

## Introduction

Most of the new oil fields are located in deepwater and are generally referred to as deepwater systems. Development of these fields sets strict requirements for verification of the various systems' functions and their compliance with current requirements and specifications. This because of the high costs and time involved in changing a pre-existing system due to the specialized vessels with advanced onboard equipment. A full scale test (System Integration Test – SIT) does not provide satisfactory verification of deepwater systems because the test, for practical reasons, cannot be performed under conditions identical to those under which the system will later operate. The oil industry has therefore adopted modern data technology as a tool for virtual testing of deepwater systems that enables detection of costly faults at an early phase of the project. This article describes how, using modern tools such as SimulationX<sup>®</sup>, models of deepwater systems can be set up and used to verify the system's functions, and dynamic properties, against various requirements specifications.

## System description

Figure 1 presents a typical deepwater system for production of oil and gas. Subsea installations are linked with the surface vessel using an umbilical. The Xmas tree (XT) of each well is controlled by an electrohydraulic subsea control module (SCM) which receives hydraulic power, electric power, and communications, via the umbilical.

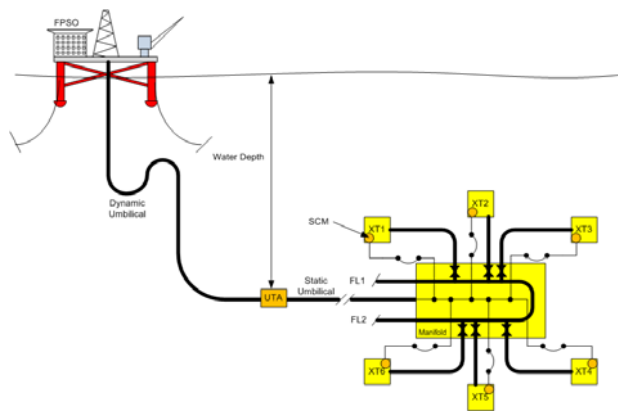


Figure 1 Subsea control system for oil and gas production

An XT has a number of valve actuators of varying dimensions. Different areas are exposed to sea pressure, process pressure and hydraulic pressure. This means that the behavior of the valve changes as the water depth or the process pressure changes. It is therefore important to verify the system's function under all the conditions that the system is known to be exposed to during the lifetime of the field.

The example in this article is one of several typical sequences that are simulated for deepwater systems. The

example represents a so-called “rapid-opening sequence” for an XT as shown in Figure 2.

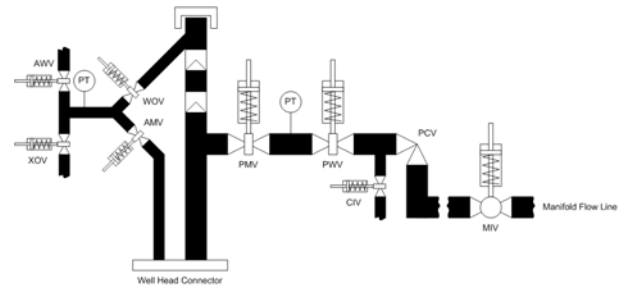


Figure 2 Sketch of XT valves and MIV

An XT normally opens in accordance with field-specific procedures, and sufficient time is allowed to ensure that all barrier elements remain intact throughout the entire sequence. However, on occasion there may be a requirement to permit opening within a given time limit in order to prevent cooling of produced oil at a non-scheduled shutdown.

One example of a rapid opening sequence for an XT is presented in the Table below.

Time	Valve actuated
10 s	Open AMV
40 s	Open AMV
100 s	Step PCV to 15% open from closed
150 s	Open CIV
190 s	Close CIV
200 s	Step PCV to closed from 15% open
250 s	Open PWV
350 s	Open MIV
450 s	Step PCV to 10% open from closed

## System model in SimulationX<sup>®</sup>

SimulationX<sup>®</sup> contains a library of generic models for components and valves that are included in the most common deepwater systems. The library makes it easy to set up a model that quickly generates results that can be used as the basis for selection of important components such as accumulator volumes, umbilical dimensions, etc.

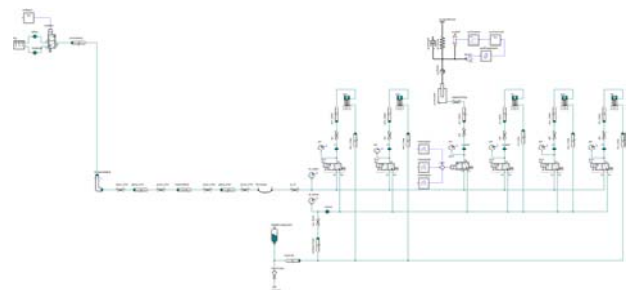


Figure 3 SimulationX<sup>®</sup> model of a deepwater system

Figure 3 presents the model for the complete system for this scenario. The model comprises elements from the SimulationX<sup>®</sup> library that is dedicated to subsea systems – hydraulics, in conjunction with elements from the standard libraries. The special elements have been developed from many years' experience with subsea systems. The individual elements have been designed so

that parameters from standard technical data sheets should be sufficient documentation to enable set up of a system and generation of reliable results. The results obtained have also been listed to facilitate model verification and a check of the simulated results.

**Results generated by SimulationX®**

The task in this example is to determine whether the proposed dimensions of the umbilical (1/2" steel pipe) are sufficient to open an XT in less than 8 minutes (480 seconds) after a non-scheduled shutdown. Figure 4 presents the positions of the XT valves during the opening sequence at the first run. It is apparent that the 2" valve, AMV, starts to close towards the end of the opening sequence when PWV opens.

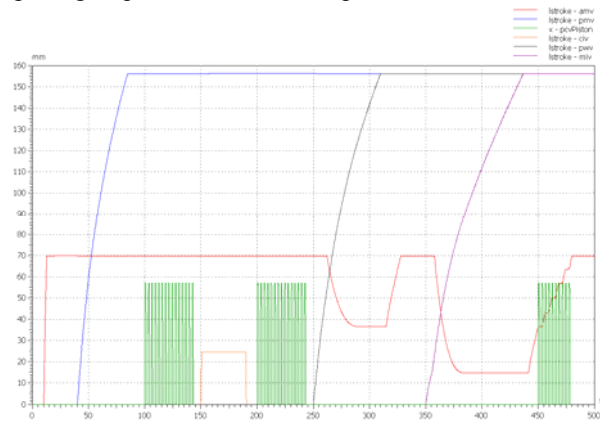


Figure 4 Opening sequence for the XT valves with 1/2" line

The reason that AMV begins to close is not only because the supply line is too small to maintain the required operating and process pressures, but the valve's return spring also forces the valve into the closed position. Figure 5 presents the SCM supply and return pressure. It is apparent that the supply pressure falls almost 150 bar during the opening sequence.

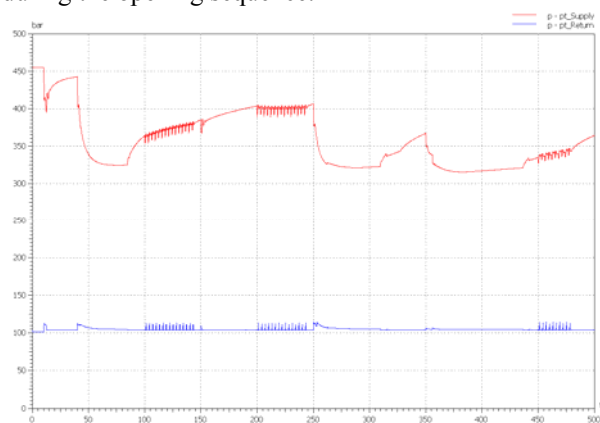


Figure 5 SCM supply pressure and return pressure with 1/2" line

*Note that this problem can only be detected on an existing system using visual monitoring of the XT during the opening sequence – which is both time-consuming and costly at depths of 1,000 meters.*

**The options**

Because we now have a mathematical model of the system, it is an easy matter to try differing solutions before taking a final decision. The simplest solution would be to change the umbilical dimensions from 1/2" ID to 3/4" ID, but that is also the most costly. The umbilical is the most expensive single component of a deepwater system, and changes in its dimensions would entail major costs. First, we will look at the other options.

The first option is to add an accumulator to the supply line for the SCM. This is not the optimal solution as this is a component that not only can fail but also requires maintenance throughout the lifetime of the field. Nevertheless, we will run this and see if it is a feasible option in this case.

Figure 6 illustrates where the accumulator would be introduced into the model.

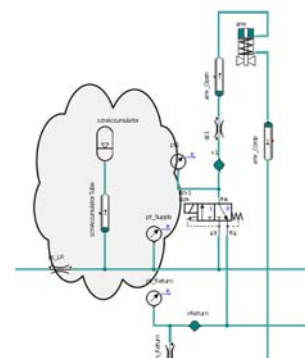


Figure 6 SCM accumulator

The resulting graph in Figure 7 reveals that there is some improvement, but that unwanted closure of AMV still occurs towards the end of the sequence. If we introduce a larger accumulator, this will undoubtedly function better, but the time needed to bleed the system will also increase substantially. Furthermore, there are physical limitations, as this needs to be a replaceable component that can be changed using a simple ROV- based solution from a smaller vessel.

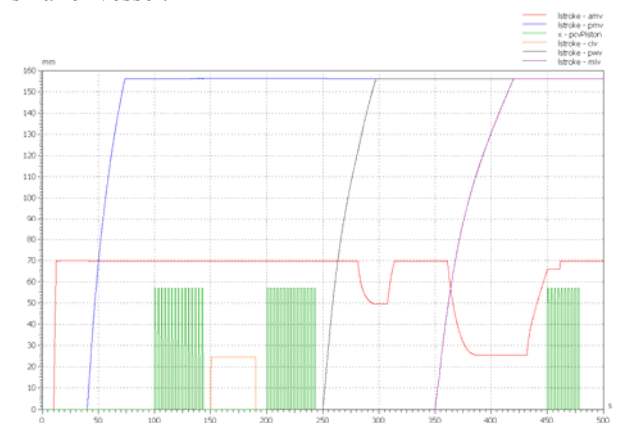


Figure 7 Opening sequence for the XT valves with 1/2" line and accumulator

The next option is to introduce additional restrictions on the function lines to the largest actuators. This would reduce the speed of the actuators providing the time

necessary for the supply system to refill and maintain the pressure above the critical level. This solution is used extensively on deepwater systems in order to avoid the use of accumulators. There are of course practical limitations here too, and the speed cannot be limited so much that the customer's requirement for full opening in less than 8 minutes cannot be realized.

The model already contains a restriction for rapid connection between the SCM and SCMMB. This restriction increases to the resultant restriction using a non-return valve for backflow when the gate valve is to close. Figure 8 illustrates this solution for the PIV circuit.

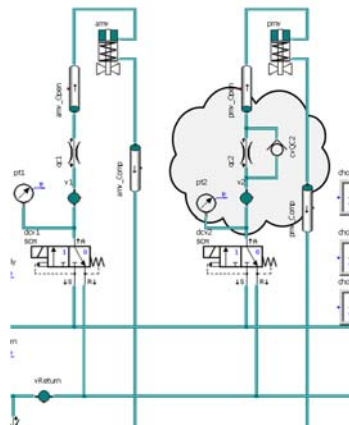


Figure 8 Additional restriction using a non-return valve

From the results graph in Figure 9 it is apparent that this does not result in any significant improvement. Combining these two solutions is also an option, but will not provide the desired results as our starting point is so far away.

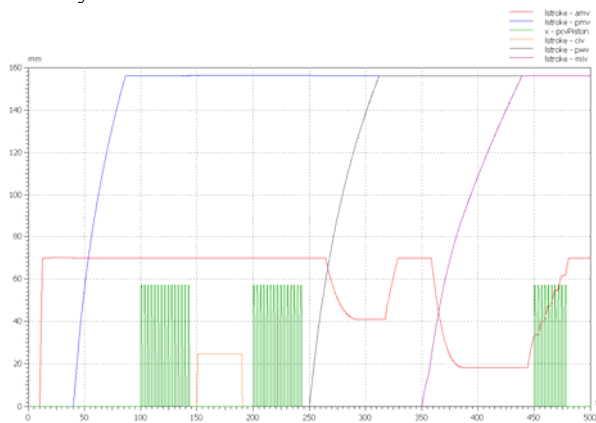


Figure 9 Opening sequence for the XT valves with 1/2" line and additional restrictions

In order to satisfy the requirements for the system, it appears that we have to use the "heavy" option and increase the umbilical's line dimension to 3/4" ID. The original model in SimulationX® is updated with the new line dimension and re-run. It is apparent from the results in Figure 10 that the AMV is now open throughout the entire sequence.



Figure 10 Opening sequence for the XT valves with 3/4" line

It is also apparent from the results graph in Figure 11 that the supply line is now dimensioned to fill up when the valves are activated, and can maintain the SCM pressure throughout the entire sequence.

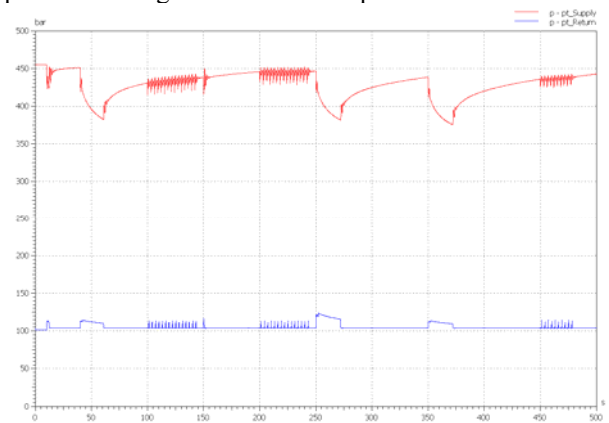


Figure 11 SCM supply pressure and return pressure with 3/4" line

**Summary**

This example demonstrates the importance of performing design verification at an early phase of a project. It also demonstrates the importance of running simulations at differing process pressures to confirm that the system will operate with good safety margins throughout the lifetime of the field. Also, after the natural over-pressure in the wells has dropped. It is important to note that the system requirements do in fact apply throughout the lifetime of the field.

Use of a tool like SimulationX® enables easy verification of a system for the various lifetime phases of a field. Extreme situations can be simulated and the system optimized, enabling delivery of a system where best performance and economy are met.

Rune Lien  
Agito AS  
www.agito.no