

Review Article

A Review Study of Oil and Gas Facilities for Fixed and Floating Offshore Platforms

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Abstract: In the early stages of oil and gas exploitation, it is important to rapidly identify which production platform is likely to deliver its utmost value. This study first explores the key features and constraints of the most commonly used fixed and floating offshore platforms then proceed to discuss the current available production technology. Platform selections are based on several factors such as stability, water depth and environmental conditions. Drilling can be done from the platform or another mobile unit. As most new offshore operations turn to semi-submersible platform and drill rigs, it is perceived as the most promising platform by oil and gas industry.

Keywords: Offshore structures, production platforms, semi-submersibles

INTRODUCTION

Studies have prescribed and demonstrated that ocean is a strategic and lucrative source of energy (Matos *et al.*, 2011). An offshore production facility is applicable for oil and gas exploration and production, navigation, ship loading and unloading and to support bridges and causeways. The offshore oil and gas exploration and production are the most significant of these applications (Sadeghi, 2007). A production facility platform is described as the equipment and its supporting structure at which the well fluid is initially received (Ronalds, 2005). The oil and gas industry plays an important role to develop new production technologies to accommodate deep-water depth as the resources are depleting in shallow water regions (Managi *et al.*, 2006). The expansion of this industry has brought to an evolution from shallow water exploration to deep water exploration. Various types of production facilities have been installed in deep and shallow waters all across the world (Sadeghi, 2007). A typical example is shown in Fig. 1. This production platform is commonly made of steel tubular structure (Wang, 2013). The offshore platform which works in harsh environments is often prone to extreme environmental loads and damages. Therefore, careful assessment in the design of offshore platform is required to ensure safety and prevent potential damages (Wang, 2013).



Fig. 1: An example of offshore oil and gas platform (Sadeghi, 2007)

There are two types of offshore platforms. The first type is the fixed structure and the second type is the floating structure. Fixed structure is employed in circumstances where the surroundings are persistently stable with limited wind movement and hydrodynamic forces. However, this kind of fixed platform is not practical in deep oil and gas extraction (Sadeghi, 2007).

With new technology advancement, floating oil and gas offshore platform is designed for deeper water operations where the use of fixed structure becomes impractical (Islam *et al.*, 2012). The design and construction of offshore platform is debatably, which is one of the most challenging sets of tasks faced by oil and gas engineering profession.

Objectives: The main objective of this study is to examine the different types of oil and gas production

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facility and determine which of these types is likely to deliver its utmost economical, efficient and effective values. The key factors for the design and selection of the types of offshore oil and gas structures will be analyzed throughout this study by introducing and comparing current available technology from various research papers. Besides that, the conceptual and preliminary design process of the offshore oil and gas structures will be further studied in brief detailed design and other succeeding phases. Thus, the main aim of this study is to present a general understanding of different types of fixed and floating offshore oil and gas structures considering the water depth and other factors.

METHODOLOGY

In this section various offshore methods of oils and gas extractions are discussed. They are categorized into two types, which are the fixed structure type and the floating structure type.

Offshore production platforms: The water depth at which exploration drilling is to be done is the primary consideration for choosing oil production structure. A whole range of distinct production structures are used depending on size and depth of water. Production platforms are built to last 20 to 30 years which is capable of carrying large amounts of development drilling and oil processing equipment and for the purpose of oil and gas field extraction operation (Reddy and Swamidas, 2013).

The most commonly used platform in the offshore industry is the fixed pile structure which is known as jacket. The pile is driven into the sea floor by means of tubular structure. When the exploration moves to a deep sea environment, the floating production platform becomes more viable. In a floating production platform, the topside is installed on a floating structure with dry well. The oil and gas extraction process occurs beneath the sea. The oil and gas are then transported by

undersea pipeline and riser to an existing offshore production platform or to an onshore facility (Devold, 2010).

Fixed offshore platform:

Jacket fixed platform: The steel jacket platform is the most commonly used offshore structure worldwide. The multifunctional role of this structure, being able to be used for oil exploration, drilling as well as production has attracted the attention of many industry players. This platform is usually used in shallow water operation (Xu *et al.*, 2009).

The world needs more and more energy. Engineer has great task going forward to produce the oil and gas going forward. Figure 2 shows an overview of different types of offshore oil and gas production platforms being used by the industry.

An offshore jacket platform as shown in Fig. 3 consists of jacket, piles and deck. The bracing for the piles against lateral loads are provided by the jacket structure. These piles are driven through the inside of the legs of the jacket structure so that the deck structure can be placed permanently upon the jacket structure. Offshore platforms are built in consideration of the complicated and harsh environmental conditions. The hydrodynamic loads of these structures usually dominate the design of offshore structures (Oua *et al.*, 2007).

The structure is generally built from tubular steel structures. One major drawback of this platform is that it is very prone to environmental loads such as wind, wave and earthquake (Patil and Jangid, 2005). The jacket platform is costly and it has been proven impractical to build such a huge steel structure under deep water conditions (Islam *et al.*, 2012).

Compliant tower: The fixed compliant tower as shown in Fig. 4 is comprised of a narrow tower joined to an establishment on the sea floor and extended up to the

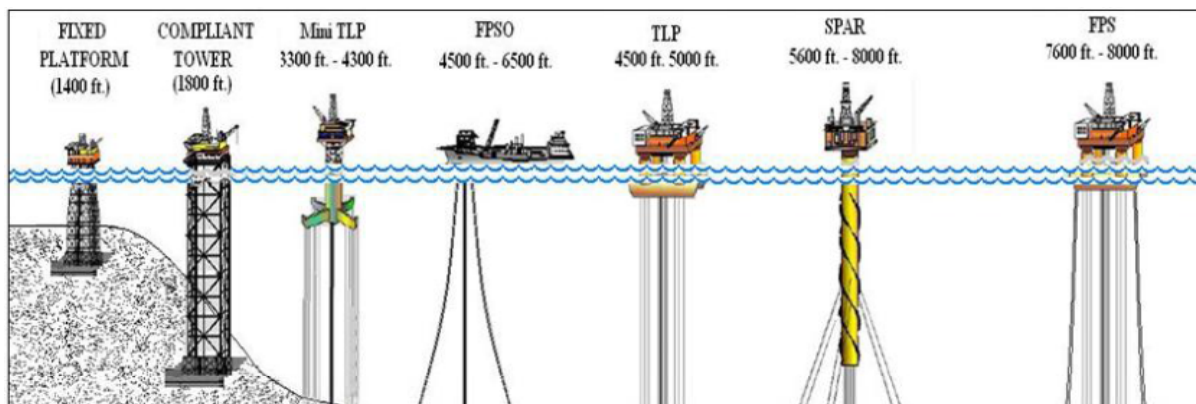


Fig. 2: An overview of different types of offshore oil and gas production platforms (Palmquist, 2008)

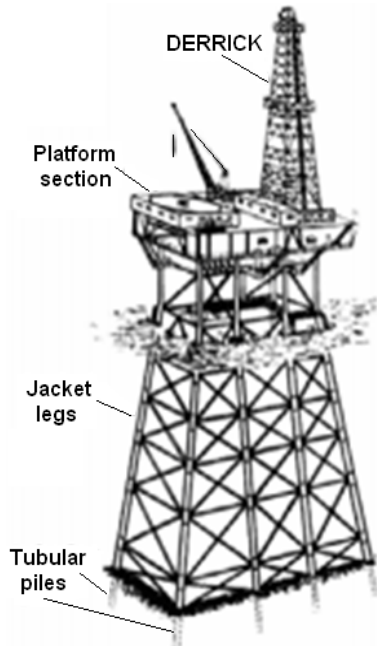


Fig. 3: A typical offshore jacket structure (Haritos, 2007)

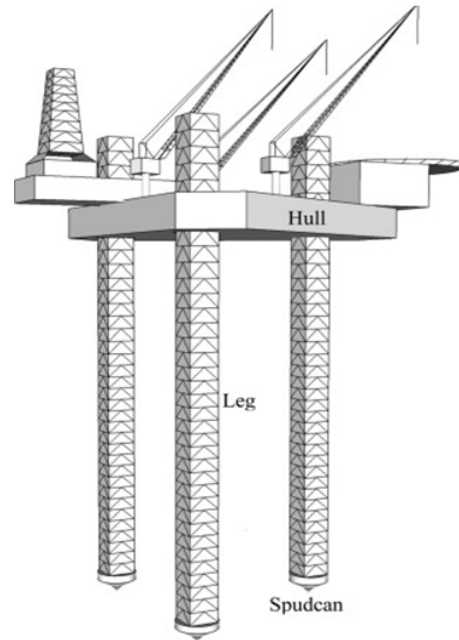


Fig. 5: A typical jack-up platform (Zhang *et al.*, 2012)



Fig. 4: A typical offshore compliant tower (Will, 2000)

platform. Generally, the design of this structure is flexible, as opposed to the conventional jacket platform. It has the ability to absorb much of the pressure exerted on it by wind and sea allowing the structure to operate in much deeper water. In addition to its functionality, the structure has the capacity to withstand hurricane conditions (Sadeghi, 2007). The tower is comprised of a topside structure which enables drilling and production to be carried out. This eliminates the need for Mobile Offshore Drilling Unit (MODU) that can be costly and difficult to operate (Will, 2000).

Jack-up platform: Jack-up platform is commonly used offshore structure for oil and gas exploration and

extraction from seabed. These are large mobile units, designed to operate at locations with varying sea-bed conditions and great water depths (Gupta *et al.*, 2006). The design comprises of a buoyant, triangular hull supported underneath by three truss-work legs resting on a spud can footings. As the structure is towed to the drilling spot and preloaded to the desired penetration, the hull is then jacked up (Tan *et al.*, 2003). Figure 5 shows a typical jack-up platform commonly used in ocean environment. Jack-up platform was initially used in shallow water applications. However, with advancement in technology, it has been designed to use in deep water and harsher environmental conditions (Bienen and Cassidy, 2006).

Floating offshore platform:

Tension Leg Platform (TLP): Tension leg platform is a floating platform as illustrated in Fig. 6 anchored to the seabed by hollow steel tubes (Managi *et al.*, 2006). It exhibits its stability with a tensioned mooring system. Several high tensioned lines provide the required restoring force to the platform and moor them to the seabed. The structure is also designed in such a way that the Centre of Gravity (CG) is above the Centre of Buoyancy (CB) and the water plane area can minimize the floating support structure cost. This study was conducted by Cermelli and Roddier (2005), Collu *et al.* (2010) and Dassault and DNV (2008) as cited by Lefebvre and Collu (2012). The mooring lines have to be specially designed due to the high tension required. As a result, the anchoring system can become challenging to the design. A major drawback of this structure is that, it does not provide the best cost performance trade off as the cost tend to increase



Fig. 6: A typical tension leg platform (Net Resource International Ltd., 2012)

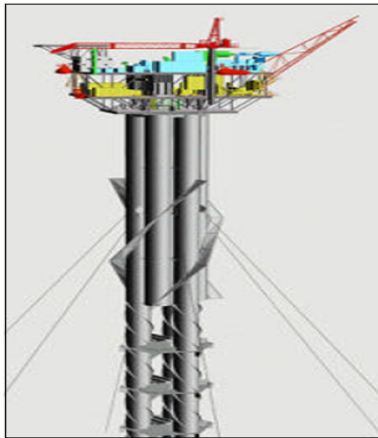


Fig. 7: A typical spar platform (Replumaz, 2013)



Fig. 8: FPSO/FSO (MODEC Inc., 2014)

significantly with water depth (Lefebvre and Collu, 2012).

Spar platform: A Spar platform as shown in Fig. 7 is designed with a rigid cylinder, structurally anchored to the sea bottom by vertical or catenary cables. This structure is suitable for ocean drilling, production and storage of oil for in deep water operation (Islam *et al.*, 2012). It has been remarked as one of the most reliable and cost effective structure. As opposed to the other floating structures, Spar uses dry well-heads and rigid

risers. The Spar is prone to resonant heave motions which are excessive for riser integrity (Tao *et al.*, 2007). The Spar floating platform achieves its static stability with the relative positioning of the CG with respect to the CB. The structure assembles a single cylinder with a small radius and a deep draught. The sea water acting as a ballasting material fills up the cylinder which eventually lowers the CG position. As the CG position is lowered, the restoring arm and the stability of the structure can be increased. However, this design is not suitable for relatively shallow water. This study was conducted by Van Hees *et al.* (2002) and Wayman (2006) as cited by Lefebvre and Collu (2012).

Floating production, storage and offloading: A Floating Production, Storage and Offloading (FPSO) unit as shown in Fig. 8 is a floating vessel used by the offshore oil and gas industry for the production, processing of hydrocarbons and for storage of oil. An FPSO vessel is designed to receive hydrocarbons produced by it or from nearby platforms or subsea template, process them and store oil until it can be offloaded onto a tanker or, less frequently, transported through a pipeline. FPSO is preferred in frontier offshore regions as it is easy to install and does not require a local pipeline infrastructure to export oil. FPSO can be a conversion of an oil tanker or can be a vessel built specially for the application. A vessel used only to store oil without processing it, is referred to as a Floating Storage and Offloading (FSO) vessel (MODEC Inc., 2014).

FPSO and FSO systems today have become the primary methods for many offshore oil and gas producing regions around the world. Most FPSOs are ship-shaped and are 'anchored' (moored) by a turret. The type of turret used is determined by the environment of the FPSO. In calmer waters spread mooring is often sufficient. In environments where cyclones or hurricanes occurred, a disconnectable mooring system is used so that the vessel can be taken out of the storm's way and replaced when the storm has passed.

FPSOs have been serving the offshore oil and gas industry for nearly 30 years. They have proved to be safe and economical. Advantages of FPSOs are:

- Earlier cash flow because they are faster to develop than fixed platforms
- Reduced upfront investment
- Retained value because they can be relocated to other fields
- Abandonment costs are less than for fixed platforms

Over the years, advanced mooring systems as well as advancements in subsea equipment have made FPSO/FSOs useful in deeper and rougher waters. Currently, approximately 160 FPSOs and 100 FSOs are in operation worldwide (MODEC Inc., 2014).



Fig. 9: A typical semi-submersible platform (Chakrabarti, 2005)

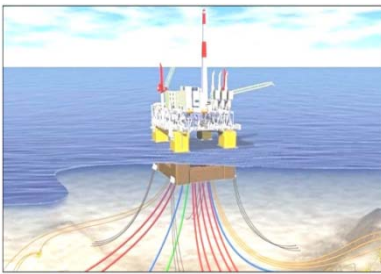


Fig. 10: Semi-submersible FPS platform module for Gumusut Kakap project (Malaysia Marine and Heavy Engineering Holdings Berhad, 2013)



Fig. 11: The semi-submersible FPS for Gumusut-Kakap project (fabricated at MMHE yard, Pasir Gudang Johor, Malaysia (Aug 09-Apr 13)

Semi-submersible platform: The viability and feasibility of semi-submersible platform as a stable floating offshore platform has been recognized for years in oil and gas exploration. The design of a conventional semi-submersible platform consists of deck, columns and derrick. The advantages of this platform have attracted the oil and gas industry to use it as an offshore oil drilling platform today. The semi-submersible platform has the capability of exploration, drilling, completion and work over. Semi-submersible platform is commonly designed with double-hull pontoon, four cylindrical columns, lateral bracing connections and box deck (Zhai *et al.*, 2012). These stabilized floating water-piercing columns are connected to submerged pontoons at bottom side. The deck is installed at the top of the columns. The platform is designed in such a way that the columns are shallow

and the pontoons are large in volume. The CG of the platform is kept right above the CB, which eventually controls the roll and pitch period of the platform (Chakrabarti, 2005). The support for the structure, mainly the columns and the pontoons, have to be ballasted. The pontoons have to be filled up to 95%, whereas the columns have to be filled up to the specified height. This structure is commonly employed in the event of a large deck is required to fit all the features (Lefebvre and Collu, 2012). As the pontoons and columns are ballasted with sea water the structure submerges to a predetermined depth in the sea. This large part of the submerged structure provides stability under extreme ocean condition. The structure is also designed with huge mooring anchors which place them in designated location (Reddy and Swamidas, 2013). Figure 9 is shown as a typical semi-submersible offshore platform.

Semi-submersible platform has been attracting the attention from many industries due to its promising advantages. This structure is remarkable with its simplicity and low cost (Lefebvre and Collu, 2012). It is mobile and has the ability to operate in much deeper water condition as compared to the other types of platforms (Sadeghi, 2007). The hydrodynamic effect on the structure can be seen through the wave cancellation effect due to forces acting on the submerged pontoons and the columns (Lefebvre and Collu, 2012). Besides this effect, the buoyancy of pontoons on the structure balances the compressive axial loads acting on the columns giving an advantage to this structure (Estefen and Estefen, 2012).

Figure 10 shows a typical semi-submersible Floating Product Solution system (FPS) platform module. Figure 11 shows the semi-submersible FPS for Gumusut-Kakap project (Malaysia Marine and Heavy Engineering Holdings Berhad, 2013), which was fabricated at MMHE Yard, Pasir Gudang, Johor, Malaysia started in August 2009 and completed in April 2013. This semi-submersible FPS platform has been anchored in a water depth of about 1,200 m. It will initially service seven sub-sea manifolds in the Gumusut-Kakap field. The semi-submersible FPS platform for Gumusut-Kakap project comprises a hull and topside. The topside which weighs around 20 kMT was designed by Technip Geo Production (M) Sdn Bhd and designed to remain on station in the field for 30 years. The topside can accommodate 19 well slots and has the processing capacity of 150 thousand barrels/day of crude oil, 300 million standard cubic feet of gas re-injection per day and 225 thousand barrels of water/day. The hull was designed by Shell and weighs approximately 19 kMT. It has a storage capacity of 20,000 barrels of crude oil, 2,582 barrels of methanol, 4,145 barrels of diesel, and 7,122 barrels of portable water (Malaysia Marine and Heavy Engineering Holdings Berhad, 2013).

Figure 12 shows the loading out of the semi-submersible FPS platform at its final offshore destination.



Fig. 12: Loading out of the semi-submersible FPS platform for its final offshore destination (Petronas Malaysia, 2013)

RESULTS AND DISCUSSION

A review study was conducted to study different types of fixed and floating offshore platforms. The oil and gas industry has moved beyond shallow water to deep water exploration. Offshore fixed structure limits its viability in deep water application with hostile weather conditions. Sophisticated designs and excessive physical dimensions are required for this offshore fixed structure to obtain the favorable stability in deep water environments and therefore, it is very costly (Adrezin *et al.*, 1996). Offshore exploration and drilling around 120 m are done from floating offshore structure, as fixed offshore structure becomes impractical (Perderson, 2012). Semi-submersible platform is one of the most commonly used floating offshore platforms in oil and gas industry. It is capable of being used as a crane vessel, drilling vessel, production platform and accommodation facilities. Thus, it has attracted the attention of many oil and gas companies (Omajene, 2013). Semi-submersible platform as a specialized marine vessel is also known for its good sea keeping and stability characteristics (Perderson, 2012).

Drilling can be done from either a platform or MODU's with the former exhibits a better cost performance. This is due to the fact that the well is accessible at any time and cost will be limited because the drilling rig is part of the platform facilities. Maintenance of the well performance can be performed without waiting for a maintenance vessel to mobilize it. In the latter case, MODU requires a wide range of subsea installations, drilling and manifold templates, flow lines and control umbilical. Installing and maintaining these facilities incurs high cost as it moves to a deep water operation (Tjuvholmen, 2007). Platform drilling can be done from fixed jacket structure, TLPs, semi-submersible platform, spar platform and drillship.

The semi-submersible platform has become the most preferred unit of choice when it comes to drilling from the floating position with the capability of performing drilling and production process within the same platform vicinity. Semi-submersible platform is well known for its platform drilling. Generally, it is the most reliable, movement free and can be fitted to all the

structures, with the existence of a drilling rig on the fixed facilities making it a viable option to be used in deep water environments (Society of Petroleum Engineers, 2013).

Semi-submersible platform is also well known for its excellent stability compared to any other floating platforms, ordinarily picked for harsh conditions due to their capacity to withstand unpleasant ocean states (Dice Holding Inc., Rigzone, 2014). As mentioned earlier, the design of a semi-submersible consists of a deck supported by columns connected to pontoons. The water pontoon provides buoyancy to the overall structure and can be ballasted with sea water whenever the draft needs to be changed (Perderson, 2012). During the transit of the platform, the water inside the pontoon will be de-ballasted and the structure rises to the surface enabling the process of transit. At this state, the pontoon's full waterline area will be entirely exposed to the ocean wave. During drilling operation, the pontoon is filled up with sea water (ballasted) to entirely immerse it below the water surface. As the pontoon submerges below the water surface, the column partially enters the water which in return reduces the exposed water plane area. The water plane area around the columns is lesser than the water plane area around the pontoon. Minimizing water plane area can greatly increase the water plane inertia which maintains the overall stability of the platform throughout the operation. This feature allows the semi-submersible platform to perform in extreme wave loadings with its known wave transparency and deep draft. Therefore, there is a known reduction in the unit's heave response and improved stability.

The semi-submersible platform as the most stable floating unit possess several advantages in terms of cost, payload, water depth, loading and transportation and stability when compared with other floating offshore structures. The wave cancellation effect brings an advantage to the overall performance of this platform type. This is achieved by cancelling the forces acting on the submerged pontoons and the forces acting on the columns (Adrezin *et al.*, 1996).

Semi-submersible platforms provide flexibility in terms of its use at different range of water depths. Designed with pontoon attached to the water piercing column combined with mooring to the seabed provides a stable installation with ideal movement attributes to the overall design. The oil and gas service provider companies have shifted their attentions to the semi-submersible platform, as this platform possesses these advantages (Aker Solutions, 2013).

Jackup platform is also one of the most commonly used drilling platforms in the offshore industry. Nevertheless, the use of this platform is only restricted for shallow water drillings. However, as the operation moves to deeper water, a platform rig is considered to be more economical. Water depths beyond 120 m favor the use of semi-submersible platform and drillship.



Fig. 13: A typical drillship operation in deep-sea location

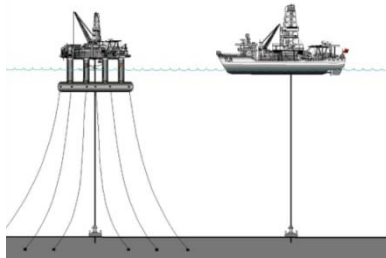


Fig. 14: Comparison of deepwater semi-submersible and drillship

Conversely, the water depth alone is insufficient to determine its viability as extreme environmental condition tends to lower the maximum water depth capacity of the jackup platform. While it offers a few remarkable advantages such as stable work platform, good availability, relatively low mobilization cost and generally a competitive day rate, it has a major disadvantage with a relatively low deck space. A low deck space is prone to facilities damages due to a long period of progressive flooding. Most of the losses and damages in jackup platform are caused by water flooding in severe storm conditions. In the case of semi-submersible platform, water can only reach the deck of semi-submersible platform if the platform remains on station for long period in severe conditions (BMT Fluid Mechanics Limited, 2006).

The use of drillship as shown in Fig. 13 is also common in offshore drilling for a particular during monsoon period. Well known for its rapid mobilization, it has been used by many oil and gas companies. However, this monohull ship is prone to severe environmental loadings. Thus, the industry shifted its attention to a more unwavering drilling platform (Perderson, 2012). Semi-submersible platform is far more a stable drilling platform as compared with drillship shown in Fig. 14. A ship is most stable only when its bow is heading to the weather loadings and least stable if it is placed at the sideways of the weather loadings. Owing to weather loadings factors, drillship is only concentrated in environment with modest weather condition as it is more susceptible to wind and wave loadings. The motion performance of the drillship limits its use in most of the applications.

The spar platform as shown in Fig. 7 is also recognized with its application in offshore industry. The stability of this platform is achieved by relative positioning of the CG with respect to the CB. The use of ballast helps in lowering the CG which in turn increases the overall stability of the platform. A major drawback associated with this platform is that it is not suitable for relatively shallow water. Besides that, the size of this structure which is huge and large complicates the fabrication and installation process at the production site. The load out, transportation, offshore installation and hookup for the topsides must be carefully planned and executed to evade cost escalation and schedule hold-up.

TLP as shown in Fig. 6 is a floating structure tethers to the seabed by several high tensioned mooring lines. This tensioned mooring system maintains the overall stability for the buoyant structure by providing the required restoring force. However, the cost of this structure tends to increase extensively with water depth. The tension lines have to be specifically and carefully designed due to the high tension required which becomes a major challenge to the design of this structure (Lefebvre and Collu, 2012).

CONCLUSION

The semi-submersible platform as shown in Fig. 9 makes its mark as the most promising offshore platform as compared to other types of platforms. Holding several advantages this platform has been growing in demand in the offshore industry. Their relatively high stability makes them as a viable option to be used in extremely harsh ocean conditions. Even though the platform experiences moderately huge movements under pervasive wave activity, it remains highly stable in extreme ocean environment with a huge part of its structure under water. Its versatile yet robust characteristics have attracted the attention of many oil and gas companies. Generally, this type of platform is preferred because of its capability and cost effectiveness to produce oil and gas (Reddy and Swamidas, 2013). From the review study, semi-submersible platform and drilling rigs have the most promising design commonly chosen and they are the viable option for offshore oil and gas extraction.

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