Effective Technology for Subsea Tiebacks

by

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David Appleford has been an engineering designer of special purpose machinery and equipment for the past 35 years. He is the managing director of Alpha Thames which he founded in 1989.

Today Alpha Thames is owned by two international corporations that cover oil production and high technology engineering/manufacture. David's overall responsibility is the marketing of the company's products. However he still has hands-on involvement in product development and systems engineering.

David's experience in the offshore industry began 25 years ago with the design of special equipment for the maintenance and intervention needs of Shell Expro's Underwater Manifold Centre. Since that time, David has worked primarily in the oil and gas industry on a multitude of different projects with particular interest in All-Electric Seabed Oil/gas/water Processing Systems. He holds several patents for underwater equipment, components and systems designed for the economic and reliable recovery of subsea hydrocarbons.

Introduction

The present market trends are towards the development of deepwater fields e.g. in the Gulf of Mexico, off the coast of Brazil and off the west coast of Africa. Seabed separation offers greater drawdown and increased production compared with topside separation. However, in UK waters at least, there is currently a drive towards the development of hitherto unexploited marginal satellite fields with tiebacks to existing infrastructure. In all these cases, there is the need for a system that can be tailored to the characteristics of individual fields and yet be sufficiently adaptable to permit changes to be made as those reservoir conditions change. Moreover, continuity of production must be safeguarded whilst these changes are made. This paper will describe such a system in addition to discussing technology that is applicable to subsea tiebacks.

Seabed Processing Technology

Seabed separation overcomes the problems associated with multiphase pumping, especially with extended tiebacks, where their higher power requirements may combine with transmission losses to become prohibitive. Seabed processing technology is highly effective over long distances whether tying back to an existing platform, to a shore-based facility or to an FPSO. As a vital bonus, seabed separation can increase the production rate, extend field life and facilitate greater flow assurance. A System-Modular approach permits maximum viability and reduced OPEX and CAPEX. Furthermore, the CAPEX may be spread over the life of the field because equipment can be installed as it is required.

When the pressure in a flowline falls below the bubble point of the oil, gas will break out and slugs are likely to form in undulations in the line with consequent risk to downstream equipment. As the line temperature falls below the gas dewpoint, there is a considerable risk of hydrate formation. Whereas multiphase pumping may overcome these problems, it does so at a cost in terms of additional power, complexity of control and the need for high pressure pipelines over long step-out distances. Hydrate inhibitor may be added to the wellflow but if separation is undertaken on the seabed, the amount of inhibitor required is significantly diminished as a minimal amount is “trickled” into the gas phase. Currently, gas flow is ensured by the separator pressure alone; the liquid phase may need to be pumped but this is usually achieved by a single speed pump in the range of 20 to 300 kW, subject to water depth and step-out distance.

Where three-phase separation is required, the separated water may be disposed of down-hole or, if sufficiently cleansed, jettisoned. Alternatively, it may be sufficiently de-oiled to be utilised for injection purposes, assuming compatibility with the reservoir. If necessary, it could be combined with additional injection water. Obviously, liquid booster pumps are required but these are also single speed. There are many economic advantages: the demand for topside processing capacity is reduced and pipeline costs may be reduced because lower specification and non-corrosion resistant materials are likely to suffice. The pipeline costs can also be reduced by the incorporation of a HIPPS (High Integrity Pipeline Protection System) in the seabed installation. This enables the pipeline to be downrated, thus saving pipeline material.

The use of two or more separators on the seabed, facilitates well testing which can be readily undertaken without the need for a dedicated test line to the host facility; the output of any single well is routed through one System-Module separator by operating manifolding valves in the seabed system. Because AlphaPRIME is installed in close proximity to the wells, well testing is accurate and more convenient. Meanwhile, the other separator(s) continue to process the output from the remaining wells.

Subsea processing systems currently being developed elsewhere, adopt a component-modular or insert-retrievable approach. They may be built from a number of separate systems: pump system, level monitoring system, power distribution system, control system, etc. By definition, they have an increased number of wet-mateable interfaces and isolation components thus leading to increased system reliability risks. A component may be changed in response to a diagnosed fault. In some instances this diagnosis may be wrong and the component retrieved in error. But even if the diagnosis is correct, the damage to the retrieved component may have been caused by a fault elsewhere in the system, increasing the possibility of the fault recurring within a very short time. Furthermore, the damaged component that has been changed may, in turn, have already caused undetected damage in downstream equipment. These systems are assembled on the seabed, so the time taken to initially commission the system, and to subsequently re-commission it after changing a component may easily run into days or even weeks, particularly if the weather changes for the worse during the operation. It is possible, of course, to duplicate critical components, but this is expensive and leads to further complexity with additional isolation/diverter valving and connectors.

By contrast, an AlphaPRIME System-Module can be retrieved, all equipment thoroughly inspected, and subjected to a complete integrated system diagnosis under controlled factory conditions.

System Description

AlphaPRIME is a system-integrated System-Modular total field development solution installation. It avoids the problems of component-modular systems and offers many additional advantages. It removes the need for multiple, complex and problematic wet-mateable interfaces and connections. Each System-Module is an autonomous processing system that has been system-integrated and tested under controlled factory conditions. System integration testing can be followed by “burning-in” so that faults which could otherwise occur relatively soon after installation may be discovered and remedied. Factory acceptance testing can be followed by stump testing on the installation vessel before deployment to the seabed. The System-Modules can incorporate manifolds, separation systems, booster pumps, or any other processing equipment that may be required.

Furthermore, AlphaPRIME can form the centre for field development and future expansion: distributing power, autonomously exercising control, providing reservoir monitoring and automatically reporting back to the host facility when necessary. It can be regarded as a hub from which the field can be developed, stage by stage.

An AlphaPRIME installation comprises a Base Structure that accommodates a Docking-Manifold which, in turn, accommodates a minimum of two System-Modules. The Base Structure utilises a monopile, piling system or a gravity base foundation system with mud skirts depending upon the particular seabed conditions.

The Docking-Manifold houses the interconnections with the remainder of the field system: the flowlines from the wells, the pipelines to the host facility and the power/control/chemical injection umbilicals. Each of the System-Modules is connected to the Docking-Manifold by means of a “wellhead-type” connector. Isolation valves are provided in the Docking-Manifold and in the System-Modules enabling either of the System-Modules to be isolated prior to being retrieved to the surface for inspection, maintenance or repair (IMR). In an AlphaPRIME installation comprising two System-Modules, each one is normally sized to be capable of processing at least 60% of the total peak throughput so that production continues without interruption during the short time in which one System-Module is removed. A replacement or reconfigured, fully system integration tested System-Module can be substituted; the System-Module that has been removed can be transported to the factory where it can be reconfigured and maintained. Commissioning for an installed System-Module is little more than a leak test and takes only a matter of minutes therefore the advantage of a short weather window can be taken. The System-Modules have a mass of 25 to 50 tonnes, depending upon the equipment within them, and so any support vessel fitted with a suitable moon-pool or stern-mounted A-frame can be utilised. All AlphaPRIME equipment is diverless and only requires ROV assistance for installation and retrieval.

The ease with which these System-Modules can be swiftly changed out, means that changes to the seabed system can be readily made in response to changing field characteristics. This is a great advantage as some changes are difficult to predict in terms of field life timescale. A fairly typical scenario has the System-Modules configured as simple manifolds at the start of field life, when the flowing wellhead pressure is sufficient for transportation of the produced fluid to the host facility without encountering undue problems. Subsequently, the System-Modules can be reconfigured, one at a time, to include two-phase separation and boosting. Later in field life, they can be reconfigured again to comprise three-phase separation, boosting and water re-injection. This example shows that the CAPEX can be spread over the life of the field and that the system does not have to include all the equipment from the outset, thus reducing the initial CAPEX and reducing equipment life requirements. It also shows that a total field can be developed stage by stage.

In the same way, new technology can be introduced as it becomes available, simply by reconfiguring each System-Module in turn. For example, when subsea gas compressors have been sufficiently developed, they could easily be added to the system, thereby freeing up topside facilities. Versatility is provided and maintained as new equipment can be introduced at any stage during field life, and provision for this does not have to be made from the outset.

Reliability is also ensured by the fact that the only wet-mateable connections to a System-Module are the mechanical and fluid connector, the high voltage connector, the electric control and chemical injection connector/ROV stab plate interface.

Alpha Thames together with Kockums Engineering have developed the ELEx High Voltage Connector which is, at present, rated at 11 kV (3-phase) and 400 A. ELEx incorporates a fluid exchange system; the contacts in ELEx are made in a liquid but are then maintained and operated in a gas environment at a notional pressure of one atmosphere. This obviates the problem of ingress of water into the contact chamber oil, leading to a tendency to induce tree-like formations of water molecules between the phases, and avoids problems with any entrapped gas ionising within the contact chamber oil. Both these problems give rise to the resultant risk of electrical breakdown. The ELEx Connector was developed from Alpha Thames' Hydro Webb Connector and can be rated for any water depth. However, it is possible to utilise alternative high voltage connectors within AlphaPRIME in place of ELEx.

Power Distribution and Control System

AlphaPRIME is essentially an all-electric system. The absence of hydraulics and the utilisation of all-electric power and control combine to minimise the number of interfaces and optimise reliability. The power is fed to each System-Module by means of a power/control umbilical cable that also incorporates 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 and/or that at the host facility. Each System-Module has a main transformer within a pressure-balanced housing and a power and control pod. The latter is a pressure vessel with two compartments, one for power equipment (secondary transformers and switchgear) and one for control equipment.

Both power and control equipment within the pod operate at a notional one-atmosphere, therefore well-proven, industry-standard, highly reliable, solid state, electronic control systems are 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. All control loops work locally without any need for fast transmission of large data quantities to and from the master control station (MCS) on the host platform. Commands are sent from the MCS and process values are sent to the MCS. As most process values vary fairly slowly, the requirements for data transmission are moderate. By this means, the seabed system is monitored and controlled continuously, sending data to a topside master control unit but only needing to alert topside staff of unusual events, whereupon manual control can be assumed. As the system is software-controlled, software changes can be made at the MCS via the communication link often without interrupting the production process. As the System-Modules function as autonomous systems, they can continue to operate (for a pre-determined time) in the absence of control signals from topsides, after which they will automatically shutdown in a controlled 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 on the electrical and electronic system conditions are provided at the MCS.

An AlphaPRIME installation can distribute power to neighbouring seabed systems, including all-electric trees. It can also act as a centre for control and feedback data especially as it operates autonomously yet offers the operational flexibility of being reprogramable from the host facility. Moreover, AlphaPRIME can be configured to include reservoir surveillance. If required, AlphaPRIME can be configured to include hydraulic power units (HPU) in order to control conventional electro-hydraulic trees.

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

If the configuration of a System-Module were to include a separation process, the fluid levels in the separator are monitored and are adjusted as necessary by the use of modulating valves in the system; these valves are operated by PROAct electric actuators. Where the modules are equipped with choke valves, they are operated by FLOAct electric actuators. The separator is protected by an isolation valve that is operated by REAct, a fail-safe electric actuator which, in the unlikely event of a power failure (or if an emergency control on the panel on the host platform is operated), will immediately close the valve.

As already stated, only single speed pumping is utilised. As a proportion of pump output may be recirculated back to the separator, any heat generated is imparted to the separator thus assisting in the processing of the fluids. An electrically powered system can, if necessary, be configured to provide additional heat to the process system and to the pipelines.

AlphaPRIME equipment can, where required, also include a fully proven diverless rigid pipeline connection system known as CUSP. However, most other proprietary remote connection systems can be utilised with AlphaPRIME installations, dependent upon Client preferences.

At the end of field life, AlphaPRIME may be decommissioned by totally retrieving it to the surface for refurbishment and subsequent re-use elsewhere.

Future Technology
Future AlphaPRIME technology is to include wet mateable connectors that are rated at 33 kV and a more compact version of the CUSP pipeline tie-in and connection system. On behalf of Alpha Thames, BEL Valves are finalising the development of the AB3 rotary, expanding plug, double block and bleed isolation valve. This new valve will be incorporated in the upgraded MATE Connector that will then be used to connect System-Modules, and will provide additional fluid ports. This will enable commingling to take place simply within the retrievable System-Modules rather than in the Docking-Manifold. The MATE Connector and the AB3 Valves will replace "wellhead-type" connectors and the isolation valves that are currently used in the AlphaPRIME system. Alpha Thames is currently holding meetings with various processing equipment suppliers; the use of dynamic separators and the development of all-electric fields are envisaged. It is worth noting that BP operated the all-electric Zakum field in the Persian Gulf in the late 60s/early 70s!

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

Conclusions
In conclusion, it may be said that seabed technology has reached the point where the problems traditionally associated with subsea tiebacks can be overcome. Furthermore, the market climate is amenable to field developments with tiebacks to existing infrastructure, be it offshore platforms or shore based facilities.

The application of AlphaPRIME has particular advantages as it provides a complete life of field solution, reducing costs, minimising risks, facilitating flow assurance, enhancing production and ensuring versatility.

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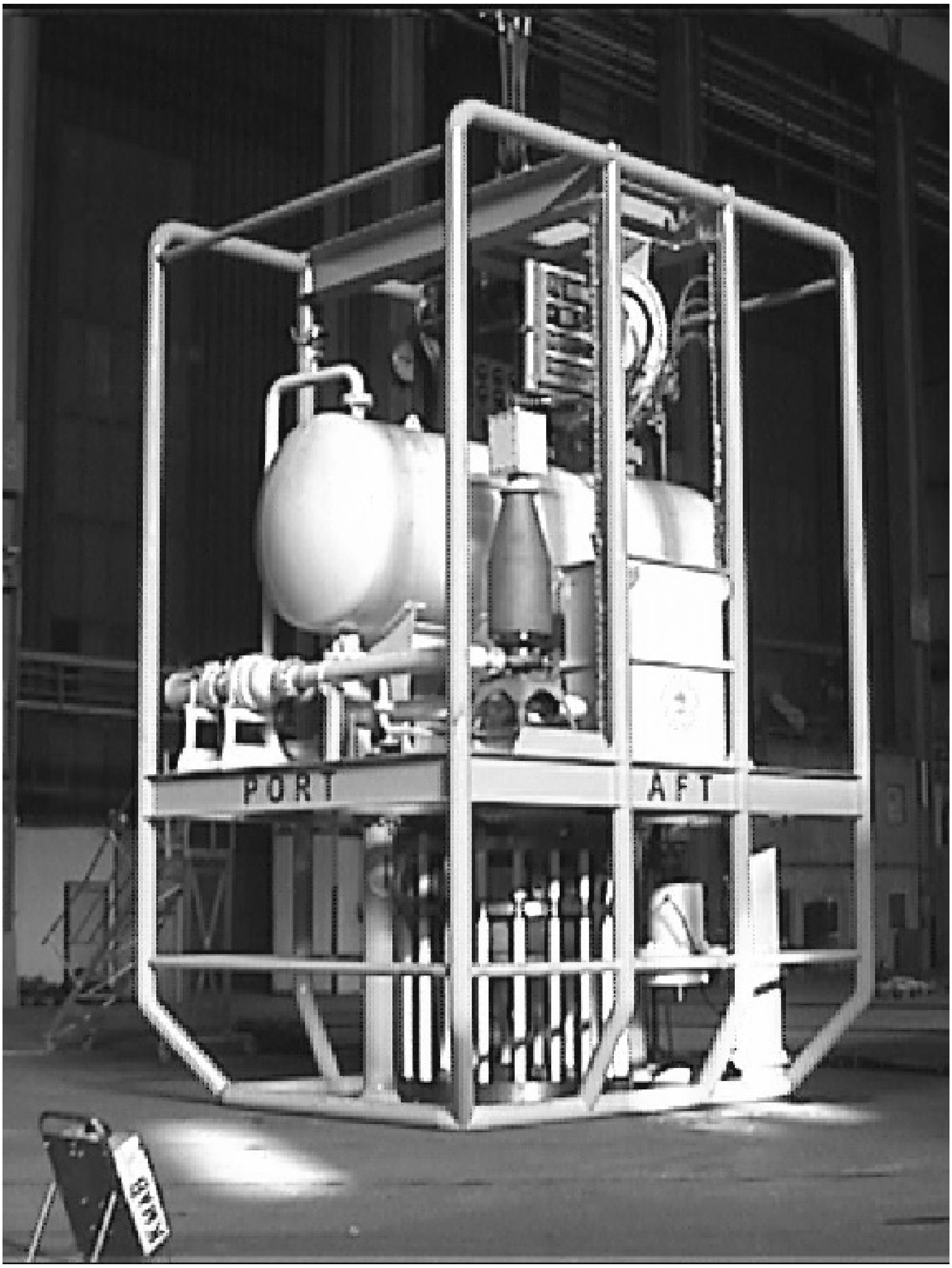
Alpha Thames Ltd is a British Company currently owned by the SAAB Technologies Group, and by the Eni Group.



AlphaPRIME: Prototype System-Module

AlphaPRIME: Prototype System-Module being demonstrated