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SHAPING OPERATING PROCEDURES BY SIMULATING COMPLEX FLOAT OVER OPERATIONS WITH HUMAN IN THE LOOP

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DNV

Abstract

This paper presents results from real-time dynamic simulations used to assess and define procedures for a topside floatover operation, scheduled for Q4 2025. The operation, performed with a semi-submersible heave lift vessel, is technically demanding due to challenging swell conditions and the need for extreme precision: only 100 mm clearance exists between elastomeric fenders and the jacket structure. Any uncontrolled motion could overload fenders, trigger adverse DP responses, and force an abort.

The simulation campaign—using DNV simulator in the loop with the actual DP control system operated by the DP operators that will run the actual operation—evaluated vessel behavior, fender-jacket interaction loads, DP control system settings, limiting weather conditions, equipment failures, and human factors such as decision-making, teamwork, and situational awareness. A strong emphasis was placed on the human element, ensuring simulations were realistic yet manageable, and providing training for high-stress scenarios. This approach represents one of the first applications of human-in-the-loop DP simulation for floatover operations with such stringent clearance requirements, directly linking operator behaviour with technical system performance. The work demonstrates how simulation can move beyond verification to actively shape operating procedures and enhance industry practice in Activity-Specific Operating Guidelines (ASOG), installation protocols, and exit plans.

Abbreviation / Definition

Abbreviation	**Description**
ASOG	Activity Specific Operating Guidelines
CAPEX	Capital Expenditure
DP	Dynamic Positioning
DPO	Dynamic Positioning Operator
FLNG	Floating Liquefied Natural Gas
Hs	Significant wave height
NNM	Not-normally manned
OPEX	Operating Expenditure
RAO	Response Amplitude Operator
T&I	Transport and installation
WCSF	Worst-case single failure

Introduction

A not-normally manned (NNM) platform, with minimal processing/utility systems will be installed with a float over operation scheduled to be undertaken in Q4 2025. The project's purpose is to supply additional ("backfill") gas (and associated liquids like condensate and LPG) to an existing Floating LNG (FLNG) facility. This represents a particular challenge due to the prevailing swell conditions. The floatover will be executed by the DP2 vessel, see a sketch in Figure 1.

Figure 1: Image of a semi-submersible heavy lift vessel (generated with CoPilot)

Within the scope of the T&I subcontractor is the engineering to support the marine operation including the development of the ASOG. Physical model tests have been performed with the semi-submersible heavy lift vessel and topside for both transport and float over operations. The model tests included preliminary tests employing different operational strategies.

The float over operation is performed in different steps:

1. Topside loadout: The fully constructed topside is loaded onto a barge or a purpose-built heavy-lift / semi-submersible vessel at a fabrication yard.
2. Transport: The vessel carries the topside to the offshore site, sometimes over long distances.
3. Jacket readiness: The jacket is already installed and secured to the seabed, with temporary structures for the float over in place.
4. Positioning: The vessel is maneuverer into position (stern on) between the jacket legs, often using Dynamic Positioning (DP)/ manual control. Extreme accuracy is required, as clearances between the vessel fenders and the jacket can be only a few centimetres.
5. Docking and Alignment: Fenders and docking cones help guide the vessel into the correct position while absorbing impacts. The vessel must remain stable in waves, current, and wind while maintaining alignment with the jacket.
6. Load Transfer: The vessel is carefully ballasted (by pumping seawater into ballast tanks) to lower its deck, transferring the topside's weight gradually onto pre-installed support points on the jacket.

This step is critical as the transfer must be slow and controlled to avoid shock loads. In a semi-submersible vessel floatover, the deck submerges so the topside structure rests on the jacket.

7. Final Positioning: Once the topside load is fully transferred, the vessel continues ballasting down and then moving out to clear the structure. The topside is then secured to the jacket via structural connections (grouting, welding, bolting, etc.).

This project was performed based on DNV's known track record to deliver simulator-based testing and DNV previous experience to integrate the actual DP control system into simulations. It was also a requirement of the Energy Company project team that the floatover DP operation ASOGs were verified and accepted by their marine assurance and risks team. The novelty of this work is the integration of human-in-the-loop dynamic positioning simulation into the procedure development phase for a floatover operation with extremely tight clearance requirements. Rather than serving solely as a verification tool, the simulation campaign actively shaped operating procedures, provided operator training under realistic conditions, and demonstrated how human performance and DP system behaviour can be jointly optimised. This represents a step forward in the use of simulation to both assure and enhance the execution of complex marine operations.

Scope and Methodology

The scope of performing dynamic simulations of the floatover operation for the installation of the platform is evaluate the performance of the operation and the behavior of the vessel during the floatover, verify and possibly update the ASOGs, and integrate the human factor by having the simulated operation to be performed by the actual DP Operators.

It was paramount to include the loads from the fender-jacket interaction and evaluate the limiting environmental conditions for performing the operation. Simulations are accomplished by connecting the actual DP control system to a real-time simulator (DNV Simulator) as shown in Figure 2.

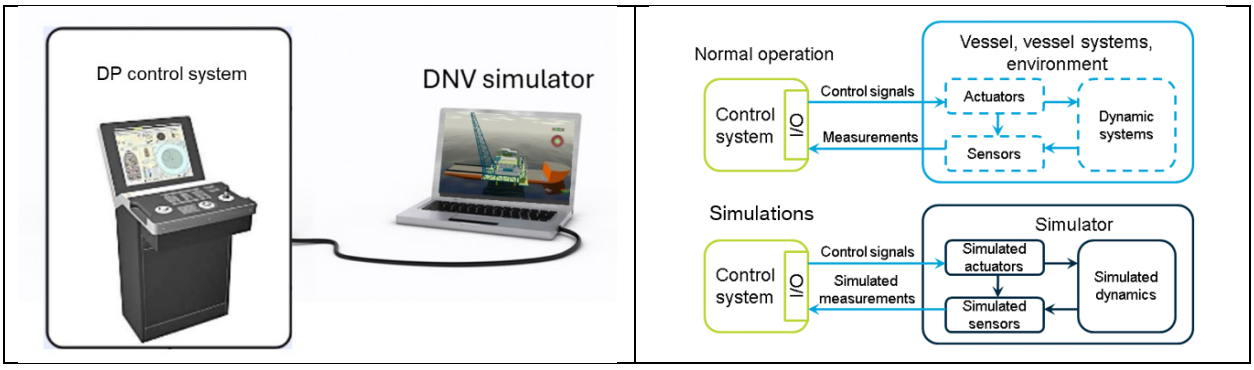

Figure 2: Simulation setup

The DNV Simulator represents the vessel , onboard systems, and surrounding environment to reproduce realistic operational scenarios. Figure 3 shows a screenshot from the DNV simulator during manoeuvring into position between the jacket legs, highlighting the dynamic interactions captured in the simulation.

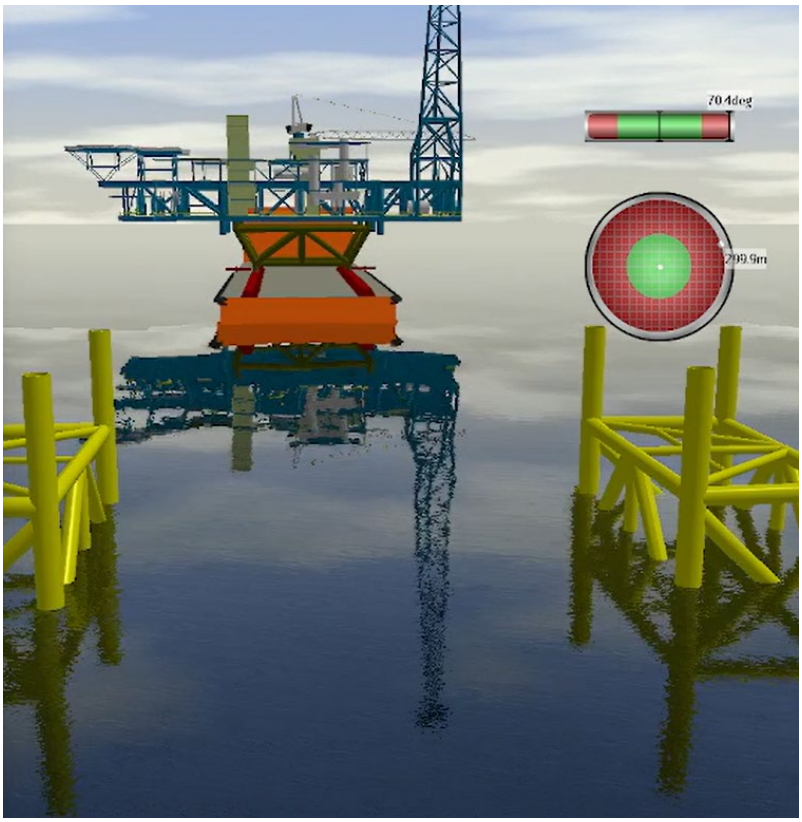

Figure 3: Screenshot from the DNV Simulation of the heavy lift vessel with the top side during stern-on maneuverering between the jacket legs.

Upon receiving the necessary data and documentation for the heavy lift vessel, DNV developed detailed models of hull and hydrodynamics, propulsion and power systems, sensor systems, and position reference systems.

The vessel is equipped with one tunnel thruster and two retractable azimuth thrusters in the bow, and two tunnel thrusters at in the stern. Two propellers with rudders are installed as main propulsion (Figure 4).

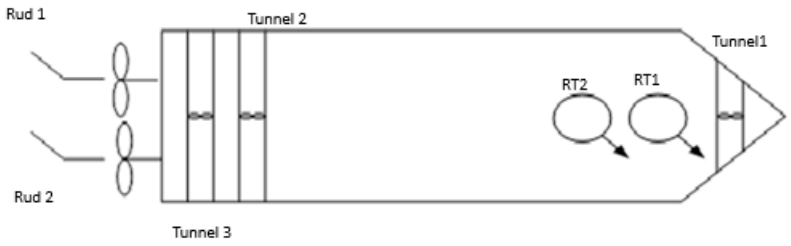

Figure 4: Thruster layout

The sway fenders and surge stoppers were modelled based on engineering drawings and their physical behavior was simulated using specifications provided by the fender manufacturer to reflect their interaction between the jacket structure and the fenders and stoppers.

DNV developed both 2D and 3D visualizations of the vessel and the jacket. The 2D presentation displays key operational elements such as the vessel, top side, jacket cylinders, guiding lines, vessel position, cross-

track error, and speed. This would be a similar view that the DPO would have in the actual operation. The 3D view provides a comprehensive representation of all physical entities involved in the float-over operation.

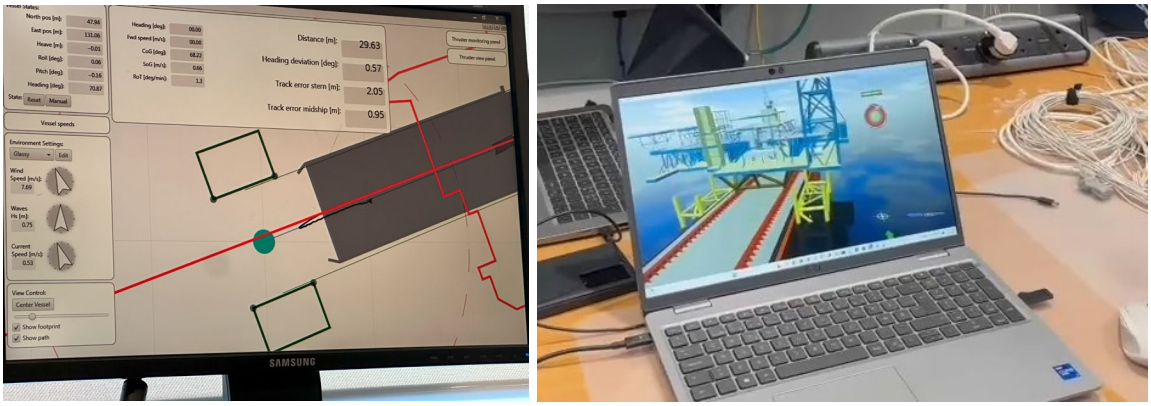

Figure 5: 2D and 3D views from the DP Simulator

DNV collaborated closely with DP control system vendor to establish the interface between the DNV simulator and the DP control system. Two dedicated PCs were configured as real-time simulators, capable of exchanging data with the DP control system. The DP control system relies on numerous sensor feedback signals to monitor vessel position and heading, motion, power usage, etc. and provides thruster and rudder command signals to control vessel behavior. In this project, the majority of signals are analog. To support this, DNV procured I/O modules to convert digital outputs from the simulator into analog signals, in line with the agreed protocol with the DP control system vendor. This setup includes dozens of I/O modules and over a hundred I/O cables.

Figure 6: Hardware prepared by DNV for interfacing

DNV developed a comprehensive test program outline, based on inputs gathered during weekly meetings with the project group and stakeholders. The program includes over 20 test scenarios, categorized into validation, functional, performance, and failure tests. In the test activity, DPOs (Dynamic Positioning Operators) were tasked with executing the float-over procedure under varying environmental conditions. In failure tests, simulated faults such as sensor or thruster failures were introduced during operations to assess system resilience and operator readiness. Feedback on the test program outline was collected from all relevant parties to ensure alignment and completeness. Based on the outline, a test program was prepared before the test.

Simulations

The simulation activities took place at DP control system vendor office, requiring all interfacing activities between the DNV Simulator and the DP control system to be completed prior to the start date.

During the initial float-over attempts, performed with auto-heading mode and controlling the vessel surge and sway motion manually, the DPOs encountered difficulty maintaining the vessel's sway position, resulting in significant cross-track errors and the need to abort the operation. It was agreed to modify the control strategy to use Joystick mode with Auto-heading, Auto-sway, and manual surge control. The revised configuration significantly reduced cross-track errors and facilitated the approach/entry phase.

Additionally, the fender forces observed during the initial testing were found to be unrealistically high. After considering the physical modelling perspective, DNV introduced a damping effect into the fender model to account for energy dissipation during contact with the jacket cylinders. A more realistic fender model was implemented and integrated into simulations.

Subsequent trials were conducted to test the float over operation with different settings such has DP filter and controller gains, entry speed, environmental magnitudes and directions. A good number of tests were devoted to understanding the DP control system performance and human response under various failure scenarios.

As a result, the test program evolved dynamically based on real-time discussions and consensus among stakeholders, deviating from the original plan to better reflect operational insights and priorities.

Summary of the simulation results

At the conclusion of the simulation activities, the simulation results were reviewed, and key conclusions were documented. The consensus among stakeholders was that the simulation activity was a considerable success and provided insight into how to perform the operation. The validity of the test results was affirmed, and it was agreed that the findings would result in improvements and updates to the float-over operation procedure and the Activity-Specific Operating Guidelines (ASOG).

Key conclusions from the simulation activities are as follows:

1. *Rudder usage*

   Simulations showed that utilizing the rudders (which was planned initially) would not improve the positioning during the float-over operation. Rudders generate minimal lateral forces when the vessel is moving astern and may create a heading destabilizing effect. Testing confirmed that enabling the rudder did not significantly contribute to course keeping, which is critical for success of the operation.

2. *DP Operational Mode During Entry Phase*

   Simulation showed that setting the DP control system in Joystick mode with both Auto-heading and Auto-sway enabled during the entry phase would provide better overall performance compared to the planned strategy. Although the float-over procedure initially specified Joystick with Auto-heading only, this configuration failed to maintain adequate sway control, resulting in cross-track errors exceeding 30 cm. This is because sway and yaw control are coupled and having one of these

manually controlled and the other automatically controlled was not optimal. Given the 10 cm clearance between the sway fender and the jacket cylinders, this mode does not meet operational precision requirements with the environmental condition simulated. Enabling Auto-sway significantly improved cross-track accuracy.

3. *DP Control Gain and Kalman Filter Settings*

   A low control gain (for surge, sway and yaw) was found to provide better performance. High gains in sway and yaw increased vessel sensitivity to position and heading changes, leading to excessive motion in the entry phase and inside the jacket (in turns resulting in fender contact and higher impact forces).

   The Kalman filter should be configured to allow the DP system to respond actively to wave-induced motion. Tests showed that successful operations were consistently achieved with a certain setting in the Kalman filter (not disclosed here for confidentiality).

4. *Setting of the bow retractable thrusters (RT1 and RT2)*

   Simulations show that no operational limitations should be imposed on the azimuth angles of RT1 and RT2. Tests showed that restricting RT1 to starboard and RT2 to port led to high thruster usage, resulting in thrust utilization closed or above ASOG limits. In the event of a bow thruster failure, DPOs would have to manually set the azimuth thruster to "free to rotate" to maintain heading control, adding a burden to the operator.

   Thrust biasing—where RT1 and RT2 apply opposing surge forces—was tested to improve damping and responsiveness. However, it resulted in increased thruster usage without meaningful performance gains and is therefore not recommended for this operation.

5. *Additional Operational Insights*

   a. During jacket entry, vessel speed should be kept below 0.25 m/s, and cross-track error should remain under 0.2 meters to minimize collision risk and reduce fender loads.

   b. DPOs must be prepared to respond rapidly to critical failure events such as the worst-case single failure and individual thruster failures. Failing to respond to such failures would lead quickly to the loss of sway position and heading.

Conclusion

In conclusion, the simulation campaign—conducted with the DNV simulator integrated with the actual DP control system and operated by the same DP operators designated for the real operation—proved highly effective in evaluating vessel behavior, fender-jacket interaction loads, DP control parameters, environmental limits, equipment failures, and human performance factors such as decision-making, teamwork, and situational awareness. By placing strong emphasis on the human element, the simulations achieved a balance between realism and manageability while also serving as valuable training for high-stress scenarios. Importantly, the trials showed that mode selection, and operator's response were critical to safe execution, particularly under failure scenarios. Human adaptability and clear communication allowed DPOs to mitigate risks that could not be solved by control tuning alone. This demonstrates that technical optimization of DP gains and filters must be complemented by procedures and training that account for human decision-making under pressure. The resulting insights directly informed the refinement

of key operational procedures, including approach strategies, Activity-Specific Operating Guidelines, installation protocols, and exit plans, thereby enhancing both safety and operational robustness.

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