

REPORT ON THE REQUIREMENTS OF THE FLOATING STRUCTURE

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wind turbine systems for power generation in
mediterranean deep waters*

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REPORT ON THE REQUIREMENTS OF THE FLOATING STRUCTURE

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Written by: Thomas CHOISNET

Checked by: Simon VASSEUR, Stéphan MAROBIN, Etienne ROGIER, Mathieu FAVRE

Approved by: Bertrand Dumas

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Brief Summary

This document defines the final requirements that will apply in the design of the floating structure.

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1. EXECUTIVE SUMMARY

1.1 SCOPE OF DOCUMENT

The scope of this document is to list the basic requirements that will apply to all components of the floating foundation.

This document is complemented by equivalent design requirement documents / specifications in order to cover the whole scope of the project : requirements applying to the wind turbine and its tower can be found in Ref [P02], while requirements for the transition piece which connects the tower of the wind turbine to the hull of the floating foundation and the umbilical are provided in documents Ref [P04] and Ref [P09] respectively.

This document outlines the codes and standards the design has to follow and provides the basic input data and design philosophy to be used while developing the concept.

Additional design brief, design basis and specification documents cascade the requirements set in this document to more refined levels of details.

The flow chart below gives an overview of project document precedence. Design brief documents mainly provide general specifications, an overview of design methods and outline design constraints, whereas design basis documents provide detailed data on how design codes are interpreted and input data for the design.

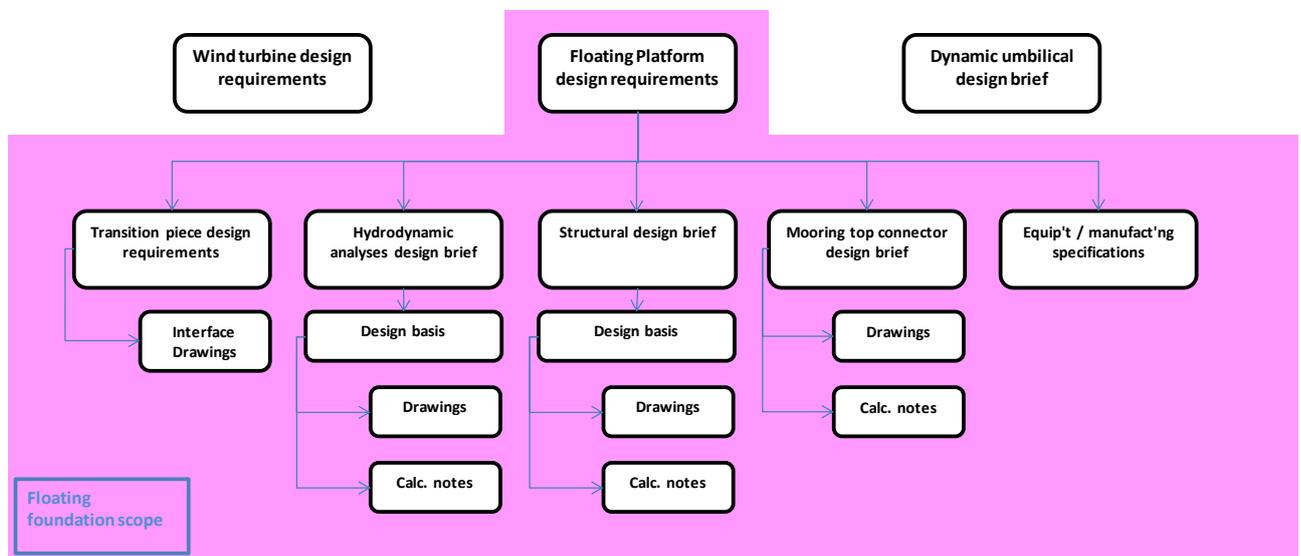


FIGURE 1 DESIGN DOCUMENTS PRECEDENCE

1.2 FLOATING WIND TURBINE DESCRIPTION

The floating wind turbine is composed of:

- The wind turbine and its tower which are supplied by Gamesa ;
- The floating foundation which incorporates the hull of the floater and its utilities, the transition piece which makes up the connection between the tower of the wind turbine and the floater, the mooring system which permits the platform to remain in position in all specified conditions; that part of the scope is under the responsibility of Ideol ;
- The umbilical system which transmits the electrical power generated by the wind turbine from the floating foundation to the static export cable resting on the seabed.

The floater is a square ring-shaped with its mooring lines grouped in three clusters of lines, each spurring at 120° from each other. The tower is located aft of the floater, the three mooring lines shown on Figure 2 spur forward towards the extreme wave conditions. The mooring system is site-dependent (number and type of mooring-lines). The umbilical (in red) is going subsea through the moonpool.

The main dimensions of the floater for Floatgen demo 1 are:

- Hull breadth x length : 34.0m x 34.0m

- Span of skirts around the hull : 2.2m
- Depth of the hull : 9.5m
- Height of hub above sea level : 61.6m
- Moonpool dimensions : 20.0m x 20.0m



FIGURE 2 VIEWS OF FLOATING FOUNDATION

2. ACRONYMS

ACI	American Concrete Institute
API	American Petroleum Institute
ASL	Above Sea Level
ASME	American Society of Mechanical Engineers
AWL	Above Water Line
DNV	Det Norske Veritas
H_s	Significant wave height
IACS	International Association of Classification Societies
ILLC	International Load Lines Conventions
ILO	International Labour Organisation
IMO	International Maritime Organisation
ISO	International Standardisation Organisation
LAT	Lowest astronomical tide
LR	Lloyd's register
MW	Megawatt (1'000'000 Watt)
MWe	Electrical Megawatt (electrical power delivered by a generator)
nm	Nautical Mile
t	Metric tonne
T_p	Wave spectrum peak period
T_z	Wave zero up-crossing period
UTM	Universal Transverse Mercator

3. DEFINITIONS

Anchors: Structures connecting the mooring line to the seabed

Bolt cage: The structure which is embedded in the concrete and which fits the transition piece so that loads from the transition piece are well distributed in the hull of the floating foundation.

Embedment plates: Each of the plates embedded in concrete which enable connecting a steel structure to the concrete hull.

Floater: part of the floating foundation which includes the hull made of concrete and embedded items, the transition piece and all related utilities and secondary structures. It also includes the mooring top connectors.

Floating foundation: That part of the floating wind turbine which includes the floater itself and its station-keeping system.

Floating wind turbine: The whole floating system producing power to the grid. It includes the wind turbine, the floating foundation and the umbilical system.

Installation aids: All equipment necessary for the installation of the platform. It includes any winch, temporary power supply, rigging equipment, towing devices, etc...

Mooring interface structure: Each of the steel structures which spread the loads from the mooring lines to the concrete hull. They do not include the Mooring top connector.

Mooring line: include all components from the anchor shackle included to the mooring top connector (excluded)

Mooring system: The station keeping system as a whole which includes anchors and all components linking the floater to these anchors. It is composed of the anchors and the mooring lines.

Mooring top connector: That part of the floater which connects the mooring line to the mooring interface structure. These parts are forged steel parts.

Pull-in winch: The winch which will be used to pull the mooring lines onboard the platform so as to connect them to the mooring top connectors.

Shall: Denotes a mandatory requirement

Should: Denotes a preferred configuration

Transition piece: That part of the floater which enables interfacing the tower of the wind turbine to the concrete structure.

Umbilical system: All components used to transfer power and data from the floater to the static umbilical resting on the



seabed. It includes the dynamic cable itself and its fittings (pulling head, bend stiffener, buoys, etc...)
The detailed list of components making up the floating foundation is shown in Ref [P10].



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4. REFERENCES

4.1 PROJECT DOCUMENTS

- [P01] Consortium document Floatgen project contract Annex 1 “Description of Work”
- [P02] Gamesa document GDOxxxxx-en “RD WTG FLOATGEN” Rev 0
- [P03] Gamesa document GDOxxxxx-en “regulatory frame” Rev 0
- [P04] Ideol document G02-SP-MEC-2523-00 “Transition Piece design requirements”
- [P05] Ideol document G02-DW-INT-0200-00 “Floatgen Interface Drawing”
- [P06] Ideol document G02-RP-ENV-0507-00 “Floating Foundation Design Environmental Conditions”
- [P07] Ideol document G02-SP-CON-9605-00 “Hull construction specification”
- [P08] Ideol document G02-SP-NAV-0508-00 “Weight control procedure”
- [P09] Ideol document G02-SP-UMB-4506-00 “Dynamic umbilical specification”
- [P10] Ideol document G02-DW-GEN-0001-00 “Product tree”

4.2 RULES AND STANDARDS

- [R01] Lloyd’s Register “Guidance on offshore wind farm certification”, April 2012
- [R02] Lloyd’s Register “Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location”, June 2013
- [R03] Lloyd’s Register “Rules & Regulations for the Classification of Ships”, 2013
- [R04] ISO 19901-1 “Metocean design and operating considerations”
- [R05] ISO 19901-5 “Weight control during engineering and construction”
- [R06] ISO 19901-7 “Stationkeeping systems for floating offshore structures and mobile offshore units”
- [R07] IEC 61400-1 “Wind turbines: design requirements”
- [R08] IEC 61400-3 “Wind turbines: design requirements for offshore wind turbines”
- [R09] “Code for construction and equipment of mobile offshore drilling units” 2001 IMO MODU code
- [R10] “International load lines convention” IMO ILLC 1966 as amended
- [R11] International ship and port facility security code” IMO ISPS code 2003 as amended
- [R12] DNV classification note 30.5 “Environmental loads and environmental conditions”

- [R13] API RP 2SK “Design and analysis of station-keeping systems for floating structures” October 2005 and addendum 2008
- [R14] API RP 2A “Recommended practice for planning, designing and constructing fixed offshore platforms—Working stress design”, 21st edition 2000 and supplements 2002, 2005
- [R15] EN 1992 - Eurocode 2 “Design of concrete structures”
- [R16] “Actions and action effects” NORSOK Standard N-003, 2007

5. PROJECT DATA

5.1 FUNCTIONAL REQUIREMENTS

The floating wind turbine shall be able to operate with no standby due to waves. This will be ensured by verifying the functionality and integrity of all components under the 50-year return period environment.

The arrangement of the floating foundation shall be such that:

- No part of the platform interferes with the operation of the turbine,
- Means of access and escape to / from the platform are safe for both the personnel and the equipment under conditions similar to fixed offshore foundations,
- Single point failures as identified in 6.1.3 are mitigated with an acceptable level of risk,
- Interference between mooring lines, umbilical, and access areas are prevented,
- Maintenance of equipment is possible by the platform's own equipment and outfitting.

5.2 INSTALLATION SITE

For Floatgen project the platform is planned to be installed in Gran Canaria, on PLOCAN site. The water depth at site ranges between 40m and 60m. Details are provided in document [P06]. Basic data from this document are reminded in this section for the sake of understanding.

The following water level variations apply:

- Water depth: 40-60m LAT over the mooring spread
- Tide range: 2.55m
- Positive storm surge: 0.15m

Full details on environmental parameters and modelling are provided in Ref [P06].

Non-directional extreme design environments are summarized in the following table:

Return period	50-year
H_s (m) (1hr sea-states)	5.2
T_{pmax} (s)	13.0
T_{pmin} (s)	9.0
Wind speed (1hr @10m) m/s	20.0
Total surface current (m/s)	0.58

TABLE 1 SUMMARY EXTREME DESIGN ENVIRONMENTS – DEMONSTRATOR DEPLOYMENT SITE

5.3 APPLICABLE CODES AND STANDARDS

Floating offshore wind turbines are subject to rules and regulations from several sources. They are ranged by order of precedence as follows:

- National/regional authorities rules which will be site-dependent,
- Certifying body rules which are defined project by project,
- Operator/test site specification which are also site-dependent,
- Marine operation warranty surveyor rules,
- Industry standards.

National authorities generally address facility and personnel safety as well as environmental issues. In general, the rules of Spain will be considered for in-place conditions. Access and working space requirements will be set according to European standards as they are usually more stringent in respect of accesses, headroom, etc...

Certifying body rules address integrity and safety-related issues during the life of the platforms. They consequently encompass structural integrity, stability, third party and owner personnel safety, etc... Marine operations do not fall within the scope of the classification except as far as the integrity of the classified floater is concerned: Class will typically witness platform construction, check the stability and structural analyses covering the transit conditions and perform survey at manufacturers' premises for critical components.

The certification body is Lloyd's Register. The following set of rules from Lloyd's register applies for the project (they are ranged by order of precedence):

- "Guidance on offshore wind farm certification" Ref [R01] set the main requirements which apply to the whole offshore wind farm. Sections pertaining to the floating foundation will be

considered as a the main design rules.

- “Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location”, Ref [R02] is quoted as the set of rules defining all main technical requirements outlined in the Guidance on offshore wind farm certification”,
- “Rules & Regulations for the Classification of Ships” Ref [R03] complement the “Rules and regulations for FOIFL” as necessary, mainly for light marine equipment.

Operator/test site specifications will normally set operating conditions, preferences in terms of system redundancy, emergency response, durability... This may have impacts on design criteria if additional margin is needed on a given component to meet a larger durability than insurance standards would require. Once site-specific conditions will be known, they will be incorporated in the present document. The general approach adopted by the tests site is that the design shall be submitted for approval without supplying specific guidelines.

The purpose of marine operations warranty survey is two-fold:

- ensuring that no harm will be caused to the people involved in, and exposed to the consequences of a marine operation;
- ensuring that the structures involved in marine operations are not damaged and ready for service as planned.

We will base on Noble Denton guidelines for marine operations as a starting point.

A number of industry standards will be used to design components. Part of them is listed in the next sections.

We summarised in Table 2 the main codes that the floating wind turbine shall comply with.

Order of precedence	Description	Code considered
1	International regulations	IMO codes & regulations
2	National regulations	Spain
3	Class for hull and mooring	Lloyd’s register
4	Operator / site specs	PLOCAN
5	Marine warranty surveyor	Noble Denton

6	Industry standards Hull, Mooring, umbilical	ISO 19900 series
6	Industry standards Turbine	IEC 61400 series

TABLE 2 BASIC CODES AND STANDARDS TO BE COMPLIED WITH BY ORDER OF PRECEDENCE

6. DESIGN PHILOSOPHY

6.1 SAFETY AND ENVIRONMENT PROTECTION

6.1.1 SAFETY PHILOSOPHY

The safety of the system and personnel onboard will rely on:

- Adequate signalling of the structure to prevent collisions,
- Stability and watertight integrity in intact and damaged conditions,
- Structural integrity of all components,
- Ease of access and escape of personnel in normal, accidental and bad weather conditions,
- Adequate systems redundancy in case of loss of power,
- Redundancy of the mooring system,
- Protection of personnel from rotating parts and harmful components / substances,
- Adequacy of design loads to the exposure time in transient conditions,
- Safety equipment to enable the safe escape of personnel,
- Emergency response procedures and equipment readiness to help rescue operations as a last resort.

For transient conditions due to damages, it shall be verified in particular that the repair time of a given component is in line with the design exposure time considered.

For example, if the repair time of a given component is 1 week (or less), then the stability of the platform must be verified under 1-year return period environments with this component ineffective. For periods less than 30 days, the 10 year return period environment will apply.

Due consideration shall be given to the stability and access criteria considered in damaged situations (seized nacelle yaw system, pitch control of a blade, damaged compartment, damaged personnel transfer equipment, etc...).

6.1.2 PROTECTION OF THE ENVIRONMENT

All materials shall be selected to prevent any pollution to the marine environment.

No oil spill will be allowed during platform operation, offshore installation works, decommissioning.

The mooring system design will be consistent with local environment protection rules in particular if noise limitations are required during offshore works, certain areas need to be free of mooring-line chafing on seabed, etc...

6.1.3 MANAGEMENT OF ACCIDENTAL CASES

In general, the consequences of all single point failures shall be checked and analysed. The analysis shall put in perspective operational, safety, integrity and remediation criteria.

Accidental loads shall be combined with safe and realistic environmental conditions. For example, as mooring line failures are very long to be repaired, the damaged condition is checked against the design return period environment with safety factors decreased compared to the intact condition.

The following failures shall be considered:

- Loss of one mooring line,
- Seizing of one blade pitch system
- Seizing of nacelle yaw system,
- Loss of grid power,
- Damaged compartment,
- Loading of one mooring line up to the breaking load,
- Consequences of dropped object,
- Collision with a crew boat.

6.2 FLOATING FOUNDATION DESIGN

6.2.1 LOAD LINE CONVENTION

Although the floater is not a ship and has unusual proportions, it will be designed to comply with the provisions of IMO 1966 Load Line convention (as amended since then), except damage stability conditions which will be assessed as per IMO MODU code (see subsequent sections on stability).

In particular, all water-tightness and weather-tightness provisions shall be fulfilled and the minimum freeboard set in this convention shall be respected both in transit and in place.

6.2.2 STABILITY VERIFICATIONS AND WEIGHT CONTROL

Stability shall be verified based on IMO MODU code. In particular, height coefficients and minimum wind speeds shall be considered as per this code even though other values are used for the design of the turbine or mooring system.

The procedure for weight control is provided in ref [P08]. This procedure is compliant with ISO 1901-5 Ref [R05].

When the turbine is in standby condition, it will orientate so that wind loads are minimised. The same assumptions in terms of azimuth, blade pitch error and the related environmental return period as in the IEC design code for wind turbine foundations shall be considered.

The consequences of a fault of either the yaw orientation of the nacelle or the blade pitch should be assessed in terms of stability. It is a minimum requirement that the damaged stability criteria are met under the 50-year return period environment with these components non-operational.

Attention shall be paid to the variation of wind loads on the blades with the list of the platform. If an additional heeling moment due to blade lift occurs at any inclination of the platform, it shall be accounted for in the stability analysis.

Damage stability calculations shall be performed in accordance with the MODU code.

During transit, the stability of the platform shall be verified based on the 10-year return period 1-minute average wind speed.

In case transit wind speeds are larger than MODU code wind speed (100 knots at 10m), this larger wind speed shall be considered in the verification of the stability of the platform. Wind speeds for stability verification are usually the 1-minute averaged wind.

6.2.3 HULL STRUCTURAL INTEGRITY

The structure of the floater shall in general be designed in accordance with Class. Tubular structures shall comply with API RP 2A and other frame works with Eurocode 3. Attention shall be paid when designing the tower, its foundation and the hull to the natural frequencies which may be excited by the turbine.

The concrete structure detailing standard will be Eurocode 2 Ref [R15] as complemented by Class rules. Details of loading conditions, methods, etc... are provided in the Structural Design Brief.

In the fatigue analysis of all components, cases with the turbine in service as well as cases with the turbine in parked condition should be considered. The turbine will be in operation around 70% of time.

6.2.4 STATION KEEPING

The floater is kept in position by its mooring system. It shall be designed according to class rules complemented by ISO 19901-7 "Station-keeping systems for floating offshore structures and mobile offshore units". Criteria apply to mooring line tensions, anchor holding capacity and fatigue life safety factor.

The minimum breaking load of the chain shall be based on the corroded, *i.e* end of life breaking load.

6.3 DESIGN FOR ALL PHASES OF PLATFORM SERVICE LIFE

6.3.1 DESIGN LIFE

The operational design life of the floating wind turbine is 2 years. An allowance of 2 years afloat in the port prior to commissioning and 2 years afloat in the port with turbine assembled but shut-down for decommissioning shall also be included.

Adequate safety factors will be considered for the fatigue performance (depending on the criticality and inspectability of the areas). Applicable safety factors are provided in the relevant design brief document. As a minimum, the following components shall be designed with a safety factor of 5 (*i.e* with a design life of 10 years):

- The umbilical and its subsea connections,
- The mooring lines, subsea connections to hull and anchors.

Other critical areas which are visually inspectable are to be designed with a safety factor of 3 applied to the design life. For example, when inspectable, the connections of the mooring system to the hull shall be designed with a fatigue safety factor of 3.

Other components shall comply with class requirements.

6.3.2 TRANSIENT CONDITIONS

Transient conditions will be considered in the design of the floater. As a minimum the following situations shall be considered:

- All damaged conditions as specified in 6.1.3,
- Platform launching,
- Tower/turbine erection,
- Platform transportation to offshore site,
- Platform hook-up operations,
- Mooring hook-up when not all lines are connected,
- Platform condition after mooring hook-up but prior to grid power supply,
- Loss of grid power.

The duration of each of these operations will be documented later so that the associated environments can be selected and combined to each particular loading scenario.

6.3.3 MAINTENANCE PHILOSOPHY

The hull and main structural items shall be designed so that no maintenance of the floater is required except inspection and damage repair. When important safety improvements or cost savings can be met by replacing some components, it can be considered. In all cases, an option free of maintenance shall be designed as a reference.

Mooring line connections to the platform shall be kept above water surface except if local regulations do not allow this.

6.3.4 MANUFACTURING AND CONSTRUCTION

The hull and all equipment will be built in materials which are proven for service in a marine environment.

No equipment requiring project-specific qualification shall be selected so as to enable reaching project schedule. In the event that qualification is required for a component, it shall be integrated early in the project.

The design shall consider constructability at all stages and for all components. This shall be met by seeking approval of all drawings and specifications by the party responsible for construction. Construction procedures shall be prepared so as to enable the smooth completion of the works and to help carrying out risk assessments.

All tolerances considered in the design shall be sufficiently slack to allow quick construction of the hull. The impact of these tolerances shall be considered by the designer on all aspects of the platform (positioning of equipment, weights, buoyancy, loads, corrosion protection, etc...). In particular, the dimensional construction tolerances set in the construction specification ref [P07] shall be consistent with those set in the weight

control procedure Ref [P08].

As a general rule all shapes shall be kept as simple as possible to allow easy fabrication.

6.3.5 OFFSHORE INSTALLATION

The design shall be planned to ease offshore installation tasks. Sufficient space shall be present onboard for offshore installation crew to operate safely and efficiently. Installation aids shall be considered in the design in terms of platform arrangement, structural strength, power supply, handling and all necessary aspects.

Design verifications will reflect planned offshore installation procedures and offshore installation procedures will reflect both main / support vessels capabilities and platform design limitations.

The safety of personnel will be monitored and considered through the application of a Health, Safety and Environment plan.

6.3.6 DECOMMISSIONING

Decommissioning shall be considered from the design phase by allowing sufficient provisions for dismantling the structure. Decommissioning will basically consist in disconnecting the umbilical, disconnecting mooring lines from the platform, towing the platform back to dismantling port, removing mooring lines and umbilical and recycling all components.

A decommissioning plan shall be prepared prior to the completion of platform construction so that specific constraints and equipment may be included in the design and fitted on the platform. A noxious substances register will be kept up to date along the project and inventories recorded in order to ease dismantling and recycling processes.

7. ENVIRONMENTAL CONDITIONS

7.1 WATER DEPTH, DENSITY, TEMPERATURE

The water depth to be considered will be different at each site analysed. Effects of astronomical tides and storm surges shall be considered in the design.

As the concept is not much depth-sensitive, it should be sufficient to design the platform and mooring system at the average water level and then perform sensitivity checks of loads at all extreme water levels. These effects shall however be checked sufficiently early in the design process.

The water density will be at the minimum value possible on site so as to maximise draft and minimise stability.

In case the platform is built in fresh water, the reduced density shall be accounted for in all stability / buoyancy / ballast calculations.

7.2 MARINE GROWTH

Marine growth on mooring lines and on the hull shall be considered in the design of the structure.

Its effects in all aspects of the floating wind turbine shall be considered: increase of drag loads, increase of structure weight (in terms of integrity, stability, etc...), accessibility for maintenance, accessibility to boat landings, etc...

In particular, design loads on mooring lines and umbilical will be assessed with and without marine growth.

7.3 ICE AND SNOW ACCUMULATION

Ice and snow accumulation effects on the whole structure shall be assessed at relevant locations.

There is no risk of ice or snow accumulation at the installation site. Once the construction site and

towing route are known, the risk will be re-assessed.

When relevant, impacts on all aspects of the structure shall be considered. In particular, detrimental effects on platform stability, wind loads, additional loads due to ice and snow weight, potential seizing of mechanical equipment, etc... are anticipated.

7.4 WAVE AND WIND SPECTRA MODELING

Wave spectra will be based on JONSWAP spectrum. The peakedness parameter γ is given by the following equations as per DNV CN 30.5 Ref [R12]:

$$\gamma = 5 \quad \text{for} \quad \frac{T_p}{\sqrt{H_s}} \leq 3.6$$

$$\gamma = \exp(5.75 - 1.15 T_p / \sqrt{H_s}) \quad \text{for} \quad 3.6 \leq \frac{T_p}{\sqrt{H_s}} \leq 5$$

$$\gamma = 1 \quad \text{for} \quad 5 \leq \frac{T_p}{\sqrt{H_s}}$$

The wind spectra provided by IEC will be the basis of the verification of the wind turbine and foundation. IEC normally uses Kaimal's spectrum.

7.5 ATMOSPHERIC CONDITIONS

The demonstrator is planned to be installed offshore in Canary Islands. The atmospheric conditions will be typical of these areas, i.e. featuring mild temperatures, high humidity rates and sea-water spraying.

External areas can be classified as follows:

- Submerged zone: Areas which are permanently immersed in the seawater,
This area extends from the seabed to 4m below the water line.
- Splash zone: areas which are alternately dry / wet
This area extends from 4m below to 4m above the water line – it includes the main deck and transition piece.
- Dry external surfaces: Areas which are never in contact with waves. These areas will however

be subject to water spraying.

This area extends from 4m above the waterline upward.

Internal areas can be classified as follows:

- Internal surfaces with controlled atmosphere
In these areas, there will be no water-spraying and only controlled moisture. These areas include the tower and transition piece.
- Bottom of internal compartment, foot of bulkheads and side shell walls
These areas will be in contact with sea-water from possible minor leaks and will be subject to drying / wetting as in the splash zone.
- Upper part of bulkhead walls and under-side of deck
These surfaces will only be exposed to moisture due to evaporation / condensation cycles within compartments

All equipment and structural components shall be able to operate under the maximum and minimum atmospheric temperatures.

7.6 CURRENT PROFILE

In the event that only the surface current is available, the current variation with depth shall be based on DNV recommendations as set in ref [R12].

The current will be considered as the sum of the current due to tide, v_{tide} and the current due to wind, v_{wind} . This yields:

$$v(z) = v_{tide}(z) + v_{wind}(z)$$

With $v_{tide}(z) = v_{tide} \cdot \left(\frac{h+z}{h}\right)^{1/7}$

and $v_{wind}(z) = v_{wind} \cdot \left(\frac{h_0+z}{h_0}\right)$

Where:

$v(z)$ is the total current velocity at level z

z is the distance from the still water level, negative downwards

v_{tide} is the tidal current and is calculated from the surface current,

$v_{wind}=0.015 U_0$ is the wind-generated current velocity at still water level

h is the water depth at still water

$h_0=50m$ is the reference depth for wind-generated current.

7.7 OPERATIONAL ENVIRONMENTS

Operating windows will be based on wind conditions like on fixed turbines or land-based turbines but also wave height and current speed.

The following criteria will be used as a guidance operating condition:

Wind speed between cut-in and cut-out speed,

Current speed equal to the 5-year return period conditions

Wave conditions equal to the 50-year return period wave height at the site of interest.

These conditions will be used as the conditions of design load case 1-6 as per IEC 61400-3. They will guarantee that the turbine can operate with no standby due to wave conditions.

7.8 ENVIRONMENTS DURING TRANSIENT CONDITIONS

All type of transient conditions shall be considered and checked for the platform as a whole and all its components. Transient conditions include conditions during construction, offshore installation, remediation to damage, maintenance, etc...

Temporary conditions may be verified under 1-year return period environments provided they last less than 7 days in total.

Critical weather-limited operations shall be considered to run under the maximum weather windows for both the normal operation and contingency plans.

7.9 EXTREME DESIGN ENVIRONMENTS

The structure of the hull, the mooring system and tower shall be designed for the 1:50 year return period design event. The following environmental combinations shall be used as a basis for the design:

	Wave return period	Wind return period	Current return period
Wave dominated event	50-year	5-year	50-year
Wind dominated event	5-year	50-year	50-year

TABLE 3 50-YEAR RETURN PERIOD EXTREME ENVIRONMENTAL COMBINATIONS

For towing and other non-weather limited marine operations, the 10-year return period will be considered:

	Wave return period	Wind return period	Current return period
Wave dominated event	10-year	1-year	10-year
Wind dominated event	1-year	10-year	10-year

TABLE 4 10-YEAR RETURN PERIOD EXTREME ENVIRONMENTAL COMBINATIONS

7.10 JOINT WIND / WAVE COMBINATIONS

7.10.1 NORMAL OPERATION ENVIRONMENTS

Normal operation environmental cases corresponding to load case 1-1 in IEC 61400-3 shall be derived from wave / wind correlation diagrams. They correspond to the most probable significant wave height.

These sea-states are defined for each 2m/s wind speed interval at hub.

7.10.2 FATIGUE ENVIRONMENTS

Fatigue sea-states to be considered in the verification of the fatigue performance are wind speed / wave height combinations with an associated number of occurrences and correspond to cases 1.2 in

IEC 61400-3.

7.10.3 EXTREME OPERATING SEA-STATES

Extreme operating sea-states corresponding to load case 1-6 in IEC 61400-3 are listed in [P06]. They correspond to the maximum sea-states under which the turbine will be considered operating. In the case of this project, it is considered that the turbine will operate up to the 50-year return period.

Hence these sea-states will be defined as sea-state/wind speed combinations having a joint return period of occurrence of 50 years. They shall be produced for the whole operating range of the turbine and wind speed intervals of 2m/s.

Due to practical reasons in their definition from environmental data-sets, these environments are generally produced from omni-directional data. For directions where the 50-year return period wave height is lower than the omni-directional sea-state, the 50-year return period wave height can be used instead.

8. HYDRODYNAMIC AND MOORING DESIGN METHOD

8.1 STABILITY ANALYSIS

In general, sufficient stability shall be granted to the platform in place in intact and damaged conditions with the turbine both free to idly rotate and with blades or the nacelle seized in the most unfavourable condition.

In transit condition, provision shall be given to the potential increase of loads due to the non-availability of adequate power supply to orientate the turbine.

Rule wind speeds shall also be checked against actual site wind speeds so that they are not underestimated.

Stability also has an impact on wind turbine loads. A stiffer platform in pitch will yield smaller loads in operational conditions but tends to increase loads on the tower in extreme storm conditions.

8.2 HYDRODYNAMIC LOADS CALCULATION

Hydrodynamic loads include current, first order wave loads and second order wave loads.

First order wave loads have an impact on:

- Platform motions and hence turbine loads,
- Hull global loads,
- Tower loads,
- Mooring system loads including drag, inertia and flexibility,
- Mooring system and particularly mooring connectors fatigue.

Current loads can be disregarded in the structural analysis of the structure provided members are not slender. They are however to be included in all other analyses (mooring, motions, umbilical, etc..)

Wave drift and low frequency loads shall be considered in the design of the mooring system. Their impact on the turbine loads through coupling with the mooring system shall be assessed and considered in the design if non-negligible.

As the area of deployment is not subject to high current speeds, no correction of wave drift loads with current speed will be applied.

Attention shall be paid to the application of viscous damping in structural analyses, especially when mapping of diffraction-radiation pressures is applied to the structural model so that structural analysis models remain balanced.

8.3 MOORING ANALYSIS

Mooring system analysis shall consider the following effects of importance:

- Wind turbine loadsWave frequency loads,
- Second order drift and low frequency loads,
- Alteration of drift loads due to current speed,
- Current effects such as Vortex-induced motions,
- Mooring line dynamics.

8.4 MOORING COMPONENTS

All mooring components shall show proven and adequate durability for the service of the platform. Besides regular mooring line tension loads, attention shall be paid to in- and out-of plane bending of mooring components.

Although the floater is anticipated to operate in shallow waters where there exist no evidence of bending fatigue failure of mooring lines, wind turbine loads may lead to larger static environmental loads on the mooring system in operating conditions than in typical shallow water oil and gas applications. This may yield unexpected chain and connectors fatigue damage and shall be assessed by calculation.

Details of the design requirements and mechanical integrity assessment methods of the mooring line top connector can be found in the “Top Connector Design Brief”.

9. GENERAL ARRANGEMENT AND UTILITIES DESIGN

9.1 PLATFORM LAYOUT

The primary function of the platform is to support a wind turbine and maximise its power yield; the tower and platform shall consequently be optimised towards this goal. The ease of maintenance of the turbine shall also be taken into consideration so that the operational downtime in case of failure is minimised.

In summary, it shall be an objective that the layout of the platform maximises the operational uptime of the turbine it supports to the extent that it does not impair safety of personnel and the environment.

Provisions shall be given in designing the general arrangement of the platform to:

- Turbine aerodynamic performance,
- Platform hydrodynamic performance,
- Platform stability and balance,
- Facilities and accesses necessary for the maintenance of the floating wind turbine,
- Accesses to all areas of the hull for maintenance,
- Platform damage control,
- Routing and integrity of mooring system and umbilical,
- Safety zones segregations (helicopter access, sea access, installation operations, lifting operations, high voltage areas, muster and evacuation, etc...).

The layout of the platform shall be designed so that access is possible under wind / wave conditions similar to fixed wind turbines. It is anticipated that sea access will be less critical on a floating platform as relative motions during vessel transfers at sea are usually smaller than relative motions between a fixed structure and a vessel. Access to equipment within the tower shall be possible from main deck.

9.2 ACCESS

Access on board shall be done using regular boat landings. The main deck shall be surrounded by handrails.

Access to turbine shall be normally closed and sufficiently high above deck to prevent flooding of the door by waves in adequate conditions.

Access by helicopter shall be possible on main deck in less favourable conditions.

Access to compartments shall be made through watertight manholes on main deck. In all

compartments with one horizontal dimension larger than 4m, two access manholes shall be provided as a minimum.

Dry access to all compartments shall be possible even in damaged condition. Ladders, platforms and handrails shall be provided in tanks for inspection.

Access shall be possible to all primary structural components. In particular, all pre-stressing bar / tendon anchor, critical weld and highly stressed area shall be made accessible by platforms, ladders or the like. Access to compartments shall be designed according to the latest recommendations from IACS and class.

9.3 EQUIPMENT TO BE INTEGRATED

A provisional list of equipment to be integrated is listed here below:

- Power and signal cables to / from shore,
- Turbine tower transition piece,
- Mooring interface structures and Top connectors,
- Mooring winch complete with stand to hook-up mooring lines,
- Navigation and work lights,
- Helicopter assistance equipment,
- Handrails, ladders, etc...
- Boat landing,
- Dynamic umbilical connection/hang-off,
- Towing brackets / bollards,
- Port mooring and positioning assistance bollards,
- Sounding pipes,
- Vents,
- Bilge piping / pumps
- Pollution prevention/remediation equipment where needed,
- Safety and evacuation equipment,
- Sensors for platform monitoring (stress gauges, accelerometers, tanks monitoring, etc...),

- Manholes,
- Installation equipment storage container,
- Sacrificial anodes.

9.4 INTERFACE WITH MOORING AND UMBILICAL

Beyond the structural function of the interface with the umbilical and mooring, the interface shall also enable easy offshore installation and require no maintenance.

Provision shall be given to enable the hook-up of the mooring lines and umbilical. Provisions shall also be given to move and transfer installation aids on deck. Installation aids may be large and weigh tens of tons.

9.5 BILGE / BALLAST SYSTEM

As the platform will be unmanned, a bilge system is not mandatory. It is however recognised that pumping arrangements can be useful for a demonstrator and they will be installed on Demo 1. A water ingress alarm system shall be fitted in all tanks necessary for the stability of the platform. The data from this monitoring system shall be monitored from the shore control room.

The bilge and ballast system shall also enable:

- Manual sounding of all tanks,
- Emptying of all tanks by portable means even in damaged conditions,
- Ballasting of the platform for balance purposes in installation condition.

Emptying of tanks may be done by pumping the water within the tanks. In all cases, vents will be needed for this purpose. Air pressing is not an option as concrete is generally not gastight. In case liquid ballast is used, potential for corrosion of the concrete in anaerobic environment will be verified.

10. STRUCTURAL DESIGN

10.1 BASIC PRINCIPLES – DESIGN LOADS

The platform proposed is aimed at providing a floating support to a wind turbine. As such the hull structure is subject to:

- dynamic loads as the bedplate of a rotating equipment,
- wave static and dynamic loads as a floating offshore structure,
- platform accelerations due to its motions resulting from environmental loads,
- large mooring loads when compared to the size of the platform (like a tanker single point mooring),
- All kind of operating loads such as boats mooring loads, installation loads, umbilical loads...

Aerodynamic, hydrodynamic wave, mooring and functional loads being of the same order of magnitude, no design procedure currently used in the civil, wind or offshore industry will be directly transferable to the floating wind turbine.

Current loads will be negligible on the structure; they will be accounted for through mooring line and umbilical tensions.

Wave loads calculation procedure shall enable to account for inertia as well as diffraction loads; this may be through either direct mapping of wave pressure from the diffraction-radiation calculation onto the FEM model or application of pressure fields on the hull yielding the exact bending, torque and shear wave forces on the hull, or calibrated Morison equation models.

Second order wave drift loads will be accounted for through mooring system design loads.

Slamming and green water loads shall be accounted for in the design of equipment located on deck and the deck itself. The tower transition piece will most probably be subject to wave impact loads and shall be designed accordingly.

Wind loads on the turbine will be accounted for through interface loads at the transition piece and the extraction of loads from dynamic simulations.

Hydrostatic pressure will probably not be a major issue in purely structural terms. However, offshore floating concrete structure rules require that a minimum portion of the wall thicknesses remains in compression in all conditions. This will be considered in the design of the primary structure.

10.2 STRUCTURE DYNAMIC BEHAVIOUR

A modal analysis of the whole structure shall be performed to confirm that the turbine will not operate within rotation rates yielding unacceptable dynamic excitation of the floater structure.

It is anticipated that the global analysis will have to account for mooring system stiffness and mass, hull dry mass and added mass, offset of the turbine on the floater and structural properties of the tower.

It is also possible that the hull structure influences the eigen frequencies of the tower as the tower will not be rigidly connected to hull. Local connection softness may influence the overall natural frequencies of the platform and shall as such be considered in the design.

All these effects shall be assessed in a single model taking into account all effects or through several models linking local and global behaviours.

10.3 MATERIALS AND DURABILITY

The hull is planned to be built in reinforced concrete. LR provides design guidance which mainly provide additional requirements to recognised civil engineering standards.

Reinforcement bars and pre-stressed members protection will be based on the application of sufficient concrete cover thickness in connection to the permeability of the concrete mix under consideration. Cathodic protection will also be applied to protect reinforcement steel in way of cracks and carbonation areas. There shall consequently be electrical continuity of bars in a zone protected by a given anode to ensure that the cathodic protection is effective. The cathodic protection will be made by means of sacrificial anodes.

The durability of steel structures is closely linked to proper earthing and coating. It shall be kept in mind that cathodic protection can cause hydrogen embrittlement for high-strength steel grades such as bolting and wires. LR rules for materials and welding provide a limit hardness not to be exceeded for steel parts.

All materials used shall feature proven performance for the project design life. All grades shall be selected from proven offshore structure grades.

Unusual and project-specific grades shall be limited to areas where they are absolutely necessary.

Pre-stressed members anchorage shall also be visible for periodic inspection where their design does not require them to be embedded in the concrete.

10.4 SECONDARY STRUCTURES AND HULL OUTFITTING

Improper connection of secondary structures on primary structural members has led in some instances to catastrophic failures. They shall consequently not be neglected in the design of the platform.

As in any marine structures, bolted manholes will need to be placed to gain access to all compartments. These manholes will need to be located close to the corners of the compartments and hence in stressed areas.

All secondary and tertiary structures shall not be directly connected to main re-bars so as to prevent the main structure from cracking in case these structures are overloaded. Weak links to control the failure of secondary structure can also be envisaged in some areas.

Load paths shall carefully be designed for platforms aimed at carrying personnel as the controlled failure of an overloaded personnel platform may be worse than the controlled damage of the primary structure carrying this platform.

Also, attention shall be paid to ensuring the water-tightness of pipe, cable penetrations and

embedment plates within the hull and bulkheads.

11. REPORTING AND FORMAT OF INFORMATION

11.1 CONTENTS OF REPORTS

All reports shall contain sufficient information to be self-supporting. In particular, the basic data used in a report shall be reminded along with the reference from which it is taken.

All codes and standards used in the report shall be listed. A sufficient level of detail shall be provided in the results to enable accurate checking of the results as part of quality control.

Hydrodynamic analysis reports shall contain as a minimum the natural periods calculated by the analysis software as well as listings of added mass, radiation damping, wave excitation forces and wave drift loads and damping.

In structural analyses, the resultant of load cases, combinations, listings of code check values, deflected shapes of the structure under the governing load cases and modal analysis results.

In mooring analysis, statistics of all variables (motions, loads on lines, anchors, etc...) shall be provided for all load cases along with statistics of wind, wave and current intensity. Modal analysis results shall also be provided.

11.2 UNITS

In general, all results shall be reported in metric units and preferably in units of the international system :

- Time : seconds (s)
- Frequencies: Hz and multiples, rad/s
- Length : metres (m) or millimetres (mm)
- Mass : kg, metric ton (m-ton)
- Forces : Newtons and multiples (N, kN, MN), alternately ton-force (m-ton)

- Moments : Newton.metres and multiples (N.m, kN.m, MN.m)
- Accelerations : m/s^2
- Speeds : m/s
- Angles : degrees

Drawings shall be drawn in accordance with ISO standard conventions.

11.3 AXIS CONVENTIONS

The forward end of the platform is opposite to the turbine, the aft end is at the turbine end. Sides are either sides of the symmetry plan of the floater.

The reference frame is defined as follows:

- Z is vertical, positive upwards,
- X is in the symmetry plan of the floater, directed forward,
- Y is positive to portside, perpendicular to the 2 other axes.

The origin of the platform reference frame is located:

- In the symmetry plan of the platform,
- On the lower side of the bottom of the platform,
- At the aft-most point of the hull in the symmetry plan of the platform, excluding skirt and appurtenances.

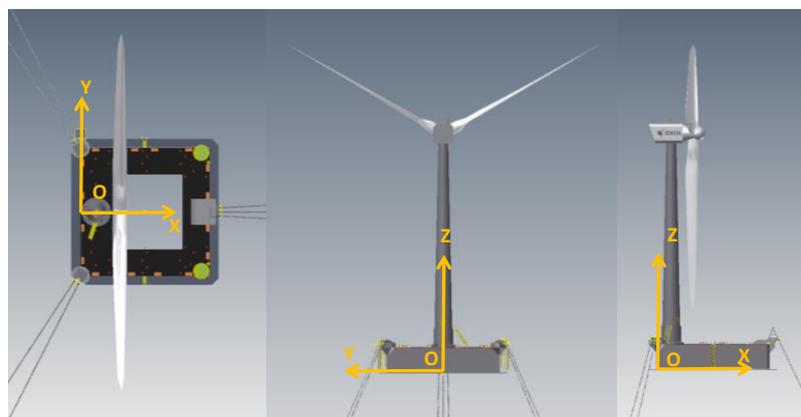


FIGURE 3 AXIS CONVENTIONS OF THE PLATFORM REFERENCE FRAME

The direction of environmental conditions is defined as the direction from which they come with respect to the Geographic North at the point considered. The direction can be merged with the North of the UTM grid applicable at the location considered.

For example, the direction of current flowing from East (*i.e* towards West) is 90° whereas the direction of waves coming from North West is 312.5° and the direction of wind blowing from the South is 180° .

Geographic conventions are reminded on the rosette in Figure 4.

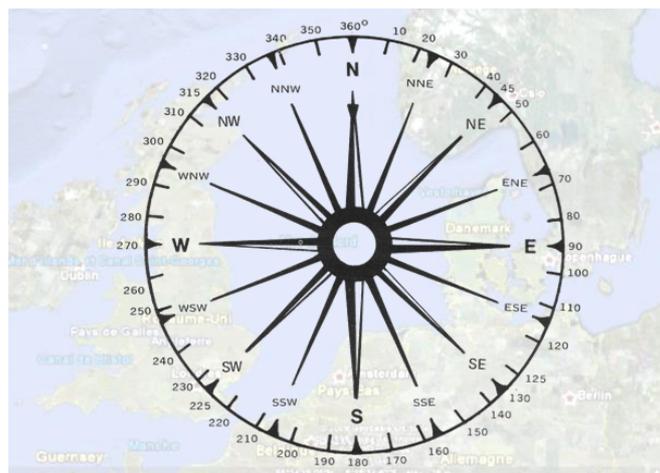


FIGURE 4 GEOGRAPHIC DIRECTION CONVENTIONS