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FLOATING PRODUCTION STORAGE OFFLOADING CONCEPT

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ABSTRACT

This article explains the advantages of Floating Production, Storage, and Offloading vessels, recent trends in mooring systems, hull construction, safety, and operational aspects. These types of vessels are vital to the modern offshore oil and gas industry. These specialized ships are designed to process and store hydrocarbons from offshore oil fields and offload them to shuttle tankers or pipelines. Their adaptability and mobility make them especially valuable in deepwater and remote locations. These vessels, converted or specifically built for oil production, represent a significant evolution in the offshore extractive industry, offering a set of operational, economic, and strategic advantages that have positioned them as preferred options in numerous projects around the world.

Keywords: Floating Production, Storage, and Offloading vessels, mooring system, offshore, renewable resources

1. INTRODUCTION

The oil industry that produces oil from the oceans uses some of the best systems today, called floating production, storage, and offloading (FPSO) units.

These are floating units that provide oil platforms, in addition to storing petroleum products, for their production/refining. The main functions of these floating units are oil and gas exploitation, separation of oil, gas, water, and impurities, storage, and transportation of crude oil, thus providing a solution where a fixed infrastructure is impractical [3]. FPSOs are equipped with accommodation modules so that they can be operated and maintained by the necessary personnel, have increased storage capacity, and functionality is adapted to specific conditions, such as extreme weather [10]. Thanks to the sophisticated mooring systems adopted by modern FPSOs, safety and efficiency are optimized during production and offloading operations [13].

If initially, offshore oil and gas were extracted from fields up to 50 meters below the water surface using pipelines, the method became economically inefficient for produc-

tion from offshore fields at depths of several hundred meters and up to 100 kilometers from shore. This inefficiency led to the emergence of FSOs and later FPSOs.

Today, oil is extracted at depths of over 2900 meters below the sea surface, and for submarine gas production, the depth is approximately 2700 meters [12].

The FPSO concept enables oil companies to produce oil in isolated offshore areas and deeper water than would have been economically feasible with other technologies, such as fixed-pile structures. In addition, it has storage capacity for the treated crude oil that has been produced, being equipped with an unloading system for the crude oil to be transferred to tankers for transport to refineries, instead of using pipelines to transport the oil to shore. These floating units are considered the best systems for storing and producing/refining petroleum products [20].

Several steps describe the functions that FPSO units perform [13]:

-Production, which implies that an FPSO unit is equipped with equipment that acts as a refinery for distilling oil extracted from the ocean;

- Storage, a function through which an FPSO filters the extracted oil, being built of safe and durable tubes and tanks to avoid unwanted oil leaks that can pollute the marine environment;

- Unloading, which involves the transfer of oil from an FPSO unit to another tanker or pipeline.

The topside system and the hull system are the two primary systems found in offshore vessels. Oil and gas are produced using topside systems, which are located on the decks of offshore processing plants [24]. Oil and gas are stored in hull systems, which are found on the lowest decks of offshore processing plants. When taking into account the primary purpose of an FPSO, topside systems are significantly more important than hull systems [11].

Because of the restricted deck area, an offshore installation needs to be small, light, and built with a high degree of inherent process safety. Stable and reliable operation in a marine environment while accounting for the vessel's motion is another necessity to take into account. A high degree of modularity, simplicity of use, minimal equipment, quick startup, and high availability are all requirements for the offshore installation [14], [15].

Such an FPSO unit is usually based on the hull of a converted oil tanker, being equipped with hydrocarbon processing equipment to separate and treat crude oil, water, and gases, which arrive on board from submarine oil wells through flexible pipes [22].

The oil, after being treated, is transferred to the cargo tanks in the FPSO hull. As for the treated gas, it is used as fuel for power generation on board, with excess gas being reinjected back into the subsea tanks or exported via a pipeline to shore. The water produced during production is discharged overboard, within the limits permitted by environmental legislation. Alternatively, the water can be injected into the tanks [25].

2. FPSO design

FPSO vessels can be classified based on various criteria, such as design origin, mooring system, and others.

2.1. Hull type

New FPSOs, built from scratch, are adapted to specific field conditions. They offer long life and modern technologies, but are more expensive and take longer to build.

FPSOs converted from old tankers, which offer lower cost and faster deployment, although they may lack some modern features, have shorter remaining life, and may have size or weight limitations [26].

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2.2. Mooring system

A crucial part of creating a deepwater moored FPSO is the integrated design of the mooring system, which includes the hull and surface of the vessel, the flow column and piping systems, and the installation location [1], [4].

However, mooring systems for numerous deepwater fields have been planned without taking into account all necessary interfaces, as demonstrated by several building projects for such vessels [7], [23]. This has resulted in expensive mid-project revisions, increased component costs, and an impact on the schedule and installation [2] [6].

FPSOs can be fitted with spread-mooring systems, shown in Figure 1a, which anchor the vessel at several locations on the seafloor to increase stability, or central mooring systems shown in Figure 1b, that allow the ship to rotate according to the weather conditions, according to the needs of the terrain [16]. Because of its fixed orientation, a spread mooring method makes the vessel more susceptible to environmental influences such as wave direction and intensity [17]. Vessels equipped with this system are vulnerable to waves striking at greater angles because of their fixed position, which raises the possibility of significant vessel oscillations, especially roll movements. In harsher maritime conditions, this can be problematic [8].

A central mooring method, on the other hand, makes use of a turret column that is anchored to the ground. Because of the turret's integration into the FPSO's structure, the ship may weathervane, or rotate, to encounter the least amount of resistance from currents, waves, and wind [9], [10]. By reducing vessel motion, its design guarantees more stable operations. Another safety advantage provided by disconnectable turret mooring systems is the ability for FPSOs to swiftly separate from their moorings and risers in the event of severe weather, including hurricanes, typhoons, or icebergs in areas like the South China Sea or the Gulf of Mexico [11].

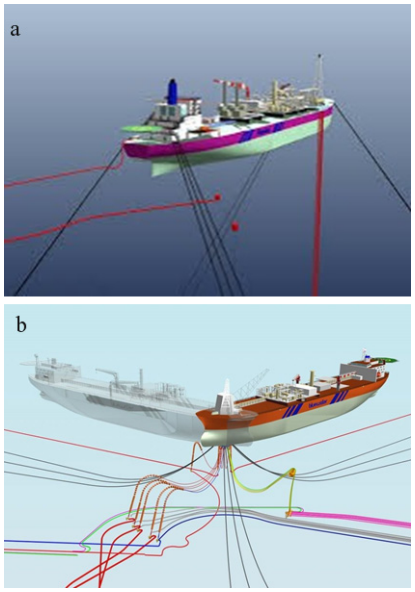

Figure 1 Spread moored floater (a) and turret moored floater (b) [16]

3 . FPSO process flow

The first step in the production process is the use of subsea wells to extract hydrocarbons from underwater reservoirs, as can be seen in Figure 2. These are connected to the FPSO by a system of risers and flowlines, which allow the gas and oil to flow up to the ship [2], [5].

After arriving at the ship, the hydrocarbons go through a series of processing steps. These are designed to separate the mixture into its parts, using specialized equipment that separates water, natural gas, and crude oil. Before being transported, the crude oil is first transferred to storage tanks inside the FPSO unit. A part of the natural gas is utilized as fuel to power the vessel itself, while the remainder is either compressed and exported, flared, or reinjected into the reservoir. This is contingent upon the particular configuration and infrastructure of the FPSO [18], [19].

In order to comply with environmental regulations, the frequently contaminated water that is obtained during the process is treated. If it's safe to do so, treated water can be discharged back into the marine environment or reinjected into the reservoir to help recover oil and maintain pressure. Strict safety and environmental regulations govern the handling of other contaminants, such as sand or chemical additives [21].

Facilities for offloading the refined crude oil are also available at the FPSO. When the onboard storage tanks are full, a system of loading arms or flexible hoses is used to move the oil to shuttle tankers. These tankers then deliver it to onshore refineries, where it receives additional processing to turn it into a product that may be used [27].

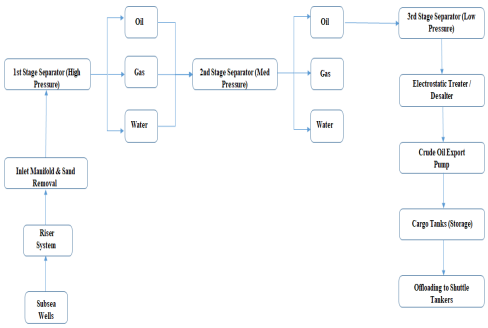

Figure 2 FPSO process flow

4. CONCLUSIONS

FPSO ships are a vital part of offshore oil and gas production, offering a flexible and efficient alternative to traditional platforms. As the industry evolves and demands more sustainable solutions, FPSOs are expected to integrate greener technologies and continue playing a central role in global energy production. Future FPSOs and other ships are expected to make a transition to greener energy sources through the implementation of renewable energy technology that will reduce the carbon footprint of the oil and gas industry. Hybrid FPSOs, which combine solar and wind energy, are a new trend that fits in ideally with the objectives of global sustainability.

Given the need to reduce greenhouse gases, the oil industry is aiming to integrate carbon capture and storage devices into FPSO operations, developments that, in addition to improving compliance with environmental regulations, fully utilize FPSOs as part of the overall energy transition process.

Therefore, one of the goals of the offshore oil and gas industry is to achieve sustainability and environmental responsibility through the diversification and integration of renewable energy sources. That is why offshore platforms today offer renewable energy options to contribute to the decarbonization process.

5. FUTURE DIRECTION

Future research could aim at a more in-depth study of modern FPSOs, which are capable of integrating advanced automation systems for remote monitoring and control of operations, thus improving efficiency and safety. The authors also propose researching the optimization of the energy consumption of FPSO units.

REFERENCES

[1]. Ahilan, R. V., Versavel, T., Lee, M. Y., and Devlin, P. "Generating Confidence in Mooring/Riser Designs in Ultra-Deep (10,000 ft) Waters—The DeepStar Challenge," *Deep Offshore Technology Conference*, New Orleans, LA, Paper No. 24-3, 2004.

[2]. Allahyarzadeh-Bidgoli, A., Dezan, D.J., Salviano, L,O., de Oliveira Junior, S., Yanagihara, J.I. "Lifetime sensitivity analysis of FPSO operating parameters on energy consumption and overall oil production in a pre-salt oil field". *Chem Eng Commun*, 207 (11), pp.1483–507, 2020.

[3]. Bell, J. M., Chin, Y. D., Hanrahan, S. "State-of-the-art of ultra-deepwater pro-

duction technologies". In: *Offshore Technology Conference*. OTC, 2005. p. OTC-17615-MS. Available in: https://onepetro.org/OTCONF/proceedings-abstract/05OTC/All-05OTC/29710. Access in: 30 October 2025.

[4]. Fontaine, E., Kilner, A., Carra, C., Washington, D., Ma, K.T., Phadke, A., Kusinski, G. "Industry survey of past failures, pre-emptive replacements and reported degradations for mooring systems of floating production units". In *Proceedings of the Offshore Technology Conference*, Houston, TX, USA, 5–8 May 2014.

[5]. Gallo, W.L.R., Gallego, A., Acevedo, V., Dias, R., Ortiz, H.Y., Valente, B.A. "Exergy analysis of the compression systems and its prime movers for a FPSO unit". *Nat Gas Sci Eng*, 44:287e98, 2017.

[6]. Girón, A.R.C., Kim, B.W., Farfán, J.A.M., Hernández, A.O.V. "Transient effects of an FPSO with a broken mooring line". In *Proceedings of the Twenty-Fifth International Ocean and Polar Engineering Conference*, Kona, HI, USA, 21–26 June 2015.

[7]. Hasan, M., S. "A Simplified Method for Analyzing the Fatigue life of a FPSO Mooring System". *Procedia Engineering* 194, pp.502 – 508, 2017.

[8]. Howell, G. B., Duggal, A. S., Lever, G. V. "The Terra Nova FPSO turret mooring system". In: *Offshore Technology Conference.* OTC, 2001. p. OTC-13020-MS. Available in: https://onepetro.org/OTCONF/proceedings-abstract/01OTC/All-01OTC/35343. Access in: 30 october 2025.

[9]. Hong, J.P., Cho, S.K., Seo, J.H., Sung, H.G., Lee, D.Y., Park, I.B., Kim, D.W. "Experimental study of effect of mooring line failure on behavior of turret-moored FPSO ship". *J. Ocean Eng. Technol.*, 29, pp. 231–240, 2015.

[10]. Howell, G., Duggal, A., Heyl, C. and Ihonde, O. "Spread Moored or Turret Moored FPSO's for Deepwater Field Developments". *Proceedings of Offshore West Africa*. 1–21, 2006.

[11]. Hwang, J.H., Roh, M.I. and Lee, K.Y. "Integrated engineering environment for the process FEED of offshore oil and gas production plants". *Ocean Systems Engineering*, Vol. 2, No. 1, pp. 49-68, 2012. https://doi.org/10.12989/ose.2012.2.1.049.

[12]. Legorburu, I., Johnson, Kate R., Kerr, Sandy A. "Offshore Oil and Gas. In Building Industries at Sea - 'Blue Growth' and the New Maritime Economy", 1st Edition, eBook ISBN 9781003337430, 2018. Retrieved from: https://www.taylorfrancis.com/reader/download/b185585d-11a5-4195-99667109bb8b7e29/chapter/pdf?context=ubx

[13]. Lin, Y., Yang, Q., and Guan, G. "Scantling Optimization of FPSO Internal Turret Area Structure Using RBF Model and Evolutionary Strategy", *Ocean Eng.,* 191, pp. 106562, 2019.

[14]. Luo, Y., and Baudic, S. "Predicting FPSO Responses Using Model Tests and Numerical Analysis", *International Offshore and Polar Engineering Conference,* Honolulu, HI, May 25–30, pp. 167–174, 2003.

[15]. Mastrangelo, C.F., Lan, C.M., Smith, C.E. "From tanker-ships to the first FPSO in the US GoM". In *Proceedings of the Offshore Technology Conference*, Houston, TX, USA, 6–9 May 2019.

[16]. Mari Voldsund, Tuong-Van Nguyen, Brian Elmegaard, Ivar S. Ertesvåg, Signe Kjelstrup. "Exergy destruction and losses on four North Sea offshore platforms: A comparative study of the oil and gas processing plants". *Energy,* 74: pp. 45-58, 2014.

[17]. Montasir, O.A., Yenduri, A., Kurian, V.J. "Mooring system optimisation and effect of different line design variables

on motions of truss spar platforms in intact and damaged conditions". China Ocean Eng., 33, pp.385–397, 2019.

[18]. Morais, José Mauro de. Petróleo em águas profundas: uma história tecnológica da Petrobras na exploração e produção offshore. 2023. 2ª Edição. IPEA. Instituto de Estudos de Política Econômica/Casa das Garças (IEPE/CdG). Available in: https://repositorio.ipea.gov.br/handle/11058/1147. Access in: 01 October. 2025.

[19]. Portella, A., G., Souza de Abreu, V. H., dos Santos, M. "Role of FPSOs in deepwater and ultra-deepwater exploration: a literature review on social manufacturing systems in industry 5.0". Conference: ENSUS 2024 - XII Encontro de Sustentabilidade em Projeto – UFMG At: UFMG, Belo Horizonte, Minas Gerais, 2024. DOI: 10.29183/2596-237x.ensus2024.v12.n1.p968-978.

[20]. Potrč, S., Čuček, L., Zore, Ž., Kravanja, Z. "Synthesis of Large-Scale Supply Networks for Complete Long-term Transition from Fossil to Renewable-based Production of Energy and Bioproducts", Chemical Engineering Transactions, 81, pp.1039-1044, 2020.

[21]. S´anchez, Y.A.C. "Exergy and Environmental Assessment of FPSO Offshore Platforms With CO2 Capture and Storage", University of S˜ao Paulo, 2017.Retrieved from: https://www.academia.edu/92313155/Exergy_and_environmental_assessment_of_FPSO_offshore_platforms_with_CO2_capture_and_storage.

[22]. Vasconcellos, Jose M., Fernandes, Antonio C., Santos, Alberto Ferreira, Marcos D. A. S. "FPSO: Tanks Optimization Design Approach". In: International Conference on Offshore Mechanics and Arctic Engineering pp. 431-436, 2005. Available in: https://asmedigitalcollection.asme.org/OMAE/proceedings-abstract/OMAE2005/431/305361. Access in: 20 October. 2025

[23]. Wihers, J.E.W., Devlin, P.V. "Effect of Coupling of Mooring Lines and Risers on the Design Values for a Turret Moored FPSO in Deep Water of the Gulf of Mexico". In *Proceedings of the Eleventh International Offshore and Polar Engineering Conference*, Stavanger, Norway, 17–22 June 2001.

[24]. Xu, S., and Ji, C. Y. "Dynamics of Large-Truncated Mooring Systems Coupled With a Catenary Moored Semi-Submersible", China Ocean Eng., 28(2), pp. 149–162, 2014.

[25]. Zhao, N., You, F. "Can renewable generation, energy storage and energy efficient technologies enable carbon neutral energy transition?", Applied Energy, 279, 115889, 2020.

[26]. Zou, T., Kaminski, M.L. "Applicability of WaveWatch-III wave model to fatigue assessment of offshore floating structures". *Ocean Dynamics* 66, pp. 1099–1108, 2016.

[27].https://www.identecsolutions.com/news/fpso-layout-pump-separate-and-store-in-one

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