Hybrid Riser Towers – Not Just for Deepwater

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Abstract
Most people know the Hybrid Riser Tower solution, combining the use of steel pipes in a freestanding bundle and multiple flexible jumpers for connection to a floating host vessel, from the 3 towers installed in 2001 offshore Angola in 1,350m water depth to the Girassol FPSO.

Little known is the fact that the first bundled riser tower, in a slightly different arrangement preceding Girassol, was actually installed by Placid in Green Canyon (1988), and the same riser tower was later re-deployed by Ensearch in Garden Banks (1994, now decommissioned), both in the Gulf of Mexico in less than 650m water depth to a semi-submersible production platform.

This paper describes the adaptation of the bundled hybrid riser tower concept for subsea connection to a FPSO in Indonesia in only 90m water depth. The ‘mini’ riser tower, comprising 6 risers in the bundle and installed in 2013, made full use locally available materials, fabrication labours, skills and facilities, and installation capabilities in the region. This project, and its successful implementation, paves the way for more SE Asian operators to maximise local contents, optimise costs and exercise better project control for their upcoming developments.

This hybrid riser tower solution can lend itself readily for HPHT field developments, or aggressive production fluids, when conventional riser solutions such as bonded or unbonded flexible pipes, and corrosion resistance alloy (CRA) clad steel catenary risers cannot handle the fluid properties or the shallow water depths, respectively. Work is underway to use high quality thermoplastic composite pipe (TCP) as the jumpers in a hybrid tower to overcome the chemical issues.

Introduction
Conventional shallow water riser systems can be categorized into those associated with dry trees and wet trees.

Dry trees provide well access at the surface on top of a platform. Examples are fixed platform and compliant tower, where the riser is synonymous with the conductor/casing system connecting the seabed well to the surface tree.
Wet trees provide well access at the seabed. Examples are semi-submersible and FPSO where production fluids are channeled through seabed flowlines, then risers, to the platform. The risers are almost always made up of unbonded flexible pipe.

In deeper water depths, however, the game changes for the dry tree platforms. While semisubmersibles and FPSOs are still dominating the scene for wet trees, restrained or deep-draught floating dry tree platforms such as TLP and spar are now common place. The riser that connects the seabed wellhead to the surface tree on the platform is commonly known as top tensioned riser (TTR).

In addition to flexible riser for wet trees, steel catenary riser (SCR), bundled hybrid riser tower, single line offset riser (SLOR, or sometimes called single line hybrid riser SLHR) have come into place.

This paper focusses on the development of hybrid riser towers from its origin to the present day in water depths beyond 400m and one unique case in a water depth of only 90m. It then suggests that the hybrid riser tower design is not just for deepwater, it deserves a place as an option during the concept design phase, particularly on projects where local content is a prime consideration or the production is chemically aggressive where special materials have to be used.

**History of Hybrid Riser Towers**

Hybrid riser combines the use of steel and flexible pipes. Steel pipes are used in the deep vertical section, and flexible pipe forms the jumper hanging between the top of the steel section and the floating vessel. The vertical steel riser section is anchored to the seabed and is kept free standing by a buoyancy tank located sufficiently below the sea level to avoid the high surface current. The flexible jumper absorbs the wave induced vessel motions so the vertical riser only moves quasi-statically with the vessel offsets.

The first bundled hybrid riser operating with a floating vessel was designed by Cameron and installed in 1988 in the Green Canyon field, Gulf of Mexico (Figure 1, from Cameron Offshore Engineering archive). The riser was installed from the submersible production unit and located directly below it. Steel riser sections were mechanically jointed and the riser weight in water was neutralized by buoyancy modules; tensioned wires from the platform made the riser follow its movements. This riser was later relocated to the Garden Bank field in 1994. In water depths of 450-650m, both fields ended up producing sand; the riser was decommissioned and not used again.
In 2002 three hybrid riser towers, in the form we recognize today, started producing in the Girassol field, offshore Angola in 1350m water depth. Adopting the basic principles of the first riser tower, the Girassol design changed from mechanically jointed to all welded steel sections, and the riser is located at an offset distance from the vessel rather than underneath it. They were fabricated on land, and then towed to site and upended (Figure 2, from 2H Offshore pictures archive).
Since Girassol, further hybrid riser towers have been installed, including Greater Plutonio and CLOV.

Hatton & Lim (1999), Dale, Karunakaran & Hatton (2007) and Tellier & Thethi (2009) have variously described the evolution and development of the hybrid riser designs.

The reasons hybrid riser towers are popular amongst African oil producing countries are as follows:

- Strong local fabrication content – in-country infrastructure, facilities and employment
- Onshore fabrication inspection – more thorough quality assurance
- Pre-installation before arrival of vessel – schedule flexibility
- Quasi-static response – vessel motion tolerant
- Simply vessel interface – flexible jumper hang-off porches
- Low payload – only partial weight of jumpers

Figure 2–Girassol Hybrid Riser Towers
Shallow Water Hybrid Riser Tower Show Case

Project Background
In 2012, a fast track project commenced in Indonesia to design and fabricate a riser system to produce from 3 pre-drilled subsea wells in 90m water depth. The estimated field life of these wells, located 55 nautical miles North of Matak Island in the Natuna Sea, was to be 5-7 years.

The base case development scheme was to produce via flexible flowlines and risers connected to an FPSO. When the authors were contacted in late 2011 by the operator, the conversion of a tanker into the FPSO was already underway, but the challenges for new built risers were:

- High costs beyond project budget
- Long lead time exceeding project schedule
- High hang-off loads requiring extra strengthening and FPSO conversion cost

An existing flexible pipe string from a stockist was evaluated and the issues encountered were:

- Pipe diameter was suitable for 6 in. production, that left 3 in. gas lift lines still to be sourced
- Its armouring was not strong enough for full dynamic riser applications
- End fitting re-termination requirements and the associated cost and schedule

System Description
A ‘mini’ hybrid bundle riser tower solution was proposed and accepted (Figure 3).

![Diagram of Shallow Water Hybrid Riser Tower](https://www.2hoffshore.com)

The solution involved:
• Riser bundle comprising
  ▪ 3 off 6 in. production pipes
  ▪ 3 off 3 in. gas lift pipes
  ▪ 1 off 20 in. buoyant core pipe
• Bundle supported at the top by a buoyancy tank and anchored to the seabed by a gravity base
• Dynamic bonded hose jumpers from riser top to FPSO
• Static bonded hose jumpers from riser base to wells

The driving considerations for the decision were:
• Maximize use of stocked steel pipes and locally available materials
• Onshore steel fabrication
  ▪ Lowest cost
  ▪ Shortest lead time
• Parallel engineering, procurement and fabrication activities
  ▪ Prioritise engineering and procurement of key components that require longer fabrication duration such as riser end terminations, spools, etc.
• Bonded flexible hoses connecting riser top to FPSO are available for a fraction of the price of equivalent unbonded flexible pipe jumpers and at much shorter delivery schedule
• Provides flexibility with installation vessel options instead of having to identify the installation vessel at the onset of the project
• Allows future riser relocation
• Has proven track record of being installed in deeper water depths

Tower Components
The key components in the riser tower and their functions are:
• Riser top assembly (RTA) - riser pipe spools to jumper departure to FPSO, Figure 4
• Riser bottom assembly (RBA) - riser pipe spools to jumper departure to seabed wellheads, Figure 5
• Buoyancy tank (BT) - provides upthrust for the riser bundle, Figure 6
• Dead mass anchor (DMA)/Riser Foundation (RF) - anchor the riser to seabed. RF is pre-installed prior to the bundle being deployed with the DMA hanging below it, Figure 7
• Tether chains - Connections between RTA & BT, and between RBA & DMA to provide articulation at the top and bottom of riser bundle
• Jumpers - bonded hoses between top of vertical riser and FPSO to cushion the vessel motions
• Umbilical - separate from the riser tower, for well control

Note: Figures 3-7 are taken from 2H Offshore project archive.
Figure 4–Riser Top Assembly

Figure 5–Riser Bottom Assembly

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Riser Dynamic Analysis
Global analysis was conducted to ensure that the hybrid riser tower, with jumpers attached to the FPSO, would meet the following in-place design requirements:

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- Acceptable stress response in the riser pipes and structures under extreme (100-year storm) and damage (1 BT compartment flooded or 1 FPSO mooring line failed in 10-year storm) conditions
- Acceptable minimum bend radius (MBR) and tension level along the dynamic surface jumpers
- No interference between the dynamic surface jumpers
- Tension is always maintained in the riser base tether chain under all design conditions
- Long-term wave and vortex-induced-vibration (VIV) fatigue in the riser pipes exceeding 10 year service life with a safety factor of 10

Failure of either tether chain was not considered in the analysis as special care had been taken to oversize them and the bearing material was chosen to outlast the tower’s service life. Nevertheless, it was checked that the release of the BT, with or without the riser bundle, would not hit the FPSO.

After several design iterations by varying the BT upthrust and compartment size, an acceptable and optimises riser configuration was achieved.

**Schedule**
The parallel engineering, procurement, fabrication and FAT/SIT phases of the project were aggressively completed in less than 9 months in the manner outlined below:

- **Detail Design and Engineering:** 5 months (January – May 2012)
- **Procurement:** 5 Months (March – August 2012)
  - Bonded hoses
  - Dynamic umbilical and buoyancy modules
  - Dead mass anchor
- **Fabrication:** 5 Months (March – August 2012) in Batam, Indonesia
  - Riser bundle
  - Riser top and bottom assemblies
  - Riser foundation
  - Riser installation aids
- **FAT and SIT:** 1 Month (September 2012) in Batam, Indonesia

Despite the original intention to install the riser tower before the year-end monsoon season, a logistic hiccup of the installation vessel availability delayed the project to complete the installation eventually in April 2013 over a 10 day period.

**Challenges**
This fast track riser EPC project maximizing local content and tapping into Batam’s regional resources was considered a success. The main challenges the project team had to overcome are highlighted below:

- Preliminary and detail design combined into fast track schedule
- Engineering of riser bundle to suit the existing pipe stock
- Structural and pipe material verification to ensure they are fit-for-purpose
- Fast track flexible hose and umbilical engineering design to enable procurement and delivery on time
- Fabrication management to ensure adherence to fabrication specifications
- FAT/SIT and additional testing requirements for riser components such as tether chain assemblies, flexible hoses and umbilical
- Depending on installation vessel availability, installation strategy and associated installation aids were developed

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Further Potential for Hybrid Riser Towers

The hybrid riser tower solution lends itself for HPHT field developments, or aggressive production fluids, when conventional riser solutions such as bonded or unbonded flexible pipes can not handle the fluid properties, or SCRs clad with corrosion resistance alloy (CRA) cannot handle the shallow water depths.

In a recent assessment of field development options for a reservoir containing a very high level of H₂S, it was found that current inner liner materials used by flexible pipe and hose manufacturers were not qualified for long term exposure to the production fluid at the design pressure and temperature condition. Furthermore, the large riser diameter required operationally rendered a CRA clad SCR solution structurally unfeasible in the shallow water depth for strength and fatigue.

A hybrid riser tower was then proposed using CRA clad steel pipes and bends for the vertical riser section, and a superior quality thermoplastic composite pipe (TCP) as jumpers to overcome the chemical issue. The TCP considered has polyether ether ketone (PEEK) as the inner liner which has been qualified for the stated H₂S operating conditions. PEEK possesses excellent mechanical and chemical resistance properties that are retained in high temperatures and, crucially, is gas impermeable. The TCP in question is qualified structurally for dynamic application to only 8 in. diameter, so multiple jumpers had to be used to make up the total flow area.

The reason TCP is proposed as jumpers as part of a hybrid riser tower, rather than a SCR on its own, was that a jumper is a short free hanging component close to the platform, it can be replaced with relatively ease should there be a need to do so. Whereas a SCR is a whole riser with a dynamic touch down zone, it will pose a greater hurdle for TCP to be adopted for field application as a ‘new boy on the block’.

Conclusions

Although flexible risers were the simplest and preferred solution for the Indonesian shallow water development, their long lead time and high costs compelled the operator to seek an alternative solution. A hybrid riser tower was selected not just because of its technical suitability for the design conditions, but chiefly of the attraction that leftover pipe stock from a previous project could be utilized and local contents, in terms of labour, materials and facilities, could be exploited. The fast track nature of the project posed some schedule and logistic challenges, they were diligently overcome; this experience and track record should pave the way for more SE Asian operators to utilize hybrid riser towers to maximize local contents, optimize costs and exercise better project control for their upcoming developments.

In certain chemically challenging production conditions, when other riser types fall short of meeting the design requirements, single line or bundle hybrid riser should be included as an option during the concept selection phase to enable new materials to be assessed, qualified and implemented in a replaceable, risk-controlled manner to advance oil field technologies for a field development solution.

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References