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DNV GL DP Capability - A New Standard for Assessment of
the Station-Keeping Capability of DP Vessels

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Abstract

The paper will present the new DNV GL standard: ***DNVGL-ST-0111 Assessment of station keeping capability of dynamic positioning vessels***. It will describe the principles behind the new standard, called DP Capability for short, and the methodology provided for calculating and presenting a vessel DP capability in three different levels: DP Capability Level 1, 2 and 3. The three proposed methods for calculating DP capabilities of vessels, which were developed in order to ensure reliable input to risk evaluations and decision processes, will be presented. The paper will demonstrate how the three different DP Capability levels provided by the standard can be used to ensure owners, operators and other stakeholders DP capability information suitable for vessel selection, assessment and comparison. The paper will also discuss how the standard provides a uniform basis for verification of the calculated results. DP Capability level 1 will also be supported by a web based software application provided free of charge to the industry on the My DNV GL portal. This software tool will also be presented.

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Introduction and History

Reliable documentation of a vessel's position and heading keeping capabilities is vital for planning and execution of safe and reliable operations with dynamic positioning (DP) vessels. The vessel's position keeping capabilities should be clearly understood. This applies to both the intact vessel condition, and for redundant DP vessels, even more important after the worst case single failures associated with the vessels Dynamic Positioning class notation.

The primary objective with the [DNVGL-ST-0111standard \[1\]\[4\]](#) is to set clear and consistent requirements for DP station keeping capability assessment. The standard includes three different levels:

- DP Capability Level 1 numbers shall be calculated based on a prescriptive static method so that results calculated for different vessels will be fully consistent and comparable.
- DP Capability Level 2 sets requirements 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.
- DP Capability Level 3 provides requirements for computing a vessels DP station keeping capability based on time-domain simulations.

For all three levels the standard sets unambiguous requirements for documentation of the calculations and how the results shall be presented.

The standard is a natural progression of the well-known DNV GL ern (environmental regularity numbers) concept. The ern was established together with the first DNV rules for Dynamic Positioning systems which were released in 1977. This concept has served the industry well for many years, but due to the general technical development and the development of the DP industry in general, it gradually became apparent that there was a need for developing also a new standard for assessment of DP Station keeping ability.



Figure 1: DP vessel and capability plot indicating the vessels station keeping ability

The DP Capability Concept

The well-known Beaufort wind scale was chosen as the basis for documenting the capability assessments. Additional information related to significant wave height, peak wave period, and current speed was specified and added to form the following environment scale for the DP Capability numbers:

Table 1 : DP Capability numbers and Beaufort scale including wind speed, wave height, wave period and current speed.

Beaufort (BF) Number	DP Capability number	Beaufort description	Wind speed*) [m/s]	Significant wave height [m]	Peak wave period [s]	Current speed [m/s]
0	0	Calm	0	0	NA	0
1	1	Light air	1.5	0.1	3.5	0.25
2	2	Light breeze	3.4	0.4	4.5	0.50
3	3	Gentle breeze	5.4	0.8	5.5	0.75
4	4	Moderate Breeze	7.9	1.3	6.5	0.75
5	5	Fresh breeze	10.7	2.1	7.5	0.75
6	6	Strong breeze	13.8	3.1	8.5	0.75
7	7	Moderate gale	17.1	4.2	9.0	0.75
8	8	Gale	20.7	5.7	10.0	0.75
9	9	Strong gale	24.4	7.4	10.5	0.75
10	10	Storm	28.4	9.5	11.5	0.75
11	11	Violent Storm	32.6	12.1	12.0	0.75
12	NA	Hurricane force	NA	NA	NA	NA

*) The wind speed is the upper limit of the mean wind speed 10 m above sea level for the given DP Capability number. The given peak wave periods represent the 95% confidence interval found from the world wide scatter diagram.

The standard sets requirements for calculation of DP station keeping capability at **three different levels**:

- **DP Capability Level 1** sets requirements to a basic and prescriptive static method for documenting DP Capability numbers for ship-shaped-mono-hull vessels. The calculation shall be based on a static balance of environmental forces and the vessel's actuator forces. The calculations shall, for benchmarking purposes, be based on the specified environmental data in table 1 for all vessels. The rigidity of the method ensures that the DP Capability numbers calculated according to the method shall be comparable between different vessels.
- **DP Capability Level 2** sets requirements for a more comprehensive quasi-static method as compared to level 1 and can be applied to all vessel shapes. This level allows for vessel specific adjustments to the calculations. Any method adjustments and use of vessel specific parameters shall be documented and justified. The calculations shall be based on a static balance of environmental forces and the vessel's actuator forces, and shall be based on the same specified environmental data as for Level 1.
- **DP Capability Level 3** sets requirements for use of time-domain simulations and can be applied to all vessel shapes. Such simulations may e.g. be used in projects where more information about the vessel dynamic capabilities is wanted. Environmental data specified for Level 1 shall be used.



Figure 2: The standard describes how to perform position keeping assessment in 3 different levels

For all the above levels, capability plots shall be produced and the results of the DP capability assessment shall in addition be documented by DP capability numbers in the following format:

DP Capability-LX(A, B, C, D)

The different elements in this string represent the following information:

- X = 1, 2 or 3 describing the DP Capability Level
- A = Maximum DP Capability number as specified in [Error! Reference source not found.](#)Table 4 where the vessel in its intact condition (no failures) can maintain station with its heading $\pm 30^\circ$ relative to the environmental forces
- B = Maximum DP Capability number as specified in [Error! Reference source not found.](#)Table 4 where the vessel in its intact condition (no failures) can maintain station with heading 0-360°
- C = Maximum DP Capability number as specified in [Error! Reference source not found.](#)Table 4 where the vessel in its Worst Case Single Failure condition relevant for the class notation can maintain station with its heading $\pm 30^\circ$ relative to the environmental forces
- D = Maximum DP Capability number as specified in [Error! Reference source not found.](#)Table 4 where the vessel in its Worst Case Single Failure condition, relevant for the class notation, can maintain station with its heading 0-360°

The information elements A, B, C and D shall be extracted from capability plots calculated in the specified conditions and according to the requirements given for the specified DP Capability Level X. The information elements C and D shall be based on capability plots representing failure of each redundancy group (as determined by the vessel DP FMEA) and the numbers shall be the lowest numbers obtained across all the redundancy group cases. The C and D parameters are not applicable for non-redundant DP systems and shall be indicated as NA (not applicable) for such vessels.

The DP capability number indicates that a vessel's position keeping ability can be maintained in the corresponding DP capability number condition and all conditions below, but not in the environmental conditions specified for the next DP capability number.

The standard also opens for assessment based on site specific environmental data different from the data specified in Table 1 with the introduction of two additional levels: **DP Capability Level 2-Site** and **DP Capability Level 3-Site**. These use the same methods as Level 2 and Level 3, respectively, in addition to allowing for site specific environmental data (and other operation specific aspects) to be used and/or inclusion of external forces. Results will only be fully comparable between vessels in case the same

calculation method and environment are used for the vessels to be compared. The capability result for Level 2-Site and Level 3-Site cannot be presented in the form of DP Capability numbers, but shall be presented in the form of capability plots showing the limiting wind speed calculated in the specified conditions.

DP Capability Level 1 only relates to the environment specified in **Error! Reference source not found.** Table 1. In cases where different environmental conditions would like to be employed, then a DP Capability Level 2-Site calculation can be performed using the DP Capability Level 1 prescriptive calculation method, as long as this is applicable to the specified environment.

In addition to the calculation methods, the standard sets requirements for how to document the calculations and how the results shall be reported. Reference is made to appendices A and B in [1][4].

Verification is vital when results are to be used for comparison of vessels and for most other purposes as well. In order to support this, the standard set requirements to verification by specifying a minimum set of activities to be performed by the verifier.

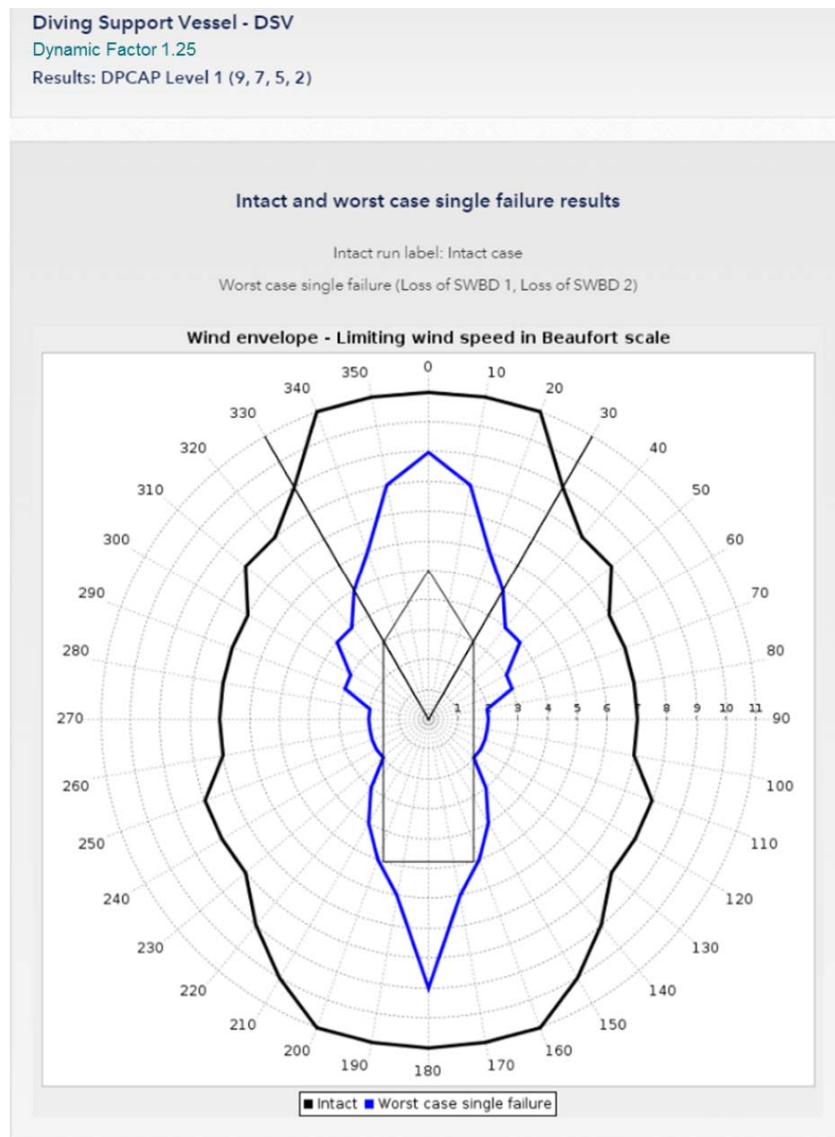


Figure 3: Example of a DP capability plot for Level 1 including the intact condition and a combined plot for the worst case single failure (WCSF) condition

The DP Capability Project

The DP Capability standard has been developed by DNV GL in close cooperation with a wide industry group consisting of almost 20 different expert companies. The group included designers, yards, thruster manufacturers, DP control system manufacturers, vessel owners, maritime research institutes, and oil companies in addition to DNV GL. During the process several workshops were arranged, in which the industry group members met to discuss the content of the standard. Between these workshops DNV GL developed proposals which were circulated within the group and discussed in the next meeting.

The project main goal was defined as: “Create a new industry standard for position keeping capability assessment”. By doing this DNV GL wanted to provide a standard to the market to sets requirements to calculation methods ensuring consistent, comparable and verifiable results, regardless of who was going to perform the calculations. The project also wanted the standard to set requirements on how to documenting the calculated results in order to provide easy understandable and comparable results, which in addition also supported vessel benchmarking.

One main input from the industry group was that the data required to do the calculations had to be on a level which made it possible to utilize the standard at design stage, i.e. before specific vendors and equipment types were chosen. This was partly based on a main concern expressed in the group concerning the flexibility in older standards being utilized to maximize and provide too optimistic results with minimum power and thruster configuration when competing for contracts. The new prescriptive and verifiable standard aims to assist in levelling the playing field among competing designers and yards.

The development process consisted of three main phases [4][4]. The first and shortest phase started in early 2013 with an industry meeting in January and aimed to develop more prescriptive acceptance criteria for environmental regularity numbers, which was denoted ern*. After this rule update, the work continued in to a second phase where the goal was to develop the technical basis for the new DP Capability standard. This phase represented the biggest part of the project and included three one-day workshops. In the third and final phase of the project DNV GL used the results from the first phase to write a draft proposal for the new standard. This draft was circulated within the industry group and further discussed in two more one-day workshops. The draft for the DP capability standard produced by the project was then sent on a wide industry hearing in the first part of 2016, and finally released as “DNV GL, ST-0111 – Standard for Assessment of station keeping capability of dynamic positioning vessels,” in July 2016.

Some of the main activities are presented in the following project event timeline:

- Internal project kick-off: January 2013
- First DP Capability meeting with industry: January 2013
- Update ern to ern*: July 2013
- TEKNA conference presentation: February 2014
- Workshop 1: April 2014
- Workshop 2: June 2014
- Workshop 3: November 2014
- Workshop 4: November 2015
- Workshop 5: January 2016
- Release of DP Capability standard: July 2016
- Release of DP Capability Level 1 software App: August 2016

DP Capability Level 1

The goal of DP Capability Level 1 is to set a new standard for easy benchmarking of vessel's DP capability. In the future this may replace ern* in the DNV GL rules [5][5]. The idea is to take advantage of general technical development and produce a new benchmarking standard giving a more comprehensive picture of the station keeping capability of DP vessels. Compared to the ern* numbers two of the major improvements in the DP Capability Level 1 standard are:

- Weather is calculated from all directions
- Results are presented in a new scale (see Table 1)

In the DP Capability Level 1 assessment environmental forces from all directions are included as opposed to ern* where only beam sea is considered. This provides a more complete evaluation of the DP capability.

The new DP Capability number scale is coarsened, extended and linked to the Beaufort scale. One issue with the ern* concept is that often users specifies the maximum performance ern*(99,99,99,99) as a target without real consideration of the actual DP capability needed for the intended industrial mission. The new standard aims at guiding the stakeholders to take a more deliberate decision on required performance on the assessment scale. Hence, it was made a decision to adopt an extended scale, with higher maximum limit compared to ern. The DP Capability scale ranges from 0 to 11, and on this scale the ern 99 weather will be between 8 and 9. The scale is also coarsened, such that a step to the next level will represent a significant improvement in the DP capability of the vessel as the environmental forces typically increases more than 50%. The Beaufort scale is used as reference with the intention to ease the intuitive understanding of the different environmental conditions.

The computation of DP Capability Level 1 numbers is based on a fully prescriptive method. This is to ensure consistency in the way the calculations are performed and thereby make the results suitable for benchmarking purposes. The rigidity of the method also paves the way for consistent verification of results.

Similar to the requirement of many of the traditional standards and specifications for DP capability plots (see for example [3][3]), the method is based on a quasi-static balance of mean forces from wind, current, waves and actuators, considering all 360 degrees environmental directions. The empirical formulas used in the standard are based on extensive literature surveys (see for example [2][2]), a significant database of advanced CFD (Computational Fluid Dynamics) simulations, and expert knowledge within the industry group. When developing the formulas it is intended to keep them on an acceptable level of complexity, while still providing sufficiently accurate information about vessels station keeping capabilities in order to be able to do comparison.

The formulas for wind and current forces can easily be related to classic drag formulations. The corresponding parameters that can differentiate vessels are the projected transverse area, the projected longitudinal area, and the longitudinal position of the centre of the projected longitudinal area. For the current forces, the projected front area is replaced by breadth times draft to simplify further, since the mid-ship section coefficients are typically very close to 1.0.

The formulas for wave drift forces are based on first principles, with correction factors for bow entrance angle and water plane area coefficient of the stern determined based on CFD simulations. In addition the relationship between the wave length and vessel dimensions are accounted for. Based on a significant database of CFD simulations, a large number of parameters which could affect the wave drift forces were investigated. In this process it was aimed to limit the number of parameters. This resulted in the wave drift forces being dependent on vessel length, breadth, bow entrance angle, aft ship water plane area, and midpoint of longitudinal distance between fore most and aft most point under water.

The nominal thrust of various actuators is based on the ern* rules and extended to include also permanent magnet thrusters and cycloidals. A new loss factor for tunnel thrusters taking into account the shape of the

tunnel entrance has been included. Credit is given to broken and rounded inlets compared to sharp ones. Further, a model of ventilation losses has been developed. This model depends on the vessel length, and the submergence and longitudinal position of the actuator. Probably one of the most significant developments on the actuator side is the inclusion of mandatory forbidden sectors limiting the possibility of flushing other thrusters and skegs on the hull. The standard, generally, does not accepted a thruster flushing the hull or other working thrusters, whereas reduced efficiency of the working thruster is assumed when flushing a dead thruster. When determining the forbidden sectors, the important vessel specific parameters are thruster diameters and the distances between thrusters in addition to the geometrical layout.

To account for time varying dynamics effects the standard specifies that wind, current and wave forces, shall be multiplied with a dynamic factor of 1.25 in the calculations.

Obtaining the DP Capability Level 1 numbers according to the new standard entails somewhat more comprehensive computations as compared to the ern*. To ease the use of the new standard, a Web application for computing the DP Capability Level 1 numbers is developed and made available to everyone through the MyDNVGL portal. A detailed description of the Web application is provided in a later section of this paper.

DP Capability Level 2 and Level 2-Site

The purpose of DP capability Level 2 is to allow for improved evaluation of DP capability compared to DP capability Level 1, by use of enhanced methods to compute environmental loads and actuator forces. DP capability Level 2 can also be used when there are project specific needs, e.g. due to novel design or technology, or for calculating capability for and comparing vessels with hull shapes not applicable to DP capability Level 1. Any deviations from the DP capability Level 1 method and any project specific data applied must be justified and documented.

The purpose of DP Capability Level 2-Site is to set a standard for production of classical DP capability plots. Compared to Level 1, it allows for any site specific environmental conditions in addition to (when wanted) more advanced methods for obtaining wind, current, wave, and actuator forces. The minimum expected levels of complexity of applied methods are summarized in Table 1. Differences should be well justified and documented in the report. Together with DP Capability Level 2-Site calculations, DP Capability Level 2 and DP capability Level 1 shall also be calculated in order to demonstrate how the enhanced computational methods in Level 2-Site compares to Level 1 and 2. For this to be effective the same methodology must be used when calculating DP capability Level 2-Site and DP capability Level 2.

Table 2: DP Capability Level 2 and Level 2-Site method complexity

	Minimum Required complexity
Wind loads	Model test or RANSE
Current loads	Model test or RANSE
Waves loads	Model test or CFD (including potential theory)
Actuator forces	Model test or CFD (including potential theory)
Thrust losses	Empirical method

DP Capability Level 3 and Level 3-Site

The purpose of DPCAP Level 3 is to get more insight on the vessel's DP capability performance by use of time-domain simulations. Simulations shall be performed with a vessel model controlled by a DP

control system which may or may not be the same control system supplied by the DP control system vendor. By performing time-domain simulations and including the relevant dynamics, DPCAP Level 3 can provide more information about the station keeping performance than the other DPCAP Levels, such as statistics of the vessel position and heading, thruster and power utilization, and of other relevant vessel states.

DP Capability Level 3, which is applicable to all vessel shapes, aims also at assessing the effect of relevant dynamics on the DP performance. Relevant dynamics are typically: Vessel dynamics, environmental load dynamics, actuators dynamics, and DP control system dynamics.

DP Capability Level 3 has many common requirements (in terms of rigidity) with the Level 1 analysis, and is therefore suitable for vessel comparison and benchmarking. It is designed to evaluate the DP performance based on environment, loading condition and operating mode as defined in DP Capability Level 1, and also here without the inclusion of external forces.

The main difference between Level 3 and the other levels is that the analysis shall employ time-domain simulations with a mathematical model of the vessel in closed-loop with a DP control system. Employing time-domain simulation implies that the vessel is free to move and the analysis is based on the evaluation of a simulated vessel footprint (contrary to Level 1 and 2 which are based on a static force balance). An example of a vessel footprint is given in [Figure 4](#).

The vessel shall be considered in station keeping if it can maintain position and heading within predefined positioning limits (position less than 5 m from the set-point and the heading less than 3 degrees from the set-point) for 3 simulated hours for a given environmental condition. Similarly to Level 1 and Level 2, the DP Capability Level 3 lists the requirements for environmental and actuator forces, and power generation and distribution models. For these models, relevant dynamics shall be included in the simulations. The standard for Level 3 sets also the requirements for the vessel dynamics to be used and the sensors to be included in the simulations. A DP control system shall be implemented to control the position and heading of the vessel. This can either be a model or the vendor DP control system software (which shall correspond to the actual vessel when available).

Similarly to Level 2, the standard defines a DP Capability Level 3-site, to relax the requirements on the environmental conditions, to allow for the inclusion of external forces and for applying positioning limits and other operating criteria suitable for the operation considered.

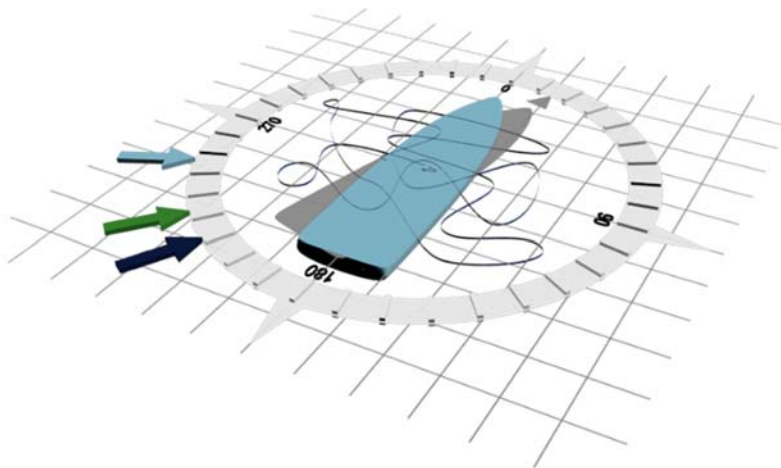


Figure 4: Vessel footprint from Level 3 simulations

Summary of the DP Capability Levels

Table 3 lists the main characteristics and differences among the different DP Capability Levels.

Table 3: Summary of the DP Capability Levels

Item	Level 1	Level 2	Level 2-Site	Level 3	Level 3-Site
Type of analysis	Quasi-static	Quasi-static	Quasi-static	Time-domain	Time-domain
Typical use	Vessel benchmarking and comparison	Vessel benchmarking and comparison; improved models compared to Level 1	Operation specific capability analysis with improved models compared to Level 1	Vessel benchmarking and comparison including vessel dynamics	Operation specific capability analysis including vessel dynamics
DP Capability calculated by	Balance of forces and moments	Same as Level 1	Same as Level 1	Evaluation of position and heading	Same as Level 3
Calculation method	Prescriptive	Same as Level 1 plus allows for vessel specific adjustment	Same as Level 2	Vessel specific	Vessel specific
Vessel shape	Mono-hull	All vessel shapes	All vessel shapes	All vessel shapes	All vessel shapes
Environmental conditions	DP Capability number scale, collinear directions	Same as Level 1	Site specific	Same as Level 1	Site specific
Dynamic Factor	1.25	Free to choose	Free to choose	NA	NA
Positioning limits	NA ^{*)}	NA	NA	5 m position, ± 3 degrees heading	Site specific
Vessel Motion considered	NA	NA	NA	Low frequency vessel motion	Site specific: low frequency or total vessel motion
Simulation time-window/ wave realizations	NA	NA	NA	3 hours/ min 3 realizations	At least 3-hours / min 3 realizations
Load condition (draught)	Summer load line draught	Same as Level 1	Site specific	Same as Level 1	Site specific
Water depth	Infinite	Infinite	Site specific	Infinite	Site specific
External forces	Not included	Not included	Site specific	Not included	Site specific
Additional computation for comparison	NA	Level 1 when applicable ^{**))}	Level 1 and Level 2 when applicable ^{**))}	Level 1 when applicable ^{**))}	Level 1 when applicable ^{**))}
Required presentation of result	DP Capability numbers and plots	DP Capability numbers and plots	Wind envelope plots	DP Capability numbers and plots	Wind envelope plots
^{*)} NA is Not Applicable ^{**))} DP Capability Level 1 cannot be computed, for example, for semi-submersible, catamaran. For Level 2-Site, the computation of Level 2 is not required if DP Capability Level 1 cannot be computed.					

DP Capability Web Application

Together with the new standard, DNV GL has developed a web tool to calculate the DP Capability numbers for Level 1. The DP Capability tool is available free of charge at www.MyDNVGL.com. A screenshot of the DP Capability results page from the web tool is provided in Figure 5.

This application helps the user to fulfil all the requirements for the Level 1 calculation providing, almost in real-time, the Level 1 numbers when all the required data are filled in.

The main tool features are described below:

- The user can input all the necessary data for the calculation and produce the results, both visually in the application and with an auto generated report.
- The application should work with all common web-browsers but it has been tested mainly for Internet Explorer and Google Chrome.
- A link to the DNV GL standard ST-0111 is available in the tool for user's reference.
- The user can request the DNV GL approval of the Level 1 calculation via the tool.
- User feedback on the Tool can be provided by sending an email to the contact shown in the tool.
- Links to other DNV GL services related to DP capability are available in the tool.
- The tool was built for working with vessel fleets – all the vessel data are recorded and reusable later.
- The tool allows to copy from existing vessels in the user's own fleet, import and export of vessel's data to a file.
- Result from the calculation are generated and shown almost immediately.
- A downloadable report in PDF file format is auto generated. Examples of three pages from the report are given in **Error! Reference source not found.** ~~Figure 6.~~
- The tool features input data checking and warn the users if data are not in the valid range or of a valid type. If a required data is missing, a red contour will appear around the correspondent input data cell.
- The tool supports the most common power and propulsion configurations.
- The tool allows for unlimited number of vessels and calculations.
- A completion bar shows the user its progress on completing the input of all required data.
- A tooltip functionality was developed to help the user to understand the meaning of the required input data
- Thruster forbidden zones are automatically generated according to the DP Capability standard. The user can also add user-specific forbidden thrust zones.
- The tool support the dynamic factor as specified in the new standard but allows also the user to apply power limitations to each individual thruster.

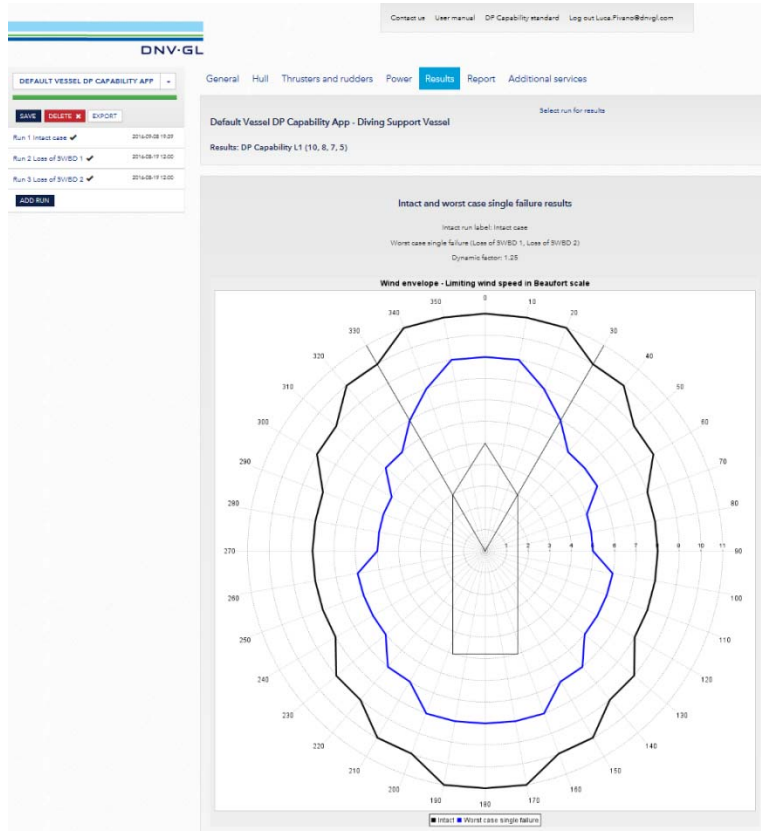


Figure 5: Screenshot of the DP Capability Level 1 Software application

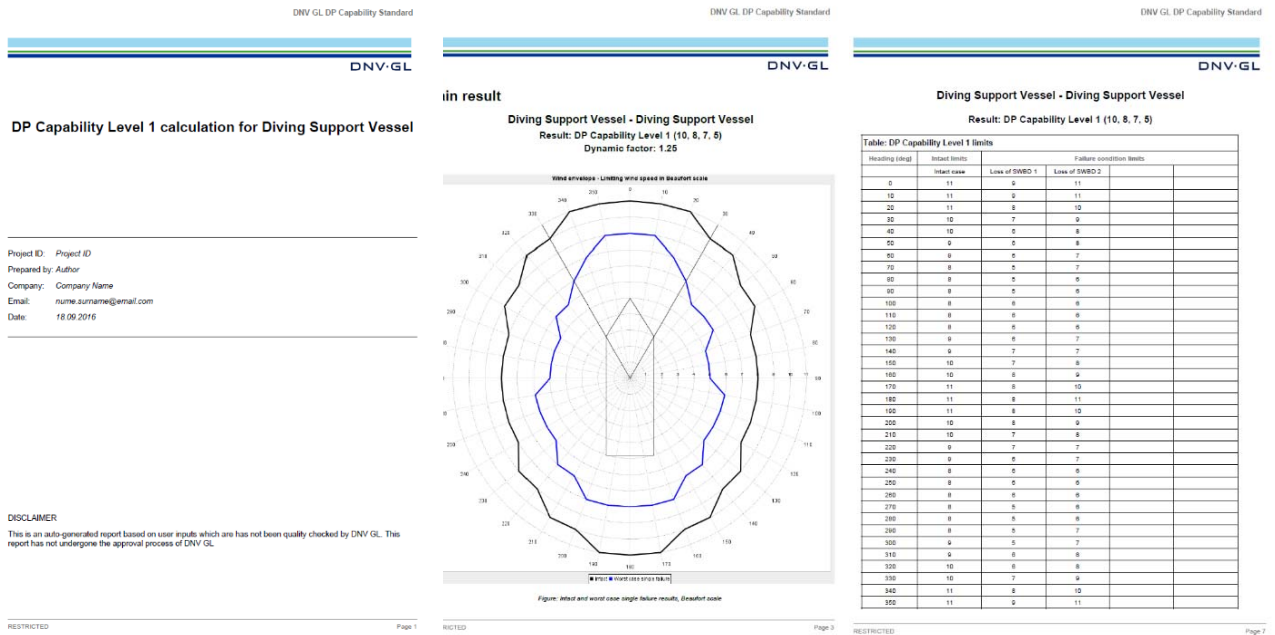


Figure 6: Example of three pages from the auto generated report.

Conclusion

The new DNV GL standard: *DNVGL-ST-0111 “Assessment of station keeping capability of dynamic positioning vessels”* provides the industry with a new basis for documenting the station keeping ability of Dynamic Positioning (DP) vessels. The standard comprises DP station keeping assessments in three levels. These levels comprise of a first level based on fully prescriptive static calculations (typically for benchmarking), a second quasi-static level with improved models compared to Level 1 (allows also for project specific adjustments compared to level 1) and a third level based on time-domain simulations to provide more information on vessel DP station keeping performance. The standard ensures the user consistent and verifiable results by setting requirements to calculations, how to perform verification of the results, and how to document the results. The standard is supported by a web tool to calculate the DP Capability numbers for Level 1. The DP Capability tool is available free of charge at www.MyDNVGL.com.

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