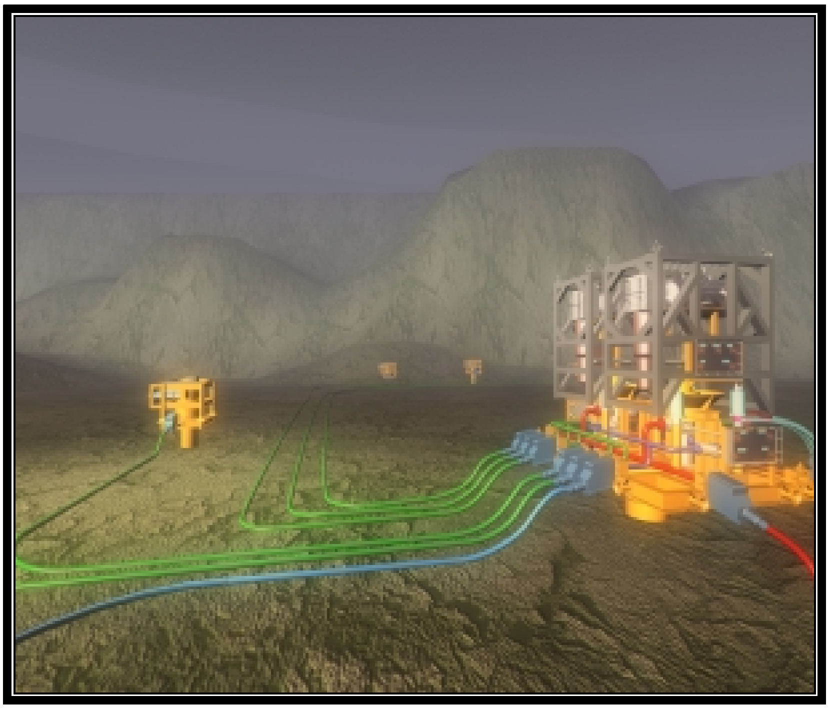
The Importance of Recoverability in Deep Water



by
David E Appleford, Managing Director, Alpha Thames Ltd

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Abstract

The task of installing seabed manifolding and processing facilities on the seabed is only part of the challenge being faced by operators having hydrocarbon reservoirs in ultra-deep water. If components fail or field conditions change, the operator is faced with the task of recovering seabed equipment for repair or modification and then re-installing it. This paper will explain how a System-Modular seabed method offers an effective solution to a problem that operators with ultra-deep water fields cannot afford to ignore. It will also explain how System-Modules can, in addition, increase the revenues earned from a field by reducing initial capital costs and by enabling higher levels of productivity.

The challenge of ultra-deep water engineering is basically one of accessibility and availability. The System-Modular approach makes it possible to install simple or complex processing, boosting, and control equipment on the seabed quickly and easily. What is more significant is that it also enables this equipment to be recovered with equal ease whilst production is maintained. As the oil and gas industry directs its attention to the challenge of installing equipment in ultra-deep water, its efforts will be doomed to failure unless the importance of recoverability is taken into account.

Challenges

An increasing number of rich hydrocarbon-bearing reservoirs are being discovered in ultra-deep water. Furthermore, it is well known that there are significant advantages to be gained by installing processing systems on the seabed and that, in many cases, these advantages are actually greatly enhanced in ultra-deep water.

However, if an operator is considering the exploitation of a subsea reservoir that is located in ultra-deep water, there are several issues that must be addressed. These include:

- the cost of installation and commissioning;
- the need to minimise CAPEX and to achieve early oil in order to improve the net present value of the field;
- the need to allow for changes in field characteristics over field life;
- the over-riding need for reliability and availability;
- the provision of a means of maintenance;
- overcoming the problems of powering and controlling the system in such deep water;
- decommissioning and retrieving the system.

This paper will show that all these problems can be overcome and additional significant advantages can be identified. One example is the facility by which a field can be developed on an incremental basis, installing systems and equipment, only when it is required, in response to economic factors and to field characteristics.

The Solution

The solution is to adopt an all-electric, System-Modular approach to field development. It has been established that a wide variety of seabed processing systems can each be packaged into a System-Module that can be readily installed by diverless means from a relatively inexpensive vessel, such as a suitably equipped DSV, with the support of a work-class ROV. Equally, recovery is readily achieved in the same way. The production systems can be as simple as a manifolding system, or as complex as three-phase separation with boosting and water re-injection.

System-Modules are installed on a simple Docking-Manifold, which has interface connectors for at least two System-Modules. The Docking-Manifold is similar to a conventional manifold and contains only field-proven equipment; however, it does not contain controls or actuated valves. When one System-Module is retrieved, the remaining System-Module(s) continue(s) processing without the need to stop production or shut-in the wells. This means that System-Modules can be changed out as seldom or as often as required in order to optimise the field development system, as economic circumstances and field characteristics change, without compromising availability.

All the System-Modules have the same footprint, 5 m x 4 m, and the same wet-mateable interface connections. In fact, there are only three wet-mateable interfaces per System-Module, namely for fluids, power and controls. This increases system reliability, particularly as 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 suitable proprietary connector, according to the Client’s choice. The controls/chemical injection connector is a proven proprietary stab plate assembly. In this way, although different processing systems can be deployed, each System-Module has a common “standard” interface, enabling a more standardised approach to be adopted for field development.

Reliability

Reliability is essential in ultra-deepwater situations and it has been addressed in the following ways. The processing, boosting, monitoring and control, and power distribution systems are integrated into each System-Module at the design stage. Upon completion of assembly, this approach enables thorough system integration testing of the complete process (contained within each System-Module) to be undertaken in the factory. The test programme includes a period of “burning-in”. This ensures that all the equipment is compatible and any faults can be thoroughly investigated and rectified. It is important to bear in mind that the apparent cause of a fault may turn out to be a symptom as opposed to the root cause.

The System-Modules are electrically powered and controlled by well-proven, industry standard, programmable electronics. All power distribution is “hard wired” within the System-Module which contains all the necessary transformers and switchgear. Each module is supplied by means of an integrated services umbilical (ISU) that delivers high-voltage power, electric control and injection chemicals. The absence of hydraulics, the utilisation of all-electric power and control, and the minimal number of wet-mateable interfaces combine to optimise reliability. As previously mentioned, this is especially important in ultra-deepwater applications.

Alpha Thames take a risk-based approach to reliability; 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, in the unlikely event of failure, only result in loss of performance rather than a complete loss of function.

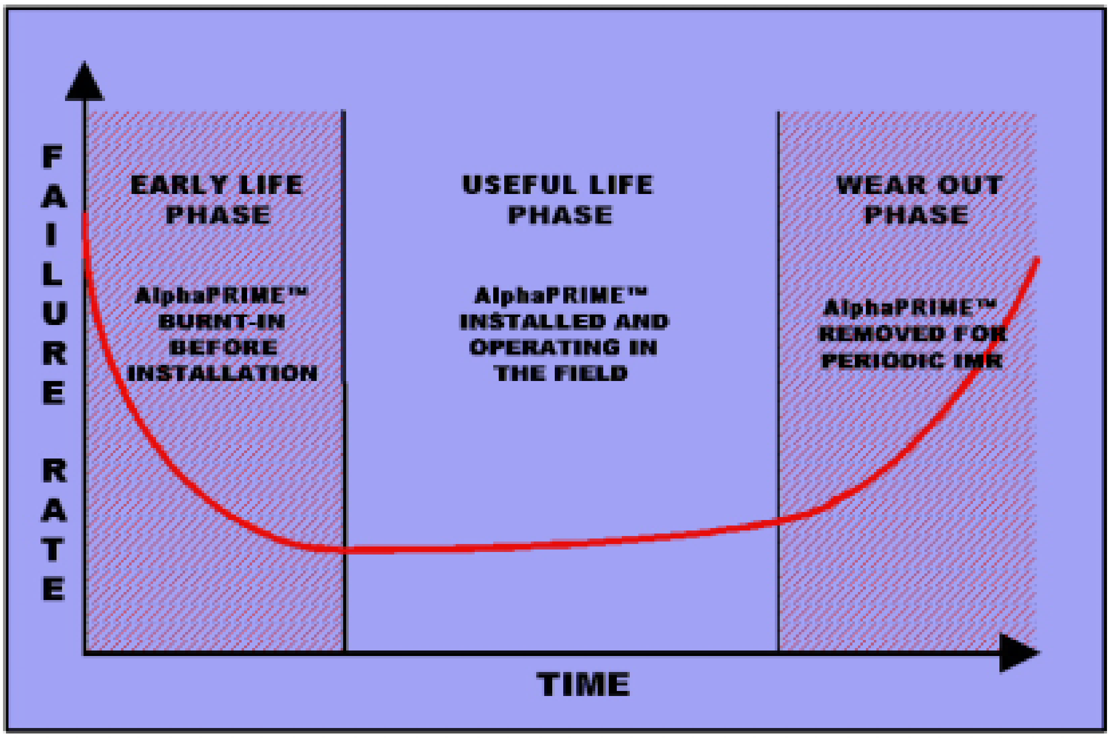

Figure 1- Reliability "Bathtub" Curve showing the optimum reliability of AlphaPRIME™ in the field

Furthermore, as each System-Module is "burnt-in" before it is shipped to site, early-life failures (as in the "bathtub" curve, Figure 1) can be identified and eliminated in the factory. This confers a significant benefit upon its in-field reliability and performance as is illustrated by the graph, which shows how any early life failures (which are the most financially significant) are identified and resolved whilst the System-Module is on test in the factory. The module is only field-installed when the entire system has been functioning faultlessly for a required period, ensuring that it will then be functioning at its optimum reliability. If required, stump testing can also be undertaken immediately before deployment. The systems are self-monitoring, ensuring that any untoward trend in equipment performance is identified and that the necessary remedial action is taken before equipment failures take place; the System-Modules can be recovered for maintenance before the wear-out phase begins. This ensures that optimal system reliability is maintained because the equipment is only in the field during its useful-life phase. Although preventative maintenance is the norm for topsides and shore-based industry in general, this philosophy has not, until now, been available to subsea systems.

The AlphaPRIME™ CPU

The System-Modular installation is known as an AlphaPRIME™ Central Processing Unit (CPU) and 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 so that there is no need to shut-in the wells or halt production.

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. This would allow a minimum of 60% of peak flow to be maintained during System-Module change-out, without shutting in any of the wells or ceasing production. 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. A typical single System-Module has a throughput of 20,000 bbl/d or 250 mmScf/d. However, the capacities of the System-Modules can be varied at the design stage to suit the Clients' requirements.

Installation and Retrieval

It may be seen from the foregoing that a 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 identical System-Modules in the installation. As each module has only three wet-mateable interfaces, installation is readily accomplished within short weather "windows". Commissioning consists only of pressure testing these connections and basic functional testing. Significant cost savings are therefore achievable. The subsequent retrieval of a System-Module for maintenance or for re-configuration and, ultimately, its decommissioning are also readily accomplished.

Figure 2 shows the installation sequence for an AlphaPRIME™ CPU. The Docking-Manifold is normally installed on a monopile (depending upon the seabed characteristics) and can be installed at the same time as the pipelines are laid. It should be noted that the Docking-Manifold only contains "dumb" equipment (e.g. ROV-operated valves) and that during the subsequent operation of the complete CPU, the valves within the Docking-Manifold remain open except when it is necessary to retrieve a System-Module. Pipeline connections to the Docking-Manifold are by means of proprietary connection systems. The male halves of the high-power, high-voltage connectors (on the terminations of the ISUs) are also located in the Docking-Manifold.

The Docking-Manifold always accommodates at least two System-Modules. These weigh between 25 and 80 tonnes, depending upon the equipment within them. They are deployed, one at a time, from a DSV or similar vessel equipped with an A-frame and are installed with the aid of a work-class ROV. The interface connections are readily made and tested, and the ROV opens the valves either side of the multiported connector on the Docking-Manifold and on the System-Modules using standard "tree-type" interfaces. Commissioning consists only of basic functional testing; significant cost savings are therefore achievable.

The retrieval of a System-Module is a similarly diverless operation, requiring the same kind of vessel and a work-class ROV. The shut-down procedure for the System-Module is initiated at the host facility. When complete, the electric power to the System-Module is switched off, whilst the other System-Modules continue to operate. The ROV closes the isolation valves on either side of the multi-ported, wellhead-type connector. The high-voltage, high-power connector socket in the System-Module is retracted from the Docking-Manifold; the controls and chemical injection connector is also disconnected. The System-Module can then be removed from the Docking-Manifold.

At the end of field life, the entire installation can be removed by recovering all the System-Modules, disconnecting the flowlines and the ISUs, and retrieving the Docking-Manifold.

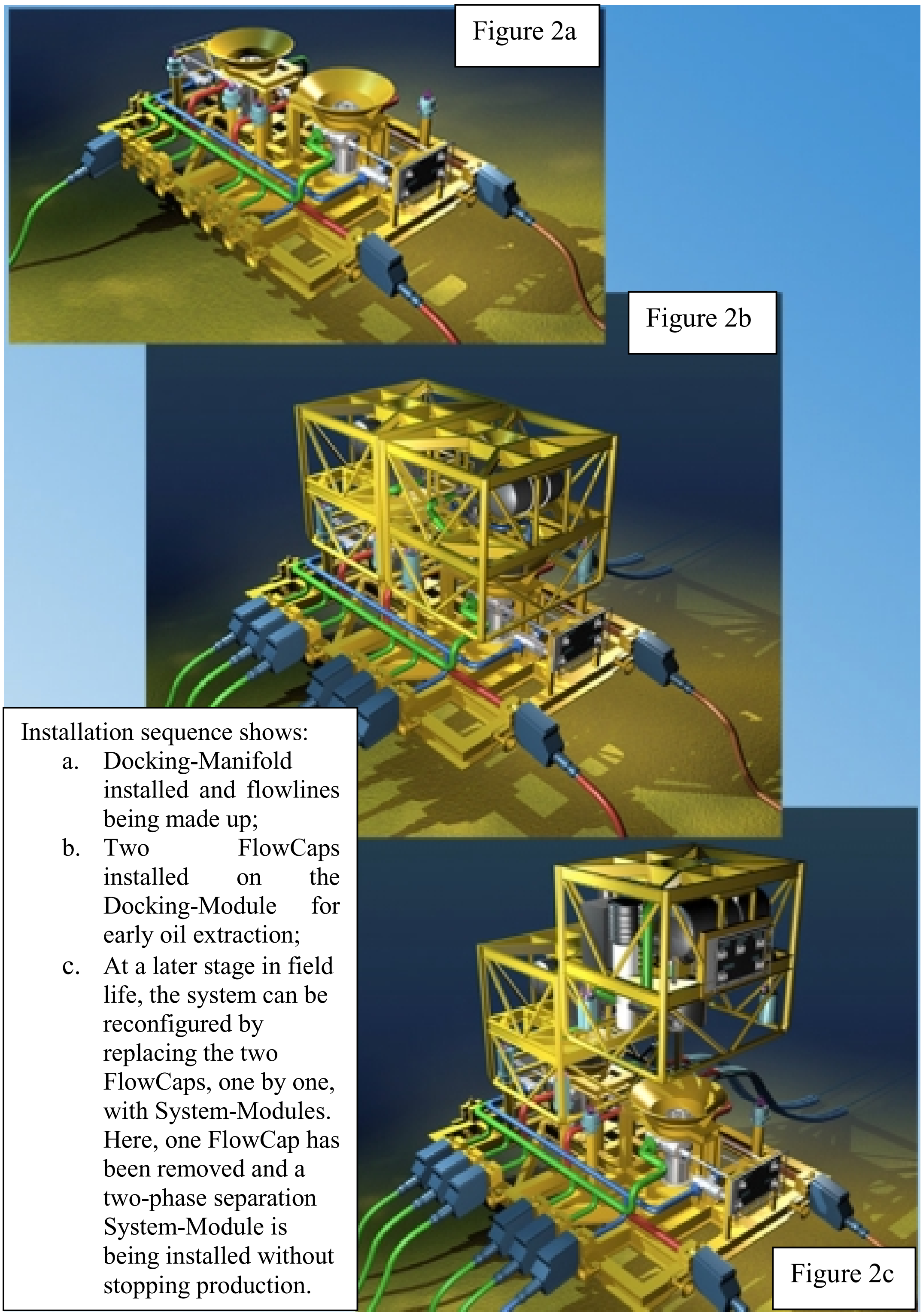

Figure 2 – AlphaPRIME™ CPU: Installation Sequence

Additional Advantages

This method enables a field to be developed incrementally, first oil being obtained shortly after the installation of the initial, basic equipment which may be a simple System-Module or "FlowCap" that enables the produced fluid to flow through the Docking-Manifold to the selected host facility. NPV is maximised by early oil and low initial CAPEX, and the cost of additional equipment is spread throughout the field life. The System-Modules can be reconfigured during field life, either in response to changing field characteristics (such as increasing water cut) or to include new technology when it becomes available (such as subsea gas compressors) without needing to interrupt production or shut-in the wells. If required, additional CPUs can be installed and tied-in to the first CPU, as the field is developed further or as additional wells or satellite fields are linked into the CPUs.

A System-Modular installation can be regarded as the central processing unit (CPU) of the complete field development system; it can act as a control centre that provides feedback data, monitoring performance in real-time, 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 hydraulic trees.

Ultra-deepwater applications are likely to involve a long tieback pipeline. As the pressure drops along the pipeline, the gas may break out of solution in the produced fluid. The resultant "slugs" could cause flow assurance problems for which multiphase pumping is sometimes specified as a remedy but it is only partially successful. However, the problem can best be overcome by first-stage gas separation on the seabed in the vicinity of the wellheads. The separated oil and gas can then be transported to the host by separate pipelines; the liquid phase(s) being pumped to the host, whilst the separator pressure is sufficient to transport the gas. The gas break-out problem is thus virtually eliminated.

Multiphase pumping needs complex, speed control systems that are often heavy, bulky and expensive whereas first stage separation on the seabed enables single speed pumps to be used; they can be selected to run at their most efficient and reliable speed. Fluid levels in the separator are continuously monitored and are adjusted as necessary by modulating valves that are fitted with fast-acting electric actuators. These actuators have been developed and thoroughly tested by Alpha Thames who have also developed and successfully tested a fail-safe electric actuator for isolating valves.

A well known additional benefit is that seabed separation and liquid boosting will enhance reservoir drawdown. It significantly increases the production rate in the early years of field life thus significantly enhancing NPV; it also increases overall yield thus prolonging viable field life whilst reducing overall expenditure. Using typical North Sea field data as a basis, it has been calculated that up to 75% extra production can be achieved by employing seabed separation and boosting in deep water, compared with conventional topside methods. Independent authorities have calculated that savings of $2 to $4 per barrel can be achieved in Gulf of Mexico or UKCS scenarios.

Seabed separation reduces the need for injected chemicals; in field studies recently undertaken by Alpha Thames, this has proved to be a highly significant economic factor. For example, hydrate formation occurs in multiphase pipelines when the produced fluid cools in the pipeline over long distances. Removing the produced water or the gas on the seabed reduces this propensity and also significantly reduces expenditure on hydrate inhibitor. The separated water may be used for water injection purposes. The need to transport significant volumes of unwanted liquid to the host may thus be avoided, together with a reduction in the requirement for topside treatment capacity and chemical plant.

Power transmission and control problems are increased with distance, particularly if hydraulic control or variable frequency electric drives are used. System-Modular installations provide an all-electric processing system which has power and control lines incorporated in an integrated services umbilical which may also include 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. The System-Module 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 power and control pod operates in a dry, notionally one-atmosphere environment; this enables well-proven, highly reliable, industry-standard, "real time" electronic control systems to be utilised. A programmable logic controller (PLC), which 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 optimum separation levels.

As most process values vary fairly slowly, the requirements for data transmission to and from the host facility are moderate. 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, safe manner.

Various sensors are located inside the power and control pod; some verify that there has been no water intrusion, others 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 at the host.

Alpha Thames successfully completed underwater trials of an electrically powered and controlled prototype System-Module at the end of the ÆSOP project that was supported by the Commission of the European Communities and by a JIP; the in-water trials of the System-Module (as shown in Figure 3) were witnessed by DNV and by representatives of the EC, Conoco, Statoil and Shell in September 1999.

Conclusion

Having examined all the issues involved, it can be concluded that the challenges of ultra-deep water, in particular high reliability combined with ease of recovery, can be realised by adopting the System-Modular approach to field development. Retrievability is assured!

Figure 3 – Demonstrating the ease of installation of Alpha Thames' prototype System-Module during its in-water trials