Subsea Production Control System Modelling

By

Omar Eid Khorshed Abd El-Aziz

Dissertation submitted in partial fulfilment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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CERTIFICATION OF APPROVAL

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A project dissertation submitted to the
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Approved by,

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UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 2013

CERTIFICATION OF ORIGINALITY

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

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OMAR EID KHORSHED ABD EL AZIZ

ABSTRACT

Subsea control systems in subsea production system (SPS) play a vital role in the safe and productive operation of any oil or gas field. These systems operate in extreme environments, thus making the installation and commissioning the system risky and costly. For a new developer, a better understanding on how the system works is needed to ensure that the system will meet all design specifications and reduce the risk and costs associated with installation and commissioning. Leading oil and gas companies turned to identify the critical responses and behaviors expected from the designed system through simulation software, where the whole subsea control systems from the Hydraulic Power Unit to the Subsea Control Module can be modeled. In this report, a case study from Cadlao field off the shores of Philippines is used to perform a simulation study on. The field uses a direct hydraulic control system, which from the literature review done, is considered to be the building stone of all other control systems available. The simulation was made by a new simulation tool called Agito ITI SimulationX. The simulation results are then compared with those from the actual field outputs recorded from the Cadlao field. The results of the simulation and the discussion showcases the response of the gate valve actuator and its relation with umbilical hose and Directional Control Valve. Comparison between the experimented results and the simulated results were made to stand upon relativeness of the simulated results.

ACKNOWLEDGEMENTS

I would like to express the deepest appreciation to my supervisor, Assoc. Prof. Dr. Fakhruldin Bin Mod Hashim, who has always provided me with valuable and detailed advice that helped me to progress and eventually make this work a reality. Without doubt, his work ethics and attitude is something that I would take on from this work experience. It has definitely been an honor to work with him.

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Special thanks to the ITI SimulationX help desk and support team who were always available 24/7 for any questions or inquiries from my side.

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CHAPTER 1

INTRODUCTION

1.1 Background

Over the last decade, there has been a huge increase in the application of subsea systems for the production of oil and gas from subsea wellheads. Figure 1 illustrates the development and business scale of the offshore oil and gas business since 1991 until its forecasted scale in 2030.

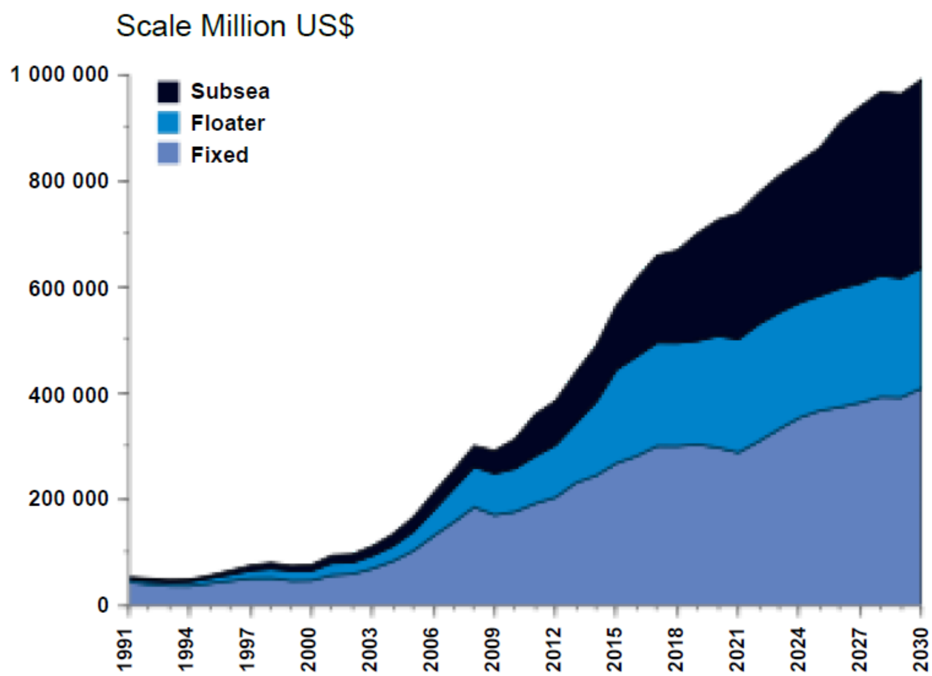

Figure 1. Scale of E&P Operations [1]

Subsea production system comprises a wellhead, valve tree ('x-mas tree') equipment, pipelines, structures and a piping system, and in many instances, a number of wellheads have to be controlled from a single location. A subsea control system is part of a subsea production system, and proper performance of the control system is the critical factor in ensuring its reliable and safe operation [2].

The control system provides operation of valves and chokes on subsea completions, templates, manifolds and pipelines. In addition to satisfactory operational characteristics, the design of a control system must also provide the means for a safe shutdown on failure of the equipment or on loss of hydraulic/electrical control from the top site (a platform or floating facility) and other safety features that automatically prevent dangerous occurrences. One example of such a safety feature is the employment of fail-safe-operated subsea valves that close upon loss of hydraulic pressure.

The control of various production functions, executed at the sea bed, is carried out from a topside production facility (a platform or a floating vessel), and a satisfactory response time for a control system is an important factor that may have a dramatic effect on reliability and safety of environmentally critical operations.

To ensure reliable and safe operation of the subsea system, the design, operation and testing, etc., of a subsea control system is regulated by industry, national and international standards, and the systems are subjected to stringent quality review processes like failure modes, effects and criticality analysis, factory acceptance tests and reliability availability and maintainability analysis, etc.

With the increasing demand of energy and the scarcity of onshore petroleum exploration and production, the need for new production facilities that can provide the needed oil and gas demand is sky rocketing. Offshore exploration and development of new oil fields became much of a focus for E&P companies around the world. Deep-water technology serves as a solution to the increasingly demand for energy with the huge prospect of exploring the deep seas and finding precious resources.

Long-term control and monitoring of subsea oil and gas production facilities requires high-performance equipment, designed for extreme environments with ultra-high reliability characteristics. Subsea oil and gas production around the globe is increasingly demanding deep-water capabilities, a high integrity control system performance and data communications capacity to deliver intensive instrumentation surveillance of the subsea plant [3].

1.2 Problem statement

A proper subsea production control system 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. This generates the opportunity to test various design options and system response times, providing the chance to alter and modify the design specifications whenever necessary. The need for accurate calculations is heightened by the fact that the umbilical is one of the most expensive individual components in a subsea installation. If it is dimensioned incorrectly, it will result in major time and cost overruns.

1.3 Objectives

The objectives of the project are as follows:

1. Develop a simulation model for a direct hydraulic Subsea Control Module.
2. Simulate control module functions that govern the Subsea Control Module.
3. Investigate simulated model’s behavior, signal and shift response times under varying parameters.

1.4 Scope of study

Scoping the project helps focusing the project efforts into specific boundaries to achieve evident and precise results, study scopes of this project are:

1. Use Agito simulationX tool to simulate the production control system using a typical direct hydraulic SCM principal operation.
2. Actual field case study from the industry is identified and its key design parameters is used to build the simulation model.
3. Focus on the behavior of the gate valve and umbilical line in the modelled system and their effect on signal and shift response times.

CHAPTER 2
THEORY & LITERATURE REVIEW

2.1 Production Control Systems

Having a reliable operations, accurate control and monitoring of subsea installations is critical to have high production in subsea production systems, while ensuring safe environment and environmental friendly field operations [2].

Control system provides operation of valves and chokes on subsea completions, templates, manifolds and pipelines. As well as allowing for safe shutdown if any equipment endures failure or loss of hydraulic/electrical control from the topside.

Production control systems consist of topside control equipment, umbilical transmission and subsea control equipment [4]. Figure 2 shows main elements involved in a typical production control system.

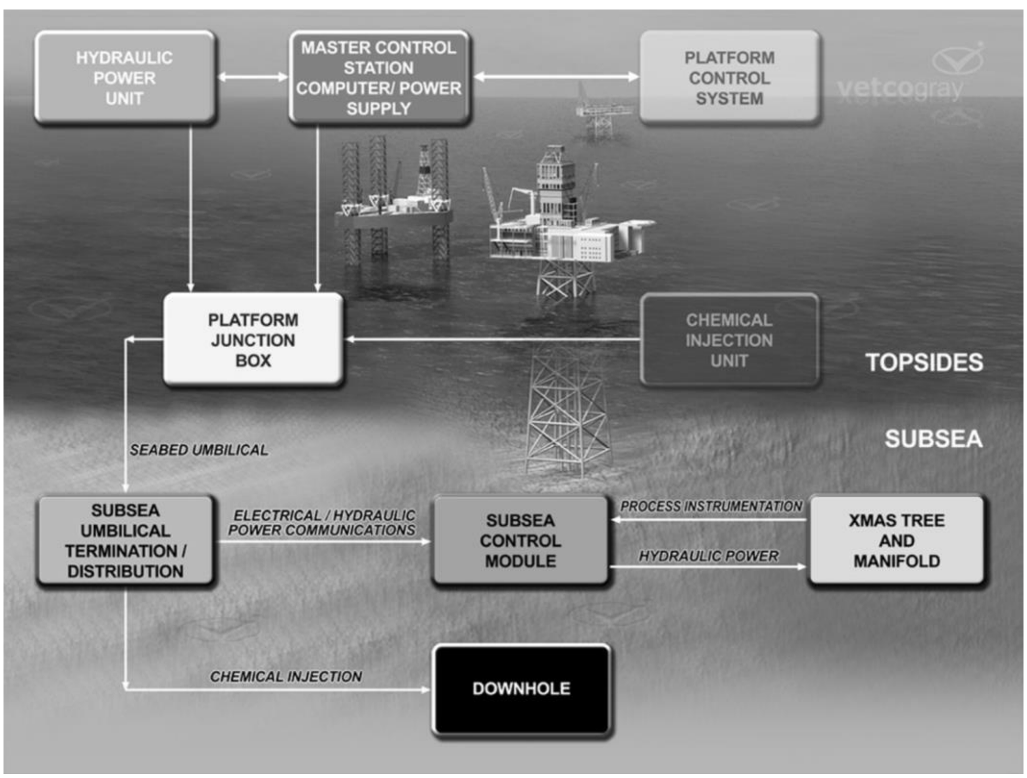

Figure 2. Subsea Control Module Schematic [5]

Two types of fluid are commonly used for subsea production systems: high water content-based or synthetic hydrocarbon control fluids. The use of synthetic hydrocarbon control fluids has been infrequent in recent years, and their use is usually confined to electrohydraulic control systems. Water- based hydraulic fluids are used most extensively [4]. The characteristics of high water content-based control fluids depend on the ethylene glycol content (typically 10% to 40%), and viscosity varies with temperature (typically 2–10°C). As government regulations do not allow venting mineral-based oil into the sea, if the system uses this type of fluid, it must be a closed-loop system, which adds an extra conduit in the umbilical, making it more complex. Required fluid cleanliness for control systems is class 6 of National Aerospace Standard (NAS) 1638.

As communication distance between topside production facilities and subsea installations increases, due both to multiple well developments and water depth, early methods of well control using direct hydraulic control of subsea valves have become less feasible due to operational limitations of such controls and due to both the size and cost of the multi-core umbilical required to provide hydraulic power transmission. This has led to the development of more advanced and complex control methods using piloted hydraulic systems, sequential piloted systems and electrohydraulic systems (hard-wired and multiplexed). The complexity and performance characteristics of subsea control systems depend on the type of control used and are application-specific. The selection of the type of control system is dictated predominantly by technical factors like the distance between control points (offset distance between the platform and the tree), water depth, required speed of response during execution of subsea functions and type of subsea installation (single or multiple wellheads).

2.1.1 Control Equipment – Topside

Topside control system equipment (Figure 3) comprises a hydraulic power unit (HPU), an electronic power unit (EPU) and a well control panel. Emergency shutdown facilities are provided to bleed off hydraulic fluid and thus to close subsea fail-safe valves. The hydraulic components are fairly standard.

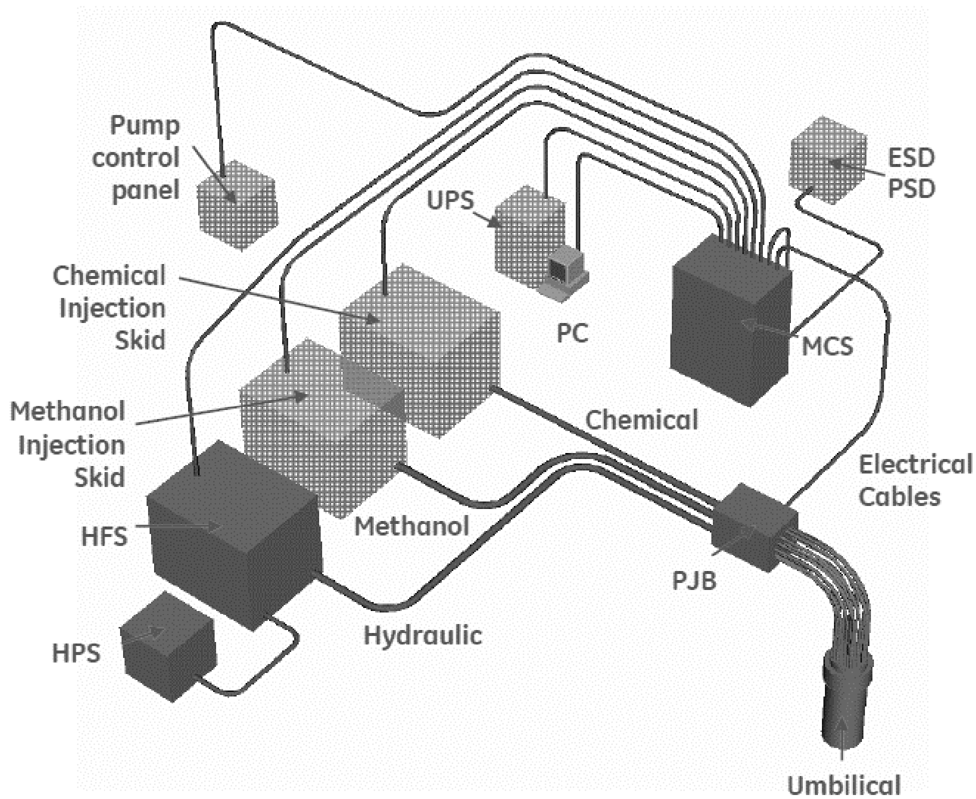

Figure 3. Top side control equipment [5]

A programmable logic controller or PC-based EPU may be integrated with the platform control system or it may be a self-contained unit [5].

2.1.2 Umbilicals

An umbilical is a conduit between the topside host facility and the subsea control system and is used for chemical and/or hydraulic fluids, electric power and electric control signals. The hydraulic power and control lines are individual hoses or tubes manufactured from steel or thermoplastic materials (most common) and encased in the umbilical [6].

The electrical control cables supplying power and control signals can either be bundled with hydraulic lines or laid separately.

Umbilical (Figure 4) acts as a transmitter between the topside facility and the subsea control system. All hydraulic communications go through separate hoses or pipes that are bundled together into the umbilical. In temporary systems, such as a Work over and Completion System, hoses are most common [1]. Umbilical with metal tubing are majorly preferred in deep-water applications and when longer lengths are required. The dimensioning of the umbilical is important to the performance and operation of the whole system. It is therefore important that the model of the hose is accurate, and that it includes the delays that are experienced in practice [7].

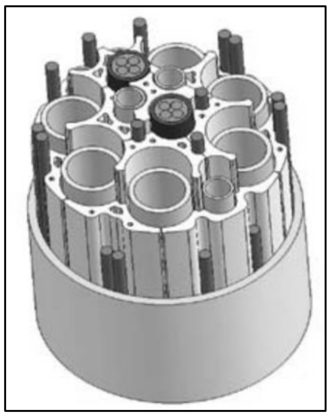

Figure 4. Umbilical [1]

To avoid any potential faults, the umbilicals are fabricated in continuous lengths, i.e. without splices. Major problems encountered with umbilicals are permeability to methanol, fluid incompatibility and mechanical damage during manufacture and installation. Current research and development efforts are directed towards improvement of thermoplastic umbilicals. In some cases, it may be advantageous to use metal umbilicals and it should be noted that, due to problems experienced with thermoplastic conduits in umbilicals [8], some operators are now using only stainless steel tubing for transporting fluid in umbilicals. Umbilicals employing metal tubing are usually considered for deepwater applications and when longer umbilical lengths are required. Metal umbilicals are also advantageous when higher working pressures, greater electrical power requirements and continuous dynamic service are necessary. However, issues of corrosion, fatigue performance and end terminations still have to be resolved [6].

2.1.3 Control Equipment – Subsea

The production control system provides control of all functions of the subsea production system. The production control systems, as such, are only concerned with controlling production and safety valves and monitoring devices and are not used to provide control of subsea connector latching and unlatching or operation of vertical access valves, for example [9]. Typically, subsea functions include operation/control of:

1. a downhole safety valve (DHSV);
2. subsea chokes;
3. production valves mounted on the x-mas tree; and
4. utility functions such as monitoring of fluid characteristics, pressure leakage and valve positions (Figure 5).

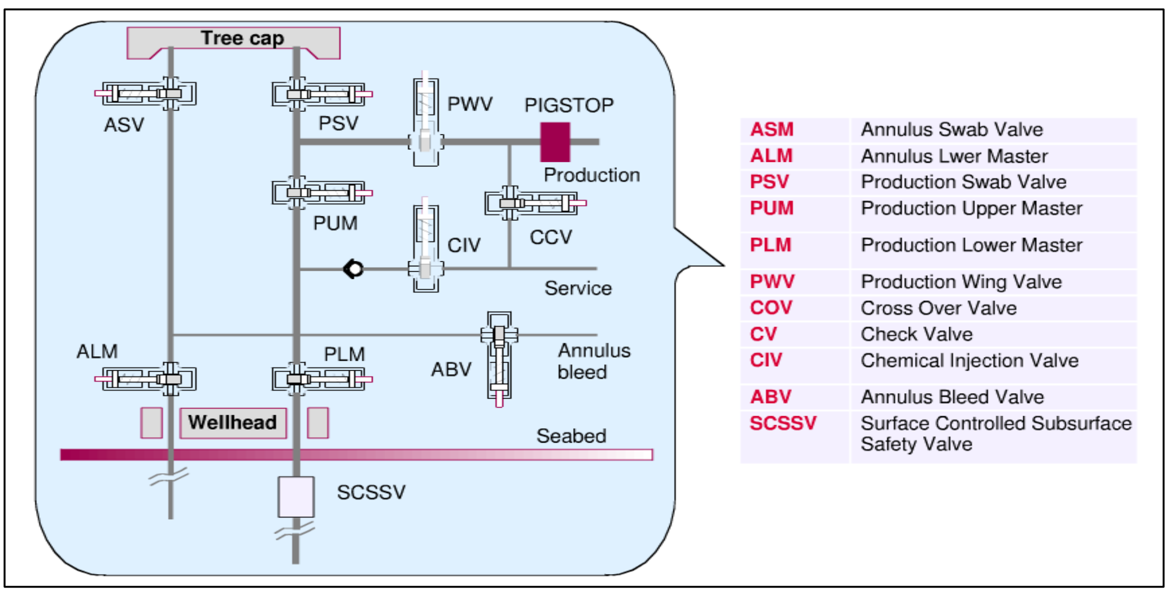

Figure 5. Subsea Production Valves [9]

Typical operation pressures are 3,000psi (200bar) for x-mas tree functions, and 9,000psi to 12,000psi (600–800bar) for DHSV functions [9]. Actuation pressures for tree valves and DHSVs vary widely as they are a function of water depth and process pressures. The maximum expected actuation pressures occur during opening of valves that are in closed, pressurized positions, typically as follows [10]:

1. Tree valve open: 750psig to 2,200psig (50–140bar).
2. Tree valve closed: 600psig to 1,000psig (20–65bar).
3. DHSV open: 2,500psig to 9,200psig (160–600bar).
4. DHSV closed: 500psig to 4,500psig (32–290bar).

2.2 Types of Hydraulic Control System

A production control system provides the means to control operation of a subsea production facility. There are several types of control systems:

1. Direct Hydraulic Control System
2. Piloted Hydraulic Control System
3. Electro-Hydraulic Piloted Control System
4. Electro-Hydraulic Multiplexed Control System
5. Subsea Powered Autonomous Remote Control System

In this chapter, only direct hydraulic control system will only be discussed. Other control systems details can be found in the Appendix.

2.2.1 Direct Hydraulic

This is the simplest type of control system in which HPU and well control panels for each individual well to be controlled are located topside. Well control panels use solenoid-operated control valves. Hydraulic signals are transmitted via umbilicals to actuators of production control valves mounted on the subsea tree. Each actuator of a tree-mounted production valve has a separate supply line. The advantages of this type of control system) are relative simplicity, high reliability, ease of service and minimization of a number of subsea components. However, the umbilical is complex because it must contain all individual hydraulic lines for all controlled tree components [8].

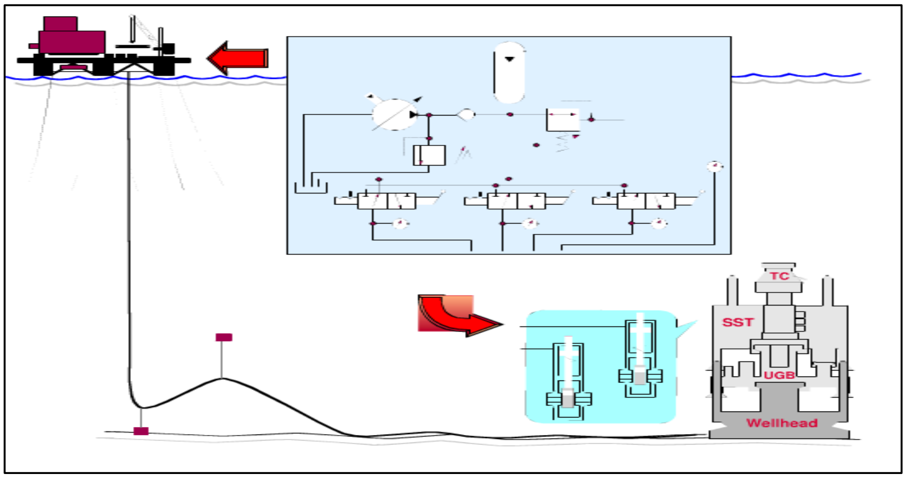

Figure 6. Direct Hydraulic Control System [9]

Direct hydraulic control systems are limited to applications where the distance between the production facility and the subsea tree is less than 3–4km. This limitation is due to low speed of response of the system caused by the necessity to pressurize the fluid and transmit it between the production facility and the tree. The response of the control system is influenced by both physical properties of hydraulic fluid, i.e. bulk modulus and viscosity, the characteristics of the umbilical, i.e. its volume, and compliance and volume of actuators. A typical closing time for tree-mounted valves (actuator volume of three liters) when using a direct hydraulic control and with an offset distance of 10km is approximately eight minutes.

No feedback information on system subsea performance is provided by the system; however, some information about subsea operations can be obtained by monitoring pressure in control lines and by measuring fluid supply and returns.

2.3 Articles & Patents review

The topic of modelling the subsea production control system has been handled by many researchers in the industry. The higher needs to explore deeper and harsher wells, pushed the researchers to simulate their introduced control technologies and test it before investing in implementation procedures.

The progression of the simulation topic has -most of the time- been correlated with the testing and validation of new control systems introduced into the markets. However, modelling and testing known technologies is still considered a main aspect of the subsea production control system simulation, as it showcases to the designers critical performance information about the designed control system in hands.

E. W. Locheed Jr. from NL Control Systems and R. Phillips from Marconi Avionics Ltd., have worked together to construct a high integrity electrohydraulic subsea production control system [11]. The authors have taken a 'zero base' design approach toward the development of a modular subsea control system. The only allowed constraints have been the functional requirements of the equipment. The resulting designs which are optimized for long term reliable operation have been implemented and the equipment tested to verify its reliable performance according to specifications. They identified relations between Hydraplex mode delay times vs. hose length used. Their work showed faster response time and a more reliable than the conventional direct hydraulic control systems used before [11].

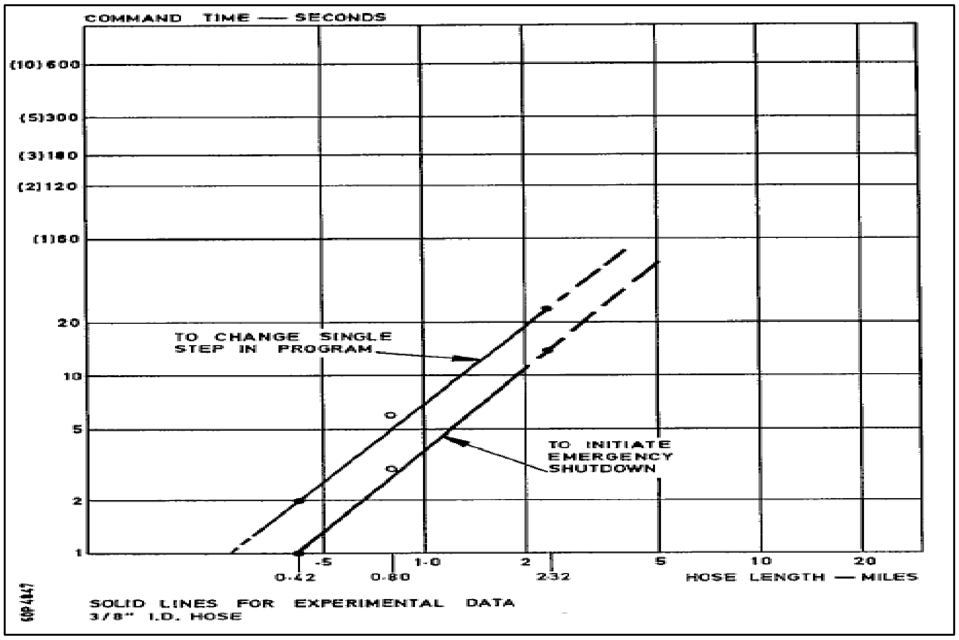

Figure 7. Hydraplex mode delay time vs hose length [11]

Tony Pipe [12], claimed that any particular system will have the same major highlighted characteristics to be considered, through his work they would be:

1. How quickly a system can be charged and ready for operation?
2. What time will it take to open or close a valve actuator under normal conditions?
3. How many valves can be operated before hydraulic pressure need to be re-charged in the accumulators?
4. What is the system leak rate likely to be?
5. What is the maximum leak rate that might be tolerated and still permit valve operations?

From his work, he as well came out with selection criteria for the type of control system that is most appropriate for each specific rig use. His classification is as follows:

Table 1. Control system selection criteria [12]

System	Distance/Km	Response Time	Subsea Line	Function Supply
Direct Hydraulic	5 Km	Very slow	Very large hose bundle	Control
Piloted Hydraulic	5 Km	Slow	Very large hose bundle	Control
Sequential Hydraulic	8 Km	Slow	Large hose bundle	Control
Electro-Hydraulic	10 Km	Fast	Large electro-hydraulic cables	Control, data limited analogue inputs
Multiplexed Electro-Hydraulic	15 Km	Fast	Small electro-hydraulic cables	Control, data limited analogue inputs, pulse counts
Subsea Hydraulic Power Generation	30 Km	Fast	Small electric cable	Control, data limited analogue inputs, pulse counts

Even though this classification is over 30 years old and without doubt the technologies have evolved vastly, but the concept and classification is still valid till today [9].

However, Brian Boles and Dennis Graney from Hydril Co. claim that with the wide development of different subsea production control systems to increase reliability [13], there is still a strong trend towards simplification and using a direct hydraulic control system. They related this increase is due to the reduced complexity of the control system, the associated reduced cost and, in part, to the improved response time offered by new innovations in hydraulic umbilicals.

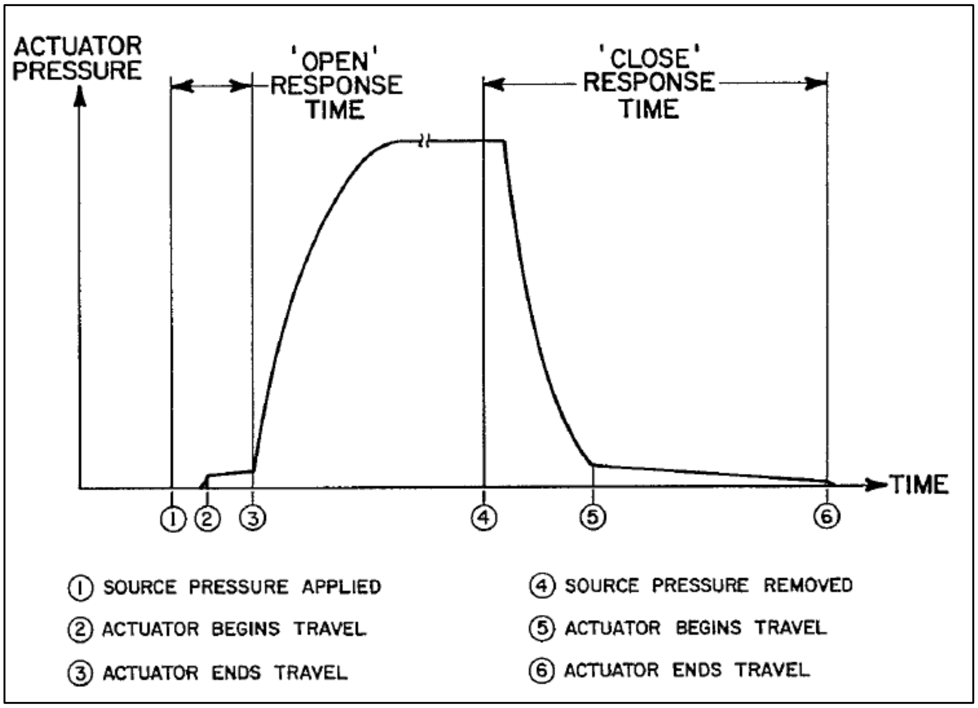

Figure 8. Typical response curve with stainless steel control line [13]

Operators also using direct hydraulic controls for other applications, such as pipeline valve control, and as continued experience with direct hydraulic controls accumulates, it is expected that the trend in simplification will continue [13].

With the continuous development in the production control system field, and the higher needs for deeper explorations are heightened. M. Theopald and his colleagues argued in 2005 that in order to produce from even greater water depths and harsher metocean conditions, the offshore industry has become technologically sophisticated. This applies both to the floating structures that support topside facilities in 2,000 meters plus water depths, and the tie-back technology to produce from long distance remote step-out wells. These can be located at many tens of kilometres from the host facility [14].

The limitations of direct hydraulics resulted in slow subsea to host actuator response times, and this permitted modest tie-back distance to around 15 kilometres. In the early days of subsea tiebacks, each of the hydraulic valves (needed to control the flow of hydrocarbons from the wellhead systems) was individually controlled by a direct hydraulic connection back to the host facility and a topside control panel. The panel consisted of hydraulic pumps, motors, valves and accumulators. This was a very successfully and reliable concept, due to its simplicity and relative low cost. In addition, the size and weight of the connecting umbilical hoses, in all but the simplest of systems, resulted in difficulties with transportation and installation. These limitations, together with the increasing requirements to collect reservoir pressure and temperature data, prompted the industry to develop more sophisticated technology, including subsea control systems. The concluded that as the business drivers for deeper water oil fields are increasing the demands on reliability performance of subsea systems, the incremental advantages of the all-electric Subsea Production Control System are set to become a significant factor. In addition, as more stringent offshore fluid legislation are gradually introduced, systems which do not rely on hydraulic fluids, will become an increasingly attractive choice compared to existing MUX E/H Subsea Production Control Systems [14].

A patented work from USA done under Chevron, discusses an extensive subsea production control system diagnosis. A hydraulic control system was used to carry the research on. The authors stated 15 claimed methods on how to identify and diagnose the hydraulic control system problems. Each method is accurate, dependable for analyzing operational parameters of subsea control systems and diagnosis/prediction of failures are provided, in particular, methods for detecting of leaking and/or clogging in hydraulic control system using recorded pressure signal and evaluation response communication strength of field equipment. Therefore, Prediction of failure(s) allows an opportunity to prepare for intervention to minimize the impact of failure before failure occurs [15].

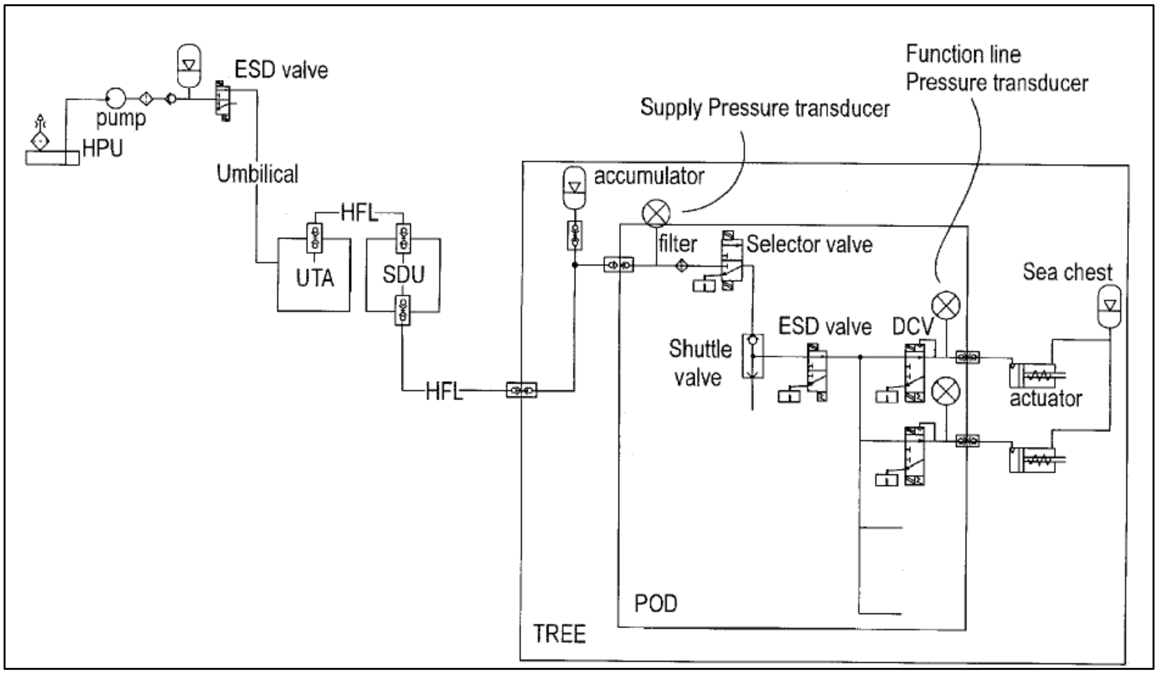

Figure 9. An embodiment of an overall hydraulic control system for a subsea project [15]

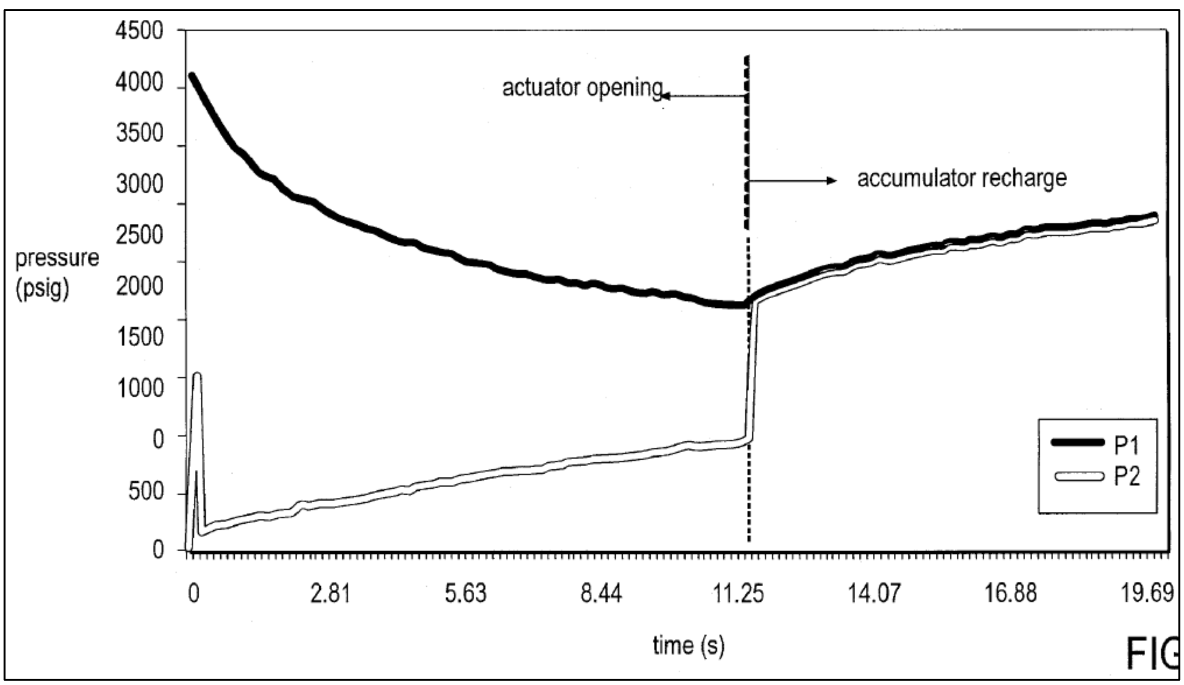

Figure 10. Typical valve signatures for a non-leaking system during actuator opening and recharge [15]

2.4 Literature summary

Below is a tabulated form of the main takeaways from the literature review.

Table 2. Highlighted literature review

Author/s	Year	Title	Finding
NORSOK Standard	2002	Subsea Production Systems	• Response time <30s
P. S Stecki,	2003	"Production Control Systems - An Introduction"	• Key explanations about various hydraulic control systems.
E. W. Locheed Jr and R. Phillips	1979	"A high integrity electrohydraulic subsea production control system"	• Design of electrohydraulic control system. • Electrohydraulic system advantages. • Relation between Hydraplex mode delay times vs. control hose length
T. Pipe	1982	"Subsea hydraulic power generation and distribution for subsea"	• Selection criteria of various production control systems.
H. C. Brian Boles and Dennis Graney	1983	"Subsea Production Controls-The Trend Toward Simplification"	• Direct hydraulic control systems are still advantageous because of its simplicity, in some subsea control scenarios.
M. Theobald and L. Curran	2005	"Benefits of All-Electric Subsea Production Control Systems"	• Disadvantages of hydraulic control systems in challenging deep operation. • Advantages of all-electric control systems.
Baha Tulu Tanju, Hailing An and Karamchandini	2008	"Subsea Control System Diagnosis"	• Diagnostic methods to identify hydraulic control system problem.

Gaps:

All simulation and performance forecasting attempts made dissolves lots of resources whether it in money or time. ITI SimulationX might prove to be a very efficient tool to simulate a subsea hydraulic system with very considerable small resources used.

CHAPTER 3
METHODOLOGY

This research seeks to investigate the behaviors of subsea production control system, signal and shift response times. In order to do this, a type of production control system needs to be identified. From the literature review, the decided production control system to be used for this project work is of a direct hydraulic control system.

Reasons for choosing a direct hydraulic control system:

1. Simplest of all hydraulic system, therefore won't generate a complex simulation model.
2. All other hydraulic systems use its concept, but with more technological utilities for performance improvements.
3. Considered to be the most common control system used, hence, many materials could be found to aid its model development.

This research is done through simulation work. Hence, there is a general framework that can be used in order to approach the project work and its methodology break down. Those elements are shown in Figure 11.

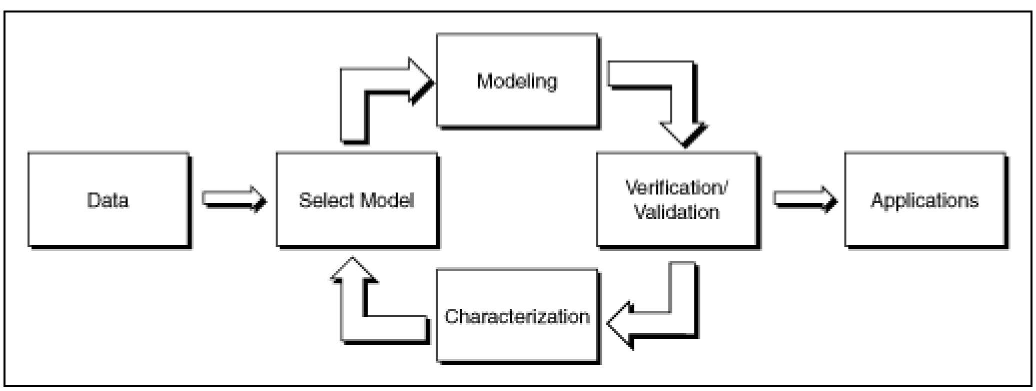

Figure 11. Mathematical modelling flow [16]

Figure 12 illustrates the process flow chart that has been used throughout the research.

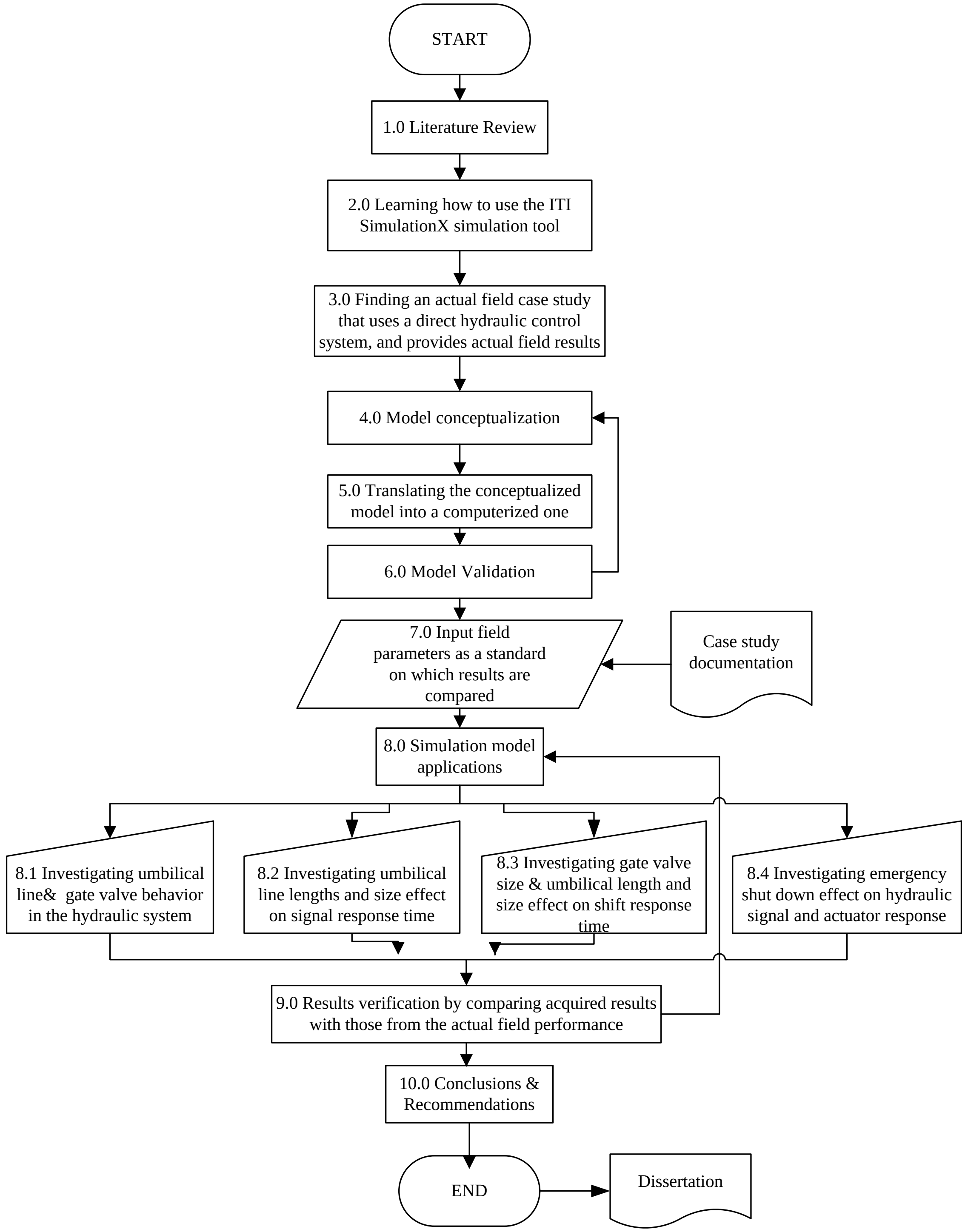

Figure 12. Project activities flow chart

3.1 ITI 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 [7].

Graphical User Interface Overview

The working area of the Agito SimulationX mainly consists of the following windows and areas:

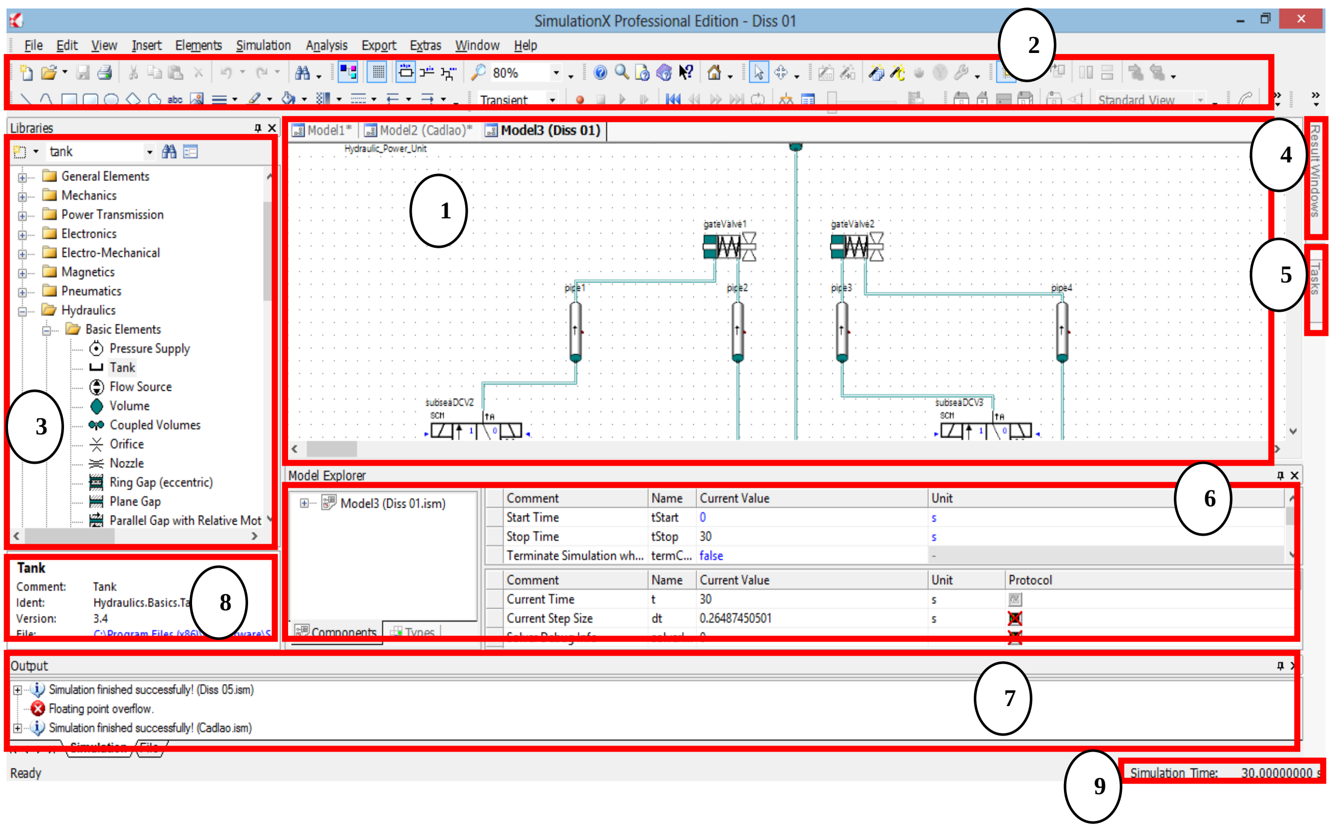

Figure 13. SimulationX GUI overview

1. Building model diagram view.
2. Menu and Tool bar: Access to all tools and commands of SimulationX.
3. Library bar: For selection, management and editing of element types.
4. Scope of tasks: Frequent commands that are used are listed and can be called directly from there.
5. Result windows manager: Facilitates the central management of the result windows of all-opened models.
6. Model explorer: Represents all in the model used components and types.
7. Output area: Shows messages, tracing output, warnings and error messages and logs them.
8. Element details: Shows specifics of the element chosen.

9. Simulation time: Shows the time interval in which the simulation is run through.

Subsea Hydraulics Library

Agito SimulationX provides an extensive subsea hydraulics library that would be greatly helpful when it comes to modelling the subsea control system, Figure 14 shows the subsea library available in the software.

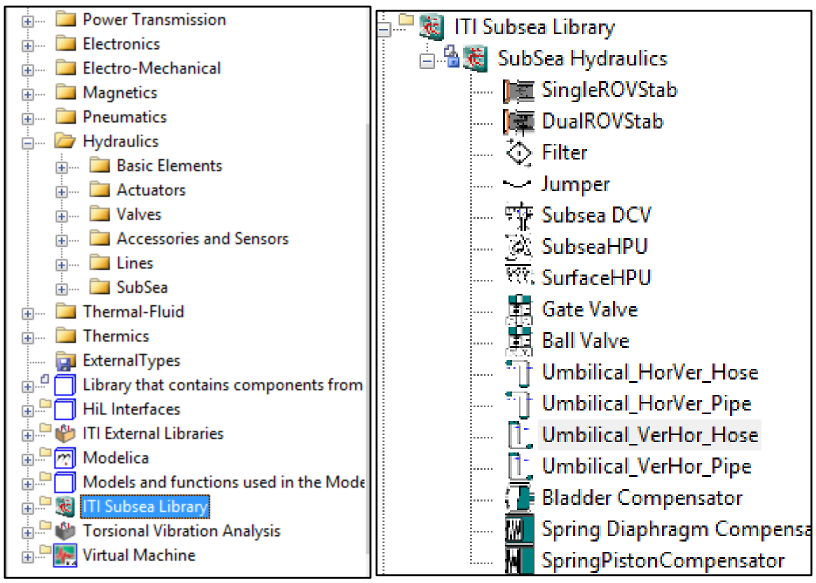

Figure 14. Subsea hydraulics libraries

Building a direct hydraulic subsea control system model using SimulationX

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. Figure 15 shows the usual arrangements of those equipment.

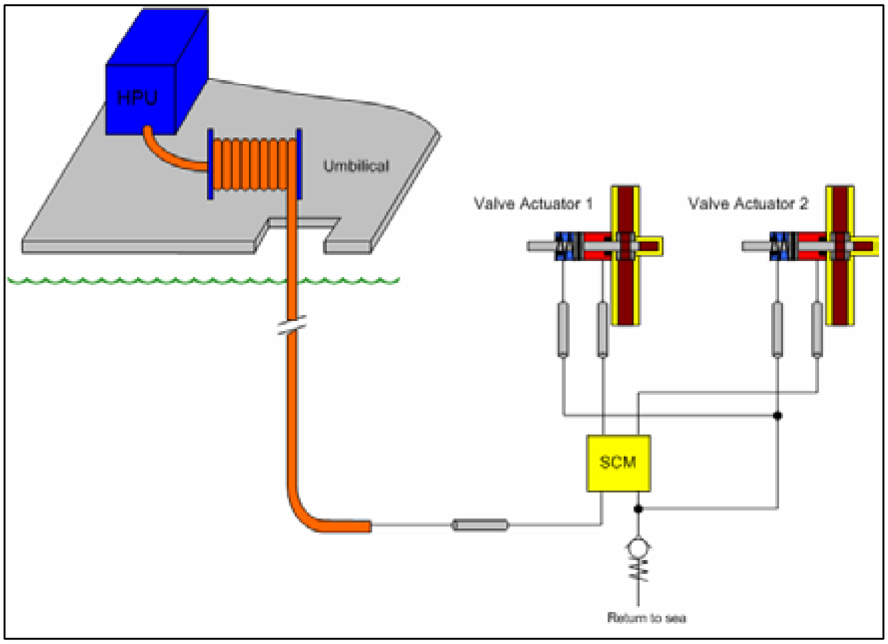

Figure 15. Hydraulic control system sketch [7]

Hydraulic Power Unit (HPU):

The Hydraulic Power Unit (HPU) for these systems is normally located on the deck of the vessel from which the operation is being controlled. The HPU is equipped with electric motors, or sometimes with air drives, that make the HPU able to provide low and high pressure hydraulic supplies for the system [7].

The HPU provides high and low-pressure hydraulic supplies and is usually powered by electric motors, although redundancy is sometimes provided by air drives. The HPU includes tanks, pumps, a contamination control system and hydraulic control valves, etc. There are different types of pumps, but the most common type uses accumulators that are charged by fixed pumps. These pumps which start and stop at various pre- programmed pressures, are controlled by a PLC [9].

Modelling:

HPU is modeled as in Figure 16 in Agito SimulationX. The figure 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.

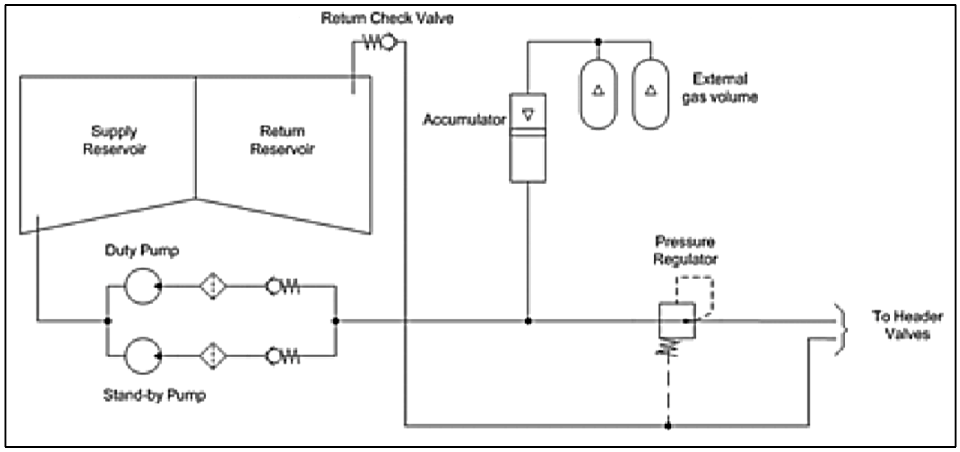

Figure 16. Simplified schematic diagram of a pumping unit (HPU) [7]

SimulationX provides an integrated element to represent the Hydraulic Power Unit, it's represented in the model diagram as in figure. Figure 17 showcase the elements parameters needed to be defined for the HPU to converge.

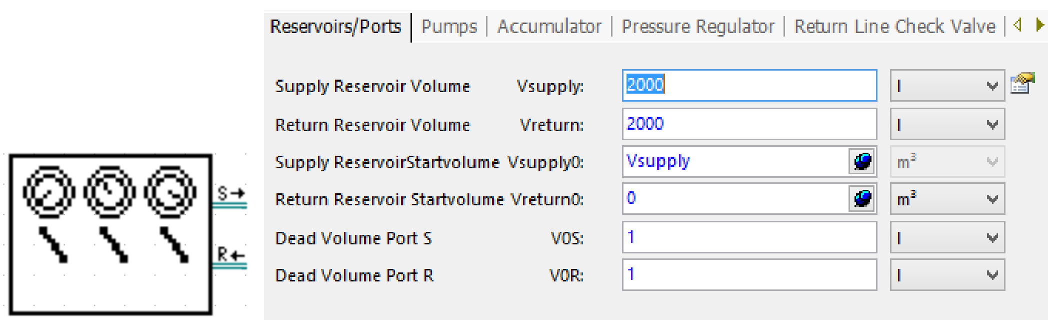

Figure 17. HPU model and parameters

The "S" resembles the Supply line to the HPU, and the "R" resembles the Return line from it.

Subsea Control Module (SCM):

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 [7]. Figure 18 shows a 4 valve SCM arrangements subsea.

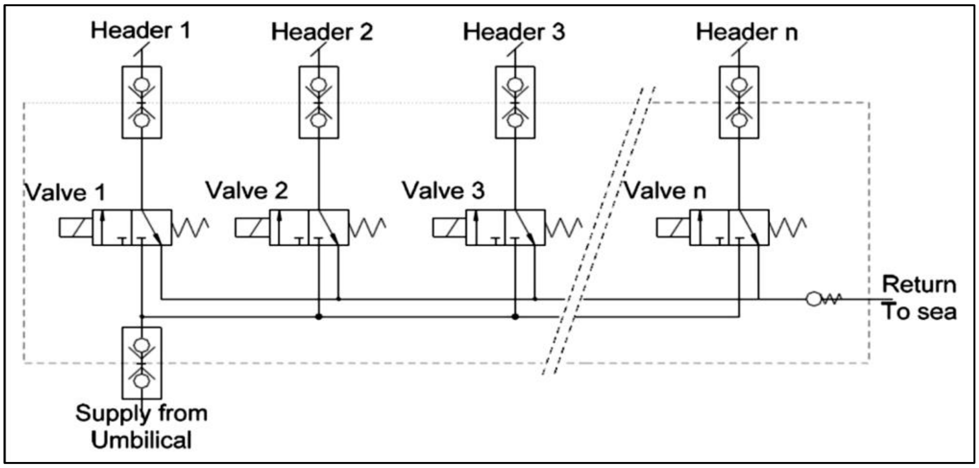

Figure 18. Schematic diagram of Subsea Control Module [7]

Modelling:

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 19).

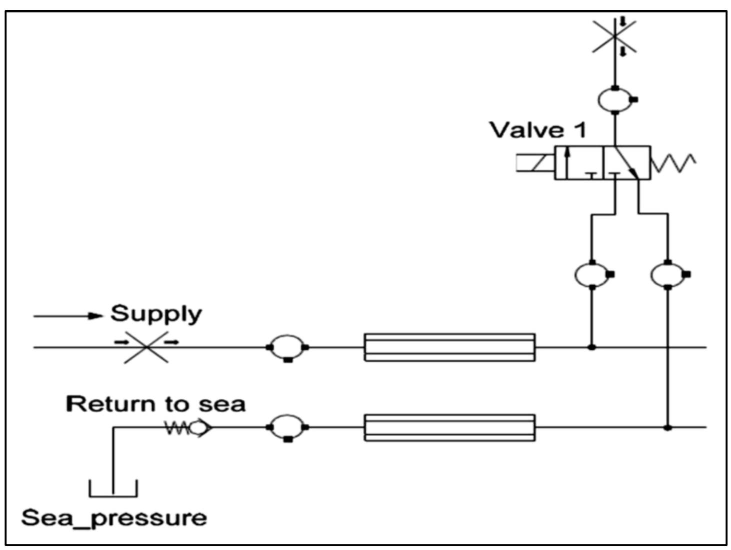

Figure 19. Subsea Control Module model [7]

SCM in SimulationX isn't represented by a single block, but rather a combination of several ones i.e. subsea control module valve, check valve, bladder compensator, orifice and a sea vent. The modelled diagram of SCM is as shown in Figure 20.

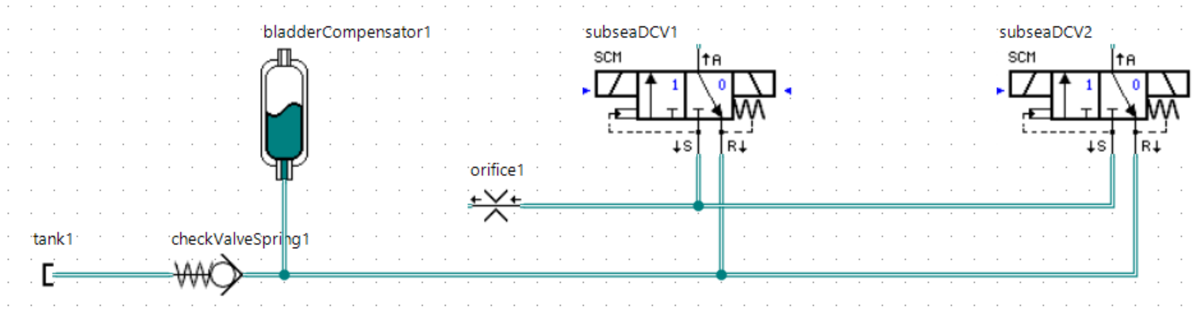

Figure 20. SCM model

Similarly, configuring the elements of the SCM, determines the specifications of the whole system. Figure 21 shows the main configuration specs needed for the subsea control valve.

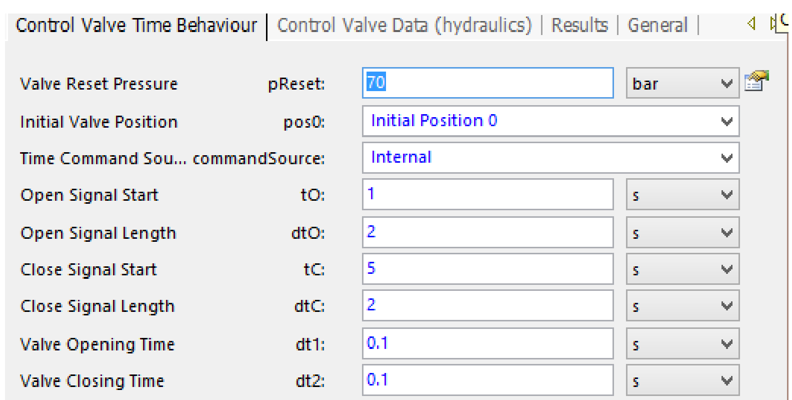

Figure 21. SCM parameters

<u>Gate valve:</u>

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 (Figure 22) 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.

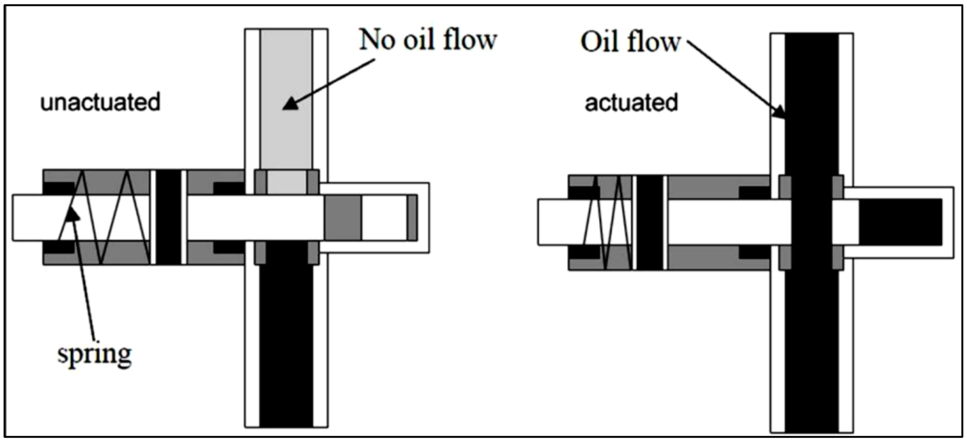

Figure 22. Gate Valve in Close and Open positions [7]

Modelling:

Gate valve model can be considered as an isolated system as in Figure 23. The valve actuator is a linear actuator.

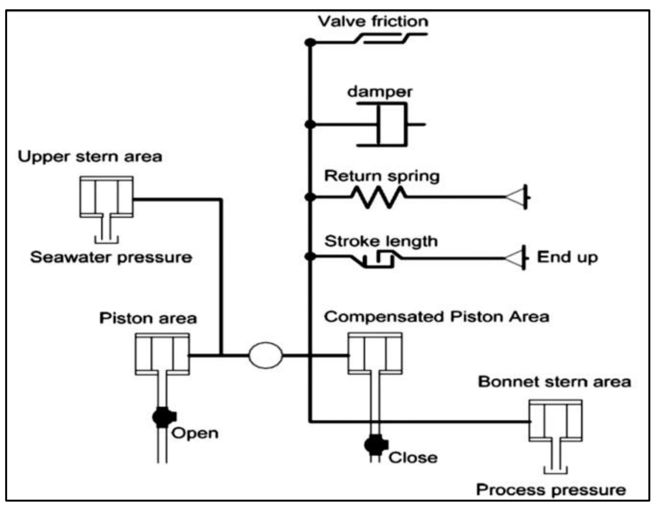

Figure 23. Gate Valve model [7]

Figure 24 shows the modelling element for the gate valve and its main configuration specs respectively.

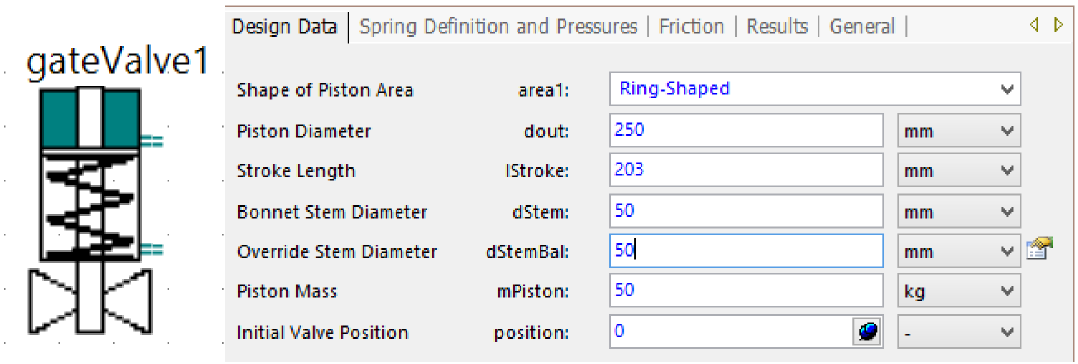

Figure 24. Gate valve model and parameters

Umbilical line:

Umbilical part will use distribution line model where separation of line into elements. 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 (Figure 25). Importance of this distribution line model is when pressurization and bleeding of lines are use in the Emergency Shutdown (ESD).

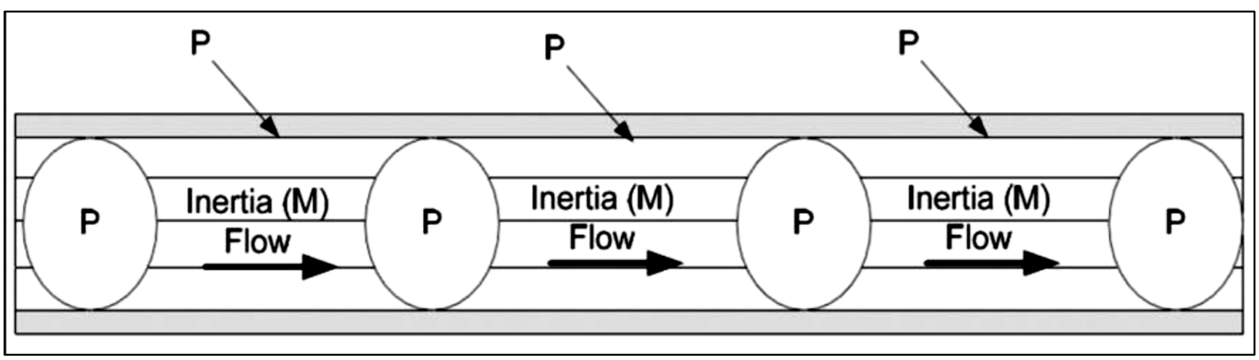

Figure 25. Distributed line model [7]

In order to configure the umbilical in SimulationX, certain parameters are needed to be understood for its geometry. These parameters are shown in Figure 26.

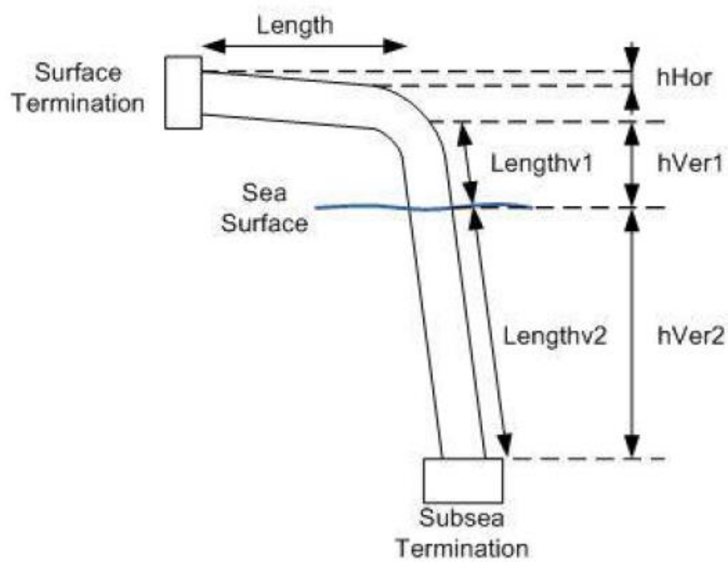

Figure 26. Umbilical line geometry configuration [17]

Figure 27 shows the modelling element for the umbilical line and its main configuration specs respectively.

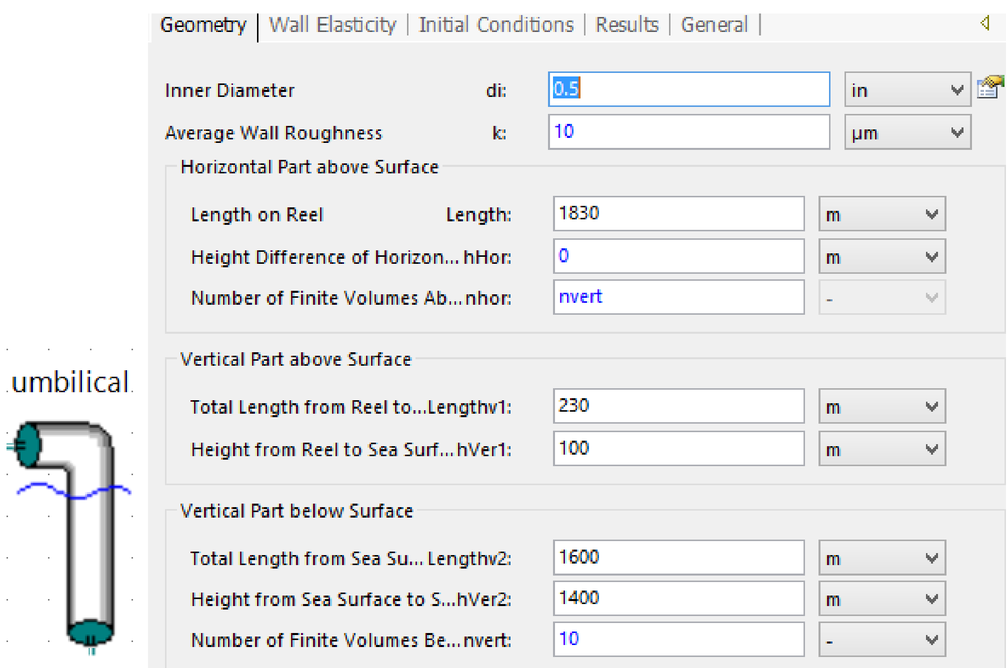

Figure 27. Umbilical line model and parameters

3.2 Case study: Cadlao field

The Cadlao oil field (Figure 28) was originally discovered by Amoco in 1977 and subsequently developed for production using a floating production, storage & offloading (FPSO) facility in 1981. Two wells produced an aggregate of around 11 mmbbl of premium (47° API) crude oil by natural flow over the ensuing eleven years [18].

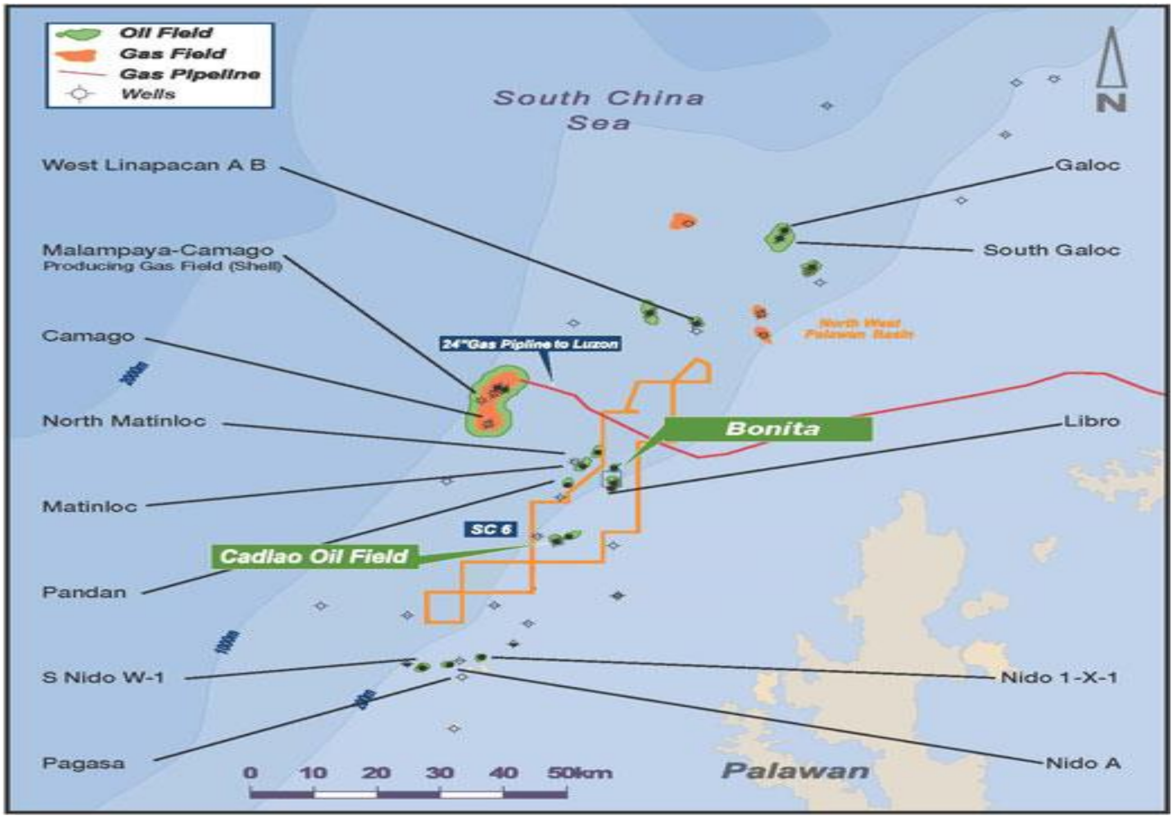

Figure 28. Cadlao Project – Philippines NW Palawan Basin [19]

Why Cadlao Field as a case study?

1. A series of tests were conducted at the Cameron Iron Works plant in Berwick, Louisiana prior to shipment of the tree to Cadlao. The purpose of the testing was to demonstrate the suitability of the control system selected for the Cadlao field and to confirm response predictions [19]. This aids in comparing the results acquired with an actual experimented system.
2. The designers' technical experience with the field are very well documented. This enables a strong understanding of the system used and its behaviors.

3. Documents available presents data and information regarding both a testing facility for the control system, as well as the actual control system used in Cadlao.

Total system response time:

Total system response time is the interval between the initiation of the hydraulic command at the surface and the end of the valve shift subsea i.e. Signal time added to shift time.

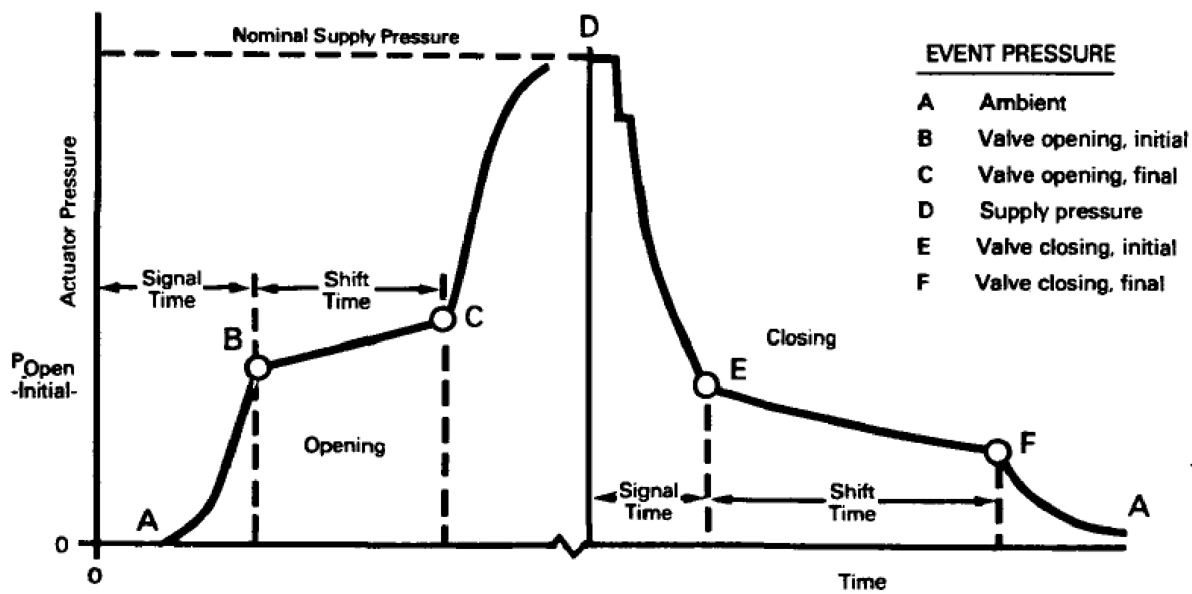

Figure 29. Signal & Shift response time [19]

Signal Time:

Signal transmission time is the time for the pressure wave to travel down the control line linking the surface panel to the subsea actuator and for the pressure to build up (or decay) to the level necessary for the valve actuator to start to shift.

Shift Time:

Shift time is the time required for the valve gate to travel from one end limit to the other. During this interval, the control line must transport the actuator's displacement volume.

3.2.1 Testing arrangement

The experimental schematic used in Louisiana by Amoco's engineers is shown in Figure 30. Conditions offshore were duplicated as much as practical. The 3/8-in. 00 stainless tubing on the tree was not disturbed and pressures were monitored where the umbilical hoses were connected to the diver-operated junction boxes at the flow-line base. An 8-track recorder was used to simultaneously plot the inputs from the four pressure transducers and the two turbine flow-meters. Signal pressure at the tree was plotted in two ranges to facilitate interpretation.

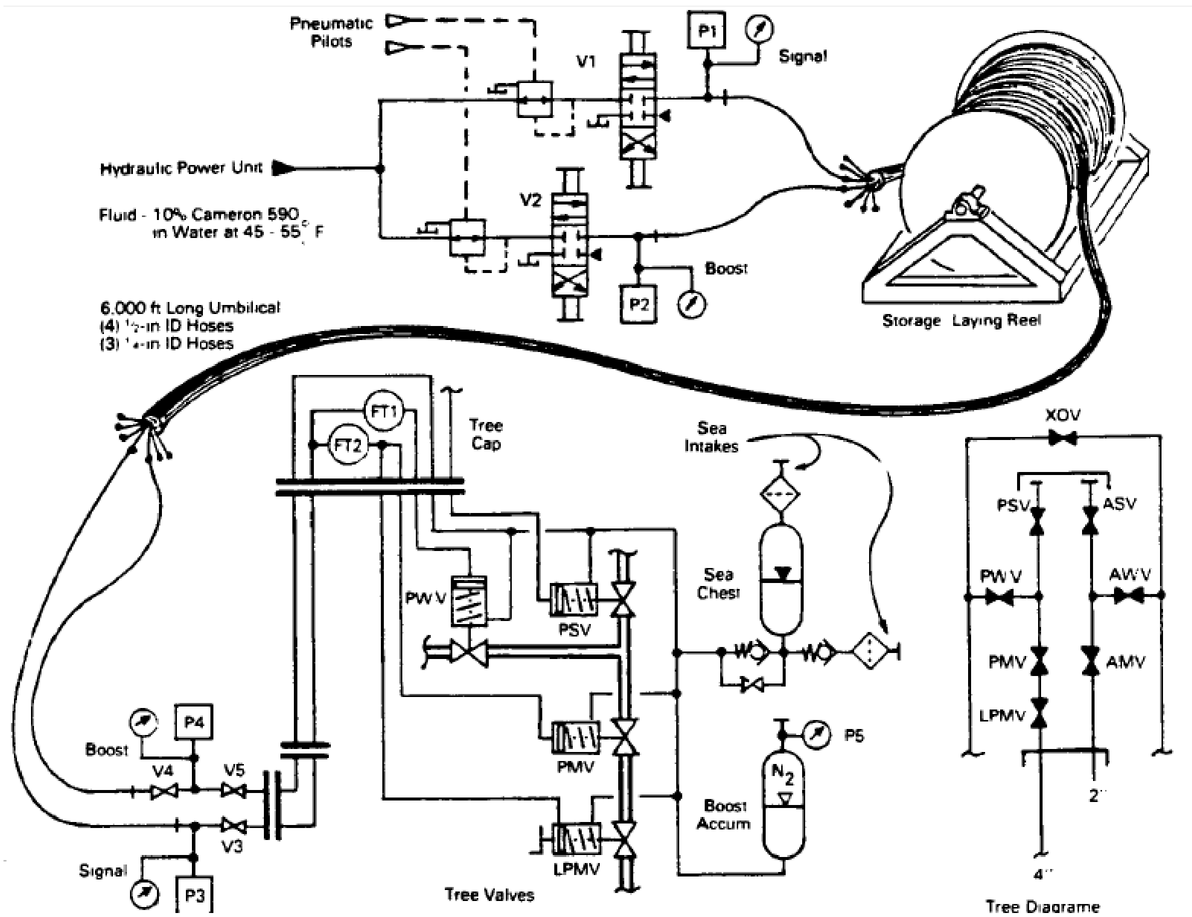

Figure 30 Schematic of Test Arrangement [19]

3.2.2 Model conceptualization

From the read literature review, as well as the study of the control system used for the case, a schematic diagram (Figure 31) representing the control system is generated to identify the elements needed included in the simulation model and their connecting relation.

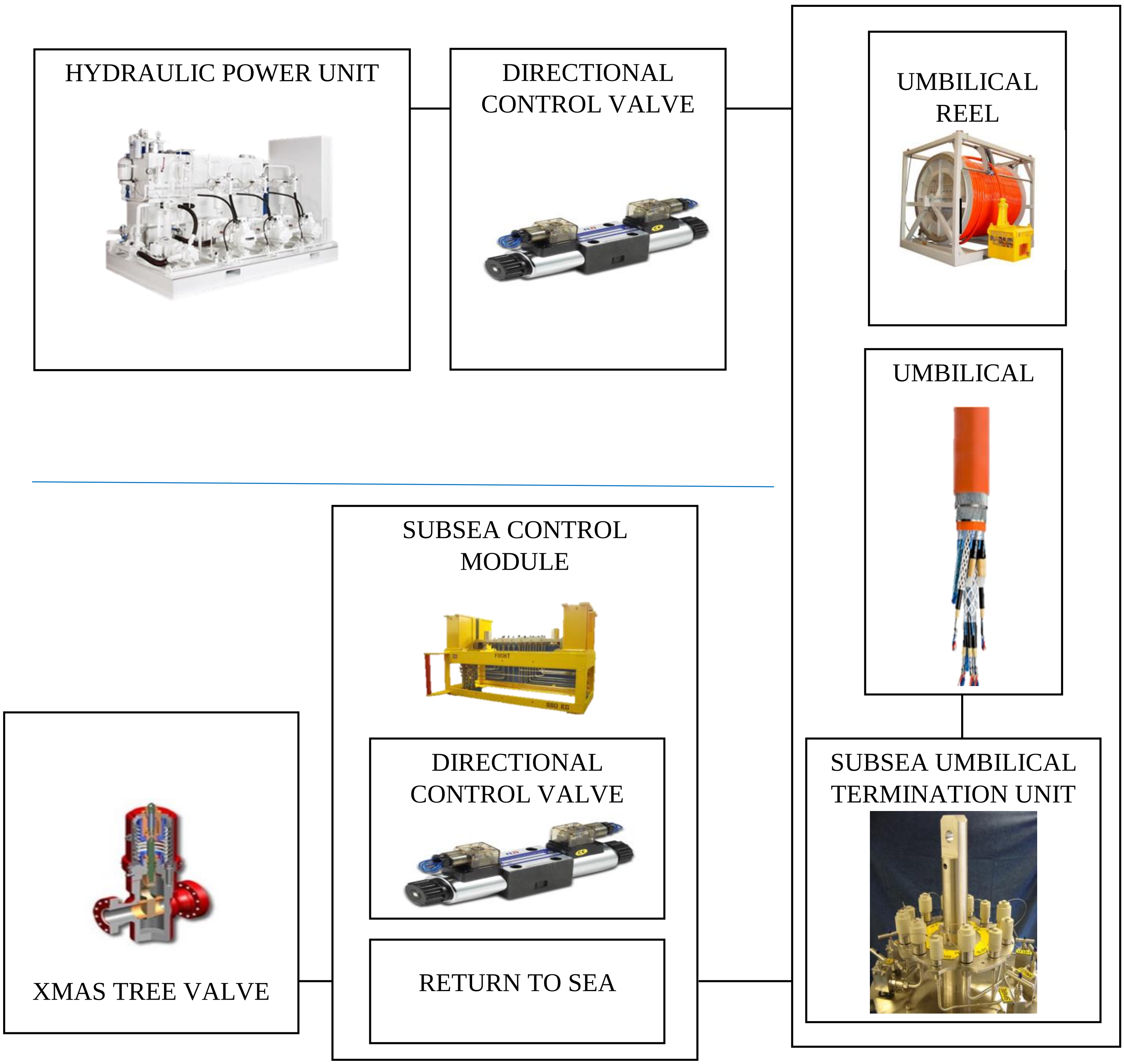

Figure 31. Model conceptualization

3.2.3 Translating the conceptualized model into a computerized one

From the model concept developed in Figure 31, a model was built on the SimulationX software (Figure 32) with the model plan and parameters known, the model is only left with building the blocks in the SimulationX software.

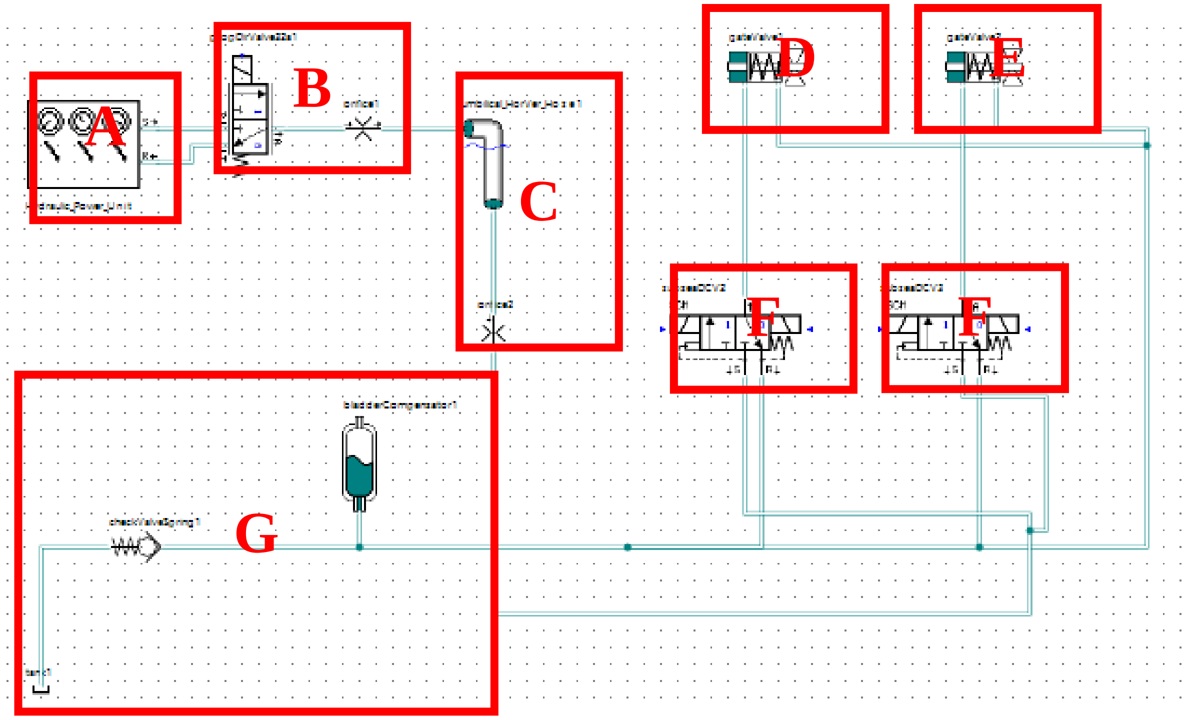

Figure 32. Simulation model

The model is constructed based on the simulation model concept, and consists of the following:

A. Hydraulic Power Unit.
B. Directional Control Valve.
C. Umbilical.
D. Xmas tree gate valve #1 (fully closed).
E. Xmas tree gate valve #2 (fully open).
F. Subsea Control module: Distribution Valve.
G. Subsea Control Module: Return to sea.

3.2.4 Model Validation

The model concept was generated upon identifying the main elements and equipment responsible for the performance of the direct hydraulic control system used in the Cadlao field. The computer generated model contains all the elements specified in the model concept. Hence, the computer generated model resembles and represents the equipment used in the Cadlao field and is capable of being provided with the parameters and configurations of the equipment used in the field. Moreover, the model generated (Figure 32) is similar to the direct hydraulic control system model provided by the Agito SimulationX manual. This shows that the model generated is capable of portraying direct hydraulic control system behaviors.

3.3 Model configuration & parameters

To stand upon the effect of changes in various subsea control parameters, a standard or base configuration had to be put in place. Below are the configurations for the direct hydraulic control system acquired from the Cadlao field case documentations [19].

3.3.1 Hydraulic Power Unit

The HPU used is with a return line check valve and with the below configuration.

Table 3. HPU configuration

Reservoir/Ports	
Supply reservoir volume	2000 lit
Return reservoir volume	2000 lit
Pumps	
Duty pump flow-rate	10 lit/min
Accumulator	
Volume	250 lit
External gas volume	250 lit
Pressure regulator	
Set pressure	1500 psi
Check valve	
Cracking pressure	2 bar
Full opening pressure	3 bar

3.3.2 Topside Umbilical: Surface Directional Control Valve

The surface directional control valve is with the following configuration

Table 4. Surface DCV configuration

Dynamics	
Natural frequency	10 Hz
Damping ration	0.8
Stroking	

Stroke signal	Normalized signal

3.3.3 Umbilical

A hose line umbilical was used for this study, with a standard configurations as follows:

Table 5. Hose line umbilical configuration

Geometry	
Inner Diameter	0.5 in
Length on Reel	500 ft
Length from reel to sea surface	25 m
Length from sea surface to sea bed	6000 ft
Height from sea surface to bottom	1 mile
Hose type	Reinforced Kevlar
Bulk modulus	700 MPa

3.3.4 X-mas tree gate valve

The X-mas tree gate valve was configured according to the following standard configurations:

Table 6. X-mas tree gate valve configuration

Shape of piston area	Ring shaped
Piston diameter	4 in.
Spring stiffness	1100 N/mm

CHAPTER 4
RESULTS AND DISCUSSION

The simulation results should enable the understanding of the direct hydraulic control system behavior, signal and shift response time.

Two equipment were mainly focused on, Umbilical and the Gate valve, their behavior and effects on the system. A closer look was given at the umbilical line configuration as well as the X-mas tree gate valve and its actuator piston, and their effects on signal and shift response time of the system.

To study these, the varying parameters affecting the signal and shift response times, were identified as follows:

1. Umbilical hose line length.
2. Umbilical hose line diameter.
3. Gate valve piston actuator size.

Each parameter value was altered to test the effect of its variation on its relevant response times.

Moreover, an Emergency Shut Down investigation was made to understand how fast the system can return to its initial state when a sudden shut off in the hydraulic power provided is made. This is considered as critical information for safety measures in the oil field.

It’s very important to understand how true the results obtained are from the reality, or maybe how far are they. In order to do that, throughout the results and discussion section, a continuous comparison/verification whenever possible is done between the simulated results obtained by SimulationX and the experimental results achieved. This is to understand the closeness & relativeness of the simulated results with that of acquired from reality.

However, getting exact or sometimes near exact results couldn’t be possible due to the following reasons:

1. Lack of detailed information about the system operating conditions.
2. Assumptions made by the author to make up for missing information.
3. Extra losses or external affecting factors on the experimental system that would affect its results from the mathematically simulated one.

4.1 System behavior

(Process 8.1 in flow chart)

4.1.1 Gate valves

To better understand the gate valve operation, a graph recording the actuator stroke length, opening chamber pressure and the spring chamber pressure is recorded. Figure 33 shows the responses taken from the closed gate valve that want to be actuated.

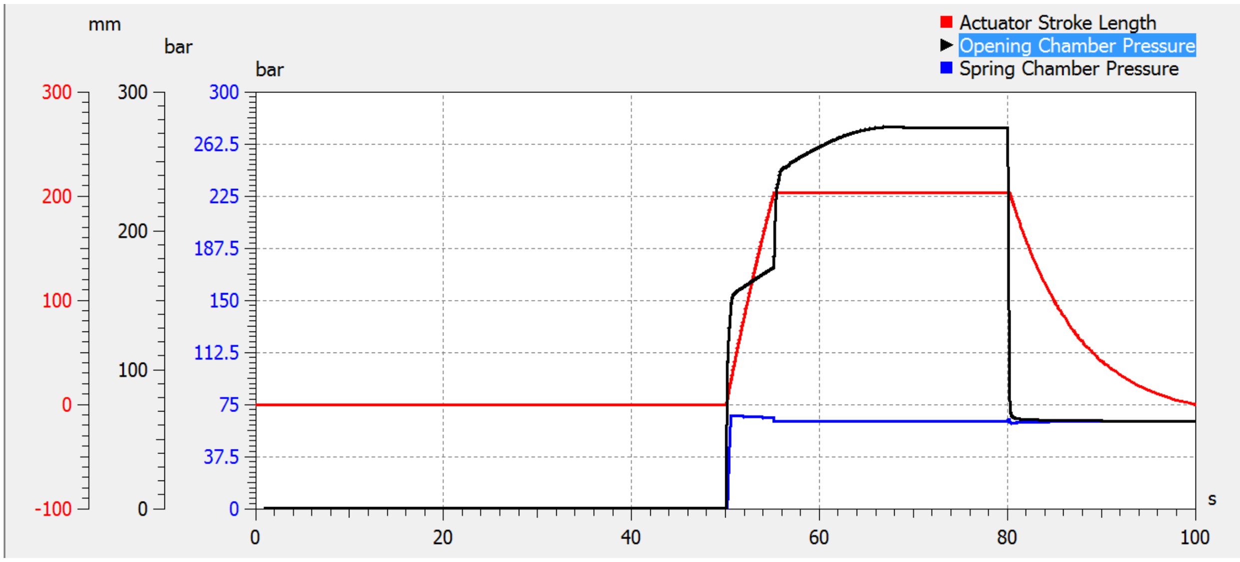

Figure 33. Pressure response curves when opening a 4 inch gate valve #1

Figure 33 shows the pressure and position during the operation of the gate valve. The opening time is approximately 55 seconds and the minimum pressure differential over the actuator piston is approximately 150 bar when opening. It’s also observed that the open chamber pressure faces a bit of disturbance during the pressure build up and fully actuating the actuator.

However, it’s very important to take a closer look at the pressure responses happening over the other open gate valve and how it’s affected by the actuated opening of the first valve.

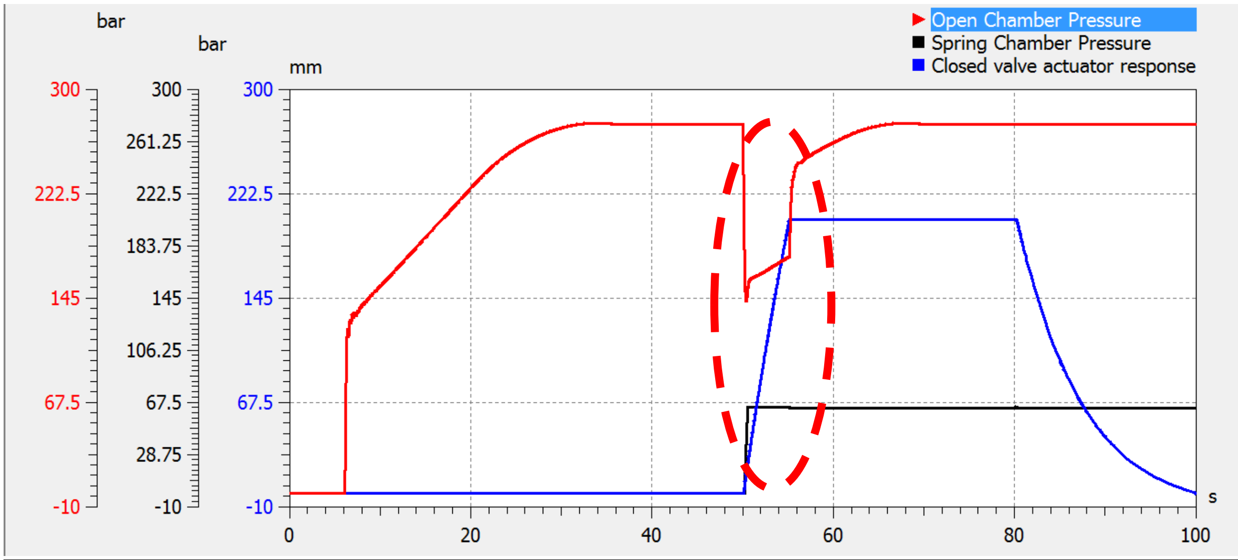

Figure 34. Pressure response curves for the open gate valve #2

In Figure 34 we can see a clear drop in pressure when the neighboring gate valve is opened. The pressure drop across the actuator piston is 131 bar.

As the directional control valve opens, pressure build up to supply 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.

As shows in Figure 34, the pressure in the open chamber increases rapidly as the valve open signal reaches the valve. Accordingly, a sudden pressure drop is observed in Figure 34, where the open gate valve #2 notices a sudden drop as well in the pressure supplied to it. The pressure drop is approximately equal to the amount of pressure used in actuating gate valve #1.

The achieved results aren't that far from those acquired through the experimental approach followed by operators of the Cadlao field in reality. As shows in Figure 35, they achieved a very similar gate valve behavior of that achieved in the simulation.

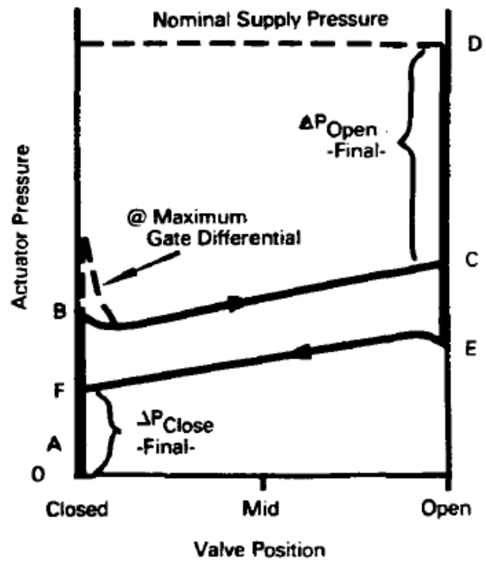

Figure 35.Gate valve behavior from Cadlao field [19]

4.1.2 Umbilical line pressurization

It's very important to the system to identify the amount of time needed for the hydraulic system to stabilize the pressure running through it before we move on to study factors affecting the stable hydraulic system. A graph investigating the amount of time needed by a 6000ft ½ inch umbilical hose line needs to stabilize.

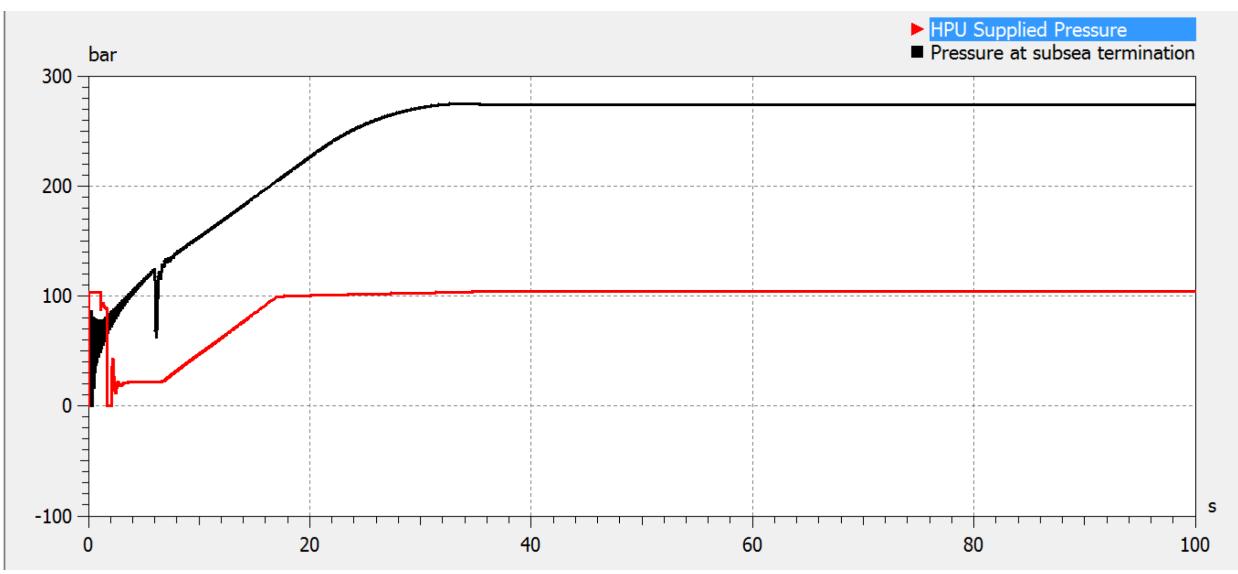

Figure 36. Umbilical hose line pressurization

Using the standard system configuration, the umbilical hose line needed approximately 35 seconds to stabilize.

4.2 Signal time

(Process 8.2 in flow chart)

4.2.1 Umbilical line diameter size effect

To demonstrate the effect of changing parameters into the response time taken by the umbilical to stabilize, the umbilical hose line diameter was altered to three varying dimensions which are 0.25 inch, 0.325 inch and 0.5 inch respectively. The previous arrangement yielded the following graph.

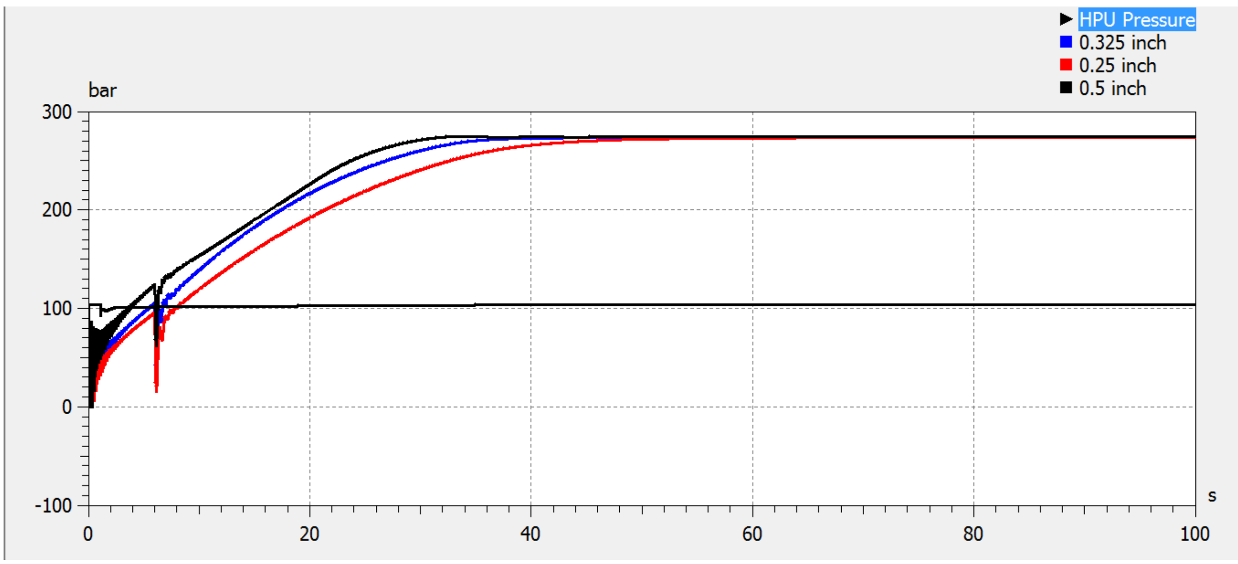

Figure 37. Umbilical line hose diameter (inch) vs. steady state time (s)

The following table shows the difference in time taken to steady state according to the specific hose line diameter size.

Table 7. Hose line diameter signal time effect

Hose line diameter	Time to steady state
0.25 inch	51 seconds
0.325 inch	37 seconds
0.5 inch	32 seconds

It's noticed that variations in hose line diameter affects the time taken by the umbilical to reach steady state. Hence, time to steady state is sensitive to hose line diameter size.

4.2.2 Umbilical line length effect

However, varying the hose line length makes a huge difference as well in the amount of time needed by the umbilical line to stabilize. To demonstrate the effect of changing parameters into the response time taken by the umbilical to stabilize, the umbilical hose line length was altered to three varying dimensions which are 6000ft, 12000ft and 18000ft respectively. The previous arrangement yielded the following graph.

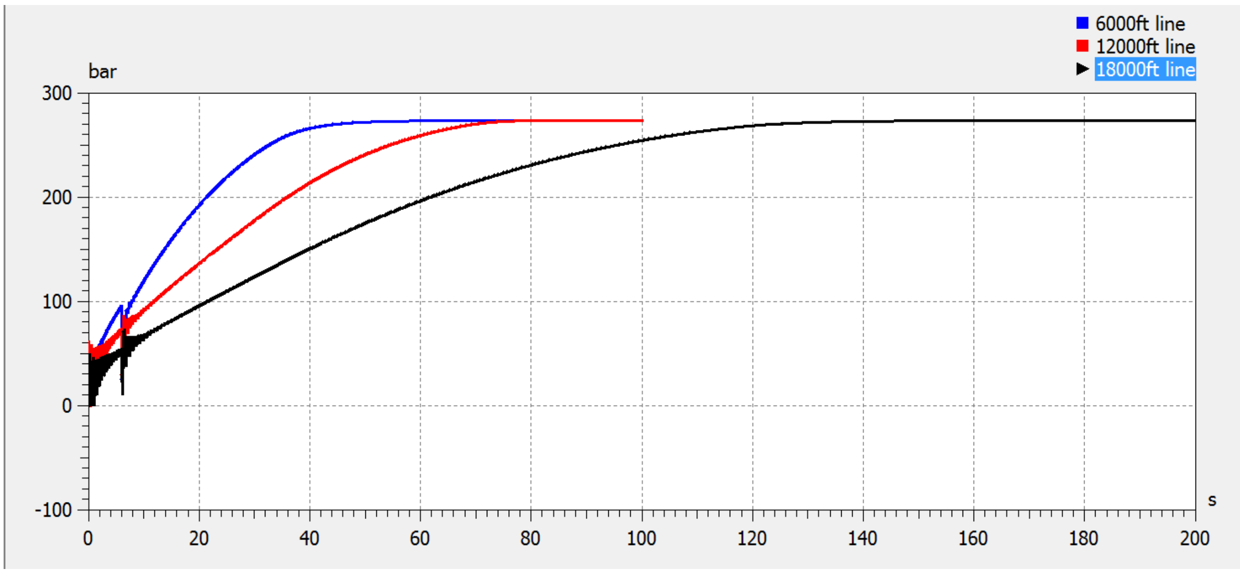

Figure 38. Effect of varying hose line length to the signal time

The following table shows the difference in time taken to steady state according to the specific hose line length.

Table 8. Hose line length effect on signal time

Hose line length	**Time to steady state**
6000 ft	32 seconds
12000 ft	75 seconds
18000 ft	140 seconds

It’s noticed that variations in hose line lengths affects the time taken by the umbilical to reach steady state. Hence, time to steady state is sensitive to hose line diameter size.

A very critical element of the whole hydraulic system is to identify how long would it take for the system with its umbilical to reach a steady state. As this will deeply affect the response time taken by the valves to be actuated.

Figure 36, showcases the time taken by the hydraulic umbilical line to reach a steady state vs. that of the pressure coming from the Hydraulic Power Unit. It’s noticed that there is an apparent increase between the supplied pressure by the HPU and that at the subsea termination. This increase of about 170 bar is accounted for the subsea pressure provided by the sea water at a depth of 1 mile.

Upon studying the effect for changing the umbilical line diameter and its length as in Figure 37 and Figure 38 respectively, it’s been found out that increasing the diameter of the hose line decreases the time taken for steady state. This is due to the increase area in which the hydraulic fluid flow, allowing the line to reach its required pressure in a faster manner.

However, by increasing the length of the umbilical line, a longer time is taken to reach the steady state.

Comparing the acquired results with that of the Cadlao field (Figure 39) shows a near results between the simulated and the experimental findings back then. The Cadlao field got the following results when comparing length and hose diameters and their effects on signal time.

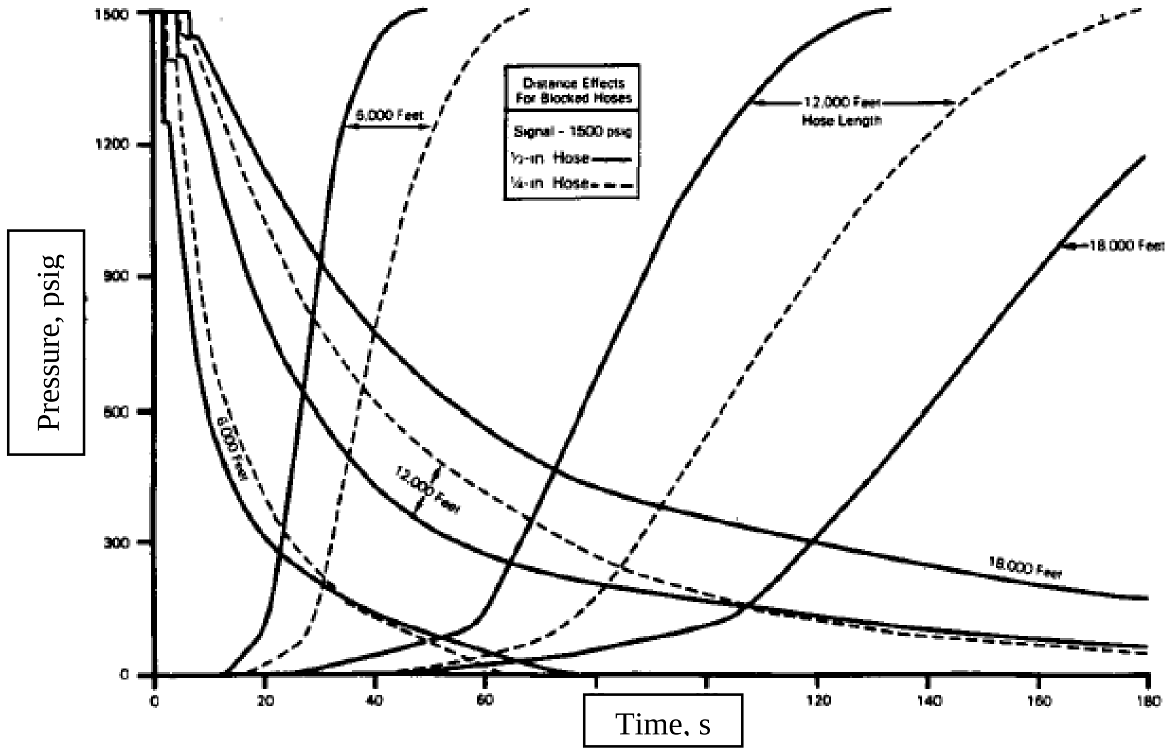

Figure 39. Effect of hose size and length on signal response from Cadlao [19]

For a 6000ft ½ inch diameter hose, the response time from Cadlao field is about 45 seconds, while that from the simulation is around 35 seconds, a difference of 10 seconds is observed. For a 12000ft ½ inch diameter hose, the response time from Cadlao field is around 130 seconds, while that in the simulation is around 80 seconds, a significant difference of 50 seconds is observed. For an 18000ft ½ inch diameter hose, the response time from Cadlao field exceeds 200 seconds, while that from the simulation is around 140 seconds.

Even though the simulated signal response results may not perfectly coincide with that from the experimental results, but the simulation does agree with the experimentations in the behavior and expected outcomes of the variations. Which indicates that the reason of the mismatch is due to incomplete information needed for a more accurate simulation results.

4.3 Shift time

(Process 8.3 in flow chart)

4.3.1 Umbilical line length effect

We can study the effect of the hose line length on the signal response time through keeping all the model configurations the same and varying only the umbilical hose line length and record the response times taken for the valve to actuate and fully open.

For the sake of proper behavior study, 3 parameter variations were put into account. Those variations were for a 6000ft, 12000ft and 18000ft umbilical hose line.

After running the simulations, Figure 40 showcases the relation between gate valve actuator stroke movements vs. time was recorded.

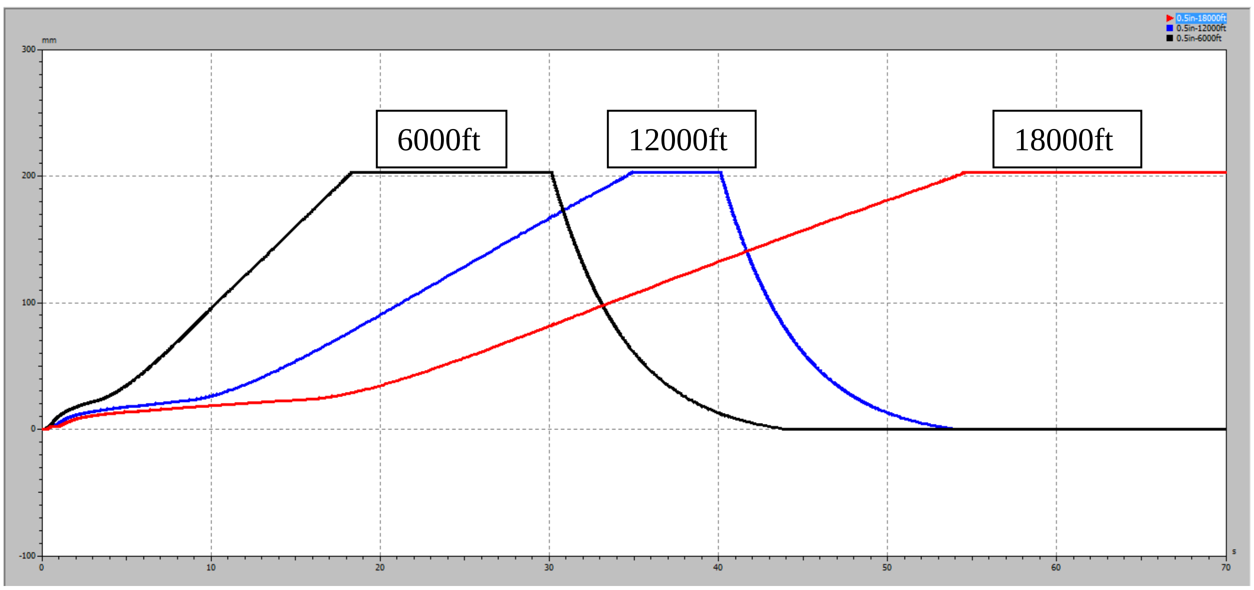

Figure 40. Effect of hose line length, valve actuator stroke (mm) vs. time (s)

The opening response time recorded is the time taken for the gate valve actuator to fully open by the hydraulic signal. The full open stroke for the valve actuator is 203 mm.

It found that the valve response time due to variation of hose line length as follows:

Table 9. Hose line length effect on actuator opening time

Hose line length	**Time to fully open**
6000ft	18 seconds

12000ft	36 seconds
18000ft	55 seconds

From the results obtained in Table 9, it’s observed that varying the umbilical hose line length has a direct impact on the signal response time. As the length of the hose line increases, the valve actuator takes more time to fully open with a 203 mm stroke.

As the length of the line increases with the fixed amount of pressure provided by the HPU to the system (1500psi), the hydraulic fluid will take more time to cover the extra distance needed to be covered, hence, taking more time to pass through the umbilical hose line.

4.3.1 Umbilical line diameter size effect

We can study the effect of the umbilical hose line diameter on the signal response time through keeping all the model configurations the same and varying only the umbilical hose line diameter and record the response times taken for the valve to actuate and fully open.

For the sake of proper behavior study, 3 parameter variations were put into account. Those variations were for a 5 inch, 7 inch and 9 inch hose line diameters.

After running the simulations, Figure 41 showcases the relation between gate valve actuator stroke movements (mm) vs. time (s) was recorded.

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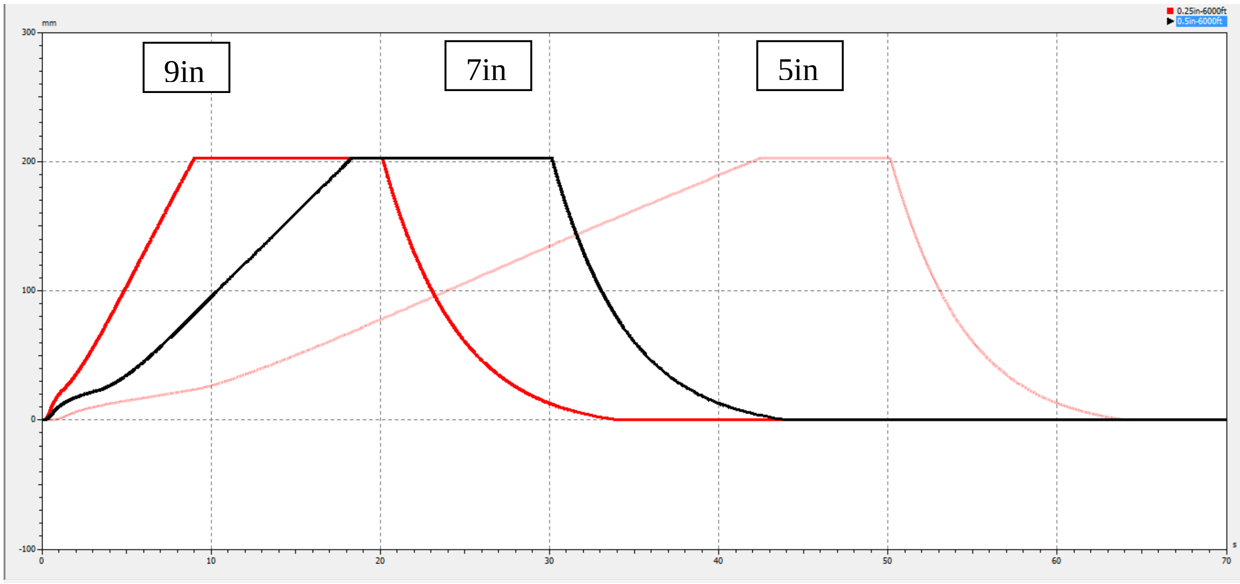

Figure 41. Effect of hose line diameter, valve actuator stroke (mm) vs. time (s)

The opening response time recorded is the time taken for the gate valve actuator to fully open by the hydraulic signal. The full open stroke for the valve actuator is 203 mm.

It's found that the valve response time due to variation of hose line diameter is as follows:

Table 10. Hose line diameter effect on valve actuator opening time

Hose line diameter	**Time to fully open**
5in	43 seconds
7in	18 seconds
9in	8.4 seconds

From the results obtained in Table 10, it's observed that varying the umbilical hose line diameter affects the signal response time. As the diameter of the hose line increases, the valve actuator less time to fully open with a 203 mm stroke.

This inverse relation is related back to simple fluid dynamics. As the hose line diameter increase, it'll allow room for a larger volume of hydraulic fluid to pass through it, hence, aid in moving the actuator to reach its full open position faster than a smaller diameter umbilical hose.

4.3.3 Gate valve actuator piston size

Not only the umbilical and its configurations affect the signal response time, but varying the size of the piston of the gate valve actuator can deeply affect the opening time of the actuator.

Now, all the model configurations are kept the same and vary only the actuator piston size. The recording are then taken to identify the time the valve took to actuate and fully open.

For the sake of proper behavior study, three parameter variations were put into account. Those variations were for a 5 inch, 7 inch and 9 inch piston diameters.

After running the simulations, Figure 42 showcases the relation between gate valve actuator stroke movements (mm) vs. time (s) as recorded.

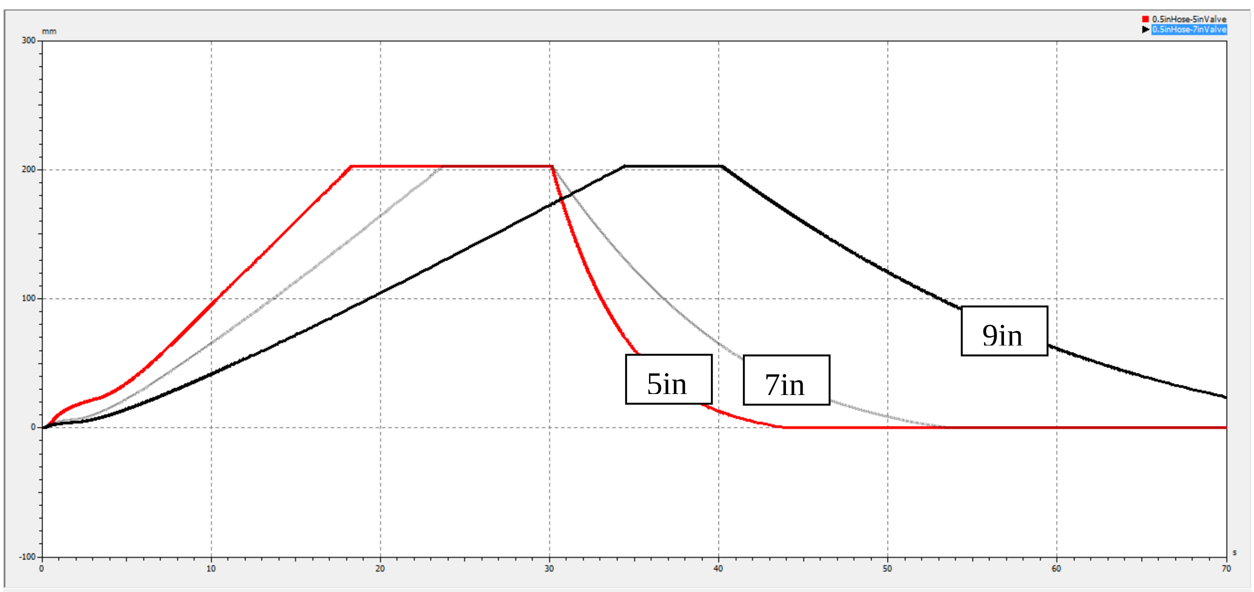

Figure 42. Effect of valve size on signal response, valve actuator stroke (mm) vs. time (s)

The opening response time recorded is the time taken for the gate valve actuator to fully open by the hydraulic signal. The full open stroke for the valve actuator is 203 mm.

It's found that the valve response time due to variation in valve actuator piston size is as follows:

Table 11. Valve actuator size effect on actuator opening time

Actuator piston size	Time to fully open
5in	18 seconds
7in	23.5 seconds
9in	34 seconds

Through examining the results obtained from Table 11, we can identify the general behavior resulting from varying the gate valve actuator size and its effect on the actuator response time.

It's observed that by increasing the actuator piston size, the hydraulics signal takes more time to operate the actuator to its fully open position. This is mainly due to the fact that to move a larger area requires a larger force to be exerted on it by the hydraulic fluid. To provide such force, the system needs to build up more volume to increase the force to that required to move the piston.

4.4 Emergency Shut Down Investigation

(Process 8.4 in flow chart)

What will happen if a system failure occurred and no hydraulic fluid pressure is being supplied by the HPU?! An answer to this question is of great importance as every control system needs to be tested to know the reaction of the subsea valves as well as the umbilical if an operating/technical failure occurs.

To test ESD for the system, all the hydraulic fluid will be vented and the sea surface DCV will close the path of fluid that's going into the umbilical. Figure 43 was recorded as a result of this situation in the case of 6000ft ½ inch umbilical line.

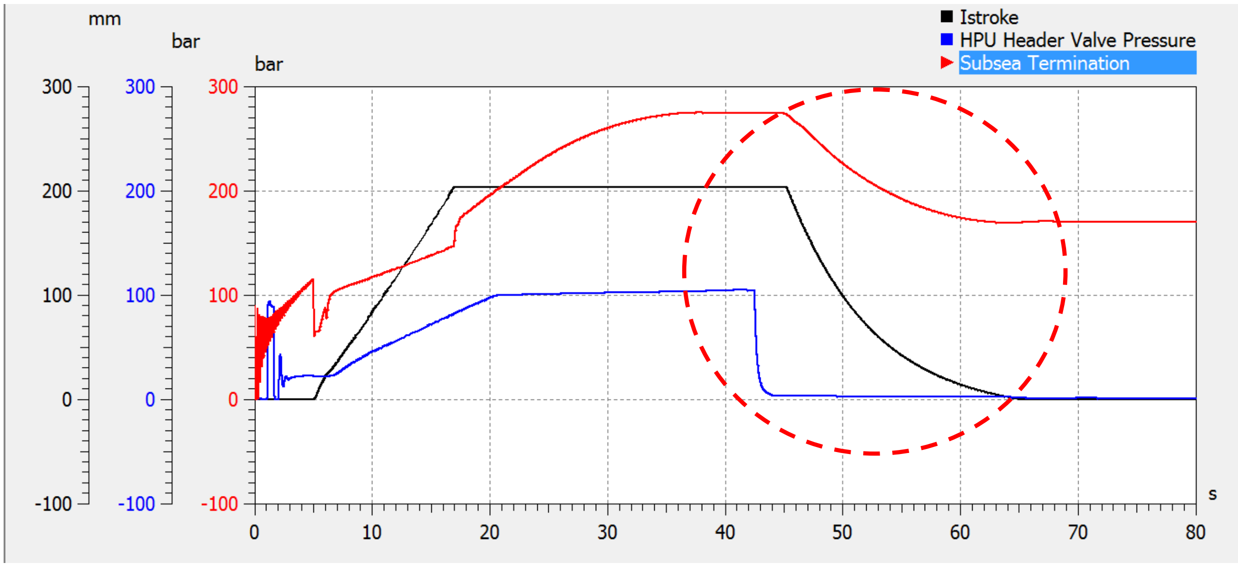

Figure 43. Emergency Shut Down (ESD) investigation

As the signal from the HPU is intercepted and killed by the Header Valve, the reaction of the components under study was as follows:

Table 12. ESD effect on initial state response

Item	**Time taken to initial state**
Umbilical Pressurization	20 seconds
Valve actuator stroke	20 seconds

At the moment when the HPU Header Valve vents the hydraulic circuit at the surface, the pressure in the umbilical lines starts to fall until it finally reaches its initial state at approximately 170 bar in around 20 seconds. Concurrently, the gate valve actuator starts to close again in the same period of time.

CHAPTER 5
CONCLUSIONS & RECOMMENDATIONS

5.1 Conclusions

Agito SimulationX is a great tool for subsea control system modelling and simulation. Through its extensive libraries and online support, it was possible to develop a direct hydraulic subsea control system with all its components. Direct hydraulic control system still proves to be a viable subsea control option for conditions that aren't considered harsh or extra deep.

By using the Agito SimulationX software, it's possible to simulate operating parameters of a subsea direct hydraulic control system to validate/acquire production gate valves response time as well as testing the correlations between umbilical lines, surface HPU and subsea control modules to the gate valve response time. These information are considered critical for subsea control systems designer or operator.

Through the simulation study carried on Cadlao field using Agito SimulationX, conclusions regarding the model's behavior, signal and shift response times are made:

1. Pressure in the open gate valve open chamber suffers pressure reduction as the neighboring gate valve receives opening hydraulic signal.
2. Umbilical lines takes times to reach a steady state pressurization. The reach of this steady state is also known as signal response time, which correlates to full signal pressure reaching the umbilical subsea termination unit.
3. Control system signal response time is directly proportional to umbilical hose line length, and inversely proportional to umbilical hose line diameter.
4. Control system shift response time is directly proportional to umbilical hose line length, inversely proportional to umbilical hose line diameter and directly proportional to valve actuator piston size.
5. Emergency Shut Down (ESD) calculations and simulation is critical to understand umbilical and gate valve behavior upon system failure, which is critical for personal and field safety.

5.2 Recommendations

This project included most of the significant simulation studies that could be made for a direct hydraulic subsea control system. The results achieved proved close to those of the behaviors and values of the experimented field. However, this project can evolve to more areas and fields even for the same case study used, some of my recommendations to improve the project are:

1. Not to only pursue more simulation work using SimulationX, but to proceed to designing an improved and up to date control system for the Cadlao field and study the differences in control system responses achieved. This study serves as a tool to understand whether direct hydraulic controls can be replaced by a better substitute under the same conditions.
2. Introduce electro-hydraulic control solutions and compare results with the achieved ones in this report.
3. Introduce boost system to the case study and study its effects on the response times. Also studying replacing the umbilical line material from hose line to steel tubing.

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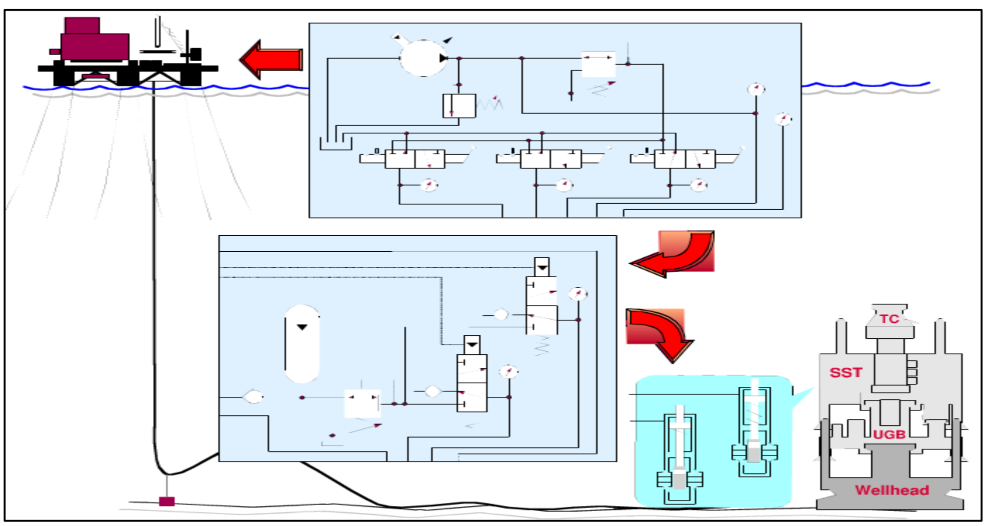
APPENDICES

Types of Hydraulic Control System:

<u>Piloted Hydraulic:</u>

In the piloted hydraulic control system, hydraulic power to operate tree functions is supplied, via the umbilical, to a control pod and accumulator on the tree. Umbilicals also contain individual hydraulic lines transmitting control signals to pilot- operated, spring-returned hydraulic valves mounted on the tree. Hydraulic valves direct fluid from the accumulator to actuators of production valves and chokes. Use of pilot-operated valves improves response of the system as only a control hydraulic signal is transmitted from the topside to the tree. In addition, as the supply of fluid to actuators is from the accumulator rather than from a remote topside location, the response time of tree valves is further improved. However, 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 distances between the topside and the tree of up to 10km.



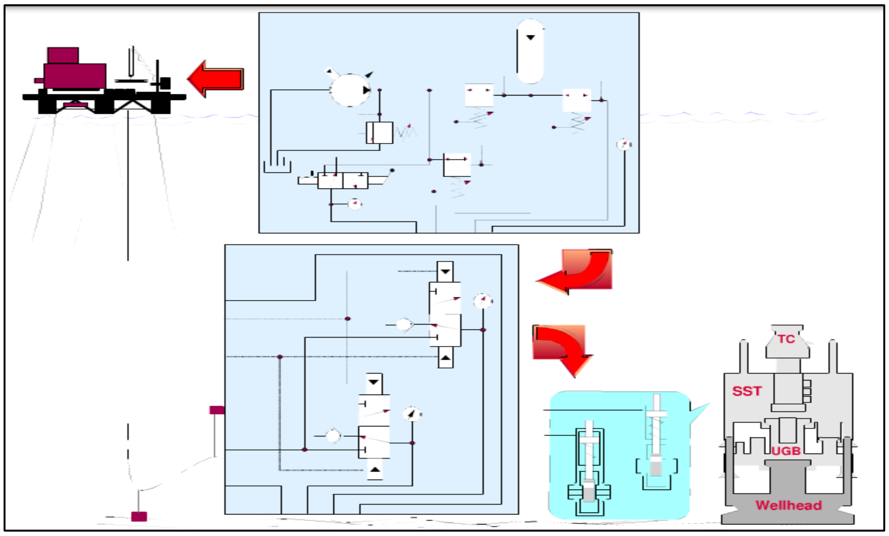
Piloted Hydraulic System [9]

The umbilical termination for a piloted system can be identical to that of a direct hydraulic system. Its design depends on the method of umbilical installation and hook-up. The accumulators are usually mounted on the tree and piped into the system. In some cases, the accumulators are part of the control pod, which allows retrievability. A separate, remotely retrievable accumulator package is also used. The size of the accumulator depends on the response time requirements, umbilical hose type/size and the distance between topside and tree location (offset distance) [6]. All subsea hydraulic-piloted control valves are located in a control pod that is usually mounted on the tree frame. Depending on water depth and diver access, etc., various types of pod are used, generally falling into two categories: remote retrievable and diver retrievable. A remote retrievable pod is locked to a pod receiver plate, usually using stab connections that interface control lines on the tree with the pod. Locking the pod to the receiver plate is carried out either using a remote operation vessel or a hydraulically operated connector [9].

A piloted hydraulic system, like a direct hydraulic system, is highly reliable and easily accessible for servicing. Although the system performance is faster and allows for larger offset distance, the piloted system requires more complex hydraulic control umbilicals and inclusion of tree-mounted components, which adds to the cost of installation. As in a direct hydraulic system, a piloted system does not have direct feedback information about performance of subsea functions, but, again, some information can be obtained by monitoring pressures and flow at the topside [6].

Sequential Piloted Hydraulic

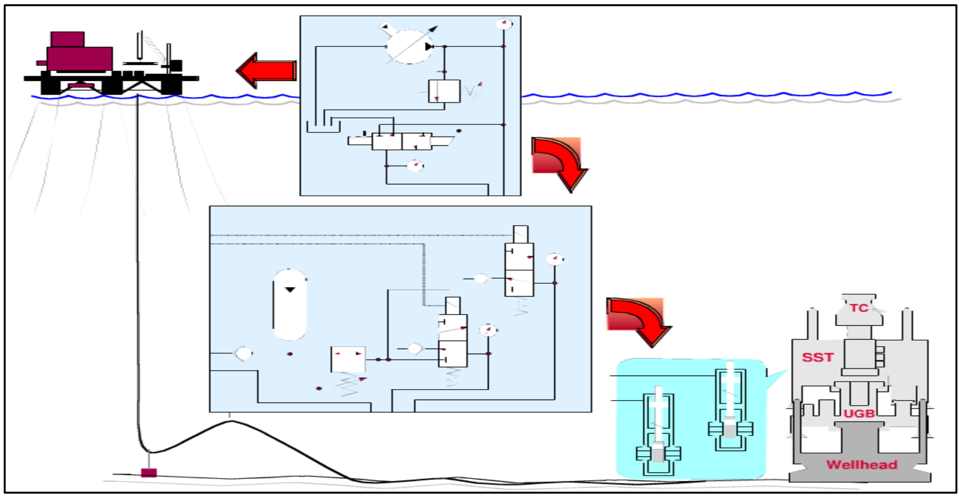
The basic set-up of a sequenced piloted hydraulic system is similar to a pilot-operated system; however, pilot-operated, two-position hydraulic valves are operated in a predetermined sequence An independent operation of individual valves is not possible in this system. Hydraulic control valves are connected in parallel to hydraulic power supply lines from the topside. The sequencing is obtained by changing the pilot pressure, which shifts the valves into an open position. The actuators of production valves are then moved in an order dictated by the magnitude of pressure. The system is relatively simple and requires fewer hydraulic lines with sequential piloted hydraulic system umbilicals in comparison with a piloted hydraulic system. An operating sequence must be determined in advance, however, which provides less operating flexibility than either direct or piloted hydraulic systems [9]. The overall response of the system is similar to the previous system and, again, the only monitoring of system operation is obtained at the topside by measuring fluid flow rate and pressure.



Sequential Piloted Hydraulic System [9]

Hard-wired Electrohydraulic

The hard-wired electrohydraulic system is similar to a piloted system but uses solenoid-operated hydraulic valves instead of hydraulically piloted valves. Like in a piloted system, hydraulic power to operate tree functions is supplied by a subsea accumulator connected, via an umbilical, to a topside hydraulic power unit. [6] A multiconductor electrical cable carries control signals from the topside to subsea solenoid valves. The control pod containing the solenoid operating valves and accumulator(s) is located on the tree, and electrical connections are included in the control umbilical termination and between the pod receiver plate and the pod.



Hardwired Electrohydraulic Control System [9]

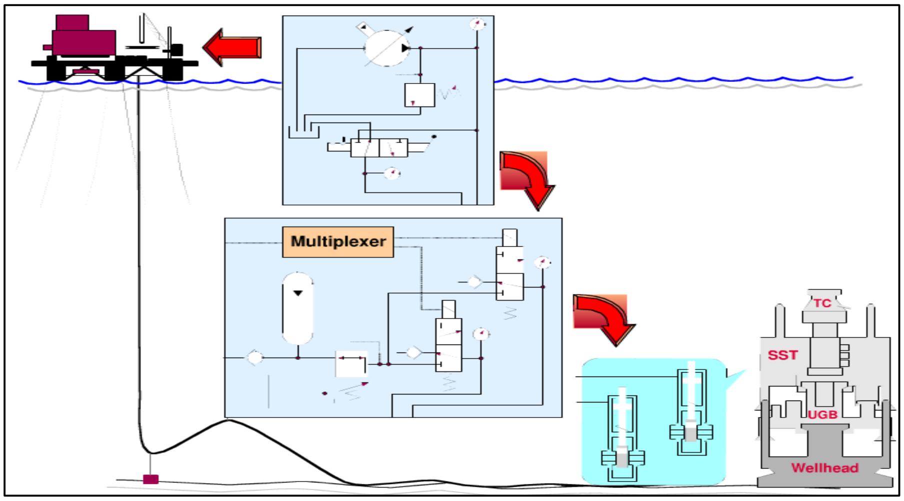
The advantages of hard-wired systems over the previous three systems are [9]:

1. a theoretically unlimited distance between production facility and subsea tree;
2. independent control of selected functions;
3. automatic sequencing if required;
4. faster valve response than in previous systems;
5. provision for data feedback from subsea functions for monitoring purposes; and
6. a small control umbilical due to reduced number of hydraulic lines in the umbilical, although this is, to some extent, offset by the necessity of providing a multiconductor electrical cable.

The electrohydraulic controls tend to be more costly and less field serviceable than the other three control systems. Hard-wired systems are the most widely used today; however, for new installations, multiplexed electrohydraulic is the preferred system.

Multiplexed Electrohydraulic

This system is similar to the hard-wired electrohydraulic system but it takes advantage of multiplex technology to reduce the number of electrical lines and the complexity of subsea electrical connections. Electronic coding and decoding logic is required at the surface and subsea, and a common cable supplies control signals (multiplexed digital data). This hydraulic power unit is mounted topside and supplies hydraulic power to a tree-mounted accumulator [10]. The control valves used in these systems are normally latching types with pulse-energized solenoids, so the valves will stay in the last commanded position when an electric control signal is removed. To switch the valve, an electrical control signal of a few seconds is required.



Multiplexed Electrohydraulic Control System [9]

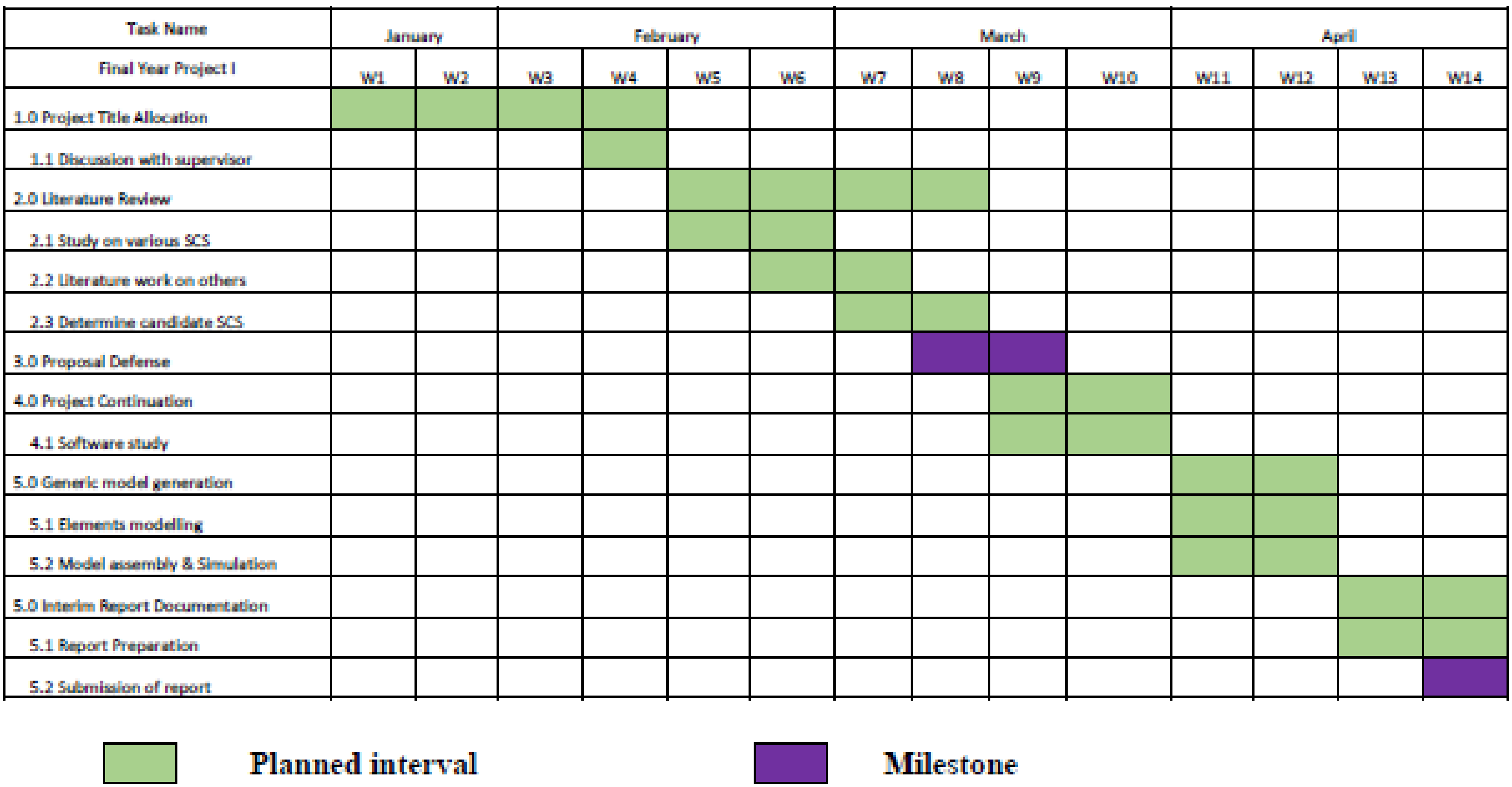
Two types of hydraulic control valves are used: direct acting and pilot operated. The direct-acting, solenoid-actuated valves require a higher voltage control signal than the pilot-operated valves. When pilot-operated valves are used, the control signals actuate small pilot valves that direct the hydraulic fluid to either sides of the spools of the main hydraulic valves, thus shifting the spools in the desired direction and allowing hydraulic fluid to enter or leave actuators of the production valves [6].

The electronic module is built into the control pod together with the hydraulic control valves, and inductive couplers are used to make and break circuits. Full monitoring can be integrated with control functions without additional power and signal transmission equipment. The system has good system performance for long distances and is well suited for multi-well installations because the same umbilical can serve many wells without reducing overall performance [9]. The simple umbilical allows redundancy to be built in without compromising the umbilical capacity, but the drawback is increased complexity subsea [6].

Project activities plan:

Below are the gantt charts showing the activities planned for the project throughout its two phases, FYP I & II,

FYP I activities plan



FYP-II activities plan

Task Name	May		June				July				August			
Final Year Project II	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1.0 Acquiring field parameters														
2.0 Development of the SCM model														
3.0 Simulate model														
4.0 Result and Observation														
5.0 Poster presentation														
6.0 Progress report														
6.1 Report preparation														
6.2 Report submission														
7.0 Model improvement														
8.0 Model validation														
9.0 Final documentation														
9.1 Technical report submission														
9.2 Dissertation preparation														
9.3 Submission of documents														
10.0 Viva														
11.0 Hardbound submission														

Planned interval **Milestone**