Modeling of Subsea Control Module using Agito SimulationX

by

Muhamad Isfan Imanullah b Adnan

Dissertation in partial fulfillment of

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(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the

Mechanical Engineering Programme

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Approved by,

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(AP Dr Fakhruldin b Mohd Hashim)

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TRONOH, PERAK

MAY 2012

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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MUHAMAD ISFAN IMANULLAH B ADNAN

ABSTRACT

This thesis describes the modeling and simulation for subsea control module. For new developer, a better understanding on how the system works is needed to ensure that the system will meet all design specifications and reduced the risk and cost associated with installation and commissioning. Hence, simulating a model of subsea control module provide engineers with ability to do multiple scenario of gate valve or production valve behavior based on its changing parameter. The methodology for this project involves collection of technical details and data regarding subsea control module, identify elements of control, arrangement of elements, and subsea control module design parameters. Simulation result shows that the gate valve is fully open at 0.203m within 11.332 seconds. This will be useful if decision to change the subsea control module parameter was done and needs to do the sensitivity analysis arise.

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CHAPTER 1
INTRODUCTION

1.1 BACKGROUND STUDY

Oil and gas subsea production includes activity such as field development, field operation, and drilling which occur for water depth greater than 182.88 meter (600 feet). Subsea production system consists of a subsea completed well, seabed wellhead, subsea production tree, subsea tie-in to flowline system, and subsea equipment and control facilities to operate the well (Yong, 2010). Subsea technology has been around since 1960s but has only taken off as a viable form of oil and gas production over the last few years (French, 2008). However, issues of supply, economic benefits, and productivity benefits had pushed for subsea exploration and extraction. Subsea control mechanism was developed as to comply with the advancement of subsea technology. The subsea control system operates subsea equipments and provides assistance such as SPS status monitoring.

1.2 PROBLEM STATEMENT

Nowadays, oil and gas industry requires continuous development of new technologies in order to produce oil effectively. Development of new technology meaning the control module for any subsea technology will have modification of its key design parameters. Hence, a sensitivity analysis needs to be done by simulating subsea control system. A proper subsea control module simulation need to be developed and tested for user to observe the response of its changing parameters. By using a simulation tool, the system can be tested virtually before putting it into production. Various solutions can be tested, and results will provide the basis for choosing the components and dimensions to be used. For example, movement of gate valve in control module needs to be observed in SimulationX in order to meet the system specification before it can be operated.

1.3 OBJECTIVE AND SCOPE OF STUDY

The objective of this project is to model a subsea control module and to simulate the model for determining its response time.

1.4 SCOPE OF STUDY

The scope of study covers a typical control system where focuses on movement and behavior of the gate valve in order to control flow of oil and gas in subsea technology. Also, gate valve behavior will be observed during simulation when several of its parameters were change and the effect to the response time.

CHAPTER 2
LITERATURE REVIEW

2.1 SUBSEA PRODUCTION SYSTEM

Subsea production systems are wells located on the seafloor, as opposed to at the surface and systems complexity ranging from any single satellite well with flowline linked to fixed platform, FPSO, or an onshore installation, towards several wells on a template or clustered around manifold, and transferring to a fixed or floating facility to an onshore installation (API, 1996). Several components considered into a subsea production system are (Yong, 2010):

a) Subsea drilling systems.
b) Subsea Christmas trees and wellhead systems: this includes the wellhead, tubing hanger, X-mas tree with choke, completion workover riser, workover control system.
c) Subsea manifold and jumper systems: includes subsea structure such as template and satellite structures, manifold, base structures, piping structures and several protection structures.
d) Tie-in and flowline systems: together with its risers, hard pipe, flexible lines, rigid risers, dynamic risers.
e) Control systems: the components include the subsea control module, distribution system, tree configuration and instrumentation, electronics and hydraulics infrastructure and components and etc.
f) Subsea installation.

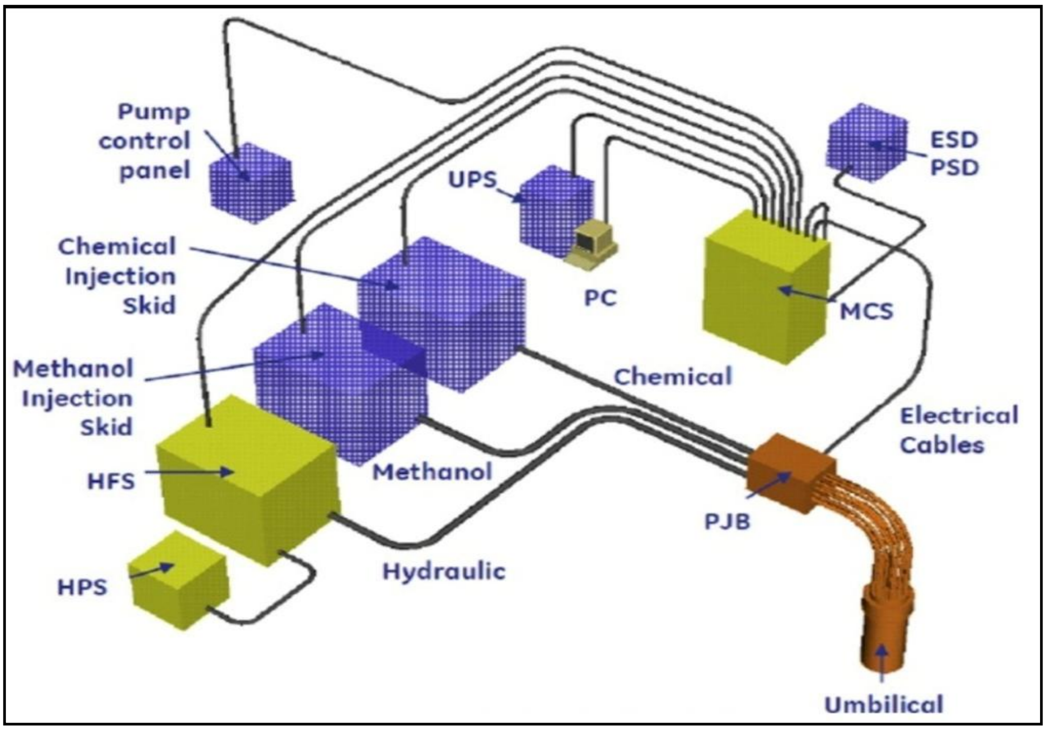

Figure 2-1: Subsea production system topside facilities. (Yong, 2010)

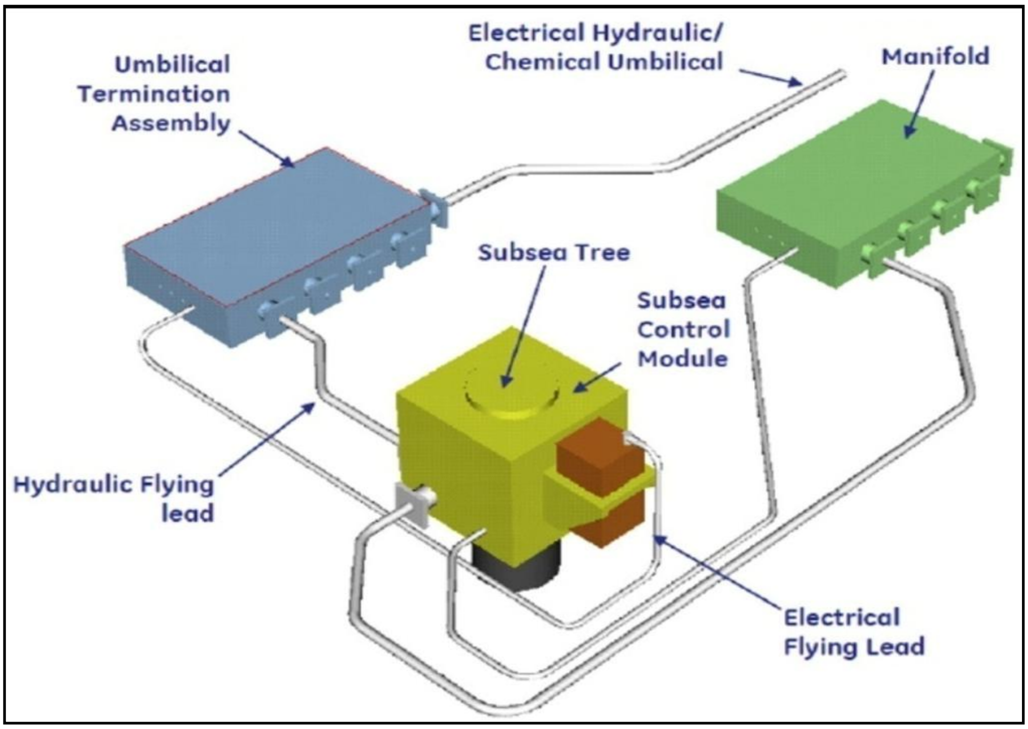

Figure 2-2: Subsea production system subsea facilities. (Yong, 2010)

2.2 PRODUCTION CONTROL SYSTEM

A production control system functions includes operational control of subsea production facilities. Types of control system include all hydraulic control, electrohydraulic control, all electric control, and autonomous system. Examples of SPS control nowadays are:

a) Direct hydraulic Control System.
b) Piloted Hydraulic Control System.
c) Sequential Piloted Hydraulic Control System.
d) Electrohydraulic Piloted Control System.
e) Electrohydraulic Multiplex Control System,
f) All electric Control Systems.
g) Subsea Powered Autonomous Remote Control System.

The all-hydraulic systems considered to be the minimally complex and most reliable control systems. ISO/DIS 13628-6 (2004) stated that the all-hydraulic systems are relatively slow to respond, compared to electrohydraulic systems, and have limited capability providing data telemetry from subsea system. The specific need of each application should be carefully considered, particularly with respect to data needs and speeds of response, before selecting an all-hydraulic system approach. All-hydraulic systems suit for single satellite wells located relatively close to host facilities.

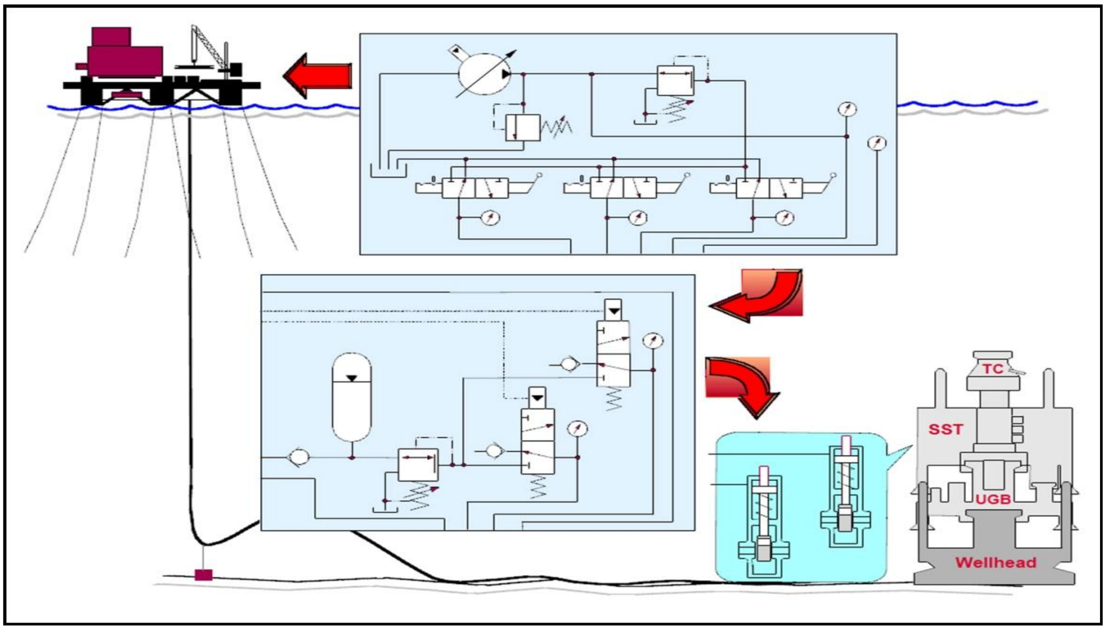

Figure 2-3: Piloted Hydraulic Control System. (Stecki, 1998)

2.2.1 Piloted Hydraulic Control System

Piloted hydraulic control system is an all-hydraulic type of subsea production control system. The system includes a subsea control module, hydraulic power unit, umbilical, and valve actuator. Components such as pilot valves, local source of hydraulic power, generally accumulators; are charged through a separate line from the surface. The lines used are required to give adequate fluid to shift one of the pilot valves, and the fluid to actuate tree or manifold valves provided by subsea accumulator. Stecki (2003) stated that this configuration affect the response time of the system as only a control hydraulic signal is transmitted from topside to the tree and the response time of the system is still dependent on the volume of pilot lines and thus application of a piloted hydraulic control system is limited to distance between topside and the tree of up to 10km. When used, a subsea control module is the interface between the control lines from surface facilities, and the control components from subsea facility. The subsea control module can also be modeled with electric and electronic components that are used for control, communications, or data gathering.

2.2.2 All-hydraulic Control System Model Specification

All-hydraulic control system separated into two distinct facilities that are top surface and subsea. The components for both facilities are:

a) Top surface facilities: hydraulic power unit (HPU) and topside umbilical termination assembly.
b) Subsea facilities: subsea control module (SCM), and valve actuators.

Hydraulic system should have return to sea or looped to the umbilical return line during opening stroke. The return line reflected pressures will not affect closed process valves to open and process valves capable for closing in the wake of event such as return line or exhaust valve blockage.

2.2.3 Hydraulic Power Unit

As part of topside facilities, the pumping unit usually includes components such as pumps, motors, accumulators, and filter fitted with dual supply lines. The HPU is a closed-loop system so all leakage and venting flows are returned to the reservoir, which is fully pressure-compensated to ambient pressure (Stecki, 2003). Pump converts mechanical power from motor to hydraulics power at actuator. There are different types of pumps, but the most common one uses accumulators that are charged by fixed pumps. These are controlled by Programmable Logical Controller, and start and stop at various pre-programmed pressures (Agito, 2008).

2.2.4 Umbilical

An umbilical is a conduit between the topside host facility and subsea control system and is used for chemical and /or hydraulics fluids, electrical power and electrical control signals. Supply and return line normally installed in the umbilical. The characteristic for an umbilical usually are very long and small in diameter (up to 20km or more and approximately 5cm), with limited cross section of hydraulic lines (approximately 12mm). According to document released by Agito (2008), the flow resistance in the hydraulic lines then becomes substantial, with result that the response time for valve actuator in the system may be unsatisfactorily long and hoses that usually were used have a properties that needs to be taken into consideration in any simulation. Hoses will able to have a liquid accumulation that give disadvantage towards systems, so bleeding of lines are required. This kind of condition required for large actuators and hoses with high volumetric expansion.

2.2.5 Subsea Control Module

System designed with subsea control module for controlling operation of valve. Type of subsea control module mostly used consists of incoming supply and return lines that operate several different actuators with its directional control valve as spool position type or orifice area type. A valve is a variable area orifice, where the orifice area may be controlled by conditions in a circuit or by operator as in the case of directional control valve.

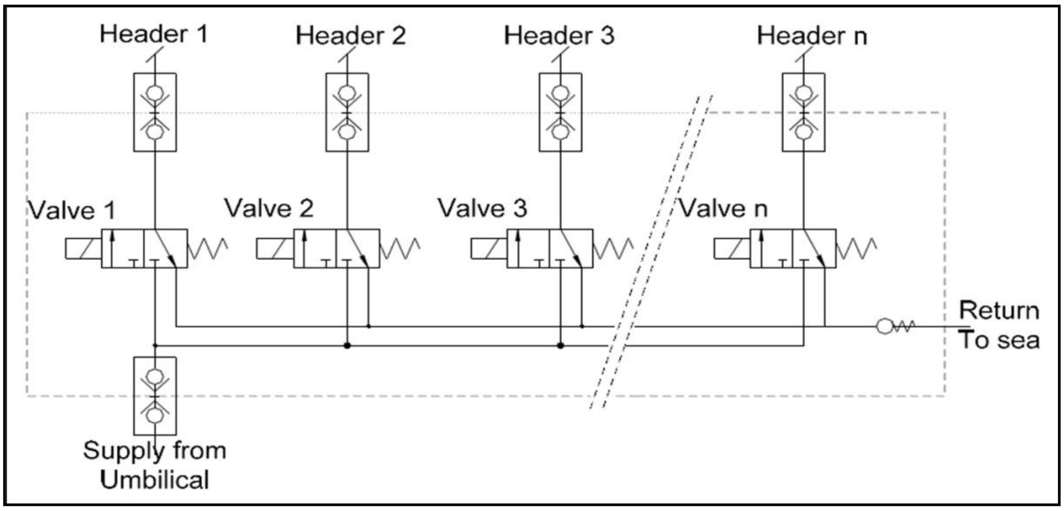

Figure 2-4: Schematic diagram of Subsea Control Module. (Agito, 2008)

2.2.6 Valve Actuator

The actuator is the component driving the gate valves on the tree. By converting hydraulic power to mechanical power, it allows the operation of control valves or gate valve. When an actuator is operated, fluid is injected at one side of a piston forcing the piston in opposite direction where either a linear or rotary motion occurs. Stavenes (2010) claims that an actuator may be single or double acting, meaning the pressure can be applied only at one side or both. For instances, in the case of push only, a spring may cause the actuator to retract by pressure bleed down. Chamber in the control valve communicates with the space surrounding the actuator. To provide attempts to move piston part in the control valve towards another chamber there will be a return spring mounted. Actuator’s movable part change in position when supplied with a pressurized fluid whose pressure is greater than the force provide by return spring. When the pressure reduced, position of actuator’s movable part once again will change in other direction and allows fluid to be forced back into the line.

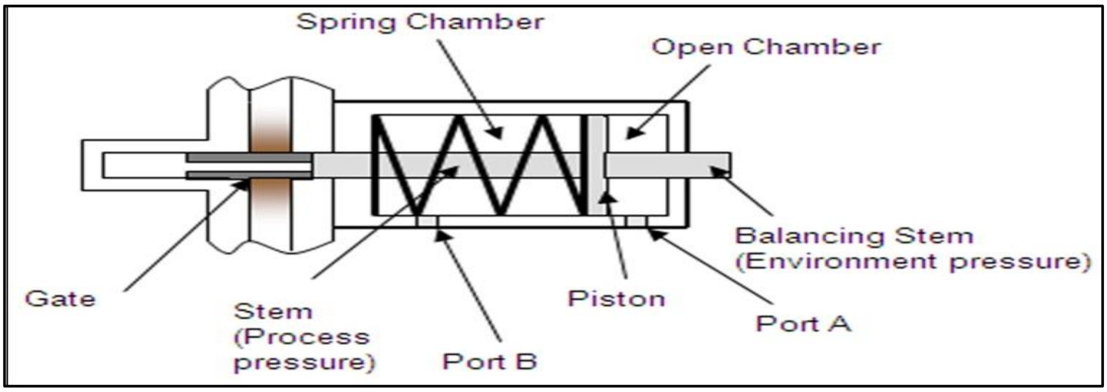

Figure 2-5 : Gate Valve principal drawing. (SimulationX, 2008)

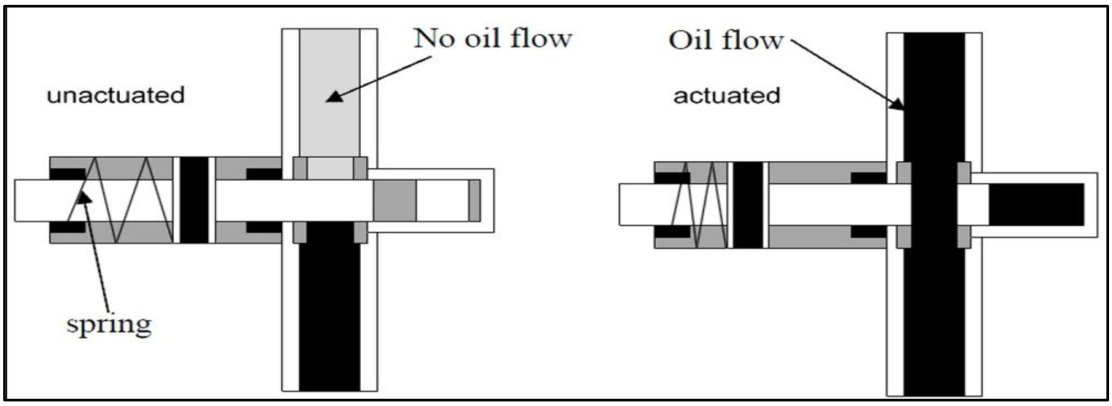

Figure 2-6: Gate Valve in Close and Open positions. (SimulationX, 2008)

2.3 AGITO SIMULATIONX

Agito SimulationX specialized in the modeling, analysis and simulation of hydraulic, electrical and fluid system. There are also subsea hydraulic library as an intuitive library where engineers can find the most used special components in a subsea hydraulic system. The graphic symbols are based on the circuit diagram symbols but can be adapted and enhanced. The software also extends its elements from all other libraries to create more comprehensive models. The library is based on existing SimulationX libraries of Hydraulics, Mechanics and signal block. Hence, all properties such as pressure, temperature, variable density, hydraulic transmission line and etc., are also available and can be manipulate to comply with system to be model. There is also the fluid library which calculates the fluid properties as function of the state variables for the hydraulic connection. Engineers handling the software only needs to select desired fluid type in the connection dialog from a list before running the simulation. The selected fluid types can still be used within one model, as long as a separate circuit is available for each fluid (SimulationX, 2008).

CHAPTER 3
METHODOLOGY

3.1 PROJECT WORKFLOW

This project was conducted according to four major stages that have been completed consists of:

a) Study of subsea control module;
b) Development process for control model;
c) Analysis and observation of result;

Figure 3-1 shows the overall methodology regarding the project.

3.1.1 Literature Review

The literature review starts after project title and meeting to discuss matter regarding the project with project's supervisor. The author conducts the study and investigation regarding various SPS control to identify a specific candidate of SPS, and available software and its capabilities in assisting the project progress. Another works done for this stage also includes, identification of SPS candidate to be used and others works on the subsea technology.

3.1.2 System Parameter Acquisition

This stage includes the review of system parameters from manufacturers of subsea technology and the selection of suitable details that will be used in the project.

3.1.3 Subsea Control Module Modeling

Modeling will be done using Agito SimulationX, the model includes hydraulic power unit, directional control valves, and gate valves. Details of this stage are on Section 3.5.

3.1.4 Result and Observation

Simulation of subsea control module will be carry on, and result analysis regarding operation of elements in the model needs to determine its operations capability. Any occurrences of failure for simulation need to be dealt with and modeling of subsea control module needs a redo until a successful simulation obtained.

3.1.5 Model Improvement

An improvement for model includes the changing of key design parameter to obtain better performance SPS control. Model improvement needs to be done because of failure of previous modeling process that unable to be simulated.

3.1.6 Documentation and Activities

Preparation and submission of documents includes the progress report, interim report, technical paper, and dissertation. Other activities includes in the stage are poster presentation, proposal defense, and viva process.

3.2 PROCESS FLOW CHART

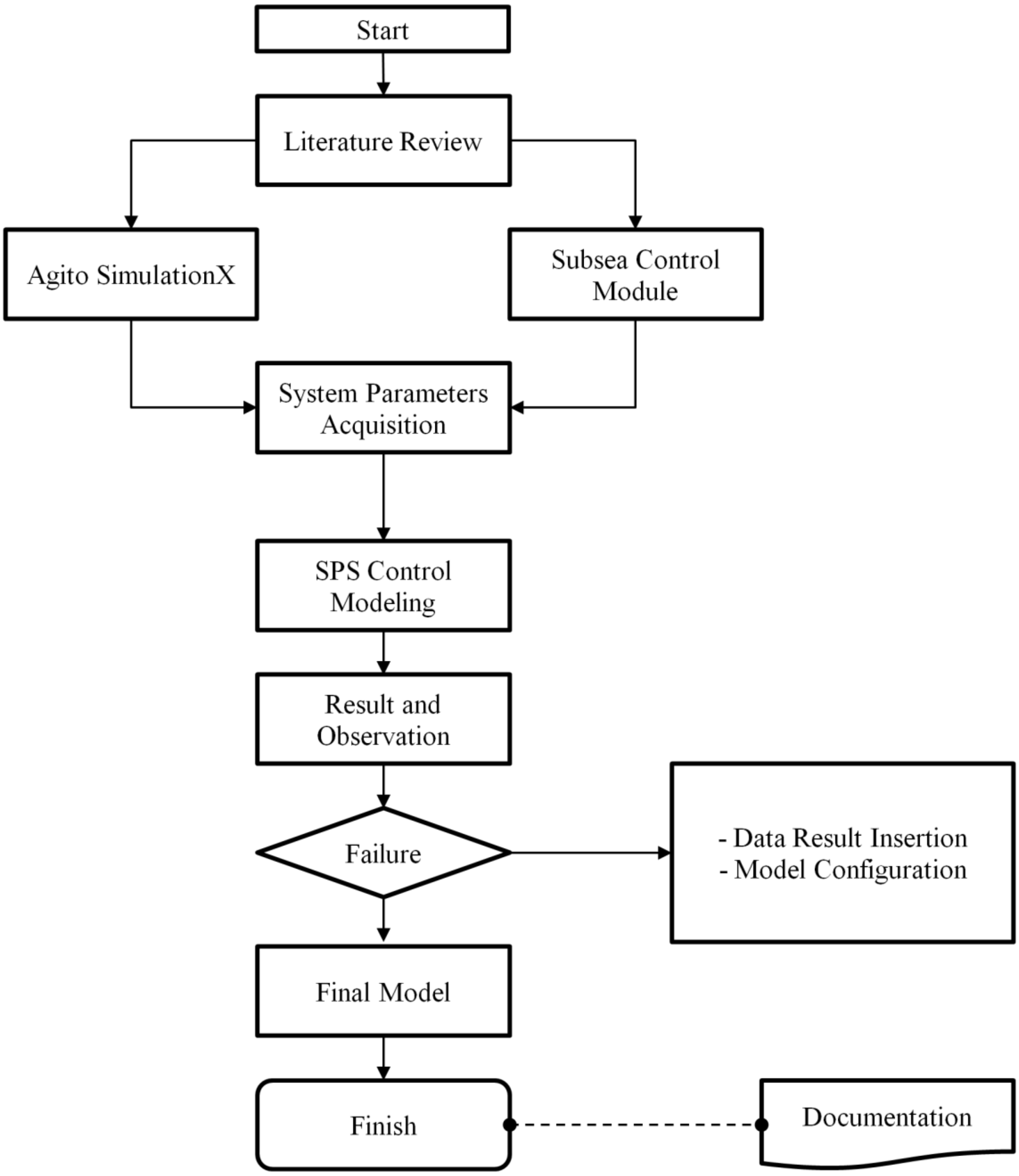

Figure 3-1: Flow Chart of the project.

3.3 PROJECT ACTIVITIES AND KEY MILESTONE

Activities incorporate for this project shown in the Gantt chart below

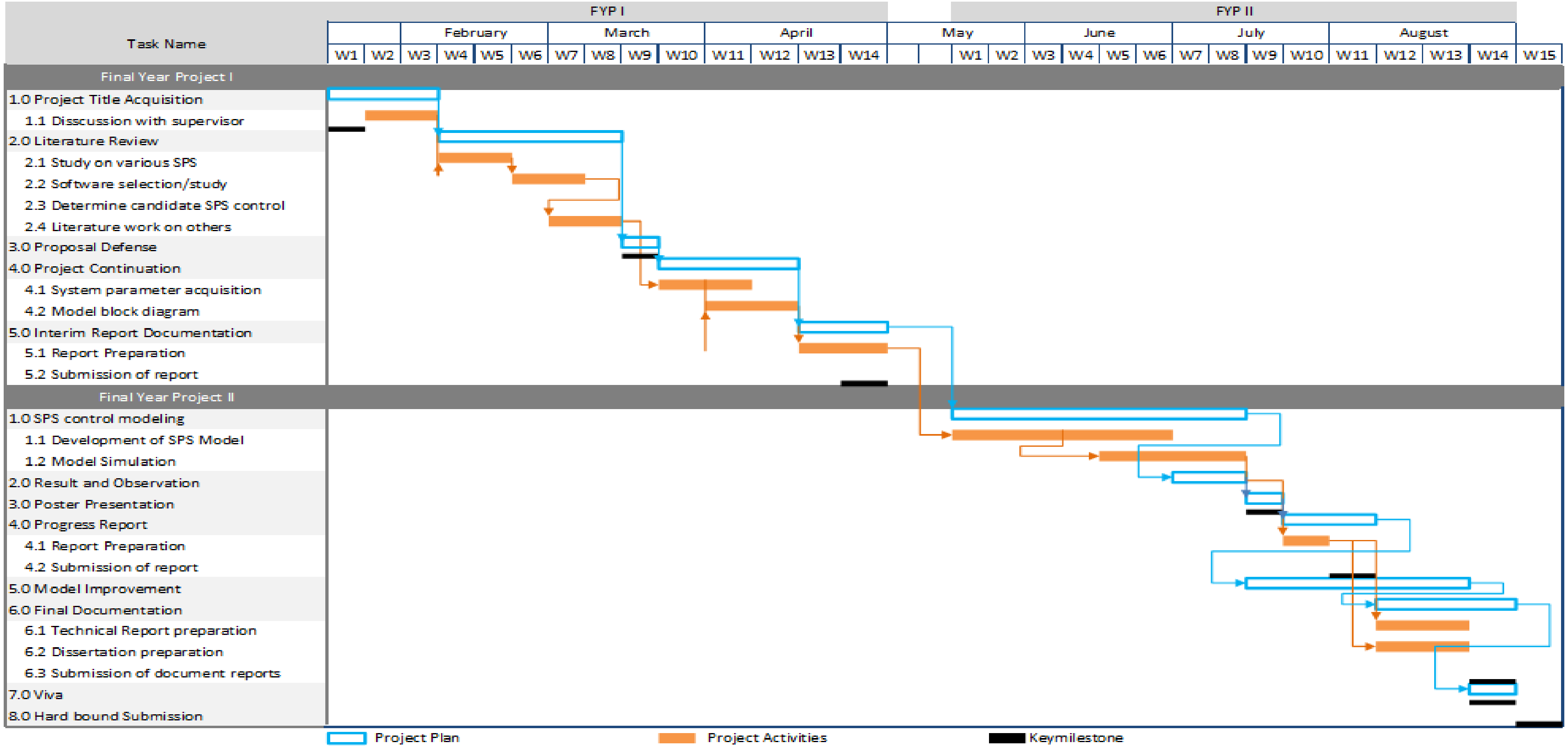

Figure 3-2: Project Activities and Key Milestone.

3.4 STUDY OF SUBSEA CONTROL MODULE

Subsea control module principal operations are referred to for the process of identification of suitable candidate to be used for the project. Existing subsea control schematics and operation from other researchers determine the outcome of simulation.

3.5 AGITO SIMULATIONX MODEL DEVELOPMENT

Basic subsea control module model will be established where its operation and specification will be based on the components used in its configuration. The main components of model based on completion and/or work-over system for subsea wells consists of hydraulic power unit, umbilical lines, directional control valves, and gate valves.

3.5.1 Hydraulic Power Unit Model

HPU is modeled as in Figure 3-3 in Agito SimulationX. Figure 3-3 includes components such as a reservoir, duty pump and stand by pump, accumulator, pressure regulator valves, and return to sea option. There will be also header valves to control the behavior of hydraulic power unit.

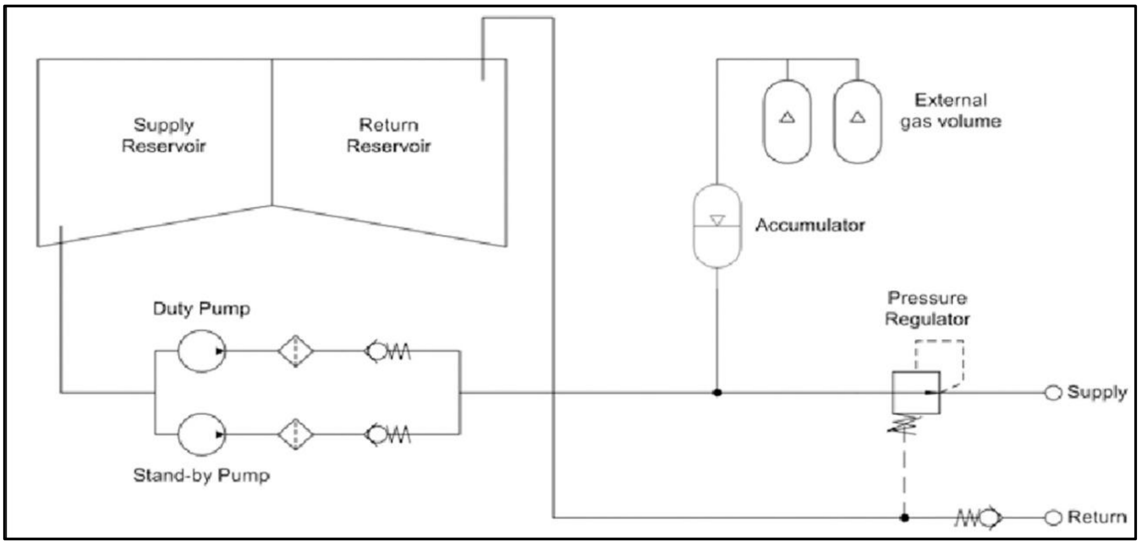

Figure 3-3: Hydraulic Power Unit model block diagram. (SimulationX, 2008)

3.5.2 Distribution Line Model

Umbilical part will use distribution line model where separation of line into elements as in Figure 3-4. Purpose of each line elements separation is to enable the pressure to be calculated from previous linear element to the next together with its volumetric coefficient expansion and to enable calculation of restriction and inertia for the flow. Importance of this distribution line model is when pressurization and bleeding of lines are use in the Emergency Shut Down (ESD).

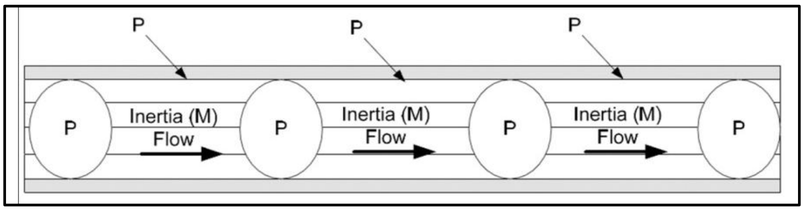

Figure 3-4: Distributed line model. (SimulationX, 2008)

3.5.3 Subsea Control Module Model

For subsea control module modeling elements, limitation for components used in the software is done as to limit only towards elements that are active in the configuration. This includes a directional control valves with supply line, return line, and connection to the gate valves. The return to sea connection includes the spring check valve.

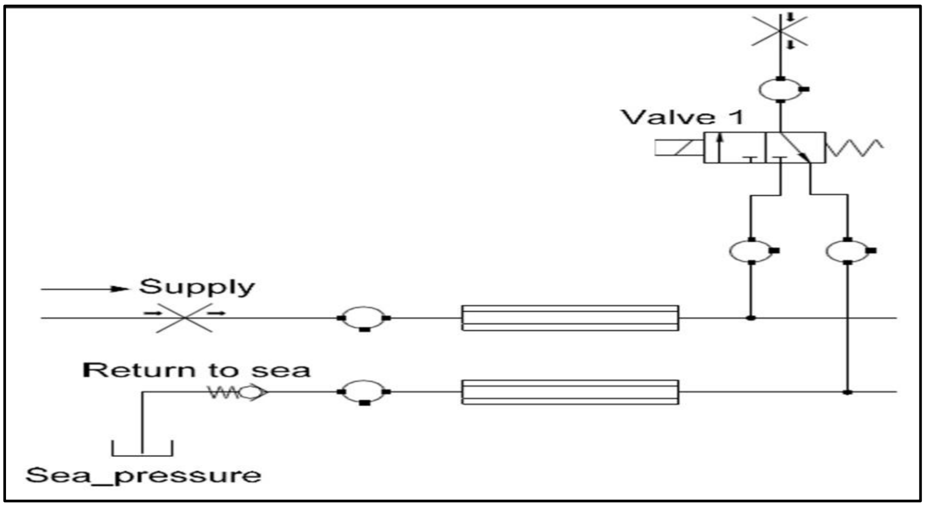

Figure 3-5: Subsea Control Module model. (SimulationX, 2008)

3.5.4 Gate Valve Actuator Model

Gate valve model can be considered as an isolated system as in Figure 3-7. The valve actuator is a linear actuator.

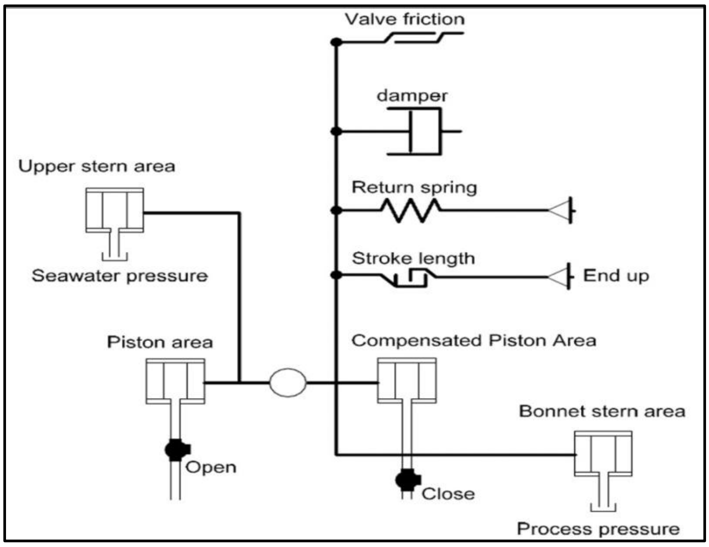

Figure 3-6: Gate Valve model. (SimulationX, 2008)

3.6 CADLAO FIELD

The Cadlao field is located at the offshore of Palawan Island, Philippines. Modeled subsea control module in this project will be using Cadlao field as a case study to validate the system.

a) Water based fluid used rather than low viscosity oils
b) Control fluid is mixed by adding concentrate to fresh water in ration of 10 to 1
c) Operating time to close or open two 4 inch production valves through ½ inch hose were estimated at between 60 until 90 seconds.
d) Opening shift time is 25s.
e) Closing shift time is 44s.
f) Umbilical line 6000 ft long.
g) Hose inner diameter ½ inch
h) 3500 psi working pressure.

3.7 RESULT ANALYSIS AND OBSERVATION

Subsea control module with all its components then will be simulate. Result analysis using Agito SimulationX able to provide output of the system.

CHAPTER 4

AGITO SIMULATIONX PARAMETER ACQUISITION

4.1 HYDRAULIC POWER UNIT SIMULATIONX

As in Figure 3-3, subsea hydraulic power unit reservoirs considered as a tank because the Agito SimulationX does not take contaminations in the fluid into account. Some parameters of the HPU include:

Table 4-1: Surface HPU parameters.

Parameter	Value
Supply Volume	2000 liter
Return Volume	2000 liter
Supply Reservoir Start Volume	2000 liter
Return Reservoir Start Volume	0 liter

4.2 SUBSEA CONTROL MODULE SIMULATIONX

An element in the subsea control module is the directional control valves. The switching behavior is internal switching for the valve where state of valve controlled using open and close signal. The parameter for open signal length and close signal length determine the signal availability.

Control valve switching behavior as open or close are based on pressure differential as to compare with reset pressure:

a) For pressure differential that is below reset pressure, valve position will change from open position to close position;
b) For pressure differential that is above reset pressure, valve position change from close position to open position with the availability of open signal;
c) For pressure differential below reset pressure, valve can be forced to open using open signal and it will stay open only in the range of open signal length;
d) Availability of close signal will ensure the valve to be in close position even though condition in (b) is followed.

4.3 UMBILICAL

The specification for umbilical line is as follow;

Table 4-2: Umbilical Line parameters.

Parameter	Value
Inner diameter	0.0127 (½ inch)
Length of umbilical line	1830 m (6000 ft)
Umbilical Type	Hoses
Hoses working pressure for ½ ID	3500 psi
Hoses working pressure for ¼ ID	5000 psi

4.4 GATE VALVE

Parameters for gate valve are as follows:

Table 4-3: Gate Valve parameters.

Parameter	Value
Shape of Piston Area	Ring shaped
Stroke Length	0.203 m
Piston Diameter	0.1016 m (4 inch)

Figure 4-1, shows the condition regarding shift time of opening and closing of valves operation for the response time.

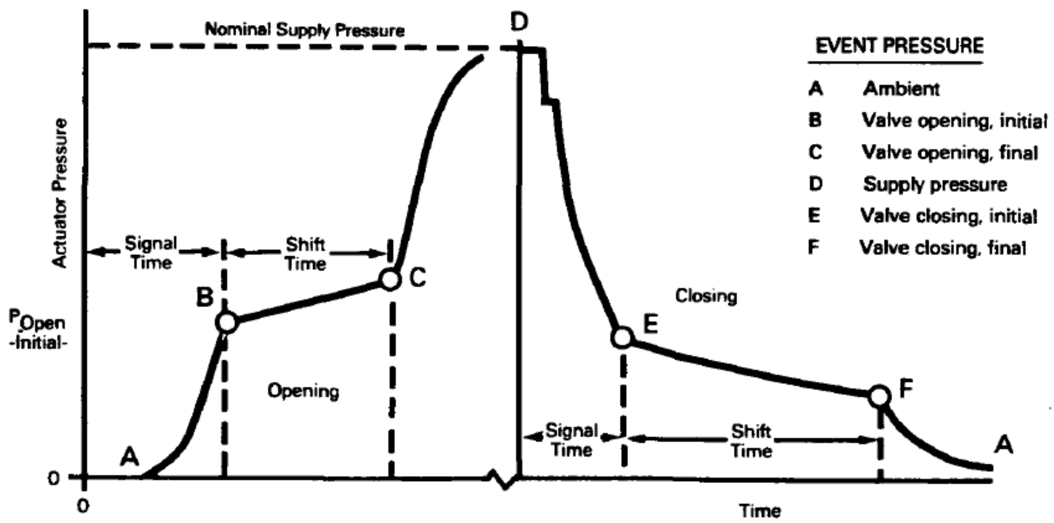

Figure 4-1: System Shift Response.

4.5 SUBSEA CONTROL MODULE SIMULATIONX MODEL

Combination of all components previously mentioned in this project would lead to full model as in Figure 4-2.

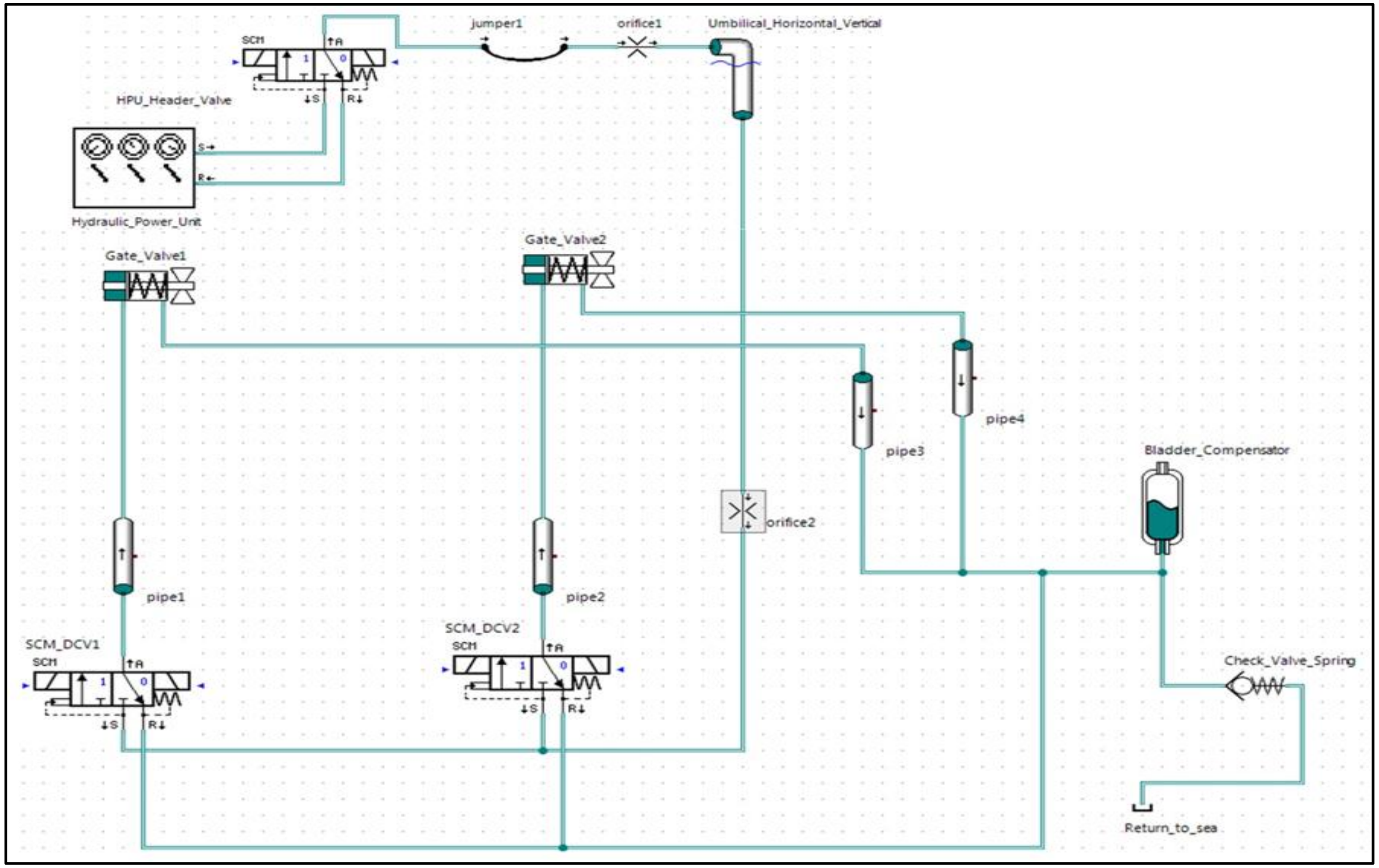

Figure 4-2: Subsea Control Module model in Agito SimulationX

CHAPTER 5

RESULT AND DISCUSSION

5.1 CONTROL RESPONSE TIME

After the simulation system is developed and executed, the results of simulation are shown in Figure 5-1 where it illustrates response time for Gate Valve 1 shift time based on the case study conduct on the subsea control module components. The main parameters for results are:

a) Valve size = 4 inch;
b) Hose size = 1/2 inch;
c) Umbilical line length = 6000ft;
d) Working pressure of Umbilical line = 3500 psi.

In every one of the result in this section, the black line represent movement of gate valve, blue line represent pressure of spring chamber for the gate valve, and the red line represent the pressure of open chamber.

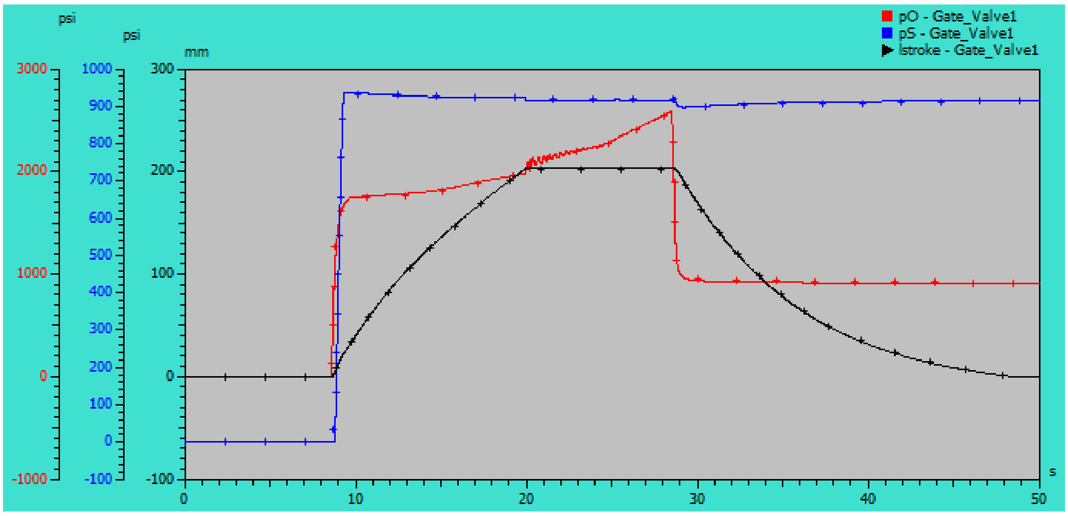

Figure 5-1: Effect of valve movement on response time.

Based on the pressure plot and movement of gate valve in Figure 5-1:

- Gate valve start to open at $t_{0\%}$ = 8.648s and $t_{100\%}$ = 19.98s.
- Valve start to close at $t_{100\%}$ = 28.66s and $t_{0\%}$ = 48.47s.
- Opening shift time is 11.332s.
- Closing shift time is 19.81s.

As the directional control valve opens, pressure build up to supplied force to actuator. The actuator position is directly proportional to pressure supplied to the open chamber. As the pressure start to build up, the movement of gate valve start and after then goes to steady state before being forced to close due to close signal availability and the pressure different value becoming less than the reset pressure. Based on the Cadlao field, its operating time is between 25 seconds to 44 seconds for open and close shift time which is almost double from the value obtains in Figure 5-1.

Plot result on Figure 5-2 has some modification to several parameters used for the system that are hose size and valve size.

5.1.1 Hose size

The main parameters for results are in Figure 5-2 are:

a) Valve size = 4 inch;
b) Hose size = 1/4 inch;
c) Umbilical line length = 6000ft;
d) Working pressure of Umbilical line = 5500 psi.

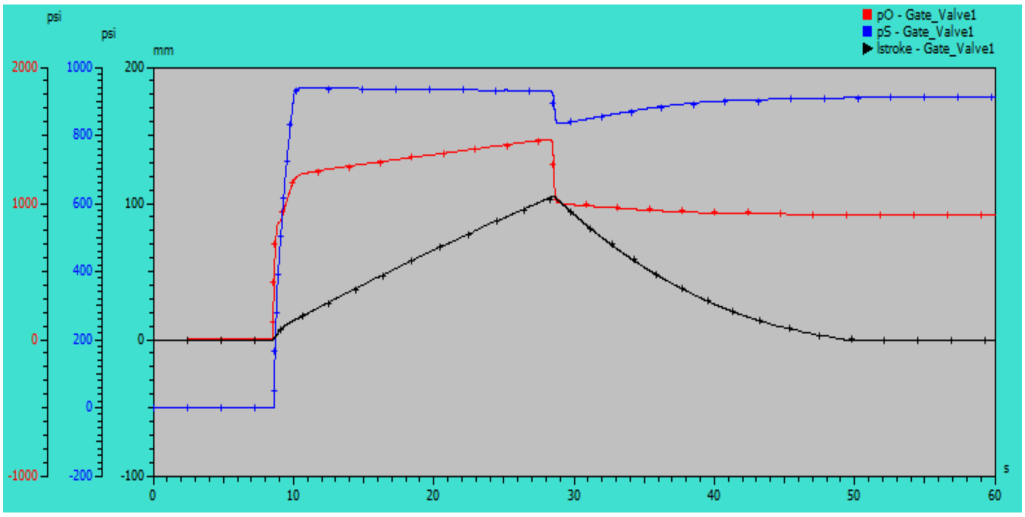

Figure 5-2: Effect 1/4 inch hose size on response time.

Based on the pressure plot and movement of gate valve in Figure 5-2:

- Gate valve start to open at $t_{0\%}$=8.581s and $t_{48\%}$=28.54s.
- Valve start to close at $t_{48\%}$=28.54s and $t_{0\%}$=49.25s.
- Response time for opening shift is 19.96s.
- Response time for closing is 20.71s.

The valve did not fully open when the response time for closing shift started. This is mainly due to pressure drop is below the reset pressure.

5.2.2 Valves size

The main parameters for results in Figure 5-3 are:

a) Valve size = 7 inch;
b) Hose size = 1/2 inch;
c) Umbilical line length = 6000ft;
d) Working pressure of Umbilical line = 3500 psi.

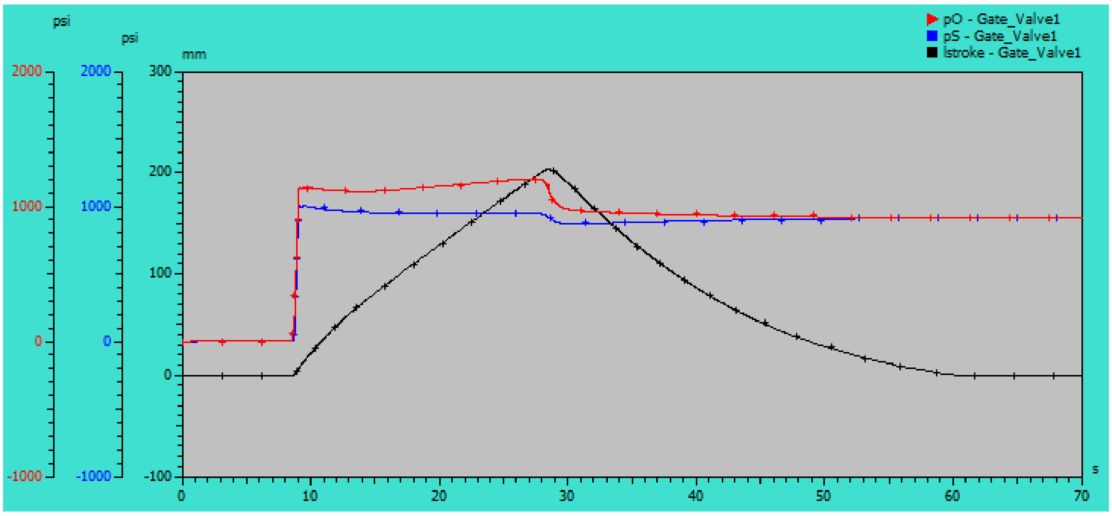

Figure 5-3: Effect of 7 inch valve size on response.

Based on the pressure plot and movement of gate valve in Figure 5-3:

- Gate valve start to open at $t_{0\%}$=8.706s and $t_{100\%}$=28.59s.
- Valve start to close at $t_{100\%}$=28.59s and $t_{0\%}$=60.27s.
- Response time for opening shift is 19.884s.
- Response time for closing shift is 31.68s.

Time taken for valve to fully open or close decrease as the valve size increase. According to law of motion, when contact area increase while the pressure supplied is constant, the force acting on the piston will decrease and the velocity of piston will also decrease. As a result, the time taken for a gate valve to fully open or close is increased.

CHAPTER 6
CONCLUSION AND RECOMMENDATION

6.1 CONCLUSION

In this last chapter, project objectives are achieved. The objectives consists of first, to model a subsea control module in order to investigate the behavior of its gate valve, and second, model simulation to determine the response time. The benefits of such model are ability to do multi scenario of valve behavior based on changing parameter such as the size of valve, working pressure and umbilical size. This can assist engineers to decide on the specification of subsea control module to be use for subsea technology.

6.2 RECOMMENDATION

Recommendation for future works is to develop a more comprehensive Agito SimulationX model for electro hydraulic control or all electric control for the subsea control module.

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APPENDICES