Subsea Field Enhancement Systems Engineering

Document No 0001 AT BD 50006 PA 03

Paper for 7th Annual India Oil & GasReview, Symposium & International Exhibition Mumbai, 11-12 September 2000

Theme: Emerging Technologies& Resourcesin Petroleum Industry in the Next Two Decades

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Abstract

The advances in modular seabed oil and gas process system technology have matured to the point at which seabed processing is a reality that will set the trend for future decades.

Modular configuration enables seabed systems to be readily deployed and recovered without shutting-in the wells. With integrated systems modules, total system integration can be completed onshore, minimising seabed commissioning time. Seabed processing technology increases production rates and lengthens field life. Programmable systems control and monitor seabed systems autonomously and continuously, only needing to alert topside staff of unusual events. Electric actuators operate subsea choke, gate and modulating valves. High voltage, high power connectors are available for seabed power. If the seabed processing systems are to incorporate gas separation, there is no need for multiphase pumping; single speed pumps are utilised and bulky speed control is avoided. Wellhead connectors enable seabed processing modules to be deployed and recovered for maintenance or reconfiguration. Therefore, systems can be reconfigured in response to changing field characteristics, or to advancing technology, without cessation of production, hence providing optimum efficiency throughout field life and permitting CAPEX to be committed only when needed.

During September 1999, a prototype diverless seabed processing module was successfully tested underwater, witnessed by DNV and demonstrated to oil companies and other interested parties. The module was installed, connected, tested and was operational within fifteen minutes due entirely to the fact that the process modules, comprising all the equipment components, controls and power distribution, are constructed as complete machines that are system-integrated before leaving the factory.

The next few years will bring further improvements in high voltage connectors rated at 33kV, the availability of completely new valves and multi-way fluid connectors. Further development is anticipated towards seabed power distribution systems, enhanced manifolding and efficient well-testing.

Introduction

Current and future offshore field development can be significantly enhanced by using modular configuration for seabed processing systems. Seabed processing, available today, increases production rates, lengthens field life and provides flow assurance. Additionally, it reduces CAPEX and OPEX whilst minimising risk. The modular approach is the enabling technology for the extraction of subsea hydrocarbons.

This paper will show that advanced, modular seabed processing systems can be readily utilised, starting with a basic "hub" and continuing stage by stage as required to develop new or existing fields; this method is expected to characterise field development during the imminent decades. However, continuing development promises further technological advances during the next few years and this will also be discussed.

Section 1 Modular Configuration

Modular configuration is a "building block" approach to field development and process system packaging. It enables seabed systems to be readily deployed, maintained, operated and recovered without interrupting production by shutting-in the seabed wells and without the need for divers.

A modular system has a base structure that can be deployed onto the seabed as a single unit that has no moving parts, pipes or valves. The base structure is an open framework and can be installed using existing piling or mud skirt methods as appropriate to the seabed conditions. The base structure is usually deployed during the field installation of templates and pipelines when heavy lift equipment/vessels are available. The deployment of the remainder of the seabed system can be undertaken at a later stage, thus permitting CAPEX to be committed in stages – hence, a "Just-in-Time" concept.

The docking module and process modules can be deployed at any stage using a smaller vessel and lifting equipment of a lower capacity. Nominal weights (20 to 60 tonnes) and dimensions will vary depending upon the application. However, the processing modules are of two standard sizes: the smaller is 5m x 4m x 6m high whilst the larger is 9m x 4m x 6m high, the choice of module being mainly due to the size of separator needed for a given application. Generally, the smaller modules have a throughput capability of 20,000 bbl/d and the larger modules 30,000 bbl/d. However, processing system modules can be configured for a variety of applications. For example, a field may have a sufficiently high flowing wellhead pressure to permit manifolding without further processing during the first years of production. The HIPPS (High Integrity Pipeline Protection System) or manifolding system would be housed in a process module; the valves within the module would be operated by electric actuators which, in turn, would be electronically controlled. Having utilised a modular system from the outset, the process system can be readily re-configured to a separation/boosting system when required without interrupting production. This is illustrated in a later section of this paper.

Installed into the base structure with ROV guidance, the docking module contains the interconnecting pipework and is capable of accommodating at least two system-integrated, autonomous process modules. The pipelines and flowlines are connected to the docking module by means of existing pipe connections systems. The process modules are connected to the docking module by means of multi-ported wellhead connectors. These connectors not only provide the mechanical connection but also the fluid connection between the docking module and the process modules.

Section 2 The Advantages of Seabed Processing

Seabed processing technology enhances production rates, lengthens field life and renders marginal fields viable as illustrated in the case of the separation configuration: When the oil pressure falls below its bubble point, gas will break out. Pressure losses then increase and slugs formed in the pipeline undulations can overload or even damage downstream equipment. Downhole or multiphase pumping will prevent gas breakout but seabed separation with single phase pumping is simpler, more reliable, requires less power and does not require the well to be shut-in for maintenance. With seabed separation, gas flows in a separate flowline under its own head i.e. the pressure within the separator. Pumping the separated liquid overcomes the static back-pressure due to the riser height and also flowline friction. The elimination of the need to overcome the head of seawater is an advantage as it significantly improves drawdown from the reservoir and results in higher production rates and extended field life. The formation of hydrates is inhibited and also the system is designed to allow pigging if and when required.

Increased step-out distances (50km or more) and/or greater working depths (1000m or more) are thus made practicable by separating the gas from the liquid products on the seabed. CAPEX savings can therefore be made because seabed oil processing now makes it possible to exploit deepwater fields without the need for additional platforms. It is also feasible to extend the life of existing platforms by tying-in satellite fields. Yet another benefit is the freeing of topside space. In the case of some installations, e.g. tension leg platforms, topside weight is critical and seabed processing has the added advantage of permitting process equipment to be moved to the seabed.

The liquid products may be further separated within the seabed system to re-inject produced water back into the well from the seabed. Seabed separation and re-injection of produced water increases oil line capacity, alleviates hydrate formation problems, obviates the need for extensive water treatment at the mother or host platform (thus freeing up more topsides capacity for oil processing) and reduces overall power demand. In addition, the seabed injection of seawater, by means of booster pumps within the separator module, is possible.

Section 3 Processing Technology

A typical processing module would accommodate a horizontally-mounted gravity separator of 1 to 1.5m diameter and 2 to 3m length, depending upon the application. Using submarine building techniques, the weight of these pressure vessels may be minimised despite having to withstand typical internal pressures of some 200 bar and external pressures due to depths exceeding 1000m. The internal details are based on the established designs offered by well-known offshore process engineering and companies; for example, there is a vertical screen inside the separator in order to minimise turbulence and separated liquid exits via a vortex breaker. Similarly, sensors supplied by appropriately accredited companies are fitted in order to monitor the gas/oil and oil/water levels.

Section 4 Electric Power

Seabed separation means that multiphase pumping is eliminated. Single speed electric pumps are utilised for boosting the separated liquid(s) and thus bulky, heavy speed control units are avoided. Single speed, electric pumps are also utilised where water injection is a requirement.

The power is delivered to the seabed installation by means of umbilical cables, and fed to each process module. Besides the power conductors, the umbilical cables have a number of data/control signal paths in the form of twisted pairs and/or optical fibres and, typically, two or three conduits for delivering injection chemicals. At the seabed installation, the various lines are individually routed within a cable termination unit. Each module has a high voltage, high power, underwater-mateable connector typically rated at 11kV/1MVA. These connectors, which do not come into contact with hydrocarbons, are available from various suppliers as are umbilical power/signal cables. The connectors do not come into contact with hydrocarbons.

A typical system is supplied with high voltage 11kV, in order to maximise efficiency, and has an 11kV/400V transformer in an oil-filled, pressure balanced housing. The secondary transformers, rectifiers and switchgear are housed in a compartment of the power and control pod which consists of a central bulkhead with two end caps that form a pressure vessel. Cable entry to the power and control pod is by means of penetrators in order to maintain high reliability. The penetrators are installed during the assembly of the process module and integrity tested during the subsequent factory acceptance programme. Unlike the wet-mateable or dry-mateable connectors that are used in combination with retrievable components, once penetrators are installed, it is not necessary to disconnect them, minimising interfaces and therefore minimising failure risks. The pod is filled with dry nitrogen at a pressure of one atmosphere.

Section 5 Electric Actuators

In an all-electric seabed processing system, the valves are operated by electric actuators that have been specially developed and are now available for use on the seabed. It should be noted that existing proprietary underwater processing system valves are used and that the actuators do not come into contact with the hydrocarbons.

For example, if the configuration of a processing module were to include a separation process, the fluid levels in the separator are monitored and are adjusted as necessary by the use of modulating valves in the system; these valves are operated by electric actuators. The modules are equipped with choke valves that are also operated by electric actuators, which have been configured for the purpose. The separator is further protected by an isolation gate valve. This is operated by another type of electric actuator that provides a fail safe closed facility; in the unlikely event of a power failure (or if an emergency control on the panel on the host platform is operated), the actuator will immediately close the valve.

Section 6 Control Systems

Electric/electronic control systems maximise reliability by avoiding the interfaces that would be necessary with hydraulic or electro-hydraulic systems. Furthermore, as the control system is housed in a one-atmosphere power and control pod within each process module, industry-standard, well-proven, highly reliable, solid state, electronic control system is utilised.

A programmable logic controller (PLC) is located in the power and control pod and this controls the process and responds to signals from the subsea sensors. All control loops work locally without any need for fast transmission of large data quantities to and from the master control station (MCS) on the host platform. Commands are sent from the MCS and process values are sent to the MCS. As most process values vary fairly slowly, the requirements for data transmission are moderate. By this means, the seabed system is monitored and controlled continuously, sending data to a topside master control unit but only needing to alert topside staff of unusual events whereupon manual control can be assumed. As the system is software-controlled, software changes can be made at the MCS via the communication link often without interrupting the process.

Pressure and temperature sensors are located inside the power and control pod and level switches are also fitted to verify that there has been no water intrusion. As there is a dry, one-atmosphere environment, standard industrial sensors are used. There are also sensors that monitor the voltages, currents, electrical insulation and contactor positions to ensure that information on the electrical/electronic system conditions are provided at the MCS.

Section 7 System Integration Testing

As each process module is autonomous and self-contained, system integration testing is undertaken in full at the factory before the module is shipped out to the offshore field; reliability is therefore maximised. As a final check, “stump” testing is carried out on board the installation vessel prior to deploying the process module into the docking module. Insert-retrievable components and the many additional interfaces that are associated with them are avoided thus contributing to high reliability. The module’s only wet-mateable interfaces are the multi-ported wellhead connector, the high-voltage connector and the control/data connector, all of which are readily available from various companies in the offshore engineering industry. Having been completely system tested, each module can be commissioned within minutes of being installed. The opportunities allowed by relatively short fair-weather “windows” can therefore be taken.

Section 8 Recovery for Preventative Maintenance or Reconfiguration

A typical seabed system is located in the vicinity of a group of production wells (not directly over them) and would comprise at least two process modules, each of which is capable of at least 60% of the normal total throughput of the system. (This can be designed to be as much as 100% throughput per module if required.) An additional, fully system integration tested module is held onshore. This arrangement enables one module to be removed for preventative maintenance whilst the other module continues the processing operation. The fully tested substitute module can be installed whilst the original module is either inspected and maintained on the installation vessel or taken ashore for the same purpose. Continuous production flow is therefore assured.

Furthermore, modules can be exchanged in the same way in order to re-configure the system in response to changes of field characteristics. For example, in the initial stages of field life the flowing wellhead pressure may be high enough to manifold the produced fluid from a group of wells without the risk of hydrate formation. If the manifolding has been incorporated in a modular processing system, the process modules can be exchanged, one by one for two-phase separation system modules. Again, towards the end of field life, the seabed processing system can be reconfigured in the same way to incorporate three-phase separation and water injection, thus prolonging viable field life. The degree of risk is minimal since existing, field-proven equipment is utilised as explained above.

Similarly, the process modules can be progressively changed in order to incorporate the latest system technology for optimum production. In all cases, the modules are system integration tested in the factory before being installed and rapidly commissioned offshore. Finally, at the end of (extended) field life, modular processing systems can be readily decommissioned and removed from the seabed for recycling or re-use elsewhere.

Section 9 The Prototype Process Module

Alpha Thames/Kockums Engineering successfully tested and demonstrated their prototype process module in September 1999 in the harbour adjacent to Kockums' factory in Malmö, Sweden. The project was known as ÆSOP (All-Electric Seabed Oil/Gas Processing). The processing system within the module comprised a two-phase separator, a single speed electric pump, an ESD gate valve electric actuator and a modulating valve electric actuator. As environmental restrictions prevented the use of hydrocarbons in the harbour area, a well simulator commingled air and water to represent the output of a subsea well. A base structure/docking module was installed on the bottom of the (flooded) dock and the process module was lowered into it. The efficacy of the process module was determined by means of a test system that monitored the flow and content of the outputs from the separator. The tests were witnessed and approved by Det Norske Veritas. The deployment and commissioning of the process module were subsequently demonstrated to various oil companies and other offshore industry companies. The module was readily installed and was commissioned within a matter of minutes, operating at its full input rate of 20,000 bbl/d.

Section 10 The Future

Development of subsea components and systems is ongoing. Whereas 11kV underwater-mateable connectors are available at present, higher power requirements e.g. the need for more booster and injection pumping, result in the need for 33kV connectors in order to deliver the power efficiently over long distances. These connectors will incorporate fluid transfer systems in order to overcome the possibility of ionisation and water-treeing. The contact chambers will also be flushed once the pins are connected, but before power is applied.

The current development of compact rotary double block and bleed valves will enable valved, multi-ported fluid connectors to be manufactured. These connectors will increase the number of fluid paths into and out of process modules and the latter will then be able to manifold the produced fluids from a number of wells with greater versatility. This, in turn will enable well testing to be completed quickly on individual wells without the need for costly test lines and test separators.

Discussion

Electrically powered seabed processing systems existed in the Persian Gulf as long ago as 1969 but they were dispersed on the seabed and they lacked reliable, high power, high voltage, underwater-mateable connectors. By means of modular systems that utilise reliable connectors, these difficulties have now been overcome. The modular approach has been described above. The alternative systems are not modular and rely on building, testing and commissioning the process system on the seabed instead of being able to undertake full system integration testing onshore. Again, expensive, insert-retrievable components are used, with the consequent multiplicity of wet-mateable interfaces, additional isolation valves, and the inability to apply a fully integrated system test ashore before re-commissioning the system.

Nevertheless, the fact that more than one company is promoting seabed processing technology indicates that the trend has already been set for the next two decades. It is anticipated that diverless seabed oil/gas processing will be the standard method by which hydrocarbons are extracted from subsea reservoirs.

The ongoing development of electrical and fluid connectors, compact valves and electric trees with all-electric seabed processing will ensure the successful continuation of the offshore industry in the foreseeable future. However, as always, future achievement can only be assured by investment in today's technology.

Conclusions

The modular seabed processing systems described represent the most technically efficient, cost effective method of extracting subsea hydrocarbons. Whereas advances will enhance seabed processing, it is essential, in the current market, to exploit today's technology. Today, the opportunity exists to enhance existing fields, maximise new field viability and gain early return on investment in the Indian Ocean and elsewhere in the world.

Acknowledgement

Alpha Thames Ltd would like to thank the Commission of the European Communities, the DTI/OSO, Scottish Enterprise and the PSTI both for their financial support and their efforts in assisting with the promotion of our systems and products to the offshore industry.

In addition, Alpha Thames Ltd would like to acknowledge the encouragement and support given by the industry as a whole which includes oil companies, licensees, contractors, manufacturers and OEMs for their continuing assistance in the ongoing development of our products.

Alpha Thames Ltd is a British Company partly owned by Kockums Holdings AB of Malmö, Sweden and thereby a member of Saab Technology's Group.

Figures

The two photographs attached show Alpha Thames' prototype seabed processing module under test.

