

A General Overview of Developments in Subsea Processing in Oil and Gas Production



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THE era of easy oil is fast becoming a thing of the past. As demand for oil escalates and resources from the relatively easy onshore and shallow water fields become depleted, oil companies are compelled to focus on the more remote, complicated and deep water reserves where a combination of floating and subsea production units are used to extract hydrocarbons. This has now become the long term drivers of the subsea market.

Subsea production, and consequently subsea processing, is expected to be one of the biggest areas of offshore technology growth in the coming years with emphasis firmly set on increased production and enhanced recovery. It opens the door to more cost efficient developments in accessing the increasingly complicated reserves, especially in dealing with long step outs, and marginal, dispersed and deeper water fields.

For an industry that is often under scrutiny for its treatment of fields in sensitive areas, subsea processing also has the potential of being truly environmentally friendly in minimising surface requirements or even taking the “platformless” approach by moving all equipment to the seabed.

WHAT IS SUBSEA PROCESSING?

In general terms, subsea processing may be defined as “any active treatment or conditioning of produced fluids, either on the seabed or downhole, prior to reaching the host installation facility”. In other words, the production equipment is located on the seafloor rather than on a fixed or floating platform. Subsea processing can encompass a number of different processes to help reduce the cost and complexity of developing an offshore field.

It consists of a range of technologies to allow production from offshore wells without the need to have surface production facilities. Originally conceived as a way to overcome the challenges of extremely deepwater situations, subsea processing has become a viable solution for fields located in harsh conditions where processing equipment on the water surface might be at risk. Additionally, subsea processing is an emergent application to increase production from mature or marginal fields. Some of the main features of subsea processing include:

- a) seabed treatment of produced fluids upstream of surface facilities
- b) separation of oil, gas and water
- c) multiphase pumping/adding energy to wellstream

- d) multiphase metering
- e) reinjection or disposal of produced water
- f) gas treatment and gas compression
- g) flow assurance and mitigation against the formation of hydrates, wax, scales, asphaltenes, etc
- h) monitoring, control and instrumented safety system.

The benefits that can be derived from subsea processing are numerous. With subsea separation, the amount of production transferred from the seafloor to the water surface can be reduced, thus debottlenecking the processing capacity of the development. This translates into space savings on the offshore production facilities. Also, by separating unwanted components from the production on the seafloor, flowlines and risers are no longer lifting these ingredients to the facility on the water surface just to direct them back to the seafloor for reinjection.

In mature field applications, a subsea processing station can contribute to increased earnings in accelerated production and increased recovery, and improves and prolongs the use of existing infrastructure while it can be flexible to all phases of field life. For new developments or green fields, it can enable cost efficient and environmentally friendly platformless solutions, where the field is tied back directly to an existing offshore facility or directly to shore. This reduces CAPEX on topside processing equipment and pipelines. In addition, previous low quality assets with low Gas Oil Ratio (GOR), high viscosity and low permeability may also be rendered commercial.

Perhaps the most important benefit from using these technologies is the increase in the Net Present Value (NPV) of the project by having an increase in production due to production boosting, improved oil and gas recovery, reduced surface production facility costs, and lowered likelihood of gas hydrate formation in flowlines.

Having stated the benefits however, there are a number of issues that have kept the technology from enjoying a wider use. Pertinent of all is the reliability of the subsea units. A subsea processing system failure is more likely to be more severe than those from a topside unit because, when a unit fails, an intervention vessel or a drilling rig needs to be deployed to repair, service or replace the unit. For this, the subsea units must be able to operate for long periods of time without any intervention and preferably designed with full retrievability options for quick turnaround to minimise the losses. A lot of focus is now directed at addressing this issue.

However, this article, will only review the two most prominent subsea processing technology components – seabed separation and seabed boosting with the latter including seabed multiphase booster pumps and seabed gas compression.

SEABED SEPARATION

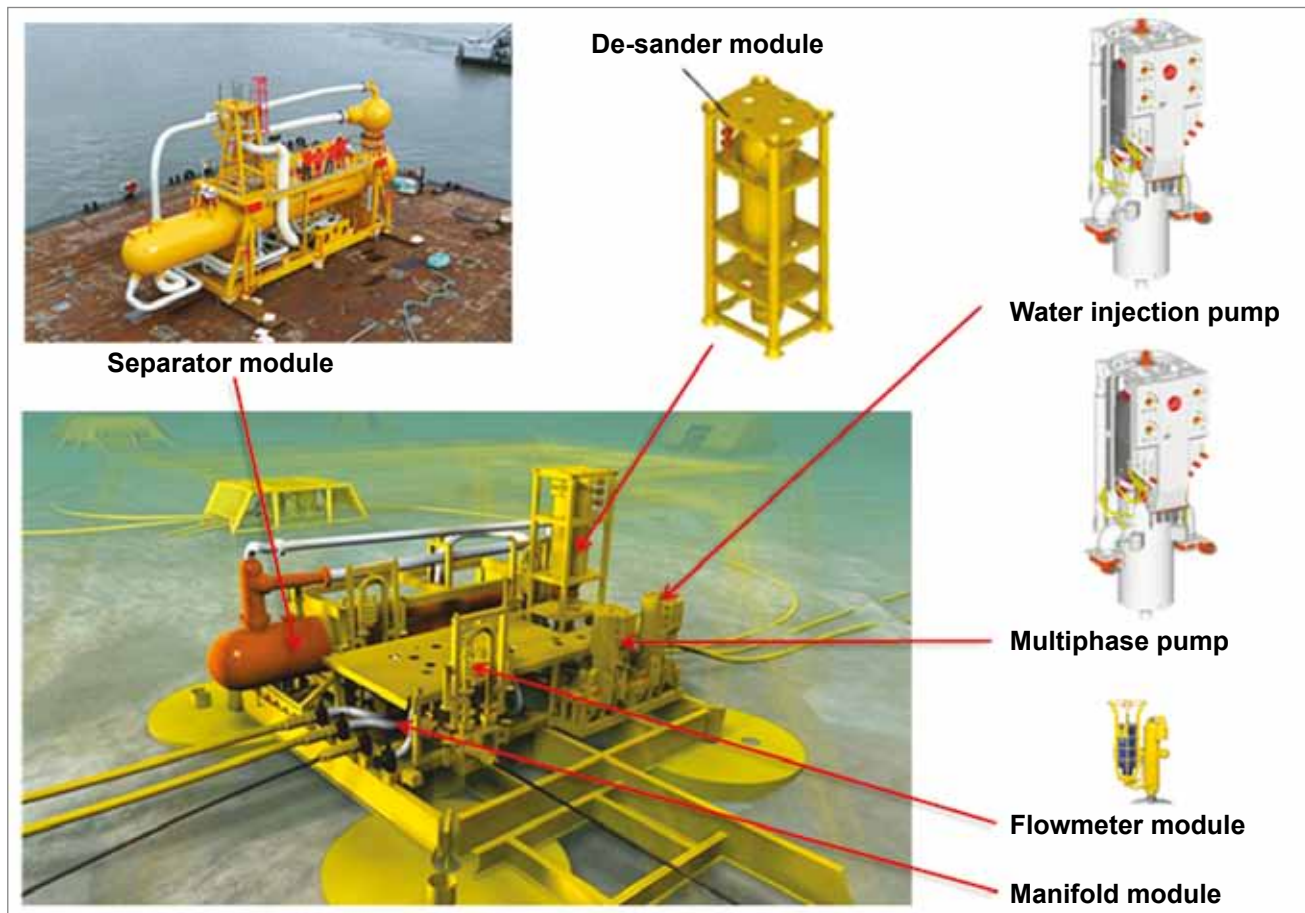
As the name implies, seabed separation involves the separation of oil, gas and water directly at the seabed as opposed to having a separator on the platform as is the norm. Increased water depth and the number of fields tied back to a hub are common key parameters for specifying either oil/water or liquids/gas separation. Other parameters are product specific.

This technology can be used in mature fields where water production increasingly exceeds oil production, and where it becomes economically unviable for operators to continue with the recovery of the field’s reserves. For liquids and gas separation in green fields, the increased distance from the host, high gas volume fractions and low reservoir pressure and temperature are considered important parameters because the transport of wet gas over tens of kilometres and at great water depths can lead to hydrate formation and, hence, pipe blockage.

The earliest seabed separation was installed back in May 2000 by Statoil (then Norsk Hydro) in a North Sea field called Troll. Even though the subsea separation at Troll was more of a pilot project instead of full-blown commercialisation of the concept, it was a proven success and a game changer. The Troll C subsea separation system is tied back 3.3km to the Troll C platform in 350m of water. Here, by means of the gravity method, the produced water is separated from the oil and gas flow from four of Troll C’s producing wells. The separated water is then re-injected back into the reservoir, while the separated oil and gas are sent up to the platform.

It is now evident from existing and upcoming seabed separation projects that the technology is often offered in combination with seabed boosting and seabed water injection. Examples include Statoil’s Tordis (Norway), Total’s Pazflor (Angola), and Shell’s Perdido Host (GoM) and BC-10 (Brazil).

The Tordis SSBI (Subsea Separation, Boosting and Injection) project in the Norwegian North Sea has been operating a subsea separation unit successfully since October 2007. By sequence, this has been only the second subsea separation project in the world, but has now become a landmark as the world’s first full scale commercial subsea separation, boosting and injection system.



*The Tordis SSBI Subsea Processing Key Technologies
(Source: FMC, Framo Engineering and Google)*

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The SSBI unit, installed in 200m water depth, separates the increasing volume of produced water and sand from the wellstream and pumps them back underground via a separate subsea well. This leaves the pipeline linking Tordis to the Gullfaks C platform free to carry only oil and gas, boosted by a multiphase pump from the SSBI. This system reduces the backpressure, improves the flow and permits Gullfaks C to process more hydrocarbons – reserves that would otherwise be destined to remain unrecovered. As an added benefit, there is no need to find space on the platform for the separation facilities. The Tordis SSBI separation station contains the following main elements:

(i) Foundation Structure and Manifold

This is a conventional protection structure or over-trawler foundation structure meant to support and protect the manifold. The structure also houses the separator module and all other modules and components within its dimension. It has four suction anchors, one in each corner for foundation and levelling. The manifold module provides connection to the flowlines via the Rovcon connection system and interconnects the various modules.

(ii) Separator Module

Well fluids from the Tordis field flows to the separator vessel where an inlet cyclone in the vessel does the first separation by allowing the majority of the gas to bypass the vessel and be routed through a separate gas pipeline outside the vessel. This minimises the size of the separation vessel. The remaining water, oil and gas inside the vessel are separated by the gravity principle.

Water, which is the heaviest part, is pumped via a water injection pump directly back into a non-hydrocarbon reservoir, while oil and gas are remixed and pumped through a multiphase pump back to the Gullfaks C platform. Any deposit of sand inside the separation tank is handled by the sand removal system. This separator module is retrievable.

(iii) Sand Removal System

Any sand coming from the well stream will deposit at the bottom of the separation vessel. A flushing system with specially designed nozzles was developed to flush out the sand at certain intervals. The sand is then transported into a Desander Module, where it is mixed with the injection water and re-injected into the reservoir downstream of the water injection pump.

(iv) Water Injection Pump

The Water Injection Pump is a liquid pump which is driven by a 2.3MW electrical motor powered by an electrical power cable from the Gullfaks C platform. The pump can be retrieved for maintenance by a pump-running tool.

(v) Multiphase Pump

The Multiphase Pump used here is identical to the water injection pump as it was manufactured by the same company. The only difference is the internal arrangement of the impellers – one to cater to single phase pumping, and the other, multiphase boosting. As a result, both pumps have the same dimensions, interfaces and power requirements, and this adds to the flexibility of the system. The use of the pumps is a must as without them, the separation will not work. As its twin sister, this pump can also be retrieved by the pump-running tool.

(vi) Other Systems

The SSBI station is also equipped with two multiphase flow-meters which measure the composition of the well flow to prepare the separation system settings. A level monitoring system is installed in the separation tank to monitor water, oil and gas interfaces, which again provides input to the water pump speed. There is also one subsea control module to control the various functions of the station and communicate back to the Gullfaks C platform.

The driver behind these installations is Statoil's improved oil recovery (IOR) strategy. The Tordis SSBI project has been designed to handle a high amount of sand (50kg to 500kg per day) by its sand management system. Along with other upgrades to the field infrastructure, the recovery factor for the Tordis field is expected to increase from 49% to 55% resulting in an additional 35 million bbl and extend the life of the field by 15 to 17 years.

SEABED BOOSTING

The deployment of subsea boosting, sometimes called seabed or mud-line boosting, has always been perceived at times as a means to ensure the flow of fluids from fields at the required rate after the natural reservoir pressure declines. It includes subsea multiphase and downhole boosting, raw seawater injection and, quite recently, subsea gas compression.

On deepwater or ultra-deepwater fields, subsea boosting is needed to get the hydrocarbons from the seafloor to the facilities on the water's surface. In later years, as reliable high boost multiphase and hybrid pumps became available, the technology saw a marked increase in its application in green fields development – providing the kinetic energy to substantially increase production from day one, thus increasing the project's NPV.

Key parameters that lead operators to use seabed booster pumps include the existence of heavy oil, the increased distance from the host, increased water depth, low reservoir pressure, high water cut, and a greater number of fields tied back to the host. Several key characteristics are similar for both seabed separation and boosting, and this explains their simultaneous use in some cases.

Subsea multiphase pumps are separated into two main categories: positive displacement and rotodynamic. Most of the positive displacement types are based on multiphase twin-screw pump technology. They are field proven onshore and on topside production facilities, but have also been tested on the seabed. Possible liquid leakage and the limited ability to handle a significant amount of solids represent some of the issues that this technology currently faces.

The other category, which is the rotodynamic pump, has been dominated by the helico-axial pump design, developed by the Poseidon Group (comprising the French Institute of Oil, Total and Statoil). The helico-axial pumps are very robust, but are more prone to stresses associated with slugging. However, the installation of a buffer tank or homogenizer upstream of the pump proves to be sufficient to dampen slugging so that this no longer poses a problem.

Finally, subsea gas compression involves gas compression at the seabed level instead of gas compression on a topside facility. Key factors driving the implementation of subsea gas compression technology are the discovery of distant offshore gas fields, increased water depth, long step-outs from the host facility, harsh environmental conditions, and low reservoir pressure and temperature.

Compared to subsea separation and booster pumps, however, this technology is still at the introductory stage and is only beginning to gain ground with the operators. This could be because operators are still questioning the reliability of the system since controlling and monitoring subsea gas compression units over long distances is not yet as proven a technology as topside gas compression.

At present, there are two competing solutions, each with its own merit and limitations. The first practically mimics the whole platform based gas compression train including separator/scrubber, conventional gas compressor, liquid pump, and marinise them for subsea duties. This system is slated for field installation around 2014/2015. The other approach makes do without the separator/scrubber and relies upon field proven experience with subsea multiphase pumps, optimising the pump (in this way called a multiphase compressor) to work within the very high GVF range that is required for wet gas compression. This second system is planned for actual deployment in 2013.

CONCLUSION

At this stage, involvement in this technology is still quite limited to partly nationalised companies such as Statoil and Petrobras, and to some extent oil majors such as Shell and Total. In Malaysia, it could be many years before we see a deployment of a complete subsea processing system such as Tordis. However, parts of the main components are now seeing increasing acceptance with subsea multiphase flowmeters being installed in all subsea and deepwater projects while seabed boosting is now being considered.

It is believed that there will be a continued effort to push the technologies associated with subsea processing, either as a full system or as individual components, to improve oil and gas recovery, boost production, reduce operating cost, and mitigate against the likelihood of gas hydrate formation in the pipelines. As such, it is clear that the reliability of subsea processing equipment will be crucial in ensuring the success of such endeavours. In the long run, if these technologies can prove themselves by increasing the NPV of the project, they can surely be the preferred systems in the future. ■

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