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Floating Production Platforms and their Applications in the Development of Oil and Gas Fields in the South China Sea

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Abstract: This paper studies the current available options for floating production platforms in developing deepwater oil fields and the potential development models of future oil and gas exploration in the South China Sea. A detailed review of current deepwater platforms worldwide was performed through the examples of industry projects, and the pros and cons of each platform are discussed. Four types of platforms are currently used for the deepwater development: tension leg platform, Spar, semi-submersible platform, and the floating production system offloading. Among these, the TLP and Spar can be used for dry tree applications, and have gained popularity in recent years. The dry tree application enables the extension of the drilling application for fixed platforms into floating systems, and greatly reduces the cost and complexity of the subsea operation. Newly built wet tree semi-submersible production platforms for ultra deepwater are also getting their application, mainly due to the much needed payload for deepwater making the conversion of the old drilling semi-submersible platforms impossible. These platforms have been used in different fields around the world for different environments; each has its own advantages and disadvantages. There are many challenges with the successful use of these floating platforms. A lot of lessons have been learned and extensive experience accumulated through the many project applications. Key technologies are being reviewed for the successful use of floating platforms for field development, and potential future development needs are being discussed. Some of the technologies and experience of platform applications can be well used for the development of the South China Sea oil and gas field.
Keywords: floating platform; deepwater development; oil field development; deepwater technology; platform host

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1 Introduction

Deepwater development activities have now become worldwide.The industry of oil and gas exploration and production worldwide has gone through tremendous developments in the last several decades as the benefits of rapidly developing and implementing new technologies become apparent. Floating systems are now becoming the leading tools for expanding the production of offshore oil and gas fields. Most future increases will come from floating production systems. These floating systems range from a water depth of several hundreds of meters to several thousands of meters. Different types of floating systems have to fit into this wide spectrum of water depth.

Floater types might be distinguished by several characteristics such as functions, stability, motions, load or volume capacities, transportability, and reusability. Currently, there are four major types of floating production systems, i.e. tension leg platform (TLP), spar platform, semi-submersible platform, and FPSO(Geyer *et al*., 2009; Zhang, 2006). Each of these floater designs have been evolving along with the subsea and riser technology to meet new field development challenges mainly related to increased water depth and reservoir operating pressures and temperatures. Design improvements continue as new developments in offshore technology are incorporated into the basic designs. Efficient design of floating structures is predicated on functionality and performance – it should be capable of supporting all the necessary equipment for production and related tasks while meeting all performance criteria. The structure should provide sufficient space and robustness to fulfill its intended purpose; also, the floating structure should be built at a minimum of cost, which is governed mainly by the hull steel weight.

China has more than 40 years of near shore development history in the oil and gas fields industry. Several successful models have been established and used in oil and gas field developments. These models include two major categories distinguished by how the oil and gas are processed. The first category is concerned with how the fields are developed with both exploration and production carried out with the facilities in offshore water; the second category includes fields with production carried out using facilities on land, while exploration is performed in offshore water.

Entering the twenty first century, oil field development offshore of China is rapidly expanding into deepwater. The conventional fixed platform models cannot satisfy the requirements of the new field developments. Floating systems, such as the tension leg platform (TLP) or Spar, will be needed to be introduced into the oil field development. Since the early 1990's, considerable interest has been expressed for concepts where the wellheads are elevated

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above sea level by means of a separate structure. In this way, dry access to the wellheads is provided and well-proven technology can be utilized to bring the wellstreams to the surface.

2 Offshore floating platforms

The current most commonly used platforms in the oil and gas industry include four types: FPSO, Semi-submersible, TLP, and Spar. Each has a significant difference in terms of design drivers, performance, construction and installation. FPSOs have a relatively shallow draft, but a large water-plane area. They provide a large area for process facilities, and large storage volumes. Semi-submersibles/TLP have a small water-plane area and moderate draft. Spars have a very deep draft and moderate to small water-plane area. As illustrated in Figure 1, the relative hull responses of the three designs vary considerably. In all cases the objective is to minimize the response to the environment.

2.1 Tension leg platform

Tension Leg Platforms have been used exclusively as the production and drilling platforms(Rainey *et al*., 2002; Wetch *et al*., 2004). TLPs consist of columns and pontoons. The unique feature of the TLP is its mooring system, which consists of vertical tendons, restraining the heave motion. The foundation is the link between the seafloor and the TLP. The foundation is secured by steel piles driven into the seafloor by use of a hydraulic hammer, but other designs can be used such as a gravity foundation. The foundations are built onshore and installed on site. The hull is a buoyant structure that supports the deck section of the platform and its drilling and production equipment. A typical hull has four air-filled columns supported by pontoons. The deck for the surface facilities rests on the hull. The buoyancy of the hull exceeds the weight of the platform, requiring taut moorings or "tension legs" to secure the structure to the seafloor. Tension legs (tendons) are tubulars that secure the hull to the foundation; this is the mooring system for the TLP. Tendons are typically steel tubes with dimensions of 2-3.5 ft in diameter with up to 1.7 inches of wall thickness, with the length depending on water depth. A typical TLP would be installed with 8, 12 or 16 tendons. A production riser conveys produced fluids from the well to the TLP surface production facilities. An example riser system for a TLP could be either a single-bore or dual-bore (concentric pipe) arrangement. Figure 2 shows the major components of a typical TLP.

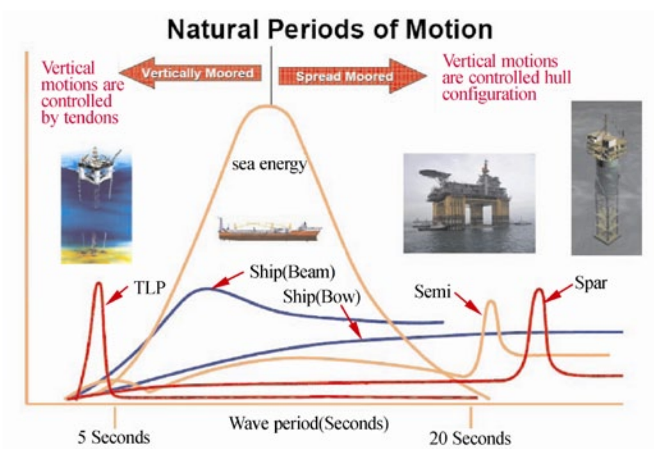

Fig.1 Heave responses in waves

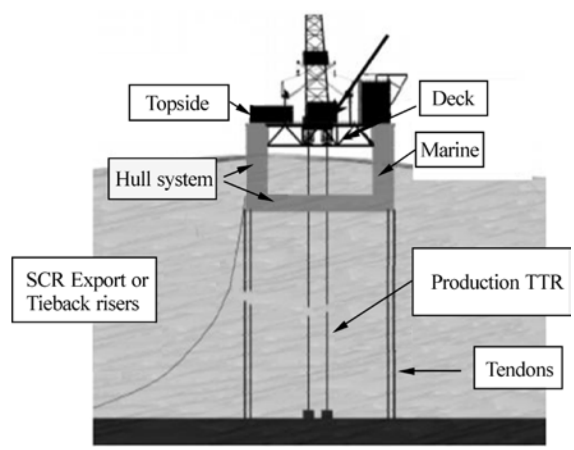

Fig. 2 Tension leg platform components

The main function of the TLP is to assure that the vertical forces acting on the platform are in balance. The VCG should be close to the platform's geometrical center. Positive displacement is obtained by locking the platform's draft below the fixed and variable payload displacement draft. This will result in an upward force applied to the tendons, thereby keeping them in constant tension. As a consequence the vertical platform motions (heave) are almost eliminated, except for the motions resulting from tendon elasticity and vertical motions as a result of environmentally introduced lateral platform motions. The tendons do allow a lateral motion of the platform as a result of wind, waves and current. The tendon tension is set within predefined values, or windows of operation. If the variable load of the platform exceeds these values by adding risers or drilling loads etc., the tendon pretension is adjusted by re-ballasting of the platform. Consequently the hull is compartmented into voids, machinery and ballast spaces. The TLP has a control system monitoring the ballast and VCG. Seawater is used for ballast adjustment.

There are three different TLP types according to the configuration -- the classic TLP, MOSES TLP and ETLP. From 1984, a total of 24 TLP platforms have been installed and put into operation around the world(16 TLPs in GOM, 3 TLPs in Europe, 4 TLPs in West Africa, 1 TLP in Asia), and three more TLPs - BigFoot TLP, Olympus, and Papa Terra will be installed in the near term future.

2.2 Semi-submersible

A semi-submersible is used in offshore drilling and oil production platforms. They are designed with good stability and seakeeping characteristics. Semi units offer a number of benefits, including large payload capacity, limited sensitivity to water depth, quayside integration and the ability to relocate after field abandonment (Luyties and Na, 2004).

A typical Semi design has four columns connected at the bottom by pontoons with a nominally rectangular cross-section. A semi-submersible obtains its buoyancy from ballasted, watertight pontoons located below the ocean surface and wave action. The operating deck can be located high above the sea level due to the good stability of the design, and therefore the operating deck is kept well away from the waves. Structural columns connect the pontoons and operating deck. With its hull structure submerged at a deep draft, the semi-submersible is less affected by wave loadings than a normal ship. With a small water-plane area, however, the semi-submersible is sensitive to load changes, and therefore must be carefully trimmed to maintain stability.

Important design variables are column dimensions and spacing, pontoon size and the ratio of pontoon width to pontoon height, draft of the hull, *etc*. In order to satisfy the stability and motion requirements, ranges for the variables and critical parameters such as the GM value, free board value, heave natural periods, etc. are set as the constraints. Columns are sized to provide adequate water-plane area to support all anticipated loading conditions, spaced to support topside modules, and tuned for a natural period of at least 20 seconds. These columns are supported by two parallel pontoons or a ring pontoon. Pontoons are sized to provide adequate buoyancy to support all weights and vertical loads, and proportioned to maximize heave damping.

As the oil industry has progressed into deeper water and harsher environments, purpose-built production semi-submersible platforms have been designed. The first purpose-built semi-submersible production platform was for the Balmoral field, in the North Sea near the UK in 1986. In the year 2007, the deepest Semi FPU - Independence Hub was installed in GOM where the water depth is 2415 m. Up until to 2013, more than 50 Semis have been put into operation around the world, and a new Semi, Jack/St. Malo, will be installed in 2014 located in GOM with a water depth of 2134 m. There is also a Semi FPU for China's South Sea LH11-1 oil and gas field – Nan Hai Tiao Zhan, which has been in operation since 1995.

2.3 Spar

A Spar is a type of floating oil platform typically used in very deep waters, and is named for logs used as buoys in shipping that are moored in place vertically. Spar production platforms have been developed as an alternative to conventional platforms.

A Spar platform consists of a large-diameter, single vertical cylinder supporting a deck. The cylinder is weighted at the bottom by a chamber filled with a material that is much denser than water to lower the center of gravity of the platform and to provide stability. Spars are anchored to the seabed by way of a spread mooring system with either a chain-wire-chain or chain-polyester-chain composition.

The basic parts of the Spar include a topsides deck, hard tank, midsection, and soft tank (Fig. 3). The topsides deck is typically a multi-level structure in order to minimize the cantilever requirement. The hard tank provides the buoyancy to support the topsides deck, hull, ballast and vertical tensions (except the risers). The term "Hard Tank" means that its compartments are designed to withstand the full hydrostatic pressure. The midsection extends below the hard tank to give the Spar its deep draft. The soft tank at the bottom of the Spar is designed to provide floatation during the installation stages when the Spar is floating horizontally and it also provides compartments for the placement of fixed ballast once the Spar is upended.

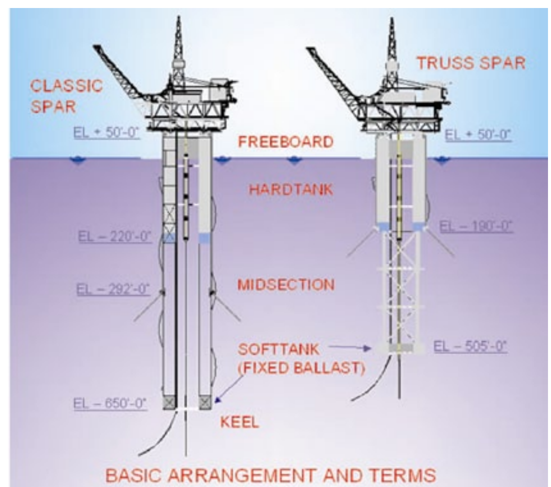

Fig.3 The basic parts of Spar

There are three primary types of Spars: the classic Spar, truss Spar, and cell Spar. The classic Spar consists of the cylindrical hull noted above, with the heavy ballast at the bottom of the cylinder.The next rendition of the Spar was the truss Spar, which is similar to the original spar design, but the cylindrical hull is shortened and a truss is incorporated below it. The truss usually includes horizontal plates that help to decrease vertical movement. The truss Spar is advantageous because it weighs less than the original design, and because it requires less steel, which costs less. The majority of spars are of this type.

Spars are often considered along with TLPs for dry tree solutions because they offer small vertical motion. However, Spars are different from both Semis and TLPs in the mechanism of motion control. One of the distinctions of the Spar is that its center of gravity is always lower than the center of buoyancy which guarantees a positive GM. This makes the Spar unconditionally stable. The Spar derives no stability from its mooring system, so it does not list or capsize even when completely disconnected from its mooring. The deep draft is a favorable attribute for minimal heave motions, its deep draft and large inertia filter wave frequency motions in all but the largest of storms. The natural period of heave and pitch are above the range of wave energy periods. The deep draft, along with the protected centerwell, significantly reduces the current and wave loading on the riser system. The first Spar designed for oil and gas production was the Neptune Spar, located in the Gulf of Mexico and was installed in September 1996 by Kerr McGee(nowAnadarko).The world's deepest production platform is Perdido, a truss Spar in the Gulf of Mexico, with a mean water depth of 2,383 meters. It is operated by Royal Dutch Shell and was built at a cost of $3 billion. Currently, there are already 18 spars in production worldwide, and 2 more SPARs will be installed in 2014.

2.4 FPSO

A floating production, storage and offloading (FPSO) unit is a floating vessel used by the offshore oil and gas industry for the processing of hydrocarbons and for storage of oil. FPSOs are generally ship shaped floaters with provisions for storing and offloading of oil simultaneously (See Fig. 4). FPSOs may be designed to weathervane so that they always face towards the weather, minimizing roll and heave motions. In benign environments such as West Africa and South East Asia, the FPSO may be spread moored to face one direction at all times. Some FPSOs in Brazil have been designed to semi-weathervane by using a spread mooring with slack aft moorings, giving the vessel the option of some limited weathervaning (Kaster *et al*., 1997).

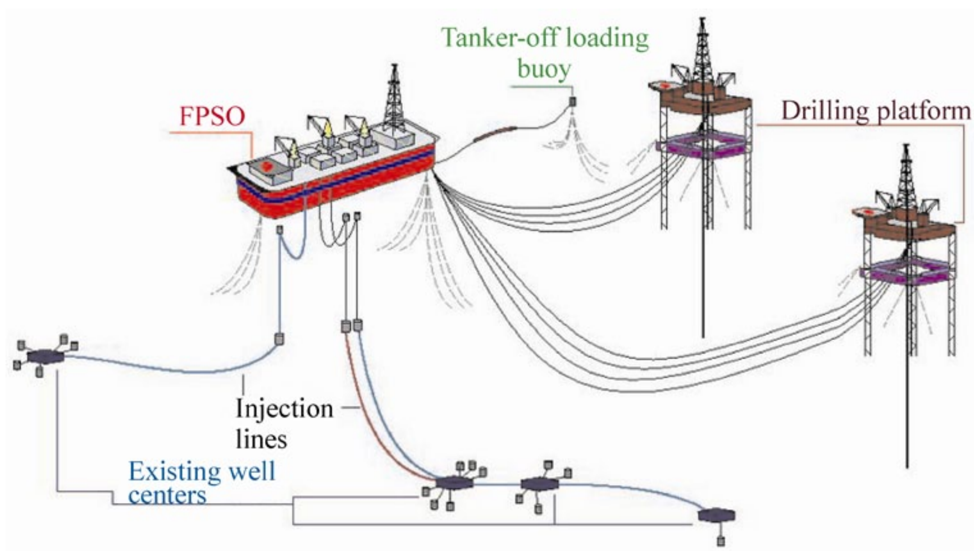

Fig. 4 FPSO diagram

An FPSO vessel is designed to receive hydrocarbons produced from nearby platforms or subsea templates, to process them, and store oil until it can be offloaded onto a tanker or, less frequently, transported through a pipeline. FPSOs are preferred in frontier offshore regions because they are easy to install, and do not require a local pipeline infrastructure to export oil. FPSOs can be a conversion of an oil tanker or can be a vessel built specially for the application.

Oil produced from offshore production platforms can be transported to the mainland either by pipeline or by tanker. When a tanker is chosen to transport the oil, it is necessary to accumulate oil in some form of storage tank such that the oil tanker is not continuously occupied during oil production, and is only needed once sufficient oil has been produced to fill the tanker. At this point the transport tanker connects to the stern of the storage unit and offloads oil.

Floating production, storage and offloading vessels are particularly effective in remote or deep water locations where seabed pipelines are not cost effective. FPSOs eliminate the need to lay expensive long-distance pipelines from the processing facility to an onshore terminal. This can provide an economically attractive solution for smaller oil fields which can be exhausted in a few years and do not justify the expense of installing a pipeline. Furthermore, once the field is depleted, the FPSO can be moved to a new location. FPSO's have been used to develop offshore fields around the world since the late 1970's. They have been used predominately in the North Sea, Brazil, Southeast Asian/South China Seas, the Mediterranean Sea, Australia, and off the West Coast of Africa. The first oil FPSO was the Shell Castellon, built in Spain in 1977. Today, over 200 vessels are deployed worldwide as oil FPSOs.

The world's largest FPSO is the Kizomba A, it has a storage capacity of 2.2 million barrels. Built at a cost of over US$800 million by Hyundai Heavy Industries in Ulsan, Korea, it is operated by Esso Exploration Angola (ExxonMobil). Located in 1,200 meters (4,000 ft) of water at Deepwater block, 150 statute miles (320 km) offshore in the Atlantic Ocean from Angola, West Africa It displaces 81,000 tons and is 285 meters long, 63 meters beam, and 32 meters high (935 ft by 207 ft by 105 ft).The FPSO operating in the deepest waters is the FPSO BW Pioneer, built and operated by BW Offshore on behalf of Petrobras Americas

INC. The FPSO is moored at a depth of 2,600 m in the US Gulf of Mexico.

Table 1 is a summary of these four types of platforms. It compares the applicability, functionality, flexibility, and installability.

Table 1 Comparison of primary characteristics

Issue	TLP	Spar	Semi	FPSO
Water Depth	More Sensitive	Less sensitive		
Platform Motions	Excellent – Very low vertical motions, i.e. heave, roll and pitch	Good – Low vertical motions (pitch to 8 - 10 deg). Sensitive to long period waves.	Motions limit application to wet trees	Motions limit application to wet trees
Transport	Single piece complete	Single piece hull	Single piece complete	Single piece complete
Installation	Quayside deck lift and integration	Hull upending and offshore deck lift and integration	Quayside deck lift and integration	Shipyard module lift and integration
Mooring System	Vertical tendons	Taut or semi-taut spread mooring legs		Spread catenary or turret moored
Mooring Footprint	Small and compact, same dimensional order as hull	Large, approximately 2X water depth. Impacts field development layout, but allows drilling flexibility.		
TTR Support	Short stroke tensioners	Air cans or long stroke tensioners	N/A	N/A
Wellbay	Conventional, within columns	Confined within moonpool	N/A	N/A
Storage Capability	No	Yes, but not typical	No	Yes, typical

2.5 Dry tree application v.s. wet tree

Offshore floating production technology has evolved since the 1970s to support development of oil and gas reservoirs beneath sea floors beyond reach of fixed platforms. Among the four popular floating production platform types, Tension Leg Platforms, along with Spars, have been proven to be capable of supporting both dry tree and wet tree productions. The applications of the other two types of popular platforms, the FPSO and Semi-submersible, have so far been normally limited to wet tree productions.

In comparison to the wet tree production system, the dry tree system has the following advantages:

- Higher production reliability and lower downtime
- Lower drilling and operating costs
- Less flow assurance risk and potentially higher recovery
- Direct vertical access for well intervention activities
- Minimal offshore construction
- Ability of extending the fixed platform drilling rig to floaters with minimum modifications.

Although there are challenges, the ability to support dry tree production has historically been a main reason for choosing this type of production system. For example, among the 24 installed TLPs, 19 are dry tree systems, and the maximum number of production risers is 36 for the Kizomba A TLP. The ultimate commercial viability of the selected production concept lies in strategic planning which strikes a balance between capital expenditures, the size, geometry, complexity and uncertainty of reservoirs and well performance requirements.

2.6 Platform safety

Due to its nature, safety is always the number one concern for offshore facilities. Commercial deep-water operation involves highly complex and risky procedures. The Macondo incidents have shown this again. Companies must coordinate the operations of sophisticated equipment to construct wells in uncertain geologic formations, often under challenging environmental conditions. Despite the impressive capabilities of the technologies, the selection and application of technologies for constructing a particular well are subject to the unpredictability of human decision making, as they were in the case of drilling the Macondo well in the Gulf of Mexico. The well blowout and subsequent explosions and fire on the *Deepwater Horizon* drilling rig on April 20, 2010, led to the deaths of 11 workers and at least a dozen serious injuries. It is estimated that nearly 5 million barrels of hydrocarbons were released into the gulf over a period of nearly three months after the blowout (McNutt *et al*., 2011).

The FPSO has large motion characteristics. It may be designed as a spread mooring type or weathervane type. The weathervane type of FPSO always faces towards the weather, minimizing roll and heave motions. For the new design FPSOs, there are trends toward the spread mooring type. Due to its large motion, the most encountered problem for the FPSO is the mooring system maintenance.

Semi-Submersible platforms also have large motions. A lot of effort has been put toward the deep draft Semi to reduce the motion of the platforms. There are quite a few incidents with Semi-Submersible platforms, including: the sinking of the P36 Semi-Submersible platform (later replaced with a new one); the sinking of the Kielland platform; the collapse of the Deepwater Horizon platform; the tilting and water flooding of the Thunder Horse platform; as well as many mooring lines broken on several platforms during hurricanes in the GoM in 2005, one even drifted a long distance to hit a bridge foundation.

The incidents involving Spar platforms are mainly related to moonpool and mooring lines. The Genesis probably has had the most number of incidents among the Spars. The incidents involving the Spar include: Genesis Spar multiple tanks leaking at several different times; mooring line failures in several Spars including the Genesis, Kikeh, Devil's Tower, etc.; rigs falling off the Medusa Spar and Devil's Tower Spar.

The TLP platforms have had two incidents during their use, while one of these was for the SeaStar TLP. The SeaStar TLP is very different from the other TLPs, and has had its shortcomings from the beginning. Just as the Spar has one column and the TTR runs through the center of the column, the SeaStar TLP also has only one column with the TTR running through the center of the column. All other TLPs have 4 columns with the TTRs staying between the columns. For the four column TLPs, the Shell Mars TLP (designed very earlier in 1993) is the only one which had its rig fall of the platform during an extreme hurricane. The other TLPs have had only very minor issues during storms.

The motions of the platforms do contribute to the platform safety, so does other factors. Due to its large implication of any failure, the safety design of the structure is always a dominant consideration, and attracts more attention from the industry. The regulatory requirements for the industry will become more stringent.

3 Deepwater field developments

There are many different approaches to develop deepwater oil and gas fields. Most of the development models will have surface units and subsea systems. The surface floating structure is designed to bring oil and gas to the surface; and the subsea development system functions for controlling the wells and gathering fluid to send. The subsea development system is relatively new technology and experienced significant advancement in recent years. Early developments were mainly counting on floating structures. With the advancement of technology, especially the subsea technology revolution, a current floating platform can function at a much larger capacity for field development, up to the capacity of four times that of the old platforms.

There are many factors affecting the approach and efficiency of field development, including reservoir characteristics, drilling capability, wet tree or dry tree options, storage and export options, riser system feasibility, operational performance, re-deployment, regulatory issues, fabrication facilities, transportation and installation, technology and execution risks, development costs (CAPEX), and operation costs (OPEX). Some of these can be essential to concept selection. One example will be with an area that lacks exporting pipelines, the FPSO has to be used as part of the field development system. We will discuss several major critical factors and options affecting field development in the following paragraphs.

The first option is the selection of dry tree vs. wet tree. There are typically four types of floaters used for deepwater fields, the TLP, Spar, Production Semi, and FPSO. Among them, the FPSO was the earliest floater used for development, and had been mostly converted from large ships such as the VLCC, etc. Newly built FPSOs have recently become popular due to the higher requirements and larger payload for deepwater. The TLP and Spar represent relatively new technology, and are the only two floating platforms which can be used for dry tree purposes. The major differences between the dry tree and the wet tree is that the BOP for the dry tree can be operated on the platform, similar to the conventional operation; while the wet tree BOP has to stay under water at the well head. The wet tree BOP is much larger and usually requires a large vessel for operation.

The second option is the export requirement, i.e. how the oil and gas are exported. Typically there are two ways used: through pipelines exporting onshore, or through the FPSO shipped to destination. This will largely be decided by the facility present, especially the pipeline. Building a pipeline system can be very expensive, and could add too much burden for one single project. In some areas it is not even feasible. In these cases, the FPSO is the only option.

The third option is to choose to develop the field in one phase or in multiple phases. This mainly applies to very large fields with spread wells or several adjacent fields. The choices made could greatly affect the costs.

4 Applications in the South China Sea

Entering the twenty first century, the oil and gas field development in offshore China was gradually expanding into deepwater. The increase of water depth has brought many new challenges to the industry. At this transitional phase, many existing technologies need to be upgraded for the new field conditions, and new technologies need to be brought in, such as floaters (TLP, Spar, Production Semi), deepwater subsea production systems, *etc*. There are many good examples of field developments and project histories around the world, which can be used for the development of China's deepwater oil fields. Most of these field developments have represented the current advanced industry technologies, and have a proven record of both technical viability and economic benefits.

The dry tree concept is a major breakthrough for deepwater development. It enables the similar well operations by placing the BOP on the deck of the deepwater platforms as conventional shallow water operations. The

TLP and Spar are the only two types of platforms which support the dry tree operation currently. Though there has been tremendous effort to make the semi dry tree more user friendly, the actual use of this type of new concept still has a way to go. The TLP, due to its maturity and superior response performance, should be easily adapted to the South China Sea environment and has the most promising future. As the exploration moves into ultra deepwater, the use of TLP may be limited. Production semi should play an important role. In the following content, we are going to discuss several potential development concepts and models which show promise for China's future deepwater development.

4.1 Field development with the FPSO, subsea system and shuttle tanker

This type of development has been the main approach for China's offshore field development, and will continue to be used. With increasing water depths, the use of this model will show certain limitations.

4.2 Deepwater field development with the TLP host and subsea system

The TLP structure has some advantages which can really contribute to China's deepwater development. It can support drilling rigs, and provide the dry tree operation. This can reduce the dependence on drilling ships for drilling/workover operations, reduce downtime, and reduce operation costs. There are several variations of the development models depending on the location of the field and the characteristics of the reservoir, including:TLP + subsea system + export pipelines for oil and/or gas fields close to shore

TLP + subsea system + FPSO for oil fields far from shore

TLP + subsea system + FLNG for gas fields far from shore

This is a proven technology in the field development and has been used in oil fields worldwide. In this system, the TLP functions as the main structure, providing the hub for drilling, production, future tie-back, etc. The reach of such development can be up to 100 km from the platform depending on the natural resource.

4.3 Field development with a combined system of floater and fixed platforms

The shelf area is the transition from going to deepwater, and has unique characteristics for oil and gas field development. With China's deepwater development, we may encounter quite a few fields in this category. Using TLP combined with fixed platforms can provide a good option for exploring both deepwater and offshore marginal fields. This approach can have several advantages.TLP can provide a host for both drilling and production dry trees. The fixed platforms can function as shallow water exploration and provide production facilities for processing oil and gas from all platforms. The produced oil and gas can be transported through pipelines to the facility onshore. This will greatly reduce the payload on the TLP and fully utilize our experience with the fixed platform design. Fig. 5 shows the Okume complex development, and is a good example of this approach(Simmon *et al*., 2005).

4.4 Application of TAD in field development

TLP with the Tender Assisted Drilling system has significantly reduced the payload of the platform and substantially decreased the investment in the floating system. This opens the door for many new deepwater field developments to use the floating system. One of the applications for a floater with the tender assisted drilling system can be for the development of the offshore marginal field. Due to increasesin water depth, the conventional fixed platform model for exploration of these fields becomes uneconomical. It also would be too expensive to use large scale floaters for these marginal fields due to the high initial investment. The floating system with tender assisted drilling can be used in order to economically develop these fields. There are many marginal fields offshore of China, especially in the shelf areas. The application of this field development model, combined with the existing field development experience in China, will open the door for many marginal field developments.

Successful execution of tender assisted drilling requires attention to various issues throughout the project from concept selection to detailed design. These factors include the overall field layout, metocean criteria, operation requirements, and applicable design requirements. Field architecture of the system is a prime concern of the design. For a tender assisted drilling system, the tension leg platform and tender vessel will be linked through a umbilical system, accessing the bridge, and hawsers. The time domain dynamic analysis is typically needed to solve the relative motion of the system under different environmental conditions.

4.5 Multi-phases field development

Large field development should take advantage of the advancement of technologies with floating systems and a subsea system, and use field development techniques that have improved in recent years. Using multiple platforms as an integrated system to develop the field has gained popularity due to its economics, operability, and flexibility. Fig. 6 shows the current on-going project, Browse LNG using two phases to develop a large gas field. The first phase includes two TLPs and production platforms. The second phase has one TLP with a subsea system.

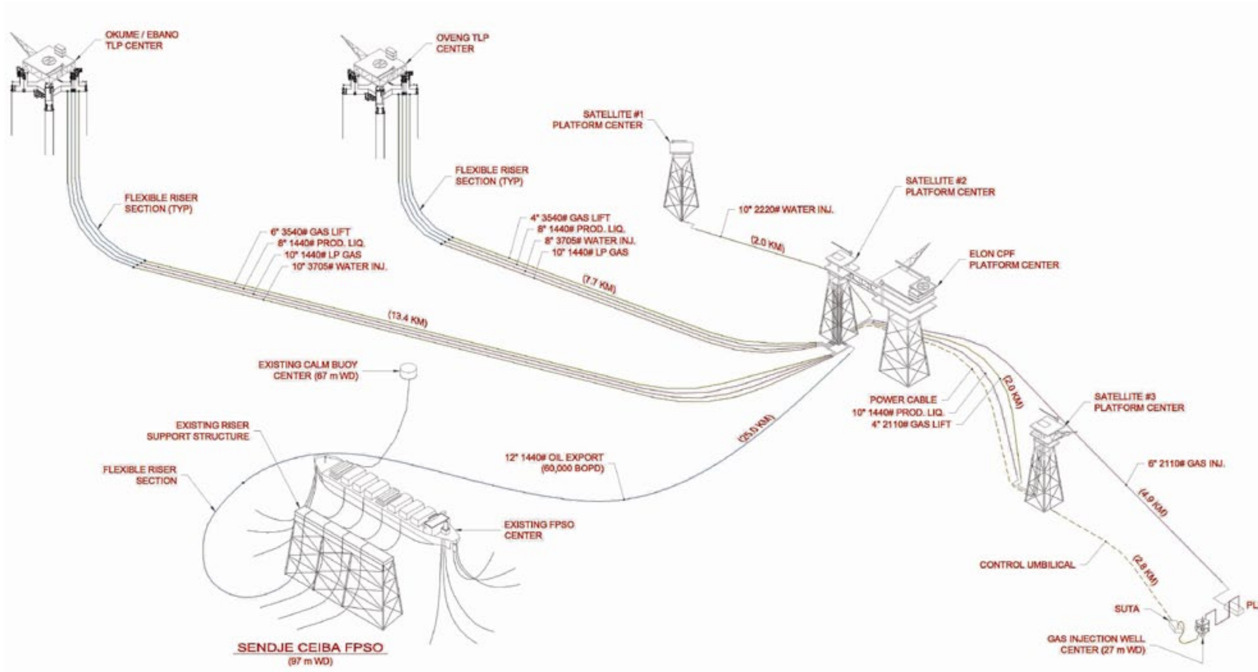

Fig.5 Example with combined systems

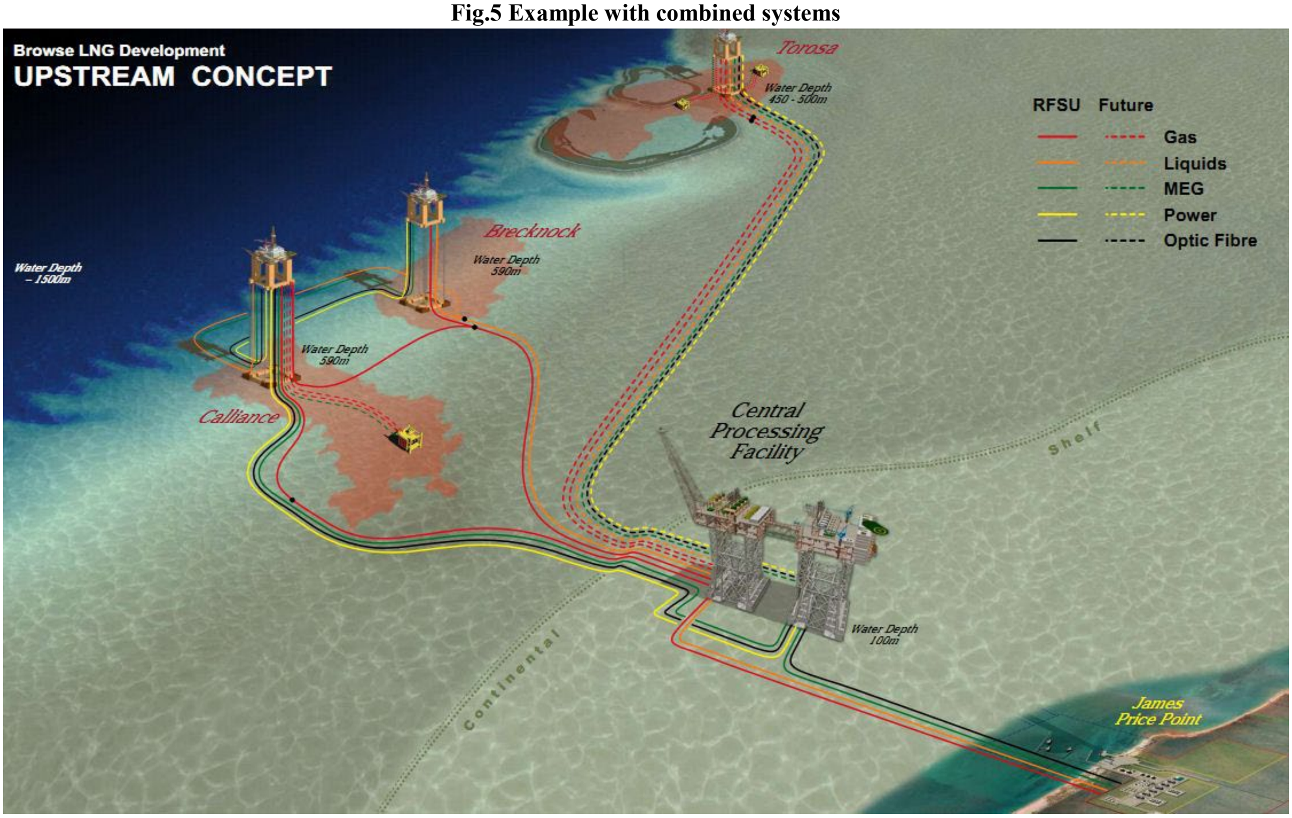

Fig.6 Example with multiple phases

Such a system does offer a significant economic advantage for the large field development. For offshore oil and gas field development, there is always the risk that a range of different scenarios might arise. The use of the multiple phases for development can have a big advantage in reducing the risk of these kinds of scenarios. One of the advantages is to be able to reduce the initial cost and start the first oil production early. The field development can be planned in a few phases depending on the production rate and the further finding of the reserves. First, the TLP and FPSO (or pipelines) can be built and installed early, with the FPSO used for storage and offloading. Tender vessels can be brought in for floater drilling. Once the field has more confirmation on the reservoir size, the second TLP structure can be built and installed. The newly built TLP can be tied back to the existing production system. This not only largely reduces the risks to the project, but also improves the cash flow and economic outcomes of the field.

5 Summary

The South China Sea deepwater field development will continue to face technical challenges in various areas as exploration goes deeper. Technology will play a very important role in overcoming these challenges and help accelerate the development. This paper explains the current available floating production platforms, reviewes the key technologies encountered, and discusses some potential development models for the South China Sea. Some new technologies are also detailed, such as tender assisted drilling, dry tree operations, etc., which are all important areas in deepwater oil and gas field development.

The actual development project could use one or more of these concepts, or even a combination of different models. For example, the model of a combined multi-phase field development can use two or more TLPs, with tender assisted drilling, and FPSO/FPU. There are a number of advantages in using this system, especially for the offshore areas of China. It not only reduces the initial investment cost, but also significantly reduces the risks of field development. This will particularly be helpful in developing the marginal fields, such as the shelf areas. Some technical issues deserve particular attention when executing these types of deepwater projects, and can have a major impact on the design and operations. Anyone making the selection decisions about the field development model has to take into account the field location. For a field far away from the shore, FPSO has to be used since the output pipeline will not be feasible; and for near shore areas, the pipeline network will be a consideration. For a shelf area, a combination of floater and fixed platforms may be a better choice for field development.

CNOOC is conducting the TLP concept study for its first floating platform application with the development of the Liuhua new field, and the design work is on-going at the office of DMAR Engineering, a Houston based company. This application will potentially mark the start of a new era for deepwater exploration of the resource-rich South China Sea, and make China the next technology center in deepwater field development.

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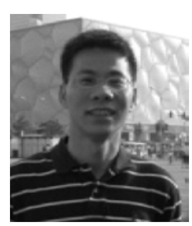

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