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CONCEPTUAL DESIGN OF INNOVATIVE RELOCATABLE WELLHEAD PLATFORM USING MULTI-COLUMN STRUCTURE “MCT” WITH BOTH BOTTOM FOUNDED AND FLOATING IN-PLACE CAPABILITIES

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ABSTRACT

This study addresses the design challenge of a relocatable wellhead platform that satisfies the complex operational and environmental requirements of both shallow and deeper water hydrocarbon extraction. A platform design capable of catering to three distinct fields: the shallow water A Field (~20 m water depth) and the deeper waters B Field (~40 m water depth) and C Field (~65 m water depth), each with a production life expectancy of less than 10 years is shown in this study. Other requirements such as the use of dry-tree, simpler fabrication and decommissioning method, and cost effectiveness were also imposed on the proposed solution.

To answer these requirements, a Multi-Column Structure (referred to as "McT") is proposed as the solution. In the initial stage, McT serve as a gravity-based substructure for the shallower water A Field. The McT's fabrication and integration with the topside will take place in a dry dock. Subsequently, the integrated McT will be floated to the installation site, where it will be ballasted and placed on the seabed. This wet-tow option provided more flexible, economical, and simpler installation and fabrication method when compared to the jacket type structure. Furthermore, the size of the columns is designed with a dimension where a simple steel rolling devices may be utilized to fabricate the hull. Ring skirts and driven pile are incorporated into the McT's foundation design to provide the in-place stability and to fulfill seismic requirement during its fixed mode utilization. Notably, well conductors and trees (up to 7 wells) will be situated alongside the McT, facilitating well drilling and production.

This study's primary objective is to devise a single McT substructure capable of accommodating the operational needs of the A, B, and C Fields. The scope of the study includes the summary of Substructure (Hull) Configuration Design, Foundation Design, Wire Tendon and Suction Pile Design, Global Performance Analysis, Pre-Service stability Analyses, Flexible and Top-Tensioned Riser Design and qualitative cost comparison with jacket type offshore platform. This innovative platform design offers a versatile, relocatable wellhead platform solution, tailored to the specific needs of multiple fields, while satisfying stringent criteria for technology, operational feasibility, and cost-effectiveness.

1. INTRODUCTION

The extraction of hydrocarbons from offshore fields presents an enduring challenge within the dynamic landscape of oil and gas industry. With a growing demand for energy, the industry seeks unconventional solutions to address the distinctive demands of various offshore environments. This study investigates the intricate design challenge posed by the necessity for a relocatable wellhead platform capable of accommodating hydrocarbon extraction in both shallow and deeper waters. The complexity arises from the diverse operational and environmental requirements of multiple target fields, characterized by unique water depths, prompting the need for an innovative approach.

Historically, offshore platforms have been custom-tailored to specific fields, limiting their adaptability and cost-effectiveness when used in multiple fields. For shallow water fields with marginal oil and gas production rate, the conventional fixed jacket structures are considered to be a suboptimal solution due to its comparatively expensive and labor-intensive installation and decommissioning works. Furthermore, the fixed jacket structure is also sensitive to land subsidence and earthquakes. On the other hand, floating platform solutions are typically restricted to deeper waters (e.g. Spar platform) or have poor dynamic performance thus making it incompatible with dry tree technologies (e.g. Ship shaped hull or semi-submersibles).

Due to these limitations, the state of the art in offshore platform technology is undergoing a significant shift, emphasizing adaptability while maintaining cost efficiency. In response to this challenge, PT Mineering Energi Internasional (MEI) aim to develop a wellhead platform that is not only operable at different water depths but also integrates dry-tree technology, streamlines fabrication and decommissioning processes, and maintains economic viability. The proposed solution, a Multi-Column Structure referred to as "McT" (FIGURE 1) represents a novel approach that has the potential to revolutionize offshore platform design. The present study is a continuation of two previous study: (Tahar et al., 2016a) which mainly focused on the McT TLP design at one typical water depth, and from (Tahar et al., 2016b) which mainly focused on the project and economic benefit of McT. In this paper, “One-Size-Fits-All” McT design concept is presented. The novel design concept showcases one McT design that fits three different water depth, which is achievable through two different configurations: floating and bottom founded. The McT design combine the advantages of gravity-based platform [3]–[5] and tension leg platform [6]–[9], therefore it can positioned itself at the forefront of this technological evolution by proposing a relocatable wellhead platform that meets the stringent environmental and operational criteria of both shallow and deep-water fields.

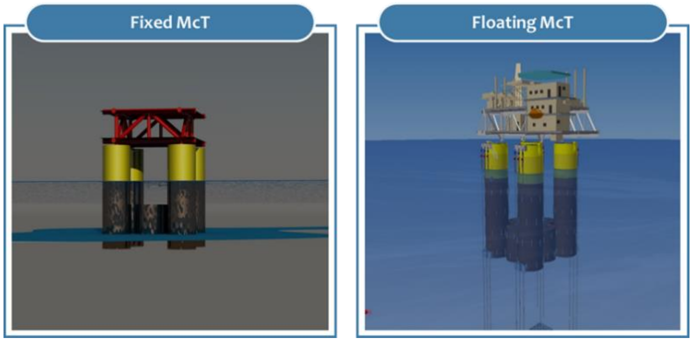

FIGURE 1: FIXED MCT (LEFT) AND FLOATING MCT (RIGHT) ILLUSTRATION

This study aims to present the innovative McT substructure, covering various aspects of its design, including Hull Configuration, Foundation, Wire Tendon and Suction Pile Design, Global Performance Analysis, Pre-Service Stability Analyses, and Flexible and Top-Tensioned Riser Design. Additionally, a qualitative cost comparison with traditional jacket-type offshore platforms is provided, emphasizing the economic viability and adaptability of the proposed solution. In essence, this paper contributes to the ongoing scholarly discourse in offshore engineering, offering a pragmatic solution to the evolving challenges of hydrocarbon extraction in diverse marine environments.

2. PROBLEM STATEMENT

The project's key client, tasked PT Mineering Energi Internasional (MEI) with developing a wellhead platform capable of catering to two distinct fields: the shallow water A Field (~20 m water depth) and the deeper waters B Field (~40 m water depth) and C Field (~65 m water depth), each with a production life expectancy of less than a decade. The field characteristic of Field A, B and C can be found in TABLE 1 as follow:

TABLE 1: TARGET FIELD CHARACTERISTICS

Field Name	Water Depth	Structure Type	Field Type
Field A	22 m	Fixed	Oil
Field B	40 m	Floating	Oil & Gas
Field C	65 m	Floating	Oil

TABLE 2: MET-OCEAN PARAMETERS

Parameters		1-Yr RP	100-Yr RP
Waves (JONSWAP)			
Hs (m)		2.9	4.3
Tp (sec)		8.1	11.3
H_{max} (m)		5.4	7.3
T_{Hmax} (sec)		7.5	9.2
Peakedness Parameter		1.29	1.5
Direction (deg.)		0-360	0-360
Wind and Current			
1hr Wind Speed @10m (m/s)		13.2	18.7
Direction (deg.)		0-360	0-360
Current	$z = 0m$	0.44	0.5
	$z = -d/2m$	0.39	0.44
	$z = -dm$	0.31	0.35
Direction (deg.)		0-360	0-360
Water Levels			
Highest Astronomical Tide (m)		1.9	
Mean Sea Level (m)		1	
Lowest Astronomical Tide (m)		0	

Based on similarity of the fileds, MEI is looking for a type of offshore structure to be used to produce the hydrocarbon with general criteria of the offshore structure as follow:

1. Relocatable offshore structure,
2. Fit for marginal field development, with a design life of minimum 13 years,
3. Suitable for shallow water region
4. Designed to accommodate Dry tree and Jack-up drilling operation,
5. Able to operate in a region known for having issue such subsidence and earthquake
6. Easy to fabricate (simpler, shorter schedule and economic),
7. Simple Offshore installation methode (shorter schedule and economic),
8. Easy to be decommissioned and economic,
9. Topside foot print minimum, for Upper Deck of 338 sq.m and Lower Deck of 712 sq.m,
10. Topside structure designed to withstand vertical load of up to 1,000 MT.

Due to the close proximity of one field to another, the met-ocean parameters are considered to be the same, which can be found in TABLE 2 .

The soil condition on the Field A location is consisted of very soft clay in the upper 13 m layer, which make it difficult for gravity-based foundation. Therefore, driven piles are required to improve the foundation strength. The maximum horizontal ground acceleration for SLE condition is 0.15g.

3. SYSTEM DESCRIPTION AND GENERAL ARRANGEMENT

The typical fixed McT components and general configurations can be found in FIGURE 2, while the floating McT can be found in FIGURE 3. In general, McT consist of four (4) inner cells / cylinder, and four (4) outer cells / cylinder, that are connected to each other by shear plates. The topside is connected to the outer cells at their vertical bulkhead locations to increase the structural capacity. The outer cell consists of lower tank and upper tank. The outer cell's lower tank consists of two (2) Air-Over-Water (AOW) ballast tank separated by a vertical center bulkhead. The outer cell's upper tank consists of four (4) void tanks separated by two vertical bulkheads. On the other hand, the inner cells only consist of a single AOW ballast tank.

The diameter of the cells is design so that they can be fabricated by most typical metal sheet rolling machines. The taller inner cell cylinder can be divided into smaller cylinder section in the workshop, and then stacked at the dry dock / yard. To minimize the topside layout modification and dry-docking time when changing from fixed to floating configuration (and vice versa), the top tension riser (for floating McT) and conductors (for fixed McT) are located at the same side. Skirt foundations [10] with 1.5 m skirt depth is installed for sit on seabed stability, however, additional driven pile foundation may be installed depending on the soil condition. On the other hand, suction pile along with wire tendons are used as station keeping system for the floating McT. Wire tendon is used instead of conventional tendon due to their versatility, ease of installation and decommissioning, and affordability.

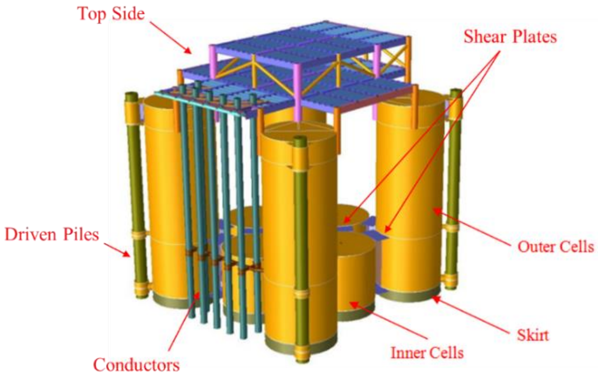

FIGURE 2: TYPICAL FIXED MCT GENERAL CONFIGURATION

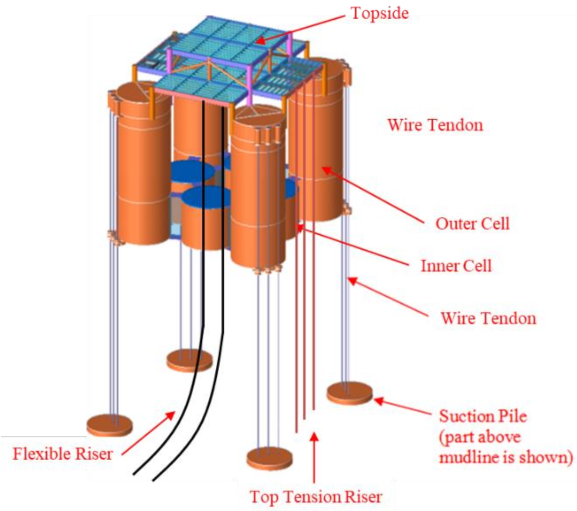

FIGURE 3: TYPICAL FLOATING MCT GENERAL CONFIGURATION

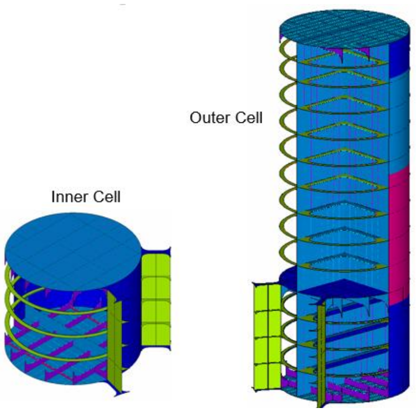

FIGURE 4: SHEAR PLATE, SCANTLING, AND BULKHEAD DESIGN

Various scantling calculation per ABS rules are considered and designed to meets the code requirements (UC<1). The scantling of the cylindrical structures is determined with ABS Buckling Guide, Section 4, in order to take the advantages of cylindrical shells. For flat stiffened panel structure (keel, deck, and bulkheads), is determined per ABS MODU. As can be seen in FIGURE 4, these design considerations resulted in a very simple and easy to fabricate scantling design.

The general arrangement, hydrostatics, and structural configuration can be found in TABLE 3 below. In summary, all design considerations are taken to increase the ease of fabrication, transportation, installation, repurposing, operation, and decommissioning, while maintaining high performance requirement. Which in turns will lower the overall cost over the structure's life cycle.

TABLE 3: MCT GENERAL ARRANGEMENT AND HYDROSTATIC DATA

Items	Values
Characteristic Length (m)	L_c
Outer/Inner Cells Diameter (m)	$0.43\ L_c$
Outer Cell Span (center to center, m)	L_c
Outer Cells Height excluding skirt (m)	$1.23\ L_c$
Inner Cells Height excluding skirt (m)	$0.36\ L_c$
Skirt Height (m)	$0.07\ L_c$
Gap between neighboring cell (m)	$0.09\ L_c$
Operating Weight Fixed / Floating (MT)	8805.8 / 8135.5
KG (m)	$0.39\ L_c$
Roll and Pitch Radii of Gyration (m)	$0.79\ L_c$
Yaw Radii of Gyration (m)	$0.76\ L_c$
Waterplane Area (sq. m)	$0.59\ L_c^2$
Area Moment of Inertia in Transverse and Longitudinal dir. (m4)	$0.16\ L_c^4$
KB (m)	$0.38\ L_c$
BM (m)	$0.21\ L_c$

4. STABILITY ANALYSIS

DNV GL Nobel Denton stability criteria were applied in the stability check. The stability of McT platform during dry dock float-out operation, submergence and wet tow operation were checked in MOSES. Both intact and damage stability were analyzed for towing. The analysis results are summarized below.

- Dry dock floating draft : 5.50 m
- Skirt height :1.50 m
- Keel clearance in dock : 0.50 m
- Dock depth needed : 7.50 m
- GM at dock : 2.21 m (>0.3 m req.)

After floating out of the dry dock, the platform is to be ballasted down to the design towing draft (15.0 m) and towed to installation site. During this process, the platform shall have adequate stability to prevent from capsizing. The analysis results in FIGURE 5 showed that minimum GM value through submerging is 0.40 m (>0.3 m required), which can keep the platform stable when submerging. The wind speed of 35-knots was used for the intact and damaged stability check for towing stability analyses. This speed is 100-yr RP extreme wind speed. The analyses results indicated that McT platform have adequate stability (both intact and damage conditions) for wet-tow conditions, as shown in FIGURE 6. In the case where the quayside / dry dock floating draft is too large for the selected yard, the McT may be loaded into transportation barge, towed to deeper water, then launched and wet-towed to the final location

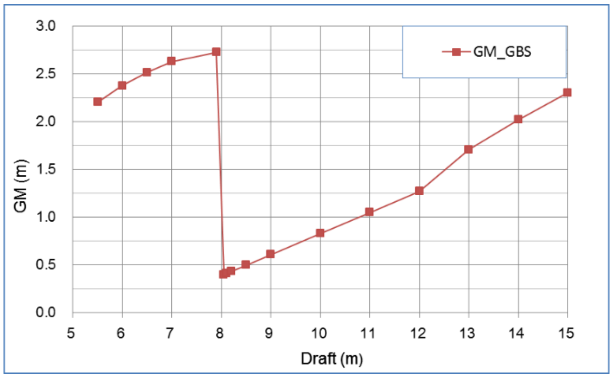

FIGURE 5: GM VALUE DURING BALLAST DOWN FOR MCT PLATFORM

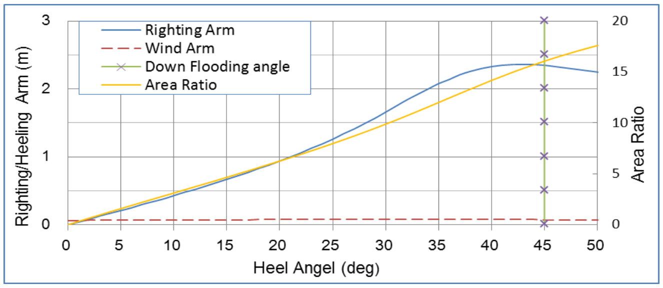

FIGURE 6: TOWING INTACT STABILITY CURVE (MOST CRITICAL CASE)

5. FIXED MCT CONFIGURATION FOR FIELD A ANALYSIS

Finite element simulation tool (SACS) is used to analyze the structural performance of the fixed McT configuration. Both inner and outer cylinder is modeled as beam elements in the SACS simulation. Due to the poor soil condition at the Field A location, four driven (4) piles with diameter of 72" and penetration depth of 60m are required to improve the foundation strength.

The piles are modeled as beam element connected to the outer column, connected by pile guides. Two conditions are check in this stage, the first one is the seismic condition, the second one is the installation and in-place condition. The natural periods of the Fixed McT configuration can be found in TABLE 4 below

TABLE 4: FIXED MCT NATURAL PERIODS

Mode	Frequency (cps)	Gen. Mass	Eigen Value	Period (sec)
1	0.2915	17409.622	0.2980	3.4300
2	0.2960	17975.908	0.2891	3.3785
3	0.4382	15410.416	0.1319	2.2819
4	2.2337	2799.399	0.0051	0.4477
5	2.2604	2868.055	0.0050	0.4424
6	2.2757	7561.956	0.0049	0.4394

Seismic Condition

The SACS model and its boundary conditions for the seismic analysis is shown in FIGURE 7. FIGURE 8 shows the member UCs plot for pile above mudline. It shows that the maximum member UC for the piles above mudline is 0.917, while the maximum member UC for the piles below the mudline are 0.785. Both shows that the pile design is sufficient to withstand SLE level earthquakes

The maximum axial forces on pile heads and pile safety factors at the design depth are presented in TABLE 5. Pile foundation axial capacity for compression is -26835.5KN. The capacity for tension is 19568.5KN. It is shown that the safety factors are larger than the allowable minimum SF of 1.2.

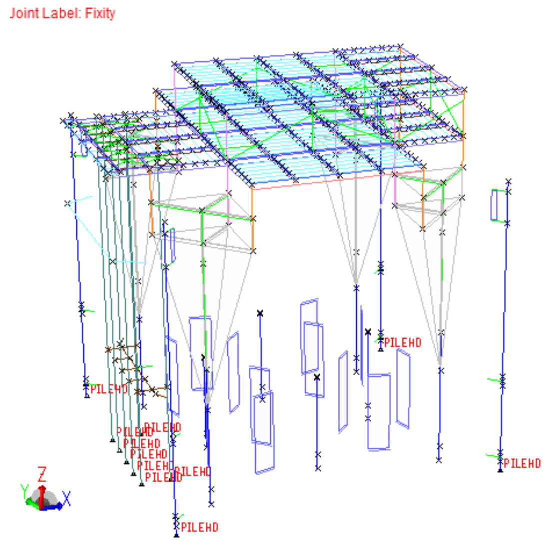

FIGURE 7: SACS MODEL BOUNDARY CONDITION

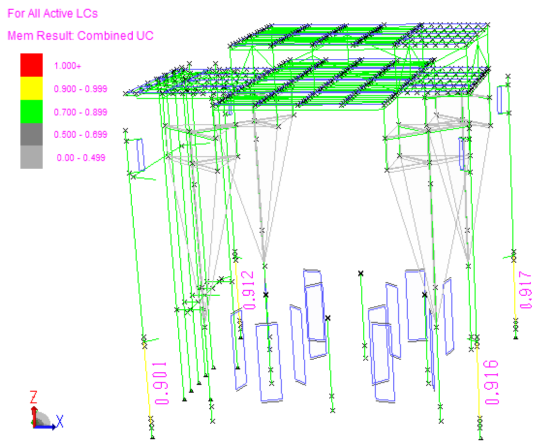

FIGURE 8: NORMALIZED HORIZONTAL RESPONSE SPECTRUM FOR SLE

TABLE 5: SUMMARY OF PILE SAFETY FACTORS FOR SEISMIC ANALYSIS

Pile	Pile Head Joint	Pile Capacity Safety Factors	
		Compression	Tension
PL-1	P100	1.79	1.60
PL-2	P200	1.74	1.62
PL-3	P300	1.69	1.48
PL-4	P400	1.72	1.59

Installation and in-Place Condition

For both the installation and in-Place condition, the wave force, wave diffraction effect, and the added mass is calculated by frequency domain panel method simulation tool.

Before piling, the McT is held in place by the skirt foundation. This "Sit on Seabed" condition is checked against the 80% non-exceedance environmental conditions in SE Monsoon season, which is the predicted installation time window. Both the maximum environmental loads and the capacity check for during the sit on seabed condition is presented in TABLE 6 below. For the sit on seabed analysis, the maximum allowable submerged weight is assumed as 400.0 MT. The results show that the foundations have sufficient bearing capacity and sliding resistance capacity under intended design critical loads.

TABLE 6: MAX ENVIRONMENTAL LOADS AND SKIRT CAPACITY CHECK DURING PLATFORM SIT ON SEABED

Max lateral Loads (MT)	Max Overturning Moment (MT-m)
163.0	2874.0
Min SF of Bearing Capacity @ environmental loads	**Min SF of Lateral Sliding Resistance Capacity**
1.672 >1.5 (Required)	1.725>1.5 (Required)

After piling, the driven pile capacity is checked by considering the operating weight as defined in TABLE 3. The driven pile capacity check and the pile stress check for the fixed McT for in-place condition can be found in TABLE 7 and FIGURE 9.

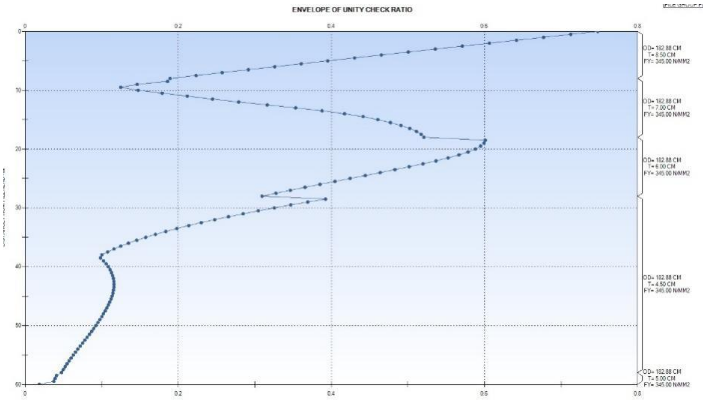

FIGURE 9: PILE STRESS UNITY CHECK FOR IN-PLACE CONDITION

TABLE 7: SUMMARY OF PILE SAFETY FACTORS FOR IN-PLACE ANALYSIS

Pile	Pile Head Joint	Pile Capacity Safety Factors	
		Compression	Tension
PL-1	P100	2.82	2.81
PL-2	P200	2.71	2.99
PL-3	P300	2.82	2.88
PL-4	P400	2.70	2.99

Based on global in-place strength analysis results, it is concluded that compared with operating condition, the 100-year extreme condition is the governing load condition. Furthermore, among all platform columns and piles, the maximum displacements occur at NE (north-east) column and associated substructure element. Therefore, local Finite Element model analysis utilizing shell elements is conducted for the NE column and its respective substructure element. The analysis shows that the skirt pile sleeve structure stresses are well below the allowable stress.

In conclusion, the temporary skirt foundation has adequate capacity to withdraw the intended loads during the platform sit on seabed; and that the pile foundation has adequate axial ultimate capacity and strength under 100-year extreme environmental loads

6. FLOATING MCT CONFIGURATION FOR FIELD B AND C ANALYSIS

Floating McT configuration analysis is conducted by using an in-house time domain fluid – structure – line direct coupling simulation tools. The McT hydrodynamic coefficients are analyzed using panel method in the frequency domain. The natural period of the McT platform in the final configuration is calculated from free decay simulations. In the final configuration, the McT platform is assumed to have all operating loads acting on the platform.

The design target is to limit the heave, roll and pitch natural periods below 4 seconds. This period will provide optimum motion characteristics similar to the Tension Leg Platform (TLP). The summary of the natural periods is presented in TABLE 8 below. The Heave, Roll, and Pitch Natural Periods are well below the wave period, which shows similar order of a typical TLP. Both the surge-sway and pitch-roll natural period are the same in both water depth, owing to the x- and y- plane symmetry of the hull design. The structural motion is therefore may be sensitive to the non-linear effects. To increase the accuracy of the analysis, it is important to consider the second-order hydrodynamic forces through the full quadratic transfer functions (QTFs). In this study, the extreme statistic values are derived from the three-parameter Weibull distribution.

TABLE 8: FLOATING MCT NATURAL PERIODS

Motion	Unit	Natural Periods	
		Water Depth 40 m	Water Depth 65 m
Surge	sec	23.6	33.8
Sway	sec	23.6	33.8
Heave	sec	1.5	1.8
Roll	sec	1.5	1.8
Pitch	sec	1.5	1.8
Yaw	sec	17.3	24.7

Global motion response

The motion summary of McT in intact and broken line conditions is shown in FIGURE 10 and FIGURE 11, respectively. Therein, offset is defined as vector summation of surge and sway motions, while heel is defined as vector summation of roll and pitch. Offset is measured in terms of water depth, heave is in meter, and heel is in degree.

The maximum values of the responses are obtained through post-processing of the 1-hour time domain analysis results in 8 different wave headings. Wind, wave and current loads are assumed to be collinear. For the broken line case, the most loaded line in the direction of wave heading is broken during the time domain simulation. The biggest absolute value between the maximum and minimum is reported as the maximum motions. The maximum offset of McT at the Mean Water Line (MWL) in the intact condition is 12.00% of water depth, while the maximum heave including set down is less than 0.48 m. Maximum heel in intact condition are negligible (less than 0.15 degree). The maximum offset of McT in the broken line conditions are 12.05% of water depth, while the maximum heave including set down is less than 0.47 m. The maximum heel in the broken line conditions is about 0.22 deg. All results shows

McT has good motion performance in both intact and broken line condition

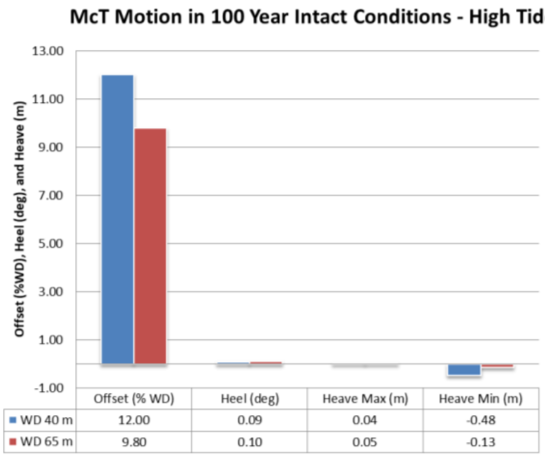

FIGURE 10: MOTION SUMMARY OF MCT IN INTACT CONDITIONS

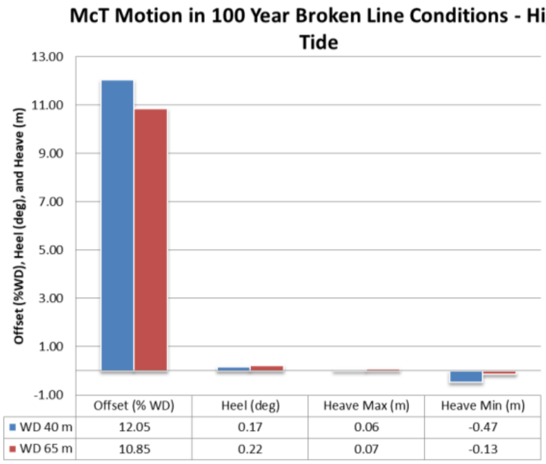

FIGURE 11: MOTION SUMMARY OF MCT IN BROKEN LINE CONDITIONS

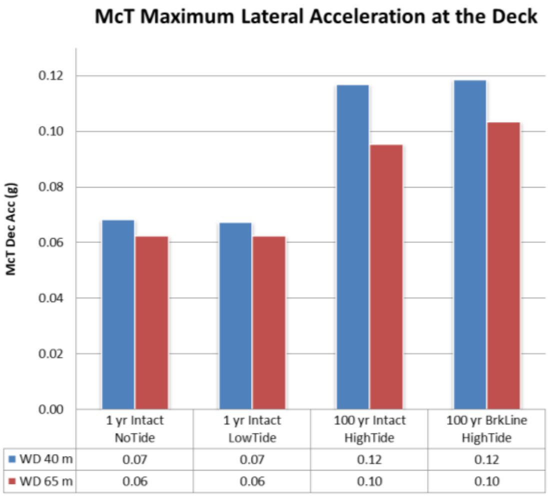

FIGURE 12: ACCELERATION SUMMARY OF MCT

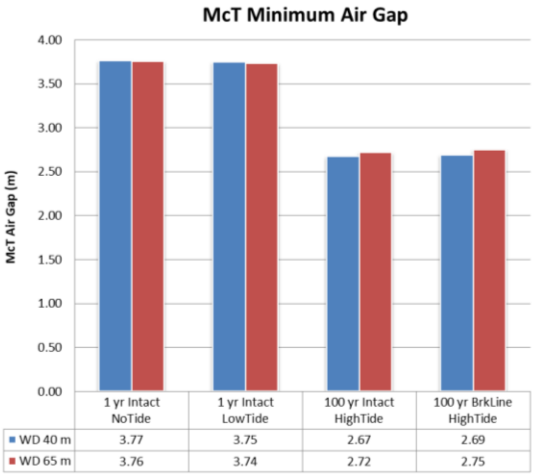

FIGURE 13: AIR GAP SUMMARY OF MCT

McT Platform Lateral Accelerations

Allowable lateral acceleration at Topsides CG is limited to 0.30 g for topside equipment design. Including the gravity component, the maximum lateral acceleration at the topside (20 m above MWL) is 0.12 g in 100 year storm for intact and one line broken conditions as shown in FIGURE 12. This acceleration is quite small in the context of designing topside equipment. In 1 year storm, the maximum lateral acceleration at the topside is about 0.07 g. All results shows the lateral accelerations is well below the allowable.

Air Gap

Minimum distance between the water surface and the McT cellar deck bottom is calculated for the primary deck girders at 7.0 m above MWL. The minimum air gap in 100-year return period, including wave diffraction effect and nonlinear effect, meet the criteria with a ~2.67 m margin. The air gap summary can be seen in FIGURE 13.

Wire Tendon Tension and Suction Pile Design

Suction pile design criteria are based on API RP 2A and API RP 2GEO. The sizes of the designed suction piles are summarized in TABLE 9. The wire tendon consists of spiral strand and R4S Studdles chain, with diameter ranging from 82 mm – 89 mm. The short section of studdles chain is located near the keel where it has sudden change in angle to protect the tendon from damage.

TABLE 9: SUCTION PILE DESIGN SUMMARY

Suction Pile Design	**Values**
Diameter (m)	8.00
Wall thickness (cm)	3.49
Penetration depth (m)	16.00
Total length (m)	17.00
Top cap plate thickness (cm)	5.00

The maximum wire tendon utilization summary is shown in FIGURE 14. The maximum wire tendon tension utilization ratio for intact and broken line condition are 0.30 and 0.40, respectively. Therefore, wire tension for both intact and broken line condition meet the design criteria. As shown in TABLE 10, based on maximum wire tendon bottom tension check, it is concluded that the suction pile design is sufficient to be used for both Field B and C current location.

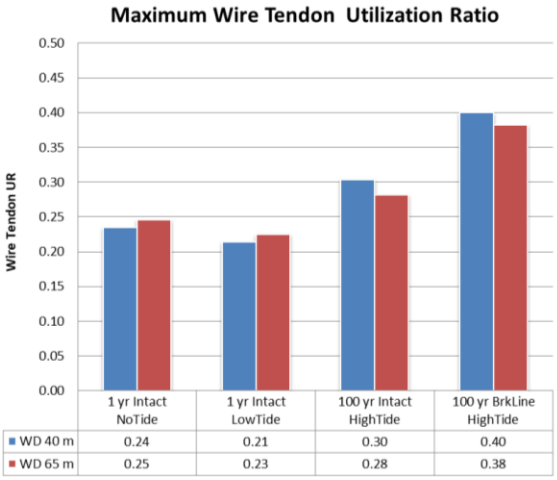

FIGURE 14: MAXIMUM WIRE TENDON UTILIZATION RATIO SUMMARY OF MCT

TABLE 10: SUCTION PILE DESIGN CAPACITY CHECK

Water Depth	Design Maximum Tendon Bottom Tension (3 tendons attached to 1 suction pile)		Check
	Max Allowable	Current Study	
40 m	10,988 kN	8,871 kN	OK
65 m		8,604 kN	OK

Flexible Risers Response

The flexible riser's response summary is shown in FIGURE 15 and FIGURE 16. Both the true tension and bending moment of the 6' gas import and 8' oil export flexible riser shows Ratio to Allowable smaller than one. Therefore, the flexible risers design meets the design criteria with considerable margin.

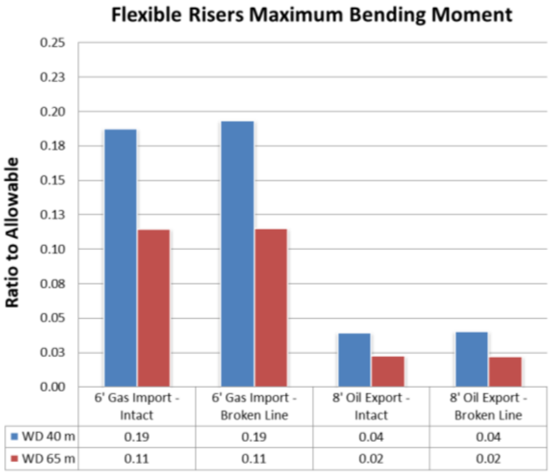

FIGURE 15: FLEXIBLE RISERS BENDING MOMENT SUMMARY – 100YR RETURN PERIOD

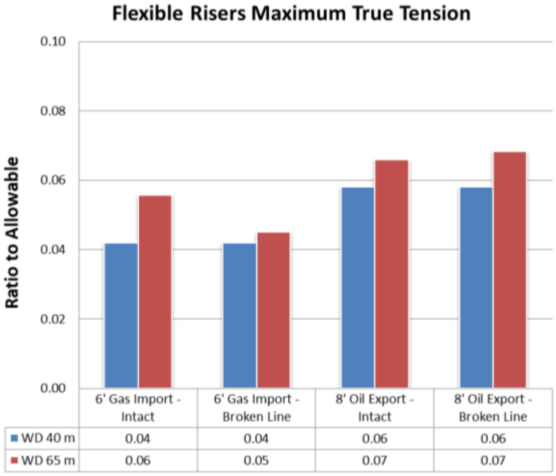

FIGURE 16: FLEXIBLE RISERS TRUE TENSION SUMMARY – 100YR RETURN PERIOD

Top Tension Risers Response

The TTR stroke and top tension riser's summary is shown in FIGURE 17 - FIGURE 18 below. The results may be used to design the Tensioner system. Minimum TTF is shown to be larger than one, which means it meets the design criteria.

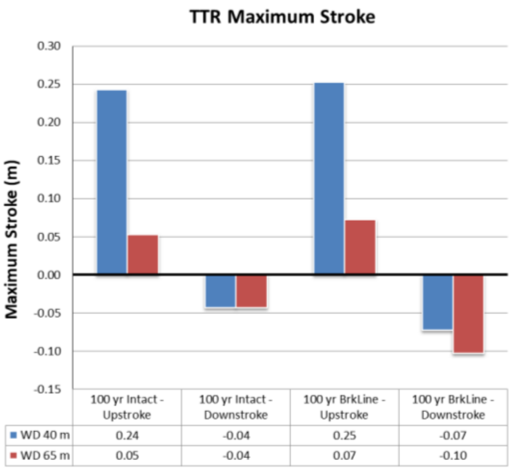

FIGURE 17: TTR UPSTROKE AND DOWNSTROKE SUMMARY – 100YR RETURN PERIOD

FIGURE 18: TTR TOP TENSION FACTOR SUMMARY – 100YR RETURN PERIOD

7. QUALITATIVE COST ANALYSIS

Jacket type structure is considered for cost comparison due to its wide spread usage in the industry and their capability to be operated with dry tree. The qualitative cost analyses is shown in TABLE 11. The analysis shows that the McT is a more financially advantageous option. The advantages of McT is further emphasized when considering multiple use of the structure to develop several marginal field. To obtain a more direct comparison, the cost of the McT must be considered for the development of all three fields. A more comprehensive cost-benefit analysis of McT can be found in [2]

8. CONCLUSION

The study shows an innovative solution of relocatable offshore platform in the form of Multi Column TLP (McT). The McT is designed to be deployed in 20 – 65m water depth, by employing both fixed (bottom founded) and floating configuration. The analysis shows that McT has adequate capacity to be wet-towed, installed, operated, and repurposed for the determined design requirements. Based on the qualitative cost comparison with a typical jacket structure, the economic viability and adaptability of the proposed solution was also highlighted. The final design resulted in an innovative and versatile offshore platform solution that is easy to fabricate, installed, operate, relocate, reused, while maintaining cost competitiveness.

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TABLE 11: QUALITATIVE COST COMPARISON BETWEEN FIXED JACKET STRUCTURE AND MCT

No.	Cost Component	Jacket Struture		McT	
		Cost	Remark	Cost	Remark
1	Engineering Work	Benchmark	Three separate design work for three field, most engineering firms are familiar with the design	Slightly lower	One design fits all
2	Procurement and Construction of Topside	Benchmark	N/A	Comparable	N/A
3	Procurement and Construction of Substructure	Benchmark	Three separate substructure need to be fabricated for three different water depth. The cost will increase as the water depth increases	Significantly Lower	Only one structure is needed to develop three separate field during its whole life cycle. Depends on the familiarity of the fabrication yard with typical TLP / cylinder type floaters, the cost may vary
4	Risers and conductors	Benchmark	Typical conductor	Higher	The use of top tension riser and their respective equipment may increase the cost. However, the cost may be offseted when considering that the jacket type structure additional steel weight for deeper water
5	Transportation & Installation Cost	Benchmark	Top side mating, Hookup, precommissioning, start-up are to be done offshore which increases the cost. Transportation barge ad HLV / crane / piling vessels are needed for three locations for lifting and piling	Significantly Lower	Top side mating, Hookup, precommissioning, start-up are to be done quayside / at the dry dock which decreases the cost significantly. Transportation barge ad HLV / crane / piling vessels are only needed for the fixed McT piling on one field (field A)
6	Decommossioning and repurpossing	Benchmark	Little evidence of financially feasible jacket substructure repurposing projects. All three fixed structures needed an elaborate decommissioning campaign involving lifting vessels and transportation barge	Significantly lower	For fixed McT, pile is cut below mudline, and the structure is deballasted to allow the structure to refloat by itself. Depending on the next project requirement, the structure can directly sail away to the next location after refitting.