AlphaPRIME

an

All-Electric Subsea Hydrocarbon Production System

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David E Appleford I.Eng, F.I.E.D., R.Des., M.Inst.P.I.

Alpha Thames Ltd.

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Introduction

AlphaPRIME is a total subsea hydrocarbon production system that interfaces with all equipment from the reservoir back to the surface facilities. The heart of AlphaPRIME is based on a novel Systems-Modular design capable of being reconfigured, as required, to suit changing reservoir characteristics. Furthermore, AlphaPRIME is completely electrically powered and controlled. The Systems-Modular design makes AlphaPRIME suitable for life of field application without the need to shut-in field production.

The AlphaPRIME system design essentially allows for two- or three-phase seabed separation and booster pumping with single well flow measurement. It can further accommodate sand removal and possibly a gas compressor. In fact, due to the Systems-Modular design approach, any new technology can be included into an existing system at a later date, when it becomes available, whilst production continues uninterrupted.

The process Systems-Modules can be initially configured as a manifolding facility. At a later date, when changing reservoir characteristics dictate, it can be reconfigured to include separation, booster pumping etc, again whilst allowing production to continue uninterrupted.

Having all-electric power and control, the response to normal and emergency signals is instantaneous, giving a greater degree of control of the equipment comprising the processing system. Numerous system parameters can be continuously monitored. Furthermore, the seabed system operates autonomously, only sending alarm signals in the event of significant hydrocarbon processing changes. The seabed part of the control system can be programmed to automatically shut down the process should a major event occur. The absence of hydraulics and the utilisation of all-electric power and control combine to minimise the number of interfaces and optimise reliability.

Reliable electric actuators with electronic motor control have now been developed for use in AlphaPRIME. The utilisation of electric actuators together with a single-speed pump is considered the most efficient method of controlling seabed processing systems without the expense and risk associated with variable speed motors. Variable speed control for megawatt motors is costly, heavy, bulky and unreliable.

System-Modularisation provides a “building block” method of developing a field, stage by stage. As each process Systems-Module is an integrated autonomous unit, it enables total integration testing to be undertaken in the factory before deployment, thus increasing reliability and reducing installation and commissioning time.

As each AlphaPRIME system has a minimum of two process Systems-Modules connected in parallel, when one Systems-Module is removed, the produced fluid continues to flow through the remaining Systems-Module. In this way, the Systems-Modules can be retrieved, one at a time, for maintenance, reconfiguration in response to changing field characteristics, or incorporation of new technology; hence a “just-in time“ concept with infinite redundancy.

Systems-Modules can be readily installed and retrieved by the use of inexpensive and readily available vessels, assisted by ROVs, without any need for divers.

It is envisaged that for deepwater and ultra deepwater applications, an electrically powered and controlled, Systems-Modular approach, as used in AlphaPRIME, will combine to give significant operational advantages over alternative methods. The main benefits will be increased production and reliability with reduced total field CAPEX and OPEX and minimal risk to production.

AlphaPRIME seabed processing systems, utilising field proven components, are available today.

System Applications

The AlphaPRIME All-Electric Seabed Processing System is suitable for any field application. However, its main attraction is for field developments where conventional technology does not make the development possible or economic, such as where the system can prolong field life.

As such, the application of the system, configured to include two or three phase seabed separation and booster pumping, is more likely to be for fields having low reservoir natural drive and for fields where large pressure losses are experienced in transporting the produced fluids to the host facility, such as deep water applications and applications having long tie-backs to an existing topsides or onshore facility.

Production from deep-water locations can be significantly enhanced by the application of AlphaPRIME. For example, in a seabed separation system, the absence of the need to overcome the head of seawater significantly improves drawdown from the subsea reservoir; this results in higher production rates and extended field life. Furthermore, by separating out the gas from the liquid stream in the separator, the formation of slugging in the pipeline back to the host facility can be avoided.

Typically, AlphaPRIME is located in the vicinity of a group of production wells (not directly over them) and would comprise at least two process Systems-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 Systems-Module if required. This arrangement enables one Systems-Module to be removed for preventative maintenance whilst the other continues the processing operation. A fully "system integration tested" substitute Systems-Module can be installed whilst the original Systems-Module is either inspected and maintained on the installation vessel, or taken ashore for the same purpose; continuous production flow is therefore assured. The Systems-Modules can be progressively exchanged in the same way, in order to re-configure AlphaPRIME in response to changes of field characteristics or in order to incorporate the latest technology for optimum production.

CAPEX and OPEX savings can be made to the field development because the application of an AlphaPRIME processing system makes it possible to exploit deepwater fields, by allowing tie-backs to an existing field topsides facility, thereby alleviating the need for a new topsides facility. It is also feasible to extend the life of existing platforms by tying-in satellite fields using an AlphaPRIME system.

Systems-Modules Configuration

AlphaPRIME comprises a Systems-Modular design approach. This is not to be confused with the industry's normal understanding of modularisation, where "components" are modularised to allow for the removal and replacement of a similar component having the same interfaces.

By utilising Systems-Modules, the AlphaPRIME design allows for equipment upgrading and reconfiguration to suit changing field characteristics at any time during field life. The Systems-Modular approach allows all equipment with moving parts and electrical items to be contained collectively in easily removable, relatively lightweight, processing Systems-Modules.

The Systems-Modular design approach allows AlphaPRIME to be configured and installed as a control centre for the stage-by-stage development of new or existing fields. The Systems-Modular configuration allows for a "building block" approach to field development and process system packaging. It enables seabed systems to be readily deployed, maintained, operated and recovered without shutting-in the subsea wells or interrupting production.

A typical AlphaPRIME seabed processing system comprises a mono-pile foundation system, a Docking-Manifold and at least two process Systems-Modules.

A piled or gravity/suction based foundation system is installed, as appropriate to the seabed conditions, followed by the Docking-Manifold, usually deployed early in field development when relatively heavy lift equipment/vessels are available.

The design allows for the process Systems-Modules to be installed, configured suitable for early field life, and then reconfigured later to take account of changing reservoir characteristics such as reduced reservoir pressure, thus permitting CAPEX to be committed only when needed – hence, a "Just-in-Time" project management scheme can be adopted. Process Systems-Modules weigh approximately 35 tonnes, dependent upon the application. Therefore, they can be deployed using smaller, more economic and readily available vessels.

Installed onto the mono-pile with ROV guidance, the Docking-Manifold contains the interconnecting pipework and is capable of accommodating at least two process Systems-Modules. The pipelines and flowlines are connected to the Docking-Manifold by means of industry-proven pipeline connections systems. The process Systems-Modules are mechanically connected to the Docking-Manifold by means of multi-ported wellhead connectors; these field-proven connectors provide the means of produced fluid flow into the Systems-Modules (via the Docking-Manifold) and separated gas, oil and water flows out of the Systems-Modules (also via the Docking-Manifold).

A typical process Systems-Module is available configured for a nominal 20,000 bbl/d production throughput. However, due to its modular design, AlphaPRIME can be configured to allow any required throughput of produced fluids, by the addition of further process Systems-Modules. Where many Systems-Modules are required, consideration can be given to installing two or more AlphaPRIME systems.

Process Systems-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. A High Integrity Pipeline Protection System (HIPPS) or manifolding system could be housed in a Systems-Module; the valves would be operated by electric actuators, which, in turn, would be electronically controlled. Having utilised a Systems-Modular approach from the outset, the process can be readily re-configured to a separation/boosting system when required without interrupting production.

Finally, at the end of (the extended) field life, AlphaPRIME systems can be readily decommissioned and removed from the seabed to be recycled or re-used elsewhere.

Seabed Processing

Seabed processing technology enhances production rates, lengthens field life and renders marginal fields viable.

Calculations show that in only 500m-water depth, total production can be increased by up to 75% by separating the gas from the produced fluid on the seabed and boosting liquid flowing pressure. Seabed separation is therefore eminently suited to deep and ultra deep water, and long step-out distances.

Produced water may be separated from the oil within the process Systems-Modules and re-injected back into the subsea reservoir, thereby allowing a reduction in the produced liquid pipeline diameter. This also avoids the need to clean the produced water suitable for disposal at the host facility.

Where water injection is required, the produced water can be combined with a reduced flow requirement from the topsides facility or, in certain circumstances, seawater. In either case a single speed booster pump incorporated into the Systems-Modules would raise the water pressure suitable for injection into the subsea reservoir.

Removal of water on the seabed, in addition to increasing production, reduces the required production pipeline diameter, alleviates hydrate formation problems, reduces overall power demand and obviates the need for extensive water treatment at the host platform (thus freeing up more topsides capacity). In the case of some installations, e.g. tension leg platforms, where topside weight is critical, this is particularly beneficial as much of the equipment can be relocated to the seabed system.

Slugging can occur in a pipeline when the pressure of the produced oil falls below its bubble point. Main pressure losses are due to the static head as a result of water depth and/or pressure losses in the pipeline as a result of long step-out distances. As pressure losses increase, slugs form in the pipeline undulations, which can overload or even damage downstream equipment. To overcome this situation, either the gas needs to be separated from the liquid flow, or the multiphase fluid flow needs to be pressure boosted sufficiently to avoid gas breakout.

Whereas an increase in fluid flowing pressure (achievable by the use of downhole or seabed multiphase pumping) may prevent gas breakout, seabed separation offers a far more reliable and cost effective solution. It permits the use of single phase pumping down stream of the separator which is simpler, more reliable, and requires less power. The separated gas flows in a separate pipeline under its own head i.e. the pressure within the separator. Increased step-out distances (50km or more) and/or greater working depths (1000m or more) are thus made practicable.

Using submarine building techniques, the weight of the separators may be minimised despite having to withstand typical internal pressures of some 200 bar and external pressures due to depths exceeding 2000m. The internal details are based on the established designs offered by well-known offshore process engineering companies.

Where Systems-Modules are configured for separation, fluid level interfaces are monitored using Industry approved level sensor instrument manufacturers.

All-Electric Power and Control

The response of all-electric systems to normal and emergency signals is instantaneous. The system parameters can be readily monitored so that a high level of control can be achieved. Therefore, AlphaPRIME can operate autonomously, only sending alarm signals in the event of significant hydrocarbon processing changes. AlphaPRIME can automatically shut down the process should a major event occur.

By contrast, hydraulic umbilicals are expensive and subject to attenuation over long distances and hydraulic pipes are prone to collapse in deep water**.** The absence of hydraulics and the utilisation of all-electric power and control combine to minimise the number of interfaces and optimise reliability.

As has been shown, if the seabed processing system is to incorporate gas separation, the need for multiphase pumping is eliminated. Single-speed electric pumps can therefore be utilised for boosting the separated liquid(s), thereby avoiding the requirement for bulky, heavy speed control units. Single-speed, electric pumps are also utilised where water injection is a requirement.

AlphaPRIME is typically supplied with an 11kV power supply. Typical umbilical cables have three power conductors, a number of data/control signal paths in the form of twisted pairs and/or optical fibres and a number of conduits for delivering injection chemicals. At the seabed installation, these various lines are individually routed within a termination unit. The main transformer is contained in an oil-filled, pressure balanced housing, which is located within each Systems-Module.

The secondary transformers, rectifiers and switchgear are normally housed in a compartment of a power and control pod supplying single phase for control of the contactors and to power some of the system monitoring devices. However, most of the control and monitoring equipment is powered by a low voltage line that is supplied from converters. A back-up battery is provided for maximum reliability. The battery is specified only for short time use, e.g. to enable monitoring of the process parameters in case of a power blackout. There is also a possibility to switch on the battery power when the main power is disconnected. Earth fault monitoring is provided for the power system as well as for the low voltage system.

The power and control pod is a pressure vessel assembly. Penetrators are used for cable entry into the pod in order to maintain high reliability. The penetrators are integrity tested during the subsequent factory acceptance programme. Unlike wet- or dry-mateable connectors that are used in combination with retrievable components used in other systems, it is not necessary to disconnect penetrators during their service life. Therefore, the number of interfaces to be made up underwater is minimised and the exposure to risk also minimised. The interior of the pod is filled with an inert gas at a pressure of one atmosphere and therefore well-proven, industry standard, highly reliable, solid-state electronic control systems can be utilised. Solid-state electronic control systems maximise reliability by avoiding the interfaces that would be necessary with hydraulic or electro-hydraulic systems.

AlphaPRIME is controlled by a distributed intelligence system: the control system is built up as a network of programmable logic controllers (PLCs) in the power and control pod and in the master control station (MCS) at the host facility. The PLCs are connected together by communication links.

The independent work of each PLC makes it possible to use local control loops, i.e. the seabed PLC handles a number of control tasks without any need to communicate with the MCS. AlphaPRIME is monitored and controlled continuously, sending data to the MCS but only needing to alert topside staff of unusual events whereupon manual control can be assumed. As the system is software-controlled, changes can be made at the MCS via the communication link.

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 can be 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.

In order to enable the AlphaPRIME System to operate all-electrically, Alpha Thames have developed a range of reliable electric actuators with electronic motor controls have been developed for use in seabed systems. The utilisation of electric actuators together with a single-speed pump is considered the most efficient method of controlling seabed processing systems without the expense and risk associated with variable speed motors. The fluid levels are adjusted as necessary by the use of modulating valves in the system; these valves are operated by electric actuators that have been specially developed for underwater use. AlphaPRIME can be 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 at the host facility is operated), the actuator will quickly close the valve.

It should be noted that the new technology items, being the electric actuators, do not come into contact with the hydrocarbon fluids. These items of equipment are housed in the retrievable Systems-Modules.

Testing

As each process Systems-Module is autonomous and self-contained, system integration testing is undertaken in full at the factory before the Systems-Module is shipped out to the offshore field; reliability is therefore maximised. A final check, "stump" testing is carried out on board the installation vessel prior to deploying the process Systems-Module into the Docking-Manifold.

By not requiring insert-retrievable components, and the many additional interfaces that are associated with them, high system reliability can be achieved. The Systems-Modules only wet-mateable interfaces are the multi-ported wellhead connector, the high-voltage connector and the control/data connector, all of which are regularly specified for underwater applications and are readily available from various companies in the offshore engineering industry.

Once system integration tested, each Systems-Module can be commissioned within minutes of being installed. This allows for installation during relatively short fair-weather "windows".

Alpha Thames/Kockums Engineering successfully tested and demonstrated their prototype process Systems-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 ÆSOP Systems-Module is the predecessor to all AlphaPRIME Systems-Modules. The separation system within the Systems-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, the outputs of an air compressor and a high-pressure water pump were commingled to represent the output of a subsea well. A test Docking-Manifold was installed on the bottom of the harbour and the process Systems-Module was lowered into it. The efficacy of the Systems-Module was determined by means of a test loop 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 Systems-Module was subsequently demonstrated to various oil companies and other offshore industry companies. The module was installed, connected, tested and commissioned within fifteen minutes, operating at its full input rate of 20,000 bbl/d.

The Future

Electrically powered seabed processing systems existed in the Persian Gulf as long ago as 1969. However, they consisted of diver-installed, separate items dispersed on the seabed and lacked reliable, high power, high voltage, underwater-mateable connectors.

By means of AlphaPRIME Systems-Modules that utilise reliable connectors, these difficulties have now been overcome. AlphaPRIME can be fully system integration tested onshore, prior to installation, and so underwater connections are kept to the minimum.

Only two companies produce seabed separation systems at the present time. The alternative system to AlphaPRIME is not of modular design and relies on assembling, testing and commissioning the process system on the seabed. More expensive, insert-retrievable components are required, with the consequent increase in the number of isolation valves, wet-mateable interfaces, and the inability to undertake full system integration testing before re-commissioning the system.

The development of seabed processing systems and system components is ongoing. Whereas 11kV underwater-mateable connectors are available at present, higher power requirements, necessary for greater booster and injection pumping, will 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 contact takes place, before the power is applied.

The current development by Alpha Thames Ltd of compact rotary, expanding plug valves will enable valved, multi-ported fluid connectors to be manufactured. These connectors will increase the number of fluid paths into and out of the Systems-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.

This paper has shown that the utilisation of the AlphaPRIME all-electric seabed processing system is the most technically efficient and cost-effective enabling technology for extracting subsea hydrocarbons. The ongoing development of electrical and fluid connectors, compact valves with all-electric, seabed processing will ensure the successful continuation of the offshore industry in the foreseeable future. The fact that more than one company is promoting seabed processing technology indicates that the trend has already been set for the next few decades.

However, it is anticipated that all-electric, modular, diverless, seabed oil/gas processing will be the standard method by which hydrocarbons are extracted from subsea reservoirs, particularly in deep and ultra deep waters. As always, future achievement can only be assured by investment in today's technology.

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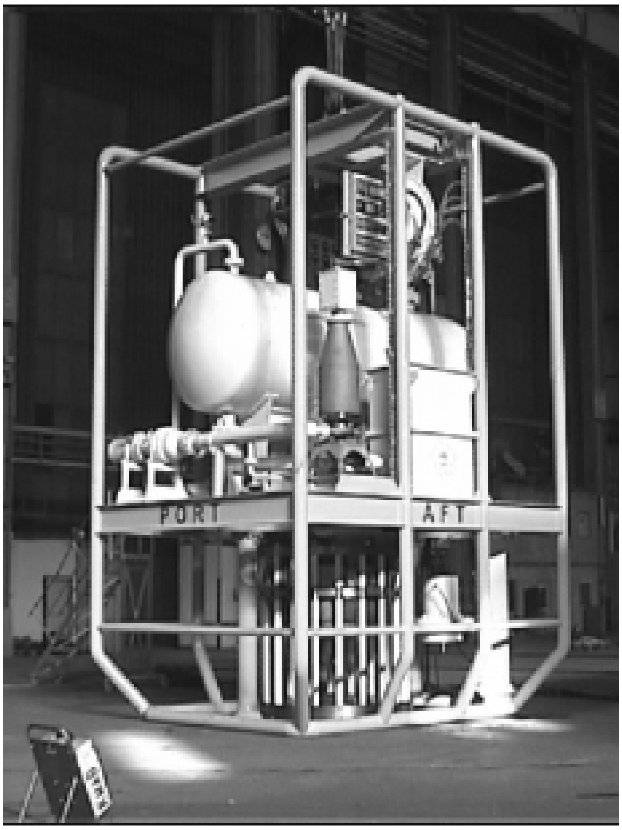
Figures



The two photographs show the prototype System-Module being demonstrated at Malmö in September 1999.