CH: 3 Operation and Maintenance Techniques of Subsea Structures

The remote operation of subsea structures can be achieved by subsea control system that the main purpose of this system is to allow the controlled operation of valves located down-hole on subsea Xmas trees and other subsea structures such as manifolds and subsea isolation valves. In addition, subsea control system transfers data from sensors on Xmas Tree and Manifolds as well as down-hole sensors at the completed feed back to the topside control facility.

3-1 Subsea Production Control System

There are 4 generic types of subsea production control system:

1- Direct Hydraulic
2- Piloted Hydraulic
3- Multiplexed Electro – Hydraulic
4- All-Electric.

Types 1, 2 and 3 are widespread use. Type 4 is still in its infancy and is being proven on non-critical well systems. Acoustic systems have only been utilized as prototypes and have not been adopted for widespread use to date.

3-1-1 Direct Hydraulic (DH)

A direct hydraulic system comprises a direct hydraulic line to each controlled subsea valve actuator through the umbilical from a topside mounted HPU (Hydraulic Power Unit). Each sensor has a dedicated twisted pair running from the sensor located subsea through the umbilical end back to a signal processing interface unit at the topside control system. Figure 3.1 illustrates a simplified layout for DH system [**16**].

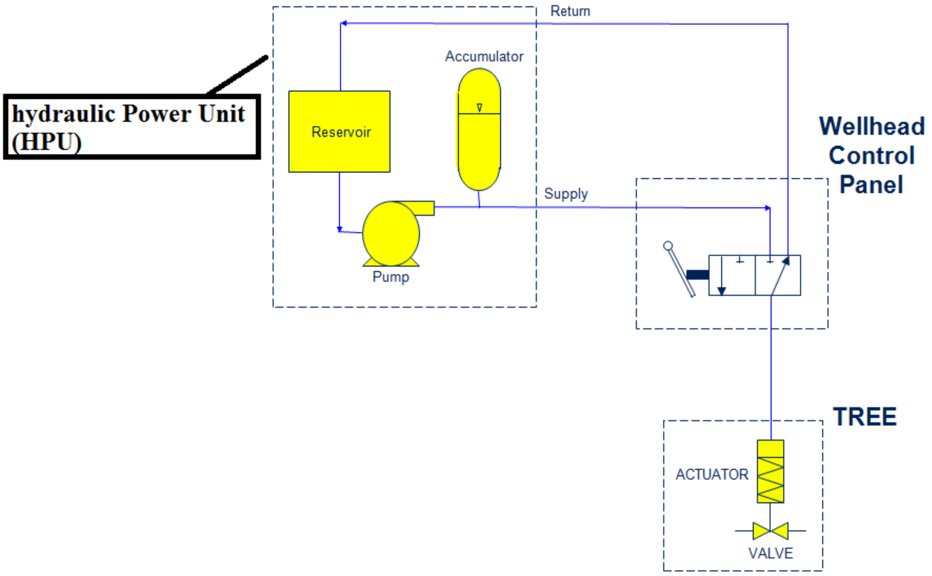

Figure 3.1 DH system [**16**]

Functioning valves on Xmas tree and manifold by using this system is as follow:
To open the tree valve, the operator sets the Wellhead Control Panel valve to the open position, directing high pressure control fluid to the valve actuator.
To close the tree valve, the operator sets the WHCP valve to the close position, venting hydraulic fluid from the actuator back to the reservoir.Generally, this system is used for work-over and small systems, but isn’t practical for larger systems, that it contains too many hoses. There is no monitoring inherent within the system that requires one pair of wires to be added to the umbilical for each monitored point.There is an example of this system:

Consider a production well with 12 valves (two dual acting) and two chokes. This would require a total of 18 hydraulic hoses per well.
(1 x 10 hoses for single acting valves + 2 x 2 hoses for dual acting valves + 2 x 2 hoses for chokes)
So, this system isn't very flexible, it is not possible to add extra wells unless there are sufficient spare hoses in the umbilical. Or, a new umbilical has to be installed. Figure 3.2 shows a typical DH system [**5, 17**].

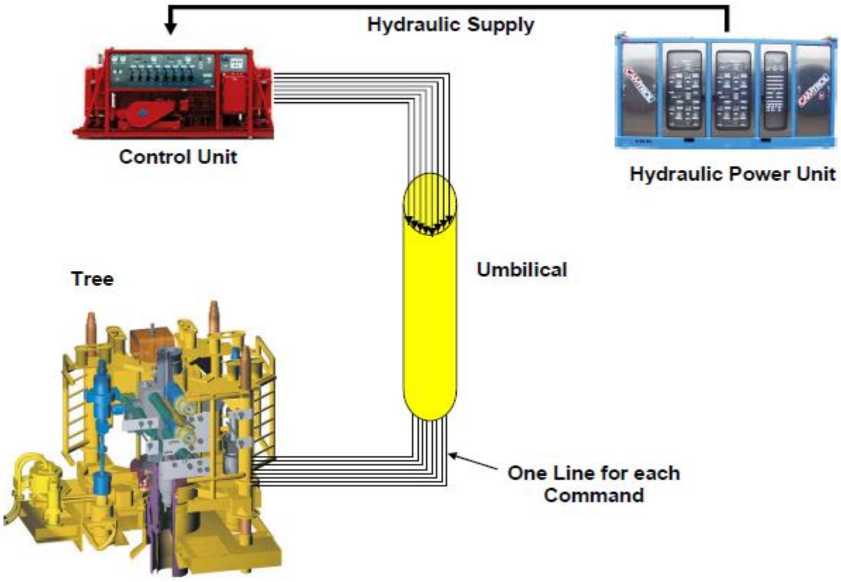

Figure 3.2 Typical DH System [**17**]

3-1-2 Multiplexed Electro-Hydraulic (MUX E/H)

The heart of the MUX E/H system is the Subsea Control Module (SCM). This comprises a hydraulic package of Directional Control Valves (DCV's) and an electronic package (SEM – Subsea Electronic Module). The DCV's are actuated by an electric signal from the SEM and are supplied with hydraulic pressure from a common hydraulic line that runs in the umbilical from the topside HPU. Figure 3.3 illustrates a simplified layout for (MUX E/H) system [**16**].

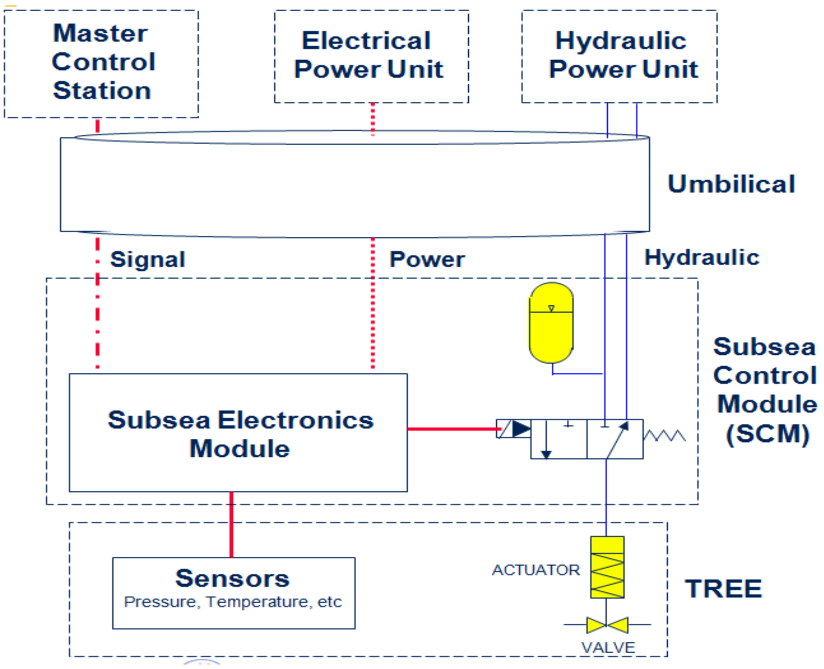

Figure 3.3 MUX E/H systems [**16**]

Functioning valves on Xmas tree and manifold by using this system is as follow:
To open a tree valve, the operator uses the MCS VDU (Visual Display Unit) and keyboard to request the required valve movement. The MCS then sends a coded message to the SEM, which interprets the message and energises the appropriate solenoid operated pilot valve, allowing hydraulic fluid to flow into the tree valve actuator.
During periods when there are no valve operations to be made, the MCS polls the SEM to retrieve sensor data, which is then stored in the MCS memory or displayed on the VDU as required.
The Multiplexed Electro-Hydraulic system allows many Subsea Control Modules to be connected to the same communications, electrical and hydraulic supply lines.
The result is that many wells can be controlled via one simple umbilical, which is terminated at a Subsea Distribution Assembly. From the SDA, the connections to the individual wells and SCMs are made with jumper assemblies. Figure 3.4 illustrates this system with multiple wells [**9, 16**].

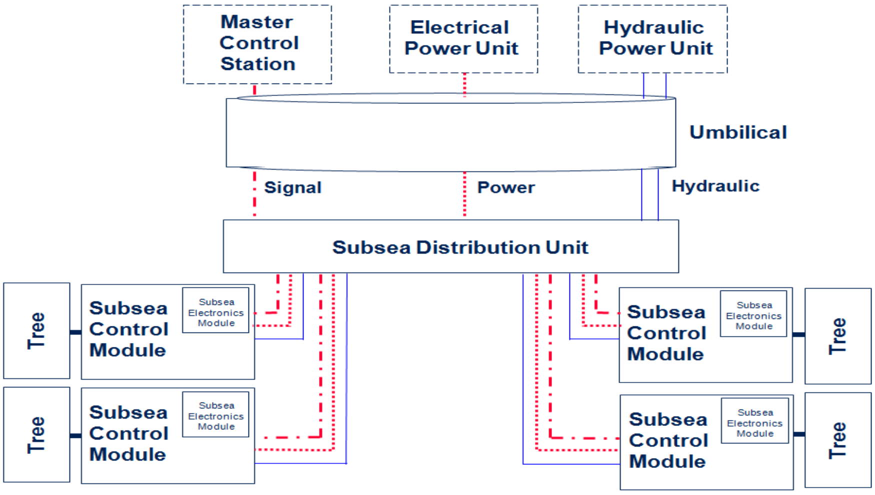

Figure 3.4 MUX E/H) system with multi wells [**16**]

These systems give good response times over long distances, a major limitation being the recharging of the hydraulic supply over such a long umbilical. Figure 3.5 shows a typical (MUX E/H) system [**17**].

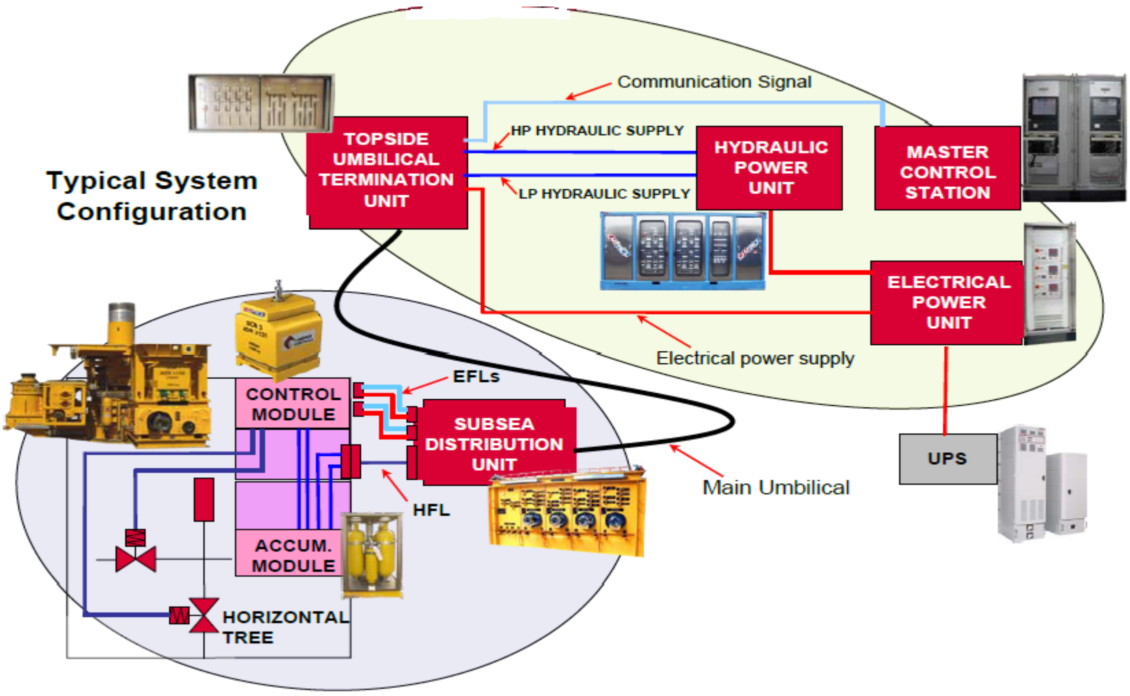

Figure 3.5 Typical MUX E/H system [**17**]

3-1-3 Piloted Hydraulic System

This is similar to the direct hydraulic but in place of a direct hose to each actuator a smaller (pilot) actuator hose is utilized to actuate a locally mounted Directional Control Valve (DCV). The smaller bore pilot hose improves response time and provides some more latitude with respect to the number of wells, however there's still one hydraulic line for each valve actuator. A hydraulic control pod (comprising of a number of DCV's) needs to be mounted on the Xmas tree or manifold. These systems are relatively rare in practice. A sequenced hydraulic system which utilizes a single pilot line and operates at different pressures to select specific valve actuators has been developed but has very rarely been used in practice. Figure 3.6 shows a layout for piloted hydraulic control system [**9**].

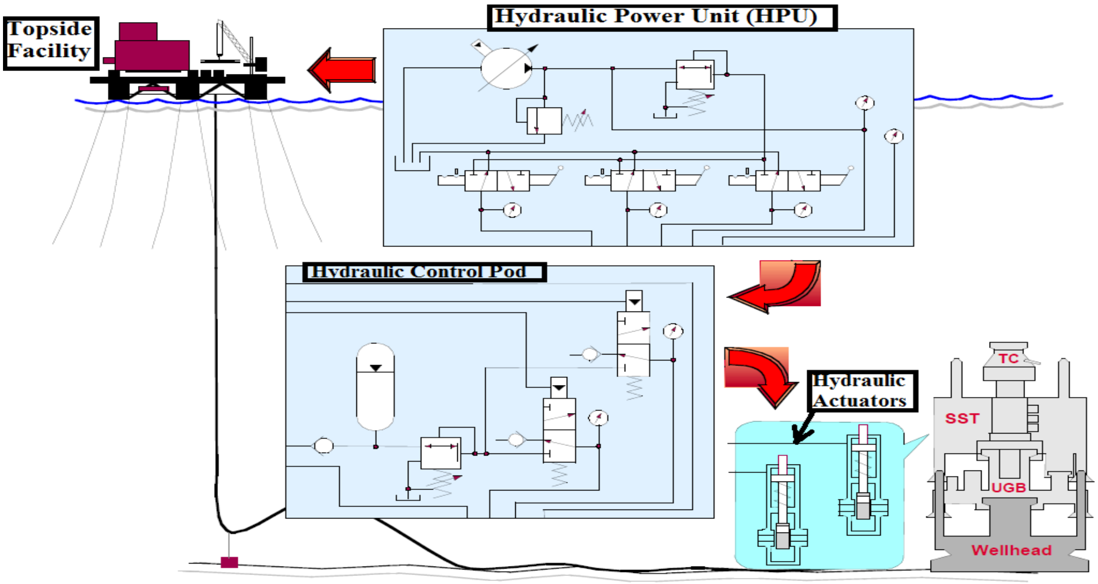

Figure 3.6 Layout for piloted hydraulic control system [**9**]

After description of all hydraulic control system, it is imperative to illustrate the typical response times as a function of hydraulic hose length on the following figure 3.7 [**16, 17**]

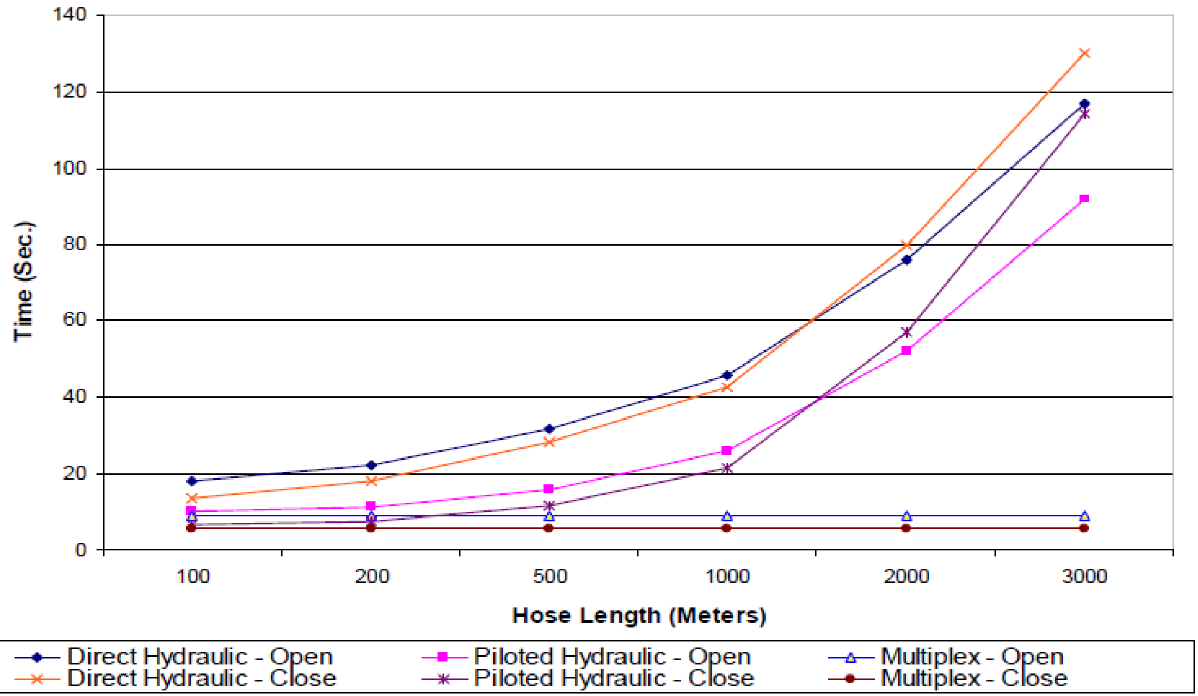

Figure 3.7 Relationship between response time and hydraulic hose length [**17**]

3-2 Subsea Structures Processes and Instrumentation Diagrams (P&IDs)

Processes and instrumentation diagrams for subsea structures like Xmas trees, manifolds, and SDA are the main points to illustrate the components and the processes carried out through these structures.
The main components of any subsea structures which carry out any process or assist to perform this process are valves, pressure and temperature transmitters, pipes, tie in connectors, and some joints. On the following subsections, some P&IDs for some subsea structures like Xmas tree and Manifold

3-2-1 Xmas Tree Processes and Instrumentation Diagram

By observation the following Figure 3.8, the main components and processes can be understood and described [**2**].

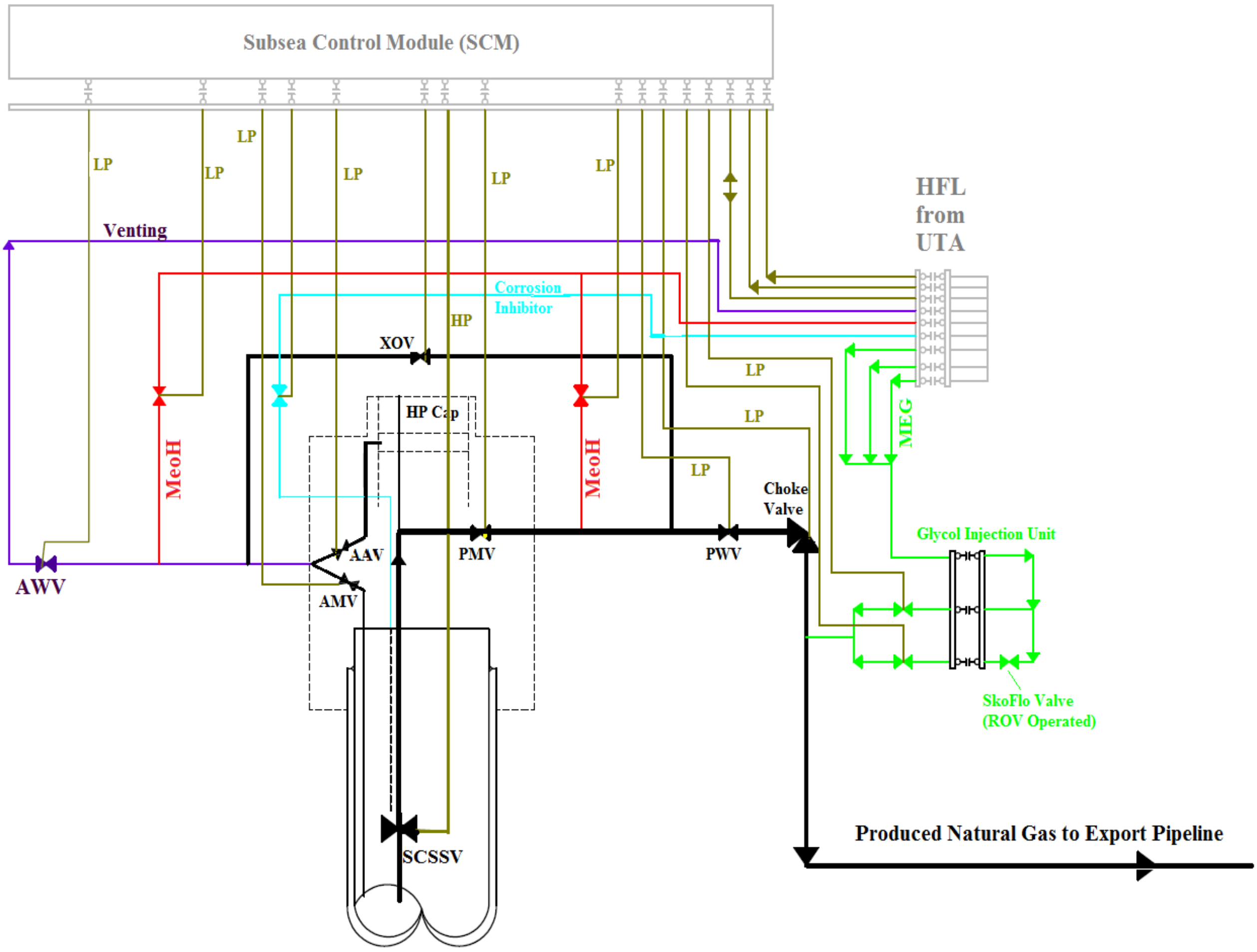

Figure 3.8 Xmas tree P & ID – drawn by ACAD [**2**]

As shown above on the figure, Xmas tree's P&ID is illustrated with different colors as follow:
Black lines are for gas paths starting from down-hole to the export pipeline and annulus path is drawn by black line as well.
Green lines are for Mono Ethylene Glycol (MEG) paths starting from HFL to supply MEG to the gas path downstream choke – produced and exporting.
Cray line is for corrosion inhibitor injected inside well bore from HFL.
Red lines for Methanol (MeoH) injected to the gas paths on the produced gas between Production Master Valve (PMV) and Production Wing Valve (PWV) and injected on the annulus paths.
Purple lines are for the venting path from annulus to HFL.

Yellow Dark lines are for the hydraulic oil supplied from HFL to each valve actuator that it's the active force to operate the valve.

3-2-2 Manifold Process and Instrumentation Diagram

By observation the following Figure 3.9, the main components and processes can be understood and described [**2**].

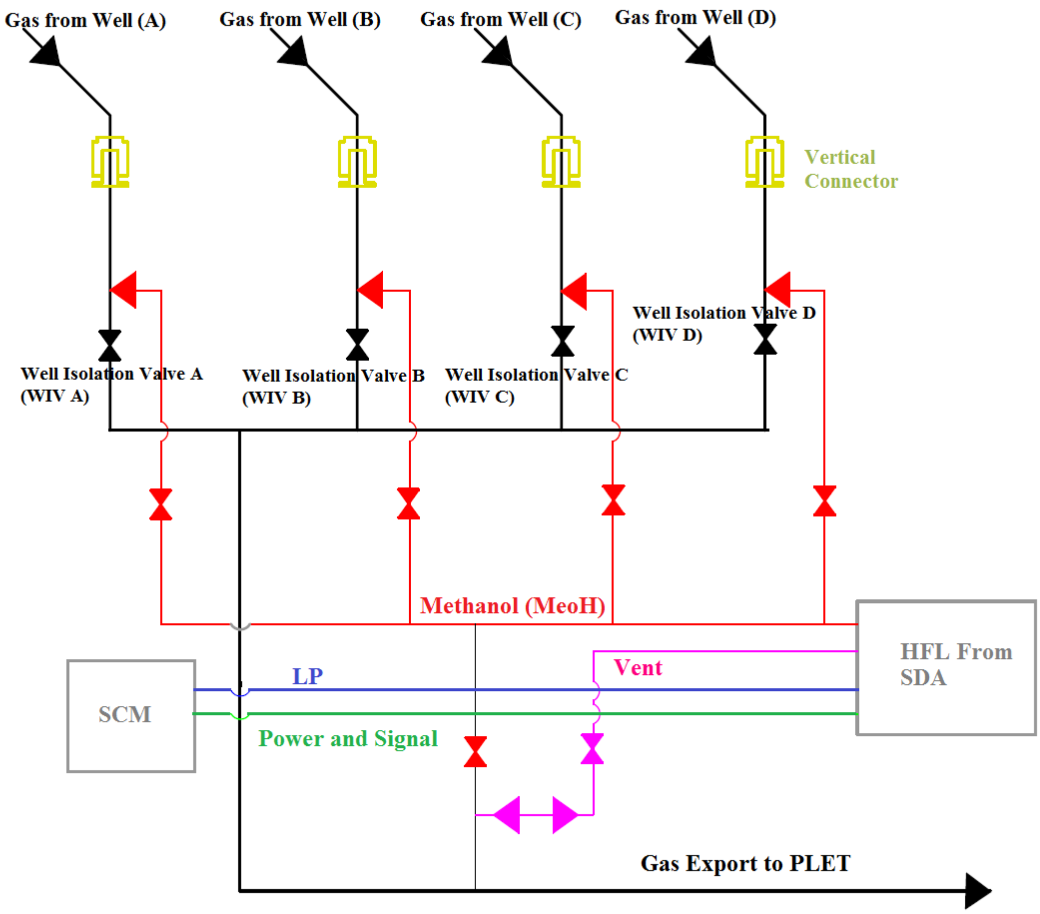

Figure 3.9 Manifold P & ID – drawn by ACAD [**2**]

Black lines are for gas paths which are transferred from different wells and started to be collected on manifold structure & for the gas export to Pipeline End Termination (PLET).
Red lines are for the different Methanol (MeoH) paths injected to the gas coming from wells.
Magenta lines are for the venting paths which may be done through manifold – will be discussed later.
Blue line is for the Low Pressure (LP) path from HFL to SCM.
Green line is for the power and signal supplied from SDA to SCM.

3-3 Wellhead Operations

Wellhead operations can be summarized as the all processes to be done at X-trees to obtain the desired production rate, to ensure the required properties of Natural Gas and to keep the wellhead's life time out of defects. These operations are controlled from topside facility and these wellheads can be maintained through it or the intervention is required if the maintenance or the remedial of the defects at wellheads is impossible through topside facility. Intervention technique will be discussed in details later.

3-3-1 Deepwater Natural Gas Production Rate Control

NG production from deepwater has many challenges to obtain the desired production rate in a safe manner without any problems due to using this technology. All X-trees and some manifolds have a choke valve which is responsible to attain the desired production rate. This valve can be adjusted to control the production rate to extend production life and operating pressure to protect the other gate valves inside tree from high pressure drops during closing and opening of the wellhead. Figure 3.10 shows a typical choke valve. This valve can be changed out if it faced any defects or damage [**2, 18**]

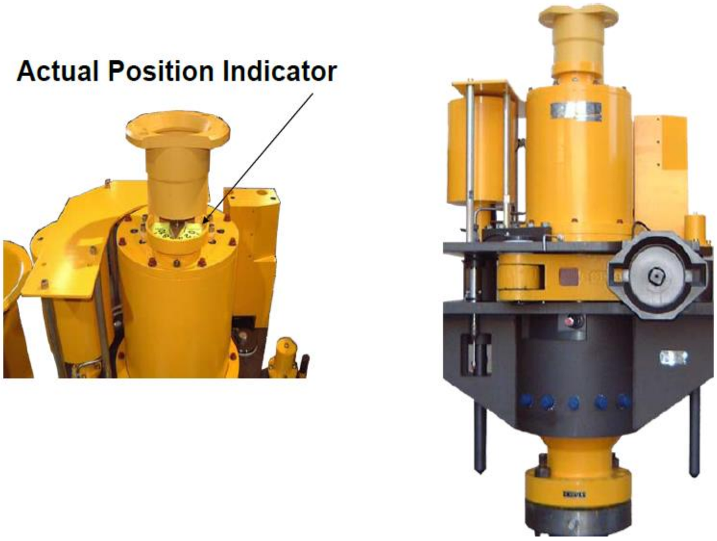

Figure 3.10 Subsea choke valve [**18**]

3-3-2 Hydrates and Chemicals Injection
3-3-2-1 Hydrates Formation

Hydrates are a solid crystal cage of water molecules encasing a light component molecule. The physical conditions that promote hydrate formation are high pressure, low temperature, fluid composition, and the presence of water. Hydrate formation can cause a flowline blockages, pipeline shut – in /loss of production, and lengthy remediation process depending on location of blockage. Figure 3.11 shows the steps of hydrates formation and some blocks of hydrates [**2, 19**].

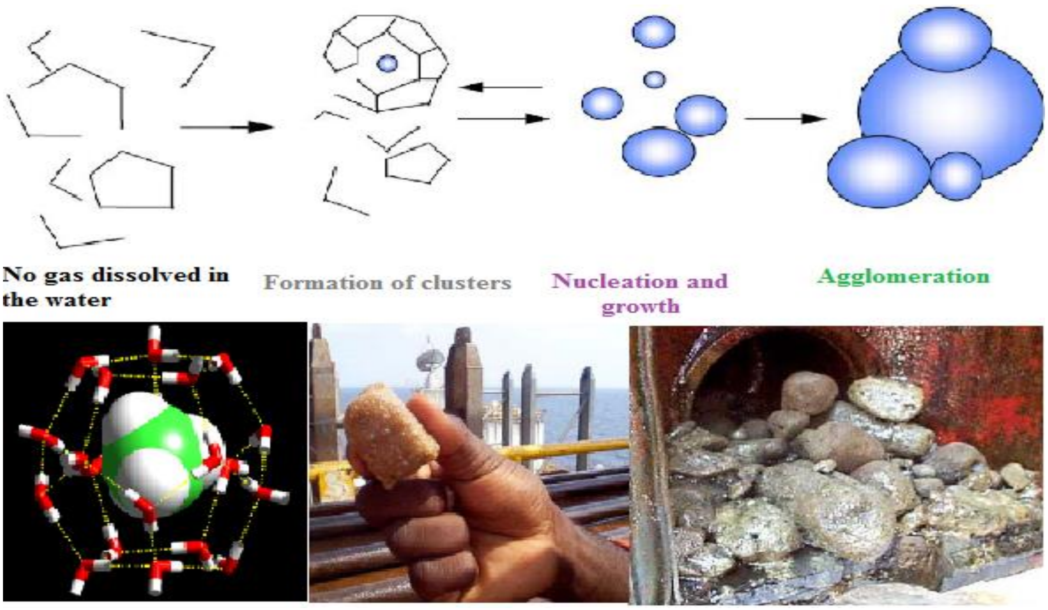

Figure 3.11 Hydrates formation [**19**]

Hydrates form in offshore systems in several ways:

- Slow fluid cooling: The produced fluid temperature quickly decays to the ambient temperature. In a pipeline, hydrate masses usually form at the hydrocarbon –water interface, and accumulate as flow pushes them downstream.
- Rapid Cooling: Cooling caused by depressurization across valves and restrictions. The low temperatures combined with the relatively high pressures can cause hydrates to form and accumulate downstram of the restriction.
- Transient Operations: Such as startup, shutdown, and blow down are very susceptible to hydrate blockage because the production system is likely to drop into the hydrate formation region.

Figure 3.12 shows a diagram for the hydrate formation condition [**2, 19**].

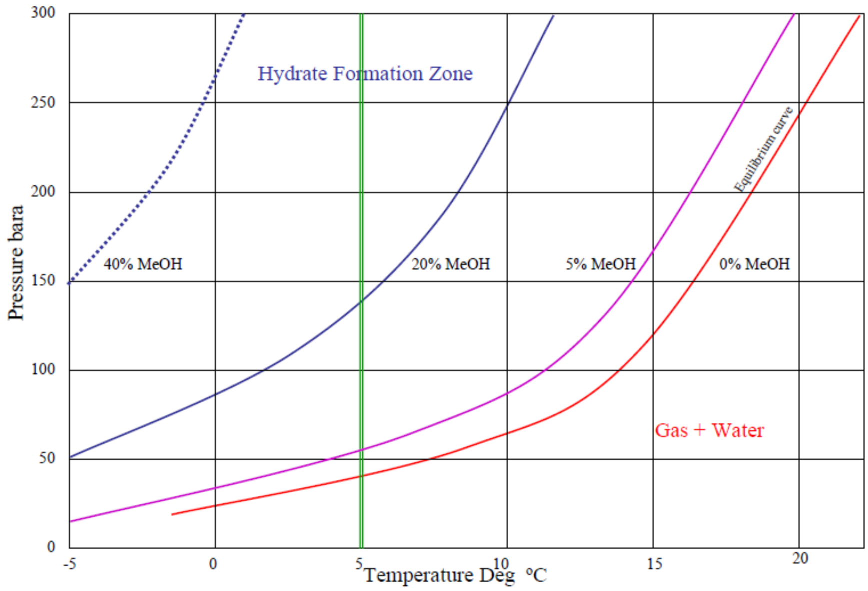

Figure 3.12 Hydrate formation conditions [**19**]

3-3-2-2 Hydrates Remediation and Prevention

Hydrates can be remediated by various methods such as depressurization, Methanol (MeoH) injection and thermal. Hydrates can also be prevented by a related permanent ways such as increase temperature by heating or insulation, decrease operating pressure, dehydration by remove water, and Mono Ethylene Glycol (MEG) which has an active action for decrease the temperature of hydrate formation, the injection of MEG should be applied at the production line of NG and the rate of injection can be adjusted through GCU (Glycol Control Unit). Figure 3.13 shows the effect of addition of hydrate inhibitor and the shape of bundled flowline [**2, 19**].

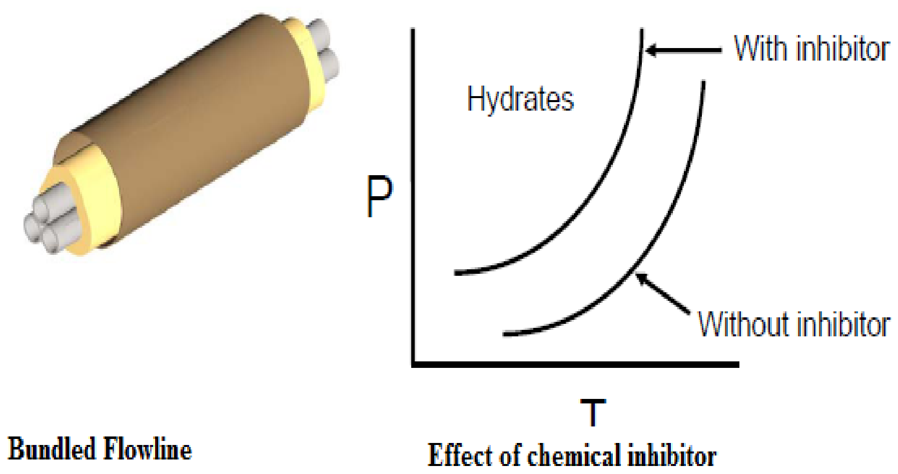

Figure 3.13 Effect of hydrate inhibitor [**19**]

3-3-3 Sand Detection and Control

There is always some level of sand production but it isn't acceptable that the sand production can have detrimental impacts that it contributes to erosion at high flow rates, settles in flowlines at low flow rates, combines with other solids, such as wax to form restrictions, and settles in topside equipment.
Sand detection is provided at the tree prior to fluid entry into the tree – PLET jumpers. The detectors indicate sand presence in the produced fluids and provide and electronic signal back to the MCS. Input to the MCS allows a sand rate calculation. If sand production is detected, the affected well will be shut in until the problem is resolved.
If these electronic detectors defected, intervention will be required by installing a sand detector to the flowline jumper, the installation of this sand detector can be done by ROV assistance. Figure 3.14 shows a sand detector to be installed and mounted at subsea using ROV for installation [**2, 20**].

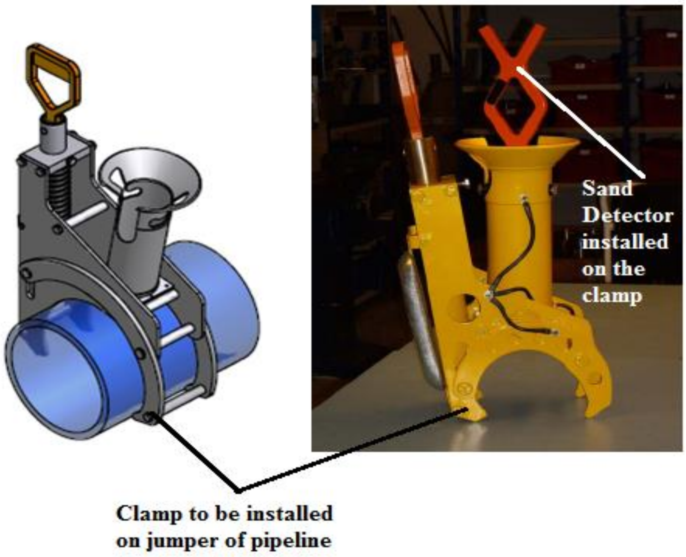

Figure 3.14 Subsea sand detector [**20**]

3-3-4 Corrosion Inhibitor

Corrosion can be defined as the Removal of material from a solid surface by chemical action, such as reaction of carbonic acid to dissolve iron. Corrosion existence condition is due to carbon dioxide or hydrogen sulfide combined with water form weak acids that attack iron and steel, other factors may affect corrosion rate: velocity, temperature, and pressure. Corrosion can be prevented by material selection, coatings, and corrosion inhibitors. Corrosion Inhibitor (CI) is added to MEG to provide the required inhibitor concentration (PPM level) in the MEG [**2**].

3-3-5 Erosion

Erosion is the removal of material from a solid surface by repeated application of mechanical forces (often sand production is of most interest). To prevent occurrence of erosion, proper sizing of tubular to limit the flow velocity to less than the velocity at which erosion may occur (maximum erosion velocity).
It is Important to look at end of life conditions when pressure is low but velocity is high [**19**].