storm™

Direct Access Wet Tree Floating Production System for Deep Water

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Introduction

Floating production systems using dry tree production risers are an industry recognised technology for deep water. Over 25 dry tree spar and TLP systems are in production, Figure 1. The main benefit provided by dry trees is direct access to the tree for production control and ease of wellbore access for workover. This feature allows lower operational costs and higher production rates to be achieved compared to an equivalent subsea development. This is particularly beneficial where reservoirs are complex.

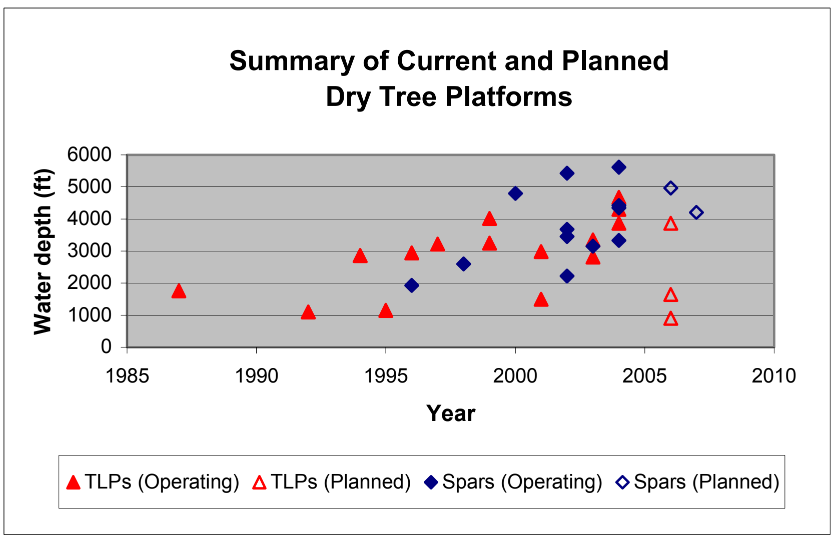

Figure 1 – Summary of Dry Tree Platforms (Year and Water Depth)

In recent years, dry tree technology has been extrapolated to deeper water depths and larger reservoir sizes. However, despite the potential benefits, it has become apparent that dry tree systems may not be such a good idea for deep and ultra deep water (4,000ft+). The justification for this view is derived from the design problems inherent with dry tree systems, which become more significant as water depth increases. Against the better judgement, the industry continues to propose dry tree technology for increasing water depths and appears willing to accept the multiplying design problems as an inevitable consequence of deep water development. The question that needs to be asked is whether this is the most appropriate technology?

To date an alternative production configuration that provides similar functionality to that of a dry tree system has not been fully explored. The possible reasons for this are:

- **Focus** - the industry has focussed on dry tree platform technology rather than well system and riser technology. The fact that drilling Capex and well systems Opex have an order of magnitude higher cost than the production platform has been largely ignored. A disproportionate effort has been expended optimising dry tree platform designs whilst risers and well systems have been regarded as "secondary".

- **Contractors** - the industry is dominated by a small number of large contractors that have significant interest in dry tree platform technology and little interest in development of alternative solutions.

- **Novelty** - the industry prefers an extrapolated field proven solution rather than a new solution. This fact greatly discourages innovation.

It takes an independent riser engineering company to take a step back to review the fundamental deep water drivers, focussing on the important riser and well system issues. By this approach they have identified a new field development solution called storm that offers an improved solution for deep and ultra deep water compared to current dry tree systems. Importantly, storm uses existing and proven technology, but configured in a way that provides a stepwise improvement over dry tree systems. This is largely realised by simplifying system interfaces at design, execution and operational phases.

Dry Tree Systems – Overview

Dry tree floating production systems have been around for almost 20 years with the pioneering Conoco Hutton TLP installed in the early 1980s. The dry tree arrangement allows direct access to surface trees and vertical well access, mimicking the functionality of a bottom founded shallow water platform system. For developments with high well count or deep and complex reservoirs it is possible to achieve lower drilling costs by avoiding the need for a high cost mobile drilling unit. For smaller well counts, predrilling and pull-over drilling can be considered and this is often more economical than providing a full drilling spread.

The two main dry tree platform solutions are the spar and the TLP. Alternatives include the wellhead barge proposed for milder environments such as West Africa and Indonesia. Over the years there has been considerable rivalry between supporters from the spar and TLP camps. However, the objective of both systems is the

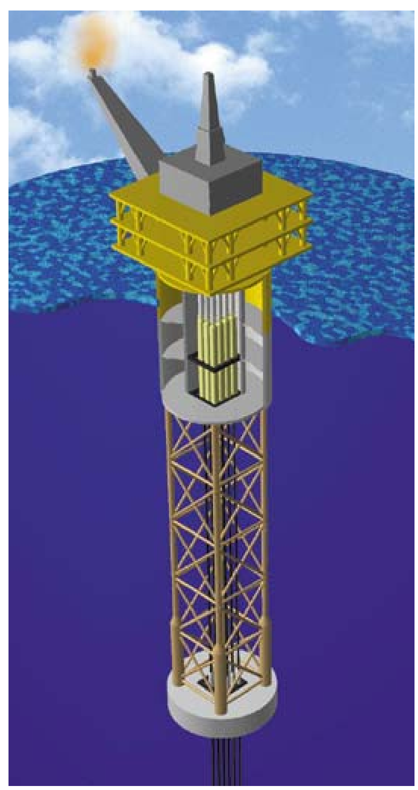

Figure 2 – Spar Dry Tree Platform

same and that is to provide a stable platform with minimum motions, particularly heave. Spar achieves this by optimising hydrodynamic loading with a deep draught and TLP by tethering to the seabed. Both concepts provide good solutions for what are now considered medium water depths 1,800-3000ft, but they are considered fundamentally troublesome for deep and ultra deep water applications.

The problem with the TLP is associated with the tether design and the practical ability to provide adequate levels of axial stiffness as water depth increases. Thus TLPs have a practical depth limitation of around 4,000ft. The Spar requires a high concentration of risers in a confined central well area where it is difficult to provide tensioning and accommodate riser motions. In addition the riser-hull interface is complex and has resulted in differing designs for all the spars currently installed. These problems are compounded with increasing depth, requiring greater tensions and imposing larger riser relative motions.

Despite this, and as demonstrated in Figure 1, spars have become the fashionable choice by many deep water operators. The spar concept has been promoted as having a simple riser design; a design in which the risers 'are shielded from current and wave loading and where the risers are tensioned with low cost aircans and thus impose no payloads on the platform'. On the contrary, it is now well known that the complexity of the hull/riser interface is often underestimated and this has led to a number of high profile problems on spars. Significant redesign has become necessary in later spars, resulting in increased design complexities and costs. It is noted that every spar has a different riser tensioning design, including all manners of steel aircans and, more recently, hydro-pneumatic tensioning systems, in order to get away from aircan problems. It is claimed that these design iterations solve the riser problems. However, it is believed that the problems are simply moved around, as the fundamental problem of the spar remains - the centre well is too small to safely and reliably configure all but a small number of deep water top tensioned risers.

Whilst a spar dry tree system is feasible in medium water depths, since the aircan size and stroke are smaller, the design problems escalate with increasing water depth. This is particularly true for dual casing systems where riser weight is more than doubled by the inclusion of a second pressure containing string. Whilst the need for the second casing is the subject of some discussions, the case for dual casings is stronger for greater water depths and higher pressure reservoirs.

The storm System

The storm system is unique in that unlike other field development concepts, which are driven by naval architectural considerations, storm has been developed with the emphasis on risers and well systems.

Compared to a dry tree system the storm arrangement offers improved technical performance, higher levels of safety, reduced interface complexity, improved development flexibility and lower cost. It also enables the step into deep and ultra deep water developments to be made with confidence, using proven components and technologies.

The focus and drivers for the storm systems are:

- Minimise riser numbers and simplify their design interfaces
- Simplify execution by providing contractual flexibility
- Provide direct well access for cost effective drilling and workover
- Eliminate requirement for heave optimised platform such as spar or TLP
- Take advantage of low cost and reliable subsea trees
- Provide development flexibility for future wells without pre-investment

The storm system uses subsea wellheads located below a permanently moored floating production platform. This may be either a barge for application in a mild environment West African development or a semi-submersible for Brazil and the Gulf of Mexico, Figure 3. The wells are drilled using a high pressure drilling riser and surface BOP in the same manner as currently conducted from a dry tree platform. The surface BOP provides efficient drilling and minimum down time. The wells are completed with 'horizontal' or 'drill through' trees that locate the tubing hanger in the tree spool. Importantly this arrangement facilitates direct vertical access through the drilling riser or a smaller diameter workover riser into the wellbore.

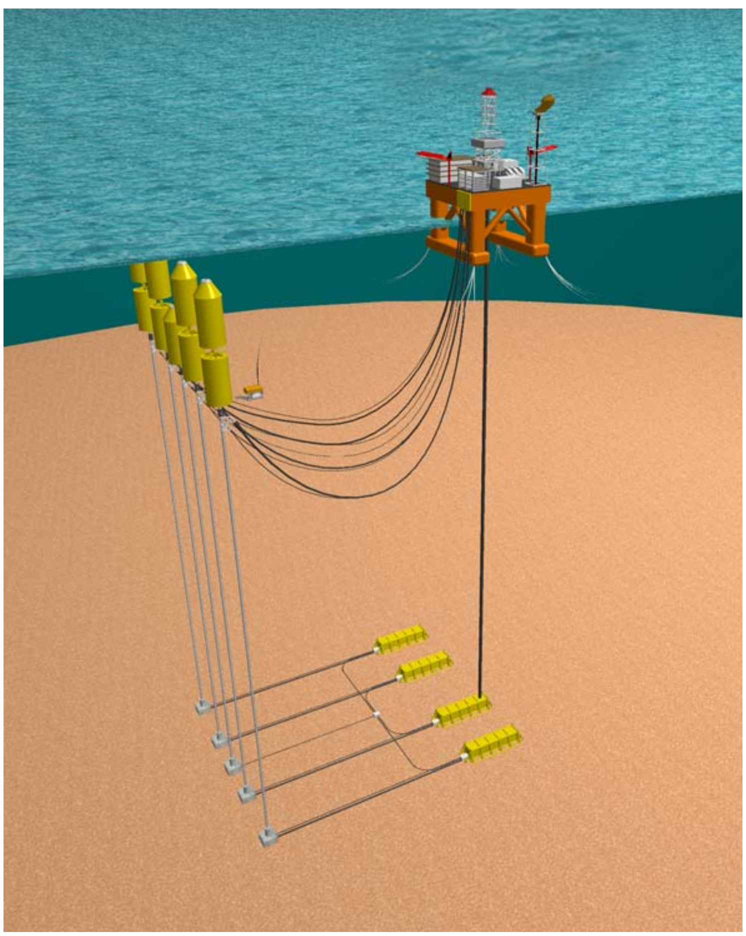

Figure 3 – storm Semi-submersible Arrangement

The subsea wells are grouped in clusters and may be situated on or off a manifold that allows up to 5 wells to be commingled. This allows the number of risers to be reduced by up to 75%. Each manifold is connected via a rigid seabed spool to the base of a free-standing riser. The riser may be either a single pipe (Single Line Offset Riser - SLOR) or a pipe in pipe design (Concentric Offset Riser - COR) that provides additional insulation and allows riser base gas lift and active heating through the annulus. These risers have a threaded construction and are tensioned by an upper aircan.

Each freestanding riser is connected to the production platform by a near surface flexible jumper. The risers, including aircan and flexible jumpers, can be quickly installed from a drilling platform, construction vessel or from the production platform itself, giving a high degree of installation flexibility. In addition freestanding risers can be used for export, enabling a fast development installation schedule by pre-installing all risers prior to arrival of the host facility. The SLORs and CORs were initially developed by 2H as part of the TRF (Threaded Risers and Flowlines) JIP; they have since been installed in two West African offshore developments.

The flexible jumper between the riser and platform offers two key advantages: firstly they can accommodate large platform motions allowing lower cost non-motion optimised platforms to be considered, and secondly they can be connected to the platform at a location to best suit the platform layout. Normally this would be away from the central drilling moonpool area, providing segregation of drilling and production activities.

The reduction in the number of risers compared to a conventional dry tree arrangement reduces the riser steel weight and aircan buoyancy. For a typical application requiring 20 wells in 4,500ft water depth this may be a saving in the order of 9,000Te of steel and 12,000Te of buoyancy. This provides significant riser cost savings and greatly reduces the sensitivity to increasing water depth.

It is noted that the storm system is neither a classic subsea system nor a dry tree system but it offers the best features of each and avoids many of the disadvantages. The arrangement is suited to a wide range of field development types and environments. The storm system is particularly suited to developments where reserves are uncertain as the system configuration allows the addition of future wells without pre-investment of additional wellbay space or platform buoyancy requirements. Storm is effectively a ‘self contained’ system that can develop the reservoir in a phased execution without the requirement for an additional installation vessel to be mobilised to install risers or flowines.

The following table compares and summarises the main features of a spar and storm semi-submersible solution:

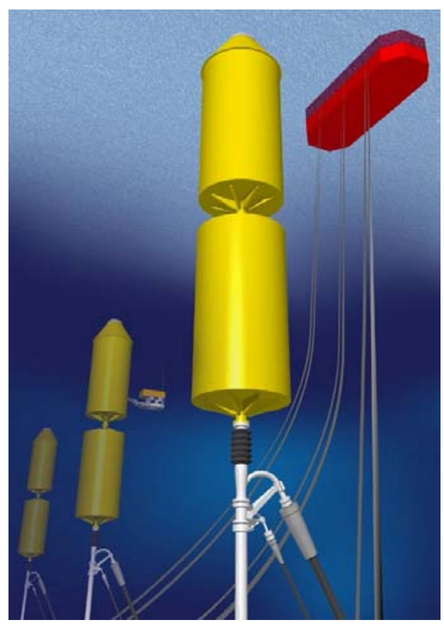

Figure 4 – COR Aircan Arrangement

Table 1 - Spar and storm Evaluation

Spar		storm
Safety		
Congested production and drilling wellbay located at centre of platform	-	Single drilling riser, no production wellbay. Separated production, drilling and export
Multiple high pressure production risers with no subsea isolation	-	Riser numbers reduced by 75%, subsea isolation provided at subsea tree and manifold
Potential for riser clashing due to limited available space	-	Reduced riser numbers and increased spacing eliminates possibility of clashing
Inability to disconnect platform in emergency	-	Riser and platform disconnect feasible in an emergency
Poor inspection and replaceability of critical aircans and hull guides	-	Easy access and ability to replace aircans; no wear components
Heavy offshore lift required for mating hull and deck and for aircan installation	-	No heavy lift required. storm system integrated and tested prior to tow out
Enclosed centre well area with possibility of hydrocarbon build-up	-	No centre well area
Cost		
High cost due to riser steel weight and large aircan tension requirement	-	Reduced cost due to reduced riser numbers
Proprietary motion optimised platform required to achieve workable riser solution	-	Non motion optimised platform such as a standard semi-submersible from international market or possible conversion
Complex dynamic riser/hull interface requiring hull guides and structure	-	Simplified static hull interface and reduced riser number
Skidable derrick required to access each well slot	-	Fixed central derrick as per conventional MODU arrangement
High cost to provide spare wellslots	-	Negligible capital cost to provide for additional wells
Heavy lift required for platform and aircan installation	-	No heavy lift required
Complexity of abandonment, deck removal and upending	-	Simple abandonment by disconnecting flexible jumpers and mooring
Low residual value at end of field life	-	Good residual value as early production system or drilling conversion
Flexibility		
Limited number of qualified platform contractors	-	Use of standard semi-submersible or barge available from many contractors worldwide
Number of wellslots need to be fixed early in development schedule	-	Well and riser numbers can be kept flexible without significant technical impact
Complex interfaces sensitive to small design changes	-	Simplified interfaces with reduced criticality. Ability to accommodate design changes
Pre-installation of production and export risers not possible	-	All risers (production and export) can be pre-installed saving schedule and providing contractual flexibility
Offshore mating of hull and deck requires heavy lift vessel	-	No heavy lift vessel, minimum offshore construction
Not easy to incorporate early production capability	-	Well suited to early production capability

Technical Features		
Surface tree allowing direct vertical access to wellbore and ability to use surface wirelining and coiled tubing WO	-	Vertical access to subsea tree for workover. Similar functionality to surface tree system but wirelining and coiled tube must be conducted through drilling or workover riser.
Efficient drilling through use of surface BOP with HP drilling riser	-	Efficient drilling through use of surface BOP with HP drilling riser
Requires special joints and interface hardware such as stem guides, centralisers, preloaded aircan guides, wear spools and fatigue resistant spools.	-	Standard proven interfaces, no special components
Complex analytical procedures to accurately capture riser response and riser/hull interaction, roller guide and stick-slip etc.	-	Standard analysis features adequately capture riser/hull response
Riser and well count limited by hull and aircan dimensions	-	No practical limit to wellcount
Platform response uncertainties such as stick-slip, centre well hydrodynamics and hull VIV	-	Semi-submersible response well proven and understood
Wake interference between closely spaced risers	-	No effects to consider due to large spacing

The Future

Storm has a wide ranging scope for potential application covering small to large developments and a range of environments from mild to harsh. However, its real potential is for water depths greater than 4000ft. Whilst there is little engineering development required, the main challenge for storm is to overcome the inertia in the industry that has developed around dry tree production systems.

Despite this inertia there is confidence that the benefits of the storm system will be seen to be attractive and storm systems will be used in preference to dry tree systems. This will lead to more widespread application of semi-submersible technology in the Gulf of Mexico. Conversely the number of new spar and TLP platforms are likely to be reduced.

Conclusions

It is concluded that the best technology for deep water is not necessarily that extrapolated from shallower water depths. Deep water solutions are required for deep water problems.

Storm provides a new way of developing deep and ultra deep water reservoirs and offers improved levels of safety, reliability, flexibility, simplicity and cost effectiveness.

In deep water we need to refocus on the most important design aspects relating to drilling and well systems and re-evaluate the most appropriate means of meeting the functional requirements.

In deep water it is not considered practical or logical to tieback individual wells through top tensioned risers. Superior well systems arrangements are possible offering step change improvements.

Storm is a development solution, which is less sensitive to water depth increase than dry tree production systems.

Development contract strategies will be simplified if the need for 'hi-tech' motion optimised platforms can be substituted by proven semi-submersible technology.

The storm system offers important benefits and sets new standards for deep water development technology.