Partial Stroke Testing of Emergency Shutdown Valve (FISHER)

by

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Interim report submitted in partial fulfilment of
the requirements for the
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CERTIFICATION OF APPROVAL

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Approved by,

____
(Assoc. Prof Dr Nordin Bin Saad)

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

December 2009

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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Nor Nadiah Binti Ab Muntalib

ABSTRACT

This report essentially discusses the basic understanding to comprehend the technology of Partial Stroke Testing (PST) of Emergency Shutdown Valve (ESV) and how it is conducted and analyzed. In general, this project deals with Yokogawa FA-M3 Controller and the FISHER, METSO and MASONIELAN rotary shutdown valves. However, this report will focus mainly on the testing of FISHER valves. The objective of the project is to perform 90 days of Partial Stroke Testing (PST) to FISHER Emergency Shutdown Valve (ESV) and to compare and verify the technology used with other vendors. This report also explained the valve components and the basic of Programmable Logic Control (PLC). The chapter on methodology explained the procedure for executing PST to the respective valve. It also lists out the tools and equipments needed to execute this project. The chapter that follows discusses the results as well as the problems faced during the execution of the project. Analysis of the findings is also shown in this chapter. Finally, the last chapter discusses the summary of the overall project. Throughout this project, the main task involved dealing with the PLC Ladder Logic Programming and the effect of the valve design to the Partial Stroke Testing. Sharing of ideas with PETRONAS engineers from Improvement Working Group (IWG) of Skill Group 14 (SKG14) are also conducted to compare the performance of various valves for use in PETRONAS plants. The outcome of this project would be very useful for the PETRONAS to adopt PST strategy in their plant nationwide.

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LIST OF ABBREVIATION

ESV	Emergency Shutdown Valve
PST	Partial Stroke Testing
FST	Full Stroke Testing
PFD	Probability of Failure in Demand
PLC	Programmable Logic Controller
SIS	Safety Instrumented System
PGTS	PETRONAS Global Technology Solution

CHAPTER 1
INTRODUCTION

1.1 Background of Study

A valve is a device that controls the flow of a fluid. Nowadays, valve not only can control the flow, but also the rate, the volume, the pressure or the direction of the liquids, gases, slurries, or dry material through a pipeline. Emergency Shutdown Valve (ESV) is an actuated valve installed in a pipeline. It isolates a process unit from an upstream or downstream inventory upon activation of the process unit alarm and shutdown system. It acts as the final defence against process upsets.

In a very safe plant whereby emergency is very rarely to occur, ESVs may never be operated; it stays to its duty position whether open or close until the plant turnaround schedule. This condition could be very dangerous as the valve is being in a static position without mechanical movement for long periods of time and this inherently increases unreliability. Thus, a regular testing is crucial to energize the valve so that it will operate smoothly during emergency.

Usually, the valves are tested during plant turnaround which is within 5 to 6 years. A study has proved that extending the turnaround will yield to great economic returns through increased in production. However, extended turnaround intervals also mean that the valves are expected to achieve the same performance even though it has to go longer between function tests [1].

There are two types of test conducted to overcome the safety performance degradation due to longer testing intervals; Full Stroke Test (FST) and Partial Stroke Test (PST). The FST requires the valve to be fully opened and fully closed during the testing. Thus, it can only be done during the plant shutdown. It also requires additional facilities, such as full-flow bypasses and possible production impacting procedures, such as reducing production flow rates during testing. Due to this, many users consider using PST instead of FST because it requires the valve to be partially opened or closed thus will not affect the production. PST also eliminates the requirement of additional facilities, and thus will ease the user [1].

PST on the other hand is an online Safety Instrumented System (SIS) testing which involves the partial stroking of the valves movement to verify that the valve would not stick. Extended turnaround period means that in order to test an ESV's functionality at a rate commensurate with the Probability of Failure Demand (PFD) requirements of the design Safety Integrity Level (SIL), alternative arrangements need to be implemented for online proof testing [2].

1.2 Problem Statement

Currently, the method used to initiate the PST is by using mechanical or jammers equipments such as mechanical limiting, position control and solenoid valves. The other popular method is using expensive, labor intensive pneumatic testing method. This method is proven to be reliable however it is very expensive and requires complex test procedures.

. Programmable Logic Controller (PLC) based systems appear to play a central role concerning initiating, registering, and responding to PST [3]. With this current technology, the operators are not required to go to the field to initiate PST. Moreover, beyond proving a valve is able to move, the industry is looking forward for proof record of tests and also record of actions in response to failed testing. This will enhance the testing method as well as increase the reliability of the system.

The development of PST software by vendors along with the emerge of PLC based system have brought new chapter in PST technology. The prime function is to prove and document the ability of the valve to move using PST function while maintaining the integrity of the emergency function. However, since this technology is relatively new especially in oil and gas industry in Malaysia, a study on the performance of PST systems from various vendors will produce valuable information for the benefits of end users, vendors and plant operations.

1.3 Objective and Scope of Study

1.3.1 Objective

The objectives of the project are:

- To execute 90 days Partial Stroke Testing for FISHER emergency shutdown valves
- To perform analysis on the findings so that can be used do comparison with other vendors

1.3.2 Scope of Study

Basically, the scope of this project is to analyze, compare and verify the performance of PST applied to three ESVs from three different vendors. The first phase of developing the PLC programming and setting of the valves software has been completed by previous group of students. The second phase is to analyze the valve performance by referring to the data gathered during valve testing. The reliability and feasibility study will be carried out to achieve the objective. Since this is one of the PETRONAS Group Technology Solutions (PGTS) and Universiti Teknologi PETRONAS (UTP) project, it is compulsory to follow the PETRONAS Technical Standard.

CHAPTER 2
LITERATURE REVIEW

2.1 Valve

Valves control the flow into a pipeline by partially or fully opening or closing their controlling devices that restrict the movement of the flow. Valves are categorized based on the movements of the stems; either sliding or rotary motion. The major different between these two types is the way it works when responding to signals. The sliding stem valve, such as globe valve and gate valve operates by the sliding up and down of the stem. Examples of rotary valves are butterfly valve and ball valve.

There are two major components in a valve; actuator and valve body assembly. Valve assembly usually comes with other features such as limit switch, positioner, pressure regulator and etc.

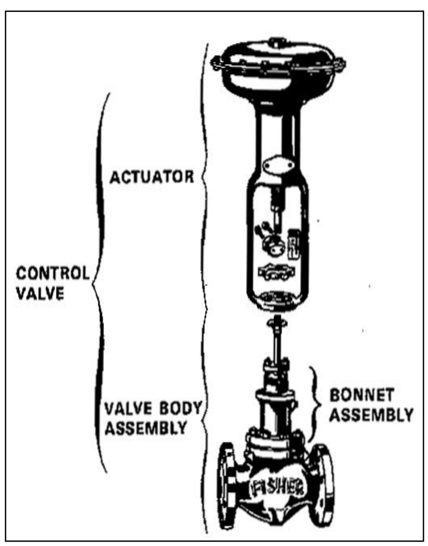

Figure 1: Typical Butterfly Valve

2.1.1 Ball Valve

Ball valve is a valve that opens by turning a handle attached to a ball inside the valve. Its controlling device is a ball which has a hole, or port, through the middle so that when the port is in line with both ends of the valve, flow will occur. The straight through design of ball valve will reduce the pressure drop. The characteristic of ball valve allows the quickness of operation, require no lubricants and give tight sealing with low torque. Most ball valves are also equipped with soft seats that conform tightly to the surface of the ball. Thus ball valve is well-suited for tight shut-off application. [5]

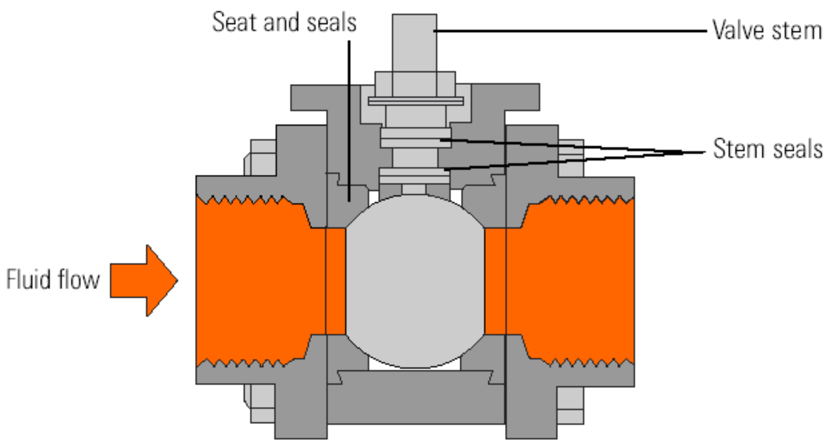

Figure 2: Ball Valve Construction

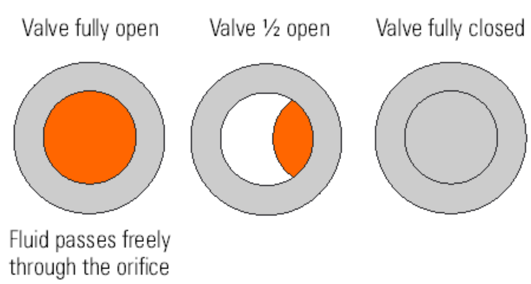

Figure 3: Flow Movement through Ball Valve

2.1.2 Butterfly Valve

For butterfly valve, the controlling device is a circular disk at the center of the pipe which is rotated 90˚ to open or close the flow passage. The actuator of the valve is connected to the rod which controls the rotation of circular disk. When the pipe rotates, it will turn the plate either parallel or perpendicular to the flow. When the valve is closed, the disc is turned so that it completely blocks off the passageway and when the valve is fully open, the disc is rotated a quarter turn so that it allows an almost unrestricted passage of the process fluid.

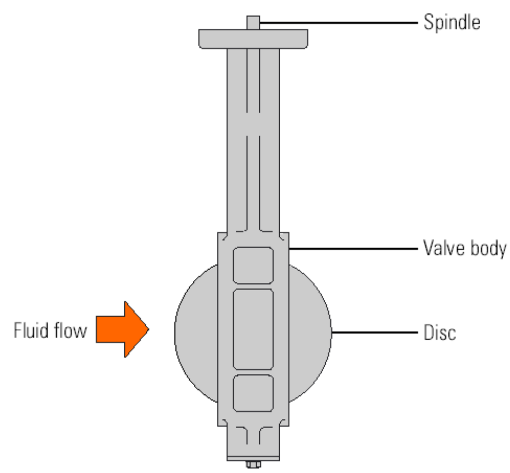

Figure 4: Typical Butterfly Valve

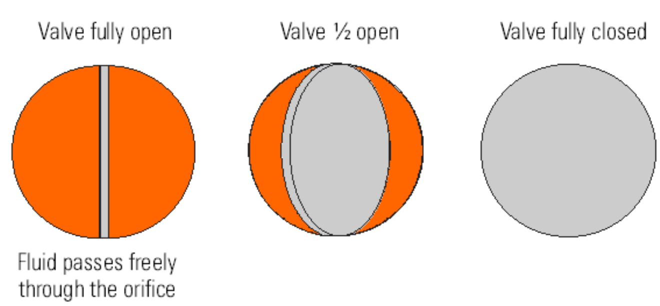

Figure 5: Flow Movement through Butterfly Valve

2.1.3 Actuator

An actuator is a powered device that supplies force and motion to open or close the valves. The power sources vary from pneumatic, hydraulic, or electrical. There are many actuator styles manufactured by FISHER such as diaphragm, piston, rack and pinion, electro-hydraulic, manual and electric actuators. The actuator used in this project is rack and pinion actuator as shown in Figure 6 [4].

Figure 6: Typical Rack and Pinion Actuator

2.1.4 Limit Switch

The purpose of limit switch is to alert when a valve is at or beyond a predetermined position because it shows the position of the valve stem at a particular instant of time. It operates discrete inputs to a distributed control system, signal lights, small solenoid valves, electronic relays, or alarms.

Figure 7: VALVETOP DXP Limit Switch

2.1.5 Digital Valve Controller

Figure 8 shows a digital valve controller or also known as smart positioner. It is a microprocessor-equipped device that controls the opening and closing of the valve by converting the 4-20mA DC current signal input from process controller and converts it to pneumatic output signal to the actuator. Besides, it communicates via Highway Addressable Remote Transducer (HART) communication protocol to provide instrument and valve diagnostic information. The smart positioner plays an important role in Emergency Shutdown (ESD) application. It will reduce the testing time taken and manpower requirement, thus it will reduce cost. The diagnostic capability of the smart positioner reports the health of the valve, thus reducing the need for scheduled maintenance and increasing process availability.

Figure 8: DVC6000 Digital Valve Controller

2.1.6 Pressure Regulator

Pressure regulator in Figure 9 is used to regulate or reduce air pressure so that it achieves the desired value. Also known as air-sets, it will reduce plant air supply to valve positioner and other control equipment. Common reduced-air-supply pressures are 20, 35 and 60 psig. The regulator mounts integrally to the positioner or nipple-mounts or bolts to the actuator. [4] The parameters that limit adjustment control on the pressure range are the regulating and adjustment range.

Figure 9: Pressure Regulator

2.1.7 Solenoid Valve

Figure 10 shows a solenoid valve. The functions of solenoid valve are to operate on/off pneumatic actuator and to interrupt the action of modulating valves by switching air or hydraulic pressure [4]. Most solenoid valves are designed to be continually energized, particularly for emergency shutdown service. The solenoid valve requires power supply for it to energize. If there is no power supply, the solenoid valve will be de-energized. Thus, it will affect the state of the valve whether fully open or fully close.

Figure 10: Solenoid Valve

2.2 Safety Instrumented System

The Safety Instrumented System (SIS) is an independent plant safety system consists of sensors, logic solver and final elements [6]. The purposes of SIS are to put an industrial process to a safe state when specified conditions are violated, permit the process to move forward safely when specified conditions allow and take action to mitigate the consequences of an industrial hazard. SIS is designed to be fail-safe that is, if a wire falls off a transmitter or a switch, the SIS goes to the safe state and trips. For ESV, if the air supply fails, it will go to its safe state which is closing the valve in order to shutdown the process.

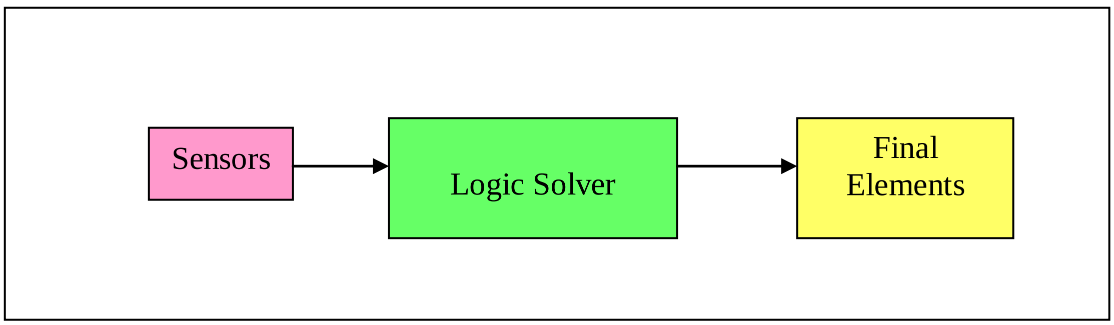

Figure 11: Block Diagram of SIS

2.2.1 Probability of Failure on Demand

Probability of failure on demand (PFD) is the probability that the safety system does not work properly when a safety action is required.

$$PFD_{SIS} = PFD_{SE} + PFD_{LS} + PFD_{FE}$$

SIS : Safety Instrumented System (Total System)

SE : Safety Sensor

LS : Logic Solver

FE : Final Element

PFD is calculated by this equation; PFD = 1/2λ * Ti where λ is the failure rate (defined by current operation) and Ti is the test interval. As in the equation, it is clear that there are two methods to reduce PFD which are to reduce the failure rate and also shortens the test interval. Study has shown that frequent PST can maintain the PFD and allow the FST interval to be extended [6].

2.3 Programmable Logic Controller

The Programmable Logic Controller (PLC) is a device that is specifically designed to receive input signals and emit output signals according to the program logic. PLCs come in many shapes and sizes from small, self-contained, units with very limited input/output capacity to large, modular units that can be configured to provide hundreds or even thousands of inputs/outputs. The PLC-based system becomes the most common choice for manufacturing controls including process plant since it can cut production cost and increase quality.

2.3.1 Programmable Logic Controller Languages

There are two methods of programming language – text and graphic language. The text languages are the Instruction List and the Structured Text type. The examples of graphic languages are Sequential Function Charts, Function Block Diagrams and Ladder Logic.

Different PLC can support different languages. There are certain types of PLC that can support more than one language. These languages have their own limitation, and they complement one another to provide programmers with more programming power. .

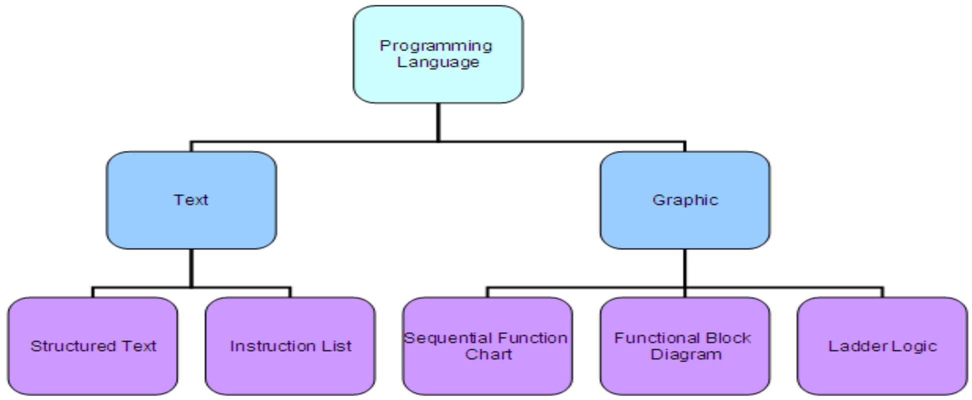

Figure 12: Type of Programming Languages

1. Structured Text

   High-level structured language designed for automation process. Statements can be used to assign values to the variables.

2. Instruction List

   Low-level programming language for smaller applications or for optimization parts of an application. It is much more like assembly language programming.

3. Sequential Function Chart

   Use graphic to describe sequential operations. It is very useful for describing sequential type processes.

4. Functional Block Diagram

   Use in applications involving the flow of signals between control blocks

5. Ladder Logic Diagram

   It is the most popular and widely used programming. It applies Boolean mnemonics to represent the process, before converting into logic diagram.

CHAPTER 3
METHODOLOGY

3.1 Project Process Flow

Figure 13 shows the flow chart of the project which is then applied throughout the project.

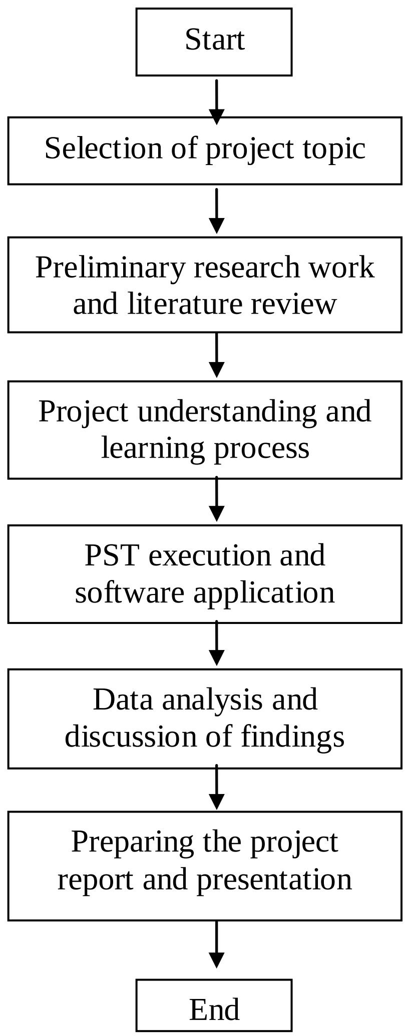

Figure 13: Project Process Flow

The Partial Stroke Testing (PST) of the FISHER Emergency Shutdown Valve is done for 90 days so that further analysis and investigation can be carried out by the data and findings obtained. The findings will be used to compare the PST performance with other vendors; METSO and MESOINELAN. This is actually the most critical part of the project where this analysis will be used by PETRONAS in order to do further development or action on PST implementation in their plants. Finally, at the last stage the author will prepare the report and conduct oral presentation to convey the findings of the project to the public.

3.1.1 PST Execution and Software Application

The basic requirements to perform the PST are as follow:

- Instrument is connected to the network
- Instrument Mode set to Out of Service
- Instrument Protection set to NONE.
- A 4 mA current is supplied to the Digital Valve Controller

Some parameters need to be set before executing the PST. These parameters are of similar values with the PST for other vendors for consistency purpose. The parameters would be the basis of comparison between the three vendors. Table 1 shows the parameters setting in Partial Stroke menu.

Table 1: Parameters Setting in AMS ValveLink

No	**Parameter**	**Setting**
1	Partial Stroke Enabled	Enabled
2	Test Start Point	Valve Open
3	Maximum Travel Movement	20%
4	Test Speed	0.5%/s
5	Test Pause Time	5 sec
6	Auto Test Interval (day)	0

After done with the initial configuration of the valve software, the PST and FST are ready to be conducted. Steps taken to execute the PST for butterfly valve using AMS ValveLink Software are as below. Same steps are taken for ball valve.

- FISHER Butterfly valve is in closed position
- The programming of PLC is being downloaded
    - Forced set I00002 – no change to the valve
    - Forced reset I00020 – FISHER Butterfly valve opened
- AMS ValveLink software can detect the valve
- Start status monitoring
- Run PST diagnostic
- PST completed
- Datasheet and graphs are saved

PST can only be done when the valve is energized, which means it is in open position. Thus, in order to open the valve from its closed position, the PLC will be used to give signal to the valve. The AMS ValveLink software could only move the valve partially with the maximum of 30% closing, thus the use of PLC software is important in order to energize and de-energize the valve before PST could be performed.

3.1.2 Data analysis

AMS ValveLink has special feature to generate the report of the testing conducted. The Analyzed Data Section in PST report was generated from the AMS ValveLink software. The report provides the testing result in graphs such Valve Signature, Dynamic Error Band and Travel Signal. These graphs were also represented in numerical value. The Analyzed Data section consists of the Dynamic Error, Dynamic Linearity, Ranged Travel and Bench Set. The value of the errors was varied according to the valve specification and condition.

The data were then converted to table form. Next, the graphs were plotted according to the value of the parameters in Analyzed Data section using Microsoft Excel, and the valve performances are analyzed. Below are the examples of tables and graphs constructed according to the numerical data generated by the software.

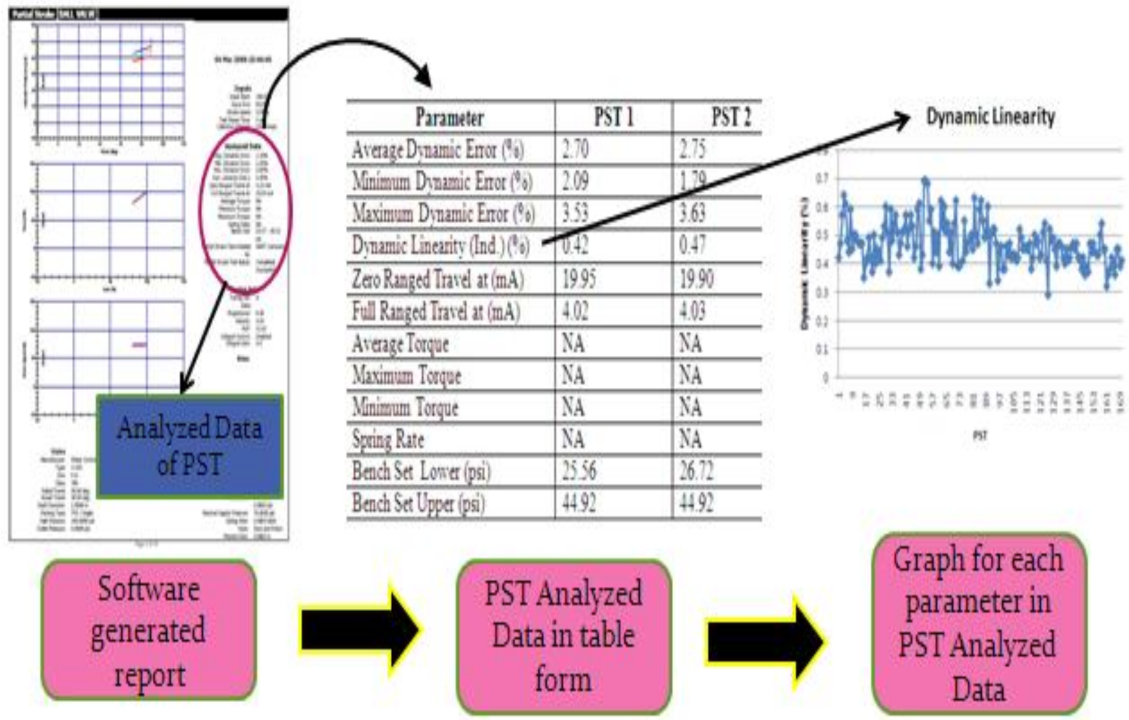

Figure 14: Steps to Analyze PST Data

Table 2: Analyzed Data for Butterfly Valve on Day 1 Testing

	Parameter	PST 1	PST 2	PST 3	PST 4	PST 5
1	Average Dynamic Error (%)	2.70	2.75	2.75	2.77	2.74
2	Minimum Dynamic Error (%)	2.09	1.79	1.85	1.93	1.94
3	Maximum Dynamic Error (%)	3.53	3.63	3.45	3.80	3.70
4	Dynamic Linearity (Ind.) (%)	0.42	0.47	0.57	0.64	0.61
5	Zero Ranged Travel at (mA)	19.95	19.90	19.84	19.86	19.90
6	Full Ranged Travel at (mA)	4.02	4.03	4.05	4.05	4.04
7	Average Torque	NA	NA	NA	NA	NA
8	Maximum Torque	NA	NA	NA	NA	NA
9	Minimum Torque	NA	NA	NA	NA	NA
10	Spring Rate	NA	NA	NA	NA	NA
11	Bench Set Lower (psi)	25.56	26.72	26.35	26.53	26.16
12	Bench Set Upper (psi)	44.92	44.92	44.66	44.69	44.6

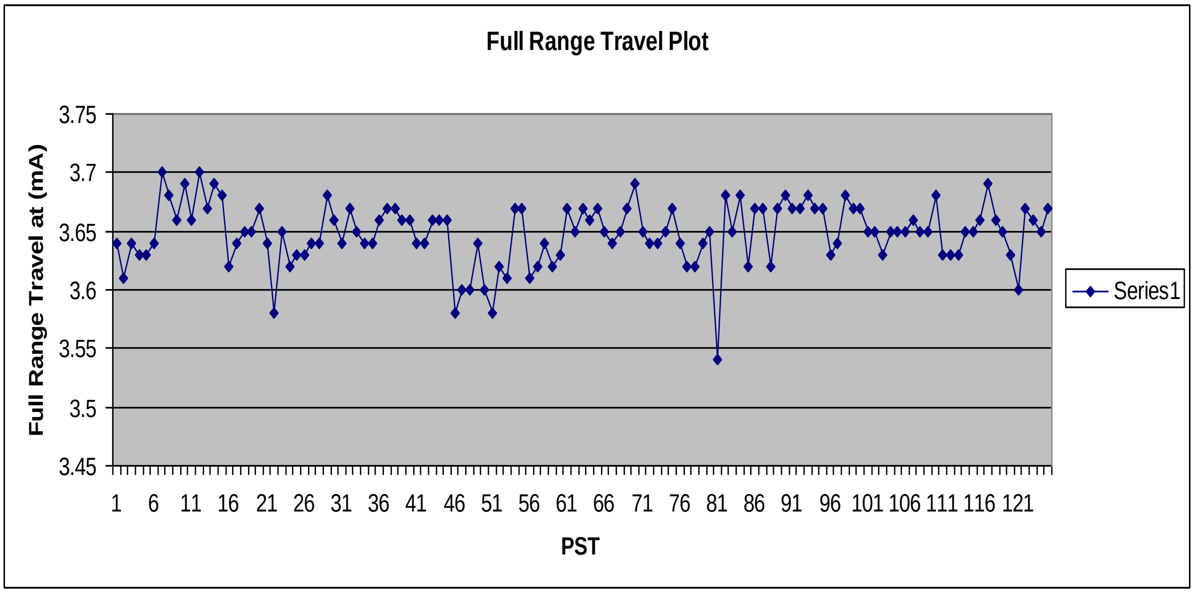

Figure 15: Plot for Full Range Travel of Butterfly Valve (Day 1- Day 25)

3.2 Tools and Equipments

3.2.1 Hardware

The hardware requirements for this project are as follow:

1. Valves

There are two types of valves use throughout this project. These valves are from different manufacturers; Fisher, Metso and Masoneilan. Table 3 shows the general specification for each valve.

Table 3: General Specification for Valves

Manufacturers	Valves	Size (inch)	Input	Minimum Pressure (psi)	Operational Temperature (^{o}C)
FISHER	Ball	6	24 VDC	5 psi	-40 – +80
	Butterfly	4	4-20 mA	5 psi	-40 – +80
METSO	Ball	6	4-20 mA	36 psi	-40 – +85
	Butterfly	6	4-20 mA	36 psi	-40 – +85
MASONEILAN	Ball	6	24 VDC	3 psi	-40 – +85
	Butterfly	6	4-20 mA	3 psi	-40 – +85

2. Yokogawa FA-M3 Controller

In this project, the PLC uses is a FA-M3 Controller, manufactured by Yokogawa. Table 4 summarizes the specifications of the Yokogawa FA-M3 Controller.

Figure 16: Yokogawa FA-M3 Controller

Table 4: General Specifications of Yokogawa FA-M3 Controller

	Item	Specifications
1	Supply Voltage	24 VDC
2	Leakage Current	-
3	Operational Temperature	0 - +55^{o}C
4	Operating environment	Free of corrosive and flammable gases, or heavy dust
5	Cooling Method	Natural-air cooled

3. Personal Computer
4. 24 VDC Power Supply
5. Pressure supply

3.2.2 Software

Software used in this project are Winfileld and ValveLink. Other types of software for different vendors are displayed in Table 5 below.

Table 5: Software Used in This Project

	Software	Vendor	Application
1	WinField2	Yokogawa	Yokogawa FA-M3 Controller
2	ValveLink	Fisher	Fisher Ball Valve and Butterfly Valve
3	FieldCare	Metso	Metso Ball Valve and Butterfly Valve
4	Valvue ESD	Masoneilan	Masoneilan Ball Valve and Butterfly Valve

3.3 Hardware Setup

This project involves 6 valves from different manufacturers. The valves will be controlled by PLC and Personal Computer (PC). The PLC is needed to trigger the demand and execute the FST according to the project requirements. Thus, it is important to develop the right hardware system between input and output devices. A complete wiring connection will ensure the communications between each device are successful. Figure 17 shows the hardware connections between PLC, PC and valves.

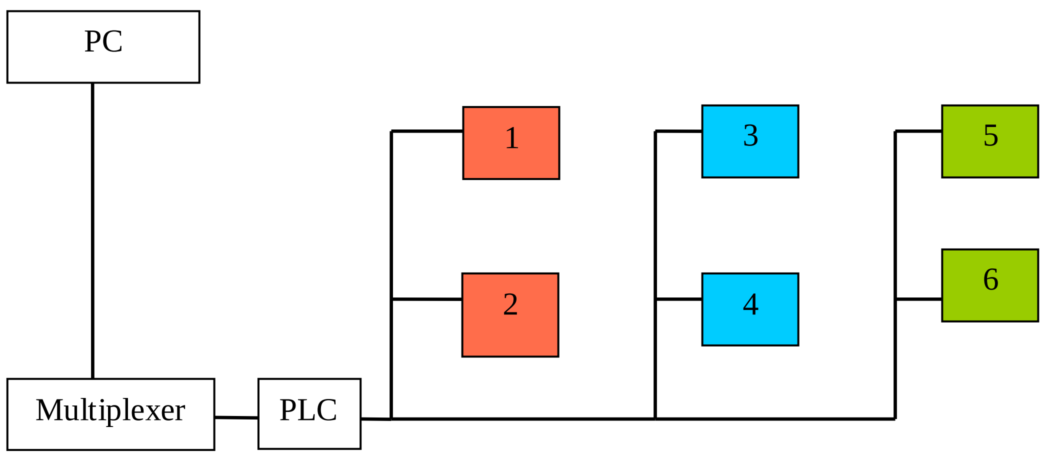

Figure 17: Hardware Connections

1 FISHER Ball Valve

2 FISHER Butterfly Valve

3 Metso Ball Valve

4 Metso Butterfly Valve

5 Masoinelan Ball Valve

6 Masoinelan Butterfly Valve

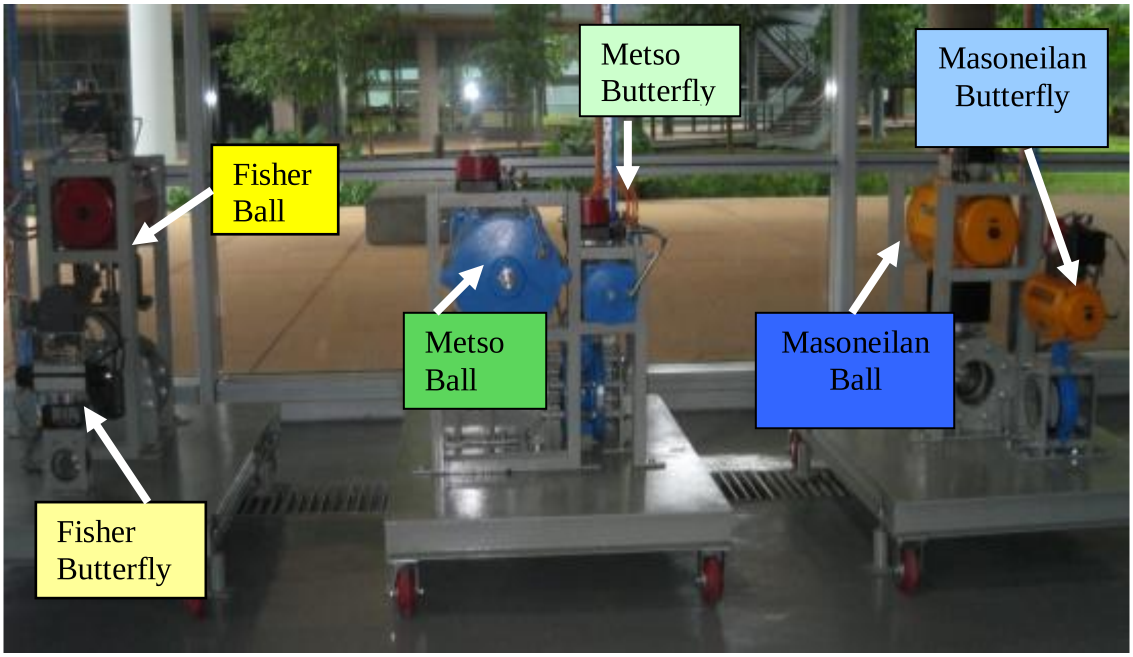

Figure 18: Valves Arrangement of the Project

CHAPTER 4

RESULTS & DISCUSSION

4.1 Testing Performed

During the first part of this project, 35 days of testing have been achieved. Thus, for the second term, testing has been continued and until the date the report is being written, the testing for ball valve has been completed (90 days) whereas 74 days of testing have been achieved for butterfly valve. The days achieved for butterfly valve are less compared to ball valve due to some problems which will be discussed in this chapter.

Table below shows the number of days in which the testing has been executed and the date for the corresponding testing.

Table 6: Current Progress for FISHER Ball and Butterfly Valve

Day of testing	Date	
	Ball Valve	Butterfly Valve
1	31 Jan 2009	31 Jan 2009
2	1 Feb 2009	1 Feb 2009
3	2 Feb 2009	2 Feb 2009
4	4 Feb 2009	4 Feb 2009
5	5 Feb 2009	5 Feb 2009
6	8 Feb 2009	8 Feb 2009
7	10 Feb 2009	10 Feb 2009
8	11 Feb 2009	11 Feb 2009
9	12 Feb 2009	12 Feb 2009
10	13 Feb 2009	13 Feb 2009
11	14 Feb 2009	14 Feb 2009
12	16 Feb 2009	16 Feb 2009
13	17 Feb 2009	17 Feb 2009
14	18 Feb 2009	18 Feb 2009
15	19 Feb 2009	19 Feb 2009
16	21 Feb 2009	21 Feb 2009

17	22 Feb 2009	22 Feb 2009
18	23 Feb 2009	23 Feb 2009
19	24 Feb 2009	24 Feb 2009
20	26 Feb 2009	26 Feb 2009
21	1 Mar 2009	1 Mar 2009
22	3 Mar 2009	3 Mar 2009
23	4 Mar 2009	4 Mar 2009
24	7 Mar 2009	7 Mar 2009
25	8 Mar 2009	8 Mar 2009
26	10 Mar 2009	10 Mar 2009
27	16 Mar 2009	16 Mar 2009
28	18 Mar 2009	18 Mar 2009
29	19 Mar 2009	19 Mar 2009
30	28 Mar 2009	28 Mar 2009
31	29 Mar 2009	29 Mar 2009
32	1 Apr 2009	1 Apr 2009
33	9 Apr 2009	9 Apr 2009
34	10 Apr 2009	10 Apr 2009
35	9 June 2009	15 July 2009
36	14 July 2009	16 July 2009
37	15 July 2009	18 July 2009
38	16 July 2009	19 July 2009
39	18 July 2009	21 July 2009
40	19 July 2009	22 July 2009
41	21 July 2009	23 July 2009
42	22 July 2009	25 July 2009
43	23 July 2009	26 July 2009
44	24 July 2009	27 July 2009
45	25 July 2009	28 July 2009
46	26 July 2009	29 July 2009
47	27 July 2009	30 July 2009
48	28 July 2009	29 August 2009
49	29 July 2009	31 August 2009
50	30 July 2009	1 Sept 2009
51	10 August 2009	2 Sept 2009
52	11 August 2009	3 Sept 2009
53	12 August 2009	4 Sept 2009
54	13 August 2009	5 Sept 2009
55	14 August 2009	7 Sept 2009
56	15 August 2009	8 Sept 2009
57	16 August 2009	9Sept 2009
58	21 August 2009	16 Sept 2009
59	22 August 2009	29 Sept 2009
60	23 August 2009	30 Sept 2009
61	24 August 2009	2 Oct 2009

62	25 August 2009	3 Oct 2009
63	26 August 2009	4 Oct 2009
64	29 August 2009	8 Oct 2009
65	31 August 2009	9 Oct 2009
66	1 Sept 2009	11 Oct 2009
67	2 Sept 2009	12 Oct 2009
68	3 Sept 2009	13 Oct 2009
69	4 Sept 2009	20 Oct 2009
70	5 Sept 2009	21 Oct 2009
71	7 Sept 2009	22 Oct 2009
72	8 Sept 2009	26 Oct 2009
73	9 Sept 2009	27 Oct 2009
74	10 Sept 2009	2 Nov 2009
75	14 Sept 2009	
76	15 Sept 2009	
77	16 Sept 2009	
78	29 Sept 2009	
79	30 Sept 2009	
80	3 Oct 2009	
81	8 Oct 2009	
82	11 Oct 2009	
83	12 Oct 2009	
84	13 Oct 2009	
85	20 Oct 2009	
86	21 Oct 2009	
87	22 Oct 2009	
88	26 Oct 2009	
89	27 Oct 2009	
90	2 November 2009	

4.2 Data and Analysis

AMS ValveLink software has special features to perform diagnostic of the valve. If the PST diagnostic is successfully conducted, it will check the ability of the valve to follow a changing set point. During the test, the controller ramp the valve from the starting point to the end point and back again. It also calculates the friction inside the valve. The friction is then compared to a baseline diagnostic to monitor the valve health in terms of internal corrosion and deposit build up. If the AMS ValveLink Software detects a value that is out of spec during PST diagnostic, it will display an exclamation point.

4.2.1 Plot of Valve Signature

Results for every test done will be the valve signature of the ESV which is the plot of actuator pressure (psi) versus travel (degree). Figure 19 below shows an example of one test result for ball valve while Figure 20 is a valve signature of butterfly valve. Whereas Figure 21 and Figure 22 show the valve signatures when Full Stroke Testing is applied coincides with Partial Stroke Testing.

Based on these results, further analysis can be done to investigate the valve behaviour. Any changes or abnormality to the plot obtained will be recorded and thus further analyzed to seek for the reason and cause for the changes.

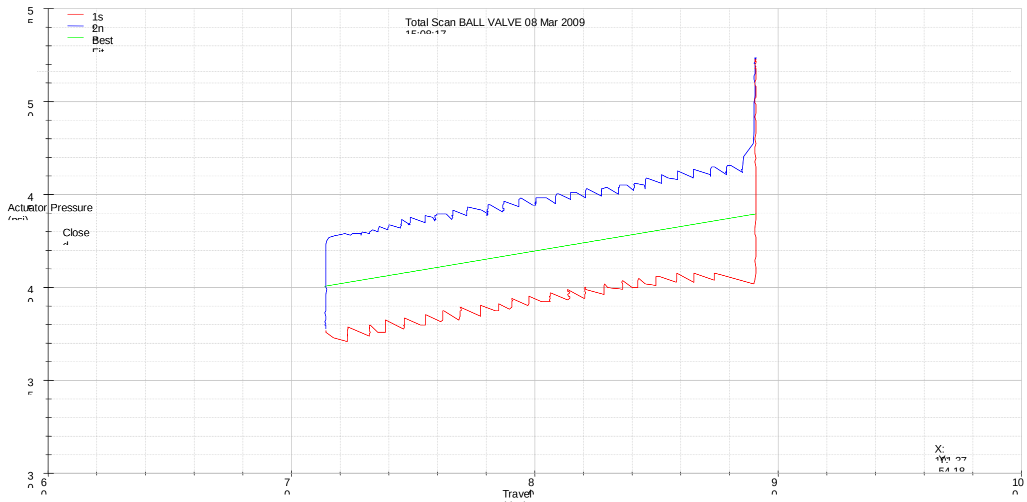

Figure 19: Plot of Actuator Pressure (psi) vs Travel (degree) for Ball Valve during Partial Stroke Testing

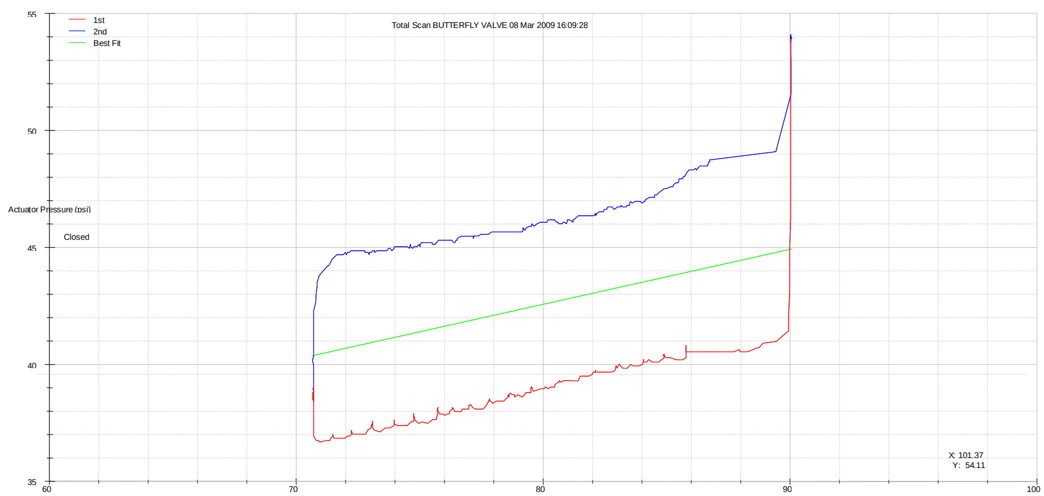

Figure 20: Plot of Actuator Pressure (psi) vs Travel (degree) for Butterfly Valve during Partial Stroke Testing

Based on the above plots, the author managed to understand the behaviour of the valve. The actuator pressure does not increase or reduce smoothly during the travel of the valve's opening due to some frictions in the actuator's spring and at valve's trim. For example, at travel from 70 degree to 90 degree in Figure 18, the actuator pressure is a jagged plot because at first, the actuator pressure will build up and exerts force to the spring. After that, due to its nature the spring will push back thus the actuator pressure will reduce a bit. This will go on until the pressure finally reaches a desired value.

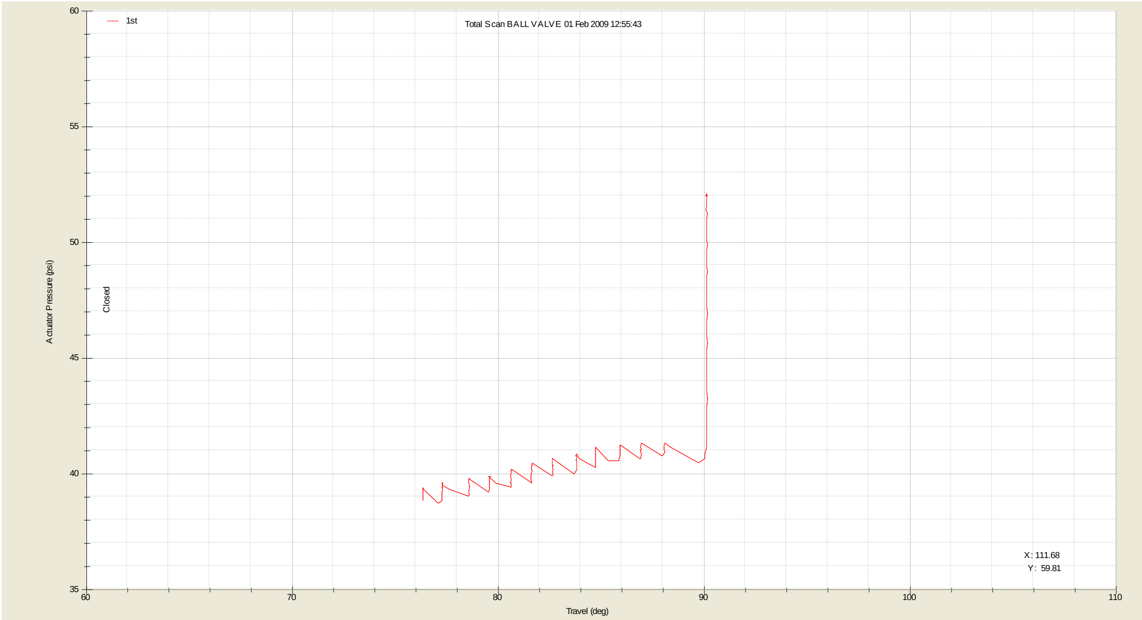

Figure 21: Plot of Actuator Pressure (psi) vs Travel (degree) for Ball Valve during Full Stroke Testing

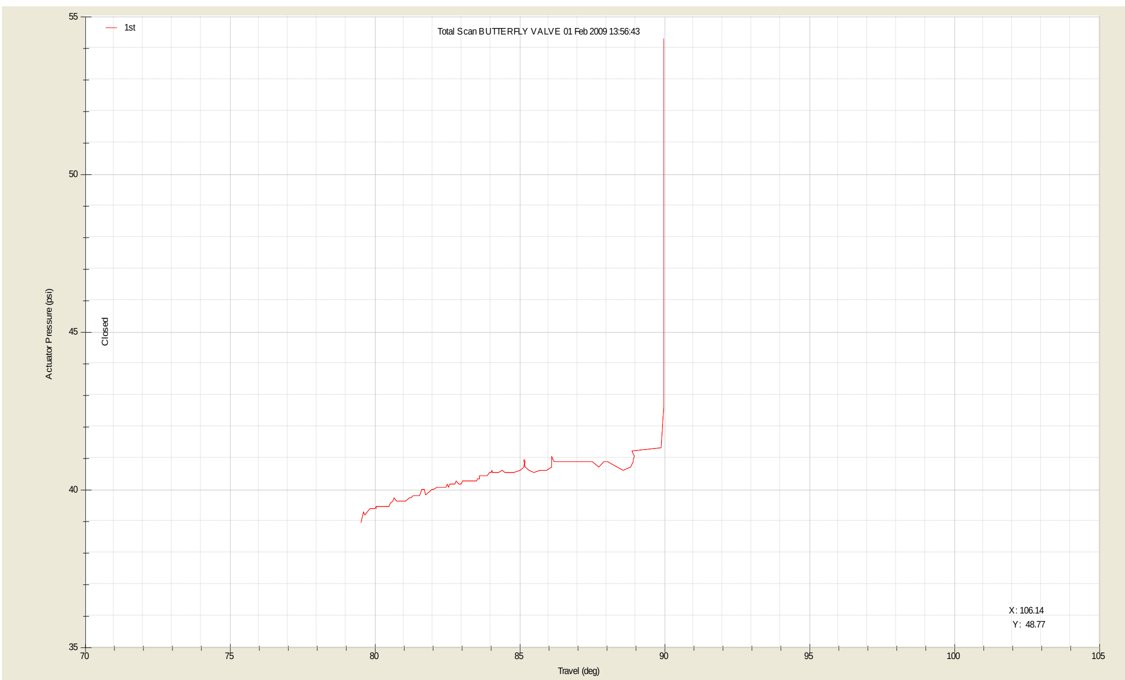

Figure 22: Plot of Actuator Pressure (psi) vs Travel (degree) for Butterfly Valve during Full Stroke Testing

The maximum travel setting for PST coincides with FST is the same as the normal PST which is 20%. When the valve starts to move, the actuator releases pressure so that the valve will move. The FST signal is sent at 81 degree or during 10% closing and cause the valve to automatically close once it received the signal.

The purpose of FST coincides with PST is to ensure that the valve can operate as per requirement even when PST is done. This is crucial in practical application, for example in the situation of an operator is doing testing to the valve and at the same time, emergency occurs.

4.2.2 Plots of Testing Parameters – Ball Valve

There are several parameters that can be analyzed from the testing results. These parameters are automatically calculated by the AMS ValveLink software. However, the author needs to use Microsoft Excel in order to generate the corresponding graphs. For this report, the data plotted will be from day 36 of testing until day 90 for ball valve.

1) Average, Minimum and Maximum Dynamic Error

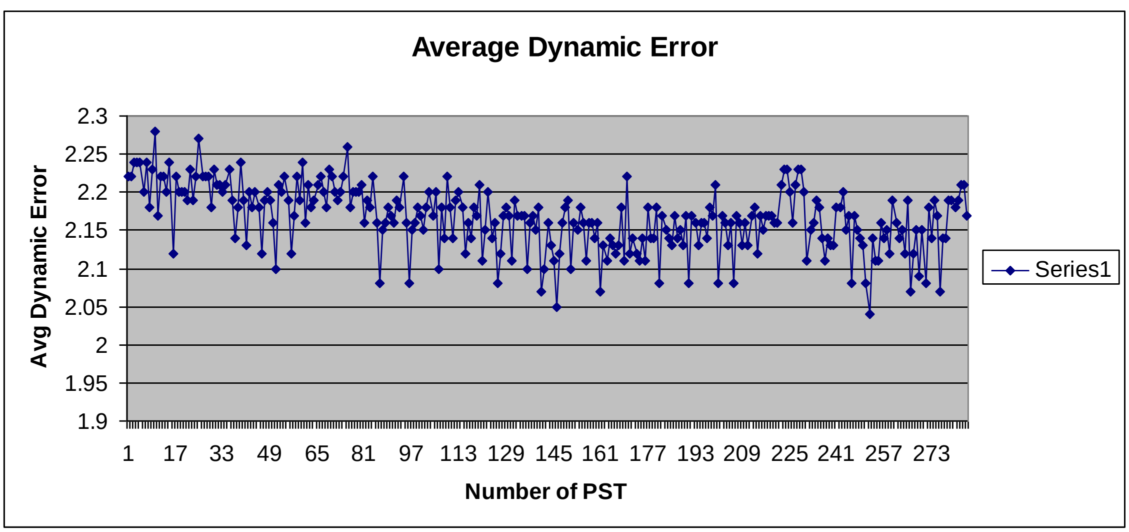

Figure 23: Average Dynamic Error Plot for Ball Valve

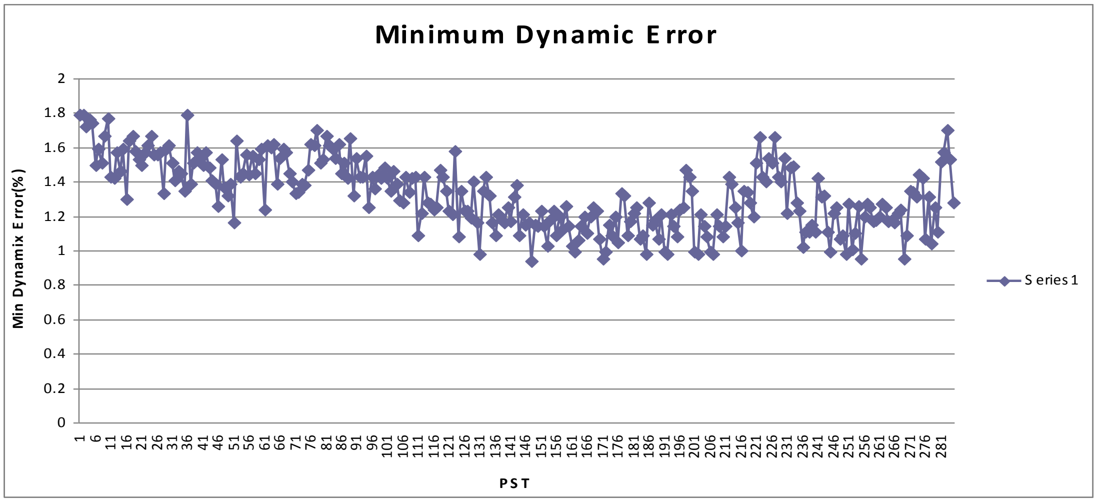

Figure 24: Minimum Dynamic Error Plot for Ball Valve

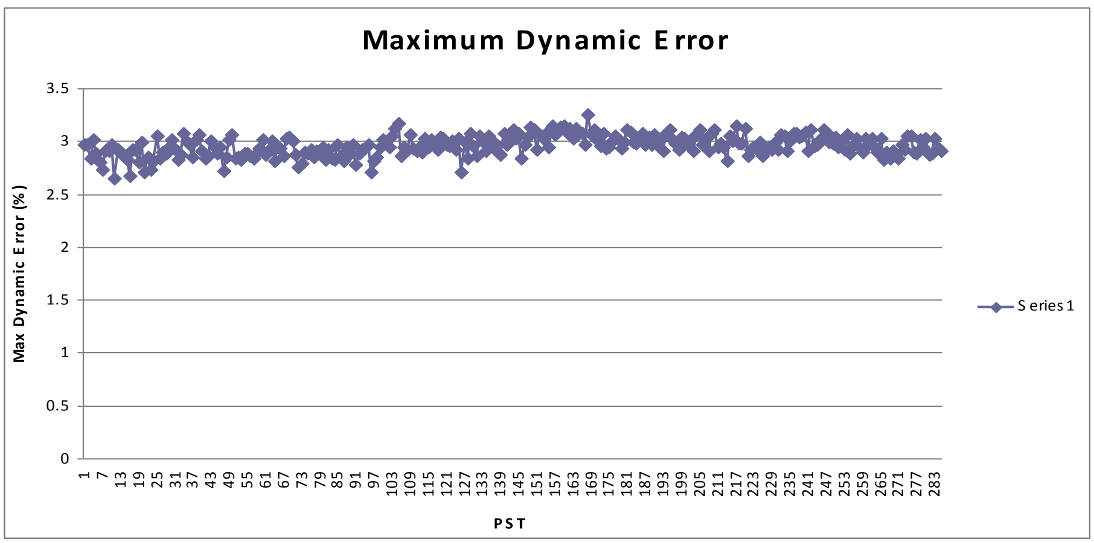

Figure 25: Minimum Dynamic Error Plot for Ball Valve

AMS ValveLink software analyzed the dynamic error curve from 5% travel to 95% travel and calculates the average, maximum and minimum difference between opening and closing curves. From figures above, it can be seen that the average dynamic error ranged between 2.1 % to 2.25%. While for minimum dynamic error, the data ranges from 1% to 1.8%. The data can be said to be constant since the percentage difference is very small. For maximum dynamic error plot, it shows that the data is concentrated at 3% value.

2) Dynamic Linearity

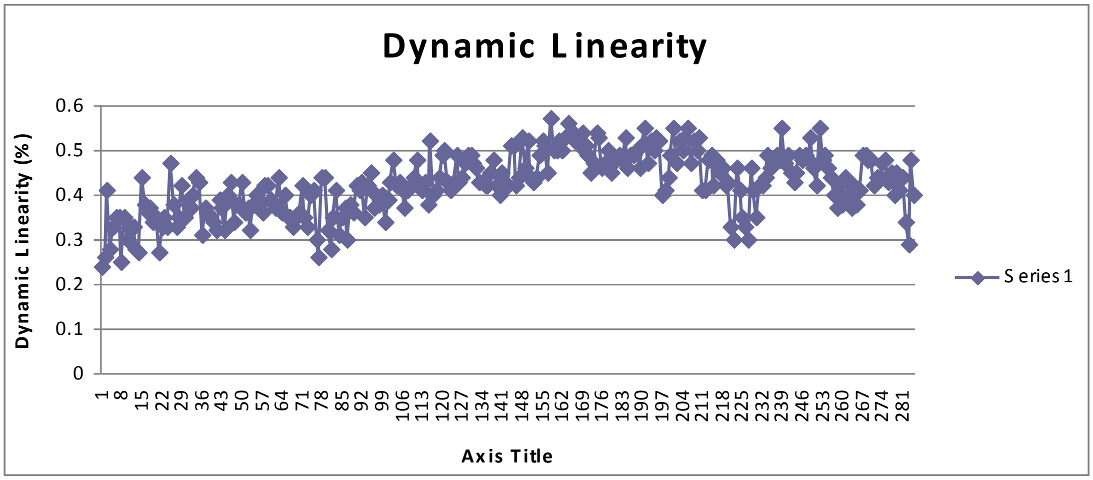

Figure 26: Dynamic Linearity Plot for Ball Valve

Linearity is the maximum deviation from a straight line best fit to the opening and closing curve and line representing the average value of those curves. Based on Figure 26, the Dynamic Linearity varies with the number of PST executed.

3) Lower Bench Set and Upper Bench Set

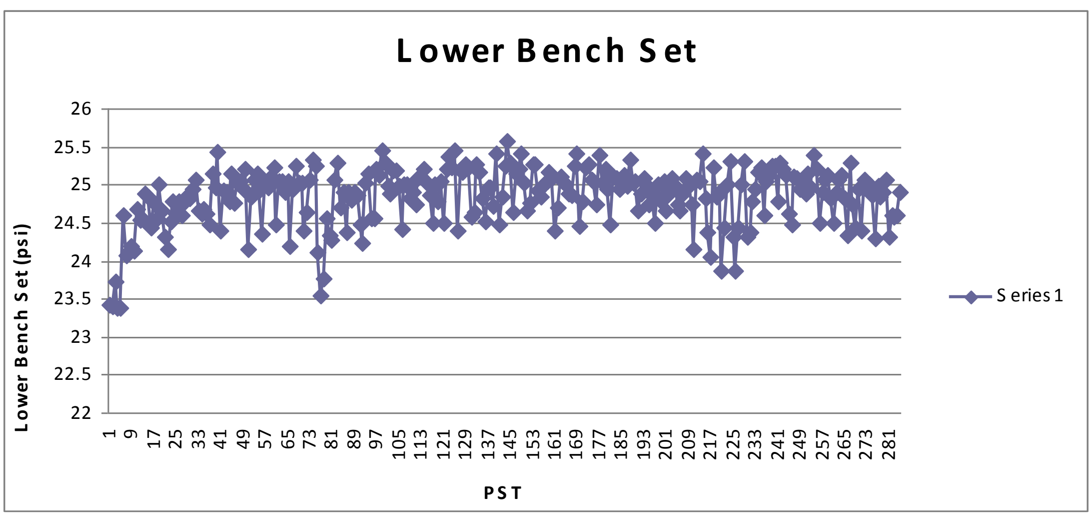

Figure 27: Lower Bench Set Plot for Ball Valve

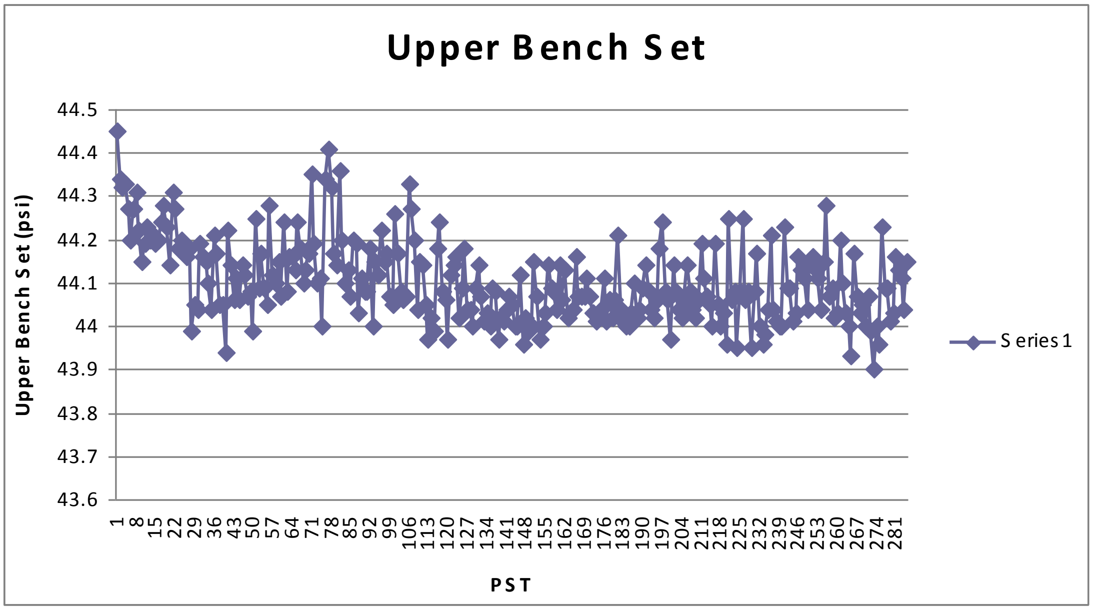

Figure 28: Upper Bench Set Plot for Ball Valve

Lower Bench Set is the amount of pneumatic pressure required to begin actuator movement while Upper Bench Set is the amount of pressure needed to drive the actuator through full ranged travel. From the plots above, the value of lower bench set is approximately 24.5 psi while upper bench set value is around 44.1 psi. There is slight variation of the values from testing to testing however it is very small.

4.2.3 Plots of Testing Parameters – Butterfly Valve

For butterfly valves, the data chosen to be discussed is from day 1 until day 74. The analysis conducted is similar with ball valve.

1) Average, Minimum and Maximum Dynamic Error

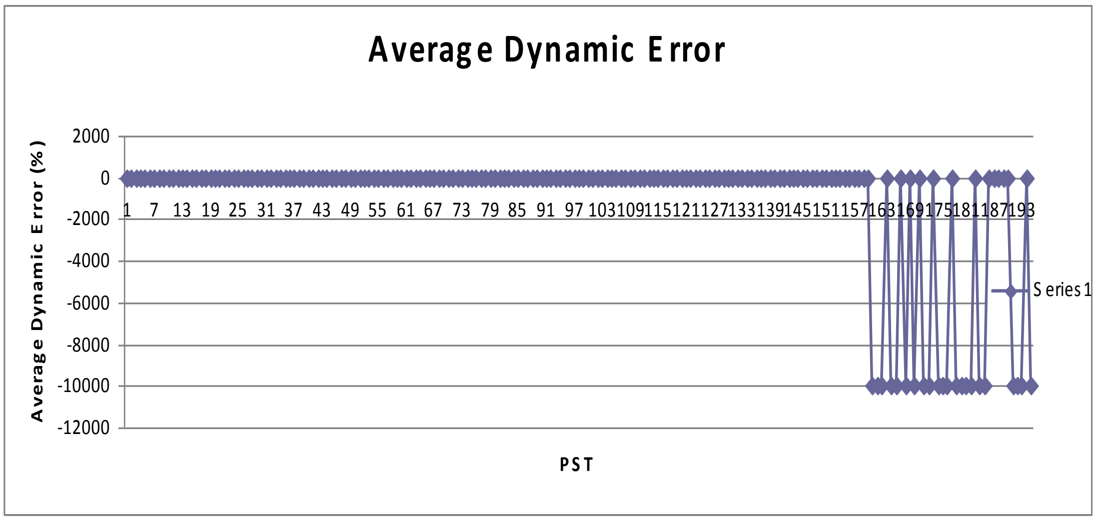

Figure 29: Average Dynamic Error Plot for Butterfly Valve

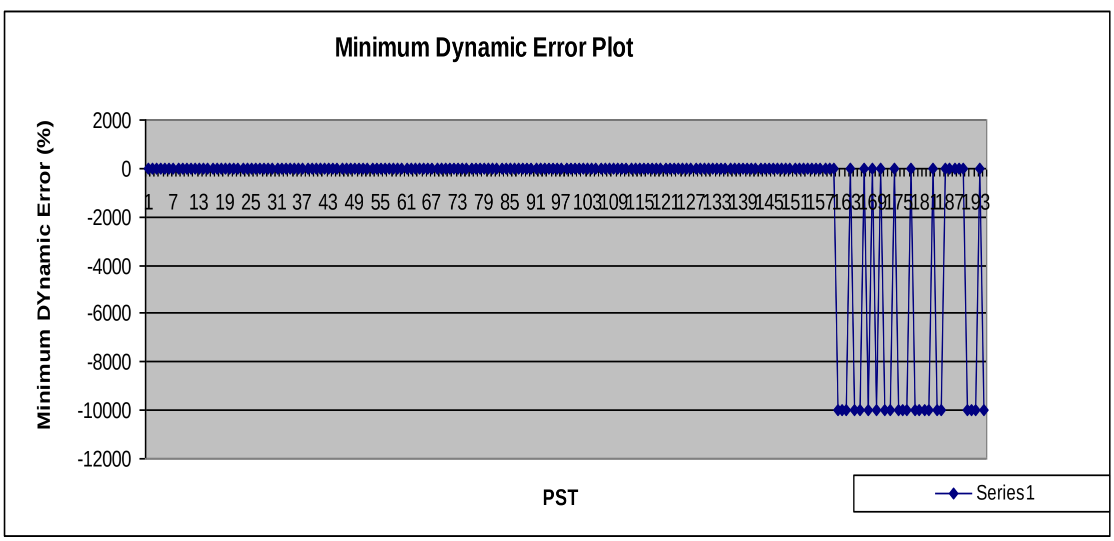

Figure 30: Minimum Dynamic Error Plot for Butterfly Valve

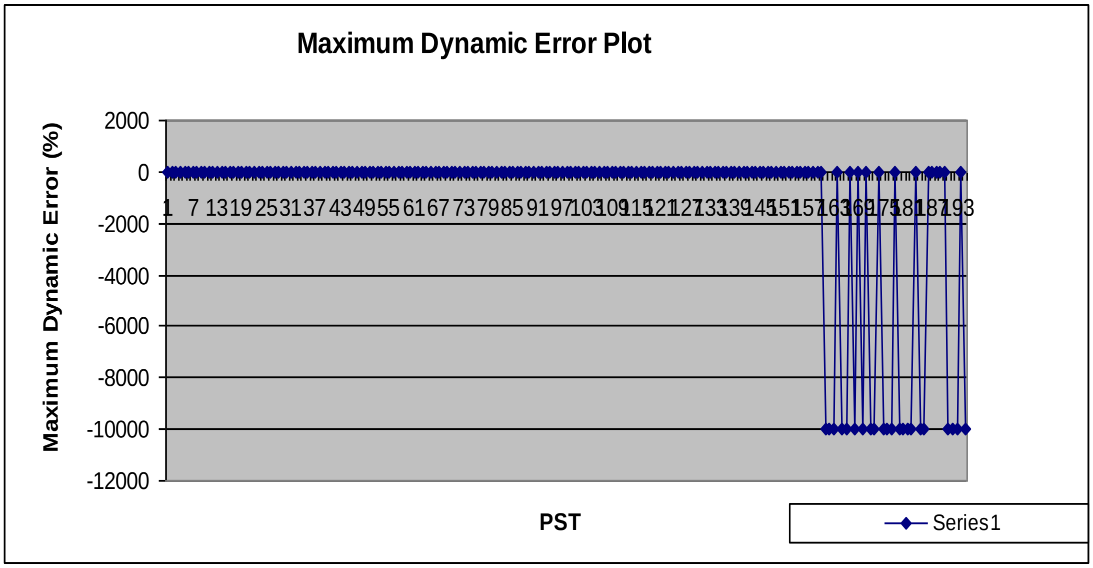

Figure 31: Maximum Dynamic Error Plot for Butterfly Valve

From Figure 29, 30 and 31, the values of dynamic error plotted is very small except for PST starts from day 69 until day 75. However, the valve signatures generated for the corresponding days are normal and the PSTs are done successfully. The extremely high value of error recorded might be due to the problem with the software.

2) Dynamic Linearity

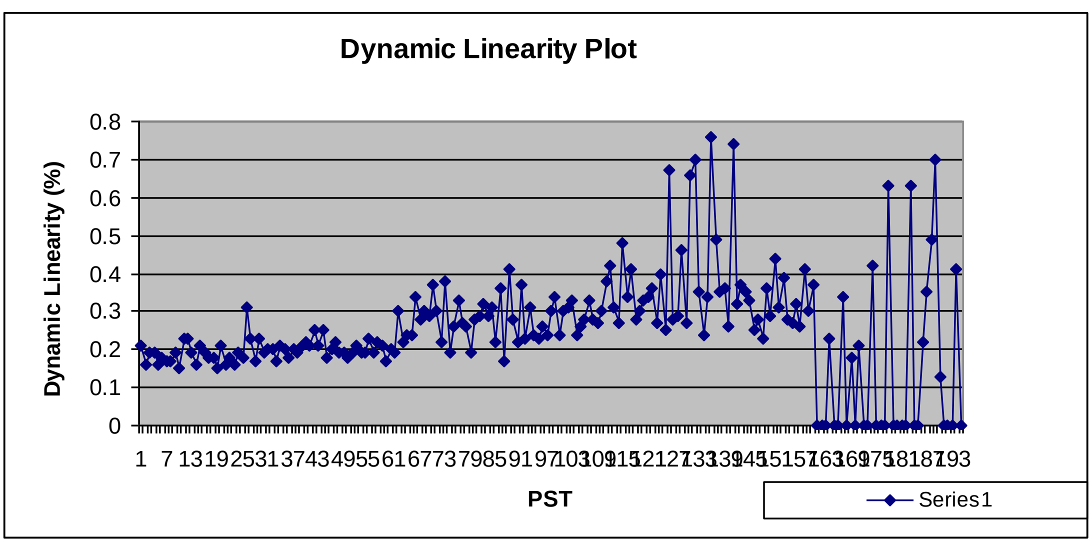

Figure 32: Dynamic Linearity Plot for Butterfly Valve

Based on Figure 32, the Dynamic Linearity plots for butterfly valve started to increase from day 62 of testing. This is the point where the butterfly valve recovered from its problem which is discussed later in this chapter.

3) Lower Bench Set and Upper Bench Set

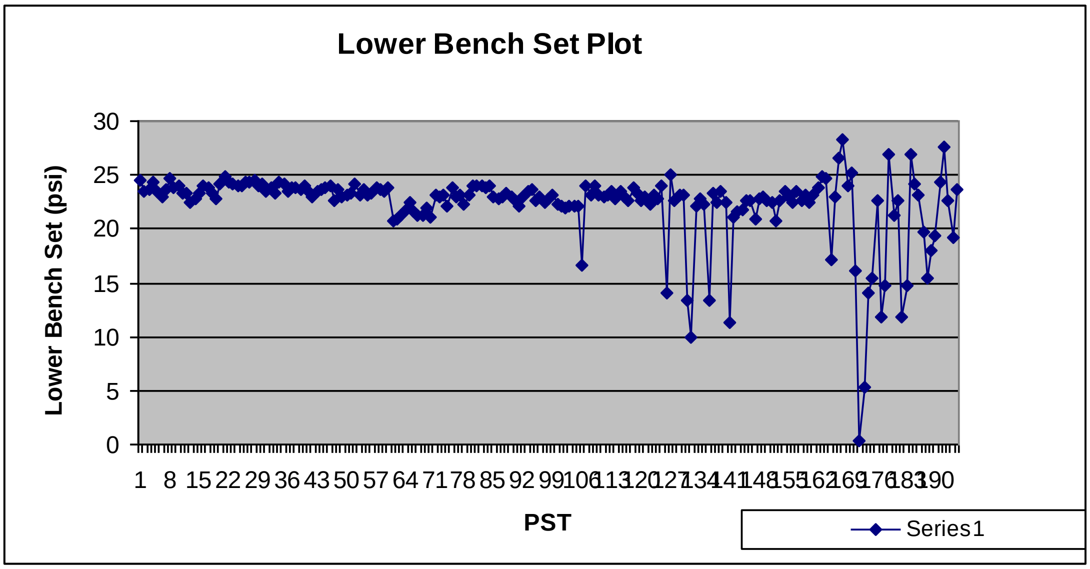

Figure 33: Lower Bench Set Plot for Butterfly Valve

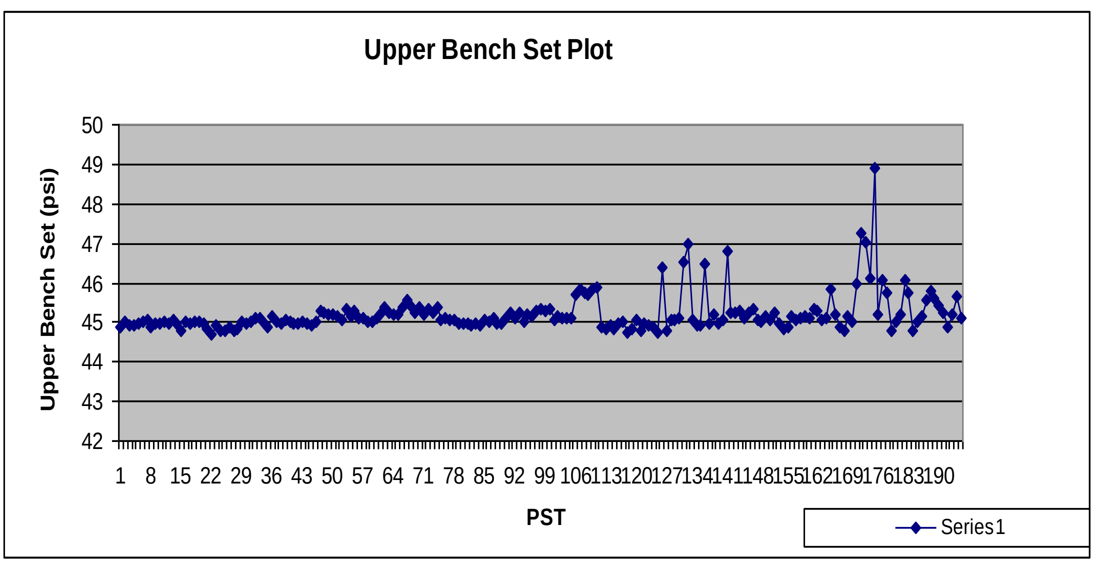

Figure 34: Upper Bench Set Plot for Butterfly Valve

For Lower and Upper Bench Set Values, the plot also started to increase when the butterfly valve having is having problem. From these plots, observation can be done to investigate on the cause of the problem.

4.3 Problem with Butterfly Valve

During the 90 days of testing been executed, the butterfly valve however only achieved 75 days of testing due to some problems. There is no problem detected for the ball valve.

4.3.1 Could Not Be Energized

On 20th August 2009 until 26th August 2009, the butterfly failed to respond to the signal sent by the PLC programming. Thus, the testing could not be done to the butterfly valve for that period. This is due to a faulty connection during the installation of the PLC cabinet on 17th August 2009 until 19th August 2009. After some troubleshooting, it is noticed the Digital Valve Controller (DVC6000) SIS was still communicating with the AMS ValveLink software however, there is no supply and output pressure from DVC after energizing the solenoid valve (SOV). Therefore, the SOV was bypassed and the DVC functionalities are checked. Later it is proved that the DVC6000 is functioning well. Thus, the SOV was suspected to be the bottleneck of the problem. Upon measuring the current through the SOV, it was found out that there is no power supply to the SOV due to the power supply cables were connected to wrong terminal in the panel. After fixing the power cable to the correct terminal, the butterfly can be operated as usual.

4.3.2 Valve Stuck Alert

On 10th August 2009 until 16th August 2009, the PST for butterfly valve failed due to the warning message generated by the AMS ValveLink software. The warning message generated was 'Valve Stuck Alert' which indicates that the valve may be stuck or the air pressure line may have an obstruction. For most of cases, the warning message appeared during 90% - 93% travel of the valve.

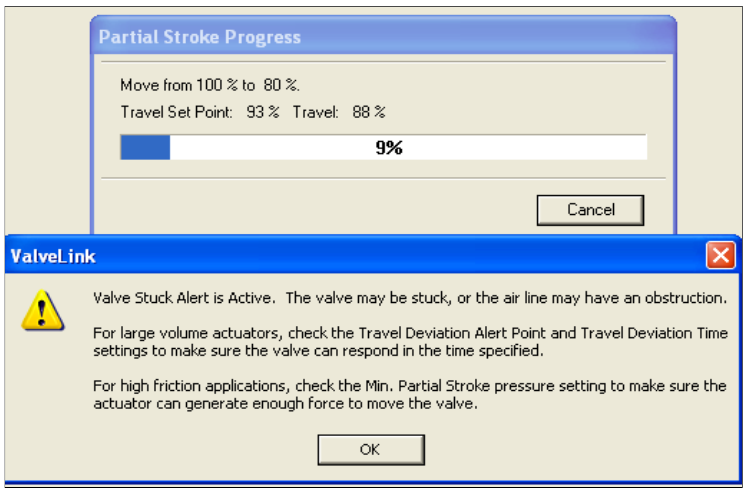

Figure 35: Valve Stuck Alert Warning Message

This problem may have occurred due to the frequent testing done to the butterfly valve. Some testing parameters set at the early stage of the testing may not be suitable anymore because at the early stage of the testing, the valve's seat has more friction than it is after about 60 days of testing.

When the DVC6000 SIS detects that the valve is stuck, it will not completely exhaust the actuator pressure. Instead, the valve will return to normal operation and alert will be generated indicating partial stroke failure. This ensures that should the valve hang loose at stuck position, it will not slam shut. The FIELDVUE controller will abort the test and send an alert, indicating that the valve is stuck.

Thus, a few steps had been taken to solve this problem. Firstly the butterfly valve was auto-calibrated using the AMS ValveLink software. After that, the test speed was reduced from 0.5% per second to 0.25% per second. It is learned that the test speed was too fast thus the valve failed to respond to the specified time.

4.3.3 Abnormal Valve Signature

On 14th August 2009, during the 4th testing, the AMS ValveLink software generated an abnormal valve signature as shown in Figure 4.4 below. From the graph, it can be seen that the valve moves from 90 degree (fully opened) to 79 degree only during first travel where it supposed to move to 72 degree which indicates 20% opening of the valve. At the second travel, the valve was indicated to move from 72 degree to 90 degree however the actuator pressure was recorded to be constant which is not possible to happen.

However, during the author's observation, the valve moved from 100% opening to 70% opening and moved back to 100% opening without any obvious problems. Thus, the problem might be due to data logging in the software. Furthermore, the problem only occurred during this fourth testing whereby the testing before and after it recorded no abnormality. It is noted also that this graph appeared during the "Valve Stuck Alert" problem.

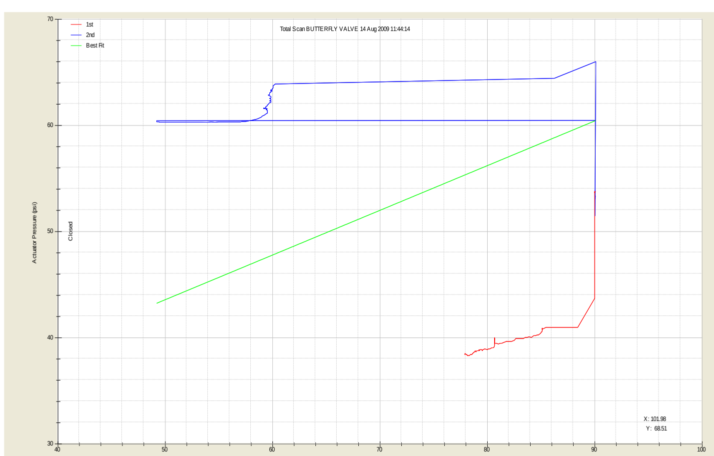

Figure 36: Valve Signature of Butterfly Valve on 4th Testing, 14th August 2009

CHAPTER 5
CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This project is a good platform for end user such as PETRONAS to evaluate and compare the performance of Partial Stroke Testing of different vendors in order to come out with a confirmation on which vendor's system is reliable to be used. If at the end of the project, all three systems recorded no problem then it indicates that all the three vendors meet their expectation. The condition and type of process would be the criteria to decide which vendor should be chosen.

The main findings of this project are:

- 90 days of testing have been achieved for FISHER ball valve with no failure record
- 75 days of testing have been achieved for FISHER butterfly valve with some problems recorded
- analysis of testing parameters done for FISHER ball and butterfly valves

From this project also, some differences can be seen between the valve vendors. FISHER has advantage of detail analysis of the data captured as discussed before. While for MESTSO and MESONEILAN, less data can be captured by the respective software such as valve test, breakaway pressure and pneumatic test. However, both the other vendors have user-friendly panel at the valves themselves where operator can also check the valve status at field. FISHER however does not have this feature.

5.2 Recommendation

Further actions can be carried out in order to improve on this project in term of efficiency, data analysis, performance as well as the presentation.

5.2.1 Recommendations to UTP and PETRONAS

- Build PLC programming to integrate the control of the three brands of valves
- Produce information board to display information regarding the project and the valve itself and place it at the lab where the valve is located
- Provide volume tank/ booster as pressure supply backup
- Perform testing using different testing parameters and compare the result
- Develop testing procedure to investigate the failure mode of the system

5.2.2 Recommendations to FISHER vendor

- Develop a more user friendly testing procedure
- Develop software that can perform PST simultaneously to more than one valve
- Provide training to students involve in this project at the beginning of semester

REFERENCES

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[5] Peter Smith and R.W. Zappe, "*Valve Selection Handbook".* Burlington, USA: Gulf Professional Publishing, 2004.

[6] Yoshinori Sato, *"Introduction to Partial Stroke Testing"* in SICE Annual Conference 2008: The University Electro-Communications, Japan, 20-22 August 2008.

APPENDIX I

Daily Report of PST for Ball Valve
(Software generated)

APPENDIX II

Daily Report of PST for Butterfly Valve
(Software generated)