

Standardisation of Deepwater Riser Systems

Tim Eyles – 2H Offshore

Frank Lim – 2H Offshore

Despite the fact that dynamic riser systems often present the most challenging element of any deepwater oil field development, there is little commonality in the selected riser designs across the multitude of current developments worldwide, even between those with similar environmental and process conditions. This has meant each project team making little use of previous experience on design, construction, installation, operation and maintenance, and the lessons learnt. This has undoubtedly resulted in inefficiencies and ultimately cost increases for operators.

An initiative to address this issue is proposed involving the introduction of a standardised deepwater riser design that could be adopted in a range of applications but still installable by a number of contractors. This approach has parallels with the standardisation adopted in the subsea tree and wellhead market some 15 year ago that led to a significant improvement in quality, schedule and cost reductions which operators are now enjoying.

This paper highlights the potential benefits from modularising and standardising a riser design together with its key requirements. A number of existing riser designs are evaluated for suitability for standardisation and a recommended solution presented. The challenges facing the implementation of a standardised riser design are addressed and an approach proposed.

Introduction

To date the designs of deepwater production, export and injection risers are often driven by the EPCI (Engineering, Procurement, Construction and Installation) contractor experience, resources, and facilities resulting in a wide range of solutions with little or no commonality between projects. There are many examples of completely different riser designs adopted for developments in adjacent licensing blocks despite similar water depth, pressures, and fluid composition. This approach is engineering intensive and associated with increased risk due to:

- Technical complexity
- Degree of novelty
- Contractor technical capability
- Qualification testing uncertainty
- Interface sensitivity
- Schedule criticality

In order to reduce these risks, a standardisation approach is proposed to adopt a generic riser design which could be applied to a number of projects without significant modification to accommodate a range of water depths, host vessel types, production fluid composition and flow assurance requirements. In addition, to allow such a riser design to be fabricated and installed by a number of offshore contractors, it would need to be installable from a range of construction vessels and therefore utilise a number of installation methods including reeling, threaded, welded or towed. In the following text, a number of currently installed deepwater riser designs are identified and considered for potential standardisation.

Deepwater Riser Design Options

Flexible Catenary Risers

Flexible pipe is built up from a number of independent spiral laid steel and thermo-plastic layers, and has been used for many years for both riser and flowline applications worldwide, Figure 1. The beneficial feature of flexible pipe is its ability to accommodate high curvature, allowing ease of installation and accommodation of dynamic motions. Flexible risers are used in a simple or wave catenary arrangements.



Figure 1 – Typical Flexible Pipe Structure

Whilst flexible pipe vendors strive for designs that meet the needs of the latest deepwater developments in terms of diameter, tension, internal and external pressures, and insulation, their capacity is somewhat more restrictive than that of rigid steel riser designs. The contradicting top (high tension) and bottom (high collapse) requirements for the continuous riser length inevitably result in a complex riser cross-sectional design. Each delivered product is normally unique and closely tailored to the specific field requirements offering little opportunity for standardisation across a number of projects.

Furthermore flexible risers are normally designed, manufactured and installed by a single vendor. There are only a small number of companies worldwide which manufacture flexible pipes for riser systems restricting supply route options. Without large investment, local in-country manufacture is also limited.

Steel Catenary Risers

Steel catenary risers (SCRs) have emerged as a major alternative to flexible risers in recent years for mild to moderate deepwater environments, such as Gulf of Mexico, West Africa, Brazil and Indonesia. The main advantage of the SCR is that steel pipe costs significantly less than flexible pipe, but is still “flexible” in a long length. The SCR consists primarily of a steel pipe string free hanging from the vessel to form a simple catenary.

A SCR is made up of a series of welded pipe joints. The fatigue performance of the welds is highly dependant on several inter related factors including pipe and weld material properties, joint dimensional tolerances, welding processes, welding procedure and inspection criteria. Good quality offshore welds are required in order to achieve sufficient fatigue lives for SCRs. As such, high specification vessels are required to perform these critical offshore welds, even if these vessels command high day rates and mobilisation costs. Furthermore SCRs are typically only used with tension leg platforms or spars as host vessels where heave motions are small, or with semi-submersibles or FPSOs where the environment is mild. In some cases, the host vessel hull design has been heave-optimised to improve SCR extreme and fatigue performance.

The majority of SCRs installed to date use the J-lay technique as S-lay is generally not suited to deepwater due to the very high back tensions required to prevent over stressing of the sag bend and overbend. The number of vessels capable of deeper water J-lay installation is limited,

therefore increased water depths reduce the number of potential installation vessels. SCRs also impose a large host vessel payload which increases with water depth, and when coupled with a high SCR count or diameters can become restrictive for some host vessel types without significant upgrading modification.

SCRs still do not generally offer many opportunities for standardisation as the design is highly dependent on water depth and vessel motions.

Single Line Offset Risers

Although relatively new in the market, the single line offset riser (SLOR) design has been proven or is planned on a number of projects including ExxonMobil Kizomba A & B and Petrobras P52. The SLOR employs a vertical steel riser section that is linked to the host vessel via a flexible pipe jumper. The key advantage of this hybrid arrangement is that the vertical riser response is largely decoupled from the host vessel motions and hence becomes less susceptible to fatigue damage.

An example SLOR development is shown in Figure 1. The vertical riser section is tensioned by steel buoyancy cans positioned at a distance below the water surface to minimize wave and current loading. The buoyancy cans are divided into a number of compartments to give redundancy should failure occur.

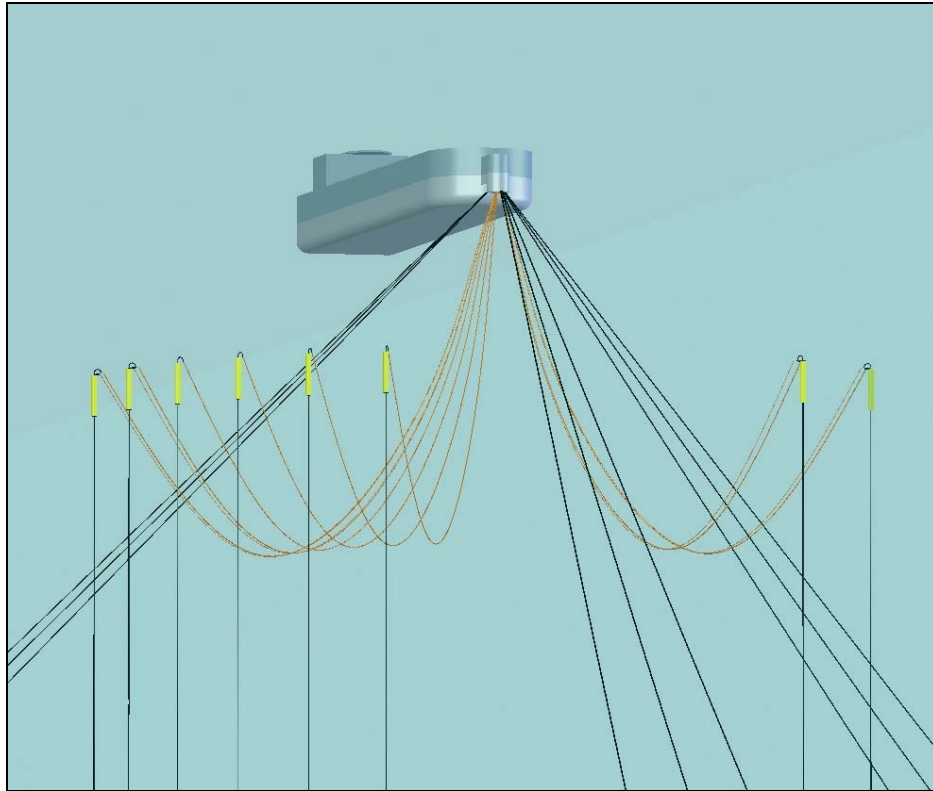


Figure 1 – Example SLOR Development

The riser is offset from the host vessel such that a suitable length of flexible pipe jumper (of a shallow water design) joining the top of the steel riser to the vessel can be fitted to accommodate the vessel motions. The SLOR can therefore be used with a wide range of host vessels and is suitable for deepwater and ultra-deepwater applications in all environments.

For production duty a concentric offset riser (COR) can be specified which features a pipe-in-pipe vertical steel riser section, the annulus of which is used to transport lift gas to the riser base. In this configuration a second flexible pipe jumper is also used to link the annulus to the host vessel.

The SLOR steel riser pipes can be either welded or mechanically connected, allowing installation from a range of vessels including pipeline construction and drilling vessels. The riser is purposefully designed using proven components and installation procedures.

A welded SLOR may be procured using established contractual frameworks. Installation of a welded SLOR is typically performed using a J-lay derrick barge. The installation window is determined by the vessel response whilst the riser pipes are being welded. Alternatively the

SLOR may be constructed horizontally at an onshore fabrication site and then towed to the project site and upended.

An alternative to welding is to use mechanical connections. An ideal solution currently being proposed is to adopt threaded and coupled pipe with installation performed using a drilling vessel. This construction technique also offers the opportunity to use higher strength and corrosion resistant pipe materials as welding can be eliminated. This would result in a lower riser mass and hence a smaller buoyancy can and a generally more optimised riser design.

The SLOR can also be pre-installed and left free standing before the host vessel arrives. Some SLOR designs allow one end of the flexible jumper to be pre-installed with the free standing riser and left free hanging such that the lower end can be picked up for connection to the vessel later; other SLOR designs present an upward facing connection hub at the top of the free standing riser to ease the installation of the whole jumper later. These features have the benefit of simplifying project schedule by eliminating complex logistics with installation vessels, and reduces riser hook up time.

As the SLOR steel riser pipe section is supported by a buoyancy can rather than the host vessel there are no significant restrictions to the diameter, pressure and depth of the riser design which in other riser designs could be restricted by the applied host vessel payload. While generally not a significant restriction, care must be taken when specify a large number of individual SLORs to avoid interference between riser pairs and other field architecture. The SLOR includes a number of fabricated components including primarily the steel buoyancy can. In some developing regions of the world, local fabrication of these assemblies is seen as a benefit to improve in-country facilities and training.

Bundled Hybrid Risers

Bundled hybrid risers consist of a number of smaller diameter steel pipe strings and umbilicals that are grouped together, usually around a buoyant structural core pipe. The bundled riser strings are kept free standing by a buoyancy can near the surface, where the vertical riser pipes are linked to the vessel by multiple flexible pipe jumpers. The free standing idea is essentially similar to the SLOR arrangement, and the riser strings can be configured in a number of ways, usually around the periphery of the structural core pipe. In the first application of bundled hybrid riser offshore Angola, the pipes were shrouded in

syntactic foam buoyancy as shown in Figure 3. Each bundle design is optimised for the number and diameters of individual pipe strings required for a particular project and therefore presents a number of challenges and restrictions if a “standard” design was to be adopted.

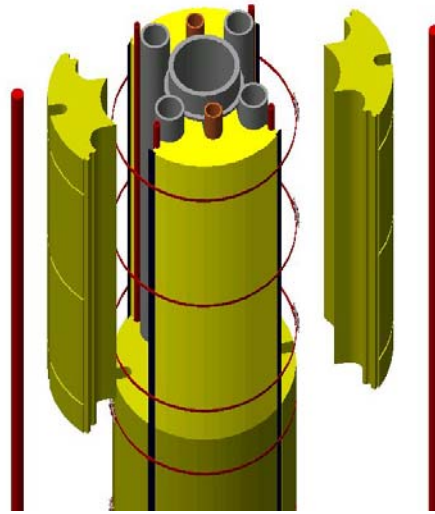


Figure 3 – Typical Bundled Hybrid Riser

Due to the complexity of assembling and testing bundled hybrid risers, onshore fabrication facilities must be used. This may be considered a positive fabrication method when contracts specify that a large percentage of local content is required for the project. After assembly, the riser is towed out before being upended and installed. The riser can be left preinstalled prior to arrival of the host vessel. Fabrication facilities for assembly and tow-out of bundled hybrid risers are already established in the Gulf of Mexico and West Africa although these are generally closely tied to individual offshore contractors and require considerable investment to develop from scratch.

As a bundled hybrid riser contains multiple pipe strings there are considerable consequences in the case failure of the system during tow, upending and once operating. Overall, the assembly and installation of a bundled hybrid riser can be time consuming and risky.

Top Tensioned Risers

Top tensioned risers (TTRs) are of a high pressure design and only used with tension leg platforms and spars.

The TTR runs directly from the subsea well to the vessel deck where a surface tree is located. Tension is applied to the riser by either buoyancy cans or deck mounted hydro-pneumatic tensioners. For spars, the installation of buoyancy cans is a complex, costly and time-

consuming process. Risers tensioned using hydro-pneumatic tensioners on spars or TLPs are less complex, and take less time to install in comparison to using buoyancy cans.

The conventional construction method for riser joints is based on ‘weld-on’ threaded connectors on the end of each riser joint. However, recent TTRs have been based on riser joints made up using integrally machined threaded and coupled connections. As the riser joints are not welded, higher strength material grades may be utilised. Extensive experience is available in the design and procurement of TTRs. Materials are readily sourced, with large diameter steel pipe, pipe upsetting and machining capabilities available from many different suppliers.

Standardisation Recommendation

Based on the review of current deepwater riser design options, the SLOR is recommended as the best candidate for standardisation and application on a number of projects as it is:

- Compatible with a wide range of host vessels types;
- Can be designed for a range of environmental conditions;
- Offers opportunities for local in-country fabrication;
- Can be designed for a range of constructions methods including welding & mechanical connections;
- Compatible with a range of installation methods;
- Available from a number of installation contractors;
- Compatible with a broad range water depths, diameters and pressures;
- Robust to changes in system design requirements.

Because the SLOR comprises a number of components, a key task is to break down, or modularise, the riser into a number of standardised building blocks from which a range of configurations can be assembled.

Modularisation – The Key to Standardisation

A typical SLOR design may be broken down into a number of modules. Each module is generally a component that is common, or can be modified to be wholly or partly common, across a number of riser diameters, pressures, duties and water depths etc. Each module is selected to have a clear function and defined interfaces with the adjacent modules. The key modules identified for the SLOR are, Figure 4:

- Buoyancy Can
- Upper Gooseneck Assembly
- Termination Joints
- Steel Riser Pipe
- Lower Off-take Spool Assembly
- Foundation Pile
- Flexible Pipe Jumper

The buoyancy can is expected to be largely identical for all applications. It is designed for the maximum anticipated loading regime for a number of projects and standard central, top, and bottom compartment details developed. All that is required is to assemble the appropriate number of standard central compartments together with a top and bottom compartment to generate a design with the required up-thrust for each SLOR, Figure 5. Knowing the number of risers and their sizes for a number of applications, materials can be ordered early with certainty. Fabrication can also commence early on the buoyancy can with only the final number of standard compartments to be confirmed.

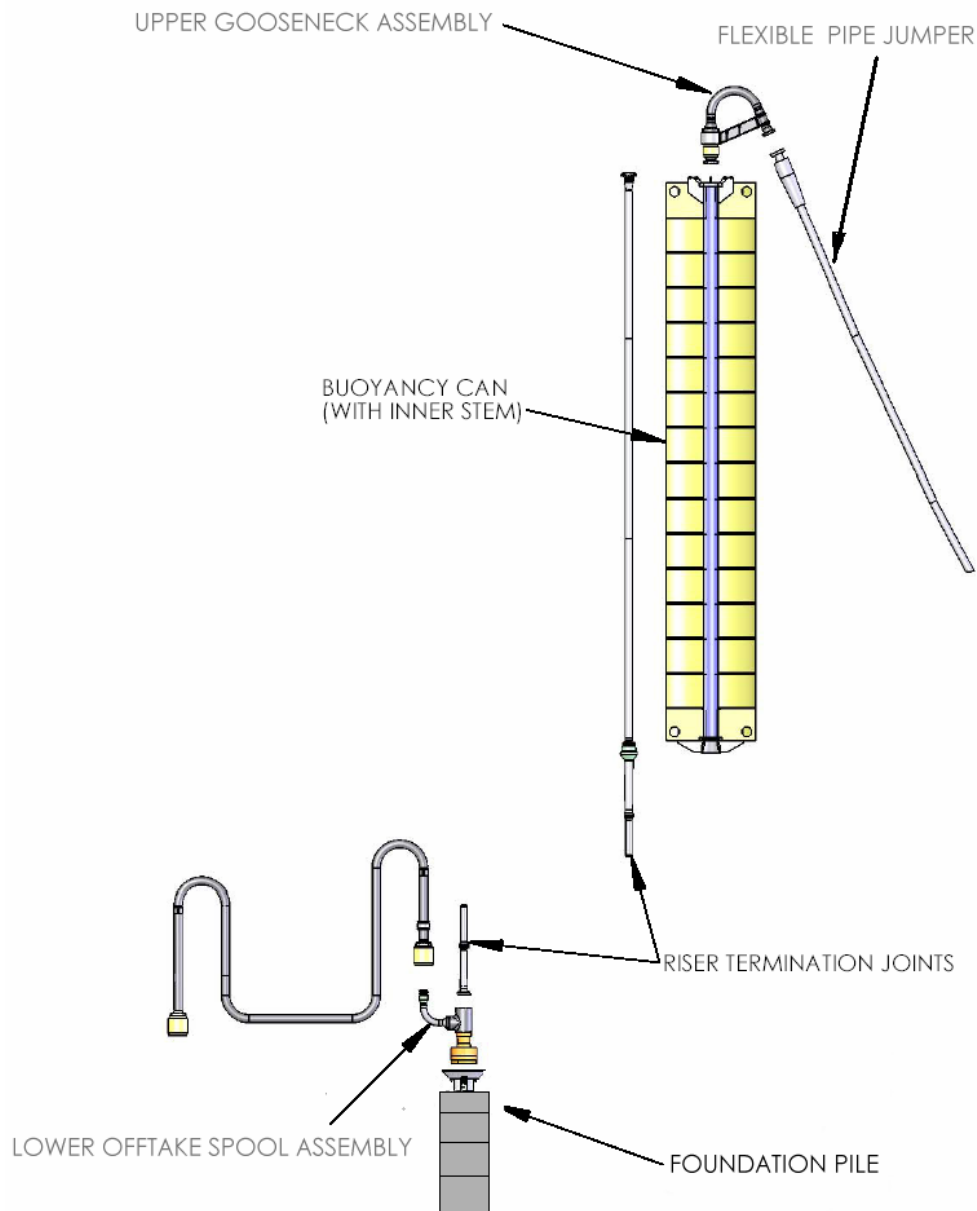


Figure 4 – SLOR Modules

Similarly, foundation piles are expected to be largely identical for all applications. There may be a requirement to alter the pile length to accommodate both the required riser base tension (which will be primarily dictated by water depth and current speeds) and variations in local soil conditions. In many cases though it would be possible to standardise on a single or a limited number of standard capacity designs. Furthermore the pile top assembly, riser connection and skin details are standardised to suit a range applications.

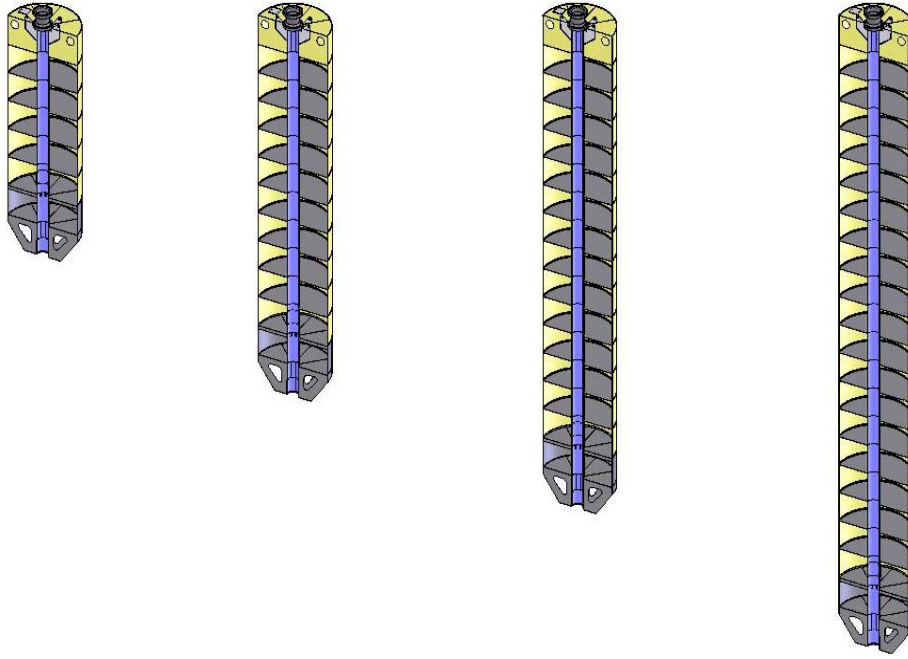


Figure 5 – Standardised Buoyancy Cans

The lower off-take spool assembly and upper gooseneck spool assembly is designed for the maximum loading/diameter expected. Where smaller diameter risers are needed, components are left oversized and short “pup” pieces used to make up length. In forged or cast off-take spools the member wall thickness are adjusted to suit the particular riser diameter, pressure and tension conditions.

The steel riser pipe is not seen as a target for formal standardisation as this component is driven by the unique combination of riser diameter, pressure, water depth, corrosion and flow assurance requirements. Adopting over-specified riser pipe in order to reduce the number of configurations is likely to lead to an inefficient riser design due to the increased overall system mass and the associated increase in buoyancy can requirements.

Similarly the flexible pipe jumper cross-section is generally designed specifically for the required combination of bore diameter, pressure and flow assurance requirements. However it may be possible to identify a number of risers with similar requirements across a range of projects to rationalise the number of unique designs. It should also be noted that as the flexible pipe jumper is always located near the surface, it is of a shallow water design and likely that the same cross section design can be used across a number of projects even with differing water depths.

Standardisation Strategy

In addition to the identification of a riser design that offers the ability to be applied and standardised across a number of projects, a strategy for its implementation must also be developed.

A key benefit of standardisation is to differentiate installation contractor on their ability to install pipe efficiently but NOT ability to develop riser concepts and conduct detail design riser products/components.

To achieve this, operators must take ownership of the global riser design and key component functionality and this will allow them to drive the technical solution – and ultimately gets what it wants and needs. The installation contractor must still however take responsibility for the component detailed design and installation. This way the risk & responsibility is fairly apportioned to those that can best manage it.

With the operator taking control over the design and functional requirements of key components it is proposed that invitation to tender (ITT) packages issued to prospective installation contractors contain outline designs for the riser system. To ensure that these designs are “installable” contractor input should be sort prior to issue of the ITT. If this occurs, operators need only accept minor deviations for the issued ITT design, thus providing a set of very comparable tenders on which to select and award the installation contractor.

Commercial Benefits

The immediate benefits of riser standardisation to the operator are improved quality and schedules. In addition, the practice will deliver a riser system that has commonality and interchangeability of modules whilst offering greater market competitiveness, resulting in overall field development cost savings.

Further commercial benefits of such a system can be presented as follows:

- The riser can be engineered once, covering most field requirements, therefore reducing engineering schedule and man-hours.
- Increased market competition between installation vessels, becoming less dependent on the ‘major’ contractors and subject to higher costs.

- Varied procurement and manufacturing route, as multiple suppliers can be approached for obtaining competitive commercial offers.
- Easier planning allowing wider application of 'available' installation vessels.
- Component standardisation reduces equipment qualification testing .
- Robust and simplified designs allow for more in-country content.
- Improved bid schedules, contractor tenders and accuracy in budgets based on increased levels of engineering.
- Common spares and stock inventory for call-off as required.
- Lessons learnt in all processes (engineering, manufacturing, procurement and installation) are transferable to future developments.

Standardisation is likely to initially increase the riser hardware cost slightly owing to the need to build-in conservatism in the component design to cater for a range of services. Initial cost increases are estimated to be 5-10% over the cost of a tailored and highly optimised riser system for the first project.

However this cost is likely to fall significantly, by some 30% or more, once the supply chain has become accustomed to the concept, understood the market requirements and become more competitive (as has been seen in the standardisation of subsea equipment).

The other benefits, such as improvement in schedules and local content, are more intangible and thus more difficult to quantify.

Conclusions

Standardisation could potentially deliver a robust and adaptable riser that could be applied to a number of worldwide projects with a broad range of requirements. Of all current deepwater riser designs, the SLOR is identified as the most suitable configuration for standardisation and is a viable technical and commercial solution in the majority of deepwater applications. The key to the standardisation of the SLOR is the design of common and interchangeable component modules.

The standardised riser design approach offers greater market place competition which is likely to result in improved quality, schedules and potentially overall field development cost

savings. The standardised riser differentiates installation contractors on their ability to install pipe efficiently, but not their ability to develop unique riser concepts or detail design riser components.