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Practical experiences and guidelines on how to use DNV GL DP Capability standard ST-0111

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DNV GL AS

Abstract

There is increased awareness of the significance of the Station Keeping Capability considering site-specific environmental conditions and Post Failure Capability. Concerns have emerged also regarding a vessel ability to maintain position/heading within specified limits during transient conditions. At the same time, the need for tools for fair and consistent comparisons of the station-keeping performance of vessels has arisen. In July 2016, DNV GL published a new standard for the assessment of vessel DP capability, DNV GL ST-0111 aiming at proving a standard to assess the DP performance with different levels, depending on the operational risk, the accuracy needed and comparability of results. A revision has been published in March 2018. Together with the standard, a web-app was also developed and released on *www.veracity.com*.

The main challenge that have emerged with the introduction of the new standard is on how to apply and use the standard as there are 5 different levels available. This has resulted in ambiguous tender specifications and wrong applications.

The main goal of this paper is to give examples of practical uses of the different levels in the DNV GL ST-0111 standard and how the results from the different levels compare to each other. This paper will provide guidance on how to use the different levels of the standard and how these could be applied to different operations, risk-management, costs and operating locations.

A comparison analyses performed between different DP Capability levels will be presented for a drillship and a semi-submersible drilling rig. Practical experiences of the use of the standard so far will be also shared.

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Introduction

Global energy demand rose by 2.1% in 2017, more than twice the previous year's rate, boosted by strong global economic growth. Recent predictions have shown that the global demand for energy per capita will peak in 2035. Most of the increase in demand for energy last year was met by the production of oil, gas, coal and renewables which accounts today for about 30% of the total production. To meet the increased energy demand, offshore drilling is moving toward more extreme environments. New technologies and increased efficiency demands has also resulted in increased drilling activities in shallow water performed by semi-submersible rigs in Dynamic Positioning (DP) mode. The exponential growth in the wind energy is predicted to continue, leading to more and more offshore wind farms to be installed offshore. This will increase the use of wind farm installation vessels and walk-2-work vessels (e.g. for maintenance) which will perform operations in DP mode.

Figure 1: Walk-2-work vessel during wind farm maintenance (courtesy of Siemens)

The increased use of DP vessels for critical operations, has resulted in an extensive use of calculations and simulations tools to assess the vessel station-keeping capability during design, tenders and operational planning phases. Operational risk management tools based on vessel simulations have become key elements for supporting incident free and efficient operations.
The prediction of a vessel station-keeping performance can be performed by implementing different method, standard and specifications. In July 2016, DNV GL published a new standard for the assessment of vessel DP capability, DNVGL-ST-0111 aiming at proving a standard to assess the DP performance with different levels, depending on the operational risk, the accuracy needed and comparability of results [6][7]. A revision has been published in March 2018 [1][8]. To support the use of the standard, a web-app was developed and released on *www.veracity.com*.
The standard includes five different levels:

- DP Capability Level 1 – a prescriptive static method so that results calculated for different vessels will be fully consistent and comparable, based on Beaufort weather scale.
- DP Capability Level 2 – a method for the assessment of the DP station keeping capability based on a more comprehensive quasi-static method which allows for more flexibility and project specific adjustments compared to the DP Capability Level 1 method. This is also based on the Beaufort weather scale.
- DP Capability Level 2-Site – same as for Level 2 but allowing the use of site specific environmental data (and other operation specific aspects) and external forces.

- DP Capability Level 3 – method for computing a vessels DP station keeping capability based on time-domain simulations.
- DP Capability Level 3-Site – same as for Level 3 but allowing the use of site specific environmental data (and other operation specific aspects) and external forces.

In the last years, much feedback has been received both concerning the standard and the web-app. The main challenge that has emerged is still on how to apply and use the standard since there are 5 different levels available. This has e.g. resulted in both ambiguous tender specifications and wrong applications. Other feedback related to how to compare different levels and understand the results from each level have been received. Examples of other industry concerns lifted are: How to write effective specifications for Leve 2-Site, how to set dynamic factor in Level 2 calculations, and how to use the results from Level 3 for drilling operations?

The main goal of this paper is to provide examples on practical uses of the different levels in the DNV GL ST-0111 standard and how the results from the different levels compare to each other. This paper will provide guidance on how to use the different levels of the standard and how these could be applied to different operations, risk-management and operation requirements.

Comparison analyses performed between different DP Capability levels will be presented for a drillship and a semi-submersible drilling rig. Practical experiences on the use of the standard so far will be also shared. The paper will also present the changes in the latest revision of the standard [8], updates in the web-app, and plans for future development of the app.

Comparison between different levels

This section will give a comparison of the different levels for a mono-hull drillship and a semi-submersible drill rig.

Case 1 – Mono-hull drillship

The example vessel is equipped with six 5500 kW ducted azimuth thrusters, connected to 3 main switchboards. Each main switchboard is powered by two 7 MW generators. The drillship main particulars are shown in Table 1. The hull geometry is shown in Figure 2.The thruster layout is presented in Figure 3, and the power system single line diagram is presented in Figure 4.

Table 1: Drillship main particulars

Description	Symbol	Unit	Value
Length between perpendiculars	Lpp	m	230
Breadth	B	m	42
Operating Draught	T	m	12

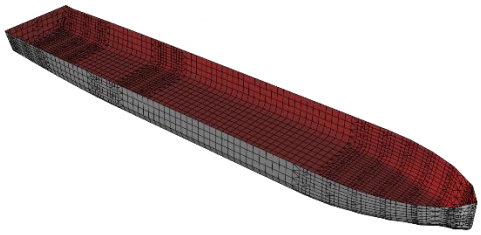

Figure 2: Drillship hull geometry

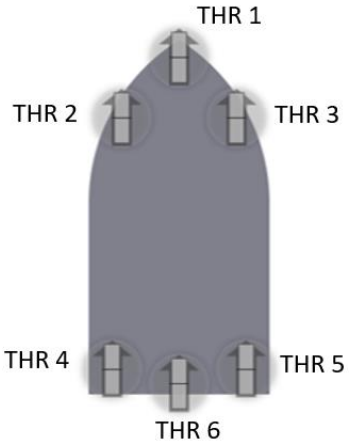

Figure 3: Drillship thruster Layout

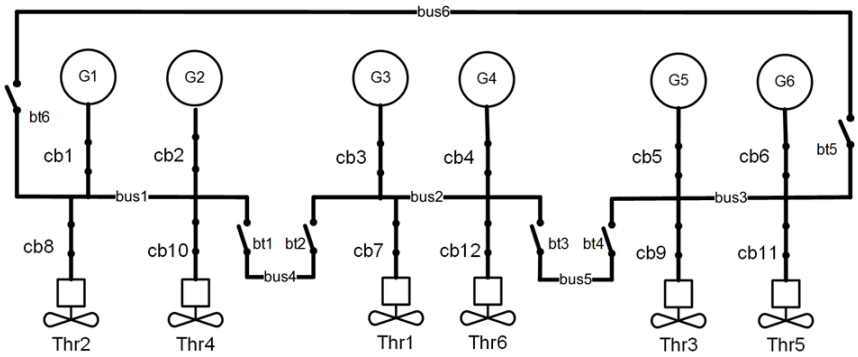

Figure 4: drillship power single line diagram

Intact conditions

Figure 5 shows the comparison between the DP Capability result (wind envelopes) from Level 1, Level 2 and Level 3 calculations with the vessel in intact condition. Level 1 and Level 2 results agree quite well. The Level 2 analysis has been carried out with vessel specific wind, current and wave drift coefficients, thruster bollard-pull values and thrust losses, and with dynamic factors equal to 1.25 for wind, current and wave loads. Although the Level 1 method is built upon generic mono-hulls and thruster models, the result fits quite well. Level 3 (time-domain) shows much smaller wind limits. In this case, only one wave realization is shown for simplicity. Note that results between different wave realization can vary so the DNVGL standard ST-0111 suggests to run at least 3 wave realizations.

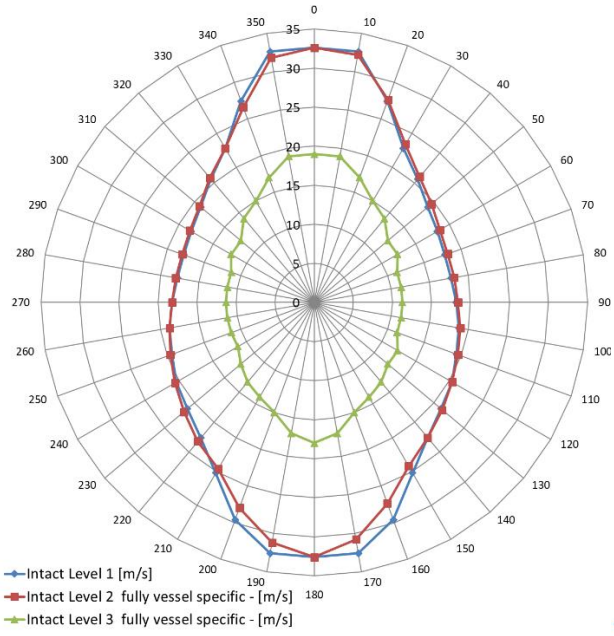

Figure 5: Drill ship – Intact conditions - comparison among Level 1, Level 2 and Level 3

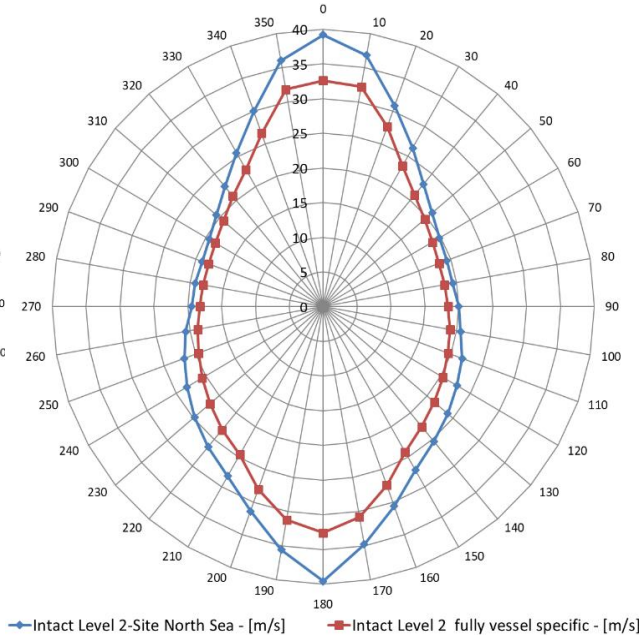

Figure 6: Drillship – Intact conditions - Level 2 (BF) and Level 2-Site for North Sea

The results from time-domain simulations are highly affected by the positioning limits set as basis for the simulations. The Level 3 method has requirements for positioning limits at 5 meters and 3 degrees for position and heading, respectively. Tighter limits result in smaller wind limits as shown in [9]. This is

also shown in Figure 7, where a comparison of results obtained with different positioning limits is presented.

To understand the difference between the Level 2 and Level 3 results, a deeper look into the analysis methods is necessary. The wind limits in static analyses, such as Level 1 and Level 2, are determined by balancing the thruster forces and moments with the environmental forces and moments amplified by the dynamic factors. The dynamic factors are introduced to account for time-varying environmental loads which are not considered in the static analyses. For Level 1 the requirement for the dynamic factors is to set the value at 1.25 for wind, current and waves loads. For Level 2 these values can be set by the user. The wind limits from the Level 2 methods can be seen as the environmental limits where the vessel cannot balance the average weather forces leading the vessel to drift-off position. Time-varying environmental loads are included in time-domain simulations due to the nature of these simulations. To compare Level 2 results with Level 3 results, we should then consider a Level 3 analysis where the positioning limits are set very large. When the positioning limits are large, this would be the closest situation to a drift-off scenario.

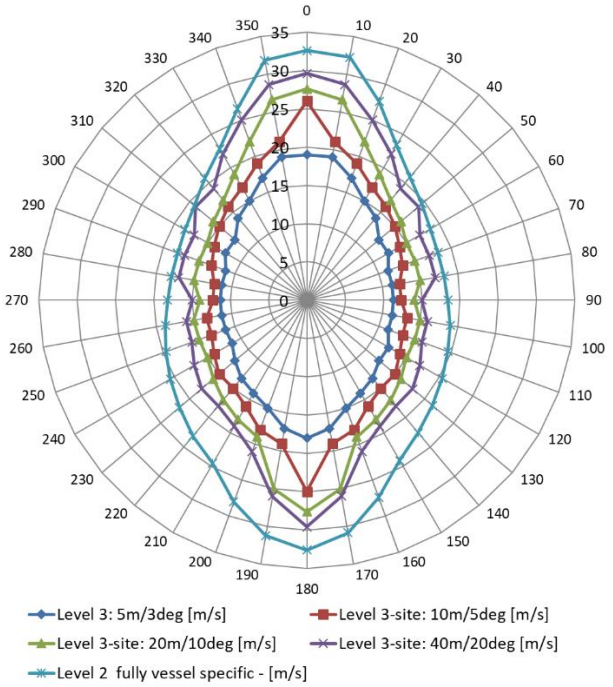

Figure 7: Drill ship – Intact conditions - comparison among Level 2 and Level 3 with different positioning limits

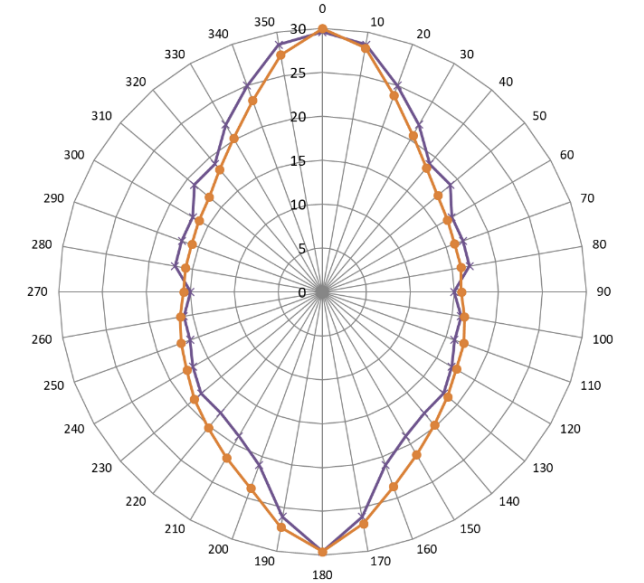

Figure 8: Drillship – Intact conditions - Level 2 (BF) with updated dynamic factors and Level 3 with large positioning limits

Figure 7 shows that the Level 3 analysis with 40 meters and 20 degrees positioning limits is close to the Level 2 results but still the different is quite significant. Experience from Level 3 analysis (see for example [14]) has shown that wind force peaks can vary from 1.25 to 2-2.5 times the average wind forces, and that the slowly-varying wave drift loads can be even 3-10 times larger than the average loads. This depends on the site-specific conditions. During full-scale trials with a drillship outside the cost of South Africa [15], the maximum wind forces were estimated to about 35% more than the average. This indicates that the dynamic factors, for this case, should maybe be larger than the 25% as required in a Level 1 analysis. When using the Level 2 method to estimate the wind limits for a case with tight vessel footprint requirements (the footprint requirement can only be set in time-domain simulations), the dynamic factor should be at least as large as the possible load fluctuation such that the thruster will have enough force to counteract the environmental peak forces. If we consider, for example, the Level 3 results with 40 meters and 20 degrees positioning limits, to obtain similar results with the Level 2 analysis, the

dynamic factors should be something between 1 and the ratio of the environmental loads and its peak forces. Assuming the current speed does not present large dynamics, the dynamic factor for current could be set closed to 1. Figure 8 shows a comparison between the Level 3 analysis with 40 meters and 20 degrees of positioning limits and the Level 2 analysis with dynamic factors equal to 1.6, 1.9 and 1.05 for wind, waves and current respectively. With these dynamic factors, the Level 2 results are close to the Level 3 with positioning limits 40 m and 20 deg. There is a correlation between the dynamic factors and the positioning limits. However, it appears difficult to derive a generic formulation that fits all vessel types and equipment dynamics. The tighter the positioning requirements are, the larger the dynamic factors should be.

Loss of Thruster 1 and 6

Figure 9 shows the comparison of the three DP capability methods for the loss of thruster 1 and 6. The results from Level 1 present larger wind speed limits for head and following seas, compared to Level 2. This difference would have been experienced also in the intact case if the wind scale were higher. Instead, in the intact condition, Levels 1 and 2 provide the same results for head and following seas because the maximum achievable wind speed is the Beaufort scale limit (32.6 m/s). For the intact condition, the wind limits are higher than the BF scale limit. This can be seen in Figure 6, where Level 2 has been applied to North Sea weather with wind limits up to 60 m/s in the wind-wave scale (the same current speed as in the BF scale is used). Level 3 presents quite a smaller capability plot, as seen also for the intact condition. Figure 8 shows the Level 2 with dynamic factors equal to 1.6, 1.9 and 1.05 for wind, waves and current respectively compared to Level 3 with 40 m and 20 deg as positioning limits. The results present a satisfactory agreement.

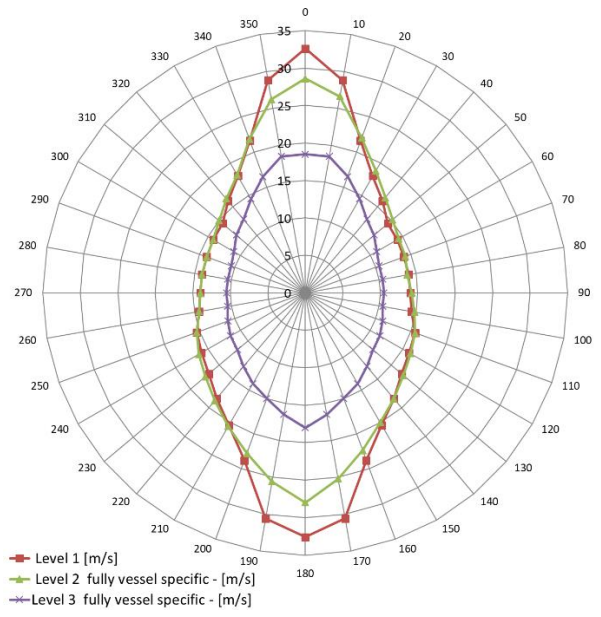

Figure 9: Drill ship – Loss of Thruster 1 and 6 - comparison among Level 1, Level 2 and Level 3

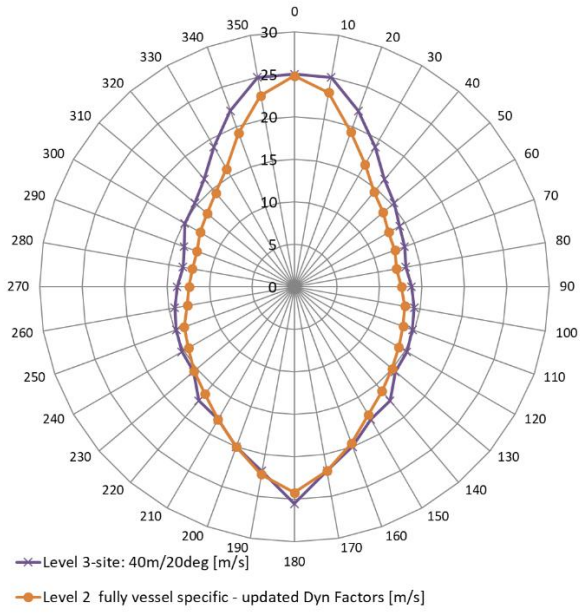

Figure 10: Drillship – Loss of Thruster 1 and 6 - Level 2 with updated dynamic factors and Level 3 with large positioning limits

Case 2 – Semi-submersible drill rig

The rig is equipped with eight 6500 kW ducted azimuth thrusters, connected to 4 switchboards. Each main switchboard is powered by two 8500 kW generators. The rig main particulars are shown in Table 2. The hull geometry is shown in Figure 11. The thruster layout is presented in Figure 12, and the power system single line diagram is presented in Figure 13.

Table 2: Drill rig main particulars

Description	Symbol	Unit	Value
Length of the pontoons	Lpp	m	120
Breadth over all	B	m	95
Breadth of pontoons	B_p	m	23
Operating Draught	T	m	24

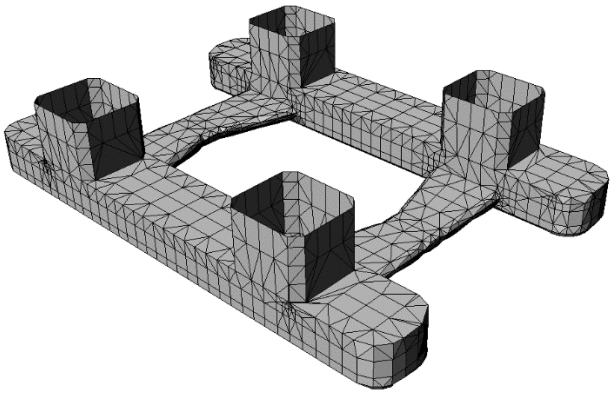

Figure 11: Drill rig hull geometry

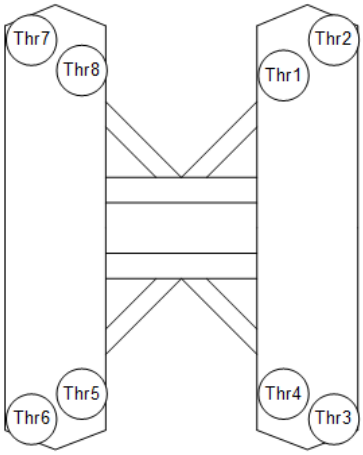

Figure 12: Drill rig thruster layout

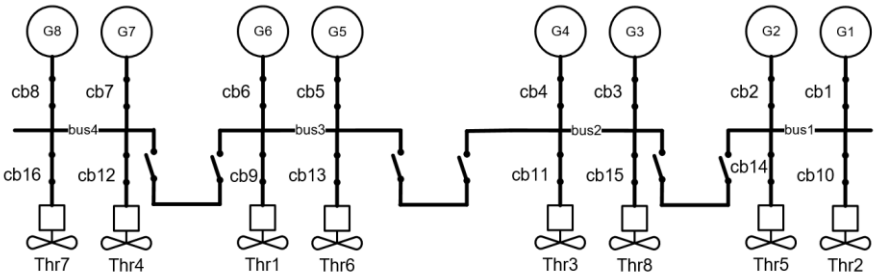

Figure 13: drill rig power single line diagram

Intact condition

Figure 14 shows the comparison between the DP Capability (wind envelopes) Level 2 and Level 3 calculations result with the rig in intact conditions (note that Level 1 is not applicable for non mono-hull vessel shapes). The Level 2 analysis has been carried out with vessel specific wind, current and wave drift coefficients, thruster bollard-pull values and thrust losses, and with dynamic factors equal to 1.25 for wind, current and wave loads. When comparing Level 2 with Level 3, the same considerations as applied for the drillship are valid here. What could be observed is that the wind envelope is more round for semi-submersible rigs compared to drillships, making the rig design typically more robust with respect to

heading changes. Different dynamic factors have been applied to the Level 2 analysis to see which factor should be applicable to math a Level 3 analysis with 40m/20deg of positioning limits. In this case the best fit was with dynamic factors equal to 1.4, 1.8 and 1.05 for wind, wave and current respectively. The resulting DP capability plot is shown in Figure 16.

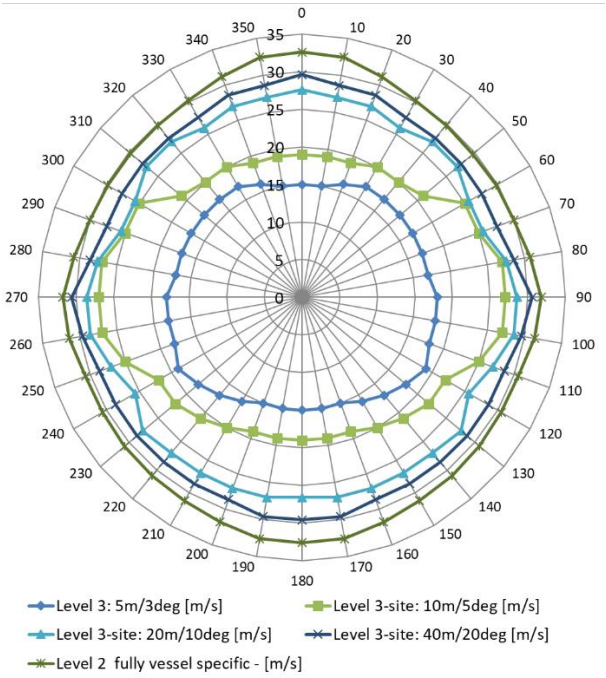

Figure 14: Semi-submersible – Intact conditions - comparison between Level 2 and Level 3, and Level 3 with different positioning limits

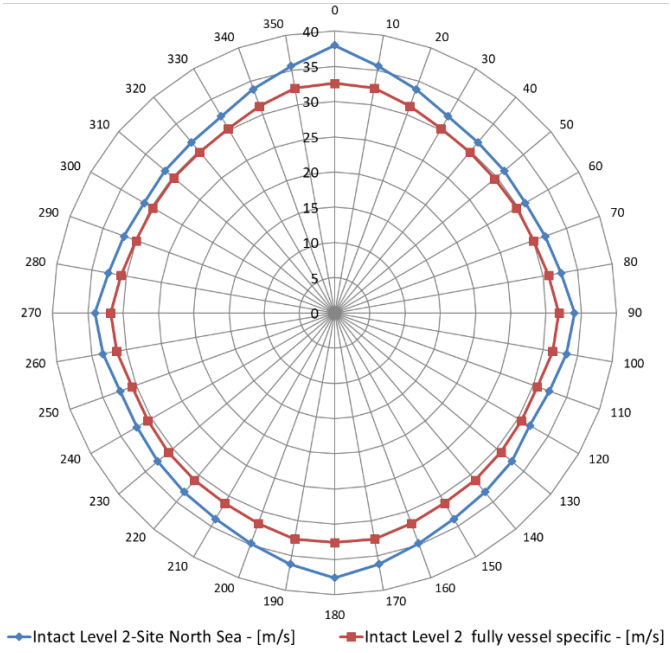

Figure 15: Semi-submersible – Intact conditions - Level 2 (BF) and Level 2-Site for North Sea

Loss of Thruster 2 and 5

Figure 17 shows the Level 2 results compared to Level 3 results with different positioning limits. Also for this case, the same consideration that applied to the drillship are valid. One difference can be noticed from the drillship results. That is the intact and the failure cases produce a very similar DP Capability wind envelope for Level 3 (positioning limits 5m/3deg) for the wave realization we have chosen. In this case, there is a large wave drift force within the 3-h simulation for which, neither with 8 nor 6 thrusters the rig is able to compensate for before it is pushed outside the 5 meter limit. By running different wave realizations, it was noticed that in average, the results in intact conditions are better than in the chosen failure condition. It should also be noticed that the positioning limits for Level 3 may be very tight for deep water drilling, where the positioning limit is typically chosen about 5% of the water depth. The Level 3 method is developed as a benchmark tool that can be applied to all the DP vessels. For drilling vessels, it will be more natural to apply Level 3-site with the actual site conditions. Figure 18 shows the Level 3 results with different positioning limits and the Level 2 result with updated dynamic factors as for the intact case (1.45, 1.6 and 1.05 for wind, waves and current respectively).

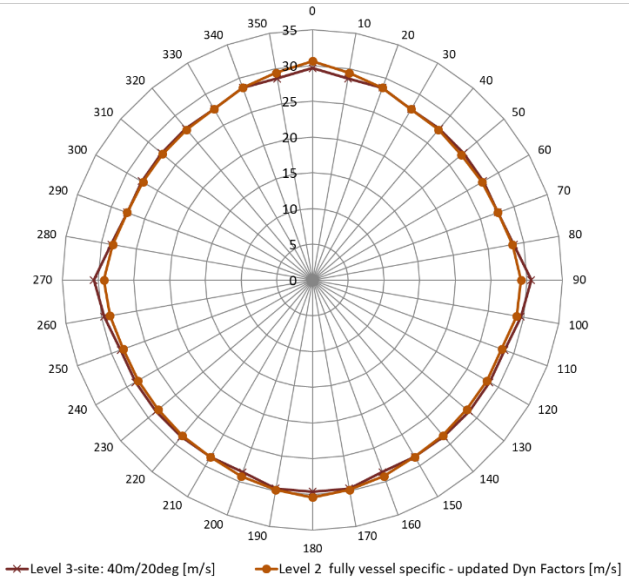

Figure 16: Semi-submersible – Intact conditions - Level 2 (BF) with updated dynamic factors and Level 3 with large positioning limits

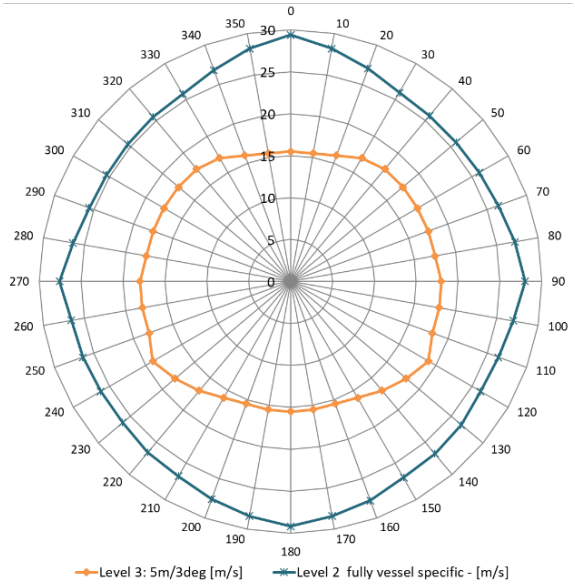

Figure 17: Semi-submersible – Loss of Thruster 2 and 5 - Level 2 and Level 3

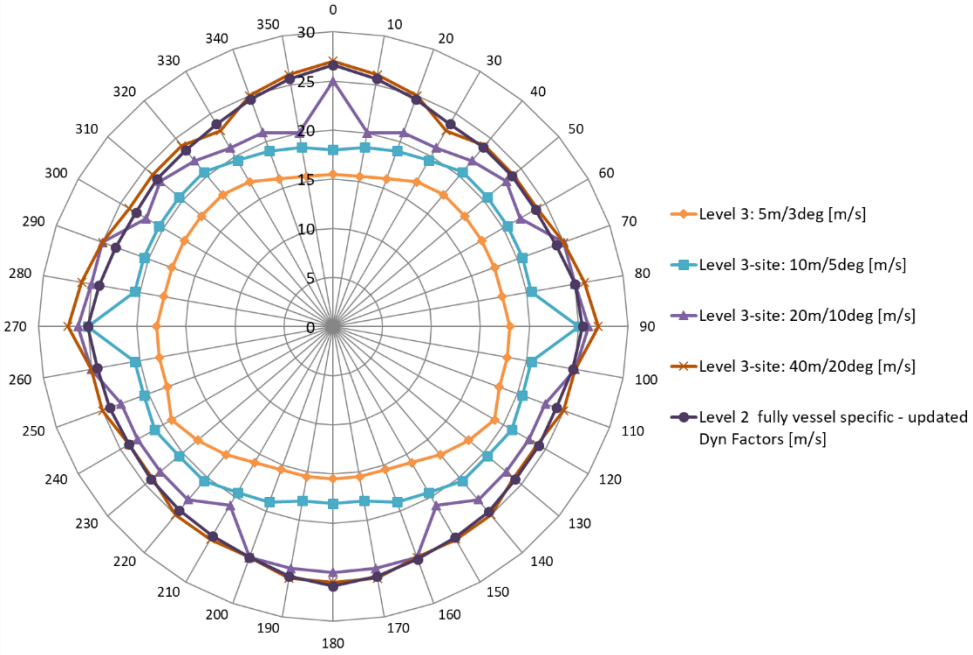

Figure 18: Semi-submersible – Loss of Thruster 2 and 5 - Level 2 and Level 3 with different positioning limits

How to apply different DP Capability levels and practical experiences of the use of the standard

Table 3 presents a summary of typical use, value for the user, and DP operation requirements for each DP Capability level. This table is meant to be used as a guide for selecting the right DP capability level based on the operation requirements and risks, and what it is important to obtain from the analysis.

Table 3: How to apply different DP Capability levels

Level	Typical use	Value for users	DP operation requirements
Level 1	• High level DP capability assessment • **Vessel performance comparison** • Want to perform first screening when many vessels will be submitted to the bid	• **Prescriptive method: Consistent and comparable results** • Improve decision input for choosing vessels • Free Web-App • Easy to deliver class required DP capability assessment numbers	• Wide vessel footprint is acceptable • Operator/owner familiar with the operation and the vessel station-keeping capability has been proven • Enough time to react to vessel failures • Mild environmental conditions
Level 2	• **When vessel specific parameters are important**	• Take advantage of **equipment/vessel specific performance** • For other hull shapes then mono hulls	• Wide vessel footprint is acceptable. It is sufficient to know in which conditions the vessel will drift off (the vessel footprint is not important to know) • Operator/owner familiar with the operation and the vessel station-keeping capability has been proven
Level 2-Site	• **When site specific environmental conditions are important** • When **external forces** are important	• Use **site specific weather** and to take in to account external forces • **Preliminary operational planning** • **Preliminary vessel design**	• Wide vessel footprint is acceptable. It is sufficient to know in which conditions the vessel will drift off (the vessel footprint is not important to know) • Operator/owner familiar with the operation and the vessel station-keeping capability has been proven
Level 3	• **When vessel and equipment dynamics are important** (e.g. position, heading or other motion in other degrees of freedom, thruster/power dynamics, gangway motion, etc.) • **Vessel performance comparison**	• Compare vessels including vessel dynamics • Improve decision input for choosing vessels	• An indication of the vessel footprint and weather operating window considering non-specific site conditions and operating criteria is sufficient
Level 3-Site	• **More information on vessel performance** (for new concept designs, planning of and vessel selection for critical operations, site specific analysis and inclusion of external forces) • **When vessel and equipment dynamics are important** (e.g. position, heading or other motion in other degrees of freedom, thruster/power dynamics, gangway motion, etc.)	**Designers and yards** • **Right size** vessels, realistic fuel consumption calculation and operability • Battery sizing **Operators and DP vessel owners** • Better data for choosing the right vessel for specific operations in a specific environment • Improved planning, improved operating limits – improved risk control • Operational and contingency planning	• Important to know the vessel footprint in different weather conditions • Little experience with the vessel station-keeping capability • Operations where the DP motion cannot be neglected • Harsh weather and challenging operating conditions • Little time to reaction to loss of position • Typically drilling operations in shallow water and harsh environment, diving, transfer of personnel with Walk2Work vessels, flotels very closed to a platform, vessel with limited capability of changing heading, offshore loading operations

Example of specification of different DP Capability levels

This section provides some suggestions on how to specify different DP Capability levels.

For Level 1:
The DP Capability plots and numbers shall be presented in form of Wind envelopes (limiting wind speed for given environmental direction) according to the standard DNV GL ST-0111 – Level 1. Below the main requirements:

- Level 1 in ST-0111 is fully prescriptive (requires zero forward speed, summer load line draft, even keel, environmental and actuator forces are calculated from prescriptive formulas, Beaufort weather scale is used, 10% of reserved power for other loads than thrusters).

What shall not be required for Level 1

No deviations from the prescriptive formulas should be specified:

- no site-specific environmental conditions;
- no extra loads (e.g. industrial mission equipment) on the switchboards other than the prescribed 10%;
- current, wind and waves not in the same direction;
- no draft other than Summer load draft;
- no actuator specific forces (generic formulas must be used);
- no external forces such as from risers, pipes, etc.;
- no vessel footprint required;

For Level 2

The DP Capability plots and numbers shall be presented in form of wind envelopes (limiting wind speed for given environmental direction) according to the standard DNV GL ST-0111-Level 2. Below the main requirements that should be defined:

- The calculation shall be performed with zero forward speed, summer load line draft, even keel. For vessels without a defined summer load line draft, the draft shall be the deepest approved operating draft.
- The calculation shall be performed with wind, current and wave drift coefficients specific to the vessel.
- The calculation shall be performed with actuator losses according to the vessel and actuator specific equipment.
- The calculation shall be performed with project specific reserved power for electrical losses, hotel loads and other loads not related to actuators
- The environmental dynamic factors can be taken as 1.5 for wind and waves, 1.05 for current if vessel specific data are not available.

Optional: Results can also be presented as thrust and power utilization for given environmental conditions.

What shall not be required for Level 2

- No site-specific weather;
- current, wind and waves not from the same direction;
- no draft other than Summer load draft for mono-hulls;
- no external forces such as from risers, pipes, etc.;
- no vessel footprint required.

For Level 2-Site

The DP Capability plots shall be presented in form of wind envelopes (limiting wind speed for given environmental direction) according to the standard DNV GL ST-0111-Level 2 site. Below the main requirements that should be defined:

- The wind envelopes shall be calculated for the site-specific operating: table with wind speed, wave height, wave period needs to be specified. Current speed needs to be specified. Wind, wave and current direction need to be specified.
- The calculation shall be performed with the draft: *draft-name, draft m; trim angle*
- The calculation shall be performed with wind, current and wave drift coefficients specific to the vessel.

- The calculation shall be performed with actuator losses according to the vessel and actuator specific equipment.
- The calculation shall be performed with project specific reserved power for electrical losses, hotel loads and other loads not related to actuators
- If external forces are relevant: External forces shall be included (specify from drilling riser, pipes, etc.)
- The environmental dynamic factors can be taken as 1.5 for wind and waves, 1.05 for current if vessel specific data are not available.

Optional: Results can also be presented as thrust and power utilization for given environmental conditions.

What shall not be required for Level 2-site

- no vessel footprint required.

For Level 3

The DP Capability plots shall be presented in form of Wind envelopes (limiting wind speed for given environmental direction) according to the standard DNV GL ST-0111-Level 3. Below the main requirements that should be specified:

- The calculation shall be performed with zero forward speed, summer load line draft, even keel. For vessels without a defined summer load line draft, the draft shall be the deepest approved operating draft.
- The calculation shall be performed with wind, current and wave drift coefficients specific to the vessel.
- The calculation shall be performed with actuator dynamics and losses according to the vessel and actuator specific equipment.
- Simulations shall be in accordance with the vessel power consumption balance.
- The positioning limits shall be 5 meters and 3 degrees. Simulations lengths shall be 3-hours. As minimum 3 wave realization to be simulated.
- The calculations shall be performed considering either the low-frequency motion when assessing the vessel positioning against the positioning limits

Optional: Results can also be presented as thrust and power utilization, vessel motion and footprints, environmental forces, individual thruster forces and angles for given environmental conditions.

What shall not be required for Level 3

- No site-specific weather;
- current, wind and waves form the same direction;
- no draft other than Summer load draft for mono-hulls;
- no external forces such as from risers, pipes, etc.

For Level 3-Site

The DP Capability plots shall be presented in form of Wind envelopes (limiting wind speed for given environmental direction) according to the standard DNV GL ST-0111-Level 3-site. Below the main requirements that should be specified:

- The calculation shall be performed the specified load conditions: Operating (or survival, etc.)
- The calculation shall be performed with wind, current and wave drift coefficients specific to the vessel.

- The calculation shall be performed with actuator dynamics and losses according to the vessel and actuator specific equipment.
- Simulations shall be in accordance with the vessel power consumption balance.
- The positioning limits shall be specific to the specified operation. Simulations lengths shall be at least 3-hours. As minimum 3 wave realizations to be simulated.
- The calculations shall be performed considering either the low-frequency motion or the total motion when assessing the vessel positioning against the positioning limits, according to the operation requirements.
- If external forces are relevant: External forces shall be included (specify from drilling riser, pipes, etc.).
- Effect of water depth shall be included if relevant.

Optional: Results can also be presented as thrust and power utilization, vessel motion and footprints, environmental forces, individual thruster forces and angles, external forces for given environmental conditions.

Updates in the last version of the standard and web-app

The main changes in the latest standard version, released in March 2018, were based on the feedback from industry, and on DNV GL experiences in applying the standard and performing verification analyses. The changes are described at the beginning in the new version of DNVGL-ST-0111 and in [8]. Beside updating and clarifying some definition, the main update in the standard are the rule for calculating the thrust losses due to thruster-skeg interaction. This represents a major update as it can affect the station-keeping capability calculation significantly. The interaction between a thruster race and a skeg will result in a thrust loss factor as described in [8].

The web-app has been released several times during the last year. The main updates are:

1. Ability to run fixed-weather scenarios
   This feature allows to run fixed weather scenarios, to get thruster and power utilization for different environmental conditions. This is particularly useful when calculating, for example, the station-keeping robustness with respect to heading changes.
2. Improved calculation speed
   The calculation code and data handling have been improved, resulting in faster calculations and reporting.
3. Added thruster tilt in the thruster data
   The tilt angle in azimuth thrusters can influence significantly thrust losses due to thrust-hull interaction. The tilt angle can now be set in the user interface and guidance if provided for setting the correct thrust losses.
4. Improved guidance and user error handling
   The user interface is improved with more help on how to do correct configuration of vessel parameters and run setting. This is achieved by adding more inline help, and by adding validations of the input fields (such as range checks, dropdown menus with limited choices, etc.).
5. Implemented changes per the standard updates
   The web-app has been updated to reflect the changes in the standard.
6. Bug fixes
   Some major and minor bugs have been fixed.

Future planned work in the web-app and standard

The next release of the standard will include further guidance for setting realistic thrust losses. The requirements for verification will be simplified and guidance on how to set electrical losses will be added.

The web-app will be updated with new features such as the possibility to run operability studies and motion analyses. Additional validation for the user input data will be also implemented.

Other updates to the standard and web-app may be included upon industry feedback.

Conclusion

This paper focused on the main challenges that have emerged regarding the use of the DNV GL ST-0111 standard, with attention on how to apply and use the 5 different levels available in the standard. The paper presented how the results from the different levels compare to each other. This was done for a drillship and semi-submersible drill rig. This paper also provides guidance on how to use the different levels of the standard, and how these could be applied to different operations, risk-management and operating locations. A suggestion on how to specify requirements for DP Capability analyses was also presented.

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