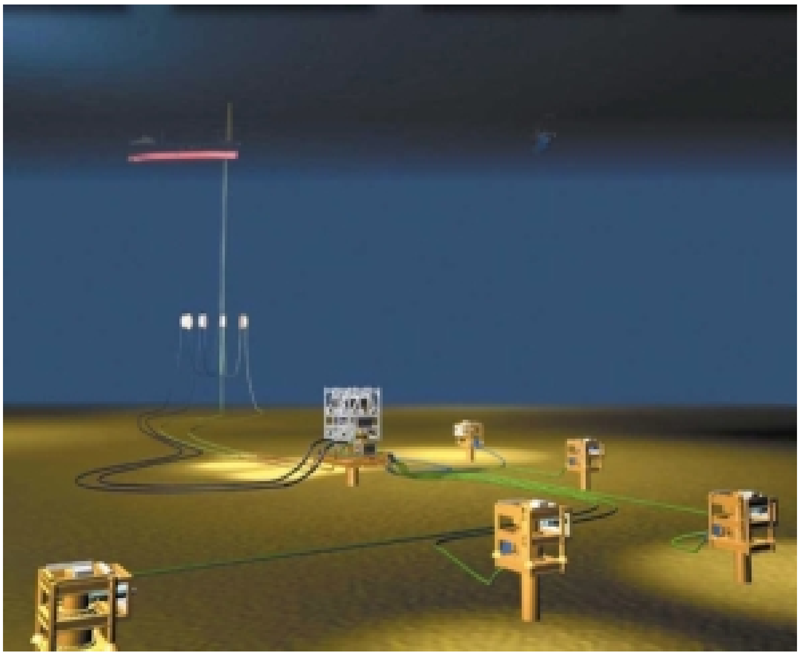
Smart Field Technology for Total Field Development



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Introduction

World demand for gas and oil is leading to the requirement to develop oil and gas reserves in ever deeper and more remote locations. A new approach using existing field-proven technology is needed in order to eliminate downtime (i.e. to ensure 100% availability) due to breakage, malfunction and even IMR.

This paper presents an all-electric total field development solution for control and processing of subsea hydrocarbons. The key element is the System-Modular Central Processing Unit (CPU) installation. All-electric System-Modular Central Processing Unit (CPU) installations not only meet these requirements, but provide many additional advantages, in particular, a means of remotely controlling entire field operations and reducing risk. The paper describes this new approach to field development and the method by which it can be implemented. The financial and other benefits are outlined.

New Approach to Field Development, Monitoring and Control

The benefits of smart wells are widely known. The natural progression from smart wells is to extend this philosophy of monitoring and control to the entire field. This can be achieved by means of modern all-electric power and control seabed systems that also provide real-time monitoring of wells. With the data link technology that is now available, smart fields can be monitored and controlled from distant locations. Furthermore, by adopting electric trees and electric seabed processing systems, power can be distributed across the whole field from a distant host.

The System-Modular CPU is the control centre of a field development system; it monitors and controls an entire field from the wells to the host facility, including the seabed processing systems. The CPU exercises autonomous control and yet provides a flow of information back to the master control point, which can be located anywhere in the world and from which control of the field can be assumed at any time. Operational flexibility is provided as the control system is capable of being reprogrammed from the host facility. Reservoir surveillance and testing can be incorporated and the CPUs can be used as centres of electric power distribution for the whole field.

CPU Architecture

A CPU consists of a foundation/base structure, Docking-Manifold and at least two identical System-Modules.

The Docking-Manifold is of simpler construction than 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 enables advantage to be taken of installation vessels already in the field, 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-Manifold and these connections remain undisturbed even during IMR operations. The pipeline and flowline connections are made by means of any proprietary connection system. 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.

Each CPU installation comprises at least two identical operating System-Modules, thus providing maximum availability even during IMR operations. Each System-Module accommodates an entire processing system including electric/electronic controls and electric power distribution. An inherent characteristic of a System-Module is that reliability is increased because it has a minimum number of connection-interfaces: multi-bored, wellhead-type fluid connectors, high-voltage electrical connectors, and control/chemical connectors.

Each System-Module weighs a maximum of 50 tonnes, dependent upon the specific equipment included, and have a footprint of only 5 m by 4 m and a height of 6 m. These “standard” System-Modules have common interfaces as described above. They can be readily installed and changed out by the use of a relatively inexpensive vessel such as a DSV. However, it should be noted that installation, operation, change-out and (at the end of field life) the total retrieval of the installation, is undertaken without the need for divers. It is therefore possible to re-use the system on other fields.

Each System-Module is a fully system-integrated processing unit that is fully integration tested and “burnt-in” under factory conditions before installation in order to ensure maximum reliability. 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.

A wide variety of module configurations can be accommodated within the System-Modules such as simple piping loops, HIPPS (High-Integrity Pressure Protection System), multiphase separation including sand removal, boosting the separated oil, and boosting and (re)injection of the separated water.

The architecture of the CPU enables the System-Modules to be readily installed, commissioned and also to be retrieved and reconfigured. When one System-Module is removed, the remaining System-Module(s) continue to process the hydrocarbons. Therefore, a “plug and play” modular philosophy can be adopted in response to changing field conditions, whilst still maintaining production.

Hence, for a typical field, the initial System-Modules might contain only simple piping loops, or HIPPS whilst flowing wellhead pressure/temperature remains high. These System-Modules would not contain long-lead items such as pumps, so early oil can be achieved. The System-Modules can be retrieved for reconfiguration, one at a time, once the flowing wellhead pressure drops and two-phase separation systems are needed, and again when water cut is high enough to justify three-phase separation.

By the same method, the System-Modules can be changed out for planned preventative maintenance purposes, or for the introduction of newly available subsea equipment incorporating the latest technology. These opportunities have not previously been available for seabed installations.

Availability is ensured because any fault in one System-Module can be isolated whilst production continues through the remaining System-Module(s). It should be noted that all System-Modules in a CPU run simultaneously. Furthermore, the CPU is scaleable: Each System-Module is capable of processing 20,000 bbl/d, and there is a minimum of two identical System-Modules per CPU, but if, for example, a throughput of 120,000 bbl/d were required, then six System-Modules would be provided. This impacts favourably on availability, e.g. if a fault occurred in one System-Module, the operator could wait for a favourable weather window or the next planned maintenance routine because the remaining five System-Modules will continue 100% production. In addition, the pump capacity may be shared amongst the System-Modules; this ensures higher overall reliability/availability compared with provisioning a very large pump in a single installation.

The System-Modular approach enables high-efficiency separator internal equipment to be utilised and also dynamic separators.

In some cases, these high efficiency separation devices have limited turn down ratios, which make them unsuitable for application over the full field life. However, in the case of a System-Modular design, where the System-Modules can be readily retrieved for reconfiguration, this does not present a problem as it is possible to design and configure the System-Modules for the best-case conditions, changing-out the System-Modules when and if necessary. By contrast, without System-Modular installations, there may well be a need to design for the worst case scenario by installing equipment at start of field life, which may or may not prove to be necessary later in field life.

All-electric Power And Control

An AlphaPRIME™ CPU provides an all-electric system that is powered by a high-voltage supply from either 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 particularly significant in deepwater applications. Furthermore, hydraulic power and control systems are prone to failure in ultradeep water because the high ambient pressure may give rise to sealing problems thereby allowing water ingress into the hydraulics leading to subsequent failure.

The power is fed to each System-Module by means of a power/control umbilical 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. The System-Module can be fitted with additional switchgear so that it can distribute power to other installations and equipment in the field such as the Xmas trees.

All the equipment within the pod operates in a dry, notionally one-atmosphere, inert gas 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. 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, to maintain the fluid interfaces at their optimum levels.

The control system sends data to a topside Master Control Station (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 pump bypass circuits in conjunction with electrically actuated control valves, allows separator level control to be achieved by the use of 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 greater reliability and 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.

Advantages of Seabed Processing and Boosting

The advantages of seabed processing (particularly first-stage separation on the seabed) are widely known and accepted. However, for ease of reference, they are summarised as follows:-

- Maximises extraction by reducing effective reservoir depth;
- Increases the production rate;
- Can overcome the need for multiphase pumping and ESPs;
- Removes sand to reduce erosional problems;
- Removes produced water, reducing corrosion and hydrate problems. Also, may eliminate the pipeline requirement where local produced water disposal is possible.
- Overcomes topside bottleneck, capacity and weight problems;
- Increases step-out distances;
- Extends the life of existing infrastructure, by allowing satellite fields to be tied-in;
- Removes the need for local offshore surface facilities and support;
- Provides flow assurance – overcomes propensity for hydrate formation and slugging;
- Integrated local well testing can be undertaken without the need for a dedicated test line or multiphase metering.

Financial Benefits

CAPEX Savings

The System-Modular CPU approach to seabed installations provides several CAPEX savings. A typical initial configuration would comprise the Docking-Manifold, and System-Modules configured with simple piping loops that do not accommodate any long-lead items. As the long lead processing and boosting items are not required for first oil, the initial costs are minimised and, “early oil” can be achieved.

The System-Modules are versatile, due to the fact that they can be reconfigured at any time during field life. This allows them to be configured for initial field conditions, then reconfigured, for example for processing and boosting, only when and if required, later in field life. This versatility also allows the latest and best technology to be included.

Separating and monitoring of the produced fluid leads to the opportunity to reduce the use of injected chemicals. This, in turn, reduces the cost of the chemical delivery lines, which can often be incorporated in the Integrated Services Umbilical (ISU).

Local well testing can be undertaken without the expense of a dedicated test pipeline back to the host facility, or multiphase flow meters. Where water separation and boosting is undertaken on the seabed, the hydrocarbon pipeline from the seabed installation can be of reduced diameter and the use of carbon steel may be possible instead of corrosion-resistant alloy.

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At the end of field life, System-Modular CPUs can be retrieved and refurbished for use on other fields, thus spreading cost over a number of fields.

Increased Revenue

When the System-Modules of a CPU are configured for separation and boosting, significantly improved reservoir draw-down and increased production rates are possible as a result of the CPU reducing the wellhead backpressure. These advantages are greater in deeper water, hence, cash flow is improved. The extra recovery of reserves may be up to 75%.

It has been calculated that, on a conservative basis, savings of $1.20 to $2.60/bbl are likely, if the System-Modular approach to field development is adopted, when compared with conventional techniques. This lowers the economic threshold of many fields.

Where such field developments use existing infrastructure, the remunerative life of that infrastructure is correspondingly extended.

System-Modular installations benefit production revenue by maintaining continuous production during IMR operations. When one System-Module is removed for IMR activities, the remaining System-Module(s) maintain production, without having to shut-in any of the wells.

OPEX Savings

Seabed processing significantly extends the possible tieback distance to the host facility, ultimately back to the beach.

It also removes the need for a local topside facility, such as an FPSO, together with the ongoing cost of supporting the facility.

Pipeline costs may be significantly reduced as existing infrastructure can, in many cases, be utilised.

Separating and monitoring the produced fluid leads to the opportunity to reduce the use of injected chemicals. On several recently studied fields, the savings in the cost of chemicals ensured the viability of the field.

IMR costs are reduced as a result of reduced installation/retrieval and commissioning time required for the change-out of the System-Modules. Smaller installation vessels, such as DSVs, can be used for the operations, and the CPU system uses a minimum of wet-mateable connections, thereby minimising module change-out time.

Reduced risk

The System-Modular CPU installations enable first stage separation or other processing to be undertaken on the seabed with consequent risk reductions on the topsides facility.

Existing equipment with known technology is utilised in the design, e.g. wellhead-type connectors, subsea pumps, valves and flanges etc.

Each System-Module is fully system-integrated in design, manufacture and test; it is "burnt-in" so that early life failures are identified and eliminated before the System-Module leaves the factory. If required, the System-Module may be stump tested on the installation vessel immediately before installation on the seabed.

Reliability and availability are enhanced because the number of wet-mateable interfaces is minimised, and the dry-mateable connections are made permanent in the factory; each System-Module has only one single-datum, mechanical/multiported fluid connector, two electric power connectors, and two control/stab plate connectors. By their very nature, insert retrievable or sub-system-modular systems have many more wet-mateable interfaces and also require many additional isolating valves and items of switchgear.

The risk of system failure is significantly reduced with a System-Modular CPU, as the system design allows for preventative maintenance to be undertaken. Risk is further reduced because all processing equipment such as pumps and actuated valves, are located within the retrievable System-Modules. There are no actuated valves or control equipment in Docking-Manifold.

Flow assurance is provided as seabed separation avoids the problems of slugging and hydrate formation, and reduces pigging requirements.

Environmental Benefits

From an environmental point of view, 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, their built-in isolation valves together with the flushing system that is operated before disconnection takes place, combine to minimise 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.

The System-Modular approach minimises the number of interfaces therefore minimises the leakage risk.

As the System-Modular CPUs are all-electric, there is no hydraulic fluid that might leak or be used in open loop systems. Even water-hydraulic systems utilise glycol, biocides and fresh water; therefore, any leak would have a detrimental affect on the local seabed eco-system.

Conclusions

As demand increases, new and existing fields will have to be developed to realise their full potential, at a competitive price. This can be achieved with an AlphaPRIME™ developed field incorporating System-Modular CPU installations, which provide a means of controlling and monitoring the entire field from a distant location.

The System-Modular approach to field development can accommodate seabed processing, allowing reconfiguration of equipment at any time during field life to provide optimum exploitation of reserves, despite changing field conditions, on a “plug and play” basis.

The smart field technology described here is confidently anticipated to become the normal method of field development and operation during the next few years.

