D5.2 - SPECIFICATIONS FOR PERFORMING THE REDUCED SCALE TEST

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FLOTANT -Innovative, low cost, low weight and safe floating wind technology optimized for deep water wind sites, has received funding from the European Union´s Horizon 2020 research and innovation programme under grant agreement No.815289

D5.2 - SPECIFICATIONS FOR PERFORMING THE REDUCED SCALE TEST

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Abstract

This document describes the technical specifications for tank testing for the FLOTANT reduced scaled prototype to be performed in the Maritime Research Institute Netherlands .

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1 INTRODUCTION

1.1 Purpose

This document aims to provide a technical specification for tank testing campaign for the FLOTANT project. The tank testing campaign described in this technical specification will be carried out at the Marin facilities (Maritime Research Institute Netherlands).

The main objectives of the tank testing campaign are to validate the technology and to calibrate the numerical model under several configuration of sea states. The wind load will be implemented with a Software-in-the-Loop (SiL) to calculate in real time the proper thrust to be applied. Based on Marin experience in this type of projects, the aerodynamic forces will be modelled with an innovative winch system, which can be adapted to simulate different wind direction.

Two different locations have been established to operate this platform (West of Barra and Gran Canarias), but only one depth will be tested in this campaign, to avoid changing the tank configuration. Note that the main properties of the platform as mass, CoG, inertial, dimensions, etc., are the same for both depths and only depth and mooring configuration will be changed.

A tests proposal is divided as follows:

- Pre-calibration test:
  - Static load test mooring system,
  - Hammer test to verify the natural frequencies of the models.
  - Hydrostatic stiffness tests for longitudinal and transversal direction.
- Decays tests for free floating and moored conditions.
- Station keeping tests for two headings.
  - White noise tests
  - Regular wave
  - Irregular wave, current and wind.
  - Transport

2 AXIS SYSTEM AND SIGN CONVENTION

Center of coordinates is situated at the geometric center of the downmost face of concrete slab. The convention for describing the motions and static displacements of the platform in the six degrees of freedom is:

- Surge is positive parallel to and in the same direction to the local X direction;
- Sway is positive parallel to and in the same direction to the local Y direction;
- Heave is positive parallel to and in the same direction to the local Z direction;
- Positive Roll/Heel is rotation about the local X axis in a clockwise direction when looking along the positive X axis from the origin;
- Positive Pitch/Trim is rotation about the local Y axis in a clockwise direction when looking along the positive Y axis from the origin; and
- Positive Yaw is rotation about the local Z axis in a clockwise direction when looking along the positive Z axis from the origin.

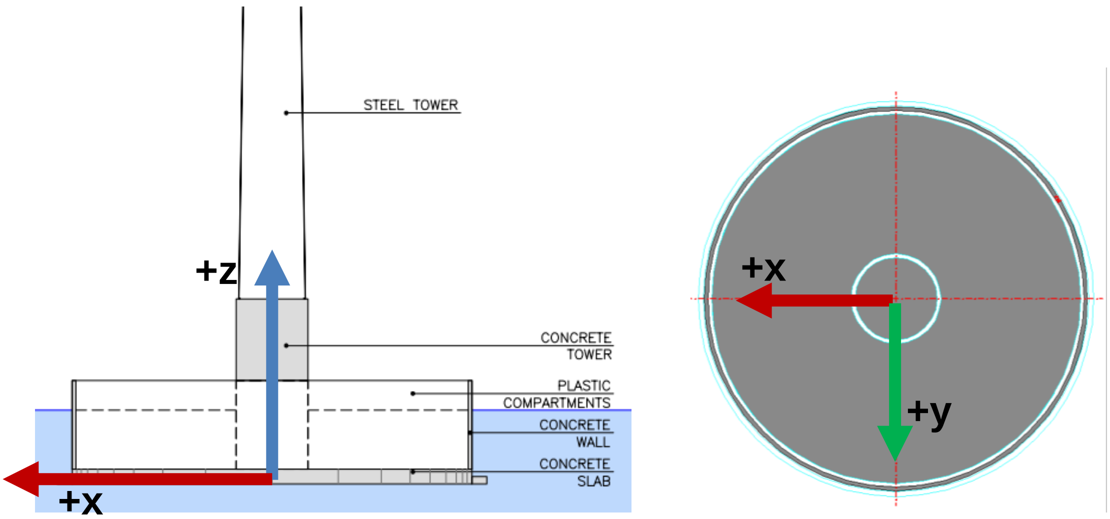

FIGURE 2.1. LOCAL AXIS SYSTEM

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The sign convention is as follows:

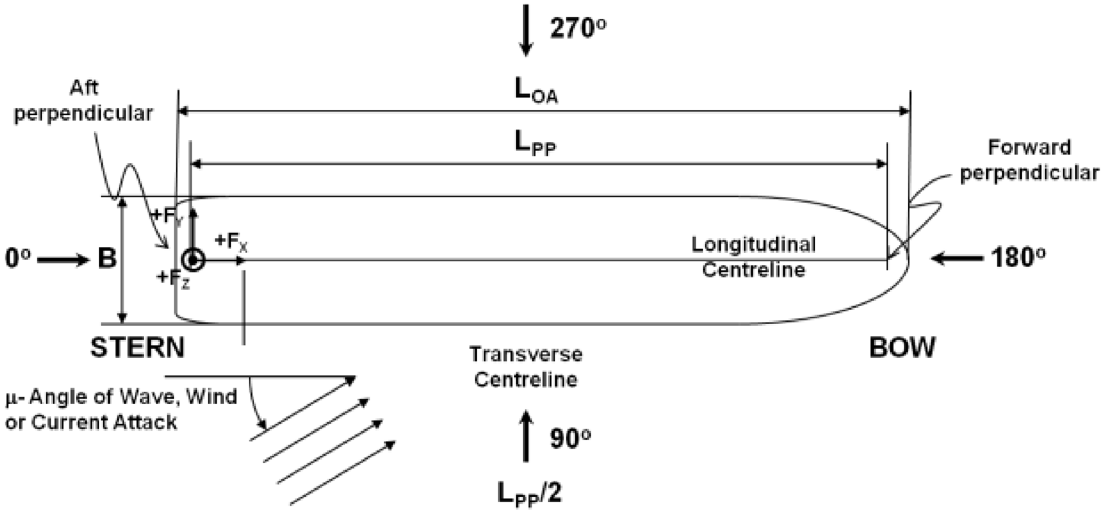

FIGURE 2.2. SIGN CONVENTION IN THE OFFSHORE BASIN

Two different heading have been considered to verify the behavior of the platform. The headings considered are: In-line at 180 deg and at 315 deg (corresponding with line 3). The following picture shows the platform positions required for station keeping tests and clarifies all headings shown in the test matrix. Line 0 and 1 are skewed 15 degrees from the nominal wind and wave direction.

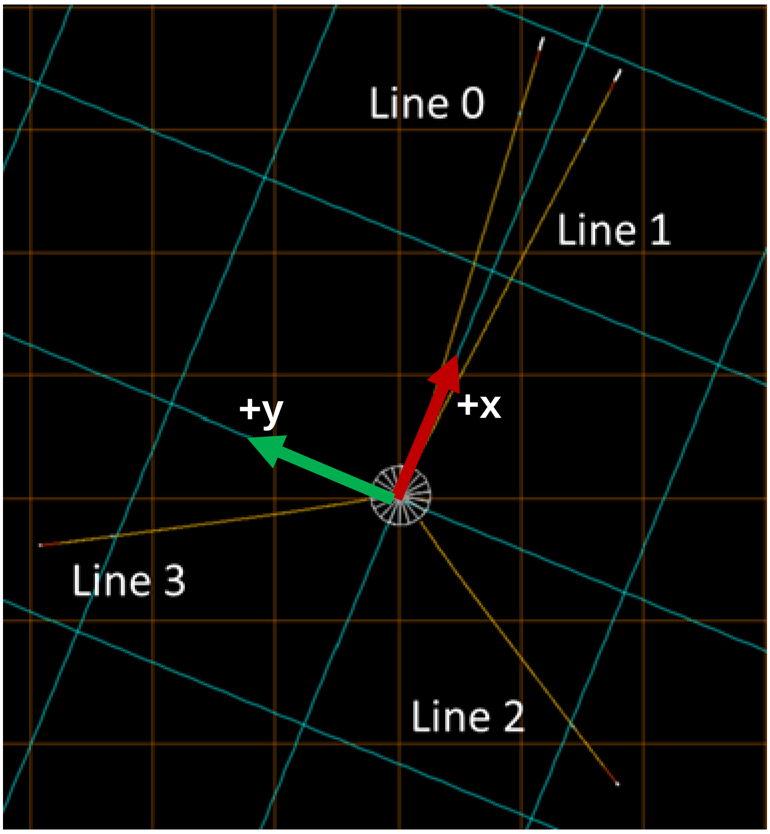

FIGURE 2.3. MOORING AND WAVE HEADING CONFIGURATION.

The fairleads position is at the bottom of the base, connecting directly to the bottom slab, as shown in the following figure:

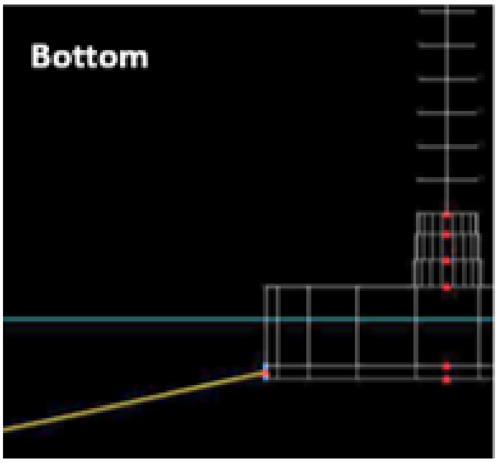

FIGURE 2.4. FAIRLEAD POSITION

Some other positions have been considered and studied, but it was found that the behavior did not improve. The mock-up will incorporate the possibility to connect the mooring lines at different heights, to test the fit of the simulations and the real behavior.

FIGURE 2.5. FAIRLEAD POSITION ALTERNATIVES

3 GENERAL DESCRIPTION OF THE PLATFORM

3.1 Model definition.

The FLOTANT technology is a barge foundation for offshore wind turbines, with concrete, steel and plastic as main materials. The tower is made of steel, the main structure in contact with seawater is made of concrete and the buoyancy is provided by plastic tanks. The following picture shows the concept after being installed.

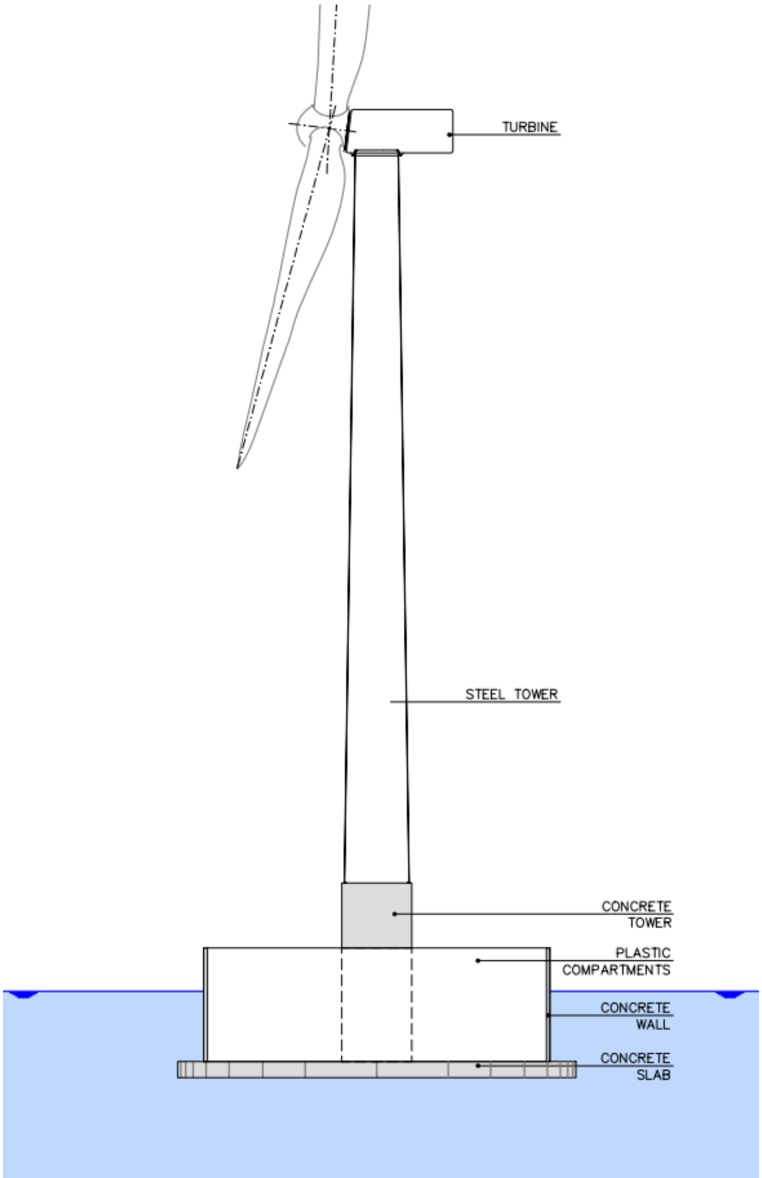

FIGURE 3.1. GENERAL VIEW OF THE FLOTANT CONCEPT. 6MD4 IMPROVED VERSION

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Following table depicts the main dimension of the model to be tested.

	6mD4 Improved	
Turbine diameter	195.4	m
Steel tower length	101.69	m
Conc. cylinder length (tower)	9.0	m
Conc. cylinder diam, (tower)	9.7	m
Conc. slab thick.	1.80	m
Conc. slab diam.	48.0	m
Heave pates ext. diameter	55.2	m
Heave pates thickness	1.8	m
Total base height	18.0	m

TABLE 1 MAIN DIMENSIONS OF THE FLOATER

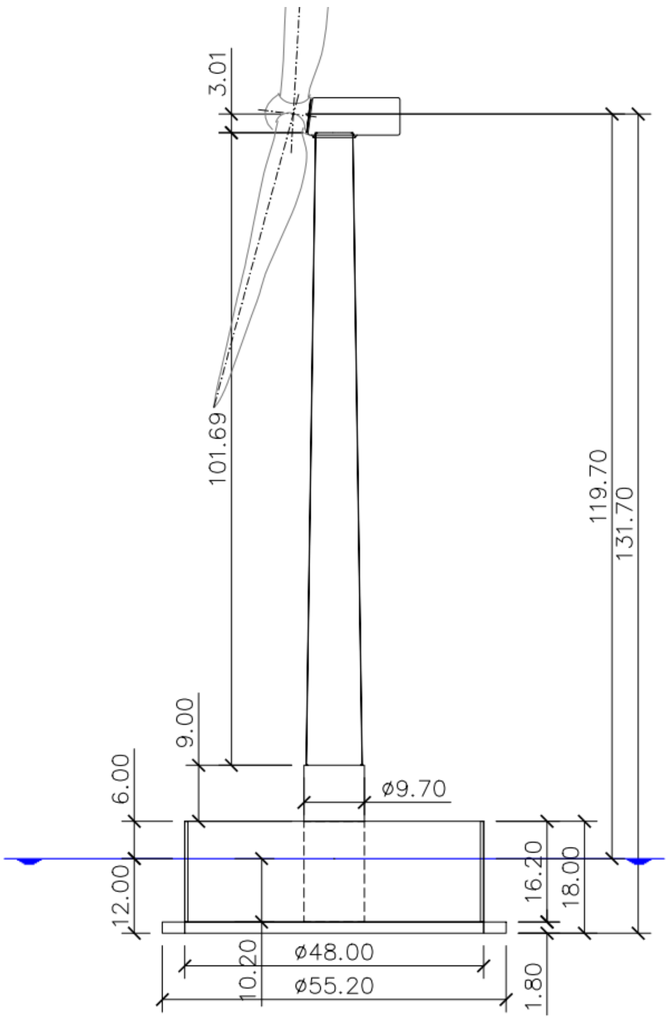

FIGURE 3.2. MAIN DIMENSION OF THE FLOTANT CONCEPT

Following table depicts the weight distribution to be tested for operation condition. Note that the mooring weight is not considered.

The local inertial values of each element shown in the next table are referenced to their respective center of gravity. Note that the CoG Z are referenced to the keel based on position defined in the FIGURE 2.1.

	6mD4 Improved							
			Local Inertia			Global Inertia		
	mass (t)	CoG Z (m)	Ixx (t·m2)	Iyy (t·m2)	Izz (t·m2)	Ixx (t·m2)	Iyy (t·m2)	Izz (t·m2)
Turbine	836	131.70	157200	24970	152400	12093491	11961261	152400
Steel tower	782	68.7	684755	684755	11437	3180211	3180211	11437
Conc. Cylinder (tower)	263	22.5	4868	4868	6185	32716	32716	6185
External platform	39	26.8	706	706	1411	9008	9008	1411
Conc. Cylinder (base)	473	9.90	20604	20604	11133	23128	23128	11133
Concrete braces	1343	5.80	193726	193726	121507	248907	248907	121507
Concrete wall	3022	9.90	1792037	1792037	1740568	1808163	1808163	1740568
Concrete boat landing	12	11.85	13827	13827	13824	13829	13829	13824
Plastic comp.	5750	8.80	919866	919866	1655869	986728	986728	1655869
Cables	35	9.90	5818	5818	10102	6005	6005	10102
Concrete slab	6514	0.90	939833	939833	1876149	1703826	1703826	1876149
Heave plate	2626	0.90	1757268	1757268	2000473	2065253	2065253	2000473
Active water ballast	1090	8.74	232326	232326	418215	268586	268586	418215
Passive water ballast	547	5.57						
TOTAL	**23333**	**12.21**				**22463966**	**22331736**	**8019274**

TABLE 2 MODEL PROPERTY. OPERATION PHASE.

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One of the most special characteristics of the FLOTANT floater is that the buoyancy is provided by plastic tanks. There are going to be several units of these in the base, placed one next to each other. The system is not thought to avoid water to be present in the interfaces of the tanks, but the geometry of these tanks is such that the amount of water is going to be little. For this reason, the model is to simulate to some extent this behavior (water circulation through minimal gaps between the tanks).

3.2 Scale model

The scale model will be defined between 1:40 and 1:60, depending on the possibilities of the tank testing facility. The model is to represent the exact exterior geometry of the prototype with the proper internal slots to allocate masses/water to get the model into the proper scaled CoG, GM and inertias.

In order to reproduce the main physical phenomena involved in wave-structure interaction, the following scaling laws are applied which are based on a constant ratio between the gravitational and inertial forces at laboratory and prototype scale. Therefore, Froude number remains constant at both scales (Froude Scale). The specific density for sea water is 1.025 ton/m3. All the data included in this report is referred to full scale unless otherwise stated.

Magnitude	Ratio
Geometry	λ
Time	$\sqrt{\lambda}$
Velocity	$\sqrt{\lambda}$
Acceleration	1
Mass	$1.025 \cdot \lambda^3$
Force	$1.025 \cdot \lambda^3$
Pressure	$1.025 \cdot \lambda$
Reynolds Number	$\lambda^{1.5}$

TABLE 3 SCALE FACTORS

3.3 Tolerances

Reference tolerances to be followed during tests campaign are outlined in the following table. The accepted tolerances in the scale model are:

Parameter Tolerance	Parameter Tolerance
Dimensions	±1.0%
KG	±2.5%
GM	±2%
Radius of Gyration	±5%
Draught	±2 mm (model scale)
Fairleads position	±1 mm (model scale)
Mooring stiffness	±2%
Mooring weight	±2%
Regular waves	
Wave height	±5%
Period	±0.1 s (model scale)
Irregular waves	
Wave height (significant)	±5%
Peak period	±0.1s (model scale)
Reflected wave at model location	±5%
Current	
Current speed	±5%

TABLE 4 TANK TESTING TOLERANCES

3.4 Mooring system

The platform is kept on station by 4 mooring lines. All lines are composed of high modulus fiber ropes with some length of chains and polymer springs. Their properties are shown in following tables.

	Line type	Length (m)
Line 0 / Line 1	S3000 polymer	16.0
	FF rope	364.0
	FF rope	54.0
	Chain	20.0
Line 2 / Line 3	S3000 polymer	16.0
	FF rope	283.1
	FF rope	53.3
	Chain	20.0

TABLE 5 MOORING LINE PROPERTIES FOR OPTION A (250M WATER DEPTH) (PER LINE)

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The following figure shows the configuration of the mooring lines. The two lines in the front have an angle of 30 degrees between them, while the other two are rotated ±135 degrees from the nominal wind and wave direction.

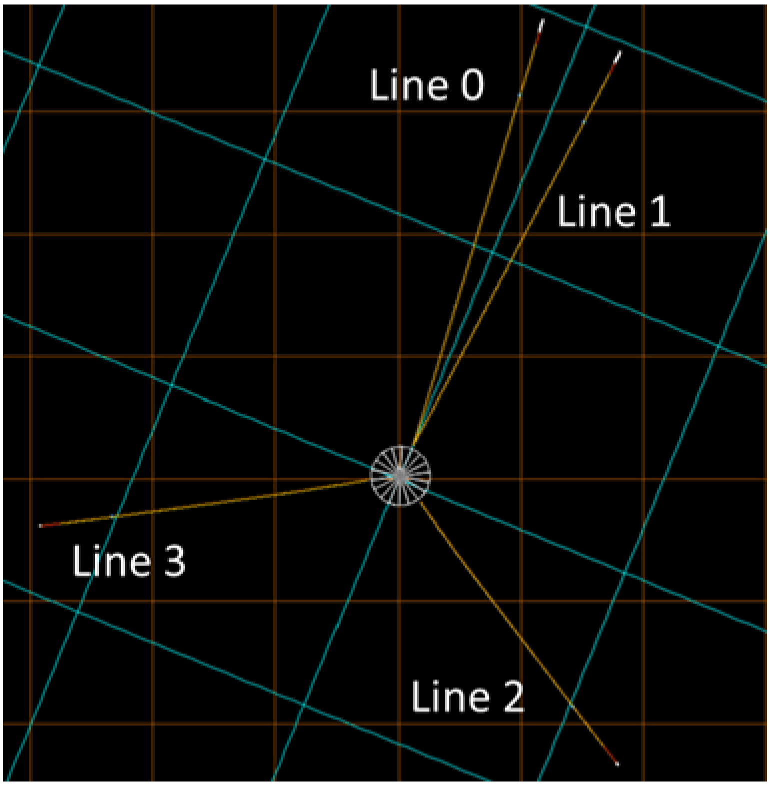

FIGURE 3.1. MOORING LINE CONFIGURATION.

The fairlead positions are depicted in the following table:

Fairlead Position			
Fairlead	X [m]	Y [m]	Z [m]
Fairlead 0-1	24.0	0.0	0.5
Fairlead 2	-16.97	-16.97	0.5
Fairlead 3	-16.97	16.97	0.5

TABLE 6 FAIRLEAD POSITION

As indicated before, the model should have the option to connect the mooring lines at other positions, with the fairleads at Z 5 and 18 m.

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3.5 Passive and active ballast system

There are two different systems of ballast: passive and active. In the passive ballast system, water does not move between tanks (hence passive), while in the active system, water is moved around depending in wind conditions to counteract heeling moment. The amount of water in each system is fixed during the service life.

The mockup should be built to simulate the action of the Active Ballast System (ABS) with weights that change position. It is not required to use water, because it would add complexity and the free surface effect has not been taken into account in the simulations so far. The ABS system has been designed to be able to counteract half the heeling generated by the nominal thrust of the turbine, this is 117670 kNm in any direction.

The static characteristics of the mockup with and without this system active are to be measured and checked to be within the tolerances. Some tests have to be performed with and without the system effect, to observe the different behavior.

3.6 Power cable

The power cable will be simulated with the correct stiffness, to ensure that the results from the test are as realistic as possible.

3.7 Instrumentation

Instrumentation to measure different variables of interest for the tests are to be defined by Marin based on their own “know-how”. The instrumentation shall include but is not limited to the following:

- Tracking and accelerations: The motions and accelerations are to be measured by means of an optical tracking system, or a similar system. All motions must be measured with respect to its center of gravity.
- Acceleration at the nacelle are to be measured by means of the accelerometers.
- Load cells: Tensions are to be monitored on each mooring line at the fairlead location.
- Load cells: The connection loads between tower and base are to be measured by another load cell to measure the six DOF forces and moments.
- Wave height is to be monitored upstream, downstream and to the side of the platform.
- The wind velocity and total rotor force is to be monitored at each time step.
- A tri-axial load cell (6 DOF) will be installed under the nacelle of the model to measure the induced wind loads.
- All tests will be monitored by means of video and photo cameras linked to the acquisition system. All videos and photos will show the basic test information. Videos from side, top, back/front, and submarine camera capturing mooring lines are required.

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3.8 Nominal thrust curve

The following image shows the nominal thrust curve for the turbine designed within the FLOTANT proyect.

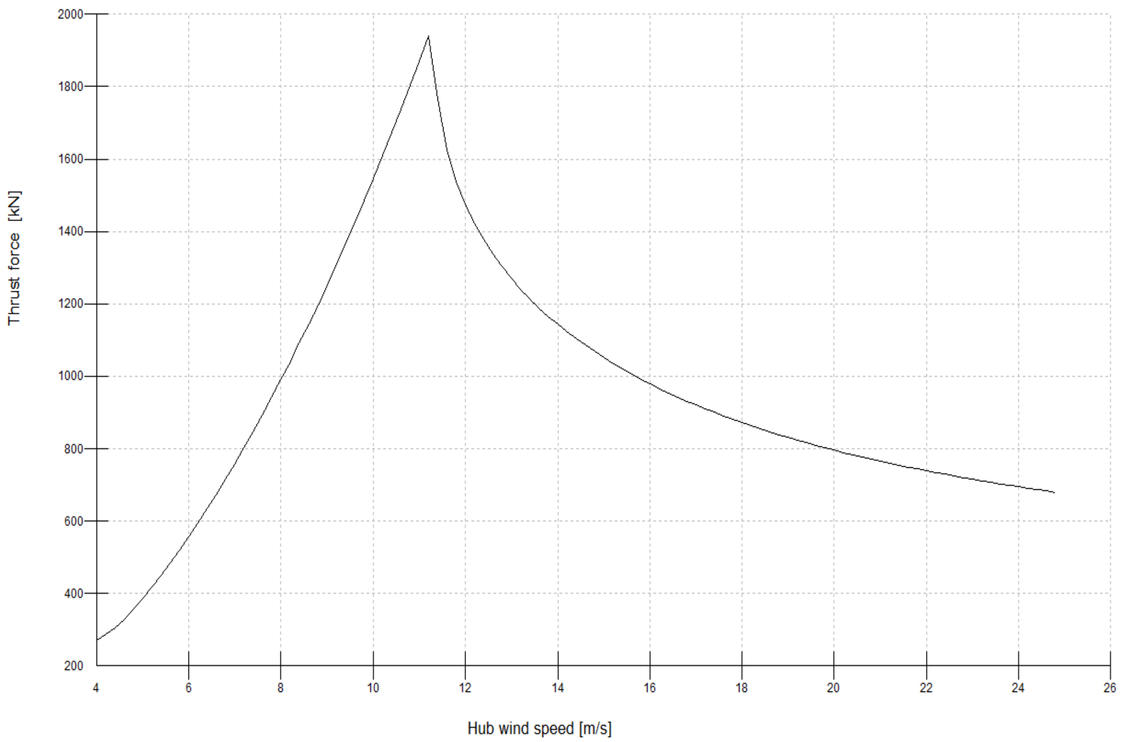

FIGURE 3.1. MOORING LINE CONFIGURATION.

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4 TESTS DEFINITION

This section describes the tests to be performed during this campaign at Marin facilities.

4.1 Standard

These tests shall follow ruling from ITTC.

4.2 Environment

4.2.1 Depth

There are two sites to install the FLOTANT platform, but only one depth will be tested in the ongoing campaign. The depth to be used for this camping is 250 m (referenced to LAT), which is the depth of the GC site**.**

4.2.2 Waves

The waves are to be calibrated prior to installation of the model in the basin. The waves will be measured at the location where the FLOTAN platform will be installed.

Irregular waves will be generated using JONSWAP spectra (or Pierson-Moskowitz when applicable). FIGURE 4.1 shows the wave generation capability at model scale.

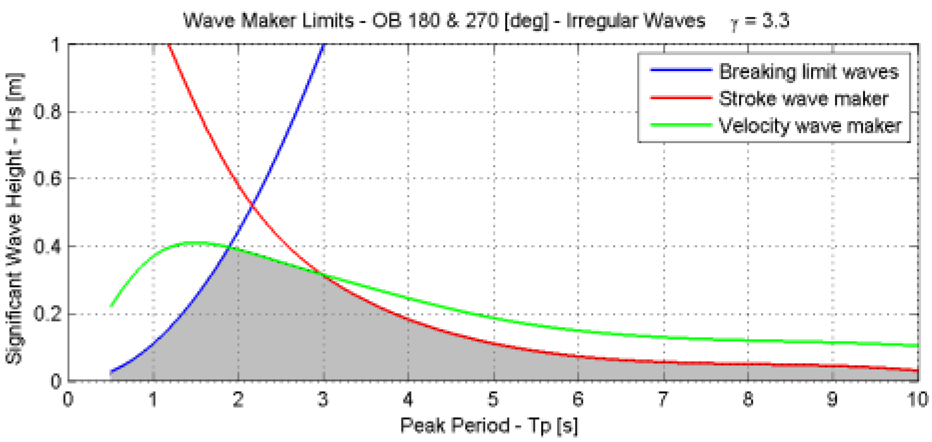

FIGURE 4.1. WAVE GENERATION CAPABILITY IN THE OFFSHORE BASIN

4.2.3 Wind

Wind will be simulated using the SiL (software-in-the-loop) based on the thrust curve of the 12MW turbine. The aerodynamic loads will be generated through innovation winch system which can reproduce the wind load based on the incident direction. The direction of the force vector will be controlled at every time.

The wind calibration procedure is summarized as follows.

- Constant thrust: This wind is important for the calibration and characterization of both the platform and the multi-fan.
- Steady wind: Steady wind time series would be simulated if required.
- Turbulent wind: Turbulent wind shall be emulated using the full features of the SiL.

4.2.4 Current

Current is to be calibrated prior to installation of the model in the basin, and measured at the location where the FLOTAN platform will be installed.

4.3 Initial checks

The initial checks are a set of essential trials to know the scaled model properties as well as the platform and mooring systems response.

4.3.1 Static load tests mooring system

The static load tests mooring systems shall be carried out to verification the stiffness of the mooring arrangement. The tests will be performed by attaching a horizontal line with a load to the fairlead on the base structure. Two pull directions shall be carried out to calibrate the tests. The restoring force is verified for a number (~5) of offset values.

4.3.2 Hammer tests

The structural natural period of the tower is to be measured with the hammer test and the model will be excited with an impulse force to verify its natural. The characteristics of the platform will influence in the bending frequencies of the tower.

Three hammer tests of the tower on the installed set-up are to be carried out to verify the natural frequencies of the floating platform.

4.3.3 Hydrostatic stiffness tests

Tilt tests are to be carried out in still water to evaluate the initial stability of each structure and to obtain the GMs. Tilt tests in roll and pitch movement are to be performed.

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4.3.4 Decays tests

Decay tests shall be conducted to obtain decay curves in every DoF. Decay curves will output damping (linear and non-linear, separately) and natural periods of the model.

Two decays test groups will be planned to carry out:

- Free decay test in calm water: the natural periods and hydrodynamics damping will be measured. The free decay tests are verified for two repetitions.
- Moored decay tests will be developed to verify the influence of the mooring in the natural periods of the systems.

4.4 Halfway report

Results of environmental and model calibration tests shall be submitted to FLOTANT partners for review as soon as they are available. These results will be reviewed prior to commencement of further testing. The report shall include:

- Wind, wave and current calibration.
- Mass properties checks.
- Inclination tests.
- Mooring properties checks.

4.5 Station keeping tests

4.5.1 Only wind tests

Only wind tests are to be performed with constant thrust to evaluate the mean tilt angle of each wind speed along with the mean excursion. The duration of the only wind tests is 30 minutes (full scale).

4.5.2 Only current tests

Only current tests are to be performed to evaluate the mean tilt angle of each current speed along with the mean excursion. The duration of the only current tests is 30 minutes (full scale).

4.5.3 Regular wave tests

The main goal of regular waves tests is to obtain the motion RAO's. Regular wave tests consist of several wave frequencies with the model moored. The number of waves for RAOs assessment shall be not less than 10 oscillation after steady state.

A range of wave periods to cover the most relevant wave frequencies in the area will be tested, from 4 to 35 s. Minimum results expected from regular wave tests are summarized in the following bullet points.

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- Displacement RAO's.
- Acceleration RAO's.
- Mooring tensions.
- Load cells RAO´s
- Time series.

4.5.4 White noise test

The purpose of white noise tests is to analyze the platform behaviour under a wide range of wave frequencies, getting a full spectral RAO.

4.5.5 Tests in wave/wind/current

The purpose of coupled tests is to analyze the response of the model facing wave, wind and current excitations in different combinations. Motions in every DoF and accelerations at CoG and nacelle are obtained. The main goal is to detect phenomena in the response which are not captured by numerical analyses.

Several irregular waves are to be tested along with different wind speeds. The wind and wave will be simulated by aligning them for both headings.

The duration of tests in which irregular waves are involved shall be 3 hours (prototype scale) after initial transients are damped. The minimum results expected from combined coupled tests are summarized in the following bullets.

- Motions
- Accelerations.
- Mooring tensions.
- Load cells.
- Time series.
- Spectral RAOs.

4.6 Transport tests

A set of transport test are to be performed, to obtain valuable data on the behavior of the floater during this stage.

Limiting conditions for this stage have been defined in the Design Basis, at least for the surviving conditions. Another set of conditions is proposed for the normal scenario, which are usual values for operations in the wind industry and allow to have enough time windows in the installation season. Taking into account the stability of the floater and the fact that the configuration is the same for transport and operation, it is very unlikely that the floater is going to be the limiting factor.

5 PROPOSED TESTS MATRIX

A tentative matrix tests can be found in this section of the specifications. The process starts with initial test which will be used for the characterization of the platform and the mooring system and then continues with the tests where the platform is moored and the wind turbine is used (Moored decay tests, regular test and combined wave, wind and current tests).

The proposed matrix for the coupled analysis considers a mix of Gran Canaria and West of Barra conditions but the values are on hold [HOLD 1], because there is still and open discussion.

5.1 Initial tests

5.1.1 Pre-calibration tests

Pre-calibration tests	
Static load tests mooring system	
1	Two pull direction shall be carried out to calibrate the tests. The restoring force is verified for a number (~5) of offset values
Hammer tests	
2	Three hammer tests of the tower on the installed set-up are to be carried out
Hydrostatics stiffness tests	
3	Heeling tests in longitudinal and transverse direction (GMt/ GMl)

TABLE 7 PRE-CALIBRATION TESTS

5.1.2 Decay tests

Decay tests			
	DOF	Model	Wind speed [m/s]
4	Heave	Free	0
5	Roll	Free	0
6	Pitch	Free	0
7	Heave	Free	0
8	Roll	Free	0
9	Pitch	Free	0
10	Surge	Moored	0
11	Sway	Moored	0
12	Heave	Moored	0
13	Roll	Moored	0
14	Pitch	Moored	0
15	Yaw	Moored	0

TABLE 8 DECAY TESTS

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5.2 Station keeping tests

The tests defined in this section follow the next sign convention:

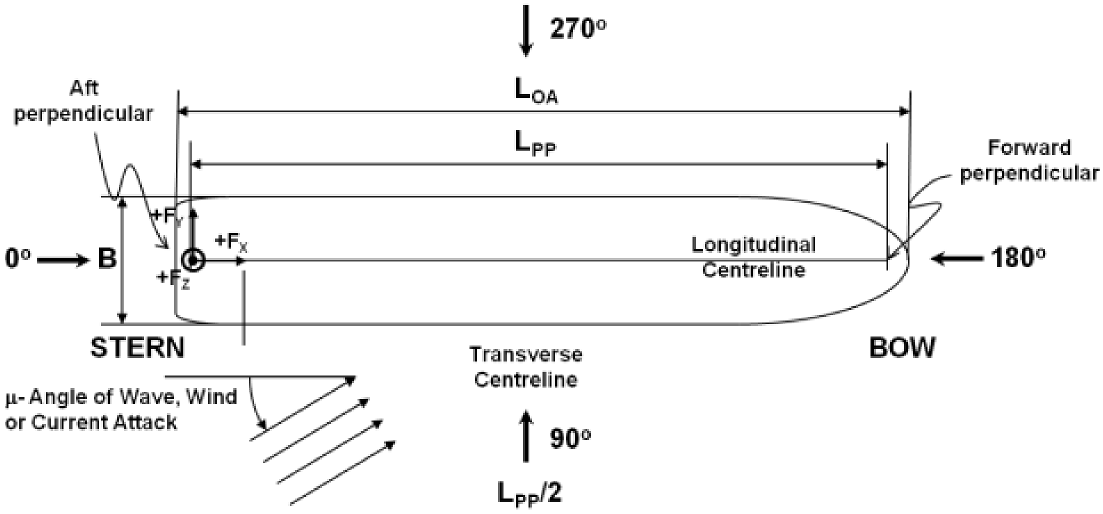

FIGURE 5.1. SIGN CONVENTION IN THE OFFSHORE BASIN

As a reminder, this is the sign convention for the prototype:

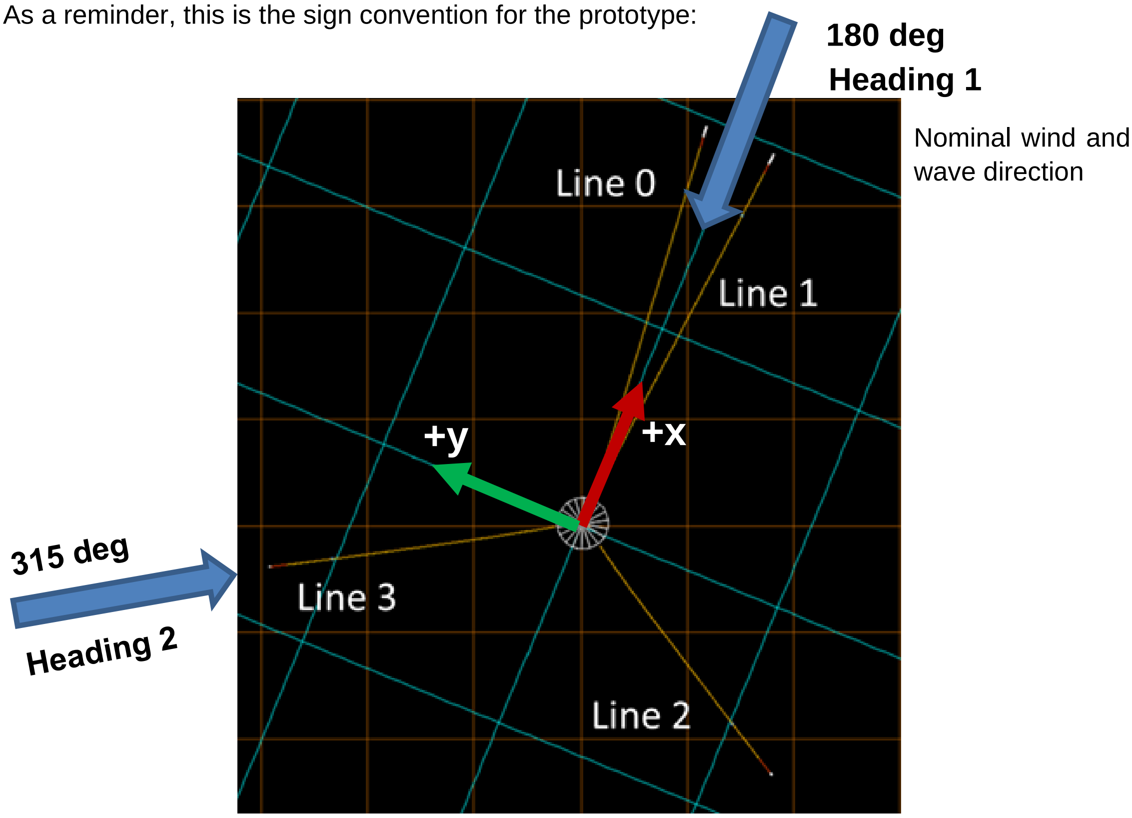

FIGURE 5.2. MOORING AND WAVE HEADING CONFIGURATION.

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5.2.1 White noise tests

White noise tests			
	H [m]	Tmax - Tmin [s]	µ [deg]
16	1.5	25-4	180
17	1.5	25.4	225
18	5.0	25-4	180
19	5.0	25.4	225

TABLE 9 WHITE NOISE TESTS

5.2.2 Regular wave

Regular wave tests			
Heading - 180 deg			
	H [m]	T [s]	µ [deg]
20	1.5	4	180
21	1.5	6	180
22	1.5	8	180
23	1.5	10	180
24	1.5	12	180
25	1.5	14	180
26	1.5	16	180
27	1.5	20	180
28	1.5	24	180
Heading - 225 deg			
29	1.5	4	225
30	1.5	6	225
31	1.5	8	225
32	1.5	10	225
33	1.5	12	225
34	1.5	14	225
35	1.5	16	225
36	1.5	20	225
37	1.5	24	225

TABLE 10 REGULAR WAVE TESTS

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5.2.3 Coupled test – Wave/current/wind

Wave/wind /Current test									
#	Hs [m]	Tp [s]	Wave direction µ [deg]	Spectrum Gamma	Wind speed at 10m [m/s]	Wind direction µ [deg]	Current speed [m/s]	Current direction µ [deg]	Active ballast System
Wind calibration									
38	---	---		---	11.4	180	---	---	No
Numerical model calibration with only wave									
39	2.5	6	180	3.3	----	---	---	---	No
40	2.5	8	180	3.3	----	---	---	---	No
41	2.5	10	180	3.3	----	---	---	---	No
42	2.5	18	180	3.3	----	---	---	---	No
43	3.0	6	180	3.3	----	---	---	---	No
44	3.0	8	180	3.3	----	---	---	---	No
Coupled calibration: wave + wind									
45	2.5	6	180	3.3	11.4	180	---	---	Yes
46	3.0	8	180	3.3	11.4	180	---	---	Yes
47	2.5	6	180	3.3	11.4	180	---	---	No
48	3.0	8	180	3.3	11.4	180	---	---	No
Coupled calibration: Misaligned wave and wind									
49	2.5	6	180	3.3	11.4	225	---	---	Yes
50	3.0	8	180	3.3	11.4	225	---	---	Yes
51	2.5	6	180	3.3	11.4	225	---	---	No
52	3.0	8	180	3.3	11.4	225	---	---	No
53	5.44	12	180	3.3	21	180	---	---	Yes
54	5.44	12	180	3.3	21	315	---	---	Yes
55	5.44	12	180	3.3	21	180	---	---	No
56	5.44	12	180	3.3	21	315	---	---	No
57	15.6	15.2	180	3.3	27	180	1.84	225	No
Incidence of waves in the mooring; Coupled calibration: wave + wind									
58	2.5	6	315	3.3	11.4	180	---	---	No
59	3.0	8	315	3.3	11.4	180	---	---	No
Incidence of waves in the mooring; Coupled calibration: Misaligned wave and wind									
60	2.5	8	315	3.3	11.4	315	---	---	No
Incidence of waves in the mooring; Extreme conditions									
61	5.44	12	315	3.3	11.4	315	---	---	No
62	15.6	15.2	315	3.3	27	315	1.84	225	No

TABLE 11 COUPLED TESTS

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5.2.4 Transport

#	Type	Hs [m]	Towing speed [kn]	Wind speed * [m/s]
63	Normal	1.5	3.0	12
64	Extreme	3.7	0.0	20

TABLE 12 TRANSPORT METOCEAN CONDITIONS

* Wind speed corresponds to the 10-minute average at the hub height.

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6 FINAL REPORT AND TEST FILES

The final report shall be made available to FLOTANT partners with the following contents:

- Summary of the report and scope of tests.
- Detail description of test setup and program.
- Description of models and instrumentation, including drawings.
- Test matrix.
- Wind, wave and current calibration.
- Mass properties checks.
- Inclination tests.
- Mooring properties checks.
- Results of free decay tests, including linear and quadratic damping terms.
- Zero crossing statistics of all channels.
- Mean, standard deviation, minimum and maximum values of all channels.
- Response amplitude operator plots of all relevant channels.
- Weibull extreme value plots of all relevant channels of no filtering, low-frequency, wave frequency and high-frequency filtering.
- Selected time histories of representative portions of each test.
- Any other relevant information pertaining to the test.

Data shall be provided in a hard drive or sharing point, with results data (raw and processed) along with photographs and videos.

Still photographs shall be taken of the following items:

- Model during and after construction.
- Mooring model (springs and weights if applicable).
- Force measuring devices.
- Motion measuring devices.
- Tank basic setup.
- Location of wave probes.
- Camera locations.
- Detail of fairlead connections.
- High quality photographs in each test at particular instances of interest.
- Towing tank setup.
- Towing tank carriage-model connection detail.
- Model being towed.
- Any other relevant subjects.

High definition video documentation of all dynamic tests shall be provided. A time stamp on the video shall be synchronized with the instrument data acquisition system and based on full scale speed. The frame rate of the video should ensure that freeze frame analyses are possible.

When the synchronizing would not be possible (e.g. submarine cameras), manual treatment of the videos shall be conducted to cut them properly and stamp the test name.

A detailed video log shall be kept which shall include at a minimum:

- Test name and number.
- Date.
- Start time of data acquisition.
- Environmental conditions.

A header with the above listed information is to be provided at the beginning of each video.

7 HOLDS IN THE SPECIFICATION

- Hold 1. Conditions for the coupled analysis.

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