Dynamic
Positioning
Committee
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Vessel DP Operability SESSION

Leveraging Simulations for Predictable Outcomes

By Zachary Clark - *Kongsberg Maritime,* Xiaobing Shi - *Shell International,*
Suman Muddusetti - *Shell International*

Abstract

Current industry practices often consider some form of analytical assessment of a vessel in preparation for a critical operation. Such assessments can be utilized to assess operability, capability, and fit for purpose. The primary benefit of performing analysis of vessels performance demonstrates that using the appropriate tools and considerations can significantly reduce risks.

The typical analysis required (contractually) for projects when Dynamic Positioning (DP) is required is a DP “StatCap” plot or static capability analysis. However, with static analysis, the performance output from such simulations often does not paint the full picture. While StatCap is useful to assess the balance of forces between thrust and the environment, it does not provide an assessment of station keeping. Given that a vessels station keeping capacity is a key consideration to assessing if a mission may be successful, it is important to appreciate what tools should be utilized to achieve specific goals.

In the past decade, the demand for dynamic analysis of DP vessels has grown substantially. This is achieved using simulated DP systems, mooring representing DP, and Coupled DP systems. Dynamic analysis is a method of performing simulations of an operation in time domain with randomized wave realizations. By performing such analysis with many different wave realizations, a statistical model can be established to provide realistic performance results. Historically, dynamic analysis has been utilized to analyse motions and loads on a vessel as an assessment for establishing boundary limits for mission critical equipment, excluding propulsion systems. For example, subsea construction activities such as riser and pipe installations/recovery where vertical motion is of concern.

Kongsberg Maritime (KM) has established an interface to several analytical simulation tools which allows simulations to be performed with a vessel model coupled to the DP system, specifically the same DP System onboard the vessel of the respective model. By performing time domain simulations where the vessel specific software is present, it is possible to fully assess the predicted capability of a vessel to perform its industrial mission. Additionally, such a configuration can be utilized to assess the control system’s performance in a controlled environment without placing crew and asset at risk. Potential activities like heavy lift, offshore loading, subsea construction, and drilling operations can benefit from increased operability, establishment of environmental boundary limits, and advise which appropriate DP user inputs that should be utilized during mission critical phases of an operation. Furthermore, the setup can be utilized to validate an Activity Specific Operating Guide (ASOG) and be utilized to support crew training for mission critical phases where experienced control of the DP system is essential to ensure predictable outcomes.

This paper will discuss:

- Requirements to establish and perform dynamic analysis, limitations, and considerations
- Assessing vessel performance in a simulation environment
- Operational benefits and insight gained from real time dynamic analysis
- How dynamic analysis can be utilized to establish and validate performance considerations in an ASOG

Contents

Executive Summary

For more than a decade, KM and Shell have collaborated to leverage simulations of critical DP operations with the objective of delivering predictable incident-free DP operations. This collaboration has led to continuous process and methodology improvement for conducting simulations. It was recognized that purposeful application simulations could result in desired risk management outcomes E.G., predictability, optimized operability, and better human performance outcomes.

Historically, the method of conducting such simulation was to perform the operation with the vessel specific software either integrated to a physical subscale vessel model in a wave tank or with a simplified virtual model of the vessel. Barriers in these methods are that the physical model is time and cost intensive and the simplified model provides low accuracy. Simulation capabilities have evolved to where a cost-effective solution can be provided by conducting operational simulations using customized tools (E.G., 'A fully coupled DP and hydrodynamic model in a simulator') in real time with the DP adjustments performed by an operator. Similarly, a wide range of multiple automated (fast time) simulations can be performed today in less time and higher fidelity than the historical methods.

As such, a fully coupled DP and hydrodynamic model in a simulator environment can be leveraged to provide a cost-effective means to vessel owners, operators, clients, and DP system original equipment manufacturer (OEM) to simulate operations intended to be carried out in accordance with procedures, specifications, and recommended practices. The objective of carrying out simulations could be varied to establish the basis for:

- Boundary or limiting conditions (environment, operational parameters, etc)
- Optimized parameterization (of DP Control System parameters)
- Procedural (administrative) controls to establish boundary limits for an operation or site
- Error Handling/Failure Response

Three case studies will be used to illustrate how simulations can provide a detailed analysis and utilized as a basis for real world application. Two of the case studies reflect leveraging simulations as part of the planning/decision making process. The third case was undertaken after a DP incident as part of the recovery effort from the incident.

Three main themes are evident from the case studies:

Optimizing Vessel Performance: - Optimization to undertake the Industrial mission within the vessel and control system design parameters while operating within defined post (worst case) failure capability and establishing boundary conditions
Procedural Controls: Parameterization (DPCS, Basis for operational boundaries and method statements)
Human Factors/Human Performance – Leveraging simulation outcomes for creating scenarios/drills/training for failure response etc in DP training simulators

Legacy approaches have relied upon empirical data, 'tribal' knowledge etc where the basis has been opaque. For example, setting operating limits (environment and procedures) for shallow water projects based on equipment, or previous construction activities not subject to the same physical constraints of the project. Leveraging progressive insights and evolving simulation capabilities results in establishing the basis for the boundary conditions in a transparent manner and facilitates in the deployment of vessels that are "fit for purpose" to undertake their industrial mission.

Introduction

DP vessels are **Designed** with redundancy, differentiation, and segregation in order to manage degradations of equipment to prevent sudden loss of position and or a critical event. **Personnel** are trained to be familiar with their equipment, procedures, and processes. **Operations** are managed through the application of operational policies, procedures, and processes specific to the vessel, industrial mission, and work site.

Vessel performance can be defined as the combined outcome of all components: **Design, Personnel,** and **Operations** which are considered for a DP industrial mission. Reliable and predictable performance can often be determined based on the strength of competence (operators), redundancy, vessel configuration, management of controls, and application of an accurate ASOG. A high-fidelity simulator can be used to assess vessel performance and verify the ASOG when said simulator includes a fully coupled hydrodynamic model, thruster model, and vessel specific DP control system described here as a "DP Digital Twin". Predictable outcomes can be achieved by verifying both the ASOG and vessel performance through the assessment of **Design, Personnel,** and **Operations** within a high-fidelity simulator. The primary benefit is that when performing simulations within a simulator the causal effects impacting performance can be assessed with consideration of the vessel, procedures, and the human factor without placing the asset(s), crew, or environment at risk.

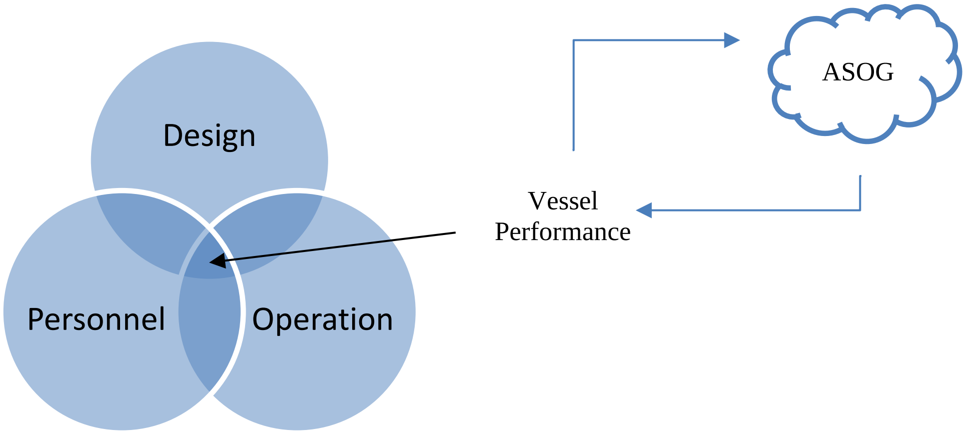


Figure 1. Vessel performance: subject to the strength in Design, Personnel, Operation, and adherence to processes and procedures like the ASOG

Simulation Process

The application of policies, procedures, and decision support tools like the ASOG should have a strong alignment to its design, configuration, redundancy, control system, personnel, and industrial mission. When assessing a vessel capability simply by static means there is a risk of unforeseen performance limitations. A static analysis can be valuable as an assessment tool to establish the maximum thrust required for an environment, or the maximum capable environment in a single moment. However, the result is often a performance plot presenting a vessel's capability as being significantly higher than in practice due to the lack in dynamic environmental factors being considered. Assessing vessel capability through static means poses a risk of unforeseen performance limitations. Conversely, time domain simulations utilize the same thruster and power considerations as in a static analysis but include the addition of vessel motions due to thruster response time, DP control methods, combined wave and wind variations, and vessel model characteristics.

Traditional, Dynamic Capability Analysis or DynCap is a time domain simulation configured to be run in batch, which provides statistically reliable results. Additionally, a real time mission specific simulation can be established with the same Dynamic Analysis simulator where the DP System is controlled by an operator which can render a near 1 to 1 perspective of the operation. One main caveat is that the time to perform such simulations can vary from a few weeks to months. KM has defined different processes for performing dynamic analysis, which can be assigned based on specific project needs**: Feasibility, Capability**, and **Operability**; all of which are mission, vessel, and DP control system specific.

Feasibility is an assessment of, if and how to perform critical phases of an operation with the utilization of a hydrodynamic digital twin coupled to the vessel specific DP System. Analysis can be performed with an operator in control of the software and digital twin as if they would their vessel in real life. This type of analysis is executed over a short period and typically at the planning phase of a project or directly before the operation. If the vessel analysis is favourable, a **Feasibility** analysis will provide support for developing, verifying, and validating human factor, procedural, and process controls.

Capability is an assessment of the vessel performance in the default DP configuration (normally considering post worst case failure - WCF). The primary goal for this type of analysis is to achieve an assessment of station keeping (footprint) and thrust utilization. A series of most expected environmental conditions or mission specific equipment operating limits like Crane, Pipe, Gangway, Tensioner/Compensator, etc. is used to define the performance limits. Similar to the feasibility analysis, capability analysis uses a hydrodynamic digital twin coupled to the vessel specific DP System and is typically performed at the planning or bidding phase for projects where a vessel must be approved for an operation and/or environmental boundary limit.

Operability is an assessment of vessel's maximum performance capability for a default control, power, and thrust configuration. Like the feasibility and capability analysis, operability analysis uses a hydrodynamic digital twin coupled to the vessel specific DP System. This analysis is applied for critical operations where maximum operating criteria must be defined considering many weather conditions and/or operability: up time is to be forecasted. This analysis is normally performed as an assessment of a vessel's performance for a new site. To provide statistically reliable results approximately 20,000 simulations must be performed to assess the weather conditions from a typical annual weather met ocean report. The benefit is that you can achieve a full picture of a vessels default performance considering thousands of weather combinations for a specific site.

Leveraging Simulations Before Operations

Case 1. A recent project Shell-KM completed is a subsea riser transfer and installation for a four-column semi-submersible floating production unit in the Gulf of Mexico. For this project, the critical concerns were the vessel performance and operator interaction with the K-POS™ system to execute manoeuvres during installation of a new subsea riser. During the operation, the vessel would be exposed to high tension and loop currents exceeding 2 kts. While connected, the vessel would also have to perform a 180° rotation with an attached riser with estimated mean tension loads of 72 tons. The simulation/analysis was performed to address the following challenges: What is the vessel's maximum capability and footprint? What is the safest manner to proceed with such an operation to ensure a predictable outcome?

In this type of configuration, the initial heading, point of load, and direction of load is known. The important factors to consider are: Post WCF - as the ASOG will require the vessel to operate at all times within its thrust and power redundancy requirements, the environmental boundary limits for mission critical equipment, and how the operation will be affected by user defined setpoints, in this case all external tension will be input manually, and during a heading change the system/vessel may be sensitive to speed of rotation, amount of rotation per step, and duration between heading and manual tension inputs.

Initially in this project KM established the hydrodynamic model coupled to the vessel specific DP software and performed a Dynamic **Capability** analysis of approximately 5,000 simulations performed over 4 weeks to assess the capability at the maximum environmental limits for the mission critical equipment. The results from such analysis were then utilized to define the maximum operating criteria for environmental force and direction during the riser installation. As an example, only environments (direction) within +/- 45° from the bow and stern can allow for a successful operation within 5-meter footprint post worst-case failure.

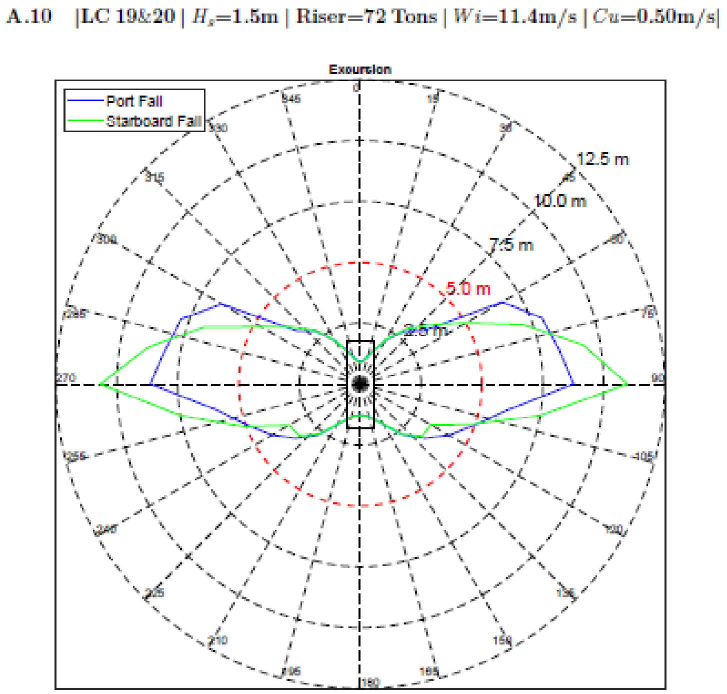
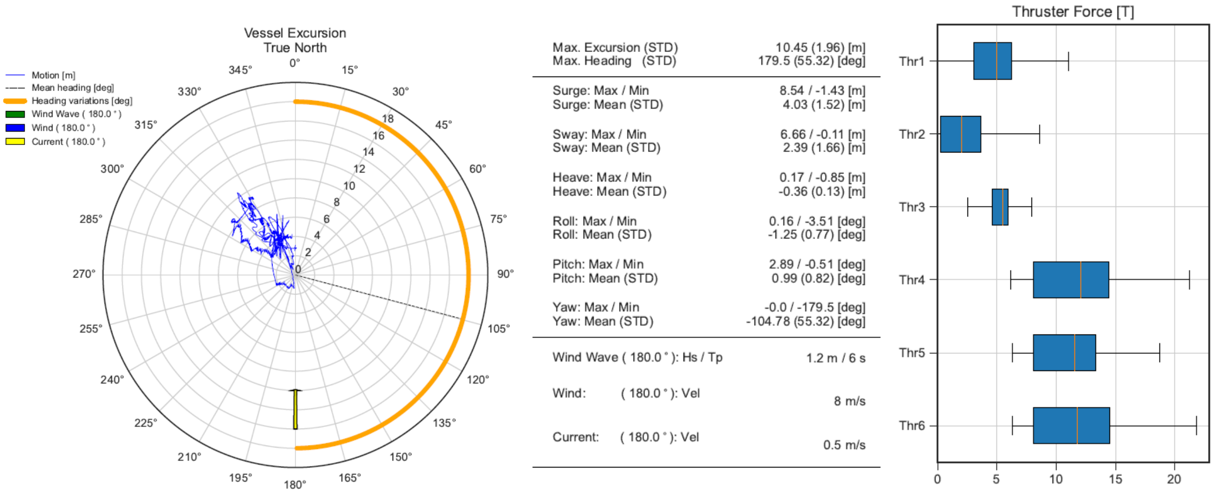


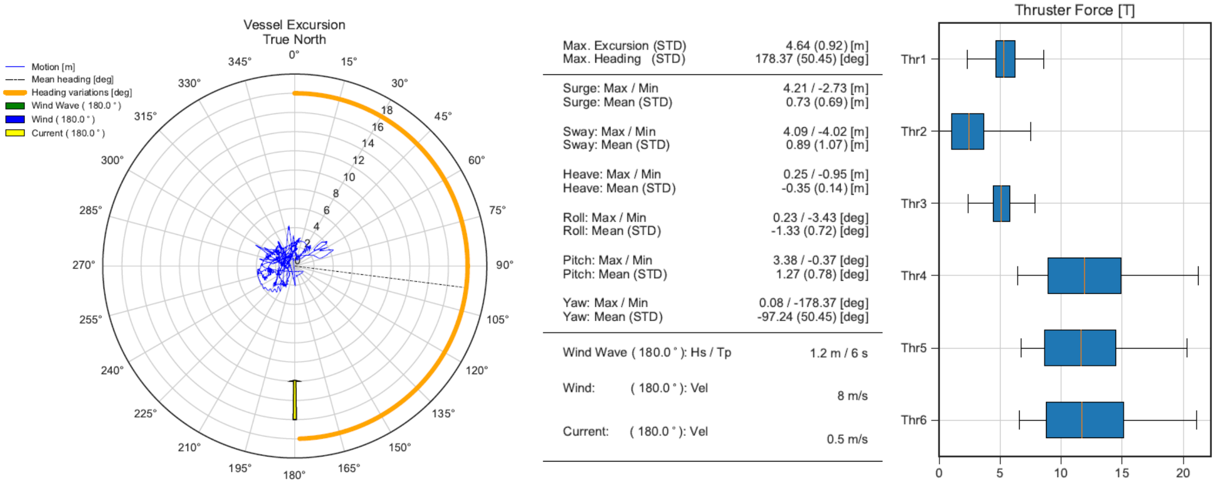
Figure 2. Post Failure DP Dynamic Capability Analysis: Riser Installation flooded maximum tension

At a later phase, prior to operations, additional simulations were commissioned for the installations and transfer of the production risers. However, this time the simulations were performed as a **feasibility** analysis with a fully coupled hydrodynamic model, riser, and the vessel specific SDP DP control system. The simulations were performed to verify the vessel performance for the most critical steps, the control system sensitivity, and the human factors based on the established operational procedures. For example, when performing a critical ‘long turn’ with high dynamic tension via the DP system while using manual tension input. The DP system will not adjust tension automatically and will be subject to the adjustments made by an operator. The typically advised procedure is to utilize measurements from a reliable sensor or lay tables as an input and to adjust rotation, speed, and manual tension in a slow controlled manner. During the simulations multiple tests were performed to compare how the system and vessel control would be improved or degraded based on heading change and manual tension input strategy. An example of comparison of different heading strategies is demonstrated in Figure 3 and Figure 4. Figure 3 presents an operator ‘walking the dog’ whereby they adjust heading setpoint (adding increments while moving) on approach to a new setpoint in order to prevent stopping until at a heading “required to pause for 10 minutes” – per the ASOG, and Figure 4 presents a different control strategy where the vessel and system is ordered to make single turn of 45 degrees and allowed to pause and stabilize every 45° for 10 minutes. As illustrated below, when comparing Figure 4 to Figure 3, the ‘walking the dog’ manouvre (Figure 3) has 100% degraded station keeping performance compared to Figure 4. The risk of human error is greatly increased when attempting to adjust inputs manually in a manner where an operator ‘walks the dog’ and does not allow for any pauses in the manoeuvre (E.G. Figure 3 requires a minimum of 72 manual adjustments over a period of approximately 70 minutes (which is adjusted quickly to “save time”), and Figure 4 requires a minimum of 22 manual adjustments over a period of approximately 70 minutes). In practice the typical industry recommendation would be to perform the operation by adjusting heading in either 5° or 10° and manual tension input also applied at 5° or 10° . However, a pause of approximately 10 minutes would occur every 5° or 10°. In this example, time would be the most significant consequence and station keeping is likely to be closer to Figure 4, but the time required would be at least 3 – 4 hours. The most significant outcome of simulations was a demonstration that the procedural methods for operating the vessel during the heading change do support the manoeuvre and that the vessel was capable. However, depending on the application of the procedure, results can vary due to the method employed by the operator and their interpretation of the procedures.



Max. Excursion (STD) Max. Heading (STD)	10.45 (1.96) [m] 179.5 (55.32) [deg]
Surge: Max / Min Surge: Mean (STD)	8.54 / -1.43 [m] 4.03 (1.52) [m]
Sway: Max / Min Sway: Mean (STD)	6.66 / -0.11 [m] 2.39 (1.66) [m]
Heave: Max / Min Heave: Mean (STD)	0.17 / -0.85 [m] -0.36 (0.13) [m]
Roll: Max / Min Roll: Mean (STD)	0.16 / -3.51 [deg] -1.25 (0.77) [deg]
Pitch: Max / Min Pitch: Mean (STD)	2.89 / -0.51 [deg] 0.99 (0.82) [deg]
Yaw: Max / Min Yaw: Mean (STD)	-0.0 / -179.5 [deg] -104.78 (55.32) [deg]
Wind Wave (180.0 °): Hs / Tp	1.2 m / 6 s
Wind: (180.0 °): Vel	8 m/s
Current: (180.0 °): Vel	0.5 m/s

Figure 3. Feasability Analysis: 5° heading setpoint change continuously only pausing every 45° with manual tension changed at every 5°. ROT 5 deg/min



Max. Excursion (STD) Max. Heading (STD)	4.64 (0.92) [m] 178.37 (50.45) [deg]
Surge: Max / Min Surge: Mean (STD)	4.21 / -2.73 [m] 0.73 (0.69) [m]
Sway: Max / Min Sway: Mean (STD)	4.09 / -4.02 [m] 0.89 (1.07) [m]
Heave: Max / Min Heave: Mean (STD)	0.25 / -0.95 [m] -0.35 (0.14) [m]
Roll: Max / Min Roll: Mean (STD)	0.23 / -3.43 [deg] -1.33 (0.72) [deg]
Pitch: Max / Min Pitch: Mean (STD)	3.38 / -0.37 [deg] 1.27 (0.78) [deg]
Yaw: Max / Min Yaw: Mean (STD)	0.08 / -178.37 [deg] -97.24 (50.45) [deg]
Wind Wave (180.0 °): Hs / Tp	1.2 m / 6 s
Wind: (180.0 °): Vel	8 m/s
Current: (180.0 °): Vel	0.5 m/s

Figure 4. Feasability Analysis: 45° heading setpoint change pausing every 45° for 10 minutes with manual tension changed at 10° increments. ROT 5 deg/min

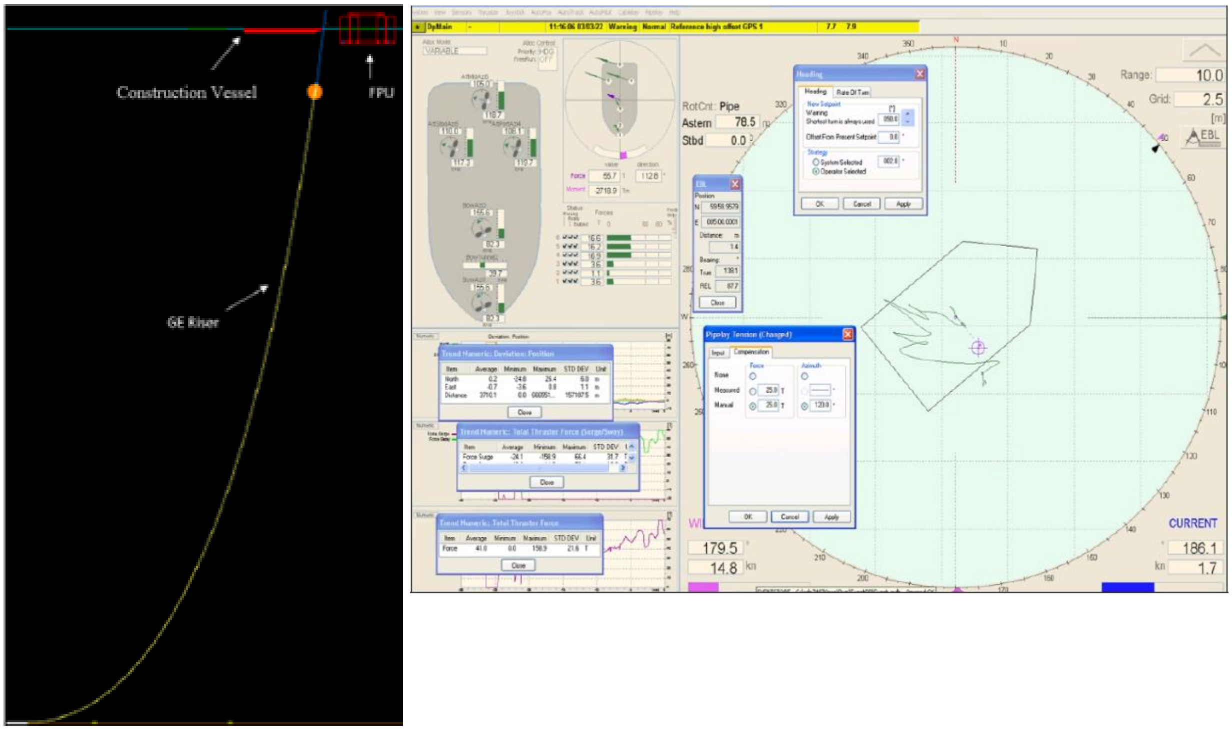


Figure 5. Feasability Analysis: Fully coupled riser and vessel model, and SDP Display during simulations(vertical profile on left, horizonal plan and parameter information on right)

How dynamic analysis can be utilized to establish and validate performance considerations in an ASOG

Case 2. For critical operations due to a complex operation, site, or method, it is valuable to perform simulation analysis to assess the total **operability**. In a recent analysis involving an Accommodation Support Vessel (ASV), performing gangway operations in three possible orientations alongside a Floating Liquefied Natural Gas Production Facility (FLNG). The critical concerns for this activity were:

1. Due to the FLNG primarily being a weathervaning facility where ASV operations are conducted at the FLNG stern and subject to high velocity rotations (at times forcing the ASV to move station at speeds of 0.5 m/s laterally).
2. The ideal method of utilizing the required follow target K-POS™ DP mode special functionality (colloquially known as enhanced or quick response follow target).
3. The maximum operational capacity of the selected ASV for the worksite where motions of the attached gangway are within performance limits for station keeping, and gangway motions.

The ASV model was established with the coupled vessel specific K-POS™ DP System and implemented within a simulator where it would station-keep along a model of the FLNG which had been previously developed from simulations in a wave tank. First, simulations were performed to establish the ideal default DP configuration based on sensitivity analysis of thrusters and DP user inputs considering normal weather. Then, simulations were performed for all environments within 99% non-exceedance limit, evaluating both station keeping and maximum rotational capability. Approximately 20,000 simulations were performed for each orientation resulting in greater than 60,000 simulations for the entire analysis. The results were utilized to establish limits and guidance implemented within the vessel's ASOG in 3 main areas:

1. Title block: defining system configuration (Follow Target settings, Thruster Bias, Speed, and Gain)
2. Maximum rotational velocity allowed up to "degraded" status per the ASOG
3. Advice on potential elevation from advisory (blue/white) to degraded (yellow) status per the ASOG based on observed degrading conditions.

At completion of the simulations (analysis) all findings and lessons learned were integrated into a simulation (training) workshop where all DPOs assigned to the ASV attended sessions to discuss and familiarize themselves with the risk management processes, high risk concerns due to the complexity of the site, and perform emergency response-scenario based simulations in a full mission simulator with their vessel specific DP System. For example, the training was focused in two key areas:

- Results and their integration within risk management processes and decision support tools (Figure 7 through Figure 11).
- Full mission scenario training mitigating faults, change in status, and emergencies maneuvers (Figure 6), as well as focus on K-POS™ DP special functionality.

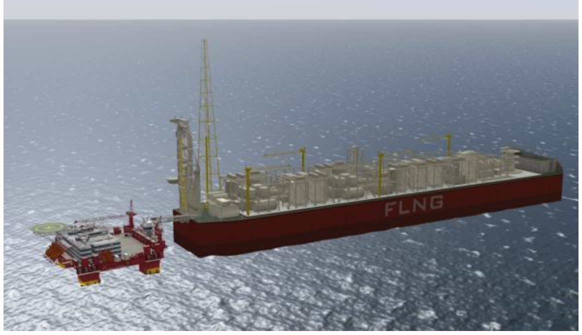
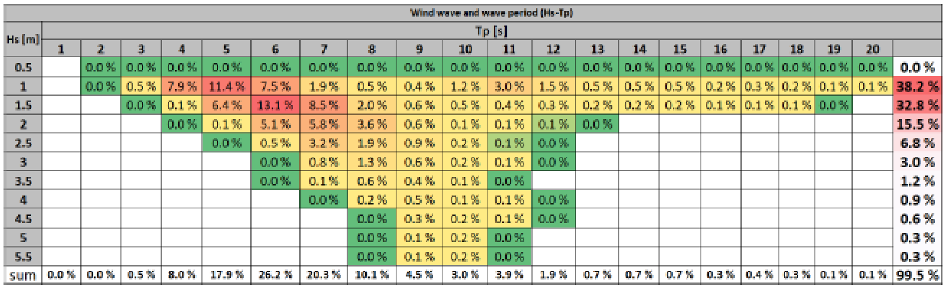


Figure 6. FLNG and ASV within Full mission Simulator (ASV gangway connected at stern) rotation point at forward turret ~480m forward of ASV



Wind wave and wave period (Hs-Tp)																					
Hs [m]	Tp [s]																				
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
0.5		0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	0.0 %	**0.0 %**
1		0.0 %	0.5 %	7.9 %	11.4 %	7.5 %	1.9 %	0.5 %	0.4 %	1.2 %	3.0 %	1.5 %	0.5 %	0.5 %	0.5 %	0.2 %	0.3 %	0.2 %	0.1 %	0.1 %	**38.2 %**
1.5			0.0 %	0.1 %	6.4 %	13.1 %	8.5 %	2.0 %	0.6 %	0.5 %	0.4 %	0.3 %	0.2 %	0.2 %	0.2 %	0.1 %	0.1 %	0.1 %	0.0 %		**32.8 %**
2				0.0 %	0.1 %	5.1 %	5.8 %	3.6 %	0.6 %	0.1 %	0.1 %	0.1 %	0.0 %								**15.5 %**
2.5					0.0 %	0.5 %	3.2 %	1.9 %	0.9 %	0.2 %	0.1 %	0.0 %									**6.8 %**
3						0.0 %	0.8 %	1.3 %	0.6 %	0.2 %	0.1 %	0.0 %									**3.0 %**
3.5						0.0 %	0.1 %	0.6 %	0.4 %	0.1 %	0.0 %										**1.2 %**
4							0.0 %	0.2 %	0.5 %	0.1 %	0.1 %	0.0 %									**0.9 %**
4.5								0.0 %	0.3 %	0.2 %	0.1 %	0.0 %									**0.6 %**
5								0.0 %	0.1 %	0.2 %	0.0 %										**0.3 %**
5.5								0.0 %	0.1 %	0.2 %	0.0 %										**0.3 %**
sum	0.0 %	0.0 %	0.5 %	8.0 %	17.9 %	26.2 %	20.3 %	10.1 %	4.5 %	3.0 %	3.9 %	1.9 %	0.7 %	0.7 %	0.7 %	0.3 %	0.4 %	0.3 %	0.1 %	0.1 %	**99.5 %**

Figure 7. Total sea with wind/wave relationship: Hs-Tp probability

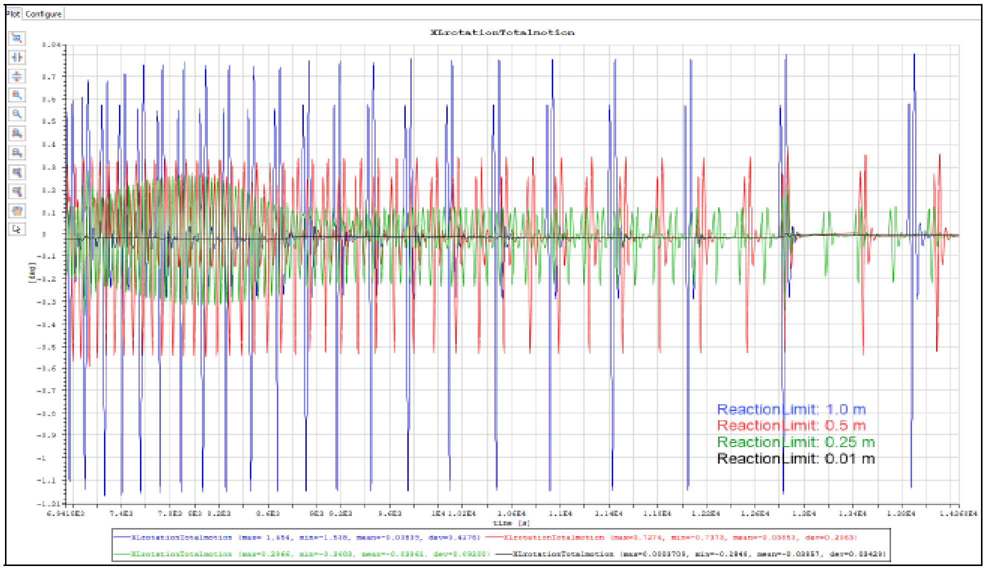
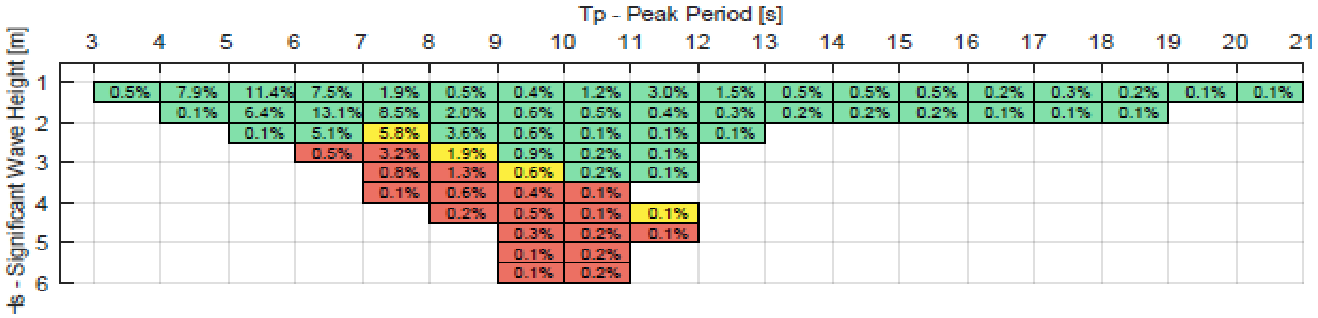
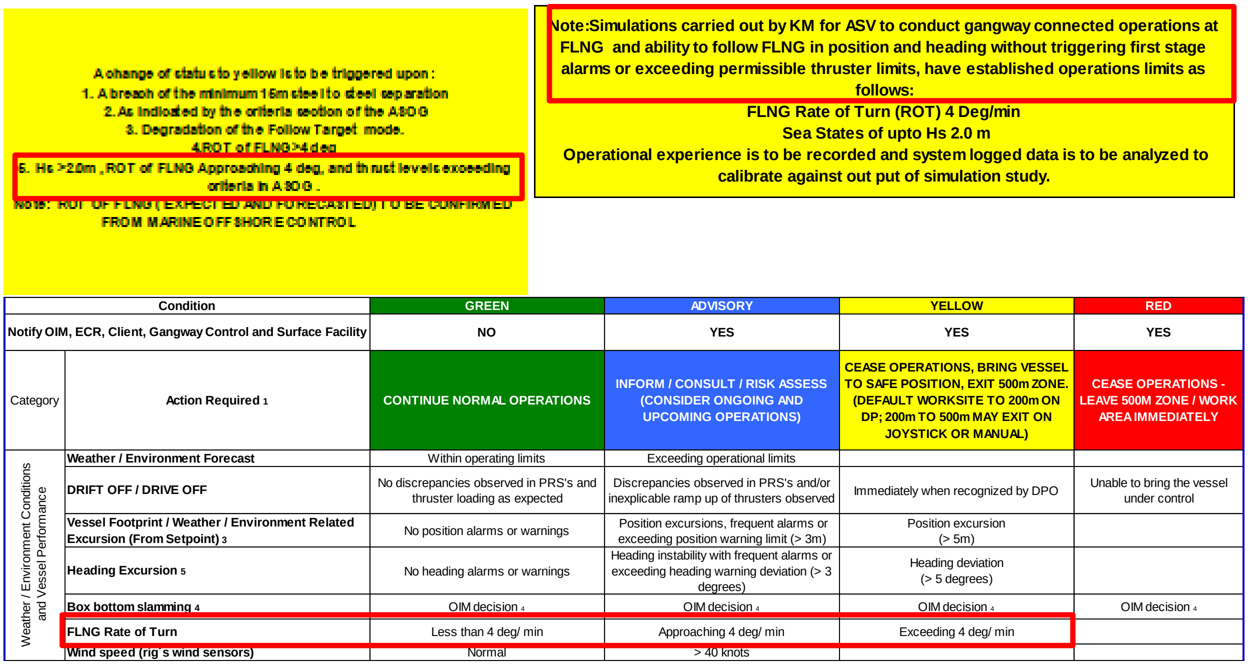


Figure 8. Sensitivity study: Roll motion due to thruster response and reaction limit in follow target. As observed for this vessel by reducing the reaction limit thruster induced roll motions were reduced. However, potential the disadvantage of a reduced reaction limit is higher sensitivity to target motions causing more thrust and power consumption. It is also advisable that such adjustments would be based on the observed motion of targets and the vessel sensitivity in the DP vessel's performance.



0.5%	7.9%	11.4%	7.5%	1.9%	0.5%	0.4%	1.2%	3.0%	1.5%	0.5%	0.5%	0.5%	0.2%	0.3%	0.2%	0.1%	0.1%
	0.1%	6.4%	13.1%	8.5%	2.0%	0.6%	0.5%	0.4%	0.3%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%		
		0.1%	5.1%	5.8%	3.6%	0.6%	0.1%	0.1%	0.1%								
			0.5%	3.2%	1.9%	0.9%	0.2%	0.1%									
				0.8%	1.3%	0.6%	0.2%	0.1%									
				0.1%	0.6%	0.4%	0.1%										
					0.2%	0.5%	0.1%	0.1%									
						0.3%	0.2%	0.1%									
						0.1%	0.2%										
						0.1%	0.2%										

Figure 9. Summary Results: considering thrust utilization and gangway motion – the boxes marked in green are successful cases and in yellow either thrust or gangway motions exceed the performance limits for which would raise status to "Advisory/Blue". All red cases are considered failed where an "Degraded/Yellow" status would be triggered, and operations would be suspended. In this example it is possible to observe that for the weather directions simulated in these cases the FLNG and ASV are more sensitive to lower frequency waves. For each of the 67 cases in the scatter diagram, 10 wave realizations of 3 hours was analyzed %= probability of occurrence.

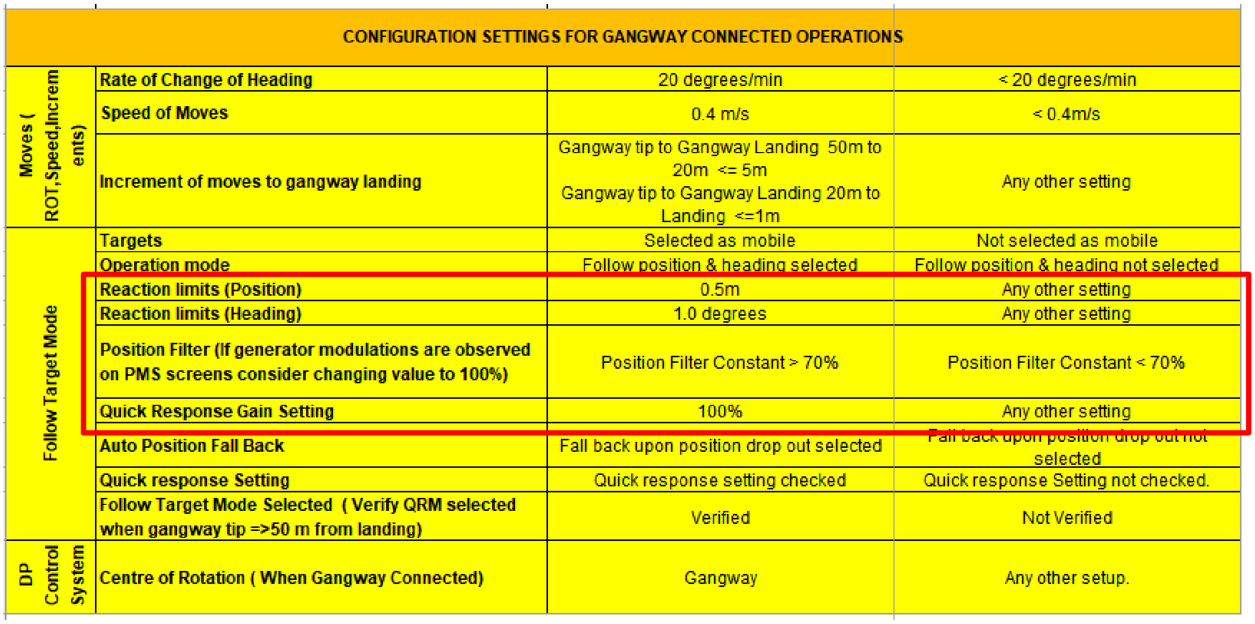


A change of status to yellow is to be triggered upon :
1. A breach of the minimum 15m steel to steel separation
2. As indicated by the criteria section of the ASOG
3. Degradation of the Follow Target mode.
4.ROT of FLNG >4 deg
5. Hs >2.0m , ROT of FLNG Approaching 4 deg, and thrust levels exceeding criteria in ASOG .
Note: ROT OF FLNG (EXPECTED AND FORECASTED) TO BE CONFIRMED FROM MARINE OFFSHORE CONTROL

Note:Simulations carried out by KM for ASV to conduct gangway connected operations at FLNG and ability to follow FLNG in position and heading without triggering first stage alarms or exceeding permissible thruster limits, have established operations limits as follows:
FLNG Rate of Turn (ROT) 4 Deg/min
Sea States of upto Hs 2.0 m
Operational experience is to be recorded and system logged data is to be analyzed to calibrate against out put of simulation study.

Condition		GREEN	ADVISORY	YELLOW	RED
Notify OIM, ECR, Client, Gangway Control and Surface Facility		NO	YES	YES	YES
Category	Action Required [1]	CONTINUE NORMAL OPERATIONS	INFORM / CONSULT / RISK ASSESS (CONSIDER ONGOING AND UPCOMING OPERATIONS)	CEASE OPERATIONS, BRING VESSEL TO SAFE POSITION, EXIT 500m ZONE. (DEFAULT WORKSITE TO 200m ON DP; 200m TO 500m MAY EXIT ON JOYSTICK OR MANUAL)	CEASE OPERATIONS - LEAVE 500M ZONE / WORK AREA IMMEDIATELY
Weather / Environment Conditions and Vessel Performance	Weather / Environment Forecast	Within operating limits	Exceeding operational limits		
	DRIFT OFF / DRIVE OFF	No discrepancies observed in PRS's and thruster loading as expected	Discrepancies observed in PRS's and/or inexplicable ramp up of thrusters observed	Immediately when recognized by DPO	Unable to bring the vessel under control
	Vessel Footprint / Weather / Environment Related Excursion (From Setpoint) [3]	No position alarms or warnings	Position excursions, frequent alarms or exceeding position warning limit (> 3m)	Position excursion (> 5m)	
	Heading Excursion [5]	No heading alarms or warnings	Heading instability with frequent alarms or exceeding heading warning deviation (> 3 degrees)	Heading deviation (> 5 degrees)	
	Box bottom slamming [4]	OIM decision [4]	OIM decision [4]	OIM decision [4]	OIM decision [4]
	FLNG Rate of Turn	Less than 4 deg/ min	Approaching 4 deg/ min	Exceeding 4 deg/ min	
	Wind speed (rig´s wind sensors)	Normal	> 40 knots		

Figure 10. Example of how results and findings from simulations are implemented into the ASOG



CONFIGURATION SETTINGS FOR GANGWAY CONNECTED OPERATIONS			
Moves (ROT,Speed,Increments)	Rate of Change of Heading	20 degrees/min	< 20 degrees/min
	Speed of Moves	0.4 m/s	< 0.4m/s
	Increment of moves to gangway landing	Gangway tip to Gangway Landing 50m to 20m <= 5m Gangway tip to Gangway Landing 20m to Landing <=1m	Any other setting
Follow Target Mode	Targets	Selected as mobile	Not selected as mobile
	Operation mode	Follow position & heading selected	Follow position & heading not selected
	Reaction limits (Position)	0.5m	Any other setting
	Reaction limits (Heading)	1.0 degrees	Any other setting
	Position Filter (If generator modulations are observed on PMS screens consider changing value to 100%)	Position Filter Constant > 70%	Position Filter Constant < 70%
	Quick Response Gain Setting	100%	Any other setting
	Auto Position Fall Back	Fall back upon position drop out selected	Fall back upon position drop out not selected
	Quick response Setting	Quick response setting checked	Quick response Setting not checked.
	Follow Target Mode Selected (Verify QRM selected when gangway tip =>50 m from landing)	Verified	Not Verified
DP Control System	Centre of Rotation (When Gangway Connected)	Gangway	Any other setup.

Figure 11. Example of how results and findings from simulations are implemented into the CAM

Leveraging simulations after an event

DP events typically occur due to one of four primary causes: human factors, sensor failures, power/thrust failures, and control system failures. Often, this is due to the lack of robust design in automatic controls, mission critical functionality, reliable interfaces and sensors, maintained equipment, legacy systems, and/or lack of fault recognition/response mechanisms. The final barrier preventing an event from becoming an incident is often left up to the DP operator’s experience. Unfortunately, due to skill fade and possible limit of experience or familiarity with the specific control mechanisms and/or vessel in the specific environment and specific situation, it can be difficult for the DPO to achieve a predictable outcome during an unforeseen event.

The DP system is designed to automate the control of vessel thrusters and propulsion. The way it calculates thrust demand and subsequently the thruster setpoint is based on one of two factors: either position and heading setpoint, or joystick position. When in auto control mode, the observer data (sensor measurements) and calculated external forces are utilized to calculate thrust demand required to achieve the position or heading setpoint. The DP system employs multiple means to validate observer data by prediction, voting, estimation, and other various IO verification/testing methods. If the observer data is in error or unreliable and the system doesn’t recognize it, an unexpected response can occur. Fault recognition and response mechanisms are not full proof across all possible circumstances. For some unforeseen/rare failures it is the responsibility of the operator to recognize degrading performance and have some form of manual response to a critical event. This is especially important in operations where physical equipment, structures, moving references, and other control systems can interact with the DP system.

Case 3. During a pipelay operation in shallow waters a DP pipelay vessel suffered a pipe buckle while the tensioner was locked (on brake). This occurred when the high stiffness of the pipe (large diameter at shallow water depth) and the DP system ordered thrust began to interact. Historically, such events can and have been observed on other DP vessels. Often symptoms experienced during this event are caused when the pipe tensioner is not compensating for the vessel's surge motions and an oscillatory resonance in surge begins to propagate as the elasticity of the pipe acts as a spring, and the direction of thrust becomes out of phase (due to controls or slowly responding thrusters) with the vessel motion. Events often occur when the DP system orders thrust astern, or thrusters are already generating a thrust astern and the pipe springs towards the vessel causing a sudden compressive force against the pipe resulting in pipe material failure (buckling). As far back as the Kongsberg SDP system first delivered in the 1990s, a special function was developed and implemented within "pipelay mode" which was designed to mitigate such a symptom. However, due to lack of training/experience with mitigatory measures required, manual intervention measures are often too slow to identify symptoms and effectively take action.

In response to the above event, simulations with integrated DP system, pipe and vessel were established to reproduce similar symptoms experienced during the pipelay incident. The key finding was that due to the limited control of the pipelay tensioner equipment and the high stiffness of the pipe, manual intervention of this event was required using the DP system special functionality for addressing oscillations. The method for utilizing the special functionality in response to the oscillatory symptoms observed was tested and verified to be an acceptable means of response. The application of this setup allowed for multiple simulations to be performed without ever placing the crew, vessel, or equipment at risk while testing various methods of response.

Ultimately, the results from the simulations supported the development of a recommended procedure for response to a similar event, should it reoccur. Subsequently, the primary control mechanism and advised configurable inputs were then integrated within the ASOG to better clarify the manner and method for fault response actions. Following the simulations and analysis, the vessel returned to work and successfully completed the operation without further events. The simulations demonstrated the ability to analyse and establish procedural mechanisms to address possible events respective to the industrial mission. This type of configuration could also allow for development of procedures, testing of functionality, and control barriers prior to the operation as comparable to case 2.

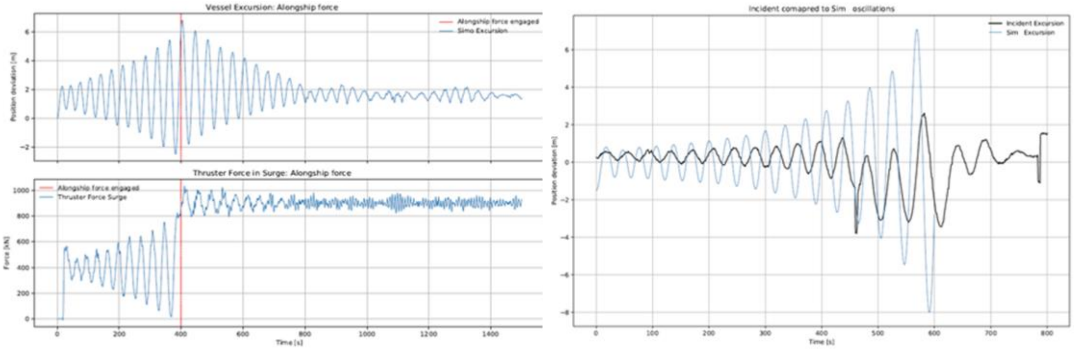


Figure 12. ***Left:*** *at 400s the activation of special functionality built into pipelay mode is observed to have a rapid and significant reduction in force resonance and position deviation.*

Right: *Surge oscillation compared to that within the tuned fully coupled pipe and vessel model. Note: tuning of such model was performed to have a similar frequency (due to stiffness) for the first 500s.*

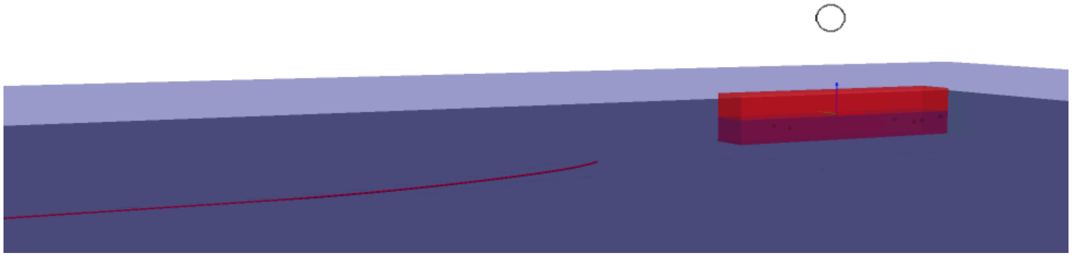


Figure 13. Coupled Vessel and Pipe model. (Pipe shown connected at stinger tip)

Conclusion

This paper has presented examples in which Dynamic Analysis/Simulations have been performed for operations where it was necessary to develop proper methods to conduct an operation considering the DP system's functionality and response. Through the utilization of the vessel specific DP control system, the same control methods and special functionality can be evaluated in addition to the propulsion and power generating equipment. By performing the simulations in time-domain, it allows for the dynamic factors like wind, wave, current, and other external forces to influence the vessel footprint which is not achievable through static means (StatCap). Given that the function of station keeping is vital for success of a mission, this type of analysis is critical. It has also presented applications for establishing boundary conditions where the decision to utilize a vessel for a specific site and environment is in question. The application of time domain dynamic simulations and analysis has provided valuable lessons learned and guidance for establishing procedural mechanisms, configuration, and training in pursuit of predictable outcomes.

For many operations, previous experience of a specific vessel or similar vessel is often leveraged for planning and decision making. With this approach, procedures are typically limited to 'tribal' knowledge and simple performance assessments. While experience is useful, for complex activities and situations where station keeping is highly critical, it is important to leverage simulation tools, controls, competence of design, and a consideration to 'real' vessel performance to achieve predictability. Even with established control and procedural mechanisms based on previous experience and lessons learned, it is valuable to utilize all the tools available, including the application of a high fidelity 'reliable' simulator which represents the operation and vessel nearly 'one to on'. This does not necessarily mean every operation requires simulations nor is it necessary to perform 5,000 or even 60,000 simulations to benefit from such analysis. The most beneficial applications are for complex applications, verification of procedural and control barriers, and potentially critical phases which have high risk of impact to personnel, the environment, and/or assets. The ASOG is and has been an integral tool for performing operations in a predictable manner. Integrating such a tool in combination with simulations allows for verifiable configuration requirements, and predictable vessel performance which is inclusive of procedures, process, and human factors.

Abbreviation / Definition

ASOG – Activity Specific Operating Guide
ASV – Accommodation Support Vessel
CAD – Computer Aided Design
CAM – Critical Activity Mode
DP – Dynamic Positioning
DPCS – Dynamic Positioning Control System
DPO – Dynamic Positioning Operator
DynCap – Dynamic Capability Analysis
FLNG – Floating Liquified Natural Gas Production Facility
KM – Kongsberg Maritime
LNG – Liquified Natural Gas
MRT – Marine Risk Team
OEM – Original Equipment Manufacture
StatCap – Static Capability Plot
WCF – Worst Case Failure

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References

DNVGL-RP-C205 - Environmental conditions and environmental loads