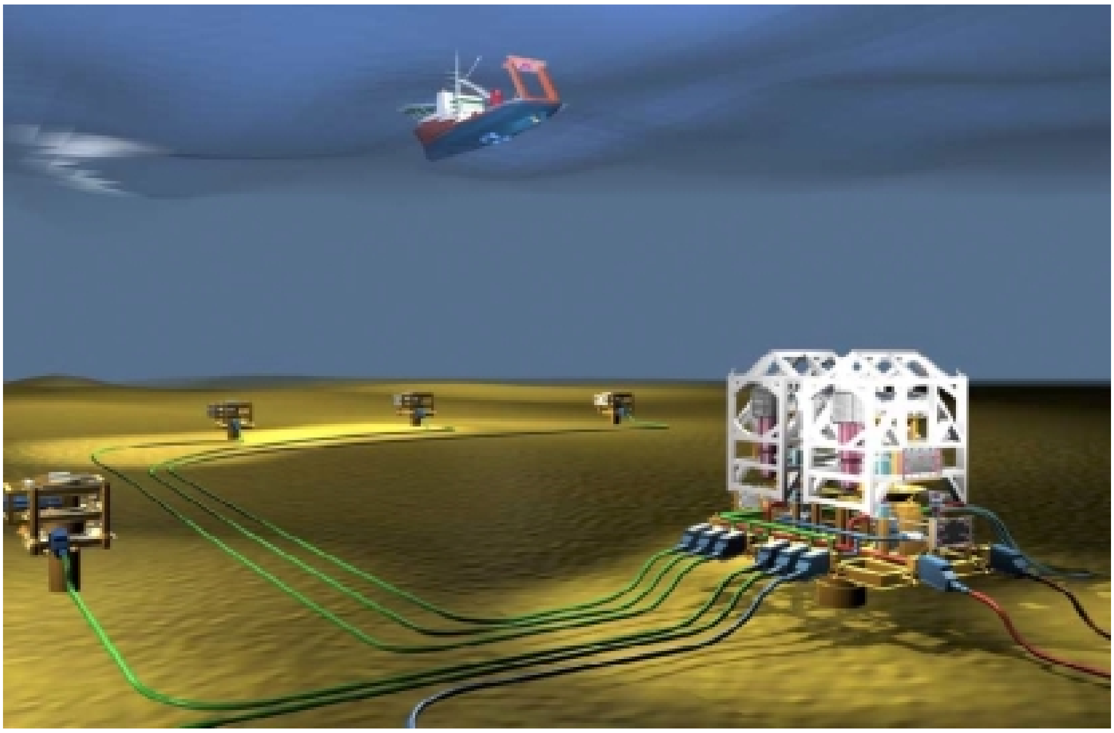
Economic Attractions for Field Development



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Introduction

This paper begins by introducing the AlphaPRIME™ system and then provides the background from which it was developed. The AlphaPRIME™ System-Modular approach to field development is described and its advantages are identified; particular emphasis is given to its all-electric power and control. The cost and risk benefits that result from the utilisation of AlphaPRIME™, especially in deep and ultradeep water, are identified.

The AlphaPRIME™ field development scenario

AlphaPRIME™ is a total field development system that incorporates one or more central processing units (CPUs). A CPU can be regarded as the control and power distribution centre from whence the entire field, including the wells, can be monitored and controlled via communication links from a location anywhere in the world.

An AlphaPRIME™ System-Modular CPU comprises a Docking-Manifold and at least two System-Modules. Each of the latter accommodates autonomous, system-integrated process, control and power distribution systems. The equipment within each identical System-Module is appropriate to the field at the time of installation. However, a System-Module can be readily reconfigured at any stage in field life in response to changing field characteristics or for the introduction of new technology. This method has been described as the “plug and play” approach to hydrocarbon field operation; it enables production to be optimised whilst minimising costs and risks. Furthermore, at the end of field life, the entire CPU can be retrieved for re-use elsewhere.

Brief history of subsea processing to date

Until now, very few subsea processing systems have actually been installed on a live field. They include the Exxon SPS in 1972-74, the Kværner Booster Station in the mid 1980s, and BOET (British Offshore engineering Technology) in 1986-89. No further examples occurred until the SUBSIS pilot was installed on Norsk Hydro’s Troll C field in 350 m water off the coast of Norway during 2000. VASPS (Vertical Annular Separator and Pumping system) was installed in the Marimba field in the Campos Basin, offshore Brazil later in the year.

However, Alpha Thames’ expertise in directly related technology encompasses significantly greater experience than all of these projects.

Alpha Thames was established in 1983, to develop, build and test seabed processing systems. The motivation for this arose from experience gained by the founding members whilst involved in the design and installation of the first seabed processing system, the Zakum Field – off Abu Dhabi, in the late 60s and early 70s. It was their firm belief that seabed-processing technology would be essential for the future low-cost extraction and enhanced production of subsea hydrocarbons. The system included two separators; they were designed by BSB and by NATCO.

The first full-scale prototype system, “GA-SP”, was designed and detailed by Alpha Thames personnel and installed in a dock for underwater testing during 1989. Testing utilised a purpose-designed and built conditioning plant to simulate three-phase hydrocarbon throughput.

The GA-SP system design ensured that maintenance could be readily achieved by adopting an equipment-modularisation approach. This approach was an improvement upon the component-retrievable (or insert-retrievable) technique being used by the industry, as it reduced the number of wet mateable connectors required for the system.

GA-SP incorporated nucleonic sensing for fluid level monitoring in the separator vessel. Signals from the level sensors were fed to modulating valves to control the output flows of the water, oil and gas from the separator. Although the system used hydraulic actuators for the valves, the system worked well. This encouraged the company to continue development, but with a view to incorporating all-electric power, control and distribution in order to simplify and increase the reliability and response times of the actuators and control functions.

The MUST (Modular Underwater System Technology) project was then undertaken. It was decided to adopt a sub-system modular approach that would be suitable for incorporating rotating and dynamic equipment. Individual removable modules were envisaged for each sub-system such as the pumps, the controls, the processing units, etc. A single datum multi-ported connecter that included integral isolation valves was devised for connection of each module to the distribution module. This sub-system modular approach concept improved on the equipment-modular technique used in GA-SP by further reducing the number of wet mateable connections required; the single datum connection was the same for each module, and could isolate the manifold piping during retrieval of the modules. DNV approval was granted in 1991.

Unfortunately, as is the case for “insert” component, or equipment modularisation, the system required many connections, particularly wet-mateable electric power and control connections. However, the concept of single datum connection for each System-Module had been established.

It became apparent that the design could be rationalised by developing a System-Modular approach in which all processing equipment such as booster pumps, metering, controls and, in particular, electric power distribution switchgear, along with transformers, would be incorporated within each System-Module. With each System-Module also incorporating its own power/control pod, it becomes an autonomous System-Module, relying only on power from the host facility to function. However, the power/control pod is in constant communication with the host facility and can be over-ridden or re-programmed if required. Lloyds Register approval in principle was granted in respect of AlphaPRIME™ in 1998.

The prototype System-Module was configured for two-phase separation with liquid boosting, weighed approximately 35 tonne, had a footprint of 5 m by 4 m and was some 6 m high. It was successfully tested in 1999 under the auspices of the EC-funded ÆSOP project. The factory acceptance tests and the in-water tests were witnessed and approved by DNV. Since then, the prototype System-Module has been demonstrated many times to visiting oil industry representatives.

The concept was subsequently taken a stage further: a System-Modular installation (the AlphaPRIME™ CPU) could act as the principal node in a total field monitoring and control network to provide optimum production operated from a remote location, providing the intelligent link between the reservoir and the host facility.

System-Modularisation: definitions & advantages

Alpha Thames realised that there were significant advantages in the System-Modular approach over component-retrievable (or insert-retrievable), equipment-modular or even sub-system modular designs.

The Docking-Manifold of an AlphaPRIME™ CPU installation is of simpler construction to that of the System-Modules. As such, it can be fabricated and installed separately from the System-Modules at an earlier date, for example, during the pipeline installation stage of the development. This facilitates taking advantage of installation vessels in the field at the time, and allows early production to be achieved.

The Docking-Manifold can be installed (without the need for divers) on a foundation system on the seabed (typically a monopile). Located in the vicinity of the production wells, the Docking-Manifold can be connected either directly to the wells or, in the case of a retro-fit, via an existing manifold facility. The pipelines, flowlines and umbilicals are connected to the Docking-Module and these connections remain undisturbed even during IMR operations. The Docking-Manifold does not contain any actuated valves or control equipment.

The Docking-Manifold includes piggable header pipes and facilitates the connection of all pipelines and flowlines. The system can include a pigging loop for round trip pigging, or can accommodate diverless pig launchers/receivers. However, it should be remembered that, when the system is configured for separation, many production pigging activities might no longer be required.

A System-Module accommodates an entire processing system including electric/electronic controls and electric power distribution. Each CPU installation comprises at least two identical operating System-Modules both of which operate continuously, thus avoiding 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 peak throughput of the system would only occur for a comparatively short period of time early in field life, each System-Module could effectively process 100% of the total throughput during the remainder of the field life. This provides little or no reduction in production capacity of the system during System-Modules change-out, thereby avoiding the need to shut-in any of the production wells. However, the capacity of each System-Module can be varied at the design stage, to suit the Clients’ requirements.

Each System-Module has hard-wired, fully factory tested connections and a minimum of wet-mateable interfaces, the entire system undergoes system integration testing and “burning-in” so that reliability is maximised. As a result, installation and commissioning on the seabed entails little more than making up and leak testing the few wet-mateable connections and, finally, functional testing.

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 tonne, depending upon the equipment accommodated. Therefore, the 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, only requiring the services of a work class ROV.

Maintenance of subsea equipment has, to date, been addressed by specifying equipment items suitable for the full field life. Where this is not achievable, the equipment is duplicated or specified as insert retrievable. Unfortunately, insert retrievable invariably means additional isolation valves and multiple wet-mateable connections, which in turn reduce system reliability and consequently availability. The System-Modular design allows for the concept of planned maintenance to be applied to subsea applications. Although this is the norm for topsides and shore based industry in general, this philosophy has not until now been available to subsea systems.

The all-electric approach

An AlphaPRIME CPU provides an all-electric system that is powered by a high voltage supply from the host facility, from neighbouring existing infrastructure, 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. Furthermore, hydraulic power and control systems are prone to failure in ultradeep water: the ambient pressure will probably be higher than the system pressure; the hydraulic system seals are often not designed for this.

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, thereby forming a “ring main”. This has the advantage that any one System-Module can be isolated by means of switchgear in the adjacent System-Module and/or the host facility. Therefore, it is possible to isolate and retrieve a System-Module, even if its switchgear is faulty, whilst maintaining power to the remaining module/s. 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) that 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.

Use of a pump bypass circuit in conjunction with electrically actuated control valves, allows separator level control to be achieved by the use single speed booster pumps. The response speed of the electrically actuated fluid flow modulating valves is such that speed control of the liquid booster pumps is not required. This in turn allows the use of single speed booster pumps designed to run at maximum efficiency, which results in a significantly reduced power requirement to drive the pumps. It also allows the processing system to be used at even greater step-out distances from the power supply at the host facility. A further advantage of being able to dispense with the speed control required by variable speed pumps is a significant saving in System-Module weight, size and complexity, whilst increasing reliability.

The CPU is the control centre of an AlphaPRIME™ field development system. It provides feedback data, operates autonomously, and 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 (HPU) in order to control conventional electro-hydraulic trees.

The economic & environmental benefits

The only two systems actually available at present utilise either insert-retrievable equipment or system-integrated modular designs. These systems will be compared and contrasted; the latter type of system being described in some detail. The enabling technology includes high voltage, high power, underwater-mateable connectors, subsea pumps, underwater electric actuators and diverless flowline connection systems.

Ongoing development engineering will provide 33 kV underwater-mateable connectors, in order to deliver higher power. Future technology will include rotary, expanding plug, double block and bleed valves principally for multi-ported fluid connectors. All-electric power and field control systems are envisaged.

Market conditions indicate that the advantages of seabed processing are particularly appropriate at the present time. Modular systems have particular advantages in terms of field development and operation. Seabed processing can be the key to achieving large capital and operating cost reductions with minimised risks on most types of fields, including marginal fields and fields in deep water and/or with long tiebacks, i.e. fields that are difficult or uneconomic to produce by traditional means.

The AlphaPRIME™ system has been designed and developed to enable a global approach to be taken regarding the operation of field development.

The design of an AlphaPRIME CPU is versatile in that it can include manifolding, separating, pumping or other processing equipment in addition to providing total field monitoring, control and power distribution. The System-Modules can be changed out at any time during field life without the need to shut-in the wells. This feature of the system design allows the minimum equipment necessary to be included for field start-up, e.g. manifolding or the inclusion of a HIPPS system, thereby reducing initial CAPEX to only what is required for early field life. The cost for including processing, pumping, metering, or any other equipment required in the future can be deferred until a later stage of field life. This flexibility also allows for the latest and best equipment solutions to be included in the system when reservoir conditions require them. The System-

Modules have been designed to be easily and quickly exchanged using low cost vessels.

When configured for subsea separation and boosting, the system provides field development savings in both CAPEX and OPEX. One such example would be the separation of water from the production fluid. The resultant savings can be identified as follows:

Reduced production pipeline diameter as a result of water removal;

Possibility of allowing the selection of carbon steel pipeline material in place of CRA (corrosion resistant alloy) material;

Reduced production pipeline diameter when booster pumping is included.

Reduced corrosion inhibitor requirement and reduced diameter of associated chemicals pipeline/umbilical;

Reduced hydrate prevention chemical requirement and reduced diameter of associated chemicals pipeline/umbilical;

A major advantage of seabed separation is the extra recovery of reserves that can be achieved over other conventional means of recovery. Independent studies have shown that subsea separation can increase the reserves recovered by up to 75%. If this figure were applied to only a small number of fields the implications to the income of an operator is substantial.

Seabed separation increases the rate at which reserves can be recovered from the field by reducing the wellhead backpressure. The deeper the water and the longer the tiebacks, the greater this advantage becomes. This increase in recovery rate has a positive effect on the operator's cash flow and can drastically alter the economic viability of marginal fields.

Calculations prepared by two separate operators, using actual field economics, indicate savings of between $2 to $4 per barrel when compared to other conventional techniques. These calculations were done on a variety fields in the North Sea and Gulf of Mexico.

Increased Revenue is therefore gained as follows:

- Improved draw-down,
- Increased production rate,
- Continuous production during IMR,
- Extended life of existing infrastructure,
- Lowered economic threshold of many fields.

CAPEX savings can be made in various ways, for example, seabed separation will, in many cases, remove need for local topside facility e.g. FPSO. Seabed separation increases step-out distances by tying fields back to a distant host facility – ultimately back to the beach. Seabed separation reduces dependency upon host support facilities, overcoming topside bottleneck problems, capacity and weight restrictions, and significantly reducing pipeline costs. Existing infrastructure can often be utilised and its useful life can be extended. All-electric seabed separation also overcomes the need for multi-phase pumping and downhole ESPs.

The System-Modular approach lowers installation, commissioning and decommissioning costs. Furthermore, the System-Modules and their Docking-Manifold are completely retrievable and recyclable; they can be utilised on other fields.

OPEX savings result from the removal of topside facilities such as leased FPSOs, once an AlphaPRIME™ CPU has been installed. The lower ongoing support costs and lower IMR costs may well be significant for field viability. The reduced chemical costs that result from seabed separation and from the autonomous and continuous field monitoring and control is also significant; some of the studies recently undertaken by Alpha Thames for international operators have shown that the reduction in injected chemicals, following water breakthrough, keeps fields viable. Furthermore, the separation of water from the production fluid has the potential to reduce the tariffs, where applicable, at the host facility.

Reduced OPEX also results from the reduced risk and increased reliability offered by the AlphaPRIME™ CPU. The System-Modules have built-in system reliability because they are fully system integrated in design, manufacture and test, they are “burnt-in” to identify any early life failures and may be stump tested immediately before installation. They incorporate the minimum number of wet-mateable interfaces: on each System-Module, these are the single-datum mechanical/multi-path fluid connector, the electric power connectors and the control/chemical stab plate. All operating equipment, e.g. pumps and actuated valves, are located within the readily retrievable System-Modules. Field proven technology is utilised e.g. multibore wellhead-type connectors provide the fluid connections between the Docking-Manifold and the System-Modules.

From an environmental point of view, AlphaPRIME™ CPU installations have several advantages: owing to their reduced footprint, they have minimal impact on the seabed eco-system. Their inherent reliability and thus their minimised need for intervention together with their built-in isolation valves minimises the risk of hydrocarbon release. In addition, being on the seabed, they are far less hazardous to shipping than platforms and FPSOs and they do not visually impair the landscape.

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 ultradeep fields, new and mature fields that might otherwise be regarded as being of high risk or of rapidly diminishing value. Seabed separation widens the scope for utilising existing infrastructure, as step-out distances can be increased allowing the tie-in of distant satellite fields. An AlphaPRIME™ installation can release surface facilities, such as FPSOs, for use on other fields.

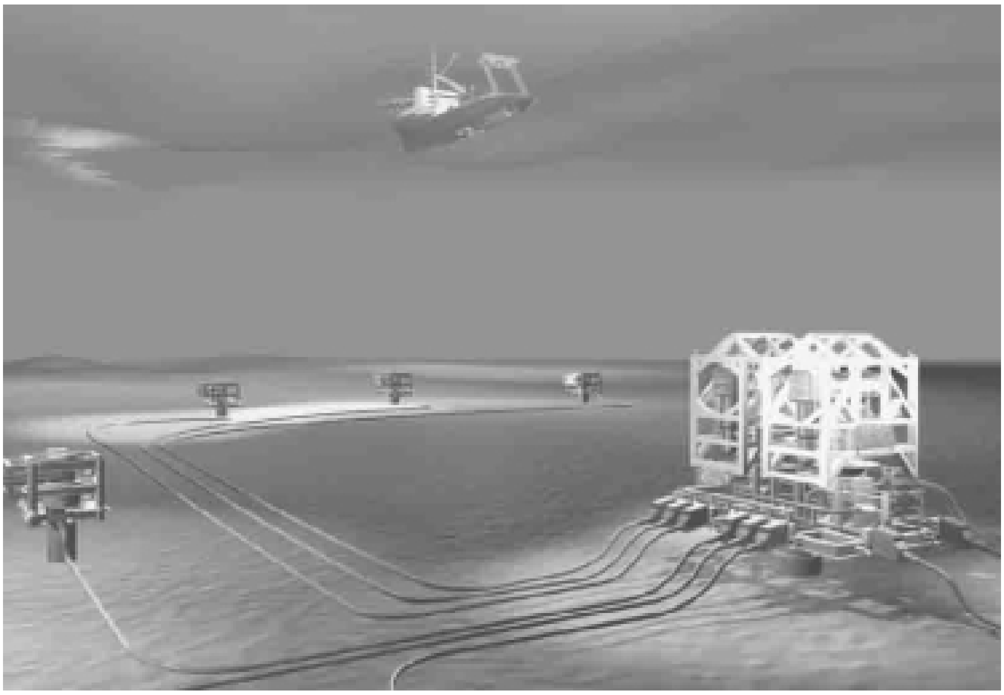
Costs are significantly reduced in many ways such as the opportunity to make pipeline savings. Risks and installation costs are minimised because of the thorough system integration testing that is undertaken before shipping the System-Modules and because wet-mateable interfaces have been reduced to the 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 production 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 systems alone; they can also be applied to installations in lakes and other inland scenarios.

Furthermore, in AlphaPRIME™ field technology, the CPUs 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. Control can be achieved from a location that may well be remote from the field in question.

The ability to readily change-out and reconfigure the System-Modules at any stage of field life in response to changing reservoir characteristics enables a "plug and play" approach to be adopted for field development.

In conclusion, AlphaPRIME™ is the ideal method by which the benefits of processing systems can be utilised to maximum advantage particularly on deep and ultradeep fields, be they existing or new field developments.



Typical field layout with one AlphaPRIME™ CPU

Prototype System-Module