Modular Design for Low Cost Minimum Facilities Platforms

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Abstract

To meet the ever increasing demands for cost and schedule efficiencies in the development of marginal fields it has become necessary to streamline the design process for platforms and employ lean engineering techniques. The introduction of minimum facilities platforms in conjunction with existing infrastructure or MOPUs has enabled operators to develop marginal assets without the large capital expenditure associated with new permanent production facilities. It has been shown that minimum facilities platforms can be produced at relatively low cost and designed to suit specific fabrication and installation requirements. As a result the popularity of minimum facilities platforms has grown and has heralded a new wave of flexible design solutions for a range of applications and water depths.

The technical challenges involved in the design of minimum facilities platforms include structural strength and fatigue resistance as well as meeting installation constraints. A typical conductor supported minimum facilities platform incorporates topside, conductor legs and a subsea template. Although the external platform loading is dependent on unique local water depth and environmental conditions, the overall platform response is primarily governed in only three ways; topside load, conductor size, conductor free-span. Through the use of pre-qualified designs and methodologies it is therefore possible to quickly develop a range of structural solutions to suit a particular application. This paper explores the potential for a modular approach to minimum facilities platform design with a focus on reducing the cost and schedule for development, fabrication and installation.

Introduction

Recent interest in marginal shallow water developments has led to a growing demand for cost efficient wellhead platforms which enable increased production capacity within an existing field infrastructure. Wellhead platforms (WHPs), also known as minimum facilities platforms (MFPs), typically house the surface wellheads, trees and manifolds but do not include extensive process or separation facilities. As such, multiphase production fluid may be exported from the MFP either to an adjacent production facility or into a larger field production network to be processed on existing assets, see Figure 1.
Among the different designs available, the Conductor Supported Minimum Offshore Structures (known as CoSMOS platforms), utilize the well conductors to support the topsides thus eliminating the need for a separate supporting jacket structure. They offer particular benefits in terms of modular design, fast procurement, low fabrication cost as well as ease of installation since they can be installed from a jack-up or crane barge without the need for costly installation vessels. An example of showing the installation of a CoSMOS platform for the Olowi field offshore Gabon is shown in Figure 2.

This paper focusses on the key design elements of MFPs and advantages to achieve cost efficient platforms for marginal developments.
Platform design

MFPs are typically installed in shallow water for marginal field developments, satellite development or infrastructure expansion. Many MFPs have been developed from traditional platform designs and are supported on battered leg jackets; however these are costly to fabricate and install owing to the size and weight of the jacket structure and associated piles. In recent years innovative designs have utilised the strength of the well conductors to support the MFP topside instead. This approach eliminates the need for a traditional jacket structure; this is shown in Figure 3.

Conductor supported platforms rely solely on the strength of the well conductors to support the topside but may also incorporate a subsea template or mid-water brace to provide additional stability. The conductor size is selected based on the structural design requirements thus a larger conductor may be required for the 4 supporting members than would otherwise be necessary simply to house the casings. In order to avoid the use of excessively large conductors the platforms are best suited to mild or benign environments and in shallow to medium water depths. In deeper water depth the stability and fatigue performance of the conductor are reduced, and additional support may be required. If the additional support becomes too substantial a jacket platform type may become a better solution. The decision to select a conductor supported platform is therefore driven by the design parameters specific to a particular field and the system is required to be engineered to meet the specific field requirements.

The benefits of the CoSMOS type platform derive from the fact that the system is engineered to fit the requirements of a specific field and as such, each platform design is different. This arises as the design is performed to minimize the steel requirements to reduce procurement and fabrication time. The platform is also designed primarily around the installation procedure that is considered to best meet the field requirements. For example the topside layout will be compacted if the installation of the topside is performed by a jack-up rig. For this particular case, the drilling window

Figure 3 – Representation of CoSMOS versus Jacket Platform.
and lifting capacity of the jack-up need to be fully understood and this will drive the dimensions of the topside. The advantage of such an approach is to design a platform that can be shipped using conventional supply vessels and does not rely on a large crane barge for the installation, this can achieve substantial cost savings for the installation as it reduces the number of vessels required for the installation and their associated mob/demob cost. Installation is one of the main drivers for the design of MFPs and is usually discussed early on any project development.

![Figure 4](image)

**Figure 4 – Small Topside for CoSMOS System at the back of a Supply Boat**

**Key elements**

The fundamental elements of the conductor supported platform are as follows:

**Topside**

The topside is designed to accommodate the wellheads, trees, piping manifolds, wellhead control panel and any other required processing equipment. The overall weight and dimensions are largely defined by the project and the method of installation selected. For this type of platform, the piping system is integral to the platform and not installed as separate unit to save weight. The topside also provides a structural connection to the conductors thus defining the conductor end condition ('pinned' or 'fixed') which affects the conductor fatigue life. A simple seated arrangement will provide axial (compressive) and lateral load transfer, similar to a pinned connection; whilst a fully clamped design will constrain the conductors in all degrees of freedom, similar to a fixed support. The clamped (fixed) connection is more complex and costly but usually provides improved fatigue response. For both scenarios, the effect of the constraint is limited by the stiffness of the topside.

The topside layout will vary depending on whether the platform is intended to be manned or unmanned and the project specific requirements including equipment, accessibility and craneage. For optimum efficiency typical layouts can be defined for common configurations and subsequently customised if necessary. However for more challenging applications complete topside design may be necessary. If on-board processing facilities are required then the platform must be much larger than a simple wellhead platform as highlighted in Figure 5.
Conductors

The conductors provide structural support to the topside through axial compression and bending resistance and support the well casings, wellhead and surface tree arrangement. The total conductor length is defined by the water depth at the platform location, the topside elevation and the foundation piling depth. The conductors are susceptible to extreme and fatigue loads the effects of which may be managed through controlling the number of conductors, the OD, wall thickness, material, free span length and connection type. Due to the dynamic loading on the conductors, fatigue enhanced connector designs are usually preferred to increase the fatigue life of the conductors above the mudline. The typical diameter of the conductor used to support the platform is 30in or 36in conductors with thicknesses ranging from 1in to a maximum of 2in.

In addition to providing structural support for the topside, the main function of the conductors is to house the wells. The minimum number of conductors is determined by the well count. The conductors can be configured to house a single well or two wells through one conductor using splitter wellheads. Additional conductors may be added to a platform to increase production capacity and/or improve structural performance of the system. Additional conductors may be either ‘free standing’ (i.e. not supported by the topside) or ‘structural’ (i.e. structurally connected to the topside by a pinned or fixed type connection as discussed in the topside section). Structural conductors are shown in Figure 6 to Figure 8. Free standing conductors only provide additional production capacity and do not aid the platform structural performance. The lateral loading generated by those conductors needs to be considered in the design of the platform. Additional structural conductors provide increased support for the topside and greater structural stiffness.

The selection between a pinned or clamped structural conductor depends on the overall performance of the system and can be driven by environmental fatigue. Typically, with a pinned type conductor, the platform is seated on the conductor using a support shoulder. While this type of connection is cheaper and faster during installation, there is a penalty in the fatigue life of the CoSMOS system that needs to be evaluated. Clamped conductors are used when fatigue life needs to be improved by increasing the stiffness of the overall structure. A summary of the benefits is given in Table 1.
As the free span of the conductor increases, so does the fatigue damage along the length of the conductor. As for the top connection to the topside, the connection of the conductor joint along the length is also fatigue sensitive, as such, a selection is required to determine the best type of connection that should be used to achieve a good balance between type of connector cost and acceptable fatigue life. A summary table showing the benefits of different conductor connection system is given in Table 2.
### Subsea Template

The subsea template ensures correct space out of the platform legs and provides a guide for any subsequently installed conductors. Additionally, depending on the requirements of the development, the template can be grouted or clamped to the conductors to provide structural support through increasing the stiffness of the system. In deep water the height of the template can be increased and thus reduce the free span length of the conductor. The template provides lateral support and stability for the conductor legs and the height can be varied to suit specific conditions. For water depth less than 10m, the template requirement can be waived and in shallow water (<20m approx.), the template may only be very short. However in in deeper water a much larger template may be required. This is illustrated in Figure 9.

Typically, the height will be driven by the fatigue performance of the conductors. This will also depend on the total weight of the topside. The heavier the topside, the more bending stress is transferred to the legs under dynamic motion. In this scenario a higher template may be required to reduce the deflection of the platform. Alternatively, the number of conductors rigidly connected to the topside can be increased to increase the stiffness of the platform, and thus to also reduce the deflection.
Design drivers

All conductor supported platforms consist of the same three fundamental elements but each platform must be tailored to suit specific design requirements as summarised below:

- Water depth – Conductor supported platforms are ideally suited for applications in water depths of up to 50m water depth. However designs can be feasible for water depths up to 70m.
- Environmental conditions – Benign environments such as those seen in West Africa, Middle East or South East Asia are better suited to ensure high fatigue life of the system.
- Soil conditions – Conductor supported platforms can be used in a wide range of soil conditions, however weak soil conditions may require additional piling depth to ensure adequate stability of the platform is achieved.
- Well count – Typically, the drilling is conducted using a jackup MODU, therefore, the well conductor slots needs to be within the drilling envelope of the jackup. This typically limits the number of platform well slots to a maximum of 9. However the use of dual or triple splitter wells is feasible to provide additional wells within a single well conductor.
- Processing / equipment requirements (topside mass and dimensions) – Conductor supported platforms are best suited minimal facility applications. Optimal topsides dimensions are typically within 15m x 15m, with a topsides weight up to 300Te. The platform equipment is therefore required be accommodated within this dimensional limits and weight target. Larger / heavier topsides can be designed, however these may require additional structural support and alternative installation processes which may reduce the advantages of a conductor supported platform design.
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- Design life for the field – A typical design life of 20 years can be achieved. Where lower fatigue live are required (i.e. a field of less than 5 years oil extraction), the design can be further simplified to meet the requirements.
- Installation method for the conductor and topside – Conductor supported platforms are designed to give the operator as much flexibility as possible as to when to install the platform and conductors. This can be done in advance using a crane barge vessel to pile the conductors and to lift the topsides, or through using the jack-up MODU during the drilling campaign prior to commencing drilling operations.
- Frequency of human intervention on the platform – MFPs are typically unmanned platforms, with only short term intervention for pigging, chemical tank refill or general inspection considered. If longer term manned intervention is required the platform access must be considered to ensure safety requirements are met for shelter and evacuation etc.
- Tie-back / interfacing requirements – The requirement for fluid export or control lines such as umbilicals, flexible risers, and steel pipelines may necessitate the use of protection structure and boat landings.

Platform behaviour

The most important aspects of the structural response of a conductor supported platform are:

- Strength
- Wave fatigue life
- Conductor stability
- Boat Impact

The greatest challenge in designing a conductor supported platform is to understand the response of the conductor. Due to the relatively low stiffness of the platform (compared with a conventional jacket structure), the platform can be subject to significant deflection and exhibits a dynamic response. This dynamic behaviour can be complex, and requires a good understanding the behaviour of dynamic bodies in hydrodynamic environments to ensure that the response of the platform is correctly understood.

Jackets are typically designed with a high structural stiffness, large footprint and widely spaced piles. For CoSMOS type platforms, the conductors act as the piles but owing to the much narrower footprint the stability of the structure is greatly reduced. This leads to deflection of the platform and topsides, hence the conductors are subject to dynamic loading.

Wave induced fatigue is usually the most critical design driver for a conductor supported platform. The conductor fatigue life is dependent on the free span distance between the seabed (or subsea template) and the connection to the topside. The greater the span, the less stable the system and the more bending moment is transferred to the conductor under wave loading. For water depths of about 40-50m, the subsea template is used to provide the effect of artificially raising the seabed to reduce the free span in the conductor leg, thus improving the stability and fatigue life of the system. By increasing the footprint on the seabed or constraining the conductors at the template and the topside, the overall stiffness of the structure can be increased and the height requirement of the template can reduced. An example of the typical template height versus topside weight for different
footprint sizes is given in Figure 14. The use of fatigue optimised conductor connectors also improves the fatigue response of the conductors as shown in Figure 12.

Increasing the platform stiffness may improve the platform fatigue response, but the boat impact resistance may be reduced. For a conductor supported platform the conductors are not protected by a jacket and therefore are vulnerable to direct impact. As the conductor may carry internal well casings, the platform structure must be sufficiently compliant to absorb the impact energy and thus avoid excessive damage occurring.

The trade-off between platform stiffness (fatigue resistance) and system compliance (boat impact resistance) drives the selection of the conductors and template dimensions, i.e. a longer free span of the conductor will provide more deflection, and hence more impact energy can be absorbed without damage, however the greater deflection will also lead to more fatigue damage under long term wave loading. If large energy absorption is required, additional boat impact bracings can be added close to the mid water level to provide additional absorption of energy.

![Figure 10 – Structure Stiffness Trade-off](image_url)
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Figure 11 – Base structure impact on VM stress response

Figure 12 – Conductor Connection Impact on Fatigue Life

Notes:
- E-class, SCF = 1.3 - Representing a good quality single sided weld;
- B-class, SCF = 4.0 - Representing a typical conductor coupling;
- B-class, SCF = 2.8 - Representing the high fatigue resistance of the NOV XLC’s connector.

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Figure 13 – Example of Boat Impact for Conductor Leg Platform

Figure 14 – Typical Template Height Requirement in 50m Water Depth

Notes:
- The required height of the template is given assuming a water depth of 50m.
- A 5 x 5 footprint represent the distance between the supporting conductor leg (5m x 5m).
- E-class, SCF=1.3 (E1.3) - Representing a good quality single sided weld;
- B-class, SCF=2.8 (B2.8) - Representing the high fatigue resistance of the NOV XLC-s connector.
Installation Considerations

One of the major advantages of conductor supported platforms are that they can be designed to be installed using a jackup MODU. The main benefit of this approach is to use the same vessel for piling the conductors, drilling the wells and installing the platform. This approach can greatly simplify the installation process through making best use of the MODU which is required in the field in any case to drill the wells, while avoiding the additional costs, complexity and risk of using multiple vessels in the field. To successfully achieve this type of installation, it is essential that a large part of the design of the platform is undertaken with the input of the rig manager to fully understand the capacity of the drilling vessel. It is critical that the limitations of the jack-up are fully understood to ensure the jack-up is capable of lifting the seabed template and topside, and that the planned lifting and handling procedures are both safe and practical.

In some instances, the installation schedule may mean that the jack-up is not available (mobilised on another field for instance) or the jack-up may not be suitable for the installation. In these scenarios a crane barge can be used to pile the conductors and install the topside prior arrival of the drilling rig, Figure 15. The modular design of the topside allows for this flexibility. When the requirements for the topside are large (over 250Te topside weight), the topside can be designed to be lifted in two separate parts so that the crane on any installation vessel is suitable for the lift. Typically, the weight of the topside prior offshore fitting is about 150Te maximum and the subsea template is about 100Te, making the use of relatively small crane possible for this type of structure.

When compared with the installation of a typical jacket structure, the installation of a conductor supported platform is significantly simpler and faster. There is no requirement for pre-installation of piles before installing the platform (as the well conductors also act as the template piles), and due to the much smaller sizes of the structures the transportation and lift requirements are greatly reduced.

![Figure 15 – Installation with a Crane Barge (Left) or Jackup (Right)](image-url)
Cost and schedule comparison

The table below provides a typical outline cost comparison and associated schedule between the EPC of a CoSMOS platform and a typical jacket type platform. At the fastest, some of the more simple platforms have been designed, procured and fabricated in about 9 months, with the more complex platforms requiring slightly over one year.

In most cases the schedule is driven by lead times for conductors and process equipment. In a saturated market as currently seen, conductor procurement can take 9 months to one year, therefore it is necessary to either place orders early or plan to use readily available stock materials. The modular approach to the platform design assists the decision making process for critical long lead items and also enables detailed engineering to be completed in a relatively short time.

Other factors affecting the cost and schedule include simplified and standardised piping layouts, reduced fabrication requirements, use of pre-qualified engineering design and methodology.

The summary example given in Table 3 is based on a typical minimum facilities platform in a benign environment and approximately 40m water depth.

<table>
<thead>
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<th>Activity</th>
<th>COSMOS Platform (40m)</th>
<th>Jacket Supported Platform</th>
<th>Notes</th>
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<td></td>
<td>Duration</td>
<td>Cost</td>
<td>Duration</td>
</tr>
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<td>Detailed design</td>
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<td>Fabrication – Template</td>
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<td>Fabrication - Jacket</td>
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<td>$5.0M</td>
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<tr>
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<td>$12.3M</td>
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Table 3 – Example Cost & Schedule Comparison between a CoSMOS and Jacket Platform
Conclusions

The CoSMOS system can provide significant cost and schedule savings for applications where traditional jacket platforms are uneconomical or where specific design requirements or constraints need to be met. Cost savings can be achieved primarily through the utilisation of the jack-up MODU to undertake the installation, or through the use of other lower specification vessels for transportation and installation when compared with those required for a jacket. Other cost savings can also be achieved through reduced procurement, fabrication and engineering requirements. Schedule optimisation is achieved through use of pre-engineered modular designs for key components. This method can also significantly reduce the FEED and detailed design duration.

The advantages of the CoSMOS platform concepts are maximised in applications where minimal platform facilities are required, and for regions of water depth of up to 50m in relatively benign environments. It is also recognised that the advantages of a CoSMOS system are reduced for applications in deeper water depths, harsh environment conditions, manned platforms or for standalone platforms which require substantial processing equipment.

The CoSMOS platform offers a field proven solution as an alternative to a conventional jacket structure design suitable for marginal field developments. The system is defined as an engineered solution that can yield significant cost saving for the operator in terms of engineering, procurement, installation and schedule.