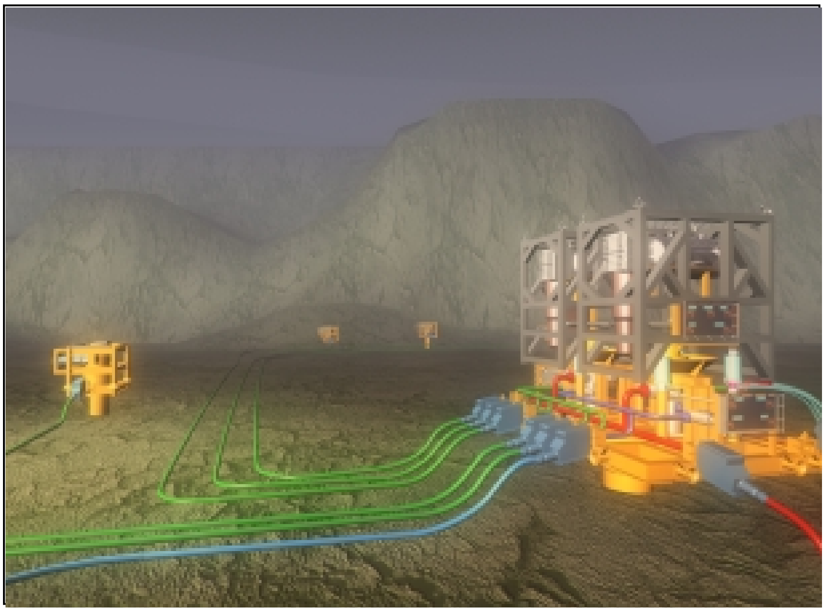
The Benefits of System-Modular Separation Systems



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Introduction

This paper presents the advantages of seabed separation and the cost-effectiveness of incorporating this into a seabed processing system which utilises System-Modules. System-Modules provide a ready means of re-configuring a processing system at any time during field life without interrupting production. Each System-Module is a reliable, self-contained, autonomous, system-integrated unit that is electrically powered and controlled. This paper also describes the testing of the prototype System-Module.

Whereas System-Modules provide an efficient and cost-effective means of accommodating and deploying separation systems, they also form an essential part of the AlphaPRIME™ field development. AlphaPRIME™ is a total “smart” field development solution for the control and processing of hydrocarbons. It enables the monitoring and operation of all systems and equipment, from the wells to the host facility thus enabling a “plug and play” approach to be adopted from a location that may well be remote from the field in question.

The advantages of System-Modular installations are discussed in terms of installation, commissioning, and subsequent retrieval for maintenance or re-configuration, decommissioning and recycling.

Advantages of seabed separation, including the effect of water depth

Seabed separation and boosting maximises hydrocarbon extraction by reducing the effective depth of the reservoir. The production rate can therefore be increased and field life is extended. Using Brent fluid data, it has been calculated that the application of first stage separation on the seabed can increase production by up to 75% compared with surface separation. This finding was first published in a paper given by David Appleford and Mike Taylor (Process Engineering Consultant) in a paper presented at the Deeptec ’98 conference, 27th January 1998. Whereas the maximum production advantage is to be gained in deep water scenarios with long tiebacks, the paper also showed that seabed separation provides significant advantages for short tiebacks in moderate water depths. Additionally, the application of seabed separation makes it possible to re-deploy FPSOs to other fields or at least makes platform facilities available for other purposes. Calculations prepared by two separate operators, using actual field economics, indicate savings of between \$2 to \$4 per barrel when utilising seabed separation instead of conventional field development techniques. These calculations were completed for a variety fields in the North Sea and Gulf of Mexico.

Seabed separation can overcome the need for multiphase pumping or ESPs; each of the separated liquids is pumped at a constant rate with the gas being transported by virtue of the pressure in the separator. Constant speed pumps obviously do not require speed control equipment; the latter is often bulky, costly and will reduce overall system reliability.

Seabed separation also significantly reduces the propensity for slugging and the formation of hydrates in the export lines. Pigging requirements are therefore significantly reduced. It should be noted that the use of injected chemicals, for hydrate prevention and the inhibition of corrosion, can be significantly reduced. It has been found that this one factor can result in very significant cost savings even to the extent of rendering viable a field that would otherwise not be viable.

The adaptability of a System-Modular seabed installation

The advantages of seabed separation can be maximised by adopting the System-Modular approach to field development.

A simple Docking-Manifold is installed, usually on a monopile, on the seabed. The Docking-Manifold contains only field-proven equipment and does not include controls or actuated valves; it can accommodate at least two System-Modules. In a “green field” scenario, early installation of the Docking-Manifold can be made at the same time as the pipelines. The fluid connections for the System-Modules are provided by multiported wellhead-type connectors which can initially be fitted with simple caps that enable the early flow of first oil. Connections can then be made using a proprietary pipeline connection system.

When the wellhead shut-in pressure is particularly high, a HIPPS (High Integrity Pressure Protection System) System-Module can be installed, thus significantly reducing pipeline costs or enabling existing infrastructure to be utilised in the case of mature field installations. HIPPS also enables high-pressure fields to be developed using FPSOs, as current technology for flexible risers has limitations as to the pressure for which it is suitable. When the shut-in pressure is sufficiently low, the HIPPS System-Module can be replaced by simple caps without interrupting production.

As the field matures and the flowing wellhead pressure falls, separation and boosting become necessary. The caps can be removed, one at a time, and replaced by separation System-Modules, thus optimising production, again without interrupting production. As there are only three wet-mateable interfaces per System-Module and as the System-Modules are thoroughly integration tested in the factory, the subsequent installation and commissioning of the System-Modules is readily accomplished.

The System-Modules can, in fact, accommodate a wide range of systems and equipment, such as manifolding, two-phase or three-phase separation and boosting, water re-injection and sand handling, to suit any field scenario. The separation systems can be gravity based or cyclonic. Separated produced water can be disposed of locally or boosted and commingled with seawater or water from the host for water injection purposes.

Furthermore, the System-Modules can be reconfigured during field life, in response to changing field characteristics or to the availability of new technology, without needing to interrupt production. In this way, equipment is only provisioned and deployed when it is needed and does not necessarily have to be provided for in the initial CAPEX budget. At the end of field life, the System-Modules and, if desired, the Docking-Manifold can be retrieved for refurbishment and re-use elsewhere, thus amortising their costs over a number of fields.

Fully integrated separation system including booster pumping, power distribution and autonomous process control

System-Modules can accommodate a variety of separation systems together with boosting pumps and other processing equipment. A significant feature of System-Modules is that the processing, monitoring and control, and power distribution systems are integrated into one entity at the design stage. Upon completion of assembly, this approach is further reinforced by thorough system integration testing in the factory. This ensures that all the equipment is compatible and any faults can be thoroughly investigated and rectified, bearing in mind that the apparent cause of a fault may be a symptom as opposed to the root cause. Therefore, the System-Module that is delivered to the field is a fully tested, self-contained system that is capable of operating autonomously but in concert with similar System-Modules in the installation.

System-Modular installations provide an all-electric system that is powered by a high voltage supply from the host facility or from a power and control buoy. The absence of hydraulics and the utilisation of all-electric power and control combine to minimise the number of wet-mateable interfaces and optimise reliability. This is an important consideration, especially in deepwater applications.

The power is fed to each System-Module by means of a power/control umbilical cable that may also incorporate chemical injection lines. The System-Modules can also be connected to each other to form a “ring main”. This has the advantage that any one System-Module can be isolated by means of switchgear in the adjacent System-Module(s) and/or that at the host facility. Therefore, it is possible to isolate and retrieve a System-Module, whilst maintaining power to the remaining modules, even if its switchgear is faulty. Each System-Module has a main transformer within a pressure-balanced housing. It also has a power and control pod that is a pressure vessel with two compartments, one for power equipment (secondary transformers and switchgear) and one for control equipment.

All the equipment within the pod operates in a dry, notionally one-atmosphere environment; this enables well-proven, industry-standard, highly reliable, solid state, “real time” electronic control systems to be utilised. The programmable logic controller (PLC) which is located in the power and control pod controls the process and responds to signals from the subsea sensors. As most process values vary fairly slowly, the requirements for data transmission to and from the host facility are moderate. By this means, the seabed system continuously monitors and controls itself. Where configured for separation, the fluid levels in the separator are monitored continuously and, when necessary, electric actuators adjust modulating valves on the output lines from the separator.

The control system sends data to a topside master control unit (MCS), 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 production process. As the System-Modules function as autonomous systems, they can be programmed to continue to operate (for a pre-determined time) in the absence of control signals from topsides, after which they will automatically shutdown in a pre-determined manner.

Pressure and temperature sensors are located inside the power and control pod; level switches are also fitted to verify that there has been no water intrusion. There are also sensors that monitor voltages, currents, electrical insulation and contactor positions to ensure that information relating to the electrical and electronic system conditions are provided at the MCS.

A System-Modular installation can be regarded as the central processing unit (CPU) of a field development system; it can act as a control centre that provides feedback data, especially as it operates autonomously yet offers the operational flexibility of being reprogramable from the host facility. Moreover, the System-Modules can incorporate reservoir surveillance and testing. The System-Modules can distribute power to neighbouring seabed systems and, if required, they can be configured to include hydraulic power units (HPUs) in order to control conventional electro-hydraulic trees.

Electrically powered valve actuators

In the seabed processing system, the valves are operated by the electric actuators that have been specially developed by Alpha Thames and that are available for use in seabed systems and land-based applications. It should be noted that existing proprietary subsea valves are used and that the electric actuators do not come into contact with the hydrocarbons.

REAct is a fail-safe actuator that is used to operate rising stem isolation valves. In the event of a power failure or if a command is received from the control system or operator, the energy stored in a spring system is released to open or close the valve as required. In System-Modules that are configured for separation and boosting, a REAct Actuator operates an isolation valve on the input line to the separator.

The PROAct Actuator operates flow control process valves. In the System-Modules that are configured for separation and boosting, PROAct Actuators operate flow control valves in order to maintain the correct fluid levels in the separator. This enables the utilisation of single speed electric motors to drive the liquid booster pumps to transport the liquids to the host facility.

The FLOAct Actuator is similar to PROAct but is configured to operate a wide range of pressure control valves such as chokes.

All three of the above actuators have been designed so that they can operate the valves on all-electric or part-electric trees. Each actuator has an electronic drive package programmed to provide the precise response characteristics required of the actuator for an individual application.

System reliability and complete system integration testing

Reliability/availability are the main concerns of any operator with regard to equipment that is either located downhole or on the seabed. Alpha Thames take a risk-based approach to reliability: rather than calculating an acceptable failure rate in terms of an equipment item’s mean time between failure (MTBF), a detailed failure modes, effects and causes analysis (FMECA) is undertaken in order to identify all possible failure modes and to enable highly reliable solutions to be realised that only result in some loss of performance rather than a complete loss of function in the unlikely event of failure.

This can be significantly improved if the number of wet-mateable interfaces/connections are minimised. However, any system containing rotating equipment and/or other control, power and processing components, will require periodic maintenance, and therefore these equipment items must be readily retrievable. The present industry solution is to make such equipment items “insert retrievable”. This solution introduces numerous additional wet-mateable process, power and controls connections for each item in order to facilitate disconnection and recovery, all of which in fact reduces reliability!

In contrast to this, each System-Module is capable of accommodating process, pumping, monitoring, control and power distribution with no wet-mateable connections being required within the System-Module. This method reduces the number of wet-mateable connections to three: process, power and controls, and thus increases system reliability. These connections utilise existing field-proven technology: the multi-ported fluid connector is a modified wellhead-type connector and the high voltage/power connector can be either an Alpha Thames ELEx Connector or any other proprietary connector, according to the Client’s choice.

Each System-Module is designed as a complete integrated system and is thoroughly system-integration tested in order to ensure that it operates reliably as a comprehensive autonomous system. Furthermore, each System-Module is “burnt-in” before it is shipped to site so that early-life failures (as in the “bathtub” curve) can be identified and eliminated in the factory. If required, stump testing can also be undertaken immediately before deployment. The systems are self-monitoring and planned maintenance can be undertaken so that System-Modules are removed and replaced before end-of-life equipment failures take place; this ensures that optimal system reliability is maintained because the equipment is only in the field during its useful-life phase.

It may be seen from the foregoing that commissioning consists of pressure testing and basic functional testing. As each System-Module has only three wet-mateable interfaces, the retrieval of a System-Module for maintenance or for re-configuration and, ultimately, its decommissioning are readily accomplished within short weather “windows”.

100% redundancy with continuous availability

Each System-Modular installation comprises at least two identical operating System-Modules, both of which operate continuously so that there are no problems associated with starting up “dormant” equipment. If one System-Module has to be removed for any reason, such as planned maintenance or reconfiguration, the remaining System-Module(s) continue(s) to function.

A typical AlphaPRIME™ developed field of say 40,000 BOEPD would use two System-Modules of 20,000 BOEPD each. For larger fields, multiples of 20,000 BOEPD System-Modules would be employed. This method proves to be the most cost effective way of ensuring maximum production throughput whilst any one of the System-Modules is retrieved for upgrading or maintenance.

For an application utilizing two System-Modules, each one would normally be sized for 60% of peak throughput, i.e. the system could handle 120% of peak flow. As the maximum peak throughput would only be for a short period of the overall field life, this would allow a minimum of 60% of peak flow to be maintained during System-Module change-out, without shutting in any of the production wells. Again, because the maximum peak throughput would only occur for a comparatively short period of time, each System-Module could have the capacity to process up to 100% of the total throughput during most of the field life. The capacities of the System-Modules can be varied at the design stage to suit the Clients’ requirements.

Another consideration is that each System-Module has a footprint of only 5 m by 4 m and a height of 6 m; it weighs between 25 and 50 tonnes, depending upon the equipment accommodated. Therefore, System-Modules can be changed out by relatively inexpensive lightweight vessels such as DSVs with suitable lifting/handling equipment. Location and connection of the System-Modules in the Docking-Module on the seabed is a diverless operation, requiring only the services of a work-class ROV.

Results of the underwater trials and demonstrations of the prototype System-Module

Having gained experience on subsystem-modular installations, Alpha Thames developed the integrated System-Modular approach to seabed processing. The initial design concept (then known as MUST) gained DNV approval in 1991 (and complies with DNV RP 0401 and API RP 17A). Intermediate designs followed and Lloyds

Register's approval in principle was gained in 1998. The prototype System-Module was successfully tested under the auspices of the EC-funded ÆSOP Project in 1999 and these in-factory and underwater tests were witnessed and approved by DNV.

Alpha Thames and its sister company Kockums Engineering undertook the testing and demonstration of a prototype System-Module and associated equipment e.g. underwater, electric actuators. The prototype System-Module was electrically powered and controlled, and was equipped with a horizontal, two-phase separator, a pump that was run at constant speed, and REAct and PROAct electric actuators. The interfaces with the Docking-Manifold were the MATE, multi-ported fluid connector, the ELEx 11 kV Connector and the control system connector. The test system included a simulation of a subsea well that fed a 20,000 BOEPD input flowrate to the System-Module. The prototype System-Module was built and tested in Kockums' factory in Malmö, Sweden, and was also tested underwater in the adjacent harbour. As there were environmental restrictions on the use of hydrocarbons, water and air were commingled in the test system. The System-Module successfully separated these two fluids and the outputs were monitored to ensure complete separation. Demonstrations of the diverless deployment and underwater tests were subsequently given to representatives of the offshore industry. The fact that it took only ten minutes to connect and commission the System-Module, immediately following installation, was the topic of much favourable comment!

Conclusions

System-Modules can accommodate a variety of seabed processing equipment including first-stage separation and boosting, all of which combine to achieve the cost-effective development of new fields and also mature fields that might otherwise be regarded as of rapidly diminishing value. Existing infrastructure can be utilised to great advantage when employing the system in such fields. Seabed separation widens the scope for utilising existing infrastructure, as step-out distances can be increased. A System-Modular installation can release surface facilities, such as FPSOs, for use on other fields.

CAPEX costs are significantly reduced in many ways such as the opportunity to make pipeline savings. Risks and installation costs are minimised because of the thorough system integration testing that is undertaken before shipping the System-Modules and because wet-mateable interfaces have been reduced to the barest minimum. Production is enhanced over a longer period and operation is optimised with minimum expenditure e.g. on injected chemicals. Re-configuration, in response to changes in field characteristics or newly available technology, can be readily achieved. Maintenance and decommissioning costs are similarly reduced.

Seabed processing can be the key to achieving additional revenue and significant cost reductions, particularly for fields that are difficult or uneconomic to produce by traditional means. However, System-Modules are not confined to seabed separation alone. They can also be applied to installations in lakes and other inland scenarios. Furthermore, as part of AlphaPRIME™, they provide an all-electric total field development solution for the control and processing of subsea hydrocarbons. AlphaPRIME™ enables the monitoring and powering of all the systems and equipment from the wells to the host facility thus enabling a "plug and play" approach to be adopted from a location that may well be remote from the field in question.

In conclusion, the System-Modular approach is the ideal method by which the benefits of separation systems can be utilised to maximum advantage on a great variety of existing and new field developments.