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TLP Design, Fabrication and Installation for GOM vs. South China Sea

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Abstract

Based on the need of the oil and gas market in having access to the reservoirs because of the world increment in the oil and gas demand and having much less easy access oil in onshore area, the oil companies have been forced to go to the offshore resources for more explorations. By passing decades from the beginning of offshore industry and depletion of reservoir in shallow waters, the companies need in going to deep water and chasing the oil in deep sea for achieving the hard access oil is emerged. Utilizing the floating structures in very deep sea water is only solution for this challenge. Among different type of floating structures, In this research we wanted to Compare, Contrast and Discuss the Design, Fabrication and Installation issues and consideration in Tension Leg Platform(TLP) structure in two different area of Golf of Mexico (Gom) and South China Sea.

Keywords: Floating structure; Tension Leg Platform; South China Sea; Golf of Mexico.

1. Introduction

Onshore reservoirs are so limited and many of them have been depleted from the time that they were discovered and exploited. The onshore reservoir which is the first generation of the reservoir exploration could be called as the easy access oil. After that easy access reservoir stage, the oil and gas companies tend to explore the offshore area, shallow water and started the first phase of the hard oil exploration. In this stage the industry needs more professional equipment, highly experienced contractors and experienced staffs. After a while, the oil and gas market based on their need entered the third stage which is the accessibility to the offshore, deep water reservoir with a very hard difficulty and complexity. In offshore deep water using the shallow water facilities such as fixed jacket and fixed platform is impossible because of the depth and the other drives of the area. Hence, the need of floating platforms is obvious and tangible.

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The floating platform could be solely for having the well or drilling facilities or the platform can accommodate more equipment such as production facilities, living quarters, storage areas, etc. Floating production has developed and improved to an almost full grown technology that open the new horizon for the companies to develop and invest on the oil and gas deep water reservoirs. Otherwise, it would be uneconomic and impossible to explore the new field for exploiting. By using the floating production platform technology, we are entitled to explore and produce far beyond the depth limitation of fixed platform. Normally the depth considered for fixed structure is 350m [1]. In area with deeper range, the offshore floating facilities enable us to find more flexible ways and solution for developing the short lived oil and gas field. It not only helps in deep water but also enables us to develop the remote locations field, in which using the fixed platform is impossible or so difficult. It has many positive side as mentioned, but on the other side, it had some limitation and challenges such as: demanding of the latest technologies, huge substructure and topside with the increasing payload of deep water, very specific and high quality and complex fabrication, very specific and special offshore installation equipment and procedure, because of the complexity of the structure, there would be a drastic increase in interface between the vendors because fulfilling the task would need a specific knowledge and experiences which each company has a part of it, and on top of all , more importantly, the lack of deep sea professional to employ.

This research would particularly focused on the comparison, contrast and discussion about the issues in design, fabrication and installation of Tension Leg Platforms(TLP) in two different area of the world. In Golf of Mexico with the huge experience and history of TLP utilising in offshore and the South China Sea which is so new to TLP industry and technology.

Tension leg platform (TLP) is one of the most broadly installed floating production systems (FPS) for the offshore deep sea oil and gas field development [1] . TLP is particularly suitable for water depths between 300 m and 1600 m, and has been in use since the early 1980s. The first TLP was built for Conoco’s Hutton Field in the North Sea in 1984. As of 2012, there are 24 TLPs installed worldwide ; 3 TLPs are under construction or installation, 6 under detailed or front end engineering design(FEED), and numerous under concept study. Among them, the shallowest TLP is Hutton TLP in depth of 147 m, which was in the North Sea and the deepest is Chevron-operated Extended Tension Leg Platform (ETLP), big foot TLP, which installed in the depth of 1615 m in Big Foot field in Gulf of Mexico [2].

TLP structure and parts normally includes of the below main components as depicted in Figure 1.

1) Topsides- production and processing facilities, drilling facilities, both dry and wet trees but that would be more beneficial to use just dry tree only, well bay in dry tree only, living quarters, helideck and utilities, deck structure and some other facilities.

2) Hull-marine system, ballast tanks, storage on hull, hull structure (columns and pontoons), which provides the positive buoyancy to the structure.

3) Tendon- tendon porches, tendon pipes, tendon foundations which could be driven pile or suction pile.

4) Riser- top tensioned risers-TTR- (production and/or drilling), but for export risers (steel or flexible), tieback risers (steel or flexible) could be used.

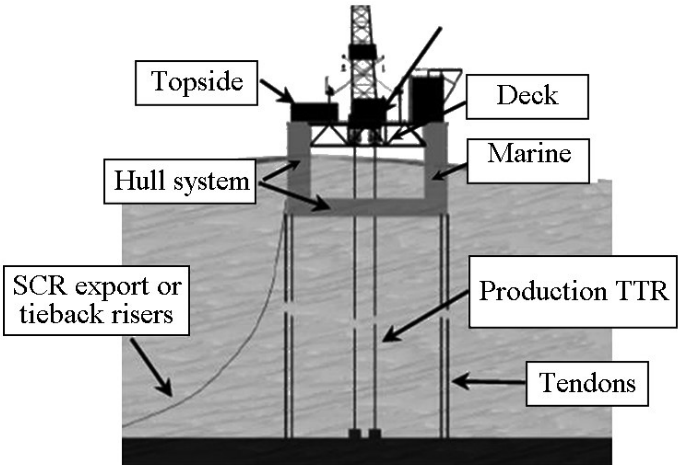

Figure 1: TLP Components [3]

Figure 2 shows the picture of the 24 installed TLPs which are installed till 2012 in oil and gas industry.

North Sea, where the first TLP has been installed, and Gulf of Mexico are the areas that most of the TLP projects have been executed in, but because of the merit and advantages of the TLP, in many other parts of the world put utilising of that under the intense scrutiny and work on the projects such as Brazil, West Africa, Asia (South China sea) and Australia. Most regions currently have TLP development projects on- going and under intense study [4].

Projects in different regions usually have their own project execution styles, but there are many common project experiences which could be applied to the projects in all regions. These common challenges include advanced technical requirements of design and analysis engineering, high fabrication requirements, challenging installation condition, complicate project interfaces, high demanding engineering management and project management, and short of competent professionals.

In this case study the first two TLPs in South China See would be compared, contrast and discussed in design, fabrication and installation with the TLPs in GOM.

China National Offshore Oil Corp. (CNOOC) awarded the Technip and China Offshore Oil Engineering Co. (COOEC) consortium a front-end engineering design (FEED) contract for two tension leg platforms (TLPs) for the Liuhua 11-1 and 16-2 joint development project located in the South China Sea [19].

Liuhua sits 240km southeast of Hong Kong, in about 370m water depth [19].

Technip will be responsible for the FEED work of China’s first two TLPs. The contract covers the design and engineering of the topsides (including two drilling rigs), hulls, mooring and riser systems. It is expected to be completed by the end of 2015. Technip's Houston operating centre will execute the FEED contract.

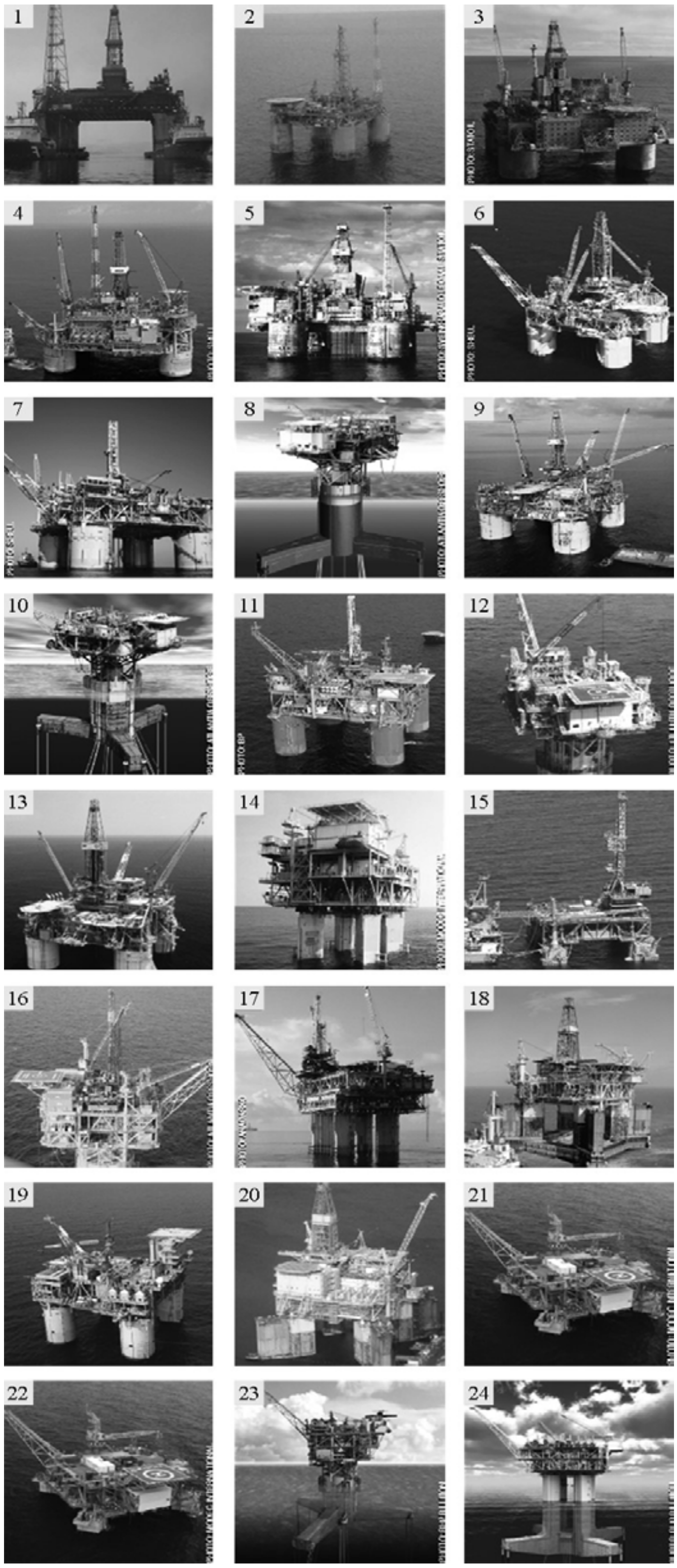

Figure 2: Installed TLPs [3]

Liuhua is described as the largest offshore field in production in China with in-place reserves estimated at 1 billion bbl of crude oil. CNOOC took over operatorship in 2003 from BP. The first discoveries on the field were in 1987 [19].

But the depth of the area in GOM, where the TLPs have been utilised is much deeper and this brings many challenges into account especially in design of the tendons.

2. TLP project technical challenges and engineering management

Most of TLP development projects have surface unit and subsea system. TLP structure is designed to host the dry tree on itself, to bring oil and gas to the surface， and subsea development system functions as controlling the wells (in case of wet tree) and transporting fluid. Early developments were mainly counting on the floating structures. Subsea development system is relatively new technology and has experienced significant advancement in recent years.

There are many factors affecting the execution of a TLP project. Technical issues are always the most important ones. The key technical issues include the correct definition of reservoir characteristics，selection of wet tree or dry tree，field arrangement，design of riser system，performance of the global system，fabrication engineering，and installation engineering. TLP is one of the two floaters which can support the dry tree production system. In comparison with the wet tree production system，dry tree system has the following advantages：

a. higher production reliability and lower downtime.

b. lower drilling and operating cost.

c. less flow assurance risk and potentially higher recovery.

d. direct vertical access for well intervention activities.

e. minimal offshore construction.

But there are challenges to the dry tree options too，such as safety concern due to well access at surface and stricter motion requirements for the host platform. Nevertheless the challenges，the superior dynamic performance and the ability to support dry tree production because of very small heave motion has historically been a main reason for choosing TLP production system.

The design of TLP is the state of art technology. There are only very few companies which have TLP design experience. TLP sizing is a design optimization process. It takes both the knowledge of floating structure and design experience. During design, each configuration considered the key objective is to minimize hull and mooring sizes for given payload, while meeting the following inter- related operational constraints：

a. minimum and maximum allowable effective tendon tension,

b. minimum air gap maintenance

c. horizontal offset

TLP hull structure provides not only the buoyancy for the entire system, but also the ballast for operation. It provides links between the production risers and topsides facilities. Hull structure takes wave loads acting on the system and is under fatigue influence all the time.

In design a tension leg platform a good knowledge of the motion behaviour and tether load is important, whereas its pitch, roll and heave responses are quite small relative to sway, surge and yaw responses. It was also noted that the survival conditions are critical to the safety of platform in heavy storm, different situations in heavy storm, different situations, including storm wave at the highest waves in 100 year return period in South China Seas and Gulf of Mexico.

One of the most important factors in the wave load which should apply on the modelled structure is the wave height. By comparing the significant wave height in the GOM and SCS we would realise that how significant the differences is. It is observed in both areas, GOM and SCS, the chance of hurricane and typhoon is so high, but the significant wave height in GOM is about 15m to 16m [6] whereas in SCS, the wave height with the same period of return (100 years) is around 2m [5]. In some cases by considering the hurricanes they increase and consider the wave height to 21 to 22m in the design phase [10]. This difference apparently shows that consequently the wave load on the substructure, tendons, risers and all appurtenances is much smaller in SCS.

The wave height is not only important for the wave load but also is a governing factor in designing and specifying the air gap space. Hence, it has a direct effect on the size of the hull of the TLPs. In the design process, the prediction of the free surface elevation is of great importance for the determination of the air gap. So far, the existing researches for predicting the air gap of the TLPs focus on the supporting columns while pay little attention to the horizontal pontoons. For the second order diffraction problem or long incident wave condition, the velocity potential decays slowly with water depth and the effect of pontoons should not be neglected. The diffraction of regular waves by a square array of truncated cylinders and a whole TLP structure is studied in detail by using both the linear and the second-order diffraction theory. Numerical calculation is performed for the free surface elevation and wave run up. Numerical results show that the near-trapping phenomenon can occur inside the TLP and leads to significantly increased wave height [7]. It is found that pontoons have an appreciable effect on the diffracted wave field for long incident regular waves and increase the largest response notably when the near-trapping phenomenon occurs at the second-order [7].

The environmental condition in South China Sea is not exactly the same as compared to other sea area, even though it is similar to Gulf of Mexico. The feasibility of TLP application in the development of oil and gas field in the South China Sea needs to be considered carefully because of the soliton (internal wave) condition in South China Sea, which is different from other areas such as Gulf of Mexico [11]. Top-Tensioned riser systems are a critical part of TLP system, so the feasibility of TTRs in South China Sea needs to be carefully addressed and paid enough attention to.

According to the previous experiences in South China Sea, Soliton is treated as a kind of current impacted on offshore structures, which should be combined with the storm associated current in some load cases [11].

Table 1: South China Sea significant wave height [5]

Table 1: Joint distribution of significant wave height and mean wave period for the same location (% of total time in an average year).

	Mean time, T_{mean} (s)							
H_s (m)	< = 2	2–4	4–6	6–8	8–10	10–12	12–14	> 14
< = 0.2	0.53	11.01	0.09	0.00	0.00	0.00	0.00	0.00
0.2–0.4	0.37	32.58	1.96	0.00	0.00	0.00	0.00	0.00
0.4–0.6	0.00	10.57	4.70	0.00	0.00	0.00	0.00	0.00
0.6–0.8	0.00	1.76	8.68	0.11	0.00	0.00	0.00	0.00
0.8–1.0	0.00	0.78	7.69	0.18	0.00	0.00	0.00	0.00
1.0–1.2	0.00	0.37	4.52	0.41	0.00	0.00	0.00	0.00
1.2–1.4	0.00	0.00	5.66	0.43	0.00	0.00	0.00	0.00
1.4–1.6	0.00	0.00	3.24	0.23	0.00	0.00	0.00	0.00
1.6–1.8	0.00	0.00	2.63	0.23	0.00	0.00	0.00	0.00
1.8–2.0	0.00	0.00	0.98	0.00	0.00	0.00	0.00	0.00
> 2.0	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00

Table 2: Gulf of Mexico significant wave height [6]

TABLE 2. Maximum recorded significant wave heights at NDBC stations (before 2005).

Northwest		Southwest		Alaska		Hawaii		Northeast	
Buoy no.	SWH (m)	Buoy no.	SWH (m)	Buoy no.	SWH (m)	Buoy no.	SWH (m)	Buoy no.	SWH (m)
46002	15.10	46011	9.20	46001	14.80	51001	12.3	44005	10.10
46005	13.60	46023	8.08	46003	16.90	51002	8.6	44007	7.30
46006	16.32	46025	8.00	46035	15.40	51003	6.85	44008	11.46
46012	9.69	46028	10.06	46060	4.34	51004	10.6	44011	12.00
46013	9.11	46047	7.75	46061	10.94	51028	3.6	44013	9.10
46014	10.30	46053	5.60	46066	12.96	51201	5.6	44018	8.58
46015	10.92	46054	8.64	46071	12.61	51202	4.1	44025	9.30
46022	12.00	46063	8.50	46072	12.49			44027	7.70
46026	7.95	46069	6.00	46075	9.96				
46027	10.00	46086	4.68	46078	10.95				
46041	10.34			46080	9.01				
46042	9.20			46081	2.38				
46050	14.05			46082	9.84				
46059	14.05			46083	12.17				
46087	7.55			46084	14.06				
46088	2.39								
46089	8.34								
46212	5.8								
46213	7.1								
Southeast (excluding Gulf of Mexico data, which are in Table 1)									
Buoy no.	SWH (m)	Buoy no.	SWH (m)	Buoy no.	SWH (m)	Buoy no.	SWH (m)	Buoy no.	SWH (m)
41001	10.90	41007	4.60	41013	4.96	44006	7.30	44019	8.90
41002	15.70	41008	5.84	41022	2.96	44009	7.70	44023	5.00
41003	4.20	41009	9.79	41023	1.26	44012	8.50	44026	4.70
41004	12.53	41010	9.93	41025	13.63	44014	9.20	chlv2	6.34
41005	5.10	41011	3.60	44001	7.80	44015	8.00		
41006	10.00	41012	6.20	44004	13.50	44017	5.91		

Solitons are solitary internal waves which exhibit remarkable coherence and permanence, and have strong associated currents. In the northern South China Sea, such waves are generated by tidal forcing at a shallow sill in the Luzon Strait. These solitons travel westward some 350 nautical miles to the Liuhua area, with transit times in the range of 2 to 4 days (mean celebrities of 3.5 to 7.5 knots). Sixty miles east of Liuhua they are refracted around Pratas (Dongsha) Island, creating a complex pattern of wave fronts [12].

The characteristics of solitons are governed by water depth and the vertical density structure of the ocean. A sudden disturbance of the normal density distribution, as at a tidal sill, leads to the formation of a group or packet of solitons. Packets have been observed in every month of the year. During some months, packets arrive at Liuhua about every 12 hours. There may be perhaps one to six in a packet, with the strongest one generally arriving first. Individual solitons measured at Liuhua have periods of 10 to 30 minutes [12].

Instantaneous profiles of horizontal currents in solitons at Liuhua look somewhat like the letter S, for a propagation direction toward the left. Commonly, they have leftward maximums of 50 to 150 cm/sec at a depth of 20 to 100 meters. Speeds at the sea surface are typically half of the maximum speed. Speeds reverse direction at about mid-depth. Below this point, they are toward the right and have a maximum about two-thirds that of the upper maximum, acting within 50 meters of the seafloor [12].

But in GOM based on observations, high-speed subsurface intensified currents, also known as jets, typically have temporal durations on the order of a few hours to one day, have subsurface speed maxima that can exceed 4 knots (200 cm/s), have peak speeds that occur between 150-350 m below the surface, and have little or no surface expressions. Offshore operators design drilling and production systems to account for forces exerted by currents at all depths; therefore frequency, persistence, and speed characteristics of jets are important design criteria [13]. The effect of the solitons on the riser design is so high and considerably important.

Fatigue design plays a very important role in TLP structure application. All major connection areas are governed by fatigue. Typically, these fatigue sensitive areas will use special materials, and have special welding requirements and profiles. These connection areas include topsides to hull connections, pontoon to column connection, tendon to hull connection, and steel catenary riser (SCR)/riser to hull connection. It should be brought into attention that the different salinity cause different corrosion speed ratio for the same material type in the sea water. It would be more hectic in the welding area and connections. Based on the report as reported and approved, the salinity in SCS is about (34.2-34.5 part per thousand) [8] and 35 part per thousand in GOM [9] . Both of them are classified as low salinity in the central water which is between 300m and 900m. With not a huge difference in those two areas we could use the same materials in constructing the substructure body or tendons.

Engineering management plays a very important role in floating system project. There are many failure projects initiated from poor engineering management. Engineering manager is the overall engineering lead of project and is responsible for all the design and analysis work of TLP. Since engineering is always the critical part of the TLP project, in order to execute a successful project, engineering manager needs to do well with the following :

a. watch over critical issues in all disciplines

b. coordinate technical interfaces within discipline

c. make sure the timely resolution on important discipline interfaces

d. help the technical compliance of vendors； e. perform site engineering and installation engineering support work

f. other duties as may be defined during the course of the project.

In regard of the engineering management both of the SCS and GOM are the same. Both of them are complicated and so hectic job and their complexity.

3. Project risk and issues

TLP Project is a highly integrated system work in all phases from design to installation. There are many disciplines and vendors participating in a TLP project phases because each single of them is specifically professional in one field or subject. It should be highly considered that the communications between these disciplines are critical to execute the project. In a typical TLP project the following maters can be identified in different stages of the project. Most of them as mentioned before are varying from one area to another. Each item would be specifically discussed if they have effect on any of the structural discipline in any stages of design, Fabrication and installation of the TLP project in GOM and SCS.

1) Geophysics & geology. Seismic surveys, processing and interpretation, log analysis, field mapping; hydrocarbon column analysis, oil/water and gas/oil contact determination. Subsea topography preparation is the another important one. It should be considered the topography preparation for the area that the TLP is supposed to be installed should be carefully provided. That is essential for foundation arrangement and better understanding of the seabed topography. In SCS one of the biggest issues is that the seabed surface is not flat or with gradual changes, it has much complexity in its topography which makes the job hard for the foundation installation and design [14].

After passing the shore and shallow region Large areas of the continental shelf in the Gulf of Mexico are relatively flat and pose no restrictions on infrastructure location [15]. This difference in the topography of the seabed dictate different methodology for the foundation type and installation methods.

2) Reservoir engineering. Well test interpretation, reservoir simulation, well profile, well production schedule.

3) Petroleum engineering. Production chemistry, completion design, tubing sizing， downhole measurements, field economics.

4) Filed layout. Well arrangement，pipeline layout, platform orientation.

5) Drilling engineering. Well design, drilling, costs, extended reach drilling limitation, drilling equipment， wellhead and tieback equipment.

6) Production operations. Process equipment selection and operation， maintenance practices, operating procedures.

7) TLP hull. Configuration, in-place analysis, pre-service requirements, metocean data and compatibility, tendon and foundation system, hull structure, import riser， export options.

8) Topsides. Production facilities design and manufacture, accommodation, deck structure design and weight, installation.

9) Subsea. Pipelines, control systems, subsea trees, installation, operating procedures.

10) Safety/environmental/QA. Hazop evaluation, safety/environmental programs, quality control, safety case.

11) Cost/purchasing/contracts. Economic evaluation, tender evaluation, contract preparation, expediting.

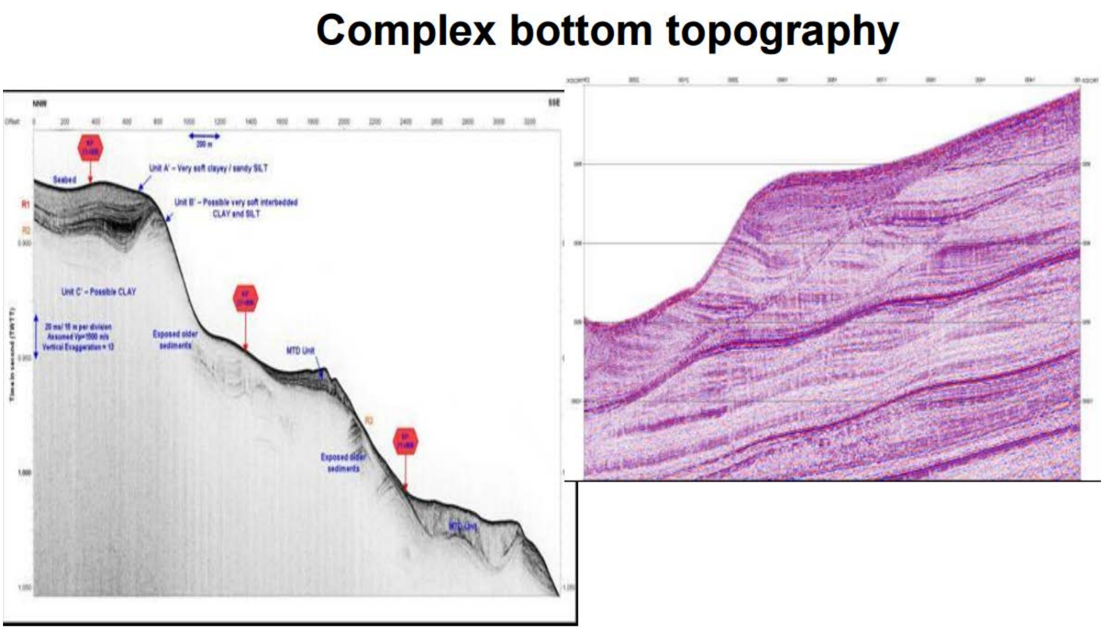

Figure 3: South China Sea complex bottom topography [14].

4. Fabrication and installation management

In bellow we would describe and explain more about the installation and fabrication issue in both area and compare them together.Due to the large scale and the involvement of many vendors, the management of fabrication and installation and associated interfaces of a TLP project is particularly challenging and hectic. The major components of fabrication activities involve the following：

a. hull fabrication

b. topside fabrication

Hull and topsides construction are usually on the critical pass. The fabrication design is site specific, taking into consideration the specific features of the shipyards. The topside and the hull are customarily fabricated in parallel in different yards. Normally, both the topside and the hull are modularized to fully utilize the yard capacity. The hull can be constructed either in a dry dock or on ground surfaces onshore equipped with appropriate tools；the latter is more frequent and easier for the TLP construction.

The full sized topside may consist of five modules：process，power，living quarters, well bay and drilling. If each module can be fabricated in covered location of the yard, the fabrication process is much less subject to weather condition such as hurricanes and typhoon than that in an outdoor operation which may get affected by the typhoon or the hurricanes and they can interrupt the activities constantly specially in winter for a long time.

As mentioned, one of the most important stages of the project is the fabrication phase. As many of the TLPs which are installed in GOM such as Mars and Ursa the hull construction and fabrication has been done in Taranto, Italy and some of them such as Mars B was fabricated in South Korea. The issue that is involved in this way of fabrication in these yards which are far away and constructed hulls and topside have to be transported across the Atlantic which has the harsh metocean environment. Hence, depends on what type of transportation the engineering team advised, either wet tow or dry tow, the structure should be designed to resist the loads which would encounter in the transportation process as well. This just put more load on the structure and make the structure heavier. On the other hand, for the first TLP which has done for South China Sea the fabrication yard is close and the structure will not be encountered with such a heavy environmental load. Hence, it does not need to be designed for the harsh metocean environmental load during the transportation and the risk of failure decrease dramatically.

c. mooring system fabrication and installation

The tendon mooring system as mentioned before has been used for TLPs. The tendons are the critical components to keep TLP's on station. The design of the tendons takes into account platform weight, payload, displacement, required pre-tension, water depth, and the metocean data [16].Tendon mooring system is another major component which their fabrication and installation is very hectic and critical. The tendons are long seam-welded tubulures joined together by girth welds. Tendon segments are joint together through threaded type intermediate connectors in other word entire tendon length contains several tendon segments，which is linked together offshore through tendon connectors. Tendon top and bottom connectors are all specially designed. Tendon bottom connector is installed into the pile connector offshore and locked in position with pretension. The top connector is mechanically designed for offshore installation. Flex element is provided at connection to allow the physical rotation between tendon and hull support. Due to the high fatigue requirements of the system，TLP structure fabrication has some unique features and needs special attention.

The material for the primary load path areas usually has high strength，high ductility and high sharp requirements. Good weldability and certain chemical contents limitation are also important. In this case there is not a huge difference in both area GOM and SCS. The only thing that makes a huge difference in tendon design between GOM and SCS is the depth. The depth of the TLP which are about to design, fabricate and installed is just about 350m whereas the TLPs in GOM mostly experience the very deep installation for example for Usra the depth is roughly about 4000 feet[20].

d. riser fabrication and installation

Top-Tensioned riser systems are a critical part of TLP system, so the feasibility of TTRs in South China Sea needs to be established. According to the previous experiences in South China Sea, Soliton is treated as a kind of current impacted on offshore structures, which should be combined with the storm associated current in some load cases [21].

The present studies and experiences show that a single casing riser system can be designed with adequate strength, sufficient fatigue life, seabed and reasonable wellbay layout that prevent clashing It is concluded that TTR system in South China Sea is feasible, which may not only benefit future study and design of TTRs, but also help accelerate the use of TLPs in South China Sea [21].

But in Golf of Mexico using the TTR for TLPs have a good and approved history.

e. subsea system fabrication,

f. load-out and integration of major components.

The major installations activities involve the following which we discussed some of them in fabrication segment:

a. transportation of platform and mooring system

b. installations of subsea system

c. driving pile foundation

d. installation of tendon，platform and riser.

In order to mitigate the commercial risk inherent in the long duration of the project execution，efforts are usually made to compress the construction schedule. Effective communication between the parties involved in the manufacturing process is essential to the success of the project，as the number of equipment suppliers could well reaches or exceed 50 [15]. Particularly，interfacing between the topside fabrication yard and the hull manufacturer is an intrinsic part of the fabrication process，as the topside will be mated to the hull.

As the offshore lifting process is more prone to adverse weather condition and costs significantly more, recent projects have come in favour of quayside or onshore integration. Taking the West Seno as an example, is designed to have the topside integrated with the hull on land, then loadout onto transportation barge. The requirement of suitable topside lifting equipment varies. The topside for a wet tree platform usually takes different shapes from a dry tree platform.

The quayside integration has its own pros and cons. In GOM most the TLPs have been installed by the quayside lift and mating the TLP with the topside, then wet towed to the final destination and just connect to the pretention leg which has been installed and is ready to be attached to the TLPs column. As an example, for the Mars TLP we had the installation of the foundation first which was driving the pile. The MARS foundation consists of 12 driven piles, one for each of the 12 tendons, which connect directly to the tendon with no foundation templates. A driveable connector was developed and tested; these were built into each pile [17]. Soil cyclic behaviour, relevant to tension pile design, was investigated in an extended series of laboratory tests. The piles were placed in 2940 feet water depth using acoustic positioning and driven to grade using a hydraulic hammer with an underwater power-pack [17].

Detailed installation engineering and preparations included model tests of the TLP and Balder while moored together and simulation of critical aspects of their positioning, including failure of mooring lines and positioning tugs [17].

The tendons were barged to location in 750 ton packages containing 12 segments, nominally 240 feet long each, which were lifted and secured to the deck of the SSCV Balder. The individual segments were stalked together in assembly towers over either side of the SSCV using pressure actuated mechanical connectors. After all 12 tendons were assembled and hung off on both sides of the vessel; the TLP was moored to the stem of the Balder using a combination of surface lines and an array of tugs for positioning control [18].

Fully assembled tendons were sequentially passed over slacked mooring lines and hung off on the TLP. Using special chain jacks, tendons were stabbed into their foundation pile receptacles with the assistance of ROV's, latched and tensioned to a balanced condition using a combination of chain jack stroke and ballasting.

Topside with a close- end dry tree centre well bay also differs from one with a dry tree open- end well bay as seen on the MOSES TLPs.

Considering the massive size of the TLP and the deepwater, early attention should be paid to the assembly and installation of TLP. This is necessary to attain schedule benefits from installation innovation and incorporate the installation- required modifications into the fast-trend construction process. The following activities are the highlight of what is normally required for a TLP offshore installation : pile installation, tendon guide cone installation, tendon installation, buoyancy can installation, TLP installation, and TTR/SCR/flow line installation.Early planning allows a more stringent review of all details.

Alternative approaches and innovative solutions can be reviewed, analysed and generally incorporated.

The planning needs to allow adequate time to level and optimize the use of various resources.

The advantage of this approach allows different scenario plans to be quickly developed and reviewed. The participation by the complete team allows all members to become familiar with the different needs and capabilities of each discipline. Early planning also affords the team the time to impact equipment delivery dates to improve the fabrication, integration and installation schedule. Minimal planning may be sufficient when things are going well, but be inadequate under different circumstances. Even perfect plans lose their value if not maintained as the environment or process changes.

5. South China Sea development TLP project

To keep up with the increasing demand for energy in the economic development，China is moving rapidly into deep-water now. South China Sea is very rich in oil and gas distribution，and has been called “the second GoM”. The TLP concept design has been undertaken as the first TLP project in China. It could pioneer deep-water platform project in China. There are many good examples of field developments and project histories around the world, which can be used in the development of China deep-water fields based on the similarity. Most of these developments have represented the current advanced industry technologies, and have a proven history of both technical viability and economic benefits. TLP concept is well developed and proven technology, and it also has many advantages. There are more than 30 TLPs around the world which have been installed or under construction/installation, or in detailed design. These projects have provided valuable insight and experiences. In order to efficiently develop SCS TLP project, in utilising the TLPs, there is an inevitable need to capture the lessons learnt from various executions of floating projects, utilizing the technologies accumulated in the advancement of TLP concept, and incorporating the experience from the same type of project. The following areas are particularly important and deserve special attention.

1) Technologies and expertise. Deep-water development is high-tech driving. The success of development is largely relying on the technologies and experienced technical experts who master the technologies. It’s very important to establish a competent team. This team should not only include experts in China, but also include experts internationally, especially people who have worked on TLP projects before. They could avoid huge problem and issues by utilising their experiences.

2) Project execution and expertise. Floating project execution is always international scale. It will involve many vendors around the world. To be effective and successfully executes the TLP project, the project management team needs to include experts from different areas who have extensive previous project experience, and can transfer the knowledge to help streamline the execution.

3) Fabrication and installation. The massive scale of TLP structure constitutes challenges to some of our current facilities and associated procedures.

Early planning and investigation is the key to overcome the weakness. Procedures need to be setup early, and be reviewed by all relevant parties, and investigation is to be done with the planned equipment. In some cases, early studies will be needed for verifying the applicability and improvement of the equipment. For the case of insufficient equipment, either modification needs to be performed or outsourcing to be planned. The risk associated with operation needs to be fully assessed. The difficulty of some special requirements for TLP projects needs to be fully understood.

Some of the areas include high welding requirement, fabrication sequence planning, tight dimension control, non- destructive evaluation requirement, stringent weight control accuracy loadout and offshore installation.

4) Schedule planning. Detailed planning needs to be conducted at the beginning of the project, kept monitored and updated during the whole implementation duration. Issues which are emerging needs to be addressed and resolved at their early stage. If issues are caught up in the early stage of the project, it will be easier to find ways to remedy the problem, and the cost would be much less. Due to the fast track nature for deepwater projects, schedule is always very tight. To plan the TLP project, it would be wise to leave some floating range for potential needs, at least for the tasks on critical pass.

5) Risk management. A through risk analysis needs to be performed to identify any potential problems. Risk plan needs to be in-place before the project starts. For the identified major risks, a mitigation plan will need to be formed. At some critical cases, if the risk can't be reduced to the acceptable level, a backup plan will be implemented.

6. Summary

All in all, based on the need of the market and workability of the TLPs among many other floating production facilities, in all around the world they tend to start using the TLPs. That is not a new case for the deep sea of the GOM, and it has a great record in there. On the other hand this technology is so new for the South China Sea, but based on the need of the area and the feasibility has done for TLP utilisation, they got a good outcome from that.

There are some similarities and differences in different stages of the TLP, from design to installation and commissioning in these two areas, GOM and SCS. Differences as mentioned in detail such as wave height, current speed, presence of soliton, etc makes some huge differences in design. Based on the site specification and requirement for the fabrication, most of the GOM TLPs built in the other areas such as Italy, Korea, and then transport across the ocean to near the last destination then have been mated with the substructure and towed to the place which had their installed tendon waiting for them to installed on. One of the other differences in TLP installation process is that the topography of the SCS shows dramatic change in the elevation which brings forth the different tendon height or the TLP which gives more complexity to the project.

On the other hand, in GOM the most of the provided topography for the areas which have TLP on themselves are uniform and somehow even.

7. Recommendation

Because of the lack of the experience and record of utilising the TLPs in South China Sea, it is recommended to use the Gulf of Mexico experiences and records with considering the reasonable safety margins for all phases, design, Fabrication, transportation and installation. The safety margins should include all the factors such as environmental and metocean loading differences, fabrications among others.

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