Jubilee Field Subsea Production System Design and Delivery
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Introduction

The Jubilee Field was discovered in June 2007 in the Gulf of Guinea, approximately 60 km offshore Western Ghana. It is a very large, light, sweet oil accumulation in 1200-1500m of water. The Jubilee Partners, along with Ghana National Petroleum Corporation (GNPC) decided in January 2008 to develop the field using a phased approach, after just one appraisal well. Kosmos Energy was appointed Technical Operator to lead an Integrated Project Team (IPT) in executing the development project and Tullow Oil (Ghana) was appointed Unit Operator to execute in-country activities, deliver wells, and operate and manage the field in the future. A third major partner, Anadarko, provided numerous key project personnel to the IPT. The IPT developed a plan to target just under 300 million barrels in Phase 1 with a 17-well subsea well system and 120,000 bopd FPSO. Phase 1 was approved by Partners in August 2008, and First Oil was achieved in November 2010, within the aggressive goal set by GNPC and the Jubilee Partners.

Challenged to achieve first production in less than 3 years from start of planning for production facilities, the IPT quickly evaluated development options and chose the predominated West Africa model of a subsea production system connected to a Floating Production Storage and Offloading (FPSO) vessel. It was immediately clear that the subsea production system design, procurement and delivery in 21 months would be key to maintaining the fast track schedule.

Subsea System Delivery Team and Philosophy

With a proven track record of deepwater project delivery, major partner Anadarko seconded, several key IPT members to the project, including the Subsea System Delivery Manager. Many of the processes, relationships and execution philosophies from their experience were combined with the Technical Operator’s philosophy and experience to establish a “fit for purpose” strategy for project execution driven by the fast track delivery requirement. The success of this strategy relied heavily on the major vendors providing field proven technologies and “off the shelf” solutions and the experience of the Subsea System Delivery Team. Within this strategy, the Team was empowered to make timely decisions with minimal management involvement. The adoption of the “fit for purpose” strategy for the execution of the project was also applied to procurement processes as well. The resulting efficiencies realized in these areas facilitated the fast, safe pace required by the project.

Another important part of the strategy was to develop the team concept. The IPT fostered a Jubilee Team philosophy with all contributors a part of “The Team” versus representatives from their respective companies resulting in a dedication by all to meet the challenge imposed by the project schedule.

Subsea Production System Design Challenge

Recognizing every aspect of the project would be schedule critical, the industry was canvassed to secure an engineering firm that could provide appropriate and sufficient technical personnel to adequately support the project. Contractor IntecSea was chosen to fill and support various roles as part of the Subsea System Delivery Team. The team was challenged to conceptualize, design and specify a subsea production system with limited
and changing information. This had to be accomplished within a compressed time frame to allow timely purchase and delivery of long lead items and fabrication of the necessary equipment to have any chance of meeting the first oil target of fourth quarter of 2010. The team began to immediately formulate a subsea production system based on the available design information as follows:

- Light, sweet crude (API 37 degrees with GOR of 1000-1300)
- Large field with reserve estimates ranging from 400 million to 1.8 billion barrels determined by only two wells
- Shut-in pressures just under 5,000 psig
- Water depths between 900 and 1700 meters
- Anticipated gas re-injection
- Anticipated pressure support by water injection
- Production to an FPSO of up to 160,000 bopd
- Notional number of wells and their locations.

The team established a design basis for a subsea oil production system based on prior experience with similar fields. A system was specified that contained the most common functionality and risk mitigations for subsea oil production systems and included the following:

- Dual insulated, piggable flowlines
- Methanol injected at the tree and other vital parts of the system
- Corrosion inhibitor at the tree
- Chemical injection (LDHI or Methanol) above the SCSSV
- Scale inhibitor injection downhole necessitated by possible water drive and anticipated water injection
- Riser base providing gas lift, methanol injection and production riser circulation
- Insulated flexible risers to the FPSO.

Souring of the reservoirs through water injection was recognized to be a threat to the project strategy of utilizing suppliers' standard designs. The fast track pace warranted elimination of specialized processes or materials which could jeopardize deliveries of various subsea equipment and pipe. The team quickly made the decision to add sulfate and oxygen removal on the FPSO demonstrating timely decisiveness that prevailed throughout the execution of the project and was paramount to keeping schedule.

As offshore Ghana was an undeveloped region, no metocean or geotechnical data existed. The team was faced with the challenge of progressing the subsea system design before any site specific environmental information was available. Wind, wave and current data was obtained from a FPSO development offshore Cote D'Ivoire and a 20% increase risk factor applied to the data based on observations of currents from the drilling rig ROVs and two regional high level “desk top” studies. Foundations for the manifolds and riser bases were based on experience, with the heavier production manifolds and riser bases supported by suction piles and the lighter injection manifolds supported on mudmats. These quick but technically sound measured decisions kept the project moving forward and their adequacy later confirmed, or the design revised as the updated design information was obtained.

Imagery and bathymetry of the Jubilee Field seafloor obtained from the 3D seismic campaign revealed that the field was bisected by a significant size canyon system which appeared to be developed by flow of water and sediment off of the continental shelf. With no information to determine if the system was active, the team had reservations about laying flowlines and umbilicals on the canyon floors. When it became apparent that a turret-moored FPSO would be chosen and a subsea production system on the east side added to the original west side system, the team located the FPSO over the canyon such that the risers were suspended above the canyon floors thus eliminating any concerns. Reference Figures 1 through 5 for the evolution of the field architecture.
The most predominate features of the Jubilee Development Area are three stream channels: Western, Central, and Eastern Channels.

Figure 2: Original Notional Directional Well Locations and Drill Centers
As the subsea architecture evolved, the team investigated the market factors and engaged suppliers on deliveries of the various system components identifying the critical delivery or long lead items and establishing the subsea portion of the project schedule. This allowed the prioritization for purchasing items and identified the overall critical path for the system which was the design and fabrication of the production manifolds, injection manifolds and the riser bases.

It was agreed within the IPT, based on close collaboration between the Subsea Delivery and the Subsurface teams, to develop the field with drill centers of four wells. This allowed a common modular four-well manifold design whether production or injection. This provided great flexibility as the reservoir understanding matured allowing the drill centers to be added or moved changing only the number or location but not the base design. This also established an “assembly line” type of manifold fabrication which facilitated the fabrication schedule.

The resultant components of the subsea system, which the Subsea System Delivery Team was responsible for timely design and delivery, comprised the following:

- Subsea production and injection trees (19)
- Production manifolds (5)
- Injection manifolds (3)
- Riser bases (2)
- Large bore valves (50)
- Vertical connectors (125)
- Chemical metering valves (18)
- Single phase water and gas injection meters (10)
- Multi-phase meters and associated samplers (9)
- Subsea control system inclusive of the seafloor distribution equipment
- Umbilicals (10)
- Flexible risers (9)

The final field schematic configuration is shown in Figure 6, after numerous revisions.

![Figure 6: Subsea System Schematic Configuration](image)

**Schedule-Facilitating Execution Methodology**

The execution methodology had to be tailored to the demands of the project schedule, yet deliver for installation a quality, fit-for-purpose, subsea production system in less than 2 years to meet the first oil goal of the fourth quarter of 2010. Several critical criteria were established by the team regarding the subsea system components:

- Leverage Jubilee Partner Anadarko’s existing frame agreement with FMC
- Choose suppliers with proven successful track records
- Utilize suppliers standard equipment and procedures wherever possible
- Perform constructability reviews for major equipment fabrication
- Foster good working relationships with suppliers and leverage their experience
- Constantly work interfaces
- Leverage experienced inspection resources.

Anadarko had a long standing business relationship with Subsea Supplier FMC for the supply of subsea trees and hardware. Through application of this agreement to the Jubilee Partnership, the IPT was able to demonstrate to stakeholders that the trees, manifolds and riser bases would be supplied at fair market pricing, eliminating a time consuming bid and evaluation process for these long-lead items. Instead of a couple of months, FMC had assembled their team and begun ordering materials, securing fabrication slots and coordinating the design with
the Subsea System Delivery Team within a few weeks. The frame agreement was also expanded to include the supply of the subsea controls and seafloor distribution equipment, again benefitting the schedule in the same manner.

Potential suppliers for the remaining components of the subsea kit were evaluated by the team. The primary criteria were an established proven track record and technology, workload, and the ability of their standard equipment designs and procedures to fulfill the specific needs of the project. The workload evaluation was critical to insure they could meet the delivery demands of the project schedule and the assurance of this enhanced by provision of their standard equipment.

Design information and performance specifications were issued to the suppliers and each supplier specifically requested to provide the solution with the application of their standard equipment. By doing this, significant engineering, evaluation and qualification time was eliminated from the schedule. This convention could be applied to almost all of the subsea kit, including major items such as the flexible risers and the subsea control system.

The leveraging of the frame agreements and the utilization of vendor’s standard equipment also provided the benefit of freeing the Subsea System Delivery Team members to move on to the next item or focus on the other critical parts of the system, thus being more productive and facilitating the fast pace schedule. The team members were able to better focus on the schedule drivers and address important issues in a timely manner.

One major schedule-assuring action instigated by the team was a constructability review involving the critical path driver for the subsea system delivery. The fabrication of the three injection manifolds, five production manifolds and two riser bases was the critical path item. A very experienced construction superintendent was added to the team to assist Subsea Supplier and their fabrication sub-contractor in assuring the tight schedule was obtained safely. A constructability review was held which included a man-power scheduling review as well. The constructability review resulted in design changes in the piping design and structural framing, eliminating welds and unnecessary or difficult structural framing. The result was three to five days work saved on each structure totaling 30 to 40 days saved overall on the original fabrication schedule as estimated by the fabricator. In addition, several man-power deficiencies were identified and the early identification allowed the contractor to rectify them in a timely manner without causing fabrication delays.

The success of the constructability review was in part due to the good working relationship between the team and the supplier as well as the supplier’s subcontractor. The review was conducted in a collaborative manner to assure the success of the suppliers and ultimately the project. This type of working relationship, focused on problem solving to meet the schedule, was fostered with all the vendors. This can be illustrated again by a delivery issue with the large bore valves. The valve actuators were behind schedule could not meet the valve delivery schedule that was necessary to keep the manifold and riser bases fabrication in sequence and on schedule. The team met with the suppliers involved, and collectively developed a recovery plan that involved some minor structural modifications; this allowed the valves to be installed without the actuators and the actuators installed at a later date off of the critical path. This kept the fabrication in the original sequence and on schedule.

Interface coordination is one of the most crucial areas in a subsea system. This was one area where the team “slowed down in order to go fast”. An interface manager was integrated into the team and an IntecSea proprietary interface management software tool was utilized to coordinate this critical function. Representatives from each major supplier and many team members were required to attend bi-weekly meetings. The meetings provided a very constructive venue for the orderly and timely transfer of design information, promoted understanding of the interdependence between each vendor’s delivery, allowed vetting of issues, avoided surprises and ultimately fostered accountability for keeping their respective commitments.

Another contributing factor to successfully meeting manufacturing and fabrication delivery schedules was the quality of the inspection effort. All subsea equipment items were inspected which is standard procedure in the industry. For the major assemblies and critical path items, the Subsea System Delivery team was able to draw on an established stable of experienced inspectors. These inspectors had established good working relationships with the suppliers and were pro-active, with the ability to recognize problems before they occurred and work with the suppliers to resolve issues and find solutions rather than just reporting problems when they occurred. It was also significant that the team recognized that the suppliers were exposed to quality issues, as the fast track pace forced them to go to secondary sub-suppliers to deliver the required number of parts and sub-assemblies within the compressed schedule. This placed a strain on their in-house quality efforts which the team supplemented with additional inspection resources. This was particularly true for high-volume items such as connectors and
seafloor distribution assemblies. Thus the IPT’s strategy of a collaborative working relationship with the suppliers was consistent in all levels of the team.

Results

The Subsea System Delivery Team and its suppliers were able to deliver all components of the subsea system on time in a greatly constricted schedule. The time saved on the front end by relying on the experience of a capable design team and applying existing frame agreements for the major subsea hardware items was a major key to delivery success. This allowed the design of these components to begin almost immediately and allowed the team members to expeditiously address the remaining schedule critical items.

The critical path manifolds and riser bases were completed two weeks ahead of the loadout schedule. This was attributable to the good efforts of a supplier and subcontractor with a proven track record and facilitated by the good working relationship and constructability review by the team.

![Figure 7: Subsea manifolds, riser bases and SDUs ready for loadout](image)

The subsea system design and architecture proved to have a reasonable amount of conservatism and flexibility to compensate for the unknowns and to absorb design changes and some minor fabrication issues. The system was installed and commissioned with no interface issues and relatively few problems. The lone significant problem encountered was a batch of 10 Electrical Flying Leads with incorrect twisted pairs which caused cross talk in the control system.

From a cost standpoint, the subsea system was delivered at six percent (6%) over the original budget. The Team incurred additional costs for inspection, service technicians, air freight, etc. to facilitate the schedule but the cost overrun was a direct result of the lack of design information at the beginning of the project. Although the team made a reasonable assumption on the metocean data, the strength of the currents through the water column offshore Ghana required the flexible risers and umbilicals to be tethered to the seafloor. The additional equipment required to accomplish this and the addition of a second water injection riser accounted for the increased subsea system cost.

Conclusions

The successful delivery of the Jubilee Subsea System demonstrates that large scale subsea systems can be delivered on a fast track schedule without compromising safety, quality or production flexibility, provided a complementary strategy is employed that limits or eliminates overly prescriptive and time-consuming processes that are often inherent in most companies. The Jubilee IPT administered a fit-for-purpose strategy of utilizing advantageous frame agreements and suppliers’ field proven technologies and their “off the shelf” solutions. The strategy included fostering a “Jubilee Team” mentality and empowering a design team of experienced
professionals to utilize their experience and engineering judgment to fill in the design data gaps and quickly establish a flexible subsea production system design.

The Subsea System Delivery Team maintained collaborative working relationships with suppliers, worked interfaces constantly and provided abundant inspection resources. As is usually the case with any major success, on time delivery of the Jubilee subsea production system can be attributed to the quality of all the personnel involved, both the team and the suppliers, who through dedication and personal commitment, accepted the challenge and delivered.