Innovative Float Over Installation Approach via Portable DP Vessel

Azlan Abu Bakar

May 18, 2020

Innovative Float Over Installation Approach via Portable DP Vessel

Azlan *Abu Bakar BEng (Hons) MIMarEST*

Synopsis

Topsides float over installation is not new in the industry but the method and technology in executing the float over operation varies and keep improving to increase project efficiency and cost effectiveness. Each method comes with own technical and operational challenges which determine its feasibility and suitability for the project.
A Deck Transportation Vessel (DTV) was upgraded with DP2 capability by adding two portable azimuth thrusters to allow safe and efficient topsides float over installation. Sea trials and annual DP trials were conducted in ensuring DP functionality and performance in compliance to Class requirement.
The operation required high precision engineering and execution considering the close proximity between topsides and existing living quarters platform during the vessel approach towards the Jacket. Additional control measures were taken for safe execution. DP checks were conducted based on certain intervals while approaching the jacket. The topsides installation commenced at first daylight on the 22 May 2017 and successfully completed by noon.
This paper aims to highlight the float over methodology for the topsides using portable DP2 vessel and the technical challenges for offshore execution. The activities during the float over operation, analysis and simulation methods are also presented in this document.
This paper should be an interest to those who will perform the offshore installation via float over method utilizing Portable DP Vessel.

KEY WORDS: Portable; DP2; Dynamic Positioning; Float Over;

1. Introduction

PETRONAS Carigali Sdn. Bhd. (PCSB) undertook the development project located offshore Sarawak, Malaysia within South China Sea. Transportation & installation scope of the Central Processing Platform (CPP) topsides include transportation of the topsides weighing approximately 15,500 MT by Deck Transportation Vessel (DTV) from fabrication yard in Korea to offshore Sarawak and performing topsides installation onto the pre-installed substructure. The platform location is within a field complex, which limit the operation if an anchored barge is used. Avoiding mooring system barge is essential due to limited gap of only 5m between topsides and existing nearby platform for the operation. There are also other marine vessels within neighbouring platforms performing simultaneous activities, which potentially introducing risk of vessel clashing should anchored barge is being used. Float over is a weather restricted operation, hence option with shorter duration float over method is required. Considering the above constraint, a DP2 vessel was proposed for the float-over installation of the topsides.

1.1. Jacket and Topsides

Jacket and topsides view as shown in Figure 1 & Figure 2. The topsides is supported on a Loadout Support Frame (LSF), which is skidded onto the grillage. The topsides have the following characteristics:

- NTE Weight: 15,500 MT
- LCG: 105.84 m (positive forward,)
- TCG: -0.27 m (positive portside)
- VCG: 36.05 m (positive upwards, above keel of DTV)

A box Centre of Gravity (COG) envelope of 2m X 2m X 3m has been applied to nominal COG to establish the worst scenario for various analyses.

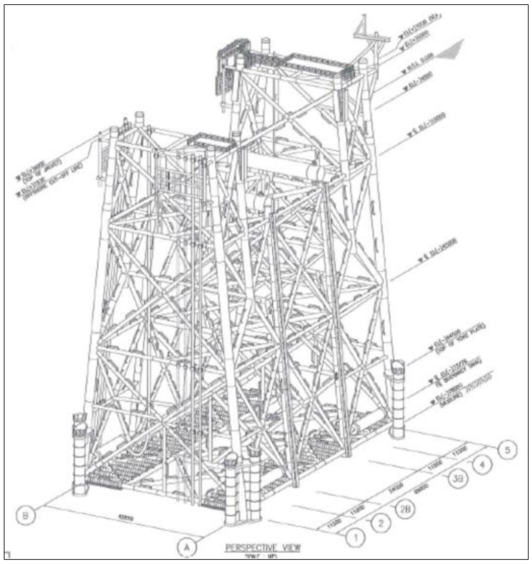


Figure 1: Jacket Perspective View

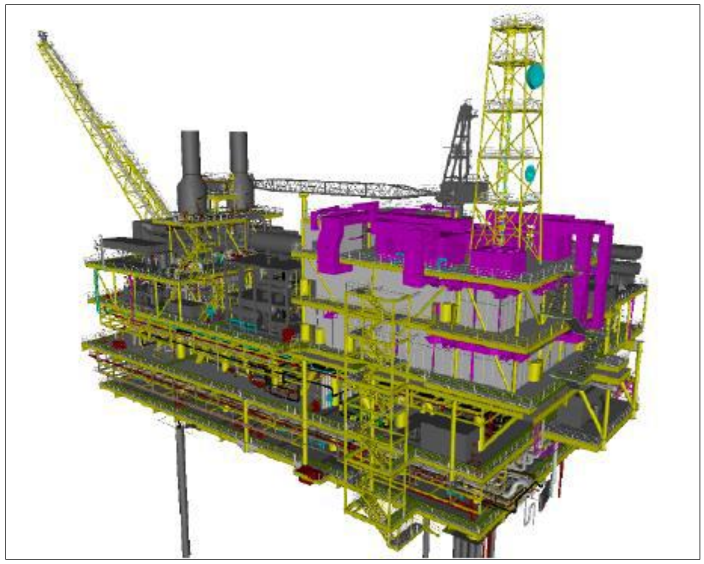
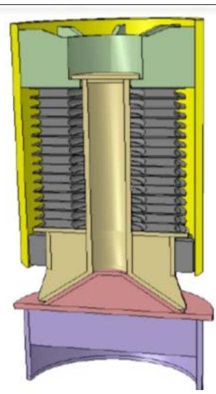


Figure 2: Topsides 3D Model

1.2. Leg Mating Units

Eight Leg Mating Units (LMUs) are installed on the topsides. The LMUs are designed to have a compression stroke of 0.5m under 70% of the topsides weight. In the horizontal direction, the elastomer units are modelled such that the load from any horizontal direction can be achieved by the load/extension value defined. A nominal stiffness of 4,000MT/m for the horizontal elastomeric pads is used for topsides mating analysis. A conceptual picture of LMU and the vertical stiffness is shown in Figure 3.



Leg	LMU Stiffness (MT/m)
A1	1680
A2	3500
A4	3500
A5	2310
B1	2310
B2	3500
B4	3500
B5	1680

Figure 3: LMU Configuration and Stiffness

1.3 DTV Particulars

Vessel characteristics and main dimensions are detailed out in Table 1.

Table 1: DTV Particulars

Particulars	Value
Length, O.A.	216.70 m
Length, P.P.	212.13 m
Breadth, Moulded	43.00 m
Depth, Moulded	13.00 m
Summer Load Draught	9.68 m
Lightship Weight	20,933.2 MT
Service Speed	14.0 knots
Web Frame Spacing	2.40 m
Uniform Deck Strength	25 MT/m2
Ballast System	Air compressors
Capacity (each)	4x6,600 m3/hr @2.5bar
Ballast pumps Forward	2x1,000 m3/hr @3.0bar
Ballast Pumps Aft	2x200 m3/hr @3.0bar

Figure 4: DTV Vessel

2. Engineering Analysis and Methodology

2.1. Hydrostatic Modelling

The stability analysis is carried out using hydrostatic software package GHS by Creative Systems. GHS is software for the design and evaluation of all types of ships and floating structures. It addresses floatation, trim, stability and strength by calculating the forces involved using mathematical/geometrical models of the vessels. The software is considered to be an industry standard and is well proven, reliable and respected by regulatory agencies and used by major design firms and shipyards. The topsides is modelled as a block for wind heeling moment calculation in GHS, which is classed as “sail” part without buoyancy provision.

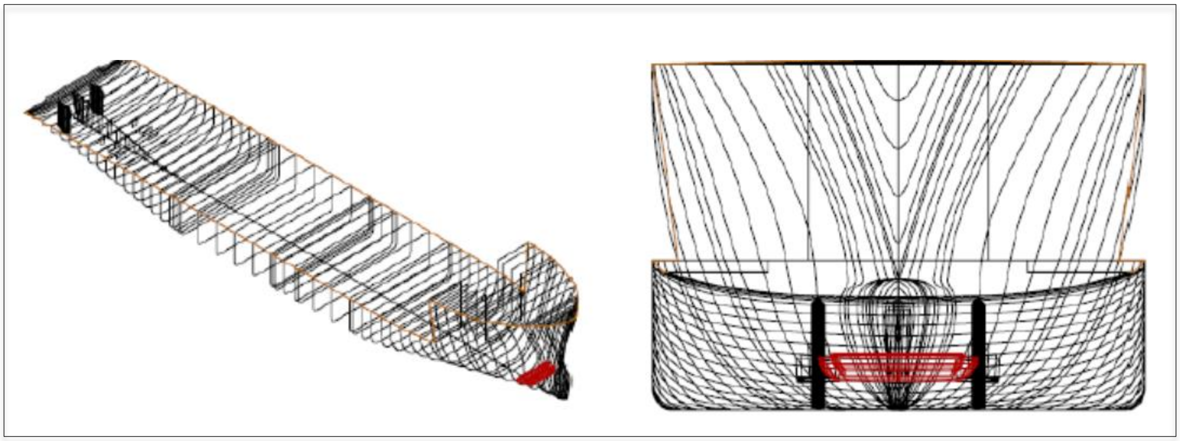


Figure 5: Hydrostatic Model – Hull Outline

First, a geometry model of the DTV is constructed using the GHS PM programs. Results of this step are hull forms and tank arrangements. Model of DTV used in GHS is shown in Figure 5. After geometry of DTV hull is obtained, tank arrangements are made, which will give the capacity and property of each tank

2.2. Ballast Arrangement during Transportation & Installation

Ballast water shall be arranged properly to maintain the floating status of DTV required for transportation and installation. Based on the weights identified, ballast water arrangements are derived for each case. Ballast is mainly controlled by compressed air. Tanks are pressurized to expel and under-pressurized to fill ballast water. Ballasting capacities:

- Total ballast tanks: 82 tank
- Total ballast water volume: 88005m3
- Tanks controlled by air compressors: 73 tanks
- Ballast water volume controlled by air compressors: 77571 m3
- Air compressor capacity: 6600 m3 /hour x 4
- The pressure of air in a tank is from -0.5 bar to 2.5 bars relative.
- Each ballast tank has an independent inlet/outlet pipe.
- Each air-compressor-controlled tank has an independent air vent pipe.
- Ballast Pump: Forward: 2 X 1000m3/h/3.0bar; Aft : 2 X 200m3/h/3.0bar

It should be noted that mating of the topsides with jacket is mainly done by ballasting the DTV, which will be helped by gravity ballast to achieve a high ballast rate. During previous ballast test, the DTV has achieved more than 45,000 m3/hour ballast rate.

2.3. Longitudinal Strength Limits

Two sets of longitudinal strength limits of DTV extracted from the loading manual are used to assess the global strength in terms of operational conditions. For the cases of transportation, strength limits of transit condition apply. For the cases during mating process, strength limits of submerged condition apply.

Based on the loading conditions, resultant longitudinal loads, consisting of bending moments and shear forces, are calculated and assessed. Maximum loads and maximum UC (maximum ratio of loads to limit) are extracted. The maximum UCs are checked to ensure all loads are within the strength limits.

2.4. Vessel Motions and Accelerations

The motion analyses are carried out using 3D hydrodynamic software package AQWA, which is based on diffraction theory. AQWA allows a full 3D model to be created and the motions and accelerations to be evaluated from a combination of environments in the frequency or time domain. The mating analysis is performed by using the software for stages and sequence are described below.

Table 2: Summary of Mating Sequence

STAGE		STAGE 1~3	STAGE 4	STAGE 5	STAGE 6	STAGE 7	STAGE 8~10
Description		Entry	Initial contact btw LMU & stabbing cone	40% Load Transfer	70% Load Transfer	100% Load Transfer	Exit
Action		Entering the Jacket	1st Ballasting	2nd Ballasting	3rd Ballasting	4th Ballasting	Final Ballasting (if required)
Vessel Draught (mm)		8000	9500	9823	10000	10000	11000
Vessel Draught Change (mm)		0	1500	323	177	0	1000
LMU - Stab Cone Gap (mm)		1050	0	0	0	0	0
LMU Compression (mm)		0	0	323	500	500	500
DSU - Under Deck Clearance (mm)		0	0	0	0	0	942
Underkeel Clearance without Considering Tolerance (mm)	EL +12(Stage 1-7) /MSL (Stage 8-10)	5444	3944	3621	3444	3444	2432
	HAT (EL+900)	6332	4832	4509	4332	4332	3332
	LAT (EL-1200)	4232	2732	2409	2232	2232	1232

2.5. Damage Condition Assessment

Both intact condition and one thrust failure condition will be assessed to ensure the DP capacity for the float over installation. The assessment will be presented in the installation vessel DP capacity assessment report. In case of whole DP failure or malfunction case during the load transfer (mating stages), two standby tugs will be used for emergency.

2.6. Time Domain Modelling

For each stage, ten (10) wave seeds will be run for each environmental condition. The simulation period for each stationary stage shall be determined separately to reflect the actual operational period multiplied by a factor of two. The operational period for each stage is estimated based on the DTV ballasting capacity of 20,800MT/hour and 30-minute simulation for each wave seed is considered sufficient. Time step of 0.02 seconds is used for mating stages and 0.05 or 0.1 seconds for docking and un-docking stages. The time series are constructed randomly in AQWA. The mean of maximum load of all ten simulations for each stage is selected as the design load.

2.7. Results Reporting

Interactions between the DTV, the topsides and the jacket will be reported in terms of loads in the LSF support points, LMUs, Sway Fenders and Surge Fenders. These loads will be used to check the structural integrity of the topsides, jacket and LSF. The maximum of significant motions at topsides legs at Stage 3 and maximum motion at the LSF tips at Stage 8 will be produced. The derived motions should be less than the allowable motions of 0.5m generally. The minimum under keel clearance during the exit stages in worst scenario is 2.058m, which meets the limiting criteria of 1.0m.

2.8. DP Capability Assessment

The API RP 2SK (2005) gives guidance on the type of analysis to assess the dynamic positioning capability, efficiency of the propulsion system and consequently the amount of thrust delivered to the water. Two methods are suggested to analyze the position keeping capability of a DP system: mean load reduction method, and system dynamic analysis. For the float-over operation in this project, the mean load reduction is adopted to perform the assessment. This is a simplified method and essentially a static equilibrium analysis. The API RP 2SK (2005) makes reference to IMCA Specification for DP Capability Plots (IMCA M140, 2000) for calculation of capability by simplified method.
IMCA Specification (IMCA M140, 2000) gives guidance on the creation of DP capability plots based on the mean load reduction method. Guidance is given on obtaining mean loads due to 1-minute averaged wind speed, current speed and wave drift loads. These loads may be obtained from model tests, or from analytical methods. It is recommended that 1-minute mean wind speed at 10m above sea level, and 1-knot current speed be applied in the analytical derivation of the capability plots. Also a range of sea-states are provided for the Forties field in the North

Sea. These include significant wave height, peak and zero crossing periods, and the 1-minute mean wind speed corresponding to the significant wave height. The significant wave height includes a component for swell, approximately 1m. The range of wind speed given is from zero to 35 m/sec.
IMCA specification (IMCA M140, 2000) also recommends approximate values for net thrust per horsepower imparted to the water. It is assumed that the tunnel thruster gives identical amount of thrust in positive and negative directions, i.e. 11 kg/hp. For the main propellers an efficiency of 13kg/hp should be assumed and the astern thrust limited to 70% when propellers are reversed. The azimuthing thrusters are assumed to give 3kg/hp in the ahead pitch and 8kg/hp in the astern pitch condition. The azimuthing thrusters may operate on either fixed or free azimuthing modes. Fixed azimuths indicate that whatever the fluctuations in wave, wind or current directions the azimuths always stay at a fixed heading relative to the vessel. Free azimuths are permitted to rotate around to compensate for the change in environmental load and direction. In the free mode of operation, there is a ‘barred’ zone in which one of the thrusters produces zero thrust to avoid thruster/thruster interaction.

2.9. Thrusters Information

The vessel has totally six thrusters equipped as illustrated in Figure 4, consisting of two bow tunnel thrusters (T1 & T2), two main propellers (T3 & T4), and two portable azimuthing thrusters (T5 & T6) that are to be installed at aft.

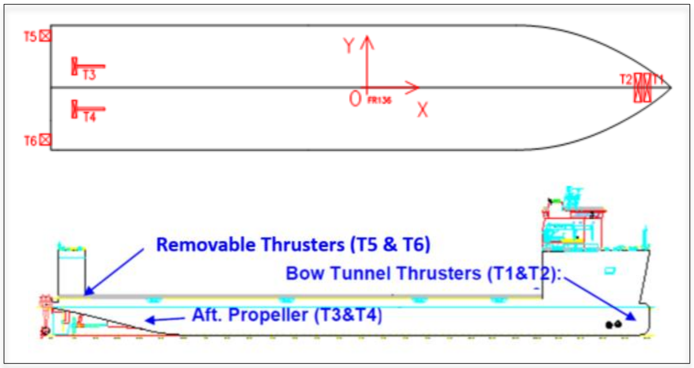


Figure 1: Sketch of Thrusters Layout

Locations (with respect to vessel coordinate system) and capacity of each thruster are listed in Table 3.

Table 3: Location and capacities of thrusters

Thruster	Locations		Power [hp]	Thrust [MT]
	X [m]	Y [m]		
Bow Thruster T1	96.40	0.00	1608	17.7
Bow Thruster T2	93.20	0.00	1608	17.7
Aft Propeller T3	-100.00	7.00	7040	91.5
Aft Propeller T4	-100.00	-7.00	7040	91.5
Portable Thruster T5	-110.60	17.80	1500	19.5
Portable Thruster T6	-110.60	-17.80	1500	19.5

2.10. DP Capability Plots

The DP Capability Plots are presented in Figure 5 for the scenario of all thrusters intact, and in Figure 6 for amalgamation of the worst cases in failure modes (single thruster failure).

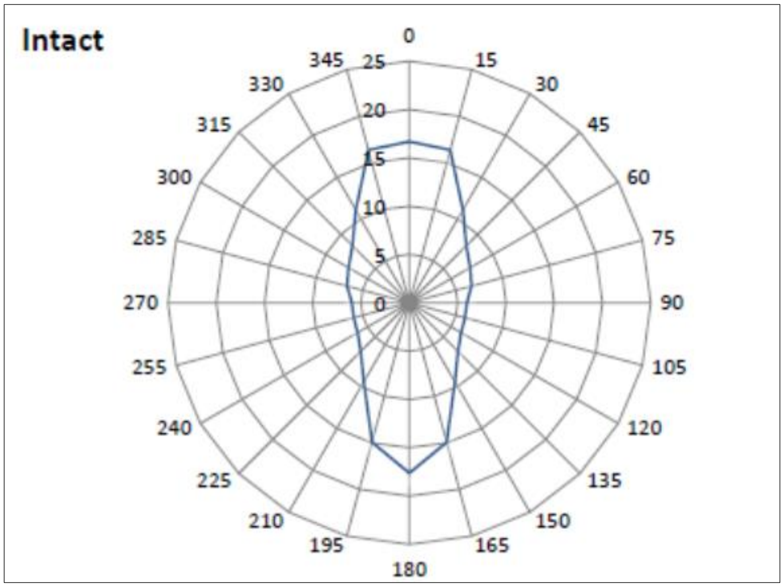


Figure 2: DP Capability Plot - All Thrusters Intact

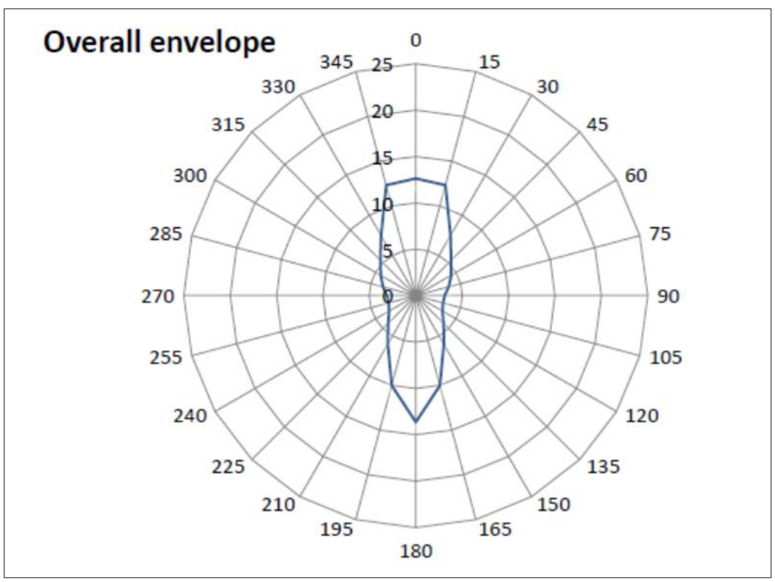


Figure 3: DP Capability Plot - Overall Envelope of Failure Modes

From the DP capability plots of all the scenarios analyzed, it is observed that the critical environmental direction with regard to the DP system is on the beam sea. Failure of any one of the two bow tunnel thrusters can result in poorer performance when subject to beam sea and quartering sea environmental forces. In conditions of head sea and following sea conditions, DP system can counter more severe sea states as main propeller with high power can effectively functioning for DP purpose and therefore enhancing DP capability. Comparison of maximum environmental parameters for DP operation and allowable sea states for mating operation are presented in Table 4.

Wave direction illustration as shown in Figure 7. Through the comparison, it can be noted the allowable sea states for mating operation are well within the maximum sea states limited by DP capability for both intact and failure modes (single thruster failure).

Table 4: Allowable Sea States for Float Over Installation

H_s [m]	T_p [s]	Spectrum	Direction	Current [m/s]	Wind [m/s]
1.5	5,6,7	JONSWAP	Stern (0°)	0.5	7.5
1.0	5,6,6.5		Stern Quarter (45°,315°)		
0.5	4,5,5.5		Beam (90°,270°)		
1.0	5,6,6.5		Bow Quarter (135°,225°)		
1.5	5,6,7		Head (180°)		

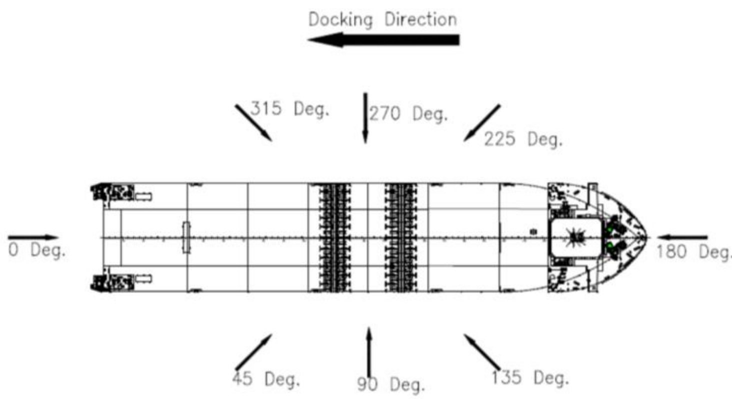


Figure7: Wave Direction Illustration

2.11. DTV DP Conversion

The DTV was originally designed as a semi-submersible vessel and was not originally intended as a DP vessel despite of having a high level of redundancy in its power, control and propulsion system to meet DNV GL RPS requirements. The DTV was converted from an anchored vessel to portable DP2 vessel in 2014. It means that two (2) portable thrusters can be attached to the vessel's stern to form the Dynamic Positioning System whenever needed by the project. The converted DP2 DTV had successfully performed its first float over project in 2014 (*Yan Zhu et al, 2016*). Since then, the portable thrusters had been detached from the vessel following different project requirement and business needs.

For this project, the installation of two (2) portable DP thrusters to the vessel was carried out in Jan 2017. Sea trials and the Annual DP Trials were conducted in stages from 17th to 19th January 2017. Also conducted were DP Performance Tests, Ballasting and Deballasting Tests. Based on the DP Trials, the vessel has been issued an Interim Classification Certificate with notation “Semi-Submersible Heavy Lift Vessel; Ice Class B; Loading Computer (S,I); In-Water Survey; AUT-0; DP-2; PR-2S; SCM” valid till 19-June-2017.

On the basis of compliance with IMO 1994 MSC/Circ. 645, IMCA guidelines, findings and recommendations, the vessel is considered capable of carrying out DP Class 2 operations within the normal operational limits of the vessel.The annual DP trials should be carried out within three months before or after each anniversary date of the initial survey.

Figure 8: Portable DP2 Thruster

2.12. Grillage

The topsides will be loaded out from the quayside skid beams onto the DTV skid beams. The load-out is transverse to the DTV and skid beams will be fitted across the DTV main deck. Once loaded out, the skid beams onboard will act as grillages for the CPP topsides transportation.

The grillage system acts as supporting structures to take the vertical load from topsides (inclusive of LSF) during loadout and transportation. Structure of grillage system is designed with characteristics of multilayer and wide span on vessel deck in order to maximize utilisation of more web frames for support. Grillage structure configuration on main deck as shown in Figure 9.

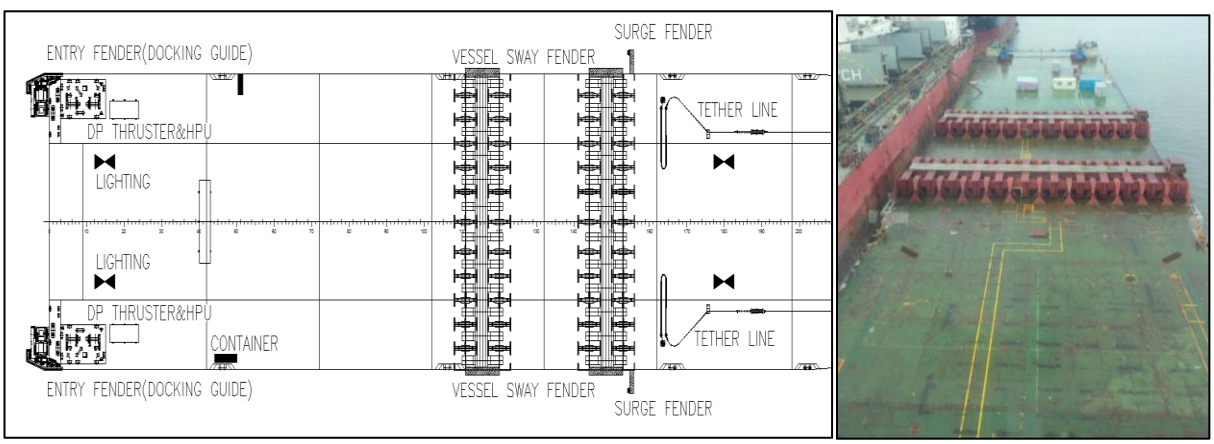


Figure 9: Grillage Layout

2.13. Fendering

Vessel sway fenders are located at starboard and portside to keep the clearance between the jacket sway fender and the DTV with 50mm when the DTV is positioned nearby the final location. Two vessel surge stoppers are fitted to DTV side shell on starboard and portside. The surge and sway fenders arrangement on DTV is presented in Figure 10.

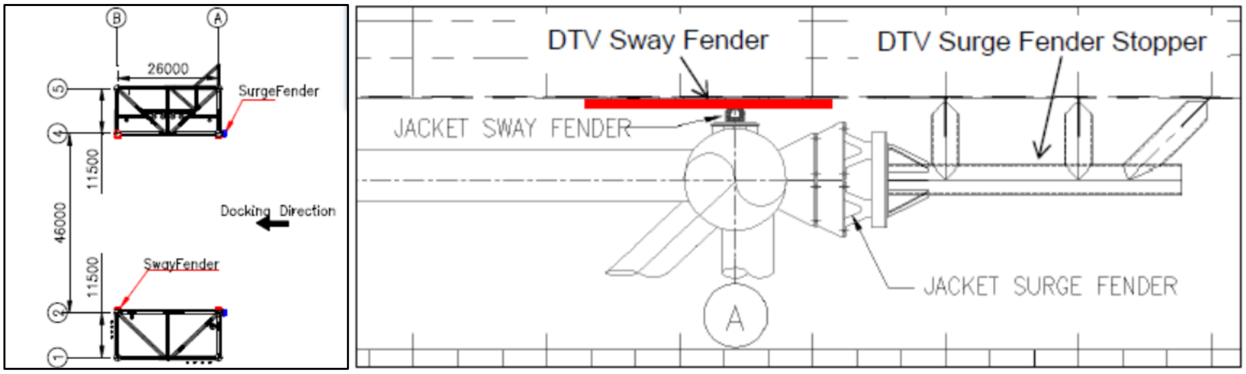


Figure 10: Surge & Sway Fender

2.14. Docking Guide

The stern guides are constructed to assist the initial docking of the DTV into jacket slot. The guides extend approximately 6m behind the stern with an angle towards the center of the DTV. During the docking operation, the stern guide allows for an approach offset from the center line of the jacket slot of approximately ±2m. The installation vessel docking guide arrangement is presented in Figure 11.

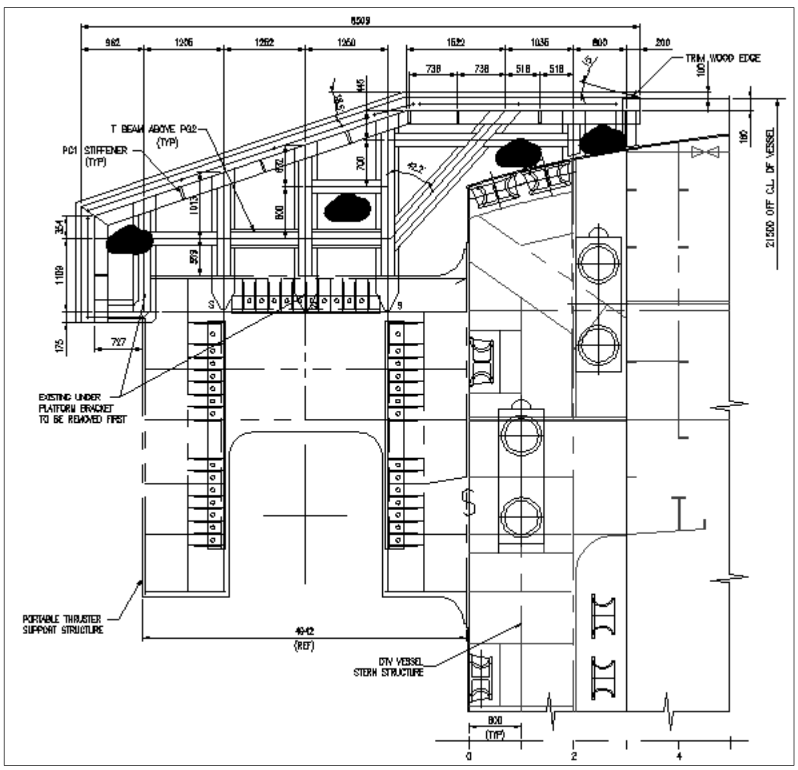


Figure 11: Docking Guide

2.15. Position Monitoring System

Function of the position monitoring system is to directly provide the DP system with the position of the DTV relative to the jacket during approach. The straight-line approach will start approximately 500m away from the jacket and continue until the DTV is in the mating position between the jacket legs.
Two local position monitoring systems will be utilized for the approach, one is laser based CyScan system (as primary) with 0.5% position accuracy and the other is microwave radar-based RADius system (as backup) with 0.25m position accuracy. The layout for DP tracking system is shown in Figure 12.

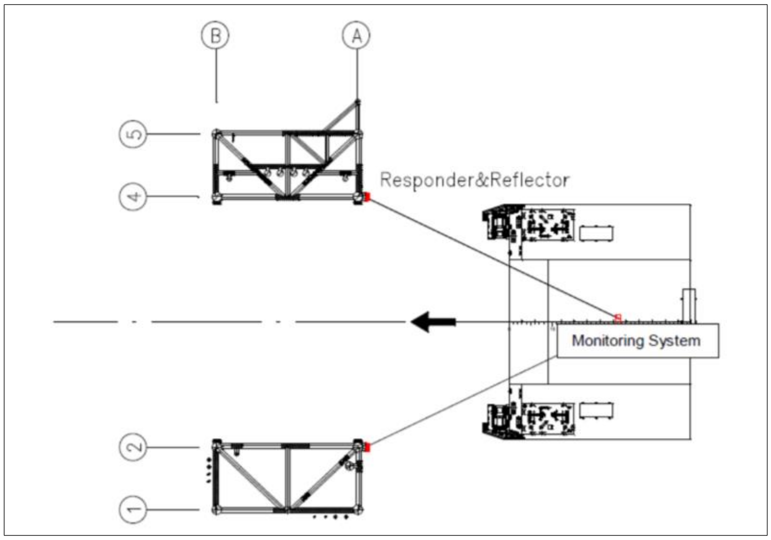


Figure 12: Position Monitoring System

2.16. Motion Monitoring Systems

Function of this system is to provide the real-time & short-term statistic motions of important points on DTV and topsides. In general, the server will start from approximately 500m away from the jacket and continue until the DTV finish undocking.
During the float-over operation, the following motions should be monitored.

- Real-time & short-term statistic motions and accelerations of DTV COG. (heave, roll, pitch, yaw, sway and surge)
- Real-time & short-term statistic motions and accelerations of topsides-mounted LMU receptacles. (heave, sway and surge)
- Real-time positions and elevations of the topsides-mounted LMU receptacles relative to the jacket-mounted stabbing cones. The clearance between the reference heights of each of the eight pairs of receptacles and cones shall be continuously displayed graphically with a time history.

2.17. Environmental Monitoring System

The environmental monitoring system has two primary functions. The first function is to confirm that the conditions are suitable for the mating operations to proceed, and to provide input for DTV's positioning system. The secondary function is to predict weather and environmental pattern prior to and during the installation operation.
The wave radar, wind gauge, tide gauge, current meter will be installed infield upon arrival of DTV to obtain the environment information. All acquired environmental information will assist in decision-making on when to proceed with the float over operation. Feedback from tug can be a source for verification of wind speed and direction.

3. DP Float Over Operation

Upon arrival of DTV at field, DP Field arrival check was performed at a standby position 1000m from the jacket .Prior to commencement of operations, readiness of all systems was verified against the infield checklist prepared. The 36 hours weather forecast was obtained and confirmed favorable. A “Go-No-Go” meeting was organized onboard DTV attended by the key personnel and upon all parties satisfied with the condition, the green light was granted for the float over operation and Certificate of Approval (CoA) was issued by the Marine Warranty Surveyor (MWS).
Although the docking operation is described in a few stages, the operation itself is a continuous operation under the control of DP Operators (DPOs) and Installation Superintendent. DTV started with initial approach to 500m from jacket while DPO performing the entry check and log the condition in checklist. DTV was then moved in steps to a position with the stern approximately 100m from the jacket and until DTV’s stern guide engaged the jacket. DTV’s motion and position, including rolling, LMU sway and clearance with the nearby platform was closely monitored. Thruster utilization was monitored and relevant data was logged.
When DTV stern guide tips were aligned with jacket Row A (this is the “No-Return Point”), manoeuvring of the DTV became a combination of DP and/or manual thrust control as determined by the DPOs. Seafastening cutting was performed as instructed by the Installation Superitendant. Final DTV position was achieved when jacket surge fenders were in contact on both sides. Ballasting was performed folllowing the mating sequence. Separation between the topsides and LSF was observed approximately after 70% transfer of topsides load.
Undocking started when the air gap between the topsides and the LSF reached a minimum 500mm for a period of time. When the DTV was confirmed free of any attachment to the platform, the thrusters was slowly powered up to exit until DTV was 500m away from the jacket indicating the successful completion of the float over. It took approximately 3 hours to complete the operation from DTV jacket entry until the exit.

4. Project Challenges

DTV arrival at Guangzhou for grillage installation was delayed 5 days from the original plan due to late completion of the previous project. Therefore, some mitigation measures need to be taken to expedite grillage installation from 45 days to 40 days to meet the deadline.
Dimensional Check (DC) accuracy is very essential for float over operation. Any significant out of tolerance may result to LMU failure and subsequently affecting the whole operation. It was found out prior to the loadout that there was a DC issue between jacket leg separation and topsides LMU separation. Hence, specific finite element analysis was performed to confirm its integrity for mating purposes. For smooth entering into the jacket slot, it is important to ensure that the minimum gap at each side of the vessel is no less than 50mm. Therefore, the dimension of the jacket sway fenders together with DTV surge fender need to be accurate and controlled to meet such requirement.
As shown in Figure 13, close proximity (5 meters) between the CPP topsides and existing neighbouring platform during the vessel approach towards jacket was a challenge to the project. A typical minimal distance of 10m as per international guideline could not be achieved hence requiring specific risk assessment to be conducted. Considering the risk, a few mitigation measures identified including mobilization of additional DPO, standby tug at field in case of emergency and putting dedicated survey system & CCTV to monitor the gap while approaching. An engineer from thruster manufacturer was also engaged and made available onboard to rectify any DP interruption due to thruster. Position Monitoring System, Motion Monitoring System and Weather Monitoring System were continuously monitored for safe execution.

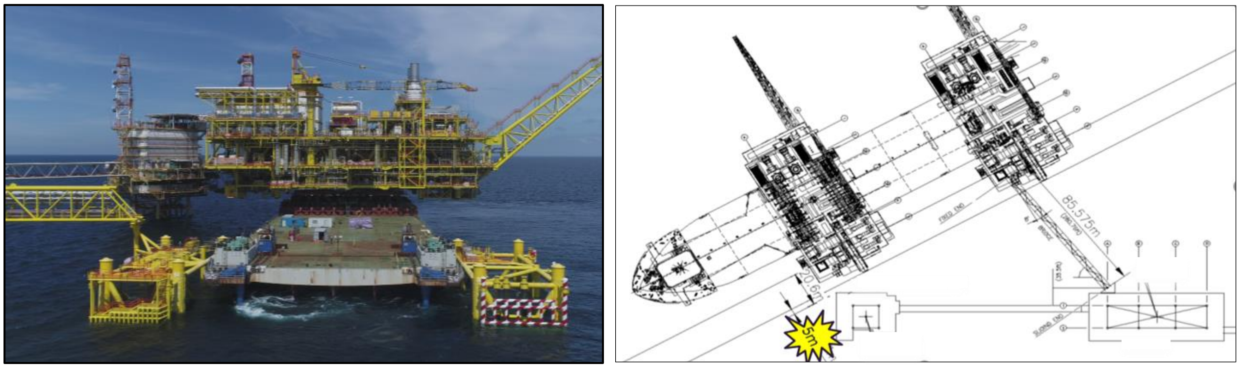


Figure 13: Closed Proximity with Existing Platform

As the weather direction was towards the beam of the vessel, significant wave height, Hs of 0.5m with peak period, Tp of 5.5s shall be the governing sea state limitation (Refer Table 4). Hence, available weather window to perform the operation need to be closely monitored. Once the window identified, careful planning with consideration of tidal condition was taken for the execution.

5. Conclusion

This paper presents a comprehensive description of the portable DP float over technology method that has been successfully applied on the float over installation of the CPP integrated topsides in South China Sea. Float over installation by portable DP2 vessel was again proven to be technically feasible and this float over project would be an example for future projects undertaking the same approach.

Utilizing portable DP2 vessel technology benefits this challenging float over operation to be operated safely, thus executing its intended activities as rapidly as possible within a much shorter timeframe.

It is anticipated that expensive daily charter rate of DP vessels become more competitive and cost-effective in the float over market with the portable DP vessels, which play an important role in the float over installations. There are clear benefits to cost due to involvement of less marine spread and higher operability, and also to operational safety due to a shorter execution period.

The DP-assisted float-over method thus offers clear advantages over the traditional, mooring-assisted approach.

6. Acknowledgements

Special thanks to the Project Management Team (PMT) and Offshore Installation Department (DCI) of Construction & De-commissioning Delivery (CDD) for the enthusiastic support, invaluable experience and expertise. Very special appreciation to PETRONAS management for granting the permission to publish this paper.

7. References

GL Noble Denton General Guidelines for Marine Projects, 0001/ND, Rev. 0, June 2013

GL Noble Denton Guidelines for Load-outs, 0013/ND, Rev. 7, June 2013

GL Noble Denton Guidelines for Load-outs, 0013/ND, Rev. 7, June 2013

General Guidelines for Marine Projects (2015), DNV GL Noble

GL Noble Denton General Guidelines for Marine Projects, 0001/ND, Rev. 0, June 2013

GL Noble Denton Guidelines for Marine Transportations, 0030/ND, Rev. 5, June 2013

GL Noble Denton Guidelines for Float-Over Installations/Removals, 0031/ND, Rev. 1,June 2013

PTS 11.03.02 Float Over Engineering Design and Installation

PTS 37.00.00.40. Positioning and Site Investigation Survey for Offshore Engineering and Construction

Specification for DP Capacity Plots, IMCA M140, Rev. 1

Yan Zu, Chunyiu Chiu, Chungun Cho, Andy Wang, Alex Ruskin, Xiaohong Qiu (2016). “DP Conversion for a Successful Float-over Installation” Proceedings of the Twenty-Sixth International Ocean and Polar Engineering Conference, 1098-6189