Top Tensioned Riser (TTR) Engineering Integrator Supply Model
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Abstract

Top Tensioned Risers (TTRs) have an established track record for deep water applications in the Gulf of Mexico (GoM), West Africa and Indonesia. However, TTRs are challenging due to their complex and highly iterative design, weight control and multiple interfaces due to numerous nonstandard equipment packages. Interface management and control is critical for successful project execution and hence a ‘systems’ approach to engineering, procurement and integration is highly beneficial.

A commonly used model for the engineering and procurement of TTRs is through an Engineering, Procurement & Construction (EPC) contract. An alternative approach is to use a riser engineering integrator to develop the system design, procurement packages and provide follow-on engineering support and fabrication management. The riser engineering integrator model allows the Operator more influence and flexibility to develop an optimized riser system and minimize the impact of changes during the course of the project. The model is currently being utilized for a high profile deep water GoM TTR development.

This paper presents an overview of the riser engineering integrator model for a top tensioned riser and compares it to the EPC approach highlighting the technical and commercial advantages and disadvantages between models.

Introduction

Top Tensioned Risers (TTRs) have been in service on floating production systems from as early as 1984 when the Hutton Tension Leg Platform (TLP) was installed in the UK North Sea, in 486 feet water depth. Since that time, more than 30 dry tree production facilities have been installed using TTRs, with either TLPs or Spars as the host vessel. The first TLP installation in the Gulf of Mexico (GoM) was Auger in 1994. Whilst this development was in a water depth of only 2,860 feet, the technology has now been successfully extended into water depths exceeding 5,000 feet.

TTRs are commonly engineered, procured and constructed via a single riser supplier that offers a full turnkey approach based on a lump sum contract. This paper presents an alternative supply model of TTRs to the EPC contract and provides the pros and cons of the riser engineering integrator model using a TLP dual barrier riser system as a case example.
TLP Top Tensioned Riser (TTR) Configuration – Case Study

Top Tensioned Risers (TTR) provide surface access to the subsea wells and consist of a section of vertical pipe (i.e. riser joints) supported at the vessel by individual tensioner systems and connected to the subsea wellhead via a tieback connector, Figure 1.

Figure 1 – Typical Gulf of Mexico Tension Leg Platform (TLP) Production Top Tensioned Riser
A typical arrangement consists of the following key components for a dual barrier top tensioned riser system.

**External Tieback Connector** - The External Tieback Connector (ETBC) provides the interface between the outer riser and the subsea wellhead and must accommodate the tension and high bending loads imposed by the riser. The ETBC bending moment capacity can be in excess of 5,000 ft-kips when combined with tension and internal pressure and hence can withstand the high loads at the base of the riser that occur in deepwater and with large vessel offsets. The connector has a hydraulically actuated internal piston which drives a cam ring, which in turn drives a set of dogs that engage into an external grooved profile located on the subsea wellhead. The engagement of the dogs on the wellhead housing energizes the gasket and provides a high preload between the interfacing components. The external tieback connector hydraulic, test and flush functions are controlled via a control panel that is accessed by a Remotely Operated Vehicle (ROV).

A guide arm assembly attaches to the exterior of the external tieback connector and provides the interface with the guide wire system during riser installation. The guide wire system is utilized to direct the riser to the target subsea wellhead during riser installation operations.

**Lower Stress Joint** - The lower stress joint connects the riser to the subsea conductor casing system at the subsea wellhead via the ETBC. The lower stress joint is utilized to manage the high bending stresses and fatigue loading at this localized section adjacent to the point of fixity at the seabed. The lower stress joint typically is manufactured from a single piece forging and is considered a primary class forging in accordance with API RP 2RD, [1]. The lower stress joint typically consists of a steel construction. Typical grades utilized are A707 and F22 as an example with 80 ksi minimum yield strength. The length of the joint is dictated by the required taper section to manage the high bending loads due to vessel offset. The length can be further increased in order to push out the first connection at the upper end away from a high fatigue hotspot. However, lower stress joints lengths in excess of 50 feet provide limitations on forging suppliers due to weight, forging process and final machine suppliers. The limitation on the forging process is during the quality heat treatment cycle that consists of quenching in a tank, where 60 feet length is the restriction. Furthermore, the combined forging supplier and final machine supplier schedules for such items are usually in the excess of 12 months.

The lower stress joint has either a cross-over joint above or connects directly to a standard riser joints depending on the structural performance and grade at the base of the riser.

**Internal Tieback Connector** - The Internal Tieback Connector (ITBC) provides the interface between the inner riser and subsea wellhead assembly or external tieback connector. The sealing of the ITBC is via a nose seal on the subsea wellhead lock down sleeve. The internal tieback connector must resist the tension overpull / preload that will be applied to the inner riser prior to setting the adjustable casing hanger in the surface wellhead. The internal tieback connector contains a lockdown sub, which when rotated by a running tool, locks into the subsea wellhead housing or external tieback connector. The interface with the production inner riser joints is via a premium casing thread. Furthermore, a cross-over joint may be required between the standard inner riser joints and the internal tieback connector.
**Standard Riser Joints** - Standard riser joints comprise the majority of the TTR to approximately 40-50 feet below Mean Water Level (MWL). For production TTRs, the riser pipe is of a dual pipe cross-section (i.e. two concentric casings), as shown in Figure 2, such that in the event of failure of the inner riser casing during a workover event, the outer casing is designed to retain the completion/workover fluid and hence maintain the hydrostatic head and riser margin in the well, [2]. Further, if a leak occurs in the primary barrier (inner casing), it can be detected by a pressure build up in the outer annulus. Dual barrier systems offer improved thermal performance over single barrier systems, often a key challenge in deep water.

The conventional construction method uses ‘weld-on’ threaded connections as shown in Figure 3(a) on the end of each riser joint, which has limitations on the maximum material yield strength of 80 ksi for joint welding fabrication. This approach results in a comparatively heavy riser due to thicker wall and the introduction of heavy couplings. An alternative construction approach is the use of higher yield strength Threaded and Coupled (T&C) connections as depicted in Figure 3(b) that do not require welding and associated qualification programs. In addition, issues relating to compatibility between riser pipe and coupling forgings is eliminated with threaded and coupled (T&C) connections. This allows material yield strengths up to 125 ksi and results in thinner riser wall thicknesses, allowing significant cost reduction to be achieved via lower total steel volume, vessel payloads and the elimination of welding qualification programs (although connector qualification programs may be required) and production welding.

Confidence in the use of T&C connections for dynamic riser applications has increased over recent years partly through more deepwater applications in TTR risers and also through Joint Industry Projects (JIP), [3]. Internal sealing of T&C connections is achieved through metal to metal seals using low make-up torques. The metal seals are located on the pin of the connector and designed with tapered, radial or elliptical profiles. The internal metal to metal seal provides the connector leak resistance, whereas the torque load shoulder provides structural strength.

A potential initiator or contributor in connector fatigue failure for T&C connectors is sea water ingress to the root radius of the last few run-out threads. This can lead to corrosion and ultimately result in a crack initiation site for fatigue failure to develop. T&C connections designed for riser applications now incorporate external metal to metal sealing for the external environmental. The external/environmental seal prevents seawater reaching the root radius of the last few run-out threads. The benefit to the T&C connection is that long term corrosion and fatigue performance is enhanced. The external seals can take the form of a metal to metal circumferential multisrase wavelets as offered by Vallourec & Mannesmann (V&M), [4] and shown in Figure 3(c), or of a shrink-fit aluminum metal to metal seal as offered by OilPatch Technologies (OPT), [5].
The standard riser joints exterior are covered with a corrosion protection system such as Thermal Sprayed Aluminum (TSA) and with VIV suppression devices such as strakes.

Splash Zone Joints - Splash zone joints with greater wall thickness and neoprene coating (to provide corrosion protection and impact resistance) are often utilized above the standard riser joints that terminate at approximately 40-50 feet below MSL. The design philosophy in the splash zone area varies from project to project as there are no specific requirements or guidelines in API RP 2RD. A standard that may be used is Norsok Standard M-001, [6], which has been utilized in North Sea projects and recommends an increase in wall thickness depending on sea water temperature and the addition of a 0.5 inch thick neoprene layer. The splash zone joints connect to a forged machined tension joint that connects to the surface wellhead at its upper end.

Tensioner System - Tension is maintained in the riser using a hydro-pneumatic tensioner system that interfaces with the outer riser via a tension joint. The tensioner provides global stability and motion performance control and ensures that positive effective tension is maintained at the base of the riser under all loading conditions. The pull-up tensioner system comprises of either four or six cylinders/rods which are suspended via bow shackles integrally mounted into the TLP deck structure. The bow shackles provide the articulation and compliance of the system. The cylinder rod slides up and down relative to the cylinder barrel and provides the stroke for the tensioner system. The cylinders and rods are downward facing and interface with the riser string via a tension ring that incorporates a concentric large pitch thread profile that is complementary to the threads machined onto the tension joint. The threaded section is incorporated to provide space out capability to accommodate riser installation stack up tolerances. The tension joint interfaces with the tensioner system tension ring and centralizer guide roller system. The centralizer guide roller at the tree deck elevation acts as the riser centralization point and provides lateral support. The roller guides are designed to accommodate lateral loads imparted by the riser in all environmental conditions.
The tensioner system design is based on the service life of the production riser, typically 20 years and on guidance of API RP 2RD that accounts for intact load cases for operating, extreme and survival conditions. In addition, the design should account for a failed cylinder scenario with an associated environmental condition. The failed cylinder load cases are classified as extreme and survival. The key parameter that defines the tensioner system is the stiffness of the system and is dictated by the nominal tension and stroke range (i.e. maximum upstroke and downstroke) required. Further inputs are the number of cylinders, maximum pressure and rod diameter. The implications of a high stiffness system may result in high interface loads (i.e. vertical, lateral) imparted into the vessel structure.

In the design of the tensioner system, moving components such as wear pads, seals and roller assemblies need to account for a 20 year design life but can be considered replaceable components. To improve design life of the cylinder assembly and the need to replace components while in service, the main rod and barrel assemblies are highly machined components with tight tolerances and polished/coated surfaces to minimize friction between wear bands and seals of moving components as excessive seal wear due to cyclic loading can lead to cylinder failure (and loss of tension on riser).

**Surface Wellhead/Tree** - The surface wellhead functions as a suspension point for the inner riser and drill casing. The surface wellhead contains casing hangers, which allow for the casing to be hung off and sealed. Typically, radial bolt connectors are utilized for the surface wellhead connections to the tension joint and surface tree to minimize installation time and facilitate surface tree orientation.

**Surface Tree** – The primary function of the surface tree is to control the flow of the production fluids. In addition, the surface tree provides additional functions including chemical injection points, pressure relief systems and connection points for devices such as down hole pressure and temperature transducers. The surface tree is controlled by the surface control umbilical. A surface production flexible jumper provides a flow path from the tree to the TLP piping. Work platforms allow operations personnel access to manual valves, monitor pressure and perform maintenance and well diagnostics.

**Flexible Jumper** – The flexible jumper is used to convey production and injection fluid between the surface tree and the topsides piping. The interface of the flexible jumpers may be either directly to the wing valve of the surface tree or to a hang off receptacle located on the tree work platform. On the topside, the flexible jumper can interface directly with topside piping or to a hang off receptacle. The flexible jumper must accommodate movement of the surface tree in the vertical and lateral directions while not exceeding the manufacturer’s Minimum Bend Radius (MBR). The MBR is dictated by the flexible pipe cross-section which is sensitive to pressure, temperature and compatibility with production, injection and completion fluids.

**Control Umbilical** – The control umbilical is used to convey voltage cables, instrument cables and hydraulic, pneumatic, chemical injection, minute amounts of production fluid and gas, water and other fluid lines between the surface tree and the topsides. The functional components of the control umbilical may be routed from the hang-off receptacles to electrical enclosures and
hose/tube bulkhead plates located on the surface tree work platform and topsides. Similar to the flexible jumper, the control umbilical must accommodate movement of the surface tree in the vertical and lateral directions while not exceeding the manufacturer’s Minimum Bend Radius (MBR). The MBR is dictated by the control umbilical cross-section which is sensitive to pressure, temperature and compatibility with production and chemical injection fluids.

‘Systems Approach’

The design of top tensioned risers is complex and highly iterative with the key design issues focused around the parameters that influence the riser strength, fatigue and clearance response as well as its configuration through the vessel wellbay. Importantly, the riser design needs to cater for requirements from stakeholders, such as the Operator’s operations, drilling and completion teams, who will be responsible for operating and maintaining the riser during its service life. The system engineering and interface management function is a key activity bridging all the disciplines and maintaining/controlling the structural, physical and operational interfaces. This is a key role within the project due to the complexity of the interfaces and the number of companies involved as illustrated in Figure 4. Hence, interface management is essential in order to ensure that all the relevant information is obtained from and provided to all concerned internal and external parties.

The ‘systems’ approach is highly evident and utilized to finalize the TLP wellbay configurations shown in Figure 1. TLP wellbays can be highly congested and hence ‘real estate’ is at a premium, particularly on the wellbay perimeter where TLP structural beams and process equipment are located. The routing of production flexible jumpers and control umbilicals from the surface trees to topside piping and junction boxes respectively can become complex and iterative if there are competing space requirements from other project groups such as Topsides. The routing is dictated by the minimum bend radius (MBR) of the flexible pipe or umbilical, which are highly sensitive to internal pressure/temperature and fluid composition. The dynamic
deflection of the riser may create further complications in routing as horizontal spatial distance requirements need to be adjusted in an already crowded wellbay.

Due to the complex interfaces and components of top tensioned risers and where project delivery schedule is aggressive, the requirement to define interfaces and procure long lead items such as long length single forgings for lower stress joints and tensioner cylinders are typically accelerated. However, a key number of design analysis activities shown in Figure 5 need to be completed first, that influence the top tensioned riser component designs. Riser global analysis is also required to provide interface loads to surrounding external interfaces such as in the wellbay and as well help to define seabed well layout and the drilling and completion sequence.

It is important in the Front End Engineering & Design (FEED) phase of a project to develop the design of the riser stack up in the wellbay as any significant changes during the Execution phase become harder to make as other structural interface details such as deck elevations, clearances and load capacities become frozen. The nominal and maximum riser top tension requirement will determine if the riser tension can be supported by a topsides deck or require a structural deck of its own to directly transfer load into the hull structure. The tilt and stroke range will feed into layout designs to ensure the riser has sufficient clearance with topsides decks and equipment. Another factor that affects the stack up of the riser in the wellbay is access to the tension ring for riser installation and inspection in service. The tensioners can be made stiffer to reduce the overall riser stroke range and resulting clearances in the wellbay as well as improve the manufacturing of high tolerance barrel and rod forging assemblies. Iterative analysis may be needed to optimize tensioner stiffness to achieve an acceptable stroke and acceptable maximum loads on supporting structures and into other riser components below the tension ring such as the tension joint.

The tensioner system is considered the ‘heart’ of the top tensioned riser system and hence the determination of its tension capacity needs to be frozen early in the design process as it dictates the stack up configuration of the riser in the wellbay as well as the design and manufacturing schedule of long lead items. In addition, the tensioner system may need to be integrated into the host vessel onshore much further in advance of when other riser long lead items are required, typically nearer to offshore installation of the riser system. Therefore, tensioner system long lead items such as barrels and rods need to be procured early to meet the integration schedule as these items have a number of processes of manufacture from forged extrusions through to final honing of barrel bores or application of corrosion coatings to the rod exteriors.

The riser components, in particular the riser specialty joints (i.e. lower stress joint and tension joint) that comprise of long length forgings have a longer delivery schedule as these components are required just prior to riser installation. This allows the specialty joints to be optimized further from the FEED stage of the project and hence the analysis effort is geared to support this supply schedule whilst still providing input into the TLP design via providing interface deck loads. The detailed strength analysis provides component drawing definition and design loads to be included into Requisition for Quotation (RFQ) documents. As detailed analysis continues, loads are continuously updated with the aim of freezing them for equipment suppliers prior to Purchase Order (PO) award as well a providing interface loads to subsea wellhead, hull and topside contractors groups that may have a more advanced schedule.
Figure 5 depicts a typical analysis schedule for supporting package design, RFQ, PO award and manufacturing activities accounting for the need to establish definition on long lead items early in the project schedule.

The riser integrator model requires a multi-disciplined team that understands the challenges of a complex TTR system that comprises of complex and highly iterative analysis, multiple interfaces, multiple non-standard hardware packages, contracts and stakeholders. The key to the riser integrator model is that the project team exists for the majority of the duration of the project to ensure continuity in the project and that its objectives are met. The responsibilities of the key members of the riser integrator team are summarized below.

The system analysis team performs global riser analysis including wall thickness sizing, strength, first and second order fatigue, Vortex Induced Vibration (VIV) fatigue, clearance, installation and operability analysis. Riser analysis activities define the system configuration as well as define requirements for specialty joints such as lower stress joints and tension joints.

The system engineering team establishes and controls the engineering activity and interfaces, maintaining a total system overview and ensuring that the riser system design meets the functional and operational requirements and is installable, operable, reliable and maintainable. This is a key role within the project due to the complexity of the interfaces and the number of companies involved. System engineering is responsible for ensuring that the component parts of the TTR system are fully integrated with each other and with external systems and facilities, during testing, assembly, installation and operation. The systems approach and understanding of the installation and operational issues is one of the fundamental activities in designing and qualifying a successful riser system.
The package engineering team ensures that all designs, technical specifications, procedures and reports are in compliance with industry standards and best practice such that the final manufactured/supplied component is of the highest quality and ultimately is fit for purpose. This involves generating, reviewing, refining and issuing as necessary all documents specifying requirements for the riser components. Definition of detailed component specifications and/or datasheets for use in equipment supply bid documentation based on data received and loading/performance criteria identified by the global analysis team. Component packages are managed by dedicated delivery package engineers from the initial requests for quotations through to final delivery. The approach of the delivery package engineer being actively involved in the procurement activity is key to the riser integrator model since the component packages are often technically complex and therefore there is benefit of maintaining a high level of technical management in the process.

The procurement team must work closely with the package engineers to ensure all technical requirements are incorporated into the overall procurement plan consisting of the scope and split of packages for suppliers to bid to. The procurement team maintains a single point of contact with the supplier during RFQ, bid evaluation and contract placement activities. After contract placement, the package engineer will assume the primary delivery responsibility for the more technically complex equipment packages with the procurement team supporting all commercial activities with the order.

The QA/QC team consisting of a lead QA/QC inspector and a team of field inspectors are required to monitor and witness manufacturing and testing activities. The package engineering team develops a criticality matrix for the various equipment packages and the project inspection philosophy requirements are defined in the technical specifications at bid phase. Inspection Test Plans (ITPs) are provided by suppliers as part of the bid response and finalized with the project engineering and QA/QC team shortly after contract award. Close dialogue between the package engineering and QA/QC inspectors is needed to ensure critical aspects of manufacturing and fabrication activities are communicated between parties. Typical riser components that require significant inspection coverage are long length forged specialty joints due to the complexity and number of steps of manufacture.

The project management team provides planning and organization of schedules, manpower, cost control and QA as well as reporting of technical progress, areas of concern, and commercial expenditure. A master riser schedule is developed by the riser integrator team to monitor the delivery schedule of each package and ensure any critical delays are mitigated at the earliest opportunity to protect the project schedule.

**Hardware Packages**

TTRs contain multiple non-standard equipment packages and hence the procurement process can be defined as technically driven to ensure the specific project technical requirements are captured in the bid documents. Many of the hardware packages may be procured from a range of suppliers consisting of wellhead equipment providers to specialized threaded connector suppliers. The rationale behind categorizing the number and scope of equipment packages is based on the fact that there is no true single supplier for all of them and in order to have a fully optimized system,
the goal is to bid to the ‘best in class’ suppliers for that specific equipment package. A bid evaluation strategy is utilized that reflects on the technical requirements, supplier capabilities, supplier track record, schedule, costs, geographic location, frame agreements, etc. Further considerations into dividing the equipment packages are:

- Identifying equipment packages that require early purchase order (PO) placement due to long lead times and/or supplier input into the riser system and component design process, the tensioner system as an example;
- Availability of an interface connection between equipment packages that is simple and industry standard such as a flange connection as an example;
- Avoiding unnecessary cost mark-ups on sub-contracted equipment;
- Avoiding including scope within an equipment package that the supplier is not set up or comfortable performing;

Each equipment package requires a well defined functional specification that has the aim to minimize room for interpretation by the suppliers and hence reduce the potential for commercial impact via change orders during the integration phase of the project. The riser engineering integrator is responsible for developing the specifications relating to the equipment packages. This involvement in the development of the specification relating to the equipment packages requires the riser integrator technical team to follow the package development from bid to manufacture and testing to ensure all project technical requirements are met.

A typical production TTR equipment package categorization may be as follows for a riser integrator approach:

- Flexible Jumper
- Control Umbilical
- Surface Tree, Surface Wellhead, Adjustable Inner Riser Hanger and Work Platforms
- Access Walkways
- Tensioners & Tension Joint
- Outer Riser Joints
- Strakes
- Joint Coatings, Strake Installation & Bolstering
- Inner Riser Joints
- Inner Riser Centralizers
- Lower Stress Joint c/w External Tieback Connector and Guide Arms
- Internal Tieback Connector
- Riser Monitoring System

The lower stress joint with external tieback connector can be supplied as an integral, as shown in Figure 6(a), or non integral configuration as shown in Figure 6(b), that allows competitive pricing and schedule to be obtained. Typically, the preference is to utilize slim line external tieback connector design to simplify installation through the rotary table, which will then narrow the number of suppliers with field track record. Active management of the interface with the subsea wellhead is required by the riser integrator to ensure critical features such as tieback
connector swallow, guidepost clearance, locking and sealing profile, and design loads are worked between the suppliers.

(a) Lower Stress Joint with integral tieback connector profile to accept ETBC
(b) Lower Stress Joint with integral flange to accept flanged ETBC

Figure 6 – Lower Stress Joint prior to Integration with ETBC

The majority of the TTR riser string consists of standard riser joints, whether it is the outer or inner riser. Non welded T&C riser joints offer a reduced payload and CAPEX over weld-on designs. Currently in the market, T&C riser joints suppliers are generally pipe or connector suppliers and are an entirely different suite of suppliers from the specialist wellhead equipment suppliers for packages such as surface trees, wellheads and tieback connectors. Utilizing an integrator supply model allows the standard riser joint packages to be placed direct with these specialist connector suppliers and thus obtain the most competitive price available. It should be noted that not all T&C riser joint suppliers are set up to manage the preparation of riser joints, i.e. corrosion coating application, strake or centralizer installation and bolstering for installation offshore. Therefore, this process can become a package in itself and bid to various suppliers and managed by the riser integrator as a separate contract.

In the event there is a material grade mismatch between interfacing riser equipment packages, such as an 80 ksi lower stress joint and a 110 ksi standard riser joint, this interface can be easily managed via utilizing adaptor joints, with intermediate yield strengths, that can be supplied by either equipment package suppliers or even a third entity.

For TLP developments, the well drilling and completion sequence can take a number of years to complete. The decision whether to procure all the riser joints for all well slots as a single order or split the riser joint order into batch orders throughout the project drilling and operation phases needs to be determined early in the procurement process. The delivery strategy for the riser joints needs to consider a number of variables such as escalation models for raw material and storage/preservation/maintenance. In addition, other issues need to be considered for either a single order or batch approach, such as:
• From procurement through manufacture for a single order, a seamless process is provided as the project and supplier teams remains the same, compared to a batch approach, where a new team is required and hence lessons learnt are not transferred, personnel may not be familiar with the product (i.e. QA/QC and logistics), etc;

• For a batched approach, any additional batches will be ordered during the operation phase of the project and the operations team will require time to familiarize themselves with project specifications, procedures, scope of supply and requisition for quotation (RFQ) documentation. The operations team will need to review any lessons learned and ensure they are incorporated into the future orders.

The tensioner system requires early definition (i.e. in FEED stage) and supplier selection due to long lead sub-assemblies that are typically sourced from multiple geographical locations. This is due to the assemblies, such as the cylinder assembly comprising of various highly machined components with tight tolerances and polished/coated surfaces. The tensioner system requires an early design freeze on nominal and maximum top tensions, stroke range and stiffness as the tensioner design is sensitive to any changes in global riser response. Furthermore, the hull and topside engineering, fabrication and integration are in a far more advanced stage in the project that the riser scope and hence the interface with the hull and topsides are on the critical path of onshore vessel integration construction schedule.

A critical interface of the tensioner system is the interface between the tension ring and tension joint. The interface may consist of a threaded connection or via a load shoulder arrangement. Therefore, due to the criticality of the interface, the tension joint supplier should provide both the tension ring and tension joint, particularly if the interface comprises of a threaded configuration. The interface between the tension joint and standard riser joints may be via a compact flange (in high fatigue region) or a threaded connection (in low fatigue region) and therefore the preferred tensioner/tension joint supplier does not have to provide the rest of the riser system. This approach requires active management from the riser integrator to ensure that all the interfaces are clearly defined and that the supplier schedule is maintained to meet hull and topside integration milestones.

The configuration and hang-off details of the flexible jumper and control umbilicals needs to be worked early as part of the wellbay design and layout as the hull and topside design are usually ahead of the riser design. Due to the topside advanced stage in the design process, the real estate for equipment placement can have competing needs from the various groups on the project. The topside hang-off for the flexible jumpers and umbilicals requires a high level of management from the riser integrator irrespective of whether the equipment packages are within the scope of a single riser system supplier or managed by an integrator. The hang-off interface of the surface tree has more scope for design and schedule flexibility by adjusting the surface tree orientation, utilizing hang-off clamps on the work platform with connecting hard pipe spools to the wing valve of the tree. The tree end connection can be worked as part of the detailed design of the tree and wellhead supplier’s scope.

There are a number of suppliers that can supply the flexible jumpers and umbilicals and hence these packages can be competitively bid. The strategy for the procurement of these packages
differ from other equipment packages that follow the drilling and completions sequence with respect to batch ordering and delivery in that the full length of flexible pipe or umbilical should be manufactured to cover all wells to be completed for the development. This approach minimizes recurring set-up costs, particularly for a short length of flexible pipe or umbilical and increase in raw material costs. Similar to the standard riser joints, these packages would most likely be subject to a cost mark up if the order is placed with a single riser system supplier.

**Contracting Considerations**

The supply of top tensioned risers is commonly via an Engineering, Procurement & Construction (EPC) contract, i.e. a single riser supplier. The contract is based on a lump sum basis which allows the Operator commercial leverage at the initial negotiation stage but the Operator’s control and influence over the design diminishes with respect to changes and change orders that commonly occur as the project progresses. This is depicted in Figure 7. However, the interface risk associated with a lump sum contract is minimized to the Operator as the risk is borne by the single supplier. The pros and cons of an EPC contract are provided in Table 1.

![Figure 7 – Riser Delivery Models](image)

The alternative to an EPC contracting strategy as described in this paper is to utilize a riser engineering integrator that uses multiple suppliers as there is no true single supplier for all the TTR equipment packages. This rational allows for the selection of ‘best in class’ suppliers and improved commercial competition resulting in an optimized hardware supply. This contracting approach is based on a man-hour contract for engineering and procurement management, allowing the operator a high level of control and influence over these activities. However, the Operator is exposed to a larger number of interfaces to manage which needs to be managed closely using the riser integrator team approach. The pros and cons of a riser engineering integrator contract are provided in Table 2.
## Table 1 – Pros and Cons of Single Riser Delivery Model

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<th>Pros</th>
<th>Cons</th>
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<tr>
<td>Single purchase order</td>
<td>All ‘eggs in one basket’</td>
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<td>Lump sum contract</td>
<td>No true single supplier for all items</td>
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<td>Reduced commercial interfaces</td>
<td>Difficult to truly ‘lump sum’ due to scope &amp; risk uncertainty</td>
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<td>Commercial leverage in initial negotiations</td>
<td>Changes and change orders inevitable – less transparency. Cost escalation due to design changes</td>
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<td>Minimum operator team</td>
<td>Inevitably accept non-optimum solution</td>
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<td>Interfaces hidden (internal) – less influence from engineering team</td>
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<td>Adversarial relationships</td>
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<td>Lack of influence</td>
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<td>‘Good enough’ has to be ok</td>
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<td>Supplier capacity limitations</td>
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## Table 2 – Pros and Cons of Integrator with Multiple Suppliers Delivery Model

<table>
<thead>
<tr>
<th>Pros</th>
<th>Cons</th>
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<tr>
<td>“Optimized” hardware supply</td>
<td>More orders to manage</td>
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<td>Improved commercial competition</td>
<td>More supplier to supplier interfaces to manage</td>
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<td>Eliminate the EPC “mark-up”</td>
<td>More supplier project teams to interface with</td>
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<td>Best in class capabilities</td>
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<td>Increased scope for innovation / optimization</td>
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<td>Improved interface and variation control</td>
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<td>Schedule optimization</td>
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<td>Improved access to project execution and direction from Integrator</td>
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<td>Less likelihood of capacity limitations</td>
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## Summary

The riser engineering integrator model is a viable alternative to the commonly used model of Engineering, Procurement & Construction (EPC) for a TTR system especially on developments that are technically challenging requiring a high level of engineering activity throughout the project lifecycle. The integrator model allows for a high technical focus to optimize the riser system performance and equipment package requirements and specifications. Due to the complexity and technicality of the various equipment packages, the procurement is technically driven with the engineering team following the package through from detailed design to delivery and integration. Key benefits to the Operator with the integration model is the level of continued influence and involvement in key decisions that is maintained through the life of the project and the riser system can be procured at the most competitive cost.
References