each instrument, including the tag numbers, polarities, telemetry, power supply, signal, sensors, type of instruments and many more. The loop drawing enables us to view the connections of the instruments and relate to the actual process. For the project, loop drawing for the particular experiment is drawn.

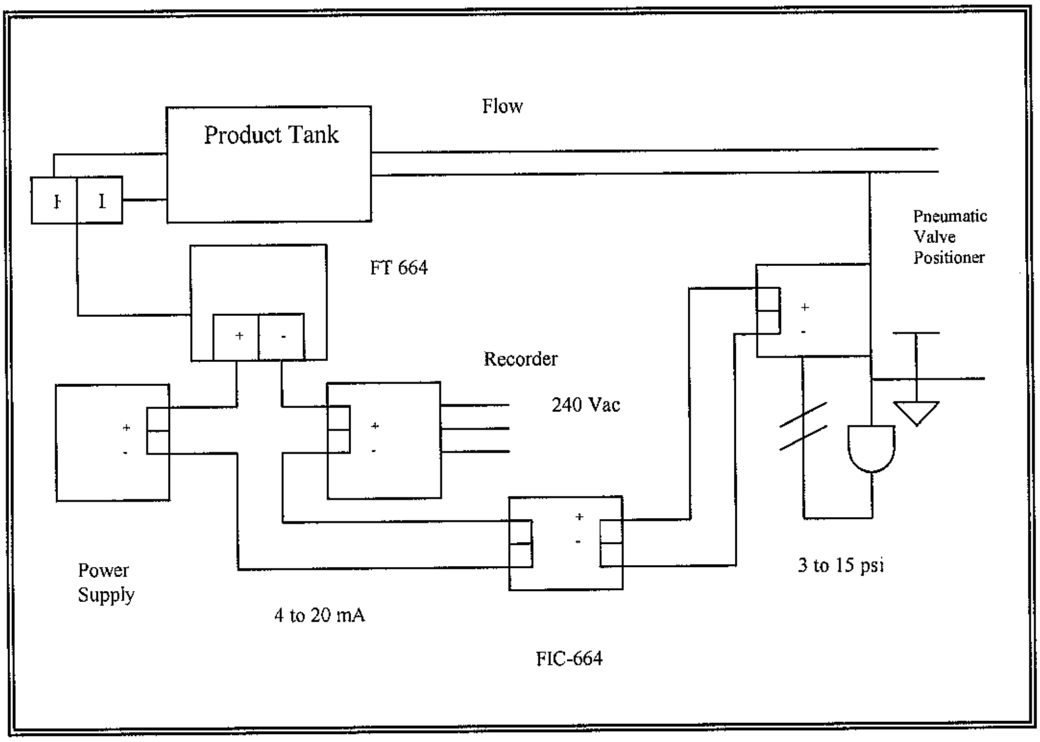

Figure 3.1: The Loop Drawing for Flow Control (Plant 6)

Process Control System Identification project is narrowed down to a single loop of Flow Control, FIC 664 for a product of heat exchanger at UTP pilot plant. This plant is both for Flow Control and Temperature Control. For the Flow Control Loop, only the items listed below are needed to take into consideration:

1. Product Tank VE660
2. Hand Valve 661
3. Pump P663
4. Pump Indicator PI663
5. Flow Transmitter FT664

6. Flow Controller (Indicator) FIC664
7. Valve FY664

Table 1: Summary of Function of Each Elements Involved in Flow Control Loop

Elements	Functions
Product Tank VE660	As a reservoir of the liquid.
Pump P663	To pump in the water in order to allow the flow of water in the pipeline.
Flow Transmitter FT664	To convert the sensed information into electrical signal that then be sent to the controller stage.
Flow Controller FIC664	To ensure that the process is run as close as possible to the desired one. The entire controller setting is being inserted at this stage. It is done by the plant personnel.

Much of the equipment in a plant is very expensive and due to cost constraint, it is difficult to replace them whenever broke down occurred. Therefore, the most economical solution is to maintain the operating condition within bounds to prevent damage. Emergency controls are used to stop operation safely when the process reaches boundary values. In this case, a pump might be damaged when there are no liquid flows through it. So, the liquid level controller become an important element by ensuring a reservoir of liquid is above the outlet of the vessel, hence protects the pump from damage. Level controller will operate based on the signal received from LT662 (Level Transmitter). Additional equipment protection could be provided by adding an emergency controller that would shut off the pump when the level decreased below a specified value.

One more important thing is the sensor part. The flow rate is measured using a differential pressure transmitter (d/p transmitter) that is orifice plate. It operates based on the principle that a restriction placed in a flow line produces a pressure drop proportional to the flow rate squared. A d/p transmitter is used to measure the pressure drop, h, produced by the restriction. The flow rate, q is proportional to the square root of the measured pressure drop.

$$q = K\sqrt{h}$$

Special passages transfer the fluid pressure on each side of the orifice plate to the opposite side of diaphragm unit in a d/p transmitter. A displacement detector senses any motion resulting from imbalance of the forces on a force arm (due to pressure difference across the orifice). An amplifier converts this displacement signal into an adjustment of the current input to the force transducer that restores the balanced conditions. The current, I is proportional to the pressure drop across the orifice late, and is used as the output signal of the d/p transmitter.

Nowadays, orifice plate is widely used as a flow sensor due to it several advantages. An orifice plate consists of a circular plate, containing a hole (orifice), which is inserted into a pipe. There are three types of Orifice Plate that are concentric, eccentric and segmental. Concentric is suitable for most clean fluids such in our Pilot Plant. A circular hole is machined in the plate so that when the plate in installed, the hole will be in the centre of the pipe. Eccentric is used in order to minimize measurement inaccuracies that can be caused by solids settling out of the liquid while segmental orifice plate is used when solids are very heavy.

The advantages of orifice plate are that they are capable of metering either gas or liquids with high degrees of accuracy, simple and it is easy to fabricate. It also has no moving parts that a single d/p transmitter can be use without regard to pipe size and flow and that it is widely accepted standard. But, obviously, orifice plate does not work well with slurries and causes a permanent pressure drop where the outlet pressure is about 60% to 80% of the inlet pressure.

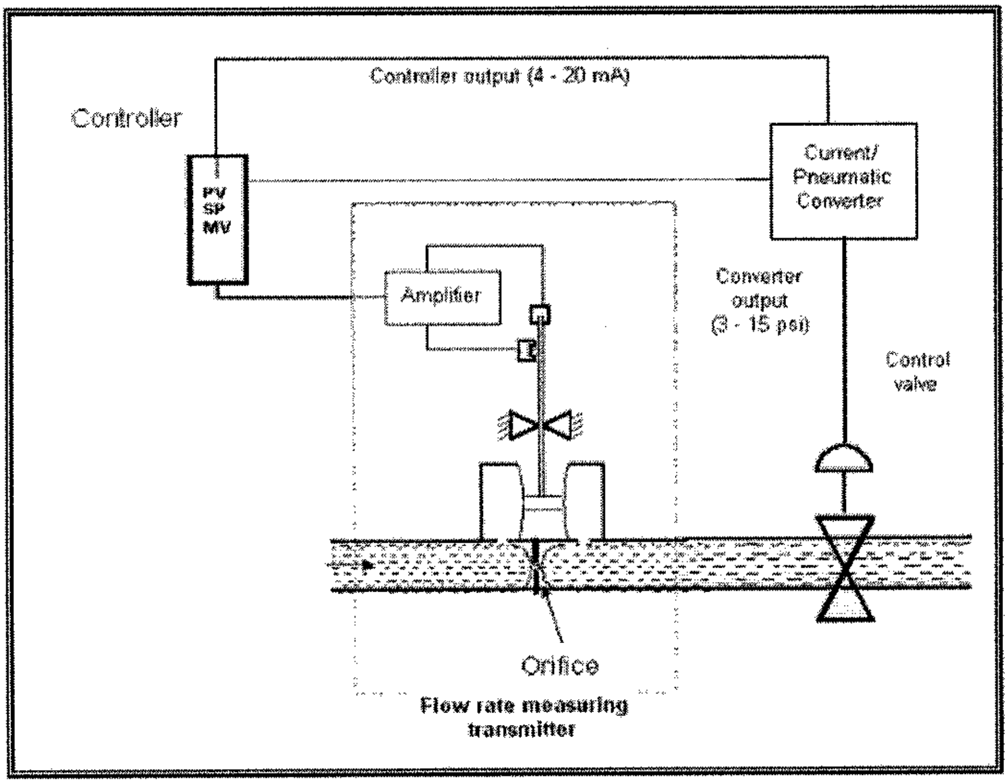

Figure 3.2: Flow Measurement Diagram

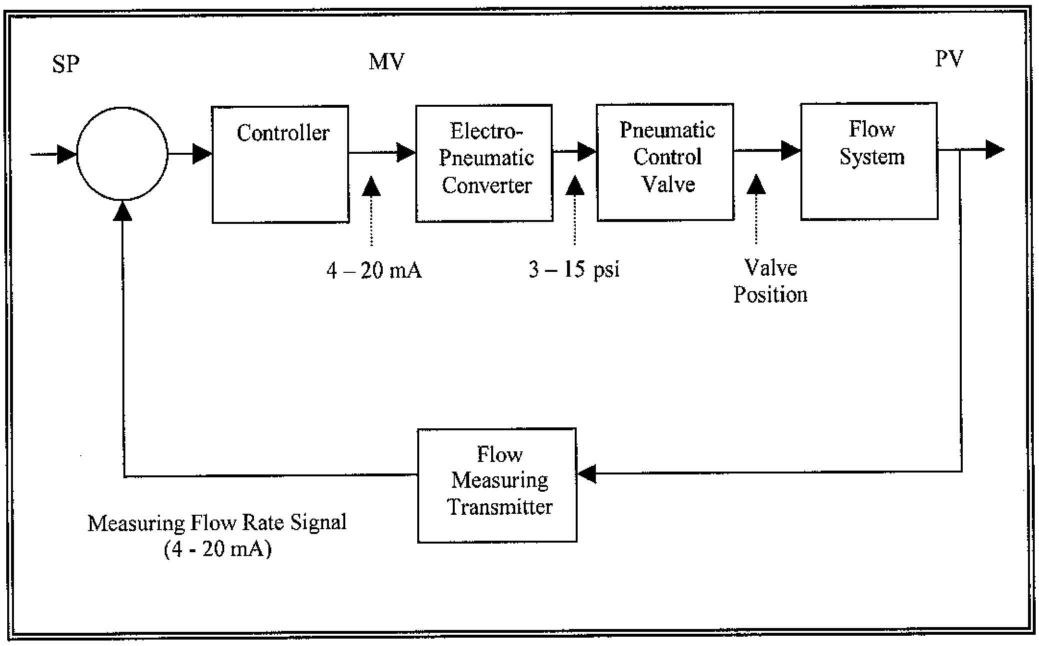

Figure 3.3: Flow Control Loop

The feedback control is makes use of an output of the system to influence an input to the same system as shown in the figure above. There are several reasons for controlling the system. The first reason is to maintain, in this case is flow rate at its desired value when disturbance occurs. It will control the valve (either open or close) in response to a changing the disturbance variables. The second reason is to respond to changes in the desired values. For example, if the desired flow rate were increased, the valve percent of opening would be increased.

3.2 SUMMARY

The model SIM305-FF-BATCH is a scalded down Liquid-phase Flow and Temperature Process Pilot Plant. It is a self-contained unit designed to: (1) simulate real processes found in Industrial Plants, and (2) serve as a teaching and for the study and application of the latest internationally adopted Foundation Field-bus Distributed Control (Field Control) technology.

The process flow loop for this project is the FIC-664, which involves the Flow Transmitter (FT 664), Flow Controller (FIC 664) and Flow Control Valve (FY 664). Loop drawing shows all the details of each instrument, including the tag numbers, polarities, telemetry, power supply, signal, sensors, type of instruments and many more. The loop drawing enables us to view the connections of the instruments and relate to the actual process. All items are identified using a standard numbering system which complies with the PETRONAS Technical Standards.

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CHAPTER 4
METHODOLOGY

4.1 PROCEDURE IDENTIFICATION

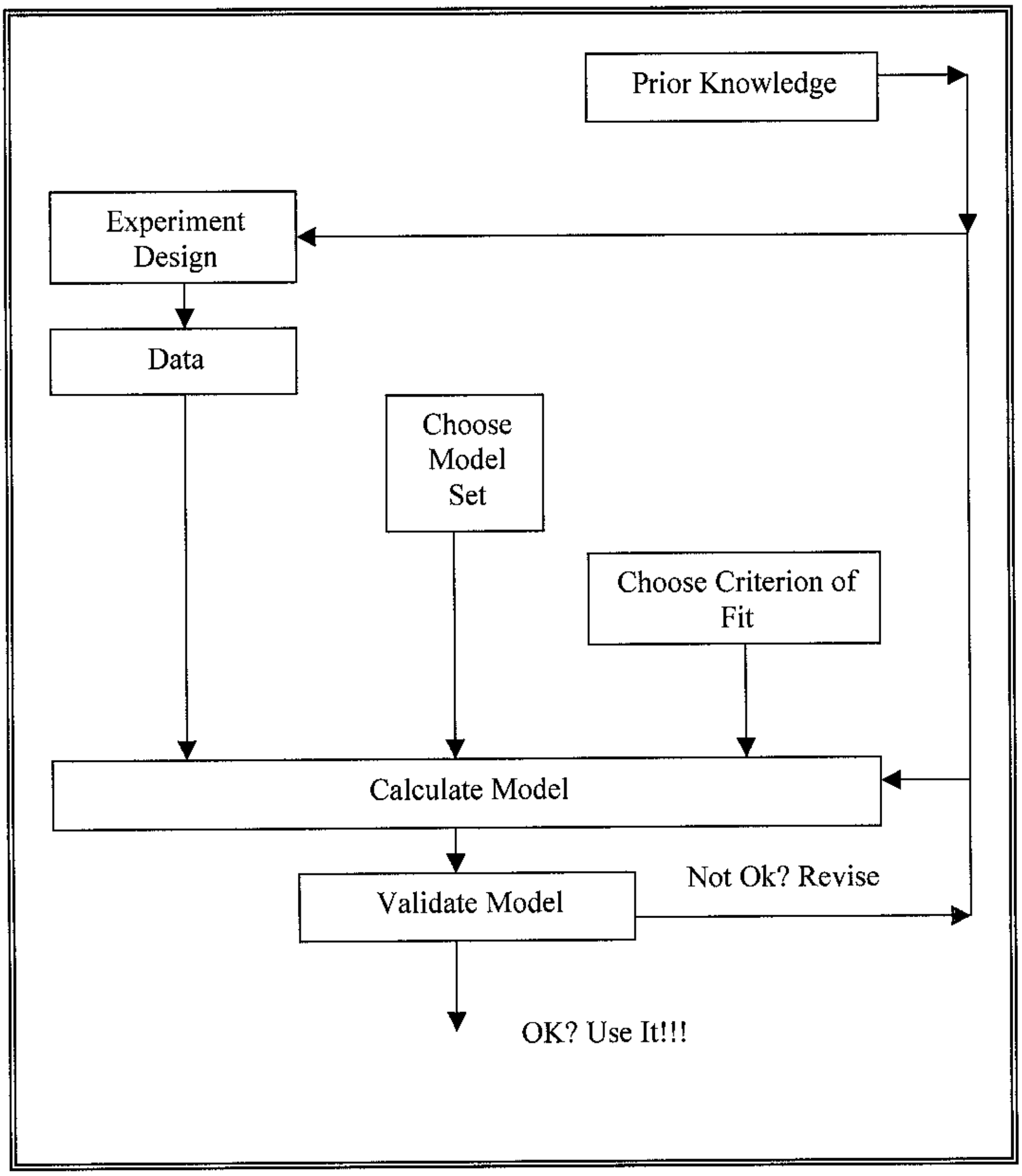


Figure 4.1: System Identification Procedure

The problem of System Identification is to obtain a mathematical model for a system from the actual dataset. The purposes of the model are engineering analysis, simulation, monitoring and control. System Identification procedure involves the construction of a model from actual data and the model validation process. The construction of a model engages with three basic entities that are data record, model structure and determination of the best model.

The input output data are recorded during a specifically designed identification experiment. At this stage, the author determines the signals to be measured, when to measure them and chooses the input signal. This is done in order to ensure that the data become maximally informative, subject to constraints that may be at hand. For this project, the author is interested in Liquid System for flow control loop. The effect of introducing the step change in valve opening to the flow rate will be analysed. The flow rate is measured just before a step change is introduced and after the process is reached steady state.

After having the actual data, a set of candidate models is obtained by specifying within which collection of models will be going to look for a suitable one. It is here that a priori knowledge and engineering intuition and insight have to be combined with formal properties of models. The author will employ only two types of modelling techniques that are empirical modelling and model predictors, which are available in System Identification Toolbox.

The process of determining the best model in the set is known as identification method. The assessment of model quality is typically based on how the models perform when they attempt to reproduce the measured data.

After having settled on the preceding three choices, the author has, at least implicitly arrived at particular model, the one in the set that best describes the data according to the chosen criterion. It then remains to test whether this model is good enough, that is whether it is valid for its purpose. Such tests are known as model validation. Deficient model behaviour in reproduce the observed data makes the author rejects the model while good performance will develop a certain confidence in it. A model can never be accepted as a final and true description of the system. Rather, it can at best be regarded as a good enough description of certain aspects that are particular interest to us.

Steps taken in accomplishing this project were as follows:

- Experimental Design
- Modelling via empirical modelling
- Simulation of System Identification via MATLAB-Simulink.
- Investigate performance: Comparison between empirical modelling and model predictor using System Identification Toolbox

4.2 EXPERIMENTAL DESIGN

An important aspect of empirical modelling is the need for proper experimental design. Generally the whole experiment will touch on several stages. The initial stage is to understand the P&I Diagram of the entire control loop as well as the process hook up and piping involved in the experiment.

Then, after clearly define the process loop; the Open Loop Tuning procedure[6] (appendix 2) is performed. This involves the suitable controller tuning and control strategy in order to achieved better process dynamic response. The method and procedure in performing open loop test, tuning and control strategy (performance test) were identified.

4.2.1 Basic Operating Procedure

Step by step procedure for operating the pilot plant has been included under each experiment. As a general guideline, some common start-up and shutdown procedure is including here:

1 **Start up**

- Switch on power to Local Control Panel and Server Panel
- Turn the selector switch to Distributed Control System (DCS) to control the process via the computer at the control room.
- Switch on the main air supply before running any experiment.

---

[6] Refer to appendix B

2 Shut down

- Shutdown the DCS first
- Switch off the Main Air supply

3 Hand valves

- Open and close the various hand valve bases on the experiment instruction.
- All hands valve need to be fully open or fully close.

3 Pumps

- All pumps may be run directly from the DCS
- Open the valve partially before starting the related pump.
- Pump must be started or stopped at the Local Control Panel (LCP) if local control mode is selected.
- Do not run the pump until its suction is completely empty. This will damage the pump.
- Stop the pump when the liquid level in the tank is approaching the outlet of the tank.

4 Dependency of one experiment on another

- Make sure the preceding experiment have been completed before running the new one.

4.3 EMPIRICAL MODELLING

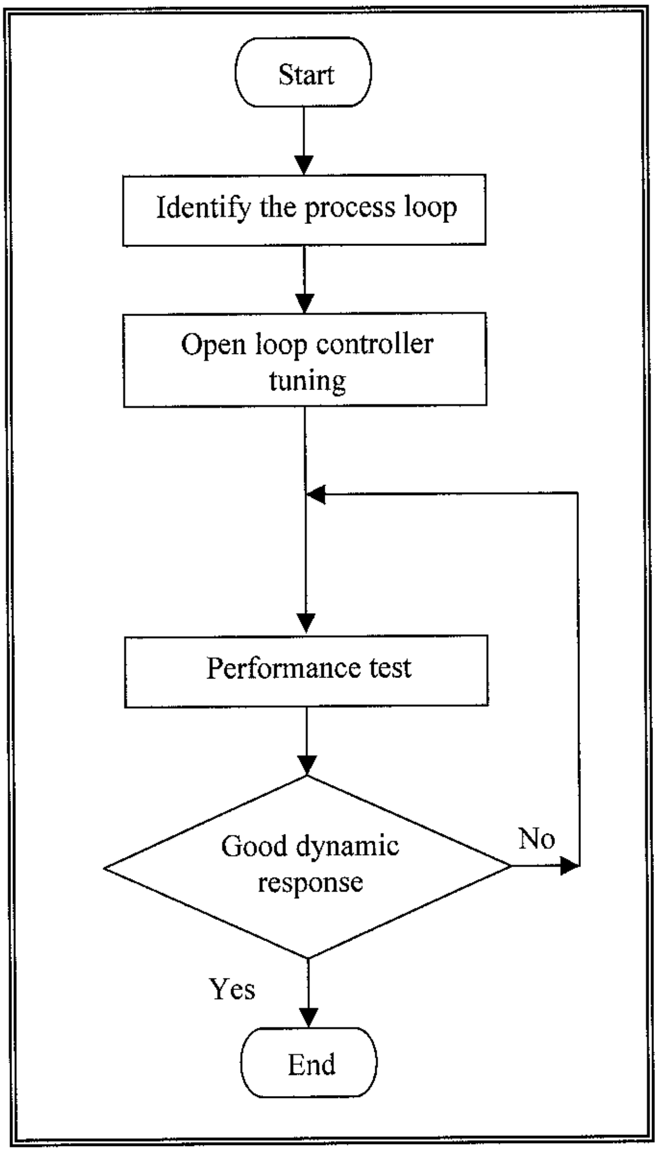
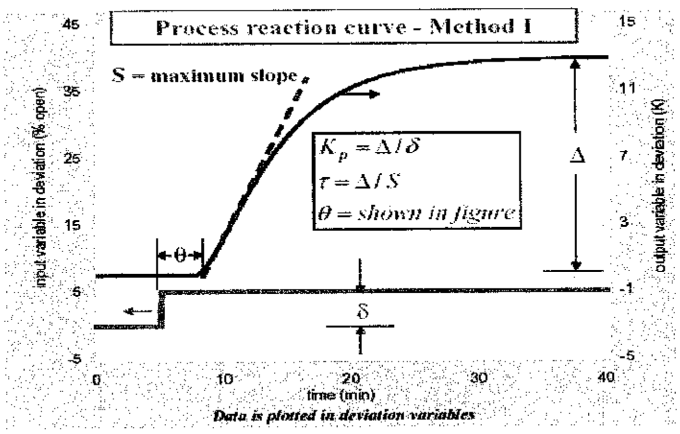


Figure 4.2: Flow Chart for Experiment Procedure

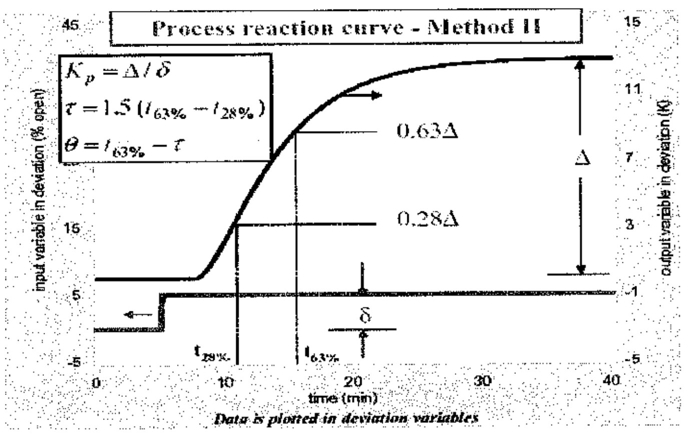
The flow chart above shows the general procedure need to be done in order to run the experiment.

4.3.1 Open Loop Tuning

1. Tabulate all the relevant data (dB_U, dM) from above method.
2. Obtain reaction curve characteristics behaviour and transfer function by using Method I or Method II reaction curve behaviour calculation. Then, identify the behaviour of the process dynamic response (dead time, rise time, time constant) via process reaction curve method.



(a)



(b)

Figure 4.3: Method I (Figure a) and Method II (Figure b) Reaction Curve Calculation

4.4 MATLAB SIMULINK – SYSTEM IDENTIFICATION TOOLBOX

Simulink provides the System Identification Toolbox that helps to ensure that observed test data represents the dynamics of the system under investigation. It provides tools for creating mathematical models of dynamical systems based on observed input - output data. MATLAB Simulink also is used when implementing the control design. The Toolbox features a flexible graphical user interface that aids in the organization of data and models. The identification techniques provided with this Toolbox are useful for applications ranging from control system design and signal processing to time-series analysis and vibration analysis

4.5 SUMMARY

The problem of System Identification is to obtain a mathematical model for a system from the actual dataset. The purposes of the model are engineering analysis, simulation, monitoring and control. System Identification procedure involves the construction of a model from actual data and the model validation process. The construction of a model engages with three basic entities that are data record, model structure and determination of the best model.

The input output data are recorded during a specifically designed identification experiment. The process of determination the signals to be measured, when to measure them and choosing the input signal are carried out at this stage in order to ensure that the data become maximally informative, subject to constraints that may be at hand. After having the actual data, a set of candidate models is obtained by specifying within which collection of models will be going to look for a suitable one. It is here that a priori knowledge and engineering intuition and insight have to be combined with formal properties of models. The process of determining the best model in the set is known as identification method. The assessment of model quality is typically based on how the models perform when they attempt to reproduce the measured data. After having settled on the preceding three choices, model validation process is developed. It is a process of testing whether the model is good enough and valid for its purpose.

By following the System Identification procedure, the four steps taken in accomplishing this project were: (1) experimental design, (2) modelling via empirical modelling, (3) simulation of System Identification via MATLAB-Simulink and (4) investigate performance Comparison between empirical modelling and model predictor using System Identification Toolbox.

CHAPTER 5
RESULTS & FINDINGS

5.1 PROCESS IDENTIFICATION & OPEN LOOP TUNING METHOD

Open loop response test is carried out in order to enable the author to define the process by determining the process time constant, process gain and process dead-time. First of all, all the variables involved are being identified, which are the Process Variable (PV), Manipulated Variable (MV) and Set Point (SP). For this kind of experiment, PV and SP are a flow rate and MV is percent of valve opening. The measurement unit for flow rate is m^3/h and for valve opening is in percent (%). A small change is applied to the manipulated variable (as input) to generate a dynamic response of process variable (as output).

Table 2: The Actual Dataset

	Time	FIC-664MV	FIC-664PV
4/1/2004	16:44:48	30	0.40
4/1/2004	16:44:49	30	0.40
4/1/2004	16:44:50	30	0.40
4/1/2004	16:44:51	30	0.40
4/1/2004	16:44:52	30	0.40
4/1/2004	16:44:53	30	0.40
4/1/2004	16:44:54	35	0.40
4/1/2004	16:44:55	35	0.40
4/1/2004	16:44:56	35	0.40
4/1/2004	16:44:57	35	0.40
4/1/2004	16:44:58	35	0.40
4/1/2004	16:44:59	35	0.49
4/1/2004	16:45:00	35	0.54
4/1/2004	16:45:01	35	0.54
4/1/2004	16:45:02	35	0.54
4/1/2004	16:45:03	35	0.54
4/1/2004	16:45:04	35	0.54
4/1/2004	16:45:05	35	0.54
4/1/2004	16:45:06	35	0.53
4/1/2004	16:45:07	35	0.54
4/1/2004	16:45:08	35	0.55
4/1/2004	16:45:09	35	0.54
4/1/2004	16:45:10	35	0.54
4/1/2004	16:45:11	35	0.54

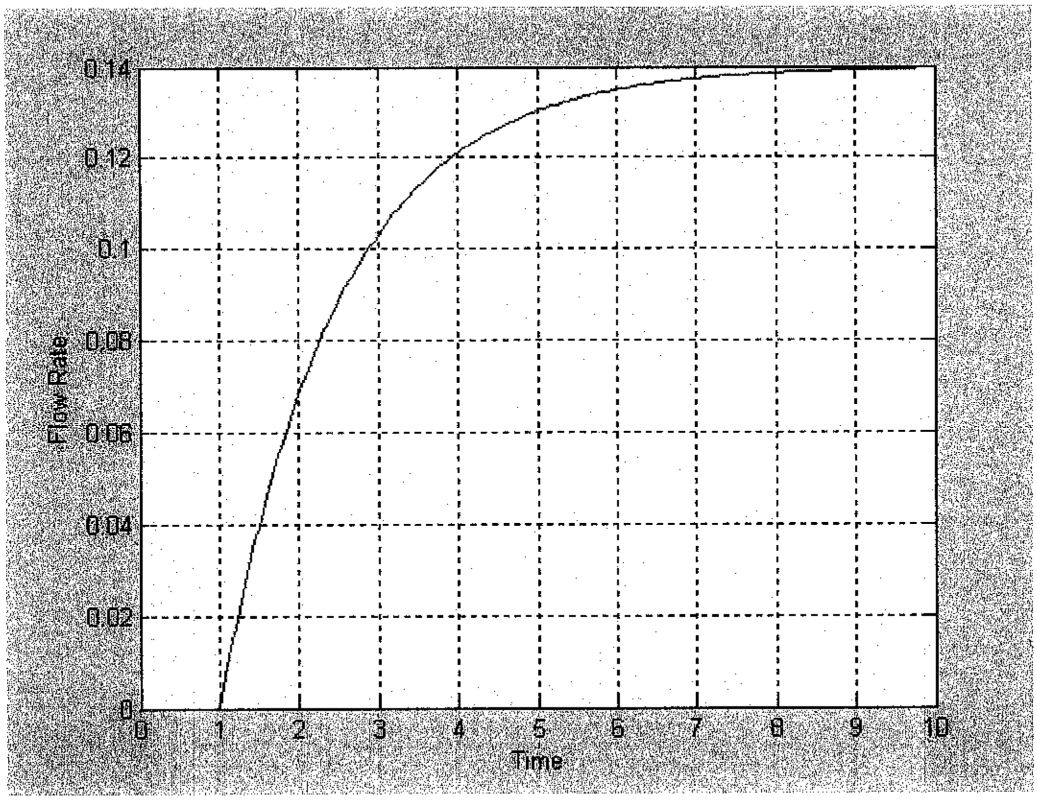


Figure 5.1: The Actual Dataset Plot

Measurement	Test
Change in Manipulated Variable, dM	0.05
Change in Ultimate Value, dB_u	0.14
Apparent Time Constant T	1.50
Apparent Dead Time, T_d	4.50
Calculations:	
Steady State Process Gain $K_p = dB_u/dM$	0.028
$R = T_d / T$	3.00
Tuning Parameters: ***Calculation are shown below**	
K_c (Gain)	13.69
Integral Time, T_I	2.54
Derivative Time, T_D	-

Table 3: Results for Open Loop Tuning

5.2 PROCESS REACTION CURVE METHOD

5.2.1 Method 1

∂ = 0.05

Δ = 0.14 m^3/h

K_p = Δ / ∂ = (0.14) / (0.05)

= 2.8

S = 0.14 / 1.5 = 0.093

τ = Δ / S = 0.14 / 0.093

= 1.50

θ = 4.5 seconds

The model transfer function:

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

$$= \mathbf{\frac{2.8\, e^{-4.5s}}{1.50s + 1}}$$

5.2.2 Method 2

∂ = 0.05

Δ = 0.14 m^3/h

0.63Δ = 0.63(0.14) = 0.0882

$t_{63\%}$ = 6.75 seconds

0.28Δ = 0.28(0.14) = 0.0392 seconds

$t_{28\%}$ = 6.00 seconds

τ = $1.5(t_{63\%} - t_{28\%})$ = 1.5 (6.75 – 6.00)

= 1.125

θ = $t_{63\%} - \tau$ = 6.75 – 1.125

= 5.625 seconds

K_p = Δ / ∂ = (0.14) / (0.05) = 2.8

The model transfer function:

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

$$= \mathbf{\frac{2.8\, e^{-5.625s}}{1.125s + 1}}$$

5.3 MATLAB SIMULINK

5.3.1 AR Model

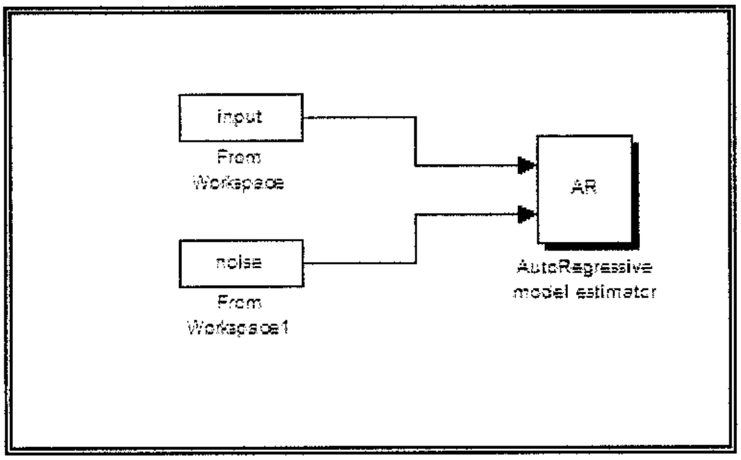


Figure 5.2: AR Configuration

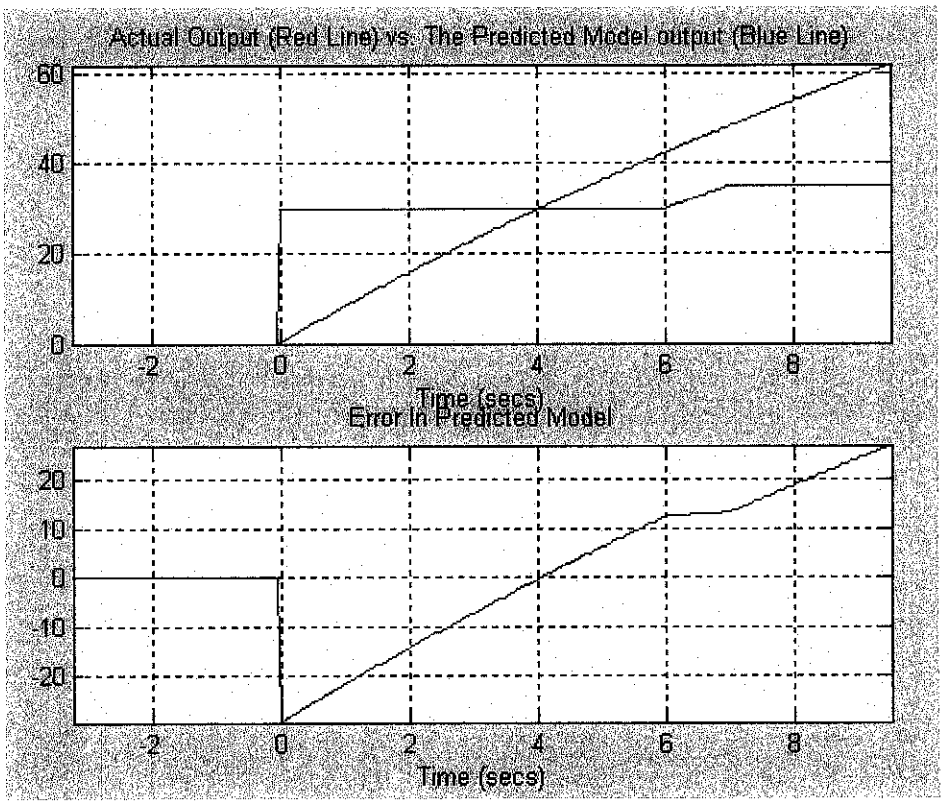


Figure 5.3: AR Simulation Result for Order 3

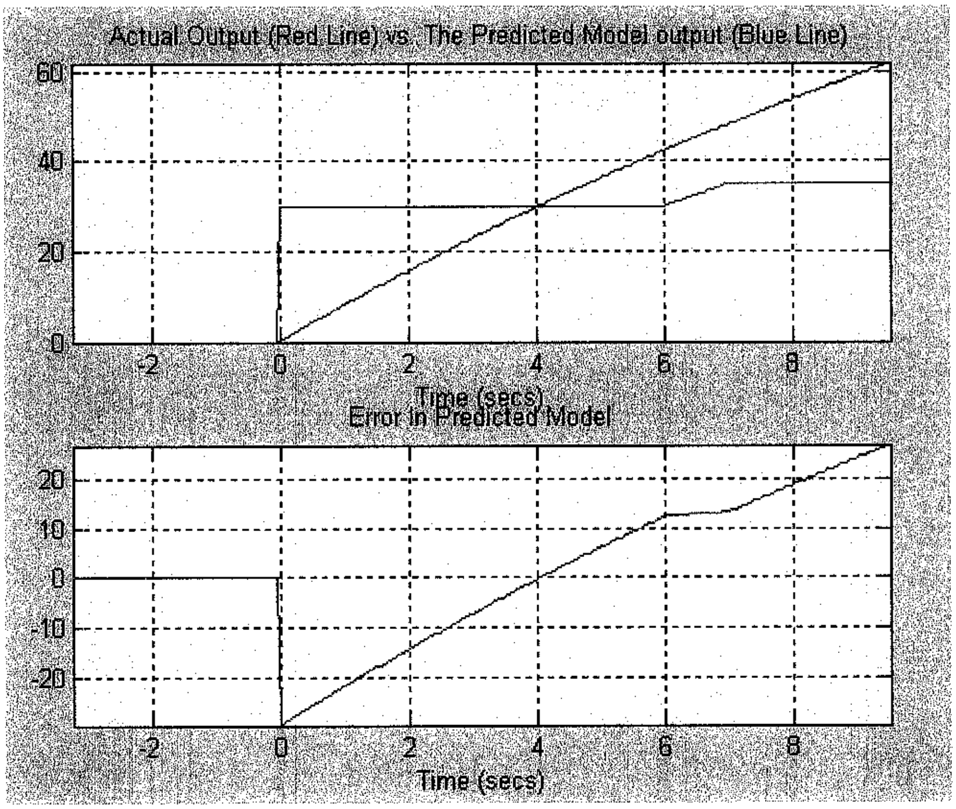


Figure5 .4: AR Simulation Result for Order 5

5.3.2 ARX Model

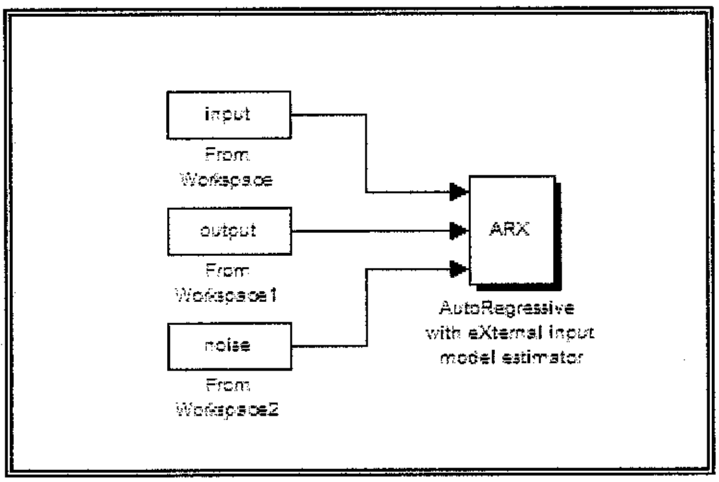


Figure 5.5: ARX Configuration

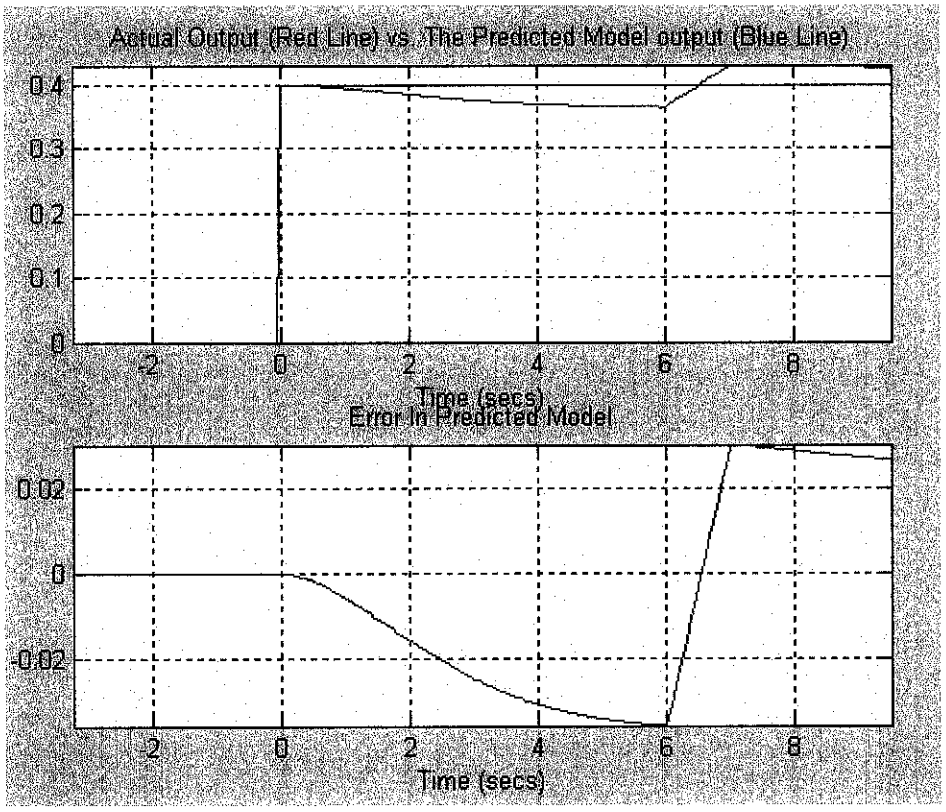


Figure 5.6: ARX (3 4 0) Simulation Result

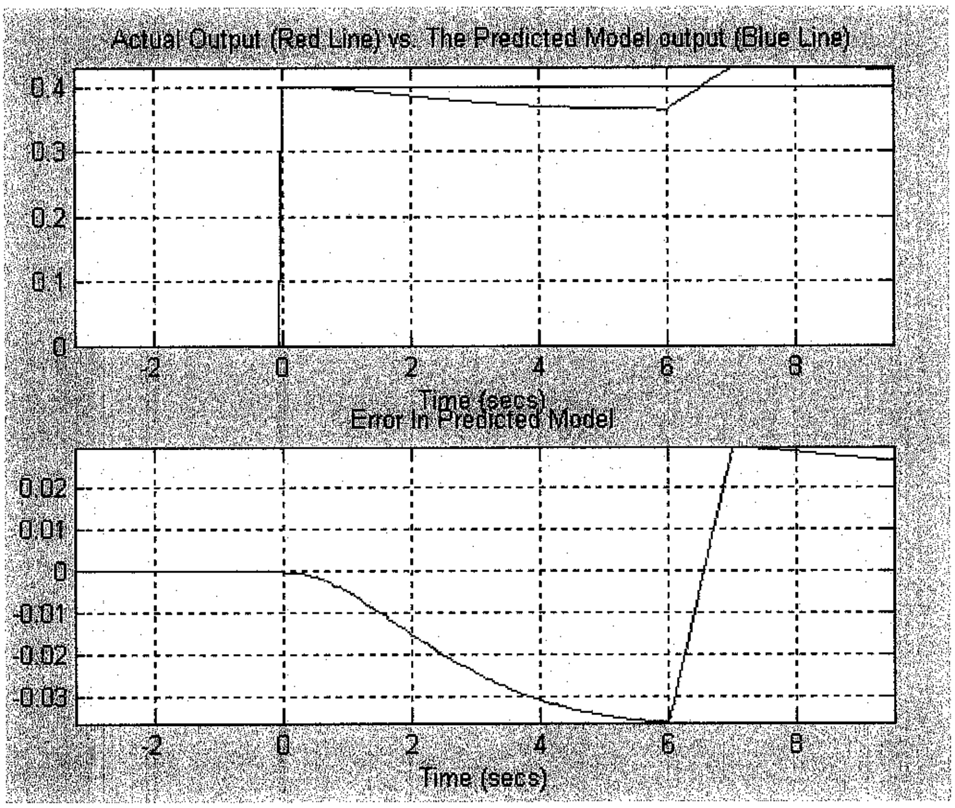


Figure 5.7: ARX (5 4 0) Simulation Result

5.3.3 ARMAX Model

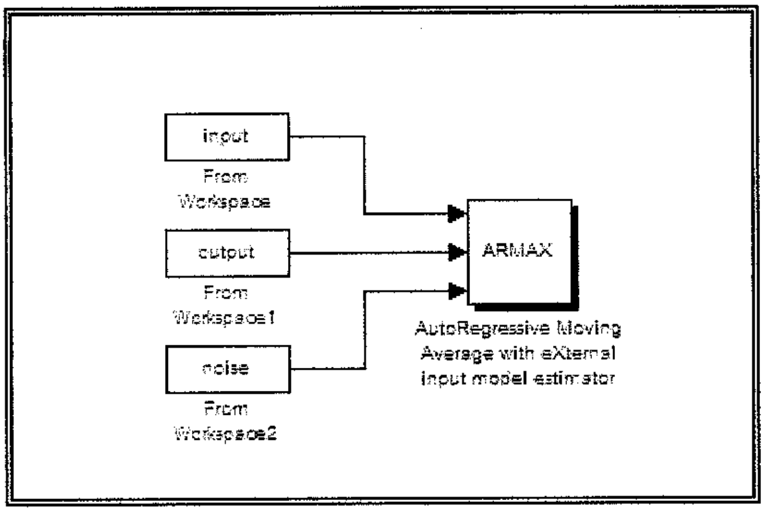


Figure 5.8: ARMAX Configuration

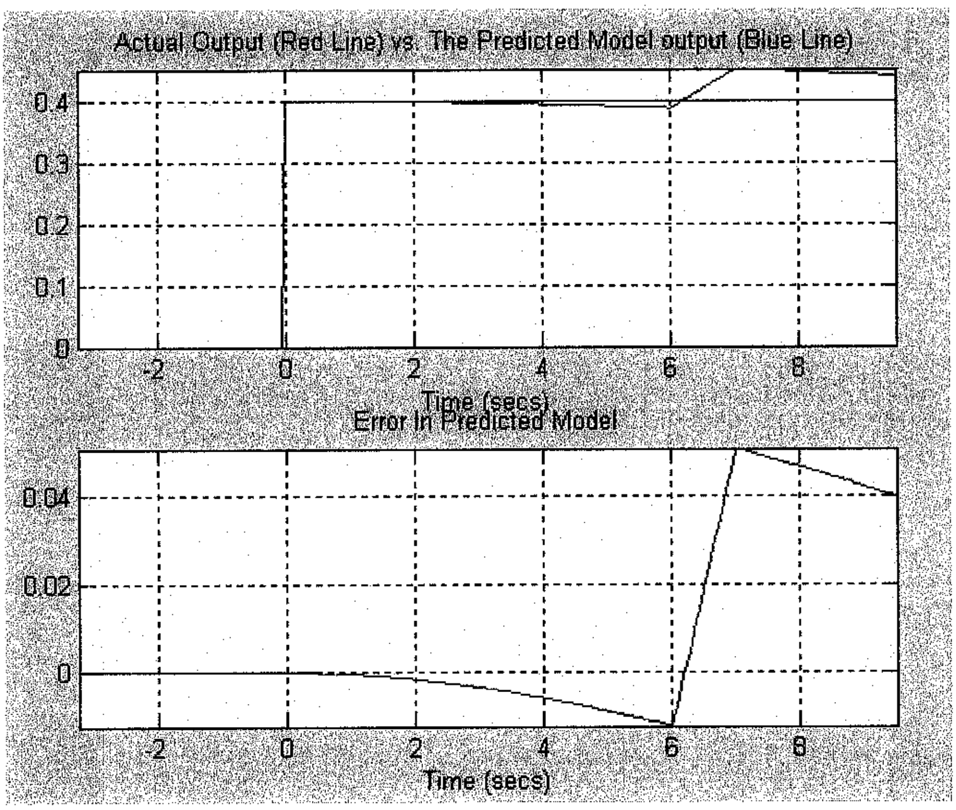


Figure 5.9: ARMAX (3 3 3 0) Simulation Result

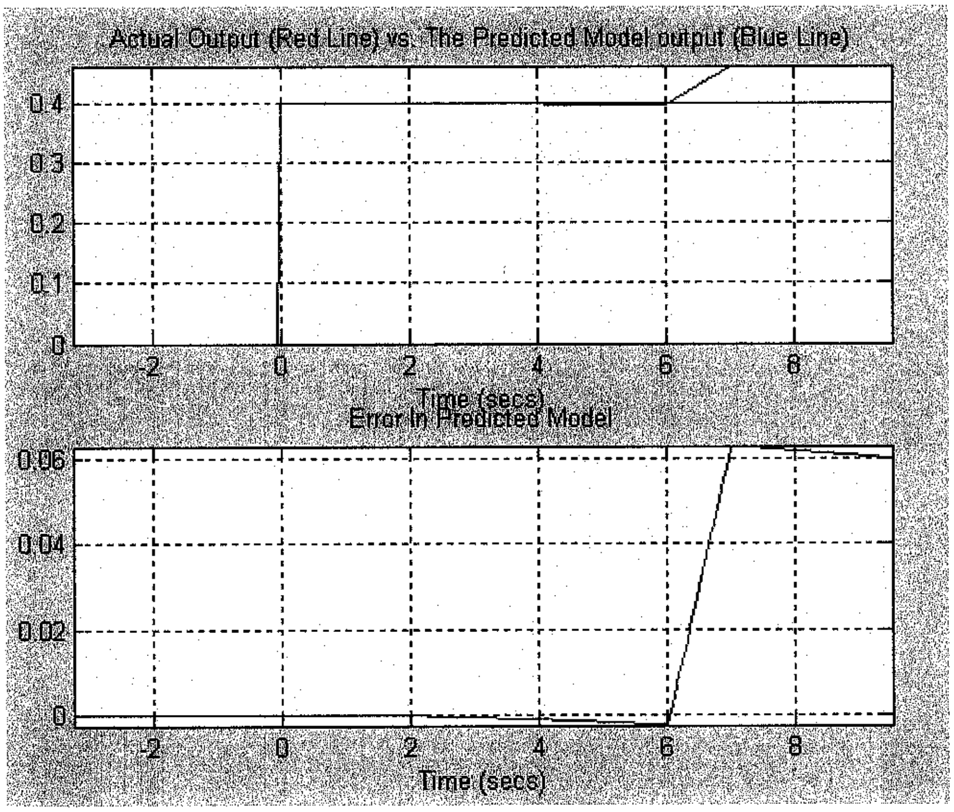


Figure 5.10: ARMAX (5 3 3 0) Simulation Result

Table 4: Model Predictors Comparison for Order 3

Transfer Function		AR				ARX				ARMAX			
		s^3	s^2	s^1	s^0	s^3	s^2	s^1	s^0	s^3	s^2	s^1	s^0
System	Numerator	0.5021	60.25	2410	175.42	0.013333	1.6	64	853.3	0.013333	1.6	64	853.3
	Denominator	1	80.49	1600	263.4	1	120	4800	349.43	1	120	4800	349.43
Noise	Numerator	-	-	-	-	0.7295	119.3	3503	199.32	0.7295	119.3	3503	199.32
	Denominator	-	-	-	-	1	120	4800	349.43	1	120	4800	349.43

Table 5: Transfer Function for AR of Order 5

Transfer Function	s^5	s^4	s^3	s^2	s^1	s^0
Numerator	0.5023	100.5	8037	477.15	2594	5641
Denominator	1	160.9	9603	384.24	1034.39	702.44

Table 6: Transfer Function for ARX of Order 5

Transfer Function		s^5	s^4	s^3	s^2	s^1	s^0
System	Numerator	0.01333	1.596	64.29	893.5	928	379.1
	Denominator	1	111.7	4823	365.86	381.97	131.75
Noise	Numerator	1.113	194.3	78.46	901.61	1658.11	5037.82
	Denominator	1	200	87.36	949.84	1403.69	3052.50

Table 7: Transfer Function for ARMAX of Order 5

Transfer Function		s^5	s^4	s^3	s^2	s^1	s^0
System	Numerator	0.01333	1.596	64.29	893.5	928	379.1
	Denominator	1	111.7	4823	365.86	381.97	131.75
Noise	Numerator	1.113	194.3	78.46	901.61	1658.11	5037.82
	Denominator	1	200	87.36	949.84	1403.69	3052.50

5.4 FINDINGS

From the results obtained, the author highlighted the followings:

1. Empirical modeling gives a linear relationship between the input and output. Although it does not provide enough information to satisfy the analysis requirements, a linear transfer function models developed using this method are adequate for the project implementations.
2. AR Model does not provide a good description of the actual system. This is proved since AR Model gives a large error in predicted model. A further explanation on this behavior will be discussed in the next chapter.
3. ARX and ARMAX Model exhibit quite the same characteristics. By analyzing the error predicted between order 3 and 5 for both models, the simulation results clearly shows that order 3 gives a small error compared to order 5. So, it seems logical to say that ARX and ARMAX model of order 3 are the best models apart from models obtained from empirical modeling.

5.5 SUMMARY

Open loop response test is carried out in order to enable the author to define the process by determining the process time constant, process gain and process dead-time. In real plant, these values are important for calculating controller settings. The resulting improvements in loop performance lead to a better overall control of process and enhanced productivity.

For this project, all the variables involved are being identified: (1) Process Variable (PV), (2) Manipulated Variable (MV) and (3) Set Point (SP). For this kind of experiment, PV and SP are a flow rate and MV is percent of valve opening. The measurement unit for flow rate is m^3/h and for valve opening is in percent (%).

The author applied two techniques that are: (1) conventional technique known as empirical modelling and (2) intelligent technique by using System Identification Toolbox available in MATLAB software.

Empirical modelling is a simple graphical and calculation technique. A linear transfer function that is obtained from this method is adequate for the project implementations. For the intelligent technique, three model predictors are being used to obtain the best model. From the analysis it is proved that AR Model does not provide a good description of the actual system since it gives a large error in predicted model. While for ARX and ARMAX Model, both of them exhibit quite the same characteristics. Simulation results clearly show that order 3 gives a small error compared to order 5. So, it seems logical to say that ARX and ARMAX model of order 3 are the best models apart from models obtained from empirical modelling.

CHAPTER 6
MODEL VALIDATION & DISCUSSION

6.1 MODEL VALIDATION

6.1.1 Empirical Modeling

From the first method, the transfer function is $T(s) = 2.8\ e^{-4.5s} / (1.50s + 1)$. Therefore for a step input, $Y(s) = \lim_{s=0} = T(s) \times sU(s) = [2.8\ e^{-4.5s} / (1.50s + 1)] \times [s\ (0.05/s)] = 0.14$.

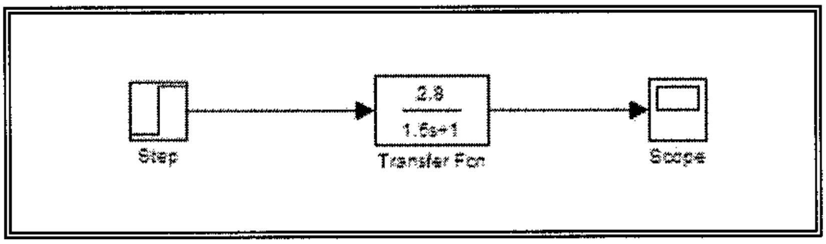


Figure 6.1: Model Validation for Empirical Modeling (Method I)

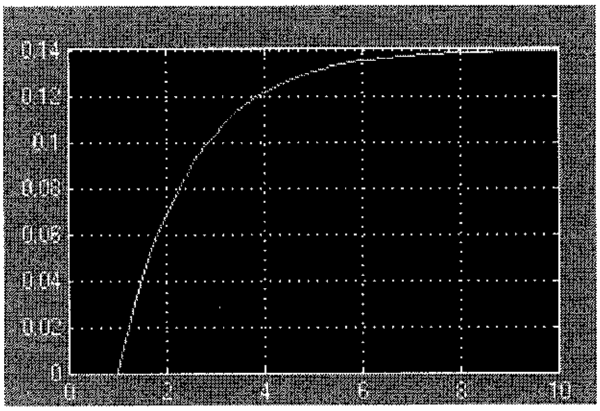


Figure 6.2: Result for Empirical Modeling (Method I)

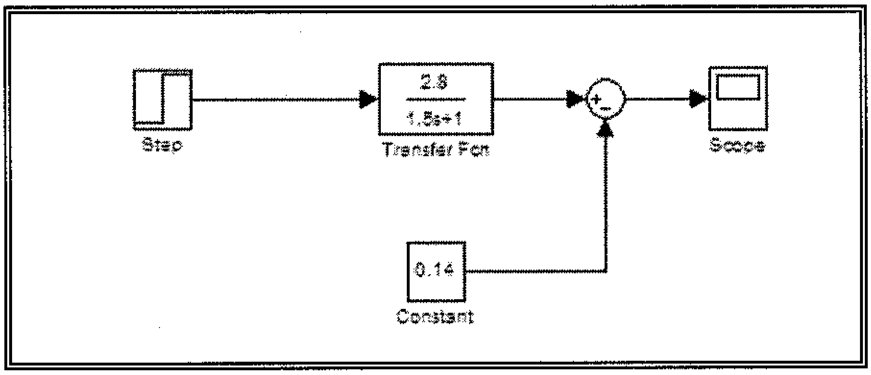


Figure 6.3: Comparison Error between Actual Value and Empirical Modeling (Method I)

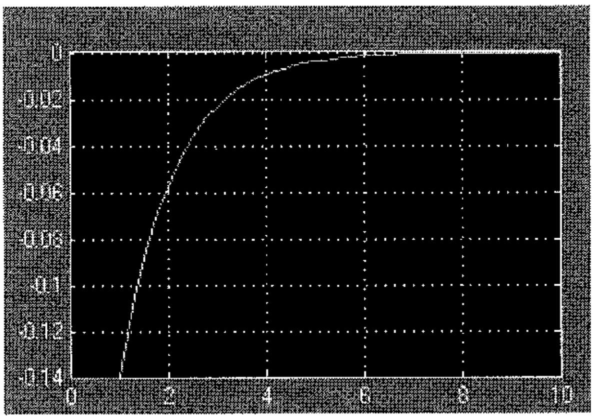


Figure 6.4: Result for Error Comparison (Method I)

The same technique is applied for second method, T(s) = 2.8 $e^{-4.5s}$/ (1.50s + 1). Therefore for a step input, Y(s) = lim $_{s=0}$ = T(s) x sU(s) = [2.8 $e^{-5.625s}$/ (1.125s + 1)] x [s (0.05/s)] = 0.14.

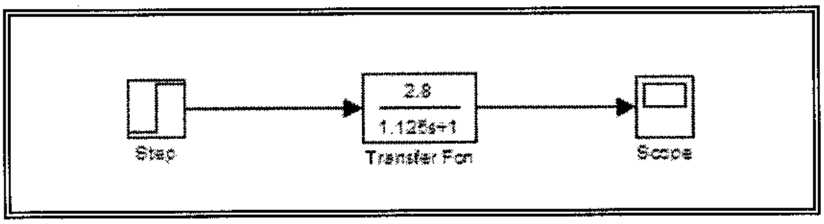


Figure 6.5: Model Validation for Empirical Modeling (Method II)

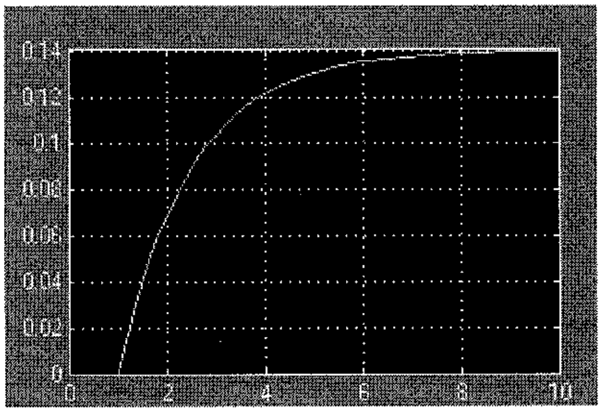


Figure 6.6: Result for Empirical Modeling (Method II)

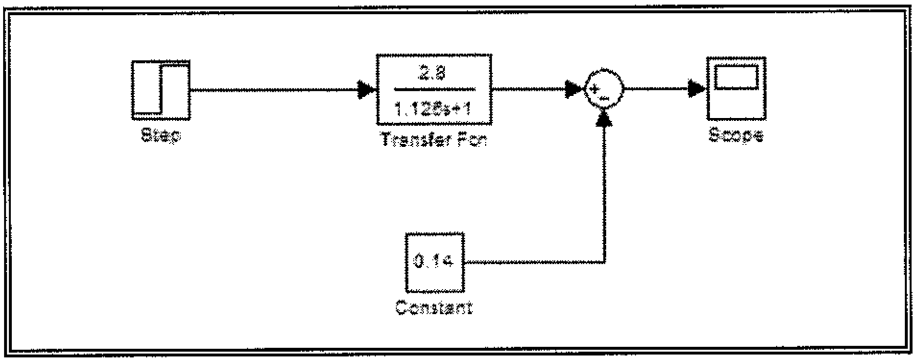


Figure 6.7: Comparison Error between Actual Value and Empirical Modeling (Method II)

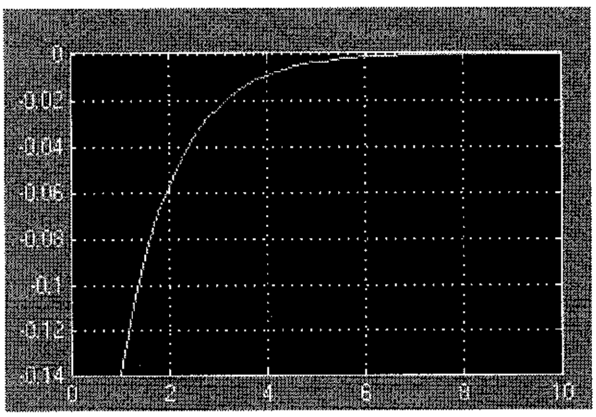


Figure 6.8: Result for Error Comparison (Method II)

After the model being tested, the result shows that both models obtained from conventional techniques are validated. Models are capable to reproduce the measured output from actual system.

6.1.2 ARX Model

Assumptions: The noise for this system is being considered as zero since the experiment is run on open loop response.

As given in Table 4, the steady state output obtained is:

$Y(s) = \lim_{s=0} = T(s) \times sU(s) = [(853.3) / (6.4e004)] \times s(0.05/s) = 0.122.$

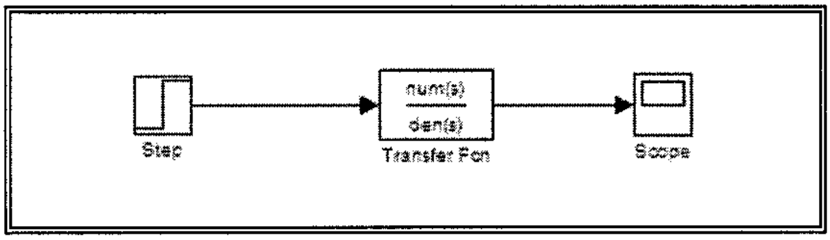


Figure 6.9: Model Validation for ARX order 3

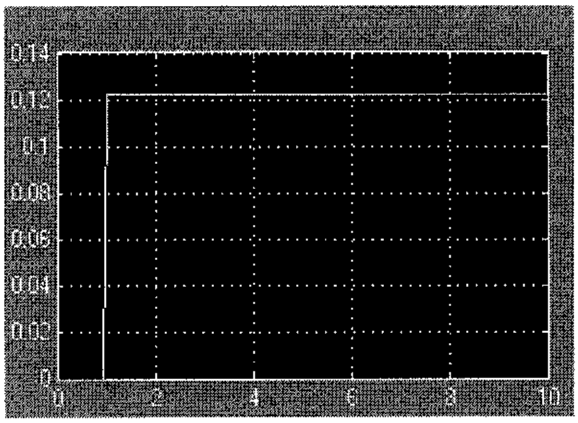


Figure 6.10: Result for ARX order 3

6.1.3 ARMAX Model

From Table 4, the steady state output obtained is:

$Y(s) = \lim_{s=0} = T(s) \times sU(s) = [(-426.7) / (-3.2e004)] \times s(0.05/s) = 0.122.$

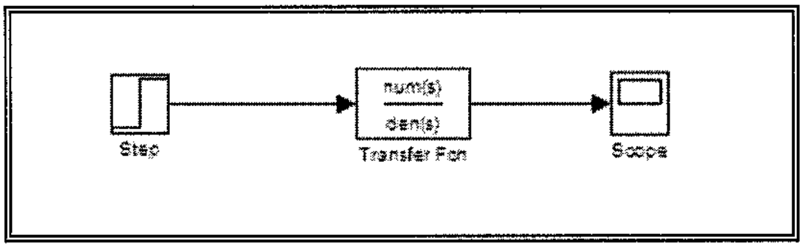


Figure 6.11: Model Validation for ARMAX order 3

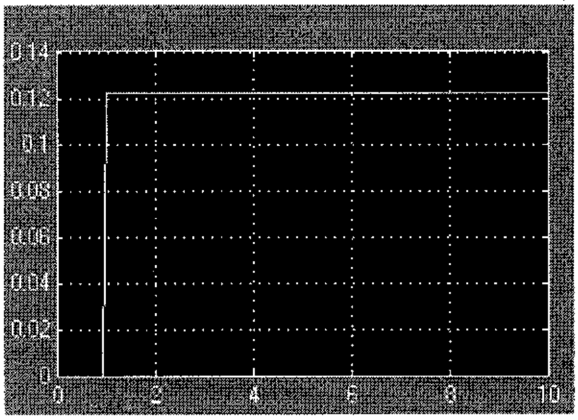


Figure 6.12: Result for ARMAX order 3

Both models obtained from intelligent technique are valid. They are capable to reproduce the observed data acquired from the actual system.

6.2 DISCUSSION

There are many techniques available in System Identification. The two methods that will be discussed in this section are empirical modeling and model predictor (using MATLAB Simulink). Empirical identification is a very efficient alternative modelling method specifically designed for process control. It is an iterative procedure which involves several experiments and potential model structure before the model has been determined. The models developed using this method provides the dynamic relationship between selected input and output variables. For this particular project, the empirical model could relate the flow rate to the percent of valve opening. Unfortunately, although the empirical model tailored to specific needs of process control; it does not provide enough information to satisfy all process design and analysis requirements and cannot replace fundamental models for all applications. One more limitation of empirical modelling is it is limited to first order with dead time system only. Instead of the limitation, model obtained from this conventional technique is valid for this particular project.

Table 8: Summary of Process Reaction Curve Method

Characteristics	**Process Reaction Curve**
Input magnitude	Large enough to give an output to noise ratio (SNR) greater than 5
Experiment duration	The process should reach steady state
Input change	A nearly perfect step change is required
Model structure	The model is restricted to first order with dead time
Accuracy with unmeasured disturbances	Accuracy can be strongly affected (degraded) by significant disturbances
Diagnostics	Plot model versus data; return input to initial value
Calculations	Simple hand and graphical calculations

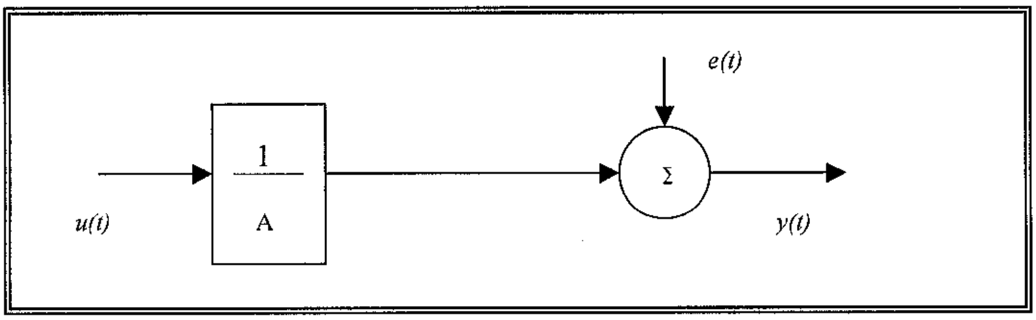


Figure 6.13: AR Model Structure

AR Model only contains one parameter denoted by A that represents the number of poles of the system. It has the simplest model structure to be compared to other model which has more parameters. For simulation purposes, only two elements are being inserted to the model that is the input and the noise. Because of this characteristic, AR Model are likely unable to describe the system accurately.

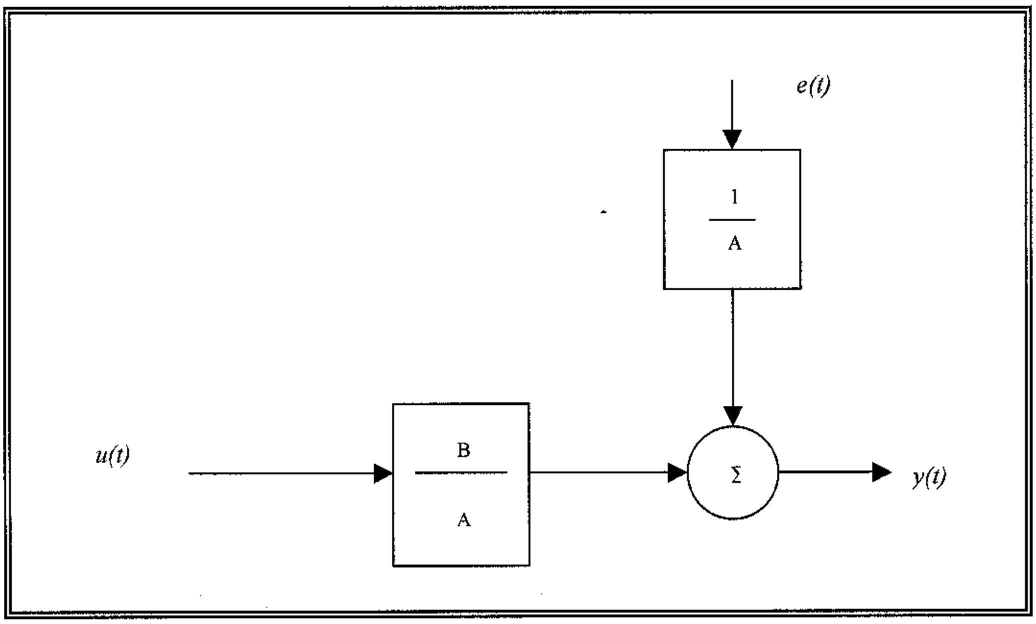


Figure 6.14: ARX Model Structure

ARX model has two parameters which are A and B. The order of this model is heavily depend on power of both parameters, which mean that ARX model has the ability to describe a system with a disturbance better. In System Identification Toolbox, the parameters of the ARX model structure, $A(q)y(t) = B(q)u(t\text{-}nk) + e(t)$ are intelligently estimated by the program using the least square method. The author only needs to define the orders and delay ([na nb nk]) of the ARX model. na (parameter A) is number of poles of the system, nb (parameter B) is number of zeros and nk is delays. Three elements are being inserted to the ARX model during the simulation process. The three elements are input, output and noise.

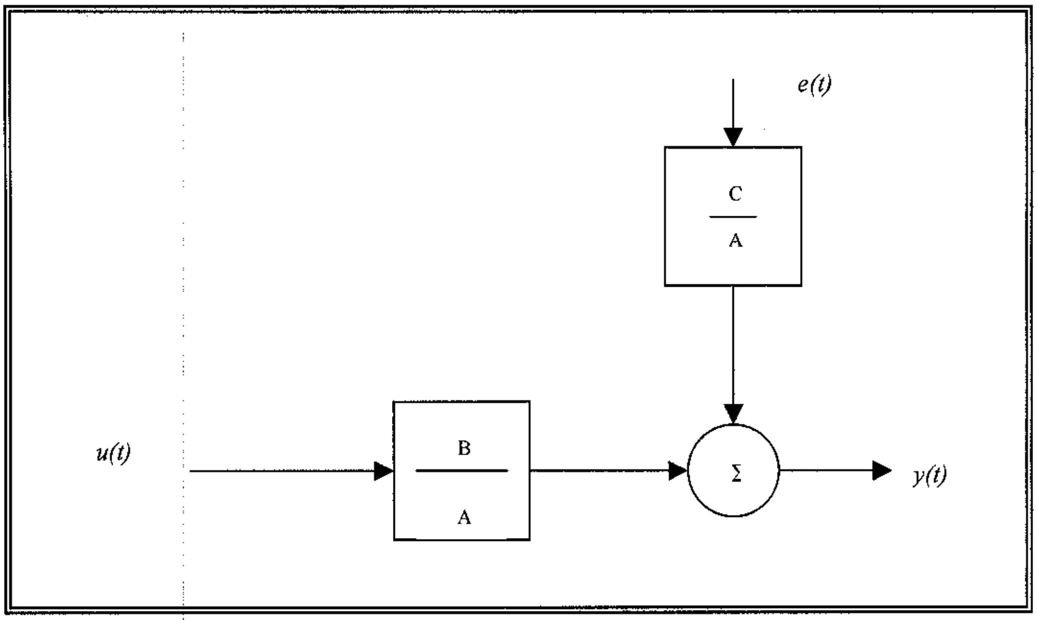


Figure 6.15: ARMAX Model Structure

The parameters of the ARMAX model structure $A(q)y(t) = B(q)u(t\text{-}nk) + C(q)e(t)$ are estimated using a prediction error method. Same as ARX model, ARMAX model needs the author to specify the order of the models. While ARX has [na nb nk], ARMAX has one more additional element that is nc (parameter C) which represents the number of zeros for the noise transfer function.

As for ARMAX model, the flexibility of describing the equation error is improved as a moving average of white noise is added. This is because ARMAX has more parameter than the previous model. Having three parameters gives advantage to ARMAX model to describe even much better than ARX model. With this capability, ARMAX are much more reliable to be compared to ARX model. This will give full advantage for ARMAX to describe a higher order model with a significant amount of noise or disturbance much better.

Criteria	Empirical	AR	ARX/ARMAX
Input magnitude	Large enough to give an output to noise ratio (SNR) greater than 5	The magnitude input does not effect the model prediction	
Experiment duration	The process should reach steady state	The process does not have to reach steady state	
Input change	A nearly perfect step change is required	No requirement regarding the shape of the input	
Model structure	The model is restricted to first order with dead time	Order of the model can be defined during simulation	
Accuracy with unmeasured disturbances	Accuracy can be strongly affected (degraded) by significant disturbances	Unable to describe the process behaviour precisely. (Output of the model yields a massive error)	Has the ability to describe the process along with the disturbance or noise of the system
Diagnostics	Plot model versus data; return input to initial value	Plot model, actual data and error prediction versus time	
Calculations	Simple hand and graphical calculations	Computer based program – MATLAB Simulation	

Table 9: Summary of Comparison between Empirical Modeling and Intelligent Method

6.3 SUMMARY

The two methods that will be discussed in this chapter are empirical modelling and model predictor (using MATLAB Simulink). The models developed using empirical modelling provides the dynamic relationship between selected input and output variables. Although the empirical model tailored to specific needs of process control; it does not provide enough information to satisfy all process design and analysis requirements and cannot replace fundamental models for all applications. One more limitation of empirical modelling is it is limited to first order with dead time system only. Instead of that, model obtained from this method is validated.

The second method is intelligent method which is carried out with the aid of MATLAB software. As the name implies, the ARX and ARMAX models is intelligently constructed by the software and the author only need to define the order of the models. Both models are capable to reproduce the observed data with minimum predicted error. So, up to this point, the author can say that the models that best described the actual system are the ARX and ARMAX model. Both models are obtained from intelligent technique.

The later part of this chapter is some explanation of the model predictors that are being used throughout the project. AR model consists of only one parameter and based on that fact, AR model unable to describe the system accurately and hence it yields a massive error. ARX model has two parameters which are A and B. The order of this model is heavily depend on power of both parameters, which mean that ARX model has the ability to describe a system with a disturbance better.

As for ARMAX model, the flexibility of describing the equation error is improved as a moving average of white noise is added. This is because ARMAX has more parameter than the previous model. Having three parameters gives advantage to ARMAX model to describe even much better than ARX model. With this capability, ARMAX are much more reliable to be compared to ARX model. This will give full advantage for ARMAX to describe a higher order model with a significant amount of noise or disturbance much better.

CHAPTER 7
CONCLUSION & RECOMMENDATIONS

7.1 CONCLUSION

System Identification is an art of dealing with a problem of generating workable model of dynamic response based on the observed dataset from the actual system. The modelling process is based on the observed input and output data of a system.

The objective of this project is to design and implement System Identification for Liquid System Pilot Plant in UTP and make some comparison between the conventional and intelligent techniques of System Identification. The author applied two techniques that are: (1) conventional technique known as empirical modeling and (2) intelligent technique by using System Identification Toolbox available in MATLAB software.

From the analysis it shows that empirical modeling came out with a linear transfer function that is adequate for the project implementations. For the intelligent technique, three model predictors (AR, ARX and ARMAX) are being used to obtain the best model. Unfortunately, AR Model does not provide a good description of the actual system since it yields a massive error in predicted model. While for ARX and ARMAX model, both of them exhibit quite the same characteristics. Simulation results clearly show that models with order of 3 are the best set of models.

After model validation tests, the model from conventional technique and both models from intelligent technique are capable to reproduce the observed data with minimum predicted error. Unfortunately, due to some limitations in conventional technique, the author can conclude that the models that best described the actual system are the ARX and ARMAX model which are obtained from intelligent technique.

In conclusion, the objectives of the project have been met since the alternative method using MATLAB Simulink implementation achieves a better performance than the conventional technique (Empirical Modelling) although this could be considered as a partially successful. There are a lot of modifications and case studies can be done for a better result performance.

7.2 RECOMMENDATIONS

As time goes by, System Identification becomes a very important part in real plant process. Therefore, having the knowledge of deducing a mathematical model by studying the behaviour of input and output data will be much helpful in a process control. This project could be further improved by means of any other approach that will develop a model that describes the real system better. Starting from now onwards, people can continually investigate and develop new method of System Identification.

CHAPTER 8

REFERENCES

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2. The Math Works-System Identification Toolbox http://www.mathworks.com/products/sysids
3. Gene F. Franklin, J. David Powell and Abbas Emami-Naeini, Feedback Control of Dynamics Systems, 4th Edition.
4. Thomas E. Marlin, Process Control, Designing Processes and Control Systems For Dynamic Performance, 2nd Edition

CHAPTER 9
APPENDICES

Appendix A: Simple PID Flow Control (FIC-664)

Appendix B: PID Flow Control Procedures

Appendix C: Graph Obtained from Open Loop Tuning Process

SIM 305 Pilot Plant : Blank *PC Automation Sdn. Bhd.*

Experiment 2 : Simple PID Flow Control (FIC-664)

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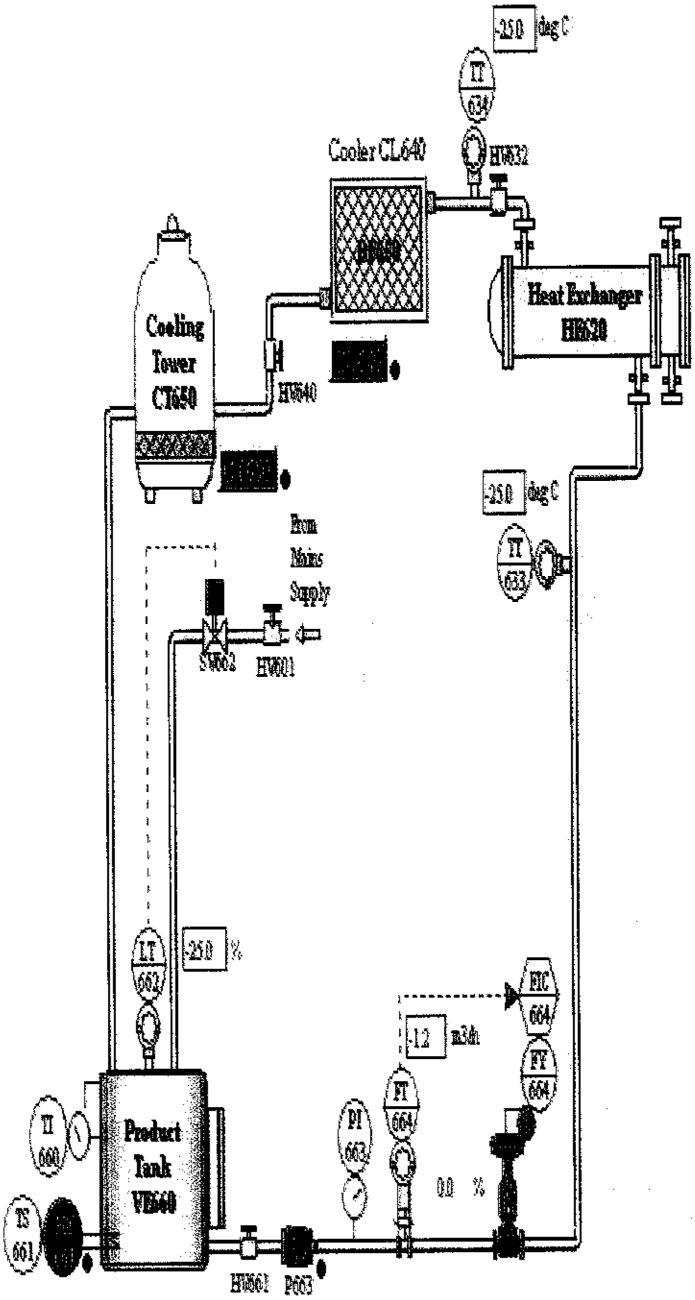

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02 AM 10	LO Limit	FI664	0	500	LO	Good - Non-			11:54:02 AM 10/20/2004

lome | Overview | Tuning | Trend | Alarm

PROCEDURES FOR EXPERIMENT 2

Experiment 2 – Simple PID Flow Control (FIC-664)

OBJECTIVES:

This experiment is to divided into Four (4) sections:

- Section A: is for the student to **Identify the Process**,
- Section B: is for the student to perform **Open Loop Controller Tuning**,
- Section C: is for the student to perform **Closed Loop Controller Tuning**, and
- Section D: is for the student to carry out **Performance Test** for the Control Loop.

Results:

The student is expected to discuss and report on the findings about the process and make a comparison of the two proposed tuning methods.

PREPARATION:

STEP	*ACTION*	*REMARKS*
1	Ensure that all Utility Services are ready (i.e. Switch on Power Supply to Control Panel and Switch on Air Supply System to the Pilot Plant).	
2	Fill The Vessel VE660 with water until it is about high-level.	
3	Ensure that the DCS is Ready (i.e. It is communicating properly with the control Panel)	
4	When the computer start up, go in the Home page and then perform the login experiment operation .	"Experiment 2 : Simple PID Flow Control (FIC-664)" will appear after user perform the login Experiment operation.
5	Set the controller to MANUAL mode	Set the "A/M " Button to "Manual"
6	Close the Control Valve **FY 664** Manually (0% open) [i.e.: a) Setting Control Mode to Manual, then b) At the MV data entry field, Key in 0 and press Enter]	Same operations to Open / Close other Control Valves manually
7	***Continue next page***	

Experiment 2 - Simple PID Flow Control (FIC 664)

PREPARATION: (continue)

STEP	*ACTION*	*REMARKS*
7	Set the Control Valve FY **664** to Auto mode	
8	Open Solenoid Valve SV**662** Manually.	
9	Open or Close Hand Valves at the Pilot Plant as follows: Open Hand Valve HV661 Open Hand Valve HV632 Open Hand Valve HV640 Open Hand Valve HV601 Close Other Hand Valves	Hand Valves to be Open / Closed Fully

Experiment 2 – Simple PID Flow Control (FIC 664)

SECTION 2A: Process Identification

2A.1 Start Experiment:

STEP	ACTION	REMARKS
1	At the PID Controller Faceplate (FIC 664), manually Open Control Valve FY664 to 20%	Set MV to 20 and press Enter
2	Start Pump P663, HE620, CL640 and CT650 via computer.	
3	Observe the Flow curve (FT 664) from the Trend Window and wait until it has stabilized to a constant value	
4	At the PID Controller Faceplate (FIC 664), manually Open Control Valve FY664 by an additional 10%	Set MV to 30 and press Enter
5	Observe the Flow curve (FT 664) from the Trend Window and wait until it has stabilized to a new constant value, then Freeze the trend window.	This is the process Reaction curve
6	Print out the PV Trend curve.	Print in color
7	Stop Pump P663, HE620,CL640 and CT650 via computer.	

2A.2 Results Analysis:

1	Compare the Flow curve with a set of expected process Reaction Curves provided in **Appendix A** of this manual.	
2	Identify the process response with the corresponding **Reaction Curve**	
3	Make several measurement as per the Reaction Curve chart.	Refer Appendix A1
4	Sketch a Block Diagram to represent the process and Describe the Characteristics of this Process.	Dead time, Capacity/Rate of Rise, Time Constant, Noise, etc
5	Suggest the suitable Control Modes for a PID Feedback Control Loop for regulating of the process.	eg. P, I, D settings

Experiment 2 – Simple PID Flow Control (FIC 664)

SECTION 2B: Open Loop Tuning Method

2B.1 Tabulation and Analysis of Results:

STEP	*ACTION*	*REMARKS*
1	Using the printed graph obtained from Section above (Process Analysis) above, measure and tabulate the relevant values as required. **Refer to Appendix B, Table B-1 as example.**	
2	Base on the equations for Open Loop Tuning, calculate the required controller tuning parameters. **Refer to Appendix C, Table C-1.**	Try to improve the accuracy of estimation by drawing three best tangential straight line for the reaction curve, calculate a set of results for each line and take the average for the calculation of P, I and D settings
3	At the FIC 664 controller faceplate, key in the calculated controller tuning parameters.	
4	You are now ready to test the performance of the Control Loop. Proceed to **Section D** to continue.	

Experiment 2 – Simple PID Flow Control (FIC 664)

SECTION2C: Closed Loop Tuning Method

2C.1 Start Experiment:

STEP	*ACTION*	*REMARKS*
1	At the Controller Faceplate (FIC664), set its Gain to 1.0, the Integral time to 9999, and the Derivative time to 0.0	
2	At the PID Controller Faceplate (FIC 664), adjust the Set Point (SP) to 1 m^3/h	
3	Start Pump P663, HE620,CL640 and CT650 via computer.	
4	Set the controller to Manual mode, and open the control Valve FY-664 by 20%	Adjust controller MV = 20%
5	Slowly open the control Valve FY-664 to to bring the process value (PV) to almost equal to the set point.	
6	Observe the Process Value (PV) from the Trend window and wait until it has stabilized to a constant value.	
7	Set the Controller to Auto Mode.	
8	Wait for the Process Value (PV) is stable.	
9	Make a small step change to the Set Point (i.e. Increase the setpoint by 10%)	
10	Observe the process Value (PV) from the trend window. If the PV response is not oscillatory , double the controller gain value until it becomes oscillatory	
11	If the PV response is oscillatory , observe whether the magnitude of PV is increasing or decreasing. If it is increasing , reduce the controller gain by 1.5 times. If the PV is decreasing , increase the controller gain by 2 times. Aim to obtain an oscillatory response with almost constant amplitude.	
12	When constant Amplitude Oscillation is archived, allow up to 3 or more oscillation cycles to be recorded and Freeze the trend window.	
13	Print out the PV response curve	Print in color
14	Stop Pump P663, HE620, CL640 and CT650, then set the Controller FIC-664 to manual mode	Set the "RUN / STOP" Button to "STOP"

Experiment 2 – Simple PID Flow Control (FIC 664)

2C.2 Results Analysis:

1	Using the printed graph obtained from Section above, measure and tabulate the relevant values as required. Refer to **Appendix B, Table B-2** as example.	
2	Base on the equations for Closed Loop Tuning, calculate the required controller tuning parameters. **Refer to Appendix C, Table C-2.**	
3	At the FIC- 664 controller faceplate, key in the calculated controller tuning parameters.	
4	You are now ready to test the performance of the Control Loop. Proceed to **Section D** to continue.	

Experiment 2 – Simple PID Flow Control (FIC-664)

SECTION 2D: Control Loop Performance Test

2D.1 Start Experiment:

STEP	*ACTION*	*REMARKS*
1	At the FIC-664 controller Faceplate, Set its P, I, D Parameters obtained from the previous experiment.	
2	Adjust the Set Point (SP) of FIC-664 to 1 m^3/h	
3	Set the Controller to Manual Mode , and open the control valve FY664 by 20%.	Adjust through MV = 20%
4	Start Pump P663, HE620, CL640 and CT650 via the computer	Set the "RUN / STOP" Button to "START"
5	Adjust the Controller output (MV) until its Process Value (PV) is close to its Set Point (SP).	
6	At the FIC-664 controller Faceplate, Set the Controller to 'Auto' mode.	
7	Observe its PV curve (FT-664) from the Trend Window and wait until it is reasonable stable.	
8	Change the Controller Set Point (SP) to 1.5 m^3/h	
9	Observe its PV curve (FT-664) from the Trend Window and look for some typical response characteristics.	
10	Capture the important process responses and Print out the Trend curve	Print in color
11	Stop Pump P663, then set the controller FIC-664 to manual mode.	

2D.2 Tabulate and Analyze Results:

1	Using the printed graph obtained from Section 2D.1 above, measure and tabulate the relevant values as required. Refer to **Appendix B, Table B-3** as example.	
2	Describe the Characteristics of the Process response.	
3	Discuss the functions of each controller tuning parameters, P, I and D.	
4	Suggest any improvements to the process control loop and its total error.	

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Experiment 2 : Simple PID Flow Control : Tuning FIC-664

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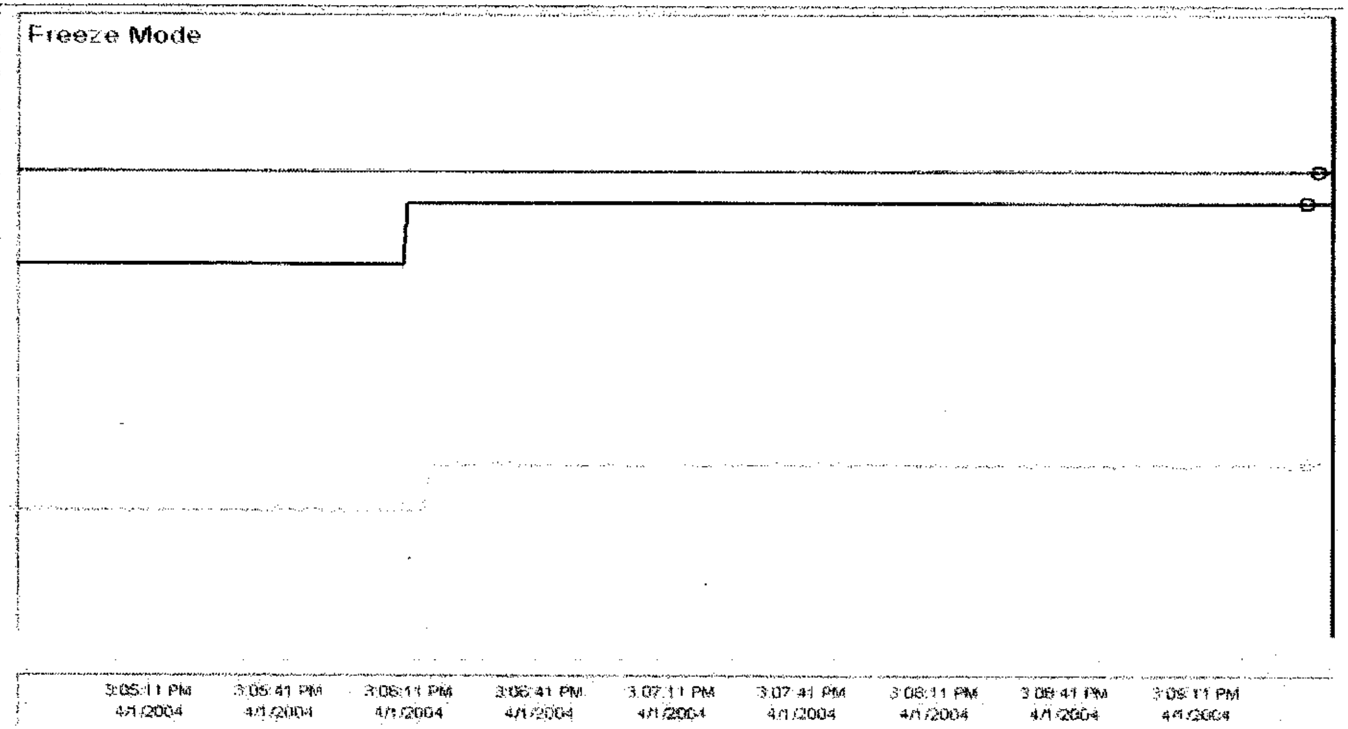

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FIC664.PV	0.55	3:09:35 PM	4/1/2004
FIC664.SP	1.50	3:09:38 PM	4/1/2004

Home	Overview		Trend						
Back		Tune FIC664							Alarm