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A NEW SOLUTION FOR

FLOATING PRODUCTION IN ULTRA DEEP WATERS

Joaquin Lopez-Cortijo (IZAR FENE), Arun Duggal (FMC SOFEC),
Radboud van Dijk (MARIN) and Sergio Matos (DNV)

ABSTRACT

As the offshore industry moves to exploit hydrocarbon reserves in ultra deep waters it will face new challenges to bring these reserves to the market. In West Africa, flow assurance considerations and the lack of pipeline infrastructure will require that hydrocarbons be brought onto a surface vessel for processing, storage and export.

One of the critical issues in the design of floating production systems in ultra deep waters is the selection of a cost-efficient station keeping system. Standard solutions include both turret moored and spread moored systems but, beyond certain water depths, technical and economical drivers may require a more cost-efficient solution such as a fully dynamically positioned FPSO. This solution is also very attractive as an efficient early production system, relatively insensitive to water depth changes and quick to re-deploy.

This paper introduces a new concept - the DP-FPSO – marrying state-of-the-art FPSO technology and latest generation technology for dynamically positioning drilling units in ultra deep waters. The concept is being developed in the form of a Joint Industry Project to qualify this new technology by documenting its feasibility and reliability for ultra deep waters. The project will address relevant technical and regulatory challenges, the reliability of the stationkeeping system, and identify some potential benefits over conventional moored systems.

1 INTRODUCTION

In the next years, there will be a growing demand for Floating Production and Storage Units (FPSOs) for ultra deep waters (say more than 2500 m) in the Gulf of Mexico, Brazil and West of Africa. In West Africa and Brazil, FPSOs are among the systems of choice for large field development, but to date there are no FPSOs in the US Gulf of Mexico due to the special regulations that were applicable until December 2001. The decision taken by the Mineral Management Service (MMS) to allow the use of FPSOs in the GOM has opened the door to deep water areas where no pipeline infrastructure is available for transferring the oil to onshore terminals (Reference 1).

Current solutions for ultra deep water FPSOs include turret-moored (both external and internal turrets) and spread-moored systems both with and without remote offloading buoys (Reference 2). An important issue in the design of these systems will be the selection of the most cost-efficient station keeping system for the specified operational requirements. The capital cost of the station-keeping system including its installation can increase dramatically with an increase in water depth. In addition, seafloor congestion, poor geotechnical conditions, or short field life may result in the traditional mooring system not being an optimum solution. Thus beyond certain water depths and for certain other conditions, the technical and economical constraints associated with mooring systems may favor other concepts more attractive and cost-efficient (Reference 3), such as the focus of this Project: A fully Dynamically Positioned FPSO. In this Concept, there is a merger between the technological challenges of FPSOs in areas of harsh weather, and those of the latest generation dynamically positioned drill ships for operation in ultra deep waters (Reference 4).

This is not a new idea, the BP Seillian FPSO has operated in the North Sea for 8 years as a dynamically positioned production platform (Reference 5), and recently deployed in deep water offshore Brazil as an Early Production System for the Roncador field (1,853 meter water depth). In Brazil the Seillian has remained on station while offloading to both standard tankers and DP shuttle tankers without incident.

2 THE DYNAMICALLY POSITIONED FPSO CONCEPT

The concept being presented in this paper takes the Seillian system one large step forward. The focus is on evaluating and engineering a dynamically positioned FPSO capable of producing 125,000 to 150,000 barrels of oil a day, with a storage capacity of 1 million barrels. The FPSO (see Figure 1) is designed with a disconnectable riser turret that allows rapid disconnection from a large number of risers, when required. The main components of the concept are:

- DP-FPSO - for loading through the turret, processing, storing the stabilized crude oil in the cargo tanks, and offloading to a shuttle tanker connected in tandem.
- Turret System - for transfer of loads and fluids between the riser system and the vessel.
- Riser buoy and riser system - allows rapid disconnection from the riser system, providing the ability to sail away from a hurricane, providing a means of evacuating the vessel and crew from a hurricane. This also provides the means of disconnecting from the riser system in case of blackout or scheduled maintenance at a shipyard.

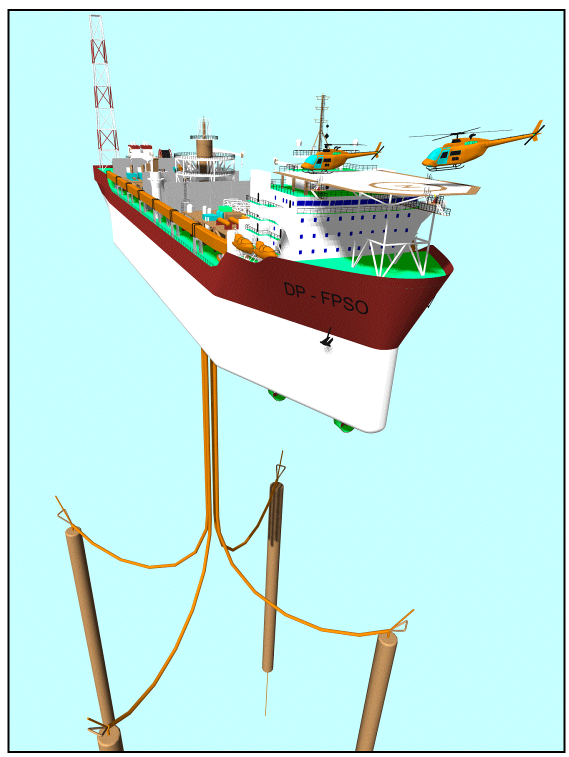

Figure 1 - The DP-FPSO Concept

Basically, this concept attempts to overcome the technology and cost limitations in applying today's station keeping solutions in ultra deep waters. These include possible design issues associated with the mooring equipment (mooring lines, anchors/piles), lack of data of such systems in deep water depths, and the high cost of deployment, inspection and maintenance of the mooring system. Another promising application is as a large early production system where the ability of rapid and relatively inexpensive deployment makes this concept very competitive with traditionally moored systems.

2.1 Main Features of the First DP-FPSO

The conceptual design of the first unit ,has been almost completed. The Unit has a crude oil storage capacity of one million barrels, and is provided with double side and double bottom to comply in full with MARPOL Regulations. The turret is located amidships, and a process plant weight of 15.000 tons is accounted for. The initial design has six azimuthing thrusters with an anticipated capacity of 5 MW each, with the final number and capacity of the thrustersto be decided upon after the model test and final simulation results have been analyzed. The power generation plant relies on dedicated dual fuel diesel generators for the DP and marine systems. Gas turbines are envisaged for powering the process plant. The accommodation and helideck are located at the fore end in order to provide adequate navigation capabilities. A shuttle tanker of 500.000 barrels storage capacity is proposed as a target tanker for the Gulf of Mexico.

The FPSO system has been designed (and model tested) for the environmental conditions from the GOM area. This area is considered the most critical for the DP system performance and FPSO stationkeeping. Results for other milder environments will be extrapolated by means of computer simulations.

The model test program included the following sets of tests: Normal Operation (fuel consumption), Survival in hurricane and loop current conditions, Squall Conditions (West Africa), Thruster Failure Conditions, Turret Buoy Connection/Disconnection Tests, Offloading with shuttle tanker in tandem, and Hurricane Escape Conditions. Model tests have been performed at MARIN (Wageningen), in the new deep water Offshore basin.

The conceptual design of the disconnectable turret and riser systems has been completed and successfully model tested. The turret design draws from the experience in designing and building a large disconnectable turret for the Terra Nova FPSO offshore Eastern Canada (Reference 6). For such a system the design of the turret and riser system need to be developed in parallel to allow the development of a robust rapid disconnect system. Current development work is focused on completing the Gulf of Mexico turret design, and completing the conceptual development of a turret for use in a DP early production system.

The second FPSO size will be engineered based on the results from the first one. Due to its application for early production, a Unit of reduced storage capacity is anticipated.

2.2 Application and Cost Advantages

It is anticipated that the DP-FPSO concept can be successfully applied for floating production and storage in the ultra deep waters of the Gulf of Mexico, Brazil and West of Africa.

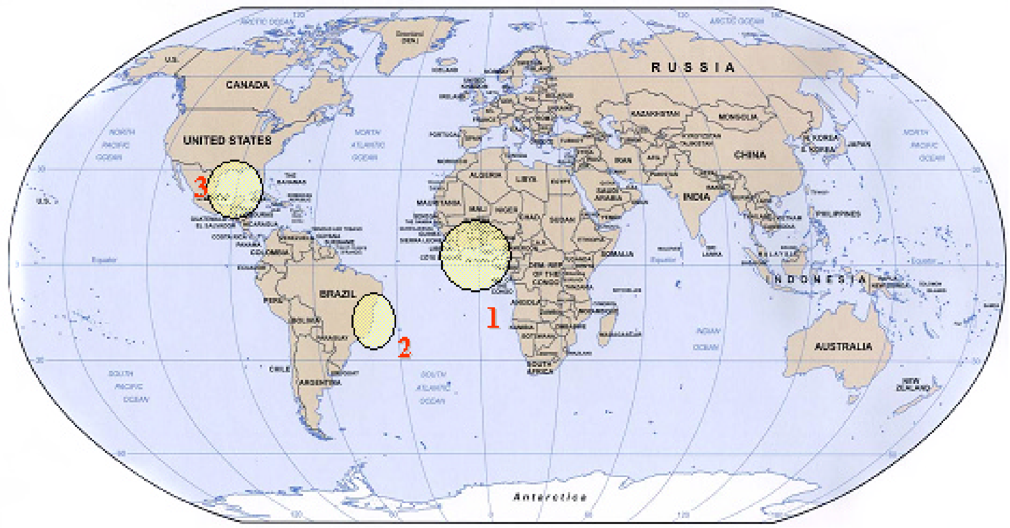

Figure 2 – Typical World Areas of Application

The possible uses of the DP-FPSO concept are:

- Oil Production, Storage, and Offloading in deep waters (>1500 m).
- Cost-efficient Early Production System. This is one of the most valuable features of the DP-FPSO, due to the ease of relocation from one site to another, and consequently the elimination of costly installation/de-installation operations.
- Exploitation of Marginal Fields. If the capacity of the reservoir is small, a new-build turret moored FPSO may not be economically feasible, while a ready-to-use DP-FPSO might be an attractive solution (e.g. Seillian).

The main advantages of the DP-FPSO compared to conventional turret moored FPSOs are the elimination ofthe mooring system(design, installation and maintenance), the ease of relocation of the Unit to other sites (early production/marginal fields) and the possibility of sailing away from approaching hurricanes or stay in stand-by mode with heading control.

3 JOINT-INDUSTRY DEVELOPMENT PROJECT

The development work is organized as a Joint-Industry Project through a Consortium established between IZAR FENE (Project Leader), FMC SOFEC, MARIN and DNV. The main objectives of the DP-FPSO Project are:

- To develop a Concept Engineering Study for a DP FPSO for operation in ultra deep waters in GOM (base case), Brazil and WOA, focusing on two FPSO sizes with transit capability and tandem offloading and having a disconnectable turret system
- To assess the reliability of DP-FPSOs compared to conventional turret moored FPSOs
- To identify and resolve regulatory issues associated to this special concept through consultation with Authorities
- To provide cost estimates for comparison studies
- To identify other relevant issues that may require further investigation.

3.1 Technology and Regulatory Challenges

The main technology challenges of the DP-FPSO project relate to the use of a DP system on a production vessel and the related issues: drift-off and riser system (Reference 6), power optimization, tandem offloading with both FPSO and shuttle tanker on DP (References 7, 8, 9, 10, 11), vessel capabilities to stay/escape from approaching hurricanes, emissions, etc. These questions will raise regulatory issues that need to be addressed for achieving compliance with Regulatory Requirements in the area of operation.

The following sections discuss the topics of classification of the FPSO and the reliability of the DP system.

3.2 Classification

One of the challenges for the project is to define regulatory (class and statutory) requirements for the DP-FPSO. Although a novel concept per se it builds on proven technologies to deliver an enabling solution for ultra deepwater applications. The regulatory compliance approach will make use of existing requirements supplemented by risk assessment of issues that are special to a floating production unit on DP. These are mainly related to the DP system, its reliability and failure implications such as disconnection arrangement and philosophy for the turret/risers (e.g. ESD and gas release scenarios).

The DP-FPSO will be provided with a DP system classified with DP AUTRO notation according DNV rules for ships Part 6 Ch. 7. This means basically that an automatic positioning keeping system with redundancy in technical design and physical arrangement will be foreseen. The main basic principle that is to be applied during the design of the DP-FPSO is that a maximum single failure shall not lead to critical situations caused by loss of position or heading. In this case a failure is defined as an occurrence in a component or system causing one or both of the following effects:

- Loss of component or system function
- Deterioration of functional capability to such an extent that the safety of the vessel, personnel or environment is significant reduced.

For the case of a DP-FPSO with DP notation AUTRO, the definition of single failure has no exceptions and shall include incidents of fire and flooding, and all technical breakdowns of system and components, including all technical and mechanical parts.

The operational mode of work will be the Automatic Mode that involves automatic position and heading control that will be the selected mode when the unit is in operation. In addition manual mode for each thruster will be made available. For periods where the unit is not in operation the provision of a Transit/Navigation Mode system is considered utilizing the aft port and starboard thruster for steering purpose and the remaining thruster in the zero position for propulsion. A full reliability study as described below will verify the redundancy and the independence of the system.

Other issues that will require regulatory compliance attention are the submersible turret, the offloading/export arrangement, emissions and arrangements for inspection and maintenance of hull and thrusters.

3.3 DP Reliability

To ensure that consequences of events initiated by the failure of the DP system are minimized for the DP-FPSO a great deal of emphasis will be placed into ensuring adequate reliability of the DP system.

The industry currently measures DP reliability through a general class system with the major classification societies base their DP classification on the guidelines set down by the International Maritime Organization (IMO) with only minor modifications. The IMO classes correspond to three increasing levels of redundancy for DP vessels. In order to qualify a DP system at the higher class levels, the operator must demonstrate that the DP system is not vulnerable to a single point failure from an active component (class 2) or a single point failure from any active or static component, including fire or flood in one compartment (class 3). The DP-FPSO dynamic positioning system will be specified as Class 3.

A Failure Mode and Effects Analysis (FMEA) will be used for the identification of single point failures to ensure the system meets the specified levels of redundancy. In order to prioritize the results of the FMEA study, a criticality ranking will be performed on the identified failures/events in tandem to the FMEA. The criticality ranking is performed by grouping the consequence and associated frequency of each of the failures to establish a risk picture in a Failure Mode, Effects, and Criticality Analysis (FMECA). This will be used to identify single point failures, identify critical operating issues and to develop a priority driven approach to addressing possible improvements. The study will also use quantitative techniques, e.g., Reliability Block Diagram Analysis (RBDA) and Fault Tree Analysis (FTA) to predict the frequency of drive off, the frequency of drift off and fraction of time with trouble-free operation over a specified period of time.

The DP system reliability study for the DP-FPSO will allow cost-benefit analysis of alternatives, e.g., increased functional redundancy versus system availability.

3.4 Preliminary Model Test Results

An extensive model test program on the DP-FPSO has been completed in MARIN's deep water Offshore Basin in January 2003 (Figure 2). The test program focused on Gulf of Mexico environmental conditions in 2,500 meters of water depth. For the DP-FPSO a thruster layout was used with both three thrusters forward and aft. An equivalent 4-riser system was developed to represent the 16 risers for the concept, along with the disconnectable turret system. The test program considered the following sets of tests:

- Normal operational conditions
- Squall conditions (West Africa)
- Offloading to shuttle tanker
- Turret/Riser disconnect and connect tests
- Survival conditions
- Free drift or hovering tests

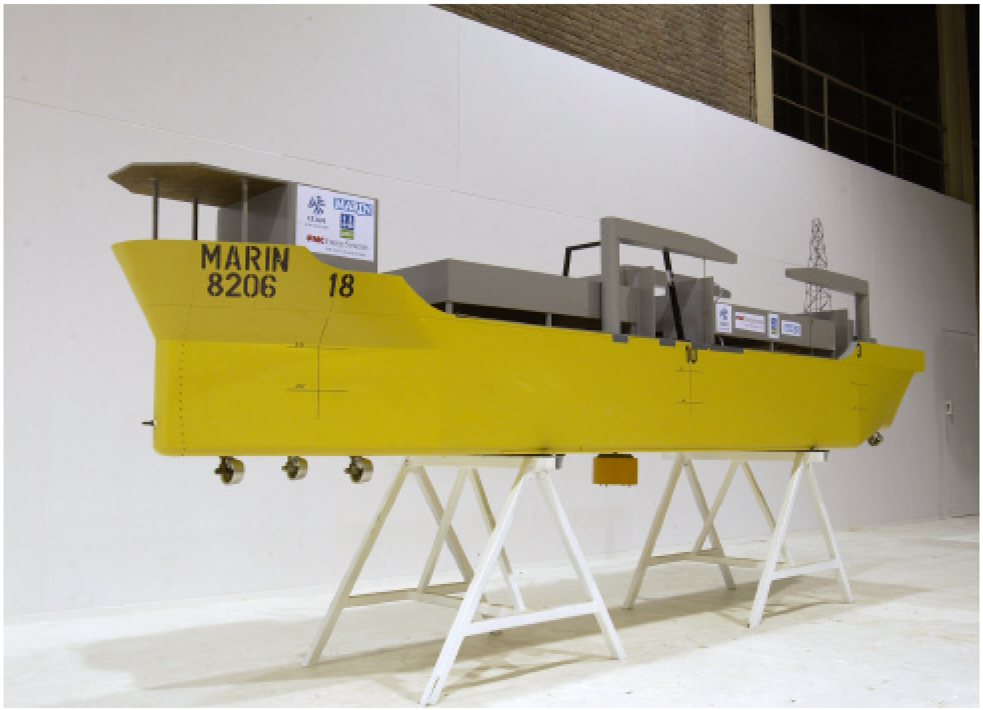

Figure 2 – Bow view of the DP FPSO model

Preliminary test results are available and the results are very encouraging. The main findings are:

- In 90% exceedance sea states (Gulf of Mexico) only two thrusters are required to maintain position. This allows maintenance on the thrusters while still having sufficient redundancy. This also indicates that the fuel consumption most of the time is very small.

- In the 99% exceedance sea state position keeping with 4 thrusters is excellent. This means that even with a maximum single failure position keeping will still be possible.

- The test in squall conditions show that position can be kept provided the vessel heading is turned into the direction of the squall wind in time. It was not possible to maintain position with a squall beam on.

- The offloading tests where done with a traditional shuttle tanker, connected to the FPSO by a bow hawser. To avoid fish tailing of the shuttle, 10 tons back thrust was applied. Due to the hawser load this can be considered a worse case for the DP-FPSO. The position keeping during offloading in 90% and 99% exceedance sea states was excellent, using only four thrusters. It is very likely that the shuttle tankers in the GOM would be of DP type and therefore what has been tested is conservative in that respect but could represent offloading in Brazil or West Africa (References 3, 4, 5).

- To demonstrate feasibility of the disconnectable turret and riser system, a number of tests were performed where the disconnectable buoy was released from the turret and reconnected. The buoy showed a very predictable behavior and no problems were encountered.

- In survival seastates (loop current and 10-Yr Hurricane) all six thrusters were needed to maintain position. Although the range of headings where position keeping is possible was limited in these conditions, position accuracy was still very good and well within limits of the riser system.

- The free drift tests were performed in 100-Yr Hurricane conditions, with the buoy disconnected. In this condition the vessel is able to maintain it's heading, but not able to maintain position above the riser pattern. Based on these tests the drift speed was determined in order to calculate the time available for an emergency disconnection procedure.

The next stepwill be to tune computer simulations to the model test results. With this tuned numerical model more accurate simulations can be performed for other environments. Also a full simulation study on the second FPSO is foreseen, possibly considering a wave following DP stationkeeping system.

4 CONCLUSIONS

Offshore production faces a continuous challenge to keep pace with aggressive drilling programs in ultradeep waters. Only just a few years ago industry celebrated a well drilled in 2000 m water depth. Today industry is already targeting exploration in 3000 m.

The DP-FPSO concept proposed in this paper is an innovative solution to meet this and other challenges in a cost efficient way.

The development project is organized in as a JIP project and will address the key issues related to offshore production on DP, including the reliability of the DP system and the regulatory compliance. The JIP is still in progress but already has demonstrated the feasibility of maintaining a large FPSO on position in extreme conditions in the Gulf of Mexico using a DP thruster system. The feasibility of the disconnectable turret riser system has also been demonstrated in the model test program.

Current work focuses on the completion of the stationkeeping simulations, and completion of the engineering of the FPSO vessel, and the disconnectable turret riser systems. Work is also underway in performing a reliability study of the DP thruster system, and ensuring compliance with the regulations in the various target regions. Future work will focus on developing a DP early production system, building off the experience developed from the Gulf of Mexico FPSO, and a detailed life of field cost analysis comparing a conventionally moored FPSO versus a DP FPSO.

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