



GUIDE FOR BUILDING AND CLASSING

FLOATING OFFSHORE WIND TURBINE INSTALLATIONS

OCTOBER 2015

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ABS Plaza
16855 Northchase Drive
Houston, TX 77060 USA**

Foreword

This Guide provides criteria for the design, construction, installation and survey of permanently sited Floating Offshore Wind Turbine Installations. It addresses three principal areas: the Floating Support Structure, the stationkeeping system, and onboard machinery, equipment and systems **including applicable marine systems and associated equipment and machinery, safety systems and associated equipment, and lifesaving appliances and machinery.**

The criteria applicable to bottom-founded offshore wind turbine support structures and foundations are provided in the *ABS Guide for Building and Classing Bottom-Founded Offshore Wind Turbine Installations (BOWTI Guide)*.

Requirements for ancillary offshore wind farm installations such as meteorological measuring towers, accommodation units, and transformer platforms are not addressed in this Guide. For the requirements for bottom-founded ancillary offshore wind farm installations, refer to the *ABS Rules for Building and Classing Offshore Installations*. The requirements applicable to floating ancillary offshore wind farm installations are provided in the *ABS Guide for Building and Classing Mobile Offshore Units* and the *ABS Rules for Building and Classing Floating Production Installations*.

This revision incorporates the following changes:

- 1-1/5 – A new optional class notion for the Rotor-Nacelle Assembly (RNA) is offered.
- 4-2/3.3 – Requirements are aligned with the new Appendix 2 for hurricane wind added to the *BOWTI Guide*.
- 4-6/17 – Guidance is provided on how the site assessment should be done with regard to electric network conditions.
- 5-2/3.1 – The requirement of considering the effect of malfunction of control systems on the integrity of the structural and stationkeeping system is clarified.
- 5-2/Table 1 – Additional requirements are provided for considering the directionality of wind and wave that may cause misaligned wave and wind conditions. A new design load case (new DLC 8.2) is added to account for possible fatigue damage during the temporary phase.
- 5-2/Table 2 – Further clarification is made of the condition of Floating Offshore Wind Turbine Installations in the robustness check.
- 6-1/1.1 and 6-2/1.1 – Reference is made to the new *ABS Guidance Notes on Global Performance Analysis for Floating Offshore Wind Turbine Installations*.
- 7-2/Table 2 – The fatigue design factor (FDF) is modified to address the unintended application of FDF = 1 to the non-critical, inspectable and repairable hull structures at or below the splash zone.
- 8-1/11 – A new Subsection is added to provide guidance on designing the non-redundant stationkeeping systems
- 8-3/Table 1 – The safety factor for ‘Damaged condition with one broken line’ is modified to better reflect actual practice.
- 8-3/7 – The case when the mooring line or tendon is over-designed (i.e., has higher than required breaking strength) for causes other than strength requirements is clarified. The design load used for the design of mooring hardware may be based on a value smaller than the breaking strength of the mooring lines or tendons. In such case, the maximum mooring/tendon tension multiplied by the safety factors defined in the Guide can be used.
- 8-3/9 – A new Subsection is added to provide guidance on how to account for the corrosion/wear in the design of mooring components.
- 8-5/9 and 8-5/11 – Two new Subsections are added to provide general guidance and design criteria for Suction Embedded Plate Anchor and Dynamically Installed Pile Anchor.

- 9-2/5.3 – The case when pre-approved procedures (repair, tow, etc.) are in place in lieu of installing pumps/blowers in the compartment is clarified.
- 10-1/11 – The requirements for safety outfitting for unmanned Floating Offshore Wind Turbine Installations are revised.
- Appendix 1 – A new Appendix is added that provides guidance on fatigue analysis of support structures.
- Various other changes are made to clarify the requirements.

This Guide becomes effective on **the first day of the month of publication.**

Users are advised to check periodically on the ABS website www.eagle.org to verify that this version of this Guide is the most current.

We welcome your feedback. Comments or suggestions can be sent electronically by email to rsd@eagle.org.

GUIDE FOR BUILDING AND CLASSING

FLOATING OFFSHORE WIND TURBINE INSTALLATIONS

CONTENTS

CHAPTER 1	Conditions of Classification	1
Section 1	Scope and Conditions of Classification	2
CHAPTER 2	Materials and Welding.....	17
Section 1	General	18
CHAPTER 3	General Design Requirements	19
Section 1	Design Considerations.....	20
CHAPTER 4	Environmental Conditions	24
Section 1	Overview	26
Section 2	Wind	27
Section 3	Waves	34
Section 4	Currents	36
Section 5	Tides, Storm Surges, and Water Levels	38
Section 6	Other Conditions	40
CHAPTER 5	Loads.....	43
Section 1	Overview	44
Section 2	Design Load Conditions.....	46
Section 3	Determination of Environmental Loads.....	55
CHAPTER 6	Global Performance Analysis.....	60
Section 1	General Requirements.....	61
Section 2	Analysis Methodologies	64
CHAPTER 7	Design of Floating Support Structures.....	66
Section 1	General Requirements.....	68
Section 2	Steel Structures	70
Section 3	Concrete Structures	78

CHAPTER 8	Design of Stationkeeping Systems.....	79
Section 1	General	81
Section 2	Design Conditions.....	83
Section 3	Steel Mooring and Tendon Systems.....	85
Section 4	Synthetic Fiber Ropes.....	89
Section 5	Anchor Holding Power	90
Section 6	Field Test	94
CHAPTER 9	Stability and Watertight/Weathertight Integrity	95
Section 1	General	96
Section 2	Stability	97
Section 3	Watertight/Weathertight Integrity	105
CHAPTER 10	Machinery, Equipment and Systems.....	106
Section 1	Design Requirements	107
CHAPTER 11	Surveys	109
Section 1	Surveys During Construction, Installation and Commissioning	111
Section 2	Surveys After Installation and Commissioning	118
Section 3	Risk-based Surveys for Maintenance of Class.....	123
APPENDIX 1	Fatigue Analysis for Floating Support Structures.....	124

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CHAPTER 1 Conditions of Classification

CONTENTS

SECTION 1	Scope and Conditions of Classification	2
1	Classification	2
3	Classification Boundaries.....	2
5	Classification Symbols and Notations.....	2
5.1	Installations Built under ABS Survey	2
5.3	Installations Not Built under ABS Survey	3
5.5	Additional Class Notation	3
7	Rules for Classification	3
7.1	Application.....	3
7.3	References	3
7.5	Alternatives.....	3
9	Design Documentation to be Submitted	4
9.1	Reports.....	4
9.3	Design Data and Calculations	5
9.5	Design Plans of Floating Support Structure.....	6
9.7	Design Documentation of Stationkeeping System.....	7
9.9	Design Plans of Machinery and Systems	8
9.11	Additional Plans.....	9
11	Manuals and Procedures	9
11.1	Operating Manual.....	9
11.3	Procedures	10
13	Information Memorandum.....	10
15	Terms and Definitions	11
15.1	Types of Floating Support Structures	11
15.3	Terminology.....	12
17	Abbreviations and References.....	15
17.1	Abbreviations of Organizations.....	15
17.3	References	15

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CHAPTER 1 Conditions of Classification

SECTION 1 Scope and Conditions of Classification

1 Classification

The general requirements for conditions of classification are contained in the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

Additional requirements specific to the Floating Offshore Wind Turbine Installation are contained in the following Subsections.

3 Classification Boundaries (1 October 2015)

The classification of the Floating Offshore Wind Turbine Installation addresses three principal areas which are subject to the requirements of this Guide:

- i) The Floating Support Structure, which carries the wind turbine Rotor-Nacelle Assembly (RNA);
- ii) The stationkeeping system; and
- iii) Applicable marine systems and associated equipment and machinery, safety systems and associated equipment, and lifesaving appliances and machinery

Additionally, at the request of the Owner, the Rotor-Nacelle Assembly (RNA) may be included in the classification subject to the ABS Type Approval requirements of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*.

When the RNA is not included in the classification, the RNA installed on the ABS classed Floating Offshore Wind Turbine Installation is required to have a type certificate in accordance with IEC 61400-22 or other recognized standards. The RNA type certificate will be reviewed by ABS solely to verify that the information of the installed RNA is consistent with the design information, criteria and limitations considered in the classification of the Floating Offshore Wind Turbine Installation. ABS will not review or be responsible for the accuracy of the RNA type certificate. Use of the RNA which does not have an appropriate type certification or the wind turbine having a non-horizontal-axis configuration will be subject to special consideration by ABS.

5 Classification Symbols and Notations

The following class notations apply to the Floating Offshore Wind Turbine Installation, as defined in 1-1/3 and further in 1-1/15.3.8.

5.1 Installations Built under ABS Survey

Installations built and constructed to the satisfaction of the ABS Surveyors and to the requirements of this Guide or to their equivalent, where approved by ABS, may be classed and distinguished in the *ABS Record* by the following symbol:

✠ A1 Offshore Wind Turbine Installation (Floating)

The mark ✠ (Maltese cross) signifies that the installation was built, installed and commissioned to the satisfaction of the ABS Surveyors.

5.3 Installations Not Built under ABS Survey

Installations not built under ABS survey but submitted for classification, are subject to special classification survey. Where found satisfactory and thereafter approved by ABS, such installations may be classed with the symbol:

A1 Offshore Wind Turbine Installation (Floating)

5.5 Additional Class Notation (1 October 2015)

The RNA, as defined in 1-1/15.3.25, may be considered for the classification at the Owner's request. Where the RNA are in full compliance with the requirements of the ABS Type Approval requirements of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*, the installation may be classed and distinguished in the *Record* by the optional class notation **RNA**.

7 Rules for Classification

7.1 Application

The requirements of this Guide are applicable to Floating Offshore Wind Turbine Installations as defined in 1-1/3 and further in 1-1/15.3.8.

This Guide is applicable to those features that are permanent in nature and can be verified by plan review, calculation, physical survey or other appropriate means. Any statement in this document regarding other features is to be considered as guidance to the designer, Fabricator, Owner, et al.

7.3 References

References are made in this Guide to ABS Rules and other criteria issued by ABS and other organizations. 1-1/17 contains a list of such references. Unless otherwise noted, the applicable edition of a reference is the one officially issued and available on the date the Agreement for Classification is accepted by ABS. Where a particular edition or date associated with a reference is given, it means that particular edition is relevant to the topic being presented in this Guide. ABS may consider at its discretion, upon the request of the Owner, the application of other appropriate alternative methods and recognized codes of practice.

7.5 Alternatives (1 October 2015)

Any departure from the requirements of this Guide may be considered by ABS on the basis of **suitable engineering analyses or risk assessments**. In the case of such departures, classification is subject to ABS's approval upon a demonstration of acceptable levels of safety in line with the principles of this Guide (see 3-1/3) and recognized and generally accepted current offshore wind industry practice. Risk acceptance criteria are subject to ABS's approval. The *ABS Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries* contains an overview of risk assessment techniques and additional information.

Using a risk assessment approach to justify alternatives may be applicable either to the Floating Offshore Wind Turbine Installation as a whole or to individual systems, subsystems or components. As appropriate, account must be given to remote hazards outside of the bounds of the system under consideration. Such account must include incidents relating to remote hazards directly affecting or being influenced by the system under consideration. ABS will consider the application of risk-based techniques in the design of the Floating Offshore Wind Turbine Installation as well as surveys during construction and surveys for maintenance of class.

Portions of the Floating Offshore Wind Turbine Installation not included in the risk assessment are to comply with the applicable parts of the ABS Rules.

The following are the responsibility of the Owner:

- i) Risk acceptance criteria
- ii) Hazard identification
- iii) Risk assessment

- iv) Risk management
- v) Compliance with the applicable requirements of the coastal State or other governmental authorities

9 Design Documentation to be Submitted

The design documentation to be submitted is to describe the data, tools, procedures and methodologies of design and analysis which are employed to establish the design of the Floating Offshore Wind Turbine Installation. The intended design life is also to be stated.

Where model testing is used as a basis for a design, the applicability of test results depends on the demonstration of the adequacy of the methods employed, including enumeration of possible sources of error, limits of applicability, and methods of extrapolation to full scale. Preferably, procedures are to be reviewed and agreed upon before model testing is done.

As required in the subsequent Paragraphs of this Subsection, calculations are to be submitted to demonstrate the sufficiency of a proposed design. Such calculations are to be presented in a logical and well-referenced fashion employing a consistent system of units. Where the calculations are in the form of computer analysis, the submittal is to provide input and output data with computer generated plots for the analysis model. A program description (not code listings), user manuals, and the results of program verification sample problems may be required to be submitted.

The design documentation to be submitted is to include the reports, calculations, plans, specifications and other documentation where applicable. The extensiveness of the submitted documentation is to reflect

- i) The uniqueness of a specific design of the Floating Offshore Wind Turbine Installation within an offshore wind farm, and
- ii) The level of experience with conditions in the area where the Floating Offshore Wind Turbine Installation is to be located.

Design documentation should generally be submitted electronically to ABS. However, hard copies will also be accepted.

9.1 Reports

Reports by consultants and other specialists used as a basis for design are to be submitted for review. The contents of reports on offshore wind farm conditions, environmental considerations, foundation data, and materials are, in general, to comply with the recommended list of items given below.

9.1.1 Offshore Wind Farm Conditions

A report on offshore wind farm conditions is to present the configuration of an offshore wind farm and the exact locations of all individual floating offshore wind turbines, subsea cables, transformer platform, service and accommodation units and any other supporting structures and facilities in the offshore wind farm where applicable.

The report is also to contain information of wind turbines, particularly those properties that are used as the input or as the basis of the input for the design of the Floating Offshore Wind Turbine Installation.

9.1.2 Environmental Considerations

Reports on environmental considerations, as described in Chapter 4, Section 1, are to describe all environmental phenomena appropriate to the areas for the pre-service (load-out, transportation, installation and commissioning) and in-service (operation, maintenance and repair) phases. The types of environmental phenomena to be accounted for, as appropriate to the type and location of the Floating Offshore Wind Turbine Installation, include wind, waves, currents, temperature, tide, marine growth, chemical components and density of air and water, snow and ice, earthquake and other pertinent phenomena.

The establishment of environmental conditions is to be based on appropriate original data or, when permitted, data from analogous areas. Demonstrably valid statistical models are to be employed to perform the extrapolation to long-term values. Any calculations required to establish the pertinent environmental conditions are to be submitted for review.

The report on environmental considerations is also to contain the calculations which quantify the effects or loadings on the Floating Offshore Wind Turbine Installation where these are not provided in other documentation.

9.1.3 Soil Data

Reports on soil data are to present the results of investigations or, when applicable, data from analogous areas on geophysical, geological and geotechnical considerations existing at and near the installation site of anchoring structures of the stationkeeping system. As appropriate to the planned anchoring structure, the manner in which such data is established and the specific items to be assessed are in general to comply with 5-4/1 and 5-4/5 of the *ABS Guide for Building and Classing Bottom-Founded Offshore Wind Turbine Installations (BOWTI Guide)*. The report is to contain a listing of references to cover the investigation, sampling, testing, and interpretive techniques employed during and after the site investigation.

Where applicable, the report is to include a listing of the predicted interaction between the soil and the anchoring structure of the stationkeeping system to be used in the design. As appropriate to the planned anchoring structure, the items which may need to be covered in the reports are: axial and lateral pile capacities and response characteristics, the effects of cyclic loading on soil strength, scour, settlements and lateral displacements, dynamic interaction between soil and structure, the capacity of pile groups, slope stability, bearing and lateral stability, soil reactions on the structure, and penetration resistance.

Recommendations relative to any special anticipated problem regarding installation are to be included in the report on soil data. Items such as the following are to be included, as appropriate: hammer sizes, soil erosion during installation, bottom preparation, and procedures to be followed in the case that pile anchor installation procedures significantly deviate from those anticipated.

9.1.4 Materials and Welding

Reports on structural materials and welding may be required for structures or welding procedures where materials or welding procedures do not conform to those provided in Chapter 2 of this Guide.

For metallic structures intending to employ new alloys not defined by a recognized specification, reports are to be submitted indicating the adequacy of the material's metallurgical properties, fracture toughness, yield and tensile strengths, and corrosion resistance, with respect to their intended application and service temperatures.

For a concrete structure, when it is not intended to test or define material properties in accordance with Chapter 2, a report is to be provided indicating the standards to be employed and their relative adequacy with respect to the corresponding standards referenced in Chapter 2.

9.1.5 Model Test

If model testing is performed (for example as per 6-1/9 for the assessment of global performance, Chapter 5, Section 3 for the determination of environmental loads, or Chapter 9, Section 2 for establishing the dynamic-response-based intact stability criteria), a model test report containing the information required in the relevant Sections is to be submitted.

9.3 Design Data and Calculations

Design and analysis calculations are to be submitted for items relating to loadings and responses for operations during the pre-service and in-service phases. Calculations are in general to comply with the items listed below.

Calculations which may be required in association with environmental considerations and soil data are described in 1-1/9.1.

9.3.1 Loadings

Calculations for loadings are to be submitted in accordance with 3-1/9 and Chapter 5.

9.3.2 Stability

Stability analyses are to be performed and the results are to be submitted in accordance with Chapter 9, Section 2.

9.3.3 Dynamic Properties

Calculations of natural periods of the Floating Offshore Wind Turbine Installation are to be submitted for review. A resonance diagram (Campbell diagram) depicting the relationship between the rotor speeds and the natural periods of turbine components and the Floating Offshore Wind Turbine Installation is to be submitted.

As applicable, the calculation of vibration amplitudes, velocities and accelerations of the Floating Support Structure may also be required.

9.3.4 Global Performance (1 October 2015)

Global performance analyses are to be carried out in accordance with 3-1/11 and Chapter 6. Descriptions of analysis methods and calculation results of the parameters listed in 6-1/1 are to be submitted for review.

The design documentation for the mooring lines and anchors (or tendons and foundation) and other stationkeeping system components is to be submitted in accordance with Chapter 8.

9.3.5 Structural Responses

Calculations necessary to verify structural adequacy of the Floating Support Structure are to be submitted for review. The needed extent and types of analyses and the sophistication of such analyses are dependent on one or a combination of the following factors:

- i) The design basis of the structure relative to the conditions to be encountered at the site
- ii) The relative lack of experience with the structure's arrangement, local details, loading patterns, and failure mode sensitivities
- iii) Potential deleterious interactions with other subsystems of the Floating Offshore Wind Turbine Installation

The required structural analyses are to employ the loads associated with the design load conditions determined in accordance with Chapter 5. More specific information on required structural analyses is given in Chapter 7 for the Floating Support Structure.

9.3.6 Other Calculations

Calculations are to include those performed in the design of the corrosion protection system. Additional calculations which demonstrate the adequacy of an overall design may also be required.

9.5 Design Plans of Floating Support Structure

Plans showing the scantlings, arrangements and details of the principal parts of the tower and hull structure of the Floating Offshore Wind Turbine Installation to be built under survey are to be submitted and approved before the work of construction is commenced. These plans are to clearly indicate the scantlings, joint details and welding, or other methods of connection. In general, plans to be submitted are to include the following, where applicable:

- General arrangement
- Body plan, lines, offsets, curves of form, inboard and outboard profile
- Layout plans indicating the locations, dimension and weights of turbine components (e.g., blade, hub, nacelle, etc.) and the components (e.g., electrical, mechanical and control systems, etc.) in nacelle housing

- Layout plans of secondary structures, fenders, ladders, access platform, boat landing, export electrical cable support, etc.
- Wind heeling moment curves or equivalent data for the Floating Support Structure carrying the RNA
- Thrust curve of the turbine rotor
- Arrangement plan of watertight compartmentation
- Diagrams showing the extent to which the watertight and weathertight integrity are intended to be maintained, as well as the location, type and disposition of watertight and weathertight closures
- Capacity plan and tank sounding tables
- Summary of distributions of weights (fixed, variable, ballast, etc.) for various conditions
- Type, location and quantities of permanent ballast, if any
- Loadings for all decks
- Turbine tower scantlings
- Tower-hull connection details
- Hull transverse section showing scantlings
- Hull longitudinal sections showing scantlings
- Decks, including helicopter deck if applicable
- Framing, shell plating, watertight bulkheads and flats, structural bulkheads and flats, tank bulkheads and flats with location of overflows and air pipes
- Pillars, girders, diagonals and struts
- Stability columns, intermediate columns, hulls, pontoons, superstructure and deck houses
- Arrangement and details of watertight doors and hatches
- Foundations for anchoring equipment, industrial equipment, etc., where attached to hull structure, superstructures or deckhouses
- Mooring turrets and yoke arms, including mechanical details, if applicable
- Corrosion control arrangements
- Welding details and procedures
- Methods and locations for nondestructive testing
- Information in support of novel features utilized in the design, where applicable

9.7 Design Documentation of Stationkeeping System

The design documentation for the stationkeeping system is to include the following, where applicable:

- Mooring arrangement or pattern
- Details of winching equipment
- Details of anchoring system
- Details of mooring line or tendon segments
- Connections at anchors and between mooring line segments
- Details of in-line (spring) buoys
- Details of buoy of catenary anchor leg mooring (CALM) system
- Details of single anchor leg mooring (SALM) structures

- Details of turret system to show turret structure, swivel, turntable and disconnecting device
- Details of yoke (hard or soft) connecting the Floating Support Structure and the CALM/SALM structure
- Reports on wind farm conditions, environmental considerations and soil data, as required in 1-1/9.1
- Global performance analysis report, as required in 1-1/9.3.4
- Model test report when the design loads are based on model tests in a wave basin (see 1-1/9.1.5)
- Thruster specifications and calculations of a system with dynamic positioning system for thruster forces and power to counteract environmental forces.

9.9 Design Plans of Machinery and Systems

Design plans of the machinery and systems addressed in Chapter 10 are to be submitted for review and approval by ABS.

9.9.1 Design Documentation of Electrical Installations

The design documentation for the electrical installation is to include the following, where applicable:

- Electrical one-line diagrams
- Short-circuit current calculations
- Coordination study
- Specifications and data sheets for generators and motors
- Specifications and data sheets for distribution transformers
- Details of storage batteries
- Details of emergency power source
- Standard details of wiring cable and conduit installation practices
- Switchboards and distribution panel
- Panel board

9.9.2 Design Documentation of Instrumentation and Control Systems

The design documentation for the instrumentation and control system is to include the following, where applicable:

- General arrangements
- Data sheet
- Schematic drawings – electrical systems
- Schematic drawings – hydraulic and pneumatic systems
- Programmable electronic systems

9.9.3 Fire Protection and Personnel Safety Design Plans

The applicability of the following requirements to the submission of design documentation may vary, depending upon the nature of a specific design of the Floating Wind Turbine Installation.

- Portable or semi-portable extinguishers
- Fire detection and alarm systems
- Fire cause and effect chart
- Heating, ventilation and air conditioning (HVAC) plan [including air handling unit (AHU)], location, duct layout, duct construction and bulkhead and deck penetration details

- Guard rails
- Escape routes (may be included on the fire control plan or separate plan)
- Lifesaving appliances and equipment plan (escape routes must be indicated)

9.9.4 Design Plans for Other Machinery and Systems

Submission of design plans for other machinery and systems which are described in Chapter 10 but not specified in 1-1/9.9.1 through 1-1/9.9.3 of this Guide is to follow 1-1-4/3 of the *MODU Rules*, where applicable.

9.11 Additional Plans

Where additional class notations or certification under the other Rules, Guides or regulations, as described in Section 1-1-5 of the *ABS Rules for Conditions of Classification – Offshore Units and Structures (Part 1)*, are requested, submission of additional plans and calculations may be required.

11 Manuals and Procedures

11.1 Operating Manual

The Operating Manual pertaining to the safe operation of the Floating Offshore Wind Turbine Installation is to be prepared and submitted for review. A copy of the Operating Manual is preferably to be stored onboard of the Floating Offshore Wind Turbine Installation. Alternatively, the Operating Manual may be retained by the Owner and made readily available to the ABS Surveyor and to service personnel prior to conducting any maintenance or inspection.

Insofar as classification is concerned, the Operating Manual is to include, as appropriate, the following information:

- i) A general description of the Floating Offshore Wind Turbine Installation, including major dimensions, lightship characteristics
- ii) A general description and the maintenance record of the RNA
- iii) Summaries of approved modes of operation (See Chapter 5, Section 2), including for each mode of operation:
 - Design environmental conditions, including wave height and period, wind speed, current velocity, minimum air and sea temperatures, air gap, and water depth
 - Turbine RNA operating mode in conjunction with the condition of turbine control, protection and electrical systems and the status of electrical network connection
 - Design deck loadings, mooring loads, icing loads, variable load, cranes and, if applicable, types of helicopter for which the helideck is designed
 - Draft or draft range, disposition of movable equipment such as crane booms, etc.
 - Maximum allowable KG versus draft curve or equivalent and associated limitations or assumptions upon which the allowable KG is based (See 9-2/1)
 - Disposition (open or closed) of watertight and weathertight closures (See 9-3/1)
 - (1 October 2015) Maximum allowable offset and heeling angle of the Floating Support Structure
- iv) Information showing:
 - General arrangements
 - Type, location and quantities of permanent ballast
 - Allowable deck loadings
 - Information related to stability and watertight/weathertight integrity, as required in 9-2/5.3, 9-2/7, and 9-3/1

- Capacity, centers of gravity and free surface correction for each tank
 - Capacity and centers of gravity of each void provided with sounding arrangements but not provided with means of draining
 - Location and means of draining voids
 - Hydrostatic curves or equivalent
 - Simplified electrical one line diagrams of main power and emergency power systems
 - Schematic diagrams of the bilge, ballast and ballast control system
- v) Ballasting and deballasting procedure
- vi) Disconnecting and reconnecting procedure, if applicable, for operating disconnectable mooring systems

The Operating Manual is to be reviewed by ABS solely to verify the operational procedures and conditions are consistent with the design information, criteria and limitations considered in the installation's classification. ABS is not responsible for the operation of floating offshore wind turbines.

The Operating Manual required by this subsection does not need to be in addition to that required by the coastal State or other governmental authorities. These administrations may require that additional information be included in the Operating Manual.

11.3 Procedures

Procedures are to be submitted for the following:

- Installation Procedures
- Hook-Up Procedures for connecting the stationkeeping system to the Floating Support Structure
- Startup and Commissioning Procedures
- Survey and Inspection Planning Document
- Underwater Inspection Procedure or, if applicable, Drydocking Survey Procedure
- Disconnecting and Reconnecting Procedure, if applicable, for operating disconnectable mooring systems

13 Information Memorandum

An information memorandum is to be prepared and submitted to ABS. ABS will review the contents of the memorandum to establish consistency with other data submitted for the purpose of obtaining classification. ABS will not review the contents of the memorandum for their accuracy or the features described in the memorandum for their adequacy.

An information memorandum is to contain, as appropriate to the Floating Offshore Wind Turbine Installation, the following:

- Specifications of turbine RNAs to be installed
- Site plan indicating the general features at the site and the layout of the offshore wind farm
- Environmental and soil design criteria, including the recurrence interval used to assess environmental phenomena
- Plans showing the general arrangement of the Floating Offshore Wind Turbine Installation
- Description of the safety, protective, security and trespass avoidance systems provided
- Description of the modes of operation
- Listing of governmental authorities having cognizance over the installation
- Listing of any novel features

- Brief description of any monitoring proposed for use on the installation
- Description of pre-service load-out, transportation, installation and commissioning procedures
- Description of on-site maintenance and repair procedures for both the Floating Offshore Wind Turbine Installation and the RNA
- Description of disconnecting, transportation and reconnecting procedures for maintenance and repair operations, if applicable

15 Terms and Definitions

15.1 Types of Floating Support Structures

15.1.1 TLP-Type Floating Support Structures (1 October 2015)

A TLP-type Floating Support Structure is a vertically moored, buoyant structural system wherein the excess buoyancy of the platform maintains tension in the stationkeeping system.

A TLP-type Floating Support Structure consists of structural components of hull connecting to the tendon system. It may also include a column top frame and topside deck. The hull consists of buoyant pontoons and columns. The tops of the columns may be connected to the Tower directly or to a column top frame or a topside deck forming the global strength of the hull. The tendon system consists of a vertical mooring system that forms the link between the hull and the foundation for the purpose of mooring the Floating Support Structure. The foundation system is used to anchor the tendons to the seafloor.

15.1.2 Spar-Type Floating Support Structures (1 October 2015)

A Spar-type Floating Support Structure is a deep draft, vertical floating structure, usually of cylindrical shape, supporting the Tower and a topside structure (if any) and moored to the seafloor.

A Spar-type Floating Support Structure typically consists of an upper hull, mid-section and lower hull. The upper hull serves to provide buoyancy to support the topside and provides spaces for variable ballast. The mid-section connects the upper hull with the lower hull. The mid-section can be a cylindrical column or a truss space frame with heave plates. The heave plates are a series of horizontal decks between each bay of the truss space frame and are designed to limit heave motions by providing added mass and hydrodynamic damping. The lower hull normally consists of a fixed ballast tank and, in the case of a truss Spar, a flotation tank.

15.1.3 Column-Stabilized Floating Support Structures

A column-stabilized Floating Support Structure consists of a topside structure connected to the underwater hull or footings by columns or caissons. The Floating Support Structure depends upon the buoyancy of columns or caissons for flotation and stability. Lower hulls or footings are normally provided at the bottom of the columns for additional buoyancy. The topside structure can be of an enclosed hull type or an open space frame truss construction. The topside structure is interconnected with the stability columns of the hull to form the overall strength of the Floating Support Structure. The Tower may be connected directly to the column or caisson or to the topside structure.

15.1.4 Other Types of Floating Support Structures

Configurations of the Floating Support Structure that do not belong to the types described in 1-1/15.1.1 through 1-1/15.1.3.

15.3 Terminology

15.3.1 Material Applications Categories

The application of structural members in the Floating Support Structure is to be in accordance with the categories listed in this Paragraph.

15.3.1(a) Special Application Structure. Special application structure refers to highly stressed members, located at intersections of main structural elements and other areas of high stress concentration where the occurrence of a fracture could induce a major structural failure.

15.3.1(b) Primary Application Structure. Primary application structure refers to primary load carrying members of a structure where the occurrence of a fracture could induce a major structural failure.

15.3.1(c) Secondary Application Structure. Secondary application structure refers to less critical members due to a combination of lower stress and favorable geometry or where an incidence of fracture is not likely to induce a major structural failure.

15.3.2 Consultant

A consultant is any person who, through education and experience, has established credentials of professionalism and knowledge in the stated field.

15.3.3 Cut-In Wind Speed (V_{in})

The lowest 10-minute mean wind speed at Hub Height at which the wind turbine starts to produce power in the case of steady wind without turbulence

15.3.4 Cut-Out Wind Speed (V_{out})

The highest 10-minute mean wind speed at Hub Height at which the wind turbine is designed or chosen to produce power in the case of steady wind without turbulence

15.3.5 Design Life

Assumed period for which a structure, a structural component, a system or equipment is expected to be used for its intended purpose with anticipated maintenance, but without substantial repair being necessary

15.3.6 Emergency Shutdown

Rapid shutdown of the wind turbine triggered by a protection function or by manual intervention

15.3.7 Fabricator

A Fabricator is any person or organization having the responsibility to perform any or all of the following: fabrication, assembly, erection, inspection, testing, load-out, transportation and installation.

15.3.8 Floating Offshore Wind Turbine Installation (1 October 2015)

A Floating Offshore Wind Turbine Installation encompasses three principal areas: the Floating Support Structure (see 1-1/15.3.9) for carrying the wind turbine RNA (see 1-1/15.3.25), the Stationkeeping System (see 1-1/15.3.28) and onboard machinery, equipment and systems **including applicable marine systems and associated equipment and machinery, safety systems and associated equipment, and lifesaving appliances machinery.**

In this Guide, the Floating Offshore Wind Turbine Installation does not include the RNA.

15.3.9 Floating Support Structure

A Floating Support Structure of an offshore wind turbine is a site dependent offshore structure supported by buoyancy and maintained on location by the Stationkeeping System. The Floating Support Structure consists of the Tower (see 1-1/15.3.32) and the Hull (see 1-1/15.3.12) structure.

15.3.10 Foundation System (for Tendons)

Structural, mechanical and geotechnical components which are located on and beneath the sea floor and transfer the loads acting on the Tendons into the seabed

15.3.11 Gust

Brief rise and fall in wind speed lasting less than 1 minute

15.3.12 Hull

Combination of connected buoyant structural components such as columns, pontoons and intermediate structural braces

15.3.13 Hub Height (1 October 2015)

Height of the center of the swept area of the wind turbine rotor above the Still Water Level

15.3.14 Idling

Condition of a wind turbine that is rotating slowly and not producing power

15.3.15 Mean Sea Level or Mean Still Water Level (MSL)

Average level of the sea over a period long enough to remove variations due to waves, tides and storm surges

15.3.16 Mean Wind Speed

Statistical mean value of the instantaneous wind speed over a specified time interval

15.3.17 Normal Shutdown

Wind turbine shutdown operation in which all stages are under the control of the control system

15.3.18 Offshore Wind Farm

A group of offshore wind turbines installed at an offshore site.

15.3.19 Omni-directional (Wind, Waves or Currents)

Acting in all directions

15.3.20 Owner

An owner is any person or organization who owns offshore wind turbines

15.3.21 Parked

Condition of a wind turbine that is either in a Standstill or an Idling condition, depending on the design of the wind turbine

15.3.22 Rated Power

Quantity of power assigned, generally by a manufacturer, for a specified operating condition of a component, device, or equipment. For wind turbines, it is the maximum continuous electrical power output which a wind turbine is designed to achieve under normal operating and external conditions.

15.3.23 Rated Wind Speed (V_r)

Minimum 10-minute mean wind speed at Hub Height at which a wind turbine's Rated Power is achieved in the case of steady wind without turbulence

15.3.24 Return Period (Recurrence Period)

A return period is the average time duration between occurrences of an event or of a particular value being exceeded. A return period in years is equal to the reciprocal of the annual probability of exceedance of an event or of a particular value of a random parameter such as wind speed, wave height or sea elevation.

15.3.25 Rotor-Nacelle Assembly (RNA)

The Rotor-Nacelle Assembly of a horizontal axis wind turbine, carried by the Floating Support Structure, consists of:

- i) The Rotor components, including blades, hub, shaft, and spinner.
- ii) The Nacelle, a housing which contains the mainframe, generator frame, drive train components, electrical generator components, wind turbine control and protection components and other elements on top of the Tower.

15.3.26 Splash Zone

Part of a Floating Support Structure containing the areas above and below the Mean Sea Level and regularly subjected to wetting due to wave actions, motions of the Floating Support Structure and, if applicable, tide and draft variations. Areas which are only wetted during major storms are not included.

15.3.27 Standstill

Condition of a wind turbine that is not rotating

15.3.28 Stationkeeping System

System capable of limiting the excursions of the Floating Support Structure within prescribed limits, maintaining the intended orientation, and helping to limit motions at Tower top

15.3.29 Still Water Level (SWL)

Abstract water level used for the calculation of wave kinematics and wave crest elevation. Still Water Level, which can be either above or below the Mean Sea Level, is calculated by adding the effect of tide and surge to the Mean Sea Level.

15.3.30 Surveyor

A Surveyor is a person employed by ABS whose principal functions are the surveillance during construction and the survey of marine structures and their components for compliance with the ABS Rules or other standards deemed suitable by ABS.

15.3.31 Tendon

A system of components, which form a link between the Hull structure and the Foundation System for the purpose of restraining motion of the TLP-type Floating Support Structure in response to environmental and other loading within specified limits

15.3.32 Tower

Structure component which connects the Hull structure to the Rotor-Nacelle Assembly

15.3.33 Turbulence Intensity

Ratio of the wind speed standard deviation to the mean wind speed, determined from the same set of measured data samples of wind speed, and taken over a specified period of time

15.3.34 Uni-directional (Wind, Waves or Currents)

Acting in a single directions

15.3.35 Water Depth

Vertical distance between the sea floor and the Still Water Level

15.3.36 Wind Profile (Wind Shear Law)

Mathematical expression for assumed wind speed variation with height above the Still Water Level

15.3.37 Yaw Misalignment

Horizontal deviation of the wind turbine rotor axis from the wind direction

17 Abbreviations and References

17.1 Abbreviations of Organizations

ABS	American Bureau of Shipping
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
API	American Petroleum Institute
ASTM	American Society for Testing and Materials
IEC	International Electrotechnical Commission
ISO	International Organization for Standardization
NACE	National Association of Corrosion Engineers

17.3 References (1 October 2015)

- i) ABS FPI Rules – ABS Rules for Building and Classing Floating Production Installations
- ii) ABS MODU Rules – ABS Rules for Building and Classing Mobile Offshore Drilling Units
- iii) ABS Offshore Installations Rules – ABS Rules for Building and Classing Offshore Installations
- iv) ABS Rules for Materials and Welding – Part 2
- v) ABS Steel Vessel Rules – ABS Rules for Building and Classing Steel Vessels
- vi) ABS Guide for Building and Classing Bottom-Founded Offshore Wind Turbine Installations
- vii) ABS Guide for Building and Classing Gravity-Based Offshore LNG Terminals
- viii) ABS Guide for Buckling and Ultimate Strength Assessment for Offshore Structures
- ix) ABS Guide for the Fatigue Assessment of Offshore Structures
- x) ABS Guide for Nondestructive Inspection of Hull Welds
- xi) ABS Guide for Surveys Using Risk Based Inspection for the Offshore Industry
- xii) ABS Guide for Surveys Using Reliability-Centered Maintenance
- xiii) ABS Guidance Notes on the Application of Fiber Rope for Offshore Mooring
- xiv) **ABS Guidance Notes on Global Performance Analysis for Floating Offshore Wind Turbine Installations**
- xv) **ABS Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries**
- xvi) **ABS Guidance Notes on Review and Approval of Novel Concepts**
- xvii) **AISC Manual of Steel Construction**
- xviii) **API Bulletin 2INT-MET, Interim Guidance on Hurricane Conditions in the Gulf of Mexico**
- xix) **API Bulletin 2N, Interim Planning, Designing and Constructing Fixed Offshore Structures in Ice Environments**
- xx) **API RP 2A-LRFD, Recommended Practice for Planning Designing and Constructing Fixed Offshore Platforms – Load and Resistance Factor Design**
- xxi) **API RP 2A-WSD, Recommended Practice for Planning Designing and Constructing Fixed Offshore Platforms – Working Stress Design**
- xxii) **API RP 2SK, Recommended Practice for Design and Analysis of Stationkeeping Systems for Floating Structures**

- xxiii) API RP 2T, *Recommended Practice for Planning, Designing, and Constructing Tension Leg Platforms*
- xxix) API SPEC 17E, *Specification for Subsea Umbilicals*
- xxv) IEC 61400-1, *Wind Turbines – Part 1: Design Requirements*, 3rd Edition, 2005
- xxvi) IEC 61400-3, *Wind Turbines – Part 3: Design Requirements for Offshore Wind Turbines*, 1st Edition, 2009
- xxvii) IEC 61400-24, *Wind Turbines – Part 24: Lightning protection*, 1st Edition, 2010.
- xxviii) IEEE 1120, *IEEE Guide for the Planning, Design, Installation, and Repair of Submarine Power Cable Systems*
- xxix) ISO 2533, *Standard Atmosphere*
- xxx) ISO 19904-1, *Petroleum and natural gas industries – Floating Offshore Structures, Part 1: Monohulls, Semi-submersibles and Spars*
- xxxi) ISO 19906, *Petroleum and natural gas industries - Arctic offshore structures*
- xxxii) NACE SP0108, *Standard Practice: Corrosion Control of Offshore Structures by Protective Coatings*
- xxxiii) NACE SP0176, *Standard Practice: Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with Petroleum Production*



CHAPTER 2 Materials and Welding

CONTENTS

SECTION 1	General	18
1	Metallic Materials	18
3	Welding	18
5	Concrete.....	18
7	Mooring Chains and Accessories	18
9	Fiber Ropes	18

CHAPTER 2 Materials and Welding

SECTION 1 General

1 Metallic Materials

Properties of metallic materials are to be in accordance with Section 3-1-4 of the *MODU Rules*. Guidance on determining the material application category (see 1-1/15.3.1) of a hull structural component is provided in Part 5B of the *FPI Rules*.

3 Welding

Requirements for welding are to be in accordance with the *ABS Rules for Materials and Welding (Part 2)*. Section 3-2-6 of the *MODU Rules* is to be used to establish weld designs for the steel Floating Support Structure.

5 Concrete

Properties of the concrete are to comply with 2-1/3 of the *ABS Guide for Building and Classing Bottom-Founded Offshore Wind Turbine Installations*, which makes further reference to applicable standards of the American Society for Testing and Materials (ASTM) and the American Concrete Institute (ACI).

7 Mooring Chains and Accessories

Materials and welding of offshore mooring chains and accessories for application in the stationkeeping system are to be in accordance with the *ABS Guide for the Certification of Offshore Mooring Chain*.

9 Fiber Ropes

For materials of synthetic fiber ropes for application in the stationkeeping system, the requirements specified in the *ABS Guidance Notes on the Application of Fiber Rope for Offshore Mooring* are to be satisfied.

CHAPTER 3 General Design Requirements

CONTENTS

SECTION 1	Design Considerations	20
1	General	20
3	Safety Level	20
5	Design Life	20
7	Environmental Conditions	21
9	Design Load Conditions and Load Calculations	21
11	Global Performance Analyses	22
13	Structural Design	22
15	Stationkeeping System	22
17	Stability and Watertight/Weathertight Integrity	23
19	Structural Material Selection, Welding and Connection	23
21	Corrosion Protection and Control	23
23	Operating Manual	23

CHAPTER 3 General Design Requirements

SECTION 1 Design Considerations

1 General (1 October 2015)

The Floating Support Structure, the stationkeeping system and onboard machinery, equipment and systems **including applicable marine systems and associated equipment and machinery, safety systems and associated equipment, and lifesaving appliances and machinery** are to be designed in compliance with the standards and requirements contained in this Guide with intention that the Floating Offshore Wind Turbine Installation can fulfill its intended functions during its design life and meet specified minimum requirements for serviceability and operability.

3 Safety Level (1 October 2015)

The design criteria specified in this Guide are intended for the unmanned Floating Offshore Wind Turbine Installation having a safety level equivalent to the medium (L2) exposure level as defined in ISO 19904-1 for unmanned floating offshore structures.

The Floating Support Structure and the stationkeeping system can be categorized at various safety levels based on the consideration of life-safety and consequences of failure. Life-safety considers the most unfavorable combination of environmental event and turbine operating mode which would be expected to occur while personnel are on the Floating Offshore Wind Turbine Installation. Consequences of failure deal with loss of life, environmental pollution, financial loss and potential negative impact to the industry.

Since the Floating Support Structure is typically unmanned and considered as having moderate consequences of failure, the Floating Support Structure can in general be designed to have a safety level equivalent to the medium (L2) exposure level as defined in ISO 19904-1. A higher safety level equivalent to the high (L1) exposure level as defined in ISO 19904-1 may be warranted when considering that:

- i) There is limited design and operation experience with floating offshore wind turbines.
- ii) The Floating Support Structure is likely to have a low level of redundancy.
- iii) The same or a similar design may be used in an entire offshore wind farm, which becomes vulnerable to “common-cause” failures.

For an offshore wind farm having multiple Floating Offshore Wind Turbine Installations located in a close proximity, failure of an individual stationkeeping system could potentially cause extensive damage to many other floating offshore wind turbines and electrical cables **as well as other offshore installations** in the offshore wind farm. The risk analysis may be used to determine the intended safety level of the stationkeeping system. However, the safety level of the stationkeeping system is not to be lower than that of the Floating Support Structure.

5 Design Life

The design life of the Floating Offshore Wind Turbine Installation is not to be less than 20 years.

Upon the request by the Owner, a shorter design life may be accepted by ABS for the Floating Offshore Wind Turbine Installation for the purpose of demonstrating viability of a new design concept or conducting pilot operations.

Continuance of classification beyond the design life is subject to the survey requirements specified in 11-2/23 and additional engineering analyses.

7 Environmental Conditions

The Floating Offshore Wind Turbine Installation is to be designed to withstand specified operational and environmental conditions at the installation site while the RNA is in various operating conditions. The environmental conditions are defined in Chapter 4.

The Floating Offshore Wind Turbine Installation is also to be designed for all pre-service operations such as load-out, transportation, installation, and commissioning.

Environmental conditions having a low probability of being exceeded when a mooring line or tendon of the stationkeeping system is broken or removed are also to be considered. Joint statistics may be used to determine a return period which, combined with the probability of occurrence of damage, produces a risk level consistent with the intended safety level.

Additionally, environmental conditions are to be specified for verifying the survivability of the Floating Offshore Wind Turbine Installation. Survival environmental conditions are those that produce responses having a very low probability of being exceeded during the design life, and that the Floating Offshore Wind Turbine Installation can endure such responses without causing catastrophic consequences.

9 Design Load Conditions and Load Calculations

The Floating Support Structure's life cycle phases, including the pre-service (load-out, transportation, installation, and commissioning) and in-service (operation, maintenance, and repair) phases, are to be investigated using anticipated loads. Permanent and variable loads together with relevant environmental loads due to the effects of wind, waves, currents, water level variations and, where deemed necessary, the effects of earthquake, temperature, fouling, ice, and other potential impacts are to be taken into account. Combinations of these loads as well as the turbine operating conditions that produce the most unfavorable local and global effects on the Floating Support Structure and the stationkeeping system, as determined by the requirements of the pre-service and in-service phases, are to be applied.

Dynamic analysis models are to be developed to predict design load effects for all relevant combinations of external site conditions and turbine operating conditions. A minimum set of such combinations, which is termed as Design Load Cases (DLCs), is defined in 5-2/3.

In addition to the Design Load Cases, other load cases are also to be considered for the situations where the Floating Offshore Wind Turbine Installation is in the survival condition. The adequacy of air gap and stationkeeping capacity, as well as structural integrity if considered relevant, are to be verified by the robustness check, in which the Floating Offshore Wind Turbine Installation is subjected to survival environmental conditions that are more severe than extreme design environmental conditions. The robustness check provides a direct indicator of the survivability of a specific design. A minimum set of Survival Load Cases (SLCs) is defined in 5-2/5.

In the process of establishing design criteria for the Floating Offshore Wind Turbine Installation, all applicable aspects contributing to the safety level need to be considered collectively. These include, but are not limited to, the following.

- i) Prescribed safety factors
- ii) Return period of extreme design environmental conditions
- iii) Statistical variation of environmental conditions at different installation sites
- iv) Load models of environmental and operational loading specific to offshore wind turbines
- v) Strength and fatigue capacity models of materials, structural members, joints and foundation elements
- vi) Characteristics of the responses of the offshore wind turbine when subjected to aggregate environmental and turbine operational loadings

Following these considerations and in particular because dynamic responses of bottom-founded offshore wind turbines exhibit a wide scattering of sensitivity to the variation of environmental conditions, the *ABS Guide for Building and Classing Bottom-Founded Offshore Wind Turbine Installations* requires the application of the 100-year return storm condition to the design of support structures of bottom-founded offshore wind turbines to be installed at a site where extreme environmental conditions are governed by tropical cyclones.

In contrast to bottom-founded offshore wind turbines, the Floating Offshore Wind Turbine Installation having the typical hull types as defined in 1-1/15.1.1 through 1-1/15.1.3 show a very different pattern of sensitivity to the return period of environmental conditions. The minimum return period for the extreme storm condition, as specified in 5-2/3, is 50 years.

11 Global Performance Analyses

Global performance analyses of the Floating Offshore Wind Turbine Installation are used to determine the global effects of environmental loads and other loads on the turbine RNA, the Floating Support Structure, the stationkeeping system, and the export electrical cable system. Global response analyses are to be performed for each of the critical design phases.

Global performance analyses using various design load cases are required. It is recommended to include the turbine RNA, the Floating Support Structure, the stationkeeping system, and the export electrical cable system in an integrated (also known as “coupled”) simulation model for global performance analyses. For those global loads and responses that are deemed as having weak coupling effects, global performance analyses may also be performed using a non-integrated model.

Either frequency or time domain methods, or a combination of both, may be used in global performance analyses. However, for those cases that have transient or highly nonlinear effects, time-domain analyses are normally required. Methods and models employed in analyses are to account for the relevant nonlinear and dynamic coupling effects of the RNA, the Floating Support Structure, the stationkeeping system, and the export electrical cable system.

Chapter 6 outlines specific requirements for global performance analyses of the Floating Offshore Wind Turbine Installation.

13 Structural Design

The Floating Support Structure is to be designed in accordance with the requirements specified in Chapter 7. In the case where the structure’s configuration or loading is not specifically addressed in this Guide, other recognized design standards may be used. Where alternative standards are followed, it is to be demonstrated that the safety level specified in this Guide has been adequately satisfied.

15 Stationkeeping System

The Floating Support Structure is restrained by the stationkeeping system, which may be either a passive or an actively controlled system, or a combination of both. A passive stationkeeping system may be in the form of

- Spread mooring (catenary, taut-line or semi-taut-line),
- CALM consisting of a buoy and several catenary anchor legs,
- Turret mooring,
- SALM, such as an articulated leg, or
- Tension leg system.

An active system could be a dynamic positioning system, a thruster-assisted mooring consisting of actively controlled thrusters, or a mooring system with the ability of changing mooring line tensions.

17 Stability and Watertight/Weathertight Integrity

Adequacy of stability of the Floating Support Structure is to be verified for all relevant pre-service and in-service phases. The assessment of stability is to include the consideration of both intact and damaged conditions. The design requirements of Chapter 9 are to be satisfied.

19 Structural Material Selection, Welding and Connection

Structural materials are to be selected with consideration of the requirements for performance, welding and inspection. The materials used for the construction of the Floating Support Structure and the stationkeeping system are to be in accordance with the requirements of Chapter 2.

The welding of steel for the Floating Support Structure is to follow the requirements of Chapter 2. Special attention is to be given to the weld details for fatigue sensitive areas, whenever relevant. Refer to the *ABS Guide for the Fatigue Assessment of Offshore Structures*.

For connections other than welded joints, such as clamps, connectors and bolts that are used to join diagonal braces to the column or the turbine tower to the support foundation, the strength and fatigue resistance are to be assessed by analytical methods or testing following established industry practices such as those specified in the *AISC Steel Construction Manual*.

21 Corrosion Protection and Control

A corrosion protection and control system utilizing anodes and/or coating in accordance with the recognized industry standards such as those published by NACE are to be provided. The design life of the corrosion protection and control system is to be in general the design life of the Floating Offshore Wind Turbine Installation, unless a monitoring and repair plan is established. In the splash zone, corrosion allowance is to be added to the external shell plating. Reference may be made to the guidance on corrosion allowance in the relevant industry standards for floating offshore structures.

23 Operating Manual

The Operating Manual, as required in 1-1/11.1, for the floating wind turbine is to be developed to specify the operating procedures and conditions that are consistent with the design information, criteria and limitations considered in the design of the Floating Offshore Wind Turbine Installation.

CHAPTER 4 Environmental Conditions

CONTENTS

SECTION 1	Overview	26
1	General	26
3	Environmental Factors to be Considered	26
SECTION 2	Wind.....	27
1	General	27
3	Wind Properties	27
3.1	Wind Speed and Turbulence	27
3.3	Wind Profile	28
3.5	Wind Spectrum and Spatial Coherence.....	29
5	Long-Term and Extreme Value Predictions.....	29
7	Wind Conditions.....	29
9	Normal Wind Conditions	30
9.1	Normal Wind Profile Model (NWP)	30
9.3	Normal Turbulence Model (NTM)	30
11	Extreme Wind Conditions	30
11.1	Extreme Wind Speed Model (EWM)	30
11.3	Extreme Operating Gust (EOG).....	31
11.5	Extreme Turbulence Model (ETM).....	31
11.7	Extreme Direction Change (EDC).....	31
11.9	Extreme Coherent Gust with Direction Change (ECD)	32
11.11	Extreme Wind Shear (EWS)	33
13	Survival Wind Conditions	33
13.1	Survival Wind Speed Model (SurWM)	33
FIGURE 1	Vector Components of Turbulent Wind Velocity	28
SECTION 3	Waves.....	34
1	General	34
3	Normal Sea State (NSS).....	34
5	Severe Sea State (SSS)	35
7	Extreme Sea State (ESS)	35
9	Survival Sea State (SurSS).....	35
11	Breaking Waves.....	35

SECTION 4	Currents	36
1	Currents	36
3	Normal Current Model (NCM)	36
5	Extreme Current Model (ECM)	36
7	Survival Current Model (SurCM)	37
SECTION 5	Tides, Storm Surges, and Water Levels	38
1	General	38
3	Normal Water Level Range (NWLR)	38
5	Extreme Water Level Range (EWLR)	38
7	Survival Water Level Range (SurWLR)	39
	FIGURE 1 Definition of Water Levels	39
SECTION 6	Other Conditions	40
1	Temperature	40
3	Air Density	40
5	Ice and Snow Accumulation	40
7	Marine Growth	40
9	Seismicity and Earthquake Related Phenomena	40
9.1	Levels of Earthquake Conditions	40
9.3	Regional and Site-specific Data	41
9.5	Other Earthquake Related Phenomena	41
11	Sea Ice or Lake Ice	41
13	Soil Conditions	41
15	Lightning	41
17	Electric Network Conditions	42

CHAPTER 4 Environmental Conditions

SECTION 1 Overview

1 General

Environmental conditions to which the Floating Offshore Wind Turbine Installation is expected to be exposed during its design life are to be determined using adequate data for the areas in which the Floating Offshore Wind Turbine Installation is to be transported and installed.

Environmental phenomena that influence the pre-service and in-service phases of the Floating Offshore Wind Turbine Installation are to be described in terms of relevant characteristic parameters. Statistical data and realistic statistical and mathematical models which describe the range of expected variations of environmental conditions are to be employed. All data used are to be fully documented with the sources and estimated reliability of data noted.

Methods employed in developing available data into design criteria are to be described and submitted in accordance with 1-1/9.1. Probabilistic methods for short-term, long-term and extreme-value prediction are to employ statistical distributions appropriate to environmental phenomena under consideration, as evidenced by relevant statistical tests, confidence limits and other measures of statistical significance. Directional data and angular separation for wind, waves and currents are to be established. Hindcasting methods and models are to be fully documented if they are used to derive the environmental data.

Generally, suitable data and analyses supplied by recognized consultants will be accepted as the basis for design. For installations in areas where published design standards and data exist, such standards and data may be cited in the design documentation.

3 Environmental Factors to be Considered

In general, the design of the Floating Offshore Wind Turbine Installation requires investigation of the following environmental factors.

- i) Wind
- ii) Waves
- iii) Currents
- iv) Tides, storm surges, and water levels
- v) Air and sea temperatures
- vi) Air density
- vii) Ice and snow accumulation
- viii) Marine growth
- ix) Seismicity
- x) Sea ice or lake ice

Other phenomena, such as tsunamis, submarine slides, seiche, abnormal composition of air and water, air humidity, salinity, ice drift, icebergs, ice scouring, etc., may require investigation depending upon specific conditions at an installation site and a specific design of the Floating Offshore Wind Turbine Installation.

The investigation of seabed and soil conditions is described in 4-6/13.

CHAPTER 4 Environmental Conditions

SECTION 2 Wind

1 General

Statistical wind data are normally to include information on the frequency of occurrence, duration and direction of various wind speeds at the location where offshore wind turbines are to be installed. If on-site measurements are taken, the duration of individual measurements and the height above sea-level of measuring devices are to be stated. A wind speed value is only meaningful when qualified by its elevation and time-averaging duration.

In the absence of site data, published data and data from nearby land and sea stations may be used upon the agreement with ABS.

3 Wind Properties

3.1 Wind Speed and Turbulence

A wind condition is typically represented by a mean wind speed and a standard deviation of wind speed. The turbulence intensity, which measures the variation of wind speed relative to the mean wind speed, is defined as the ratio of the wind speed standard deviation to the mean wind speed (i.e., coefficient of variance of wind speed).

In this Guide, the mean wind speed, denoted as V_{hub} , at turbine hub height with 10-minute averaging duration is employed to define the design load conditions in Chapter 5, Section 2 and to calculate the rotor generated aerodynamic loads and thrust forces as described in 5-3/3.

Mean wind speeds with 1-minute or 1-hour averaging time duration are used in the calculation of steady and dynamic wind forces exerted on exposed components of the Floating Support Structure, as described in 5-3/3.

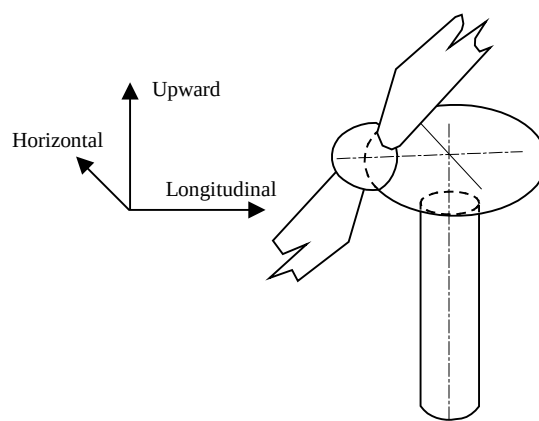
Conversion of a mean wind speed from one averaging duration to another is to be based on site-specific wind conditions. Use of conversion factors in recognized industry standards appropriate to the installation site may be acceptable and is subject to approval by ABS.

For wind speeds given in terms of the “fastest mile of wind”, V_f , the corresponding time-averaging period t in seconds is given by $t = 3600/V_f$, where V_f is the fastest mile of wind at a reference height of 10 m (32.8 ft), in miles per hour.

The turbulence of wind within 10 minutes is generally considered stationary and can be modeled by a power spectral density function and a coherence function. The turbulence model is to include the effects of varying wind speed, shears and directions and allow rotational sampling through varying shears. The three vector components of turbulent wind velocity, as depicted in 4-2/Figure 1 are defined as:

- i) *Longitudinal* – Along the direction of the mean wind speed
- ii) *Lateral* – Horizontal and normal to the longitudinal direction
- iii) *Upward* – Normal to both the longitudinal and lateral directions and pointing upward

FIGURE 1
Vector Components of Turbulent Wind Velocity



3.3 Wind Profile (1 October 2015)

The mean wind speed profile (vertical wind shear) is to be defined by the power law:

$$V(z) = V_{hub} (z/z_{hub})^\alpha$$

where

$V(z)$ = wind profile of the 10-minute mean wind speed as a function of height, z , above the Still Water Level (SWL), in m/s (ft/s)

V_{hub} = 10-minute mean wind speed at turbine hub height, in m/s (ft/s)

α = power law exponent, values of which are given in 4-2/9 and 4-2/11, (dimensionless)

z = height above the SWL, in m (ft)

z_{hub} = hub height above the SWL, in m (ft)

The power law wind profile can also be applied to the mean wind speeds with 1-minute or 1-hour averaging duration, except that the exponent is to be determined based on site-specific conditions or using published data, such as those in the *FPI Rules*, as appropriate to the installation site.

For storm wind conditions, the mean wind speed profile may be represented by the following logarithmic wind shear law as recommended by API Bulletin 2INT-MET (2007). It is expressed using the 1-hour mean wind speed at 10 m (32.8 ft) above the SWL.

$$V(z, t) = V(z, t_0) [1 - 0.41 I_u(z) \ln(t/t_0)] \quad \text{for } t < t_0$$

where

$V(z, t)$ = mean wind speed at height z and corresponding to an averaging time period t , in m/s (ft/s)

z = height above the SWL, in m (ft)

t = averaging time period shorter than $t_0 = 3600$ s, in seconds

$V(z, t_0)$ = 1-hour mean wind speed at height z , in m/s (ft/s)

$$= V_0 \left[1 + C \ln \left(\frac{z}{10\phi} \right) \right]$$

t_0 = reference averaging time period (1 hour), in seconds

= 3600 s

$$C = 0.0573 \sqrt{1 + 0.15V_0 / \phi}, \text{ (dimensionless)}$$

$$V_0 = \text{1-hour mean wind speed at 10 m (32.8 ft) above the SWL, in m/s (ft/s)}$$

$$I_u(z) = \text{turbulence intensity, [i.e., the ratio of the wind speed standard deviation to the mean wind speed, at height } z \text{ (dimensionless)]}$$

$$= 0.06[1 + 0.043V_0/\phi] \left(\frac{z}{10\phi} \right)^{-0.22}$$

$$\phi = \text{unit conversion factor (dimensionless)}$$

$$= 1 \quad \text{when using SI units (m, m/s)}$$

$$= 3.28 \quad \text{when using US Customary units (ft, ft/s)}$$

Guidance on the wind profile suitable for tropical cyclones (also known as hurricanes or typhoons) is provided in Appendix 2 of the *BOWTI Guide*.

Other wind profile models may also be used provided that they can be justified by site-specific data.

3.5 Wind Spectrum and Spatial Coherence (1 October 2015)

Site-specific spectral density of wind speed and spatial coherence are preferable to be determined based on measured wind data.

When the site assessment is not available, the Mann uniform shear turbulence model or the Kaimal spectrum in combination with the exponential coherence model, as recommended in Annex B of IEC 61400-1 (2005), may be applied.

For the tropical cyclone wind, API Bulletin 2INT-MET (2007) recommends using the NPD (Frøya) wind spectrum in conjunction with the two-point coherence function. Refer to Appendix 1 of the *ABS BOWTI Guide* for the definition.

5 Long-Term and Extreme Value Predictions

Long-term and extreme value predictions for sustained and gust winds are to be based on recognized techniques and clearly described in the design documentation. Preferably, the statistical data used for the long-term distributions of wind speed are to be based on the same averaging periods of wind speeds as are used for the determination of loads.

7 Wind Conditions

A wind condition for the design of the Floating Offshore Wind Turbine Installation is represented by a steady mean flow and associated turbulence. The design wind conditions are further categorized into

- i) The normal wind conditions, which occur more frequently than once per year;
- ii) The extreme wind conditions representing rare wind conditions with a given return period; and
- iii) The survival wind conditions having a very low probability of being exceeded during the design life of the Floating Offshore Wind Turbine Installation.

The design wind conditions for the Floating Offshore Wind Turbine Installation are specified in 4-2/9 through 4-2/13. The load case descriptions in Chapter 5, Section 2 specify which wind condition is to be applied.

9 Normal Wind Conditions

9.1 Normal Wind Profile Model (NWP)

The normal mean wind speed profile (vertical wind shear) is to be defined by the power law specified in 4-2/3.3, where the power law exponent $\alpha = 0.14$.

9.3 Normal Turbulence Model (NTM)

The normal turbulence model (NTM) is to be applied together with the normal wind profile model (NWP) as defined in 4-2/9.1.

The standard deviation of turbulence of the normal turbulence model, denoted as σ_{NTM} , is defined as the 90% quantile in the probability distribution of wind speed standard deviation conditioned upon a given 10-minute mean wind speed at hub height (V_{hub}).

The value of the turbulence standard deviation is to be determined using appropriate statistical techniques applied to measured and preferably de-trended data. Where the site assessment is not available, the recommended approach provided in Section 12.3 of IEC 61400-3 (2009) may be used to estimate the standard deviation.

11 Extreme Wind Conditions

The extreme wind conditions are represented by peak wind speeds due to storms, extreme operating gust and turbulence, extreme wind shear events, and rapid changes in wind speed and direction.

11.1 Extreme Wind Speed Model (EWM) (1 October 2015)

The EWM is defined as a turbulent wind model with a specified return period. Both the 1-year and 50-year return extreme wind conditions are considered in the design load conditions as specified in Chapter 5, Section 2.

When site data are not available, the wind profile of 10-minute mean wind speeds for the EWM with return periods of 1 year and 50 years, respectively, is to be represented by the power law model as follows:

$$V(z) = V_{hub} (z/z_{hub})^{0.11}$$

where

$$\begin{aligned} V_{hub} &= 10\text{-minute mean wind speed at hub height, in m/s (ft/s)} \\ &= V_{10\text{min},1\text{-yr}} \quad \text{for 1-year return extreme wind condition} \\ &= V_{10\text{min},50\text{-yr}} \quad \text{for 50-year return extreme wind condition} \end{aligned}$$

$$V_{10\text{min},1\text{-yr}} = 10\text{-minute mean wind speed at hub height with a return period of 1 year, in m/s (ft/s)}$$

$$V_{10\text{min},50\text{-yr}} = 10\text{-minute mean wind speed at hub height with a return period of 50 years, in m/s (ft/s)}$$

$$z = \text{height above the SWL, in m (ft)}$$

$$z_{hub} = \text{hub height above the SWL, in m (ft)}$$

The standard deviation of longitudinal turbulent wind speed of extreme wind condition, σ_1 , at hub height is to be calculated as:

$$\sigma_1 = 0.11 \times V_{hub}$$

Alternatively, the logarithmic wind shear law given in 4-2/3.3 may be used to calculate the wind profile and standard deviation of extreme wind conditions with a 50-year return period.

Guidance on the wind profile, the turbulence intensity and the gust factor suitable for tropical cyclones (also known as hurricanes or typhoons) is provided in Appendix 2 of the BOWTI Guide.

11.3 Extreme Operating Gust (EOG)

The EOG is represented by the hub height gust magnitude, V_{gust} , as defined in the following equation:

$$V_{gust} = \min \left\{ 1.35(V_{3sec,1-yr} - V_{hub}); \quad 3.3 \left(\frac{\sigma_{NTM}}{1 + 0.1D / \Lambda_1} \right) \right\}$$

where

- $V_{3sec,1-yr}$ = 3-second mean wind speed at hub height with a return period of 1 year, in m/s (ft/s)
- V_{hub} = 10-minute mean wind speed at hub height, as defined in 5-2/Table 1, in m/s (ft/s)
- σ_{NTM} = longitudinal turbulence standard deviation defined in 4-2/9.3, in m/s (ft/s)
- Λ_1 = longitudinal turbulence length scale, in m (ft)
 - = $0.7z$ when $z \leq 60$ m (196.8 ft)
 - = 42 m (137.8 ft) when $z \geq 60$ m (196.8 ft)
- D = rotor diameter, in m (ft)

The time history of transient wind speed at height z is to be defined by:

$$V(z, t) = \begin{cases} V(z) - 0.37V_{gust} \sin(3\pi t / T)[1 - \cos(2\pi t / T)] & 0 \leq t \leq T \\ V(z) & \text{otherwise} \end{cases}$$

where

- $V(z)$ = normal wind profile defined in 4-2/9.1, in m/s (ft/s)
- z = height above the SWL, in m (ft)
- T = 10.5 s

11.5 Extreme Turbulence Model (ETM)

The ETM is to be represented by the normal wind profile (NWP) model specified in 4-2/9.1 and the turbulence whose standard deviation of longitudinal component is given by:

$$\sigma_1 = cI_{ref} \left[0.072 \left(\frac{V_{ave}}{c} + 3 \right) \left(\frac{V_{hub}}{c} - 4 \right) + 10 \right]$$

where

- c = 2 m/s (6.56 ft/s)
- V_{hub} = 10-minute mean wind speed at hub height, as defined in 5-2/Table 1, in m/s (ft/s)
- V_{ave} = site-specific annual mean wind speed at hub height, in m/s (ft/s)
- I_{ref} = expected value of turbulence intensity at hub height when $V_{hub} = 15$ m/s (49.2 ft/s)

11.7 Extreme Direction Change (EDC)

The extreme direction change magnitude, θ_e , is to be calculated by:

$$\theta_e = \pm 4 \arctan \left(\frac{\sigma_{NTM}}{V_{hub} (1 + 0.1D / \Lambda_1)} \right) \quad -180^\circ \leq \theta_e \leq 180^\circ$$

where

- σ_{NTM} = longitudinal turbulence standard deviation defined in 4-2/9.3, in m/s (ft/s)
- V_{hub} = 10-minute mean wind speed at hub height, as defined in 5-2/Table 1, in m/s (ft/s)
- Λ_1 = longitudinal turbulence length scale, defined in 4-2/11.3, in m (ft)
- D = rotor diameter, in m (ft)

The time history of transient extreme direction change, $\theta(t)$, is defined by:

$$\theta(t) = \begin{cases} 0^\circ & t < 0 \\ \pm 0.5\theta_e [1 - \cos(\pi / T)] & 0 \leq t \leq T \\ \theta_e & t > T \end{cases}$$

where $T = 6$ s is the duration of the extreme direction change. The sign in the equation is to be chosen such that the most unfavorable transient loading occurs. At the end of the time history of direction change, the direction is assumed to remain a constant value (θ_e). The wind speed is to follow the normal wind profile (NWP) model in 4-2/9.1.

11.9 Extreme Coherent Gust with Direction Change (ECD)

The extreme coherent gust with direction change is to have a magnitude of:

$$V_{cg} = 15 \text{ m/s (49.21 ft/s)}$$

The time history of transient wind speed at height z , is defined by:

$$V(z, t) = \begin{cases} V(z) & t < 0 \\ V(z) + 0.5V_{cg} [1 - \cos(\pi / T)] & 0 \leq t \leq T \\ V(z) + V_{cg} & t > T \end{cases}$$

where

$$\begin{aligned} V(z) &= \text{normal wind profile defined in 4-2/9.1, in m/s (ft/s)} \\ T &= \text{rise time of gust wind, in second} \\ &= 10 \text{ s} \\ z &= \text{height above the SWL, in m (ft)} \end{aligned}$$

The rise in wind speed is assumed to occur simultaneously with the time history of direction change:

$$\theta(t) = \begin{cases} 0^\circ & t < 0 \\ \pm 0.5\theta_{cg} [1 - \cos(\pi / T)] & 0 \leq t \leq T \\ \pm \theta_{cg} & t > T \end{cases}$$

where

$$\begin{aligned} \theta_{cg} &= \text{magnitude of direction change, in degree} \\ &= \begin{cases} 180^\circ & V_{hub} \leq 4 \text{ m/s (13.12 ft/s)} \\ 720^\circ (V_{hub} / \phi)^{-1} & V_{hub} > 4 \text{ m/s (13.12 ft/s)} \end{cases} \\ V_{hub} &= 10\text{-minute mean wind speed at hub height, in m/s (ft/s)} \\ T &= \text{rise time of gust wind, in second} \\ &= 10 \text{ s} \\ \phi &= \text{unit conversion factor (dimensionless)} \\ &= 1 \quad \text{when using SI units (m, m/s)} \\ &= 3.28 \quad \text{when using US Customary units (ft, ft/s)} \end{aligned}$$

11.11 Extreme Wind Shear (EWS)

The extreme wind shear is to be applied in both vertical and horizontal directions. The two extreme wind shears are considered independent events and therefore they are not to be applied simultaneously.

The time history of transient positive and negative vertical shear is given by:

$$V(z, t) = \begin{cases} V_{hub} \left(\frac{z}{z_{hub}} \right)^\alpha \pm \left(\frac{z - z_{hub}}{D} \right) (2.5\phi + 0.2\beta\sigma_{NTM} (D/\Lambda_1)^{1/4}) [1 - \cos(2\pi t/T)] & 0 \leq t \leq T \\ V_{hub} \left(\frac{z}{z_{hub}} \right)^\alpha & \text{otherwise} \end{cases}$$

The time history of transient horizontal shear is given by:

$$V(y, z, t) = \begin{cases} V_{hub} \left(\frac{z}{z_{hub}} \right)^\alpha \pm \left(\frac{y}{D} \right) (2.5\phi + 0.2\beta\sigma_{NTM} (D/\Lambda_1)^{1/4}) [1 - \cos(2\pi t/T)] & 0 \leq t \leq T \\ V_{hub} \left(\frac{z}{z_{hub}} \right)^\alpha & \text{otherwise} \end{cases}$$

where

V_{hub}	=	10-minute mean wind speed at hub height, as defined in 5-2/Table 1, in m/s (ft/s)
σ_{NTM}	=	longitudinal turbulence standard deviation defined in 4-2/9.3, in m/s (ft/s)
Λ_1	=	longitudinal turbulence length scale, defined in 4-2/11.3, in m (ft)
z	=	height above the SWL, in m (ft)
z_{hub}	=	hub height above the SWL, in m (ft)
y	=	horizontal distance from hub in the cross wind direction, in m (ft)
D	=	rotor diameter, in m (ft)
α	=	0.14, (dimensionless)
β	=	6.4, (dimensionless)
T	=	12 s
ϕ	=	unit conversion factor (dimensionless)
	=	1 when using SI units (m, m/s)
	=	3.28 when using US Customary units (ft, ft/s)

The sign for the transient wind shear is to be determined such that the most unfavorable transient loading occurs.

13 Survival Wind Conditions

The survival wind conditions are described by the Survival Wind Speed Model (SurWM).

13.1 Survival Wind Speed Model (SurWM)

The Survival Wind Speed Model (SurWM) is similar to the Extreme Wind Speed Model (EWM) defined in 4-2/11.1, but with a return period longer than 50 years, as specified in 5-2/5.

When site data are not available, the wind profile and turbulence spectrum for the SurWM is to be defined according to 4-2/3.3 and 4-2/3.5. When the wind profile is assumed to follow the power law, the power law exponent $\alpha = 0.11$ and the standard deviation of longitudinal turbulent wind speed is to be taken as $\sigma_1 = 0.11 \times V_{hub}$.

CHAPTER 4 Environmental Conditions

SECTION 3 Waves

1 General

The development of wave data is to reflect conditions at the installation site and the type of Floating Offshore Wind Turbine Installation. Statistical wave data used to determine design parameters are normally to include the frequency of occurrence of various wave height groups, associated wave periods and directions. Published data and previously established design criteria for particular areas may be used where such exist. Hindcasting techniques that adequately account for shoaling and fetch limited effects on wave conditions at the site may be used to augment available data. Analytical wave spectra employed to augment available data are to reflect the shape and width of the data and to be appropriate to the general site conditions.

As applicable, wave data are to be developed in order to determine the following:

- i) Dynamic responses of the Floating Support Structure and the stationkeeping system
- ii) Maximum responses of structures and stationkeeping system components
- iii) Fatigue
- iv) Air gap
- v) Wave impact on the local structure

All long-term and extreme value predictions employed for the determination of design wave conditions are to be fully described and based on recognized techniques. Because the wave-induced global responses may be increased due to the change of wave period and direction, consideration is to be given to waves of less than the maximum height but with a different period and/or direction. Waves that cause the most unfavorable effects on the overall structure may also differ from waves having the most severe effects on individual structural components. In addition to the most severe wave conditions, frequent waves of smaller heights are to be investigated to assess their effect on the fatigue and dynamic responses.

The design wave conditions for the design of the Floating Offshore Wind Turbine Installation are described below in 4-3/3 through 4-3/9. The design load conditions defined in Chapter 5, Section 2 specify how these sea states are to be applied in combination with other design environmental conditions.

3 Normal Sea State (NSS)

The Normal Sea State (NSS) is represented by a significant wave height, a peak spectral period, and a wave direction. It is to be determined based on the site-specific long-term joint probability distribution of metocean parameters. The Normal Sea State (NSS) is used in 5-2/Table 1 to define a number of Design Load Cases (DLCs) requiring either strength analysis or fatigue analysis.

For strength analyses, the Normal Sea State (NSS) can be characterized by the expected value of significant wave height, $H_{s,NSS}$, conditioned upon a given value of V_{hub} (i.e., $H_{s,NSS} = E[H_s | V_{hub}]$). A range of peak period, T_p , associated with each significant wave height is to be determined for load calculations. The resultant highest loads are to be used in the design of the Floating Support Structure.

For fatigue analyses, the number and resolution of sea states are to be determined in such a manner that the fatigue damage associated with the full long-term distribution of metocean parameters can be sufficiently accounted for.