



China Classification Society

Guidelines for Floating Offshore Wind Turbine Installations

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Chapter 1 GENERAL

Section 1 GENERAL PROVISIONS

1.1.1 General requirements

1.1.1.1 The Guidelines are the basis for China Classification Society (hereinafter referred to as “CCS”) to provide classification service for floating offshore wind turbine installations (FOWT installations) and provide the service of documents of compliance (DOC) in terms of safety equipment, tonnage, load lines, environmental protection, etc.

1.1.1.2 The requirements in the Guidelines are not mandatory. However, once accepted and adopted, they will become the technical basis for all parties to abide by and follow.

1.1.1.3 In order to guarantee the normal use of FOWT installations, in addition to the requirement of the Guidelines, relevant regulations of competent authorities shall also be complied with. If there is any contraction or inconsistency, applicable regulations of competent authorities shall prevail.

1.1.2 Scope of application

1.1.2.1 The Guidelines apply to unattended FOWT installations and their accessory systems, mainly including the buoyant structure, anchor foundation, mooring system, electromechanical equipment and dynamic cables of the installation but exclude the rotor-nacelle assembly as well as the tower structure.

1.1.3 Equivalent and exemption

1.1.3.1 The design provisions involved with classification that are inconsistent with the requirements in the Guidelines (including the requirements of the acceptable standards) can be accepted and used as the substitute for the corresponding requirements of the Guidelines, provided that those provisions have the safety level proven or indicated by written documents to be at least equivalent to the requirements in the Guidelines and have been agreed by all parties to the contract and CCS.

1.1.3.2 For FOWT installations with new structure and novel feature, the part involved with classification may be exempted from any provision in the Guidelines if the application of the Guidelines may severely impede the application of its feature or the use of its structure, subject to agreement of CCS.

Section 2 DEFINITION

1.2.1 Definition

1.2.1.1 Unless otherwise specified, the definitions of the terms adopted for the purpose of the Guidelines are as follows:

(1) “Unattended” is the unmanned state without any regular personnel on duty for operation and maintenance; operations like monitoring and control are conducted remotely; patrol inspection and maintenance are conducted regularly for equipment;

(2) A rotor is a device that can transform wind energy to mechanical energy, which is composed of blades and hubs;

(3) The rotor-nacelle assembly (RNA) is a combination of the rotor, nacelle structure and related electromechanical equipment;

(4) A tower is a structure connecting the RNA and the FOWT installation;

(5) A support structure is a structure supporting the RNA, including the tower and FOWT installation;

(6) A floating offshore wind turbine (FOWT) installation is the support structure, including the buoyant structure, mooring system, anchoring foundation as well as the relevant mechanical systems and equipment on the installation, electric instruments and equipment, except for the

tower;

(7) A FOWT is an offshore floating facility transforming wind energy to electrical energy, which is generally composed of the RNA and support structures.

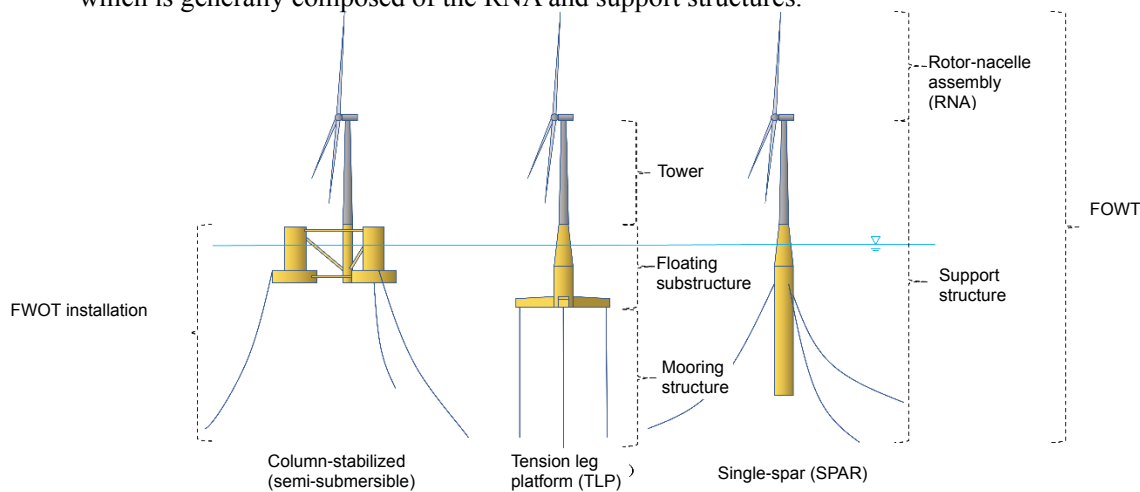


Figure 1.2.1.1 Schematic diagram of floating offshore wind turbines

Section 3 ACCEPTABLE STANDARDS

1.3.1 General requirements

1.3.1.1 The standards listed in this section are acceptable to CCS for providing services. All appropriate requirements in the acceptable standards shall be adopted unless special consents have been obtained.

1.3.1.2 The standards other than the acceptable standards listed in this section can also be adopted, provided that they have a safety level proven to be equivalent to or higher than the requirements of the Guidelines and have been agreed by CCS in advance. The relevant requirements, if any, of competent authorities shall prevail.

1.3.1.3 Any inconsistency with the design standards as well as any exemption and change of requirements in design standards shall be explicitly stated in design documents, and shall be agreed by the owner and CCS.

1.3.2 Acceptable standards

1.3.2.1 The main standards acceptable to the Guidelines are:

CCS Rules for Classification of Offshore Floating Installation (referred to as “*Rules for Offshore Floating Installations*”)

CCS Rules for Classification of Mobile Offshore Units (referred to as “*Rules for Mobile Offshore Units*”)

CCS Rules for Classification of Sea-going Steel Ships (referred to as “*Rules for Sea-going Steel Ships*”)

CCS Rules for Materials and Welding;

CCS Rules for Construction of Sea-Going Ships Engaged on Domestic Voyages;

CCS Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures;

CCS Guidelines for Buckling Strength Assessment of Offshore Engineering Structures;

CCS Guidelines for Survey of Corrosion Protection of Ship Structures

IMO International Convention on Load Lines, 1966 (referred to as “*Load Lines Convention*”);

IMO International Convention for the Safety of Life at Sea, 1974 and amendments thereto (referred to as “*Convention for the Safety of Life at Sea*”);

IMO International Convention on Tonnage Measurement of Ships, 1969 (referred to as “*Tonnage Measurement Convention*”);

IMO International Convention for the Prevention of Pollution from Ships, 1973, as modified

by the Protocol of 1978 relating thereto (referred to as “Convention on Pollution Prevention”);
 IMO International Convention on the Control of Harmful Ant-fouling Systems on Ships, 2001 (referred to as “Anti-fouling Convention”);
 IMO International Convention for the Control and Management of Ship’s Ballast Water and Sediments, 2004 (where applicable) (referred to as “Ballast Water Convention”);
 IMO International Regulations for Preventing Collisions at Sea, 1972 (referred to as “Regulations for Preventing Collisions”);
 China MSA Technical Regulations for Statutory Survey of Mobile Offshore Units;
 China MSA Technical Regulations for Statutory Survey of International Sea-going Ships;
 China MSA Technical Regulations for Statutory Survey of Domestic Sea-going Ships;
 China MSA Technical Regulations for Statutory Survey of Towage at Sea;
 China MSA Technical Regulations for Statutory Survey of Lifting Appliances;
 IEC 61400-1 Wind Energy Generation Systems – Part 1: Design Requirements;
 IEC 61400-3-1 Wind energy generation systems – Part 3-1: Design requirements for fixed offshore wind turbines;
 IEC 61400-3-2 Wind energy generation systems – Part 3-2: Design requirements for floating offshore wind turbines;

Section 4 CLASSIFICATION SERVICE

1.4.1 General requirements

1.4.1.1 The classification service refers to the service in which CCS determines, in accordance with its technical criteria, that the structural strength and integrity of the main body of the FOWT installation as well as the reliability and functions of the mooring system, dynamic cables and other facilities or auxiliary systems assembled on the installation can maintain the basic functions of the installation. In the service, different signs and notations are used for identification.

1.4.1.2 The classification process generally includes the approval of design plans, construction surveys, issuance of classification certificates and the signing or issuance of the classification certificates after operational surveys.

1.4.2 Character of classification

1.4.2.1 The character of classification is a statement of major features of the FOWT installation, and it is mandatory.

1.4.2.2 The main structure and machinery of a FOWT installation that meet CCS rules, guidelines or equivalent provisions will be assigned the appropriate characters of classification and class notations by CCS.

1.4.2.3 The main structure and machinery of a FOWT installation that are classed with CCS will be assigned one of the following characters of classification and class notations as appropriate in accordance with different conditions:

★ CSA Offshore Wind Turbine Installation (Floating)

or

★ CSA Offshore Wind Turbine Installation (Floating)

The meanings of the characters of classification are:

★ CSA —denotes that the product survey, plan approval, and survey during construction of the main structure and essential auxiliary equipment of the FOWT installation are conducted by CCS, and they meet CCS rules.

★ CSA —denotes that the product survey, plan approval, and survey during construction of the main structure and essential auxiliary equipment of the FOWT installation were NOT conducted by CCS, but later, their classification survey is conducted by CCS, which regards they meet CCS rules.

Section 5 SERVICE OF DOC

1.5.1 General requirements

1.5.1.1 CCS can provide part or all of the services, as listed in the Guidelines, of the documents of compliance (DOC) for FOWT installations based on the applications or contracts/agreements of the owner, the designer or the shipyard.

1.5.1.2 The DOC service provided as per the Guidelines should first be confirmed by CCS that the classification part has met the requirements of CCS classification specifications.

1.5.1.3 For those who are applying for both classification service and DOC service for their FOWT installations, CCS will combine the two services to provide.

1.5.1.4 For the turbines subjected to both classification and DOC services by CCS, where the invalidation of the classification certificate, if any, affects the conditions for issuance of relevant DOC, the latter will be invalidated simultaneously.

1.5.1.5 In addition to the provisions in this section, the format, issuance, valid period and other aspects of DOC shall meet the appropriate provisions in the *Technical Regulations for Statutory Survey of Mobile Offshore Units*.

1.5.2 Documents of compliance (DOC)

1.5.2.1 The CCS Surveyor will issue or sign on the appropriate DOC (if selected) after conducting compliance surveys for the FOWT installation and deeming it qualified:

- (1) DOC for safety (life-saving, signals and communications);
- (2) DOC for tonnage (if applicable);
- (3) DOC for load lines (if applicable);
- (4) DOC for oil pollution prevention (if applicable);
- (5) DOC for domestic sewage pollution prevention (if applicable);
- (6) DOC for air pollution prevention (if applicable);
- (7) DOC for garbage pollution prevention (if applicable);
- (8) DOC for anti-fouling system (if applicable);
- (9) Survey Book and Test Certificate of Lifting Devices (if applicable);

Section 6 SURVEY FOR CLASSIFICATION SERVICE

1.6.1 General requirements

1.6.1.1 In addition to the special provisions in this section, the classification survey of FOWT installations shall meet the applicable provisions in *CCS Rules for Offshore Floating Installations*.

1.6.1.2 The scope of the plans to be submitted for the classification surveys shall meet the applicable rules specified in 1.6.1.1, and shall be determined by considering the structural types and functions of the FOWT installation, including but not limited to:

- (1) Design conditions and loads
 - 1) Calculations about wind, waves, current, mooring and other environmental loads, including effects of icing (if applicable);
 - 2) Model test reports (if applicable);
 - 3) Calculations of the global performance (based on the related parameters, analysis methods and calculation data provided in Section 4, Chapter 2);
 - 4) Calculations of loads of wind turbines.
- (2) Overall arrangement and structure
 - 1) General arrangement;
 - 2) Technical specifications of the installation;
 - 3) Summary of distributions of fixed and variable weights;
 - 4) Basic structural plans: including the main transverse section, longitudinal section, decks and installations, inner bottom structure, superstructure and deckhouse;
 - 5) Booklets of structural joints;
 - 6) Plans of deck loads;
 - 7) Plans of watertight bulkheads;
 - 8) Lines plan and table of offsets (if applicable);
 - 9) Global strength calculations;
 - 10) Fatigue strength calculations;

- 11) Plans of foundations for the wind turbine tower and their support structures, including the strength and fatigue calculations;
- 12) The structure plans of important equipment foundations and the plans of their support structures, including strength calculations, such as cranes, suspending of mooring chain cables and suspending of submarine cables;
- 13) Structure plans for ice strengthening (if applicable);
- 14) Corrosion control, including coating and cathodic protection;
- 15) Construction specifications;
- 16) Instructions of construction procedures and principles, including welding details and specifications, non-destructive testing and tightness testing;
- 17) Table of welding specifications;
- 18) Installation procedures and drawing data as well as corresponding calculations of facilities, such as wharf loading, marine transportation and site installation;
- 19) Operation manual;

(3) Stability and subdivision

- 1) Intact stability calculations (including the transit, installation and in-position stability);
- 2) Damage stability calculations (including the transit, installation and in-position stability);
- 3) Freeboard calculations (if applicable);
- 4) Load line marks and scale;
- 5) Calculations and curves for permissible height of center of gravity;
- 6) Plans of integrity of watertight and weathertight doors, scuttles and other openings;
- 7) Plans and information to be submitted for information:
 - ① lines plan;
 - ② hydrostatic curves;
 - ③ cross curves of stability;
 - ④ capacity plan;
 - ⑤ plan of watertight boundaries of spaces.

(4) Position mooring systems

- 1) Position mooring arrangement showing mooring patterns, mooring fittings and equipment,
- 2) Details of mooring fittings and equipment, showing foundation and connections with FOWT,
- 3) Winch arrangement (if applicable);
- 4) Calculations of wind (support structure and blades of the wind turbine), current and wave forces on the FOWT installation;
- 5) Calculations for mooring analysis;
- 6) Calculations for the strength of fairleads, chain/wire stoppers and windlass support structures;
- 7) A copy of the following supporting drawings shall be submitted for reference (if applicable):
 - ① Test reports of environmental load models, including wind (support structure and blades of the wind turbine), current and wave forces;
 - ② Test reports of models showing wave-frequency and low-frequency motions of the FOWT installation.

(5) Installation system and equipment

- 1) Specification of machinery and electrical equipment/system;
- 2) Schematic diagrams and arrangement of ballasts;
- 3) Schematic diagrams and arrangement of ventilation;
- 4) Schematic diagrams and arrangement of draining;

(6) Electrical and communication systems;

- 1) Electrical load estimations of the main and emergency sources of electrical power;
- 2) Power system plan and arrangement of electrical equipment;
- 3) Schematic diagrams of main lighting and emergency lighting systems;
- 4) Schematic diagrams of internal and external communication systems (if any);
- 5) Arrangements of signaling lights and obstruction lights.

(7) Life-saving appliances and safety systems

- 1) Diagrams of escape routes for personnel;
- 2) Schematic diagrams and arrangement of fire protection systems and equipment (if any);

- 3) Configuration and arrangement of life-saving appliances;
- 4) Arrangements of fire detection and alarm systems.

1.6.1.3 The production survey is a part of the facility classification survey and the surveys for DOC. Its scope shall be determined based on the applicable rules specified in 1.6.1.1, in combination with the structural types and functions of the installation.

1.6.2 Surveys during construction

1.6.2.1 The requirements of the builder assessment for construction surveys, pre-commencement surveys and verification of test and survey documents, the items and requirements of test for surveys, the requirements of non-destructive testing, documents and data and other aspects shall be determined based on the applicable rules specified in 1.6.1.1 and in combination with the structural types and functions of installations.

1.6.2.2 The FOWT installations of the same series built by the same shipyard can be exempted from partial test items specified in the application rules as sister ships.

1.6.3 Surveys after construction

1.6.3.1 The re-classification, damage or modification surveys in the surveys after construction, the preparation before surveys, survey plans, welding and materials, survey types, survey items and requirements, thickness measurement and the requirements of other aspects shall be generally determined by the applicable rules specified in 1.6.1.1, combined with the structural type and functions of the installation.

Section 7 SURVEYS FOR SERVICE OF DOC

1.7.1 General requirements

1.7.1.1 The surveys for DOC shall generally meet the applicable requirements in *Technical Regulations for Statutory Survey of Mobile Offshore Units* and *Technical Regulations for Statutory Survey of Domestic Mobile Units* as well as relevant requirements of competent authorities of the operation ocean area.

Section 8 OPERATION MANUAL

1.8.1 General requirements

1.8.1.1 The operation manual approved by CCS shall be provided on FOWT installations for all personnel. This manual can be used as the guidelines for safe operation of installations under normal conditions and in anticipated emergencies. In addition to the introduction of the necessary overall condition of the installation, its contents shall also include the guidelines and procedures of important operation of personnel and installations. The manual shall be simple, concise and pellucid. It shall be provided with a table of contents and an index, and shall enable the cross-reference retrieval of the detailed data that are accessible for the installation.

1.8.1.2 For the conditions of normal operation and emergency operation, the content that shall be included in the operation manual shall be determined by referring to the applicable specifications in 18.1 of *Technical Regulations for Statutory Survey of Mobile Offshore Units*.

1.8.1.3 If necessary, the data provided in the operation manual shall be supported by the corresponding data, which can be in the forms of plans, the product manuals of manufacturers and other data that are necessary for the operation and maintenance of the installation. It is not necessary to include the detailed data provided in the product manual of the manufacturer again in the operation manual. These data can be listed as reference items. The operation manual shall be kept at an easily accessible place on the installation for reference at any time.

Chapter 2 DESIGN LOADS AND CONDITIONS

Section 1 GENERAL PROVISIONS

2.1.1 General requirements

2.1.1.1 This chapter provides guidance for the design loads of FOWT installations.

2.1.1.1 In addition to the methods provided by this chapter, design loads can also be calculated by adopting other accepted methods. Calibration can be conducted based on model tests if necessary, and the reports of model tests shall be submitted to CCS for review and approval.

2.1.1.3 The owner or operator is responsible for providing the marine environmental conditions used for design and analysis of FOWT installations. For the methods and process of obtaining marine environment conditions, CCS's *Guidelines for Application of Environmental Conditions for Design and Assessment of Offshore Engineering Structures* can be referred to.

Section 2 DESIGN LOADS

2.2.1 General requirements

2.2.1.1 For design loads, the actual load conditions that are possibly encountered in the stages of transportation, installation, operation and maintenance of FOWT installations shall be considered. The design loads of the FOWT installations generally include fixed loads, variable load, environmental loads, accident loads and other loads.

2.2.2 Fixed loads

2.2.2.1 Fixed loads refer to the loads that do not change during the service life of structures.

2.2.2.2 The fixed loads of the FOWT installation include but are not limited to:

- (1) The weight of the RNA;
- (2) The weight of the tower;
- (3) The weight of the buoyant structure;
- (4) The weight of the mooring system and the pretension of mooring lines;
- (5) The weight of mechanical equipment;
- (6) The weight of the permanent ballast (if applicable);
- (7) The loads of permanent deformation and the loads generated during manufacturing, etc.

2.2.3 Variable loads

2.2.3.1 Variable loads refer to the loads that are variable during the service life of structures. Variable loads can be changed, moved or removed. Therefore, the maximum and minimum effective loads of variable loads shall be considered.

2.2.3.2 The variable loads of the FOWT installation include but are not limited to:

- (1) Driving loads generated by the operation and control of the wind turbine generator system (WTGS), including the generator torque, control loads for yaws and pitches and mechanical brake loads;
- (2) Loads applied by lifting appliances during maintenance and repair;
- (3) Impact loads generated during normal operation of service ships;
- (4) Loads generated for ballast adjustment (if applicable), etc.

2.2.4 Environmental loads

2.2.4.1 Environmental loads are those which are directly or indirectly generated by environmental actions, including all external forces due to environmental loads, for example, mooring forces, inertia forces and sloshing forces (if any).

Environmental loads are generally composed of the following loads:

- (1) Wind loads;
- (2) Wave loads;
- (3) Current loads;

The impact of earthquake, seabed bearing capacity, temperature, marine growth, ice/snow and other parameters on loads shall also be taken into account, if the owner/designer considers it as required and necessary.

2.2.4.2 Wind loads

(1) The wind loads acted on the nacelle, tower and floating structures can be calculated by adopting the formula for wind pressure, for which the related requirements of Section 2, Chapter 2 of PART TWO in *CCS Rules for Mobile Offshore Units* can be referred to;

(2) The aerodynamic loads of the rotor shall be calculated by adopting accepted methods, e.g. the blade element momentum theory (BEM).

2.2.4.3 Wave loads

(1) The parameters of design waves that are specified by the owner/designer can be described using the design wave energy spectrum or deterministic design waves with appropriate shapes, scales and periods;

(2) For the selection of the design wave height, wave period and wave theory, the related requirements of Section 3, Chapter 2, PART TWO of *CCS Rules for Mobile Offshore Units* can be referred to;

(3) The wave loads of slender members ($D/L \leq 0.2$, in which D refers to the feature size of the structure section while L to the characteristic wavelength) are generally calculated by using the Morison equation. The wave loads on large-scale floating installations are generally calculated by using the theory of three-dimensional radiation and diffraction to integrate the hydrodynamic pressure imposed on buoyant structure wet surfaces. The related requirements of Section 3, Chapter 2, PART TWO of *CCS Rules for Mobile Offshore Units* can be referred to.

2.2.4.4 For calculation of current loads, the related requirements of Section 4, Chapter 2, PART TWO of *CCS Rules for Mobile Offshore Units* can be referred to.

2.2.5 Accident loads

2.2.5.1 Accident loads are generally generated by abnormal operation or technical failure, including but not limited to:

(1) Accidental flooding in compartments;

(2) Failure in mooring systems;

(3) Collision with installation ships, maintenance ships, adjacent wind power facilities or other objects;

(4) The equipment that may fall onto the ship hull or deck during transportation and operation;

(5) Fires, explosion, etc.

Section 3 DESIGN CONDITIONS

2.3.1 General requirements

2.3.1.1 Design conditions refer to the typical conditions selected for installation design, covering the conditions at all stages including the transportation, installation, operation and maintenance of FOWT installations.

2.3.1.2 The design conditions of the FOWT installation are the combined conditions between design conditions and environmental conditions, which at least shall include typical conditions such as operating conditions and survival conditions. If necessary, special consideration shall be given to accident conditions, such as allision.

2.3.1.3 The design conditions of the FOWT installation that are listed in the Guidelines (Table 2.3.1) shall be formulated by referring to the specifications and technical standards accepted by the industry, which cover IEC 61400-1, IEC 61400-3-1, IEC 61400-3-2, etc. Any difference between the adopted condition and the requirements of the Guidelines shall be specified in the design documents and accepted by CCS.

2.3.2 Design conditions

2.3.2.1 Design conditions refer to the design status of FOWT installations. At least the following design conditions shall be considered:

(1) Normal design conditions refer to the conditions under which FOWT installations are in

intact status and normal operation, and allowable small faults that possibly and frequently occur during life cycles can be considered;

(2) Abnormal design conditions refer to the design conditions in which the severe failure caused by FOWT in abnormal status leads to the startup of protection systems. Abnormal status includes:

① The abnormal status of the structure, including structural damage, flooding, damage of the mooring system, fires or explosion;

② Abnormal status of non-structures, e.g. off-grid, the internal or external failure of the power system, control system failure or protection system failure.

2.3.3 Environmental conditions

2.3.3.1 General requirements

(1) Environmental conditions include wind condition, sea state, water levels and other external conditions;

(2) The parameter combination of the wind condition, sea state and water level that are selected for design conditions shall cover the combinations that lead to the worst conditions;

(3) The sea state conditions used for calculation of environmental loads shall include but not be limited to the monotone extremum of the return period, conditional extremum and directional extremum in environmental parameters as well as the distribution of joint probability. The recommended calculation methods in *CCS Guidelines for Application of Environmental Conditions for Design and Assessment of Offshore Engineering Structures* can be referred to.

(4) In the design of the FOWT installation, the correlations of wind conditions and sea state shall be considered. When there is a lack of data about the long-term distribution of joint probabilities of wind conditions and sea state, it shall be assumed that the 10 min extreme mean wind speed with a 50-year return period occurs in the 3 h extreme sea state with a 50-year return period. Such assumption shall also be applicable for the combination between the 10 min extreme mean wind speed with a one-year return period and the 3 h extreme sea state with a one-year return period;

(5) The position mooring system of the FOWT installation shall be designed in accordance with the wind, wave and current combinations of the extreme loads caused by the design environment. In actual design, it shall be obtained generally through the approximate value of the combination of multiple design criteria.

For example, for the design environment with the return period of N years, the following three design criteria shall be considered generally:

① For the waves with the return period of N years, the corresponding wind and currents shall be added;

② For the wind with the return period of N years, the corresponding waves and currents shall be added;

③ For the currents with the return period of N years, the corresponding waves and wind shall be added;

2.3.3.2 Wind conditions mainly include normal wind conditions and extreme wind conditions:

(1) Normal wind conditions refer to the wind conditions that occur frequently during the normal operation of offshore wind turbines;

(2) Extreme wind conditions refer to the wind conditions such as extreme wind shear and the extreme wind speed peak generated by the rapid changes of storms, wind speed and wind directions. The 10 min mean extreme wind speed at the hub height with a one-year or 50-year return period is generally taken.

2.3.3.3 Sea states includes the normal sea state, severe sea state and extreme sea state. For each sea state, the combinations of the significant wave height, peak spectral period, wave direction, wind speed and current speed shall be considered.

(1) For the normal sea state, the combination of normal wind speed, normal wave height and normal current speed shall be considered;

(2) For the severe sea state, the combinations of the normal wind speed, the extreme sea state conditions allowing normal power generation and normal current speed shall be considered. If the extreme sea state conditions allowing normal power generation cannot be determined, it shall be replaced by the 3-h extreme wave height with a 50-year return period;

(3) For extreme sea state, the combination of the 10-min mean extreme wind speed at the hub height with a 50-year return period, the 3-h extreme wave height with a 50-year return period and the extreme current speed with a 50-year return period shall be considered, or the combination of the 10-min mean extreme wind speed at the hub height with a one-year return period, 3-h extreme wave height for one-year return period and the extreme current speed with a one-year return period shall be considered.

2.3.3.4 Water level conditions mainly include the normal water level range and extreme water level range:

(1) The normal water level range is generally used for the fatigue load conditions and extreme load conditions. For extreme load conditions, the severe sea state and the extreme sea state with a one-year return period shall be considered. In the conditions in the lack of the long-term probability distribution data of water levels in specific sites, the scope of the water levels between the highest astronomical tide and the lowest astronomical tide can be considered;

(2) The extreme water level range is generally used for extreme load conditions, for which the combination with the extreme sea state with a 50-year return period shall be considered. In the conditions in the lack of the long-term probability distribution data of water levels in specific sites, at least the high water level with a 50-year return period of the appropriate combination between the highest astronomical tide and the positive storm tide, the low water level with a 50-year return period of the lowest astronomical tide and the negative storm tide as well as the water level of the highest breaking wave shall be considered (if applicable).

Design load conditions Table 2.3.1

Condition of wind turbine	DLC	Wind condition	Waves	Direction of wind and wave	Current	Water level	Other description	Type of analysis	Load factor
1) Normal power generation	1.1	NTM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Co-directional, uni-directional	NCM	MSL	Used for extrapolating the extreme loads of the RNA	U	N (1.25)
	1.2	NTM $v_{in} < v_{hub} < v_{out}$	NSS Joint probability distribution of H_s, T_p, v_{hub}	Different directions, multiple directions	Non-current	NWLR or \geq MSL	—	F	*
	1.3	ETM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	—	U	N
	1.4	ECD $v_{hub} = v_r, v_r \pm 2$	NSS $H_s = E[H_s v_{hub}]$	Different directions, variable wind directions	NCM	MSL	—	U	N
	1.5	EWS $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	—	U	N
	1.6	NTM $v_{in} < v_{hub} < v_{out}$	SSS $H_s = H_{s,SSS}$	Different directions, multiple directions	NCM	NWLR	No safety control and protection systems in maximum sea state are set.	U	N
	1.7	NTM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Different directions, multiple directions	NCM	MSL	An instantaneous condition in which the integrated status transfers to the status with one mooring line broken	U	A
	1.8	NTM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Different directions, multiple directions	NCM	MSL	The condition in which the new balance is fulfilled after one mooring line is broken	U	A
	1.9	NTM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Different directions, multiple directions	NCM	MSL	Condition with compartments damaged and flooded	U	A
2) Normal power generation with failure	2.1	NTM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	Normal control system failure, disconnection of electrical network, or the failure of primary-layer control functions	U	N
	2.2	NTM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	Abnormal control system failure, or the failure of second-layer protection functions	U	A
	2.3 ⁽¹⁾	EOG $v_{hub} = v_r, v_r \pm 2, v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	Including the external or internal electrical system failure in the disconnection of electrical network	U	A

	2.3 ⁽²⁾	NTM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	External or internal electrical fault including loss of electrical network	U	N
	2.4	NTM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	Non-current	NWLR or \geq MSL	Failures in the control system, electrical system or loss of electrical network	F	*
	2.5	NWP $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	Low-voltage ride through (LVRT)	U	N
	2.6	NTM $v_{in} < v_{hub} < v_{out}$	SSS $H_s = H_{s,SSS}$	Different directions, multiple directions	NCM	NWLR	Fault of sea state limit protection system	U	A
3) Startup	3.1	NWP $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	Non-current	NWLR or \geq MSL	Fatigue conditions caused by startup of the wind turbine	F	*
	3.2 ⁽¹⁾	EOG $v_{hub} = v_{in}, v_r, v_r \pm 2, v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	—	U	N
	3.2 ⁽²⁾	ETM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	—	U	N
	3.3	EDC $v_{hub} = v_{in}, v_r \pm 2, v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Different directions, variable wind directions	NCM	MSL	—	U	N
4) Normal shutdown	4.1	NWP $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	Non-current	NWLR or \geq MSL	Fatigue conditions caused by shutdown of the wind turbine	F	*
	4.2 ⁽¹⁾	EOG $v_{hub} = v_r \pm 2, v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	—	U	N
	4.2 ⁽²⁾	ETM $v_{in} < v_{hub} < v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	—	U	N
	4.3	NTM $v_{in} < v_{hub} < v_{out}$	SSS, or sea state in which safety control and protection systems are activated	Different directions, multiple directions	NCM	NWLR	If any safety control and protection system in sea state is set.	U	N
5) Emergency shutdown	5.1	NTM $v_{hub} = v_r \pm 2, v_{out}$	NSS $H_s = E[H_s v_{hub}]$	Same direction, single direction	NCM	MSL	—	U	N
	5.2	NTM $v_{in} < v_{hub} < v_{out}$	SSS, or state specified in the operation manual, or motion response limits	Different directions, multiple directions	NCM	NWLR	If sea state or motion responses reach the limits, manual remote shutdown shall be conducted.	U	N

6) Shutdown (motionless or idle)	6.1	EWM (turbulent flow) $v_{hub} = v_{50}$	ESS $H_s = H_{s,50}$	Different directions, multiple directions	ECM (50-year return period)	EWLR (50-year return period)	Considering the mean yaw error of $\pm 8^\circ$	U	N
	6.2	EWM (turbulent flow) $v_{hub} = v_{50}$	ESS $H_s = H_{s,50}$	Different directions, multiple directions	ECM (50-year return period)	EWLR (50-year return period)	Loss of electrical network	U	A
	6.3	EWM (turbulent flow) $v_{hub} = v_1$	ESS $H_s = H_{s,1}$	Different directions, multiple directions	ECM (1-year return period)	NWLR	Considering the extreme yaw error of $\pm 20^\circ$	U	N
	6.4	NTM $v_{hub} < v_{in}$ and $v_{out} < v_{hub} < 0.7v_{ref}$	NSS Joint probability distribution of H_s, T_p, v_{hub}	Same direction, multiple directions	Non-current	NWLR or \geq MSL	—	F	*
	6.5	EWM (turbulent flow) $v_{hub} = v_{50}$	ESS $H_s = H_{s,50}$	Different directions, multiple directions	ECM (50-year return period)	EWLR (50-year return period)	An instantaneous condition in which the integrated status transfers to the status with one mooring cable is broken	U	A
	6.6	EWM (turbulent flow) $v_{hub} = v_{50}$	ESS $H_s = H_{s,50}$	Different directions, multiple directions	ECM (50-year return period)	EWLR (50-year return period)	The condition in which the new balance is fulfilled after one mooring cable is broken.	U	A
	6.7	EWM (turbulent flow) $v_{hub} = v_1$	ESS $H_s = H_{s,1}$	Different directions, multiple directions	ECM (1-year return period)	NWLR	Condition with compartments damaged and flooded	U	A
7) Shutdown with failure	7.1	EWM $v_{hub} = v_1$	ESS $H_s = H_{s,1}$	Different directions, multiple directions	ECM (1-year return period)	NWLR	At least considering the failures of the braking, pitch and yaw systems	U	A
	7.2	NTM $v_{hub} < v_{out}$	NSS Joint probability distribution of H_s, T_p, v_{hub}	Same direction, multiple directions	Non-current	NWLR or \geq MSL	—	F	*
8) Transportation, installation, maintenance and repair	8.1	Conditions defined by the constructor or the owner						U	N
	8.2	EWM $v_{hub} = v_1$	ESS $H_s = H_{s,1}$	Same direction, single direction	ECM (1-year return period)	NWLR	—	U	A
	8.3	NTM $v_{hub} < 0.7v_{ref}$	NSS Joint probability distribution of H_s, T_p, v_{hub}	Same direction, multiple directions	Non-current	NWLR or \geq MSL	No grids during installation.	F	*
	8.4	Conditions defined by the constructor or the owner						F	*

Remarks:

NTM: normal turbulence model

ETM: extreme turbulence model

N: normal

A: abnormal

ECD: extreme coherent gust with direction change

EWS: extreme wind shear

EOG: extreme operating gust

NWP: normal wind profile model

EDC: extreme wind direction change

EWM: extreme wind speed model

NSS: normal sea state

SSS: severe sea state

ESS: extreme sea state

NCM: normal current speed model

ECM: extreme current speed model

MSL: mean sea level

NWLR: normal water level range

EWLR: extreme water level range

U: ultimate strength verification

F: fatigue strength verification

v_{ref} : reference wind speed, referring to the 10 min mean wind speed at the hub height with a 50-year return period

v_1 : the 10 min mean wind speed at the hub height with a one-year return period

v_{50} : the 10 min mean wind speed at the hub height with a 50-year return period

v_{hub} : the 10 min mean wind speed at the hub height

v_{in} : cut-in wind speed

v_{out} : cut-out wind speed

v_r : rated wind speed

H_s : characteristic wave height

$H_{s,SSS}$: characteristic wave height under severe sea state

$H_{s,1}$: characteristic wave height with a one-year return period

$H_{s,50}$: characteristic wave height with a 50-year return period

$E[H_s|v_{hub}]$: condition expectation of characteristic wave height under the wind speed of v_{hub}

T_p : peak spectral period

2.3.4 Design load condition

2.3.4.1 General requirements

(1) The table of design load conditions, i.e. Table 2.3.1, classifies based on the condition of the WTGS, covering the normal power generation condition, normal power generation condition with failure, startup condition, normal shutdown condition, emergency shutdown condition, shutdown (motionless or idle) condition, shutdown condition with failure as well as the conditions of transportation, installation, maintenance and repair;

(2) The table of design load conditions, i.e. Table 2.3.1, applies to the verification of the ultimate strength and fatigue strength of the FOWT installation. The verification of ultimate strength consists of two conditions, i.e. normal and abnormal conditions, and the corresponding partial load factors can be in accordance with the related requirements in Table 3.2.5.2, Chapter 3, of the Guidelines;

(3) The normal power generation condition, DLC1.7–1.9, normal power generation condition with failure, DLC2.6, shutdown (standing still or idling) condition, DLC6.5–6.7, and normal shutdown condition, DLC4.3, are the design load conditions proposed by IEC 61400-3-2 (2019) for FOWT;

(4) If the design of the mooring system of the FOWT installation is non-redundant, the conditions of DLC1.7, DLC1.8, DLC6.5 and DLC6.6 can be ignored. However, other safety factors shall be taken, and the relevant requirements in 5.4.3.2, Chapter 5, of the Guidelines can be referred to;

(5) The selection interval of wind speed in the table of design load conditions, i.e. Table 2.3.1, is generally not larger than 2 m/s. If the rated wind speed is within the calculated range of the wind speed, the rated wind speed can be considered as a calculated wind speed;

(6) For the conditions in which wind and waves are in different directions in the table of design load conditions, i.e. Table 2.3.1, the angles between wind and waves in the worst condition shall be considered, and the angle range of $\pm 30^\circ$ shall be considered;

(7) For the FOWT provided with safety control and protection systems for sea state, if the system mentioned above functions under severe sea state (or the sea state activating the system), i.e. the turbine is shut down, the calculation shall be conducted based on the normal shutdown condition, DLC4.3; if shutdown controlled manually and remotely is required when the sea state or the motion response limit indicated on the operation manual is reached, the calculation shall be conducted based on the emergency shutdown condition, DLC5.2, and the condition is considered normal; if there is any failure in the above system, i.e. the system still operates in severe sea state, the calculation shall be conducted based on the normal power generation state with failure, DLC2.6, and the condition is considered abnormal. For the FOWT that is not provided with this system, the calculation shall be conducted based on the normal power generation condition, DLC1.6, and the condition is considered normal;

(8) For the load conditions formed by combining the deterministic wind fields and random sea state, e.g. DLC1.4, DLC1.5, DLC2.3⁽¹⁾, DLC3.2⁽¹⁾, DLC3.3⁽¹⁾ and DLC4.2⁽¹⁾ that are listed in Table 2.3.1, the characteristic loads of the WTGS shall be the instantaneous value calculated in the worst condition; for the load conditions formed by combining turbulent wind fields and random sea state, the characteristic load of the WTGS shall be the mean value of load effects under the worst condition; for the DLC2.1, DLC2.2 and DLC5.1 in Table 2.3.1, the characteristic load of the WTGS shall be the mean value of the 1/2 maximum load effect.

2.3.4.2 Definition of design load conditions

(1) Normal power generation conditions (DLC1.1–1.9) refer to the power generation conditions of normal operation of the WTGS and the normal connection of electrical network. In these conditions, except DLC1.4, the 10 min mean wind speed v_{hub} at the hub height is within the ranges of cut-in wind speed v_{in} and cut-out wind speed v_{out} .

① DLC1.1 refers to the load used for extrapolating the extreme loads of the RNA, and at least the blade root in-plane and out of plane moment and blade tip deflection shall be exported. The combination of the normal turbulent model (NTM), normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction.

② DLC1.2 refers to the fatigue condition of the WTGS during normal power generation. If the normal turbulent model (NTM) and normal sea state (NSS) are adopted, the joint probability distribution of the characteristic wave height, peak spectral period and 10 min mean wind speed at

the hub height shall be considered, and it shall be considered that wind and waves propagate in different, multiple directions. If the normal water level range (NWLRL) or the value larger than the mean sea level (MSL) is taken, the effect of the current speed needs no consideration.

③ DLC1.3 refers to the combined condition of the extreme turbulent model (ETM) and normal sea state (NSS). At the same time, the normal current speed model (NCM) and mean sea level (MSL) as well as the same, uni-direction propagation of wind and waves shall be considered. If the ultimate bending moment limit of the blade root in DLC1.3 does not exceed the bending moment limit of the blade root in DLC1.1, the factor c in the turbulent strength in DLC1.3 shall be increased, until the obtained bending moment limit of the blade root exceeds the bending moment limit of the blade root in DLC1.1. The value of the factor c shall be taken in accordance with the relevant requirements of 6.3.3.4 in IEC 61400-1 (2019);

④ DLC1.4 refers to the instantaneous condition of the extreme coherent gust with direction change (ECD). The 10 min mean wind speed v_{hub} at the hub height shall be v_{r-2} , v_r and v_{r+2} (m/s). The combination of the normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be taken. It shall be considered that wind and waves are in different directions and have the directions varying with wind directions. The wind profile is related to the height and time. The angle change of wind directions is related with v_{hub} , and specific equations shall be in accordance with the relevant requirements of 6.3.3.6 in IEC 61400-1 (2019);

⑤ DLC1.5 refers to the instantaneous condition under extreme wind shear (EWS), including the instantaneous vertical wind shear and horizontal wind shear; for the calculation equation of the parameters of the wind field, refer to the relevant requirements of 6.3.3.7 in IEC 61400-1 (2019). The combination of the normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction.

⑥ DLC1.6 refers to the condition requiring verification when no safety control and protection systems in maximum sea state are set. The combination of the normal turbulent model (NTM), severe sea state (SSS), normal current speed model (NCM) and normal water level range (NWLRL) shall be considered, and it shall be considered that wind and waves propagate in different, multiple directions. The description of severe sea state (SSS) is detailed in 2.3.3.3 of this section;

⑦ DLC1.7 refers to the instantaneous condition in which the status of an integrated mooring system transfers to the status with one broken mooring line. Such condition can be ignored if the mooring system is non-redundant. The combination of the normal turbulent model (NTM), normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in different, multiple directions;

⑧ DLC1.8 refers to the condition in which the new balance is fulfilled after one mooring line is broken. Such condition can be ignored for non-redundant mooring systems. The wind field model, wind speed, sea state, current speed, water level, wind-wave direction and other aspects are consistent with DLC1.7;

⑨ DLC1.9 refers to the condition in which the compartment of the buoyant structure is damaged and flooded. The wind field model, wind speed, sea state, current speed, water level, wind-wave direction and other aspects are consistent with DLC1.7.

(2) The normal power generation with failure (DLC2.1–2.6) refers to the transient event activated by the failures or the disconnection of electrical network when the WTGS is generating power. The 10 min mean wind speed v_{hub} at the hub height is within the ranges of the cut-in wind speed v_{in} and cut-out wind speed v_{out} ;

① DLC2.1 refers to the normal control system failure, loss of electrical network, or the failure of primary layer control functions. The combination of the normal turbulent model (NTM), normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction;

② DLC2.2 refers to the abnormal control system failure, or the failure of second-layer protection functions. The wind field model, wind speed, sea state, current speed, water level, wind-wave direction and other aspects are consistent with DLC2.1;

③ DLC2.3⁽¹⁾ refers to the external or internal electrical system failure in loss of electrical network. The combination of the extreme operating gust (EOG), normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered. It shall be considered

that wind and waves propagate in the same, single direction, and the combination shall be considered as the normal condition. DLC2.3⁽²⁾ is the alternative calculation condition of DLC2.3⁽¹⁾. The normal turbulent model (NTM) shall be considered, and the condition shall be considered normal;

④ DLC2.4 refers to the fatigue condition caused by the control system failure, electrical system failure or loss of electrical network, etc. The combination of the normal turbulent model (NTM), normal sea state (NSS), normal water level range (NWL) or the condition with the level higher than the mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction;

⑤ DLC2.5 refers to the low-voltage ride through (LVRT) condition. The combination of the normal wind profile model (NWP), normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction. For the normal wind profile model (NWP), the relevant requirements of 6.3.2.2 in IEC 61400-1 (2019) can be referred to;

⑥ DLC2.6 refers to the condition of the failure in the safety control and protection systems in maximum sea state. The combination of the normal turbulent model (NTM), severe sea state (SSS), normal current speed model (NCM) and normal water level range (NWL) shall be considered, and it shall be considered that wind and waves propagate in different, multiple directions.

(3) The startup conditions (DLC3.1–3.3) refer to the transient events of the transfer of the WTGS from the shutdown idle or standing still status to power generation status;

① DLC3.1 refers to the fatigue condition caused by startup. If there is no relevant history data of startup, the annual number of startups mentioned in 7.4.4 of IEC 61400-1 (2019) can be referred to, i.e. 1,000 start-up procedures under the cut-in wind speed v_{in} , 50 start-up procedures under the rated wind speed v_r , and 50 start-up procedures under the maximum start-up wind speed. The maximum startup wind speed is generally provided by the wind turbine manufacturer. If there is no relevant parameter, the cut-out wind speed v_{out} is used as a substitute for the maximum startup wind speed. The combination of the normal wind profile model (NWP), normal sea state (NSS), normal water level range (NWL) or the condition with the level higher than the mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction. However, no consideration of the effect of current speed is necessary;

② DLC3.2⁽¹⁾ refers to the condition combining the startup and extreme operating gust (EOG). At least four different timing events between the EOG and the startup event shall be considered for each wind speed. The first timing shall be chosen so that the beginning of the EOG occurs when the power production reaches 50 % of maximum power. The last timing shall be chosen so that the beginning of the EOG occurs when the power production reaches 95 % of maximum power. At least two additional timings shall be chosen, evenly distributed within the interval from 50 % to 95 % of maximum power. The extreme operating gust (EOG) can also be replaced by the extreme turbulent model (ETM), i.e. DLC3.2⁽²⁾. However, the simulation of at least 12 random wind fields is required for each 10 min mean wind speed v_{hub} at hub height, and the mean value of response extreme value is the nominal response extreme value. The combination of the normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction;

③ DLC3.3 refers to the condition combining the startup and extreme wind direction change (EDC). Before the wind direction changes, it shall be assumed that wind and waves are in the same direction, and the combination of the normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered.

(4) The normal shutdown conditions (DLC4.1–4.3) refer to the instantaneous condition of the transfer of the WTGS from the power generation status to shutdown idling or standstill status, and the frequency of these conditions is generally related to the control system.

① DLC4.1 refers to the fatigue condition caused by normal shutdown. If there is no relevant history data of shutdown, the annual frequency of shutdown mentioned in 7.4.5 of IEC 61400-1 (2019) can be referred to, i.e. 1,000 shut-down procedures under the cut-in wind speed v_{in} , 50 shut-down procedures under the rated wind speed v_r , and 50 shut-down procedures under the

cut-out wind speed v_{out} . The combination of the normal wind profile model (NWP), normal sea state (NSS), normal water level range (NWLRL) or the condition with the level higher than the mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction. However, no consideration of the effect of current speed is necessary;

② DLC4.2⁽¹⁾ refers to the condition combining the normal shutdown and extreme operating gust (EOG). In accordance with 7.4.5 in IEC 61400-1 (2019), at least 6 occasions of the occurrence of the extreme operating gust shall be considered, i.e. 10 s before the beginning of shutdown and the occasions when the generating capacity reaches 50% of the initial generating capacity. Four occasions shall be selected evenly based on the percentages of the initial generating capacity between these two occasions, and at least 4 evenly-distributed azimuth angles of the rotor shall be considered for different occasions. The extreme operating gust (EOG) can also be substituted with the extreme turbulent model (ETM), i.e. DLC4.2⁽²⁾. However, the simulation of at least 12 random wind fields is required for each 10 min mean wind speed v_{hub} at hub height, and the mean value of extreme response is the nominal extreme response. The combination of the normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered, and it shall be considered that wind and waves propagate in the same, single direction;

③ DLC4.3 refers to the normal shutdown condition with severe sea state (SSS) or the sea state activating the safety control and protection systems. The consideration of such condition is not required if no safety control and protection system is arranged. The combination of the normal turbulent model (NTM), normal current speed model (NCM) and normal water level range (NWLRL) shall be considered, and it shall be considered that wind and waves propagate in different, multiple directions.

(5) Emergency shutdown conditions (DLC5.1–5.2) refer to the instantaneous condition when the WTGS in normal power generation status is suddenly shut down.

① DLC5.1 refers to the instantaneous condition when the WTGS in normal power generation status is suddenly shut down. The loads caused by the emergency shutdown shall be considered. The normal turbulent model (NTM) shall be considered, and v_{r-2} , v_r , v_{r+2} and v_{out} (m/s) shall be taken for the 10 min mean wind speed v_{hub} at the hub height. The combination of the normal sea state (NSS), normal current speed model (NCM) and mean sea level (MSL) shall be considered. It shall be considered that wind and waves propagate in the same, single direction.

② DLC5.2 refers to the condition in which emergency shutdown is controlled manually and remotely. That is, when the sea state or the motion response limit indicated in the operation manual is reached, manual remote control is required for shutdown. The combination of the normal turbulent model (NTM), severe sea state (SSS) or the sea state specified in the operation manual or the sea state when the motion response limit is reached, the normal current speed model (NCM) and normal water level range (NWLRL) shall be considered. It shall be considered that wind and waves propagate in different, multiple directions.

(6) The parked (standstill or idling) conditions (DLC6.1–6.7) refer to the conditions in which the WTGS is in the parked standstill or idling status. Except DLC6.4, which is the fatigue analysis condition, all conditions are ultimate strength analysis conditions.

① For DLC6.1, the extreme wind speed model (EWM) and extreme sea state conditions (ESS) with a 50-year return period under the parked (standstill or idling) status shall be considered. The turbulent model of the wind field shall be considered, and the wind speed v_{50} with a 50-year return period shall be taken as the 10 min mean wind speed v_{hub} at the hub height. The combination of the characteristic wave height $H_{s,50}$ with a 50-year return period, extreme current speed with a 50-year return period and the extreme water level range (EWLR) with a 50-year return period shall be considered. It shall be considered that wind and waves propagate in different, multiple directions. Under the turbulent wind field model, the mean yaw error of $\pm 8^\circ$ shall be considered;

② DLC6.2 refers to the condition of loss of electrical networks at the early stage of storm. The wind field model, wind speed, sea state, current speed, water level, wind-wave direction and other aspects are consistent with DLC6.1. However, such condition is abnormal. Unless power back-up is provided for the control and yaw system with a capacity for yaw alignment for a period of at least 6 hours, the effects of $\pm 180^\circ$ wind direction change ranges shall be considered;

③ For DLC6.3, the combination of the extreme wind speed model (EWM) and extreme sea state (ESS) with a one-year return period under the parked (standstill or idling) condition shall be considered, and the extreme yaw misalignment of $\pm 20^\circ$ shall be considered. The turbulent model of the wind field shall be considered, and the wind speed v_1 with a one-year return period shall be taken as the 10 min mean wind speed v_{hub} at the hub height. The characteristic wave height $H_{s,1}$ with a one-year return period, extreme current speed with a one-year return period and the normal water level range (NWLR) shall be considered. It shall be considered that wind and waves propagate in different, multiple directions;

④ DLC6.4 refers to the fatigue condition caused by parked (standstill or idling) conditions. When the normal turbulent model (NTM) and normal sea state (NSS) models are adopted, the 10 min mean wind speed at the hub height includes two ranges, i.e. the wind speed lower than the cut-in wind speed v_{in} and the range between the cut-out wind speed v_{out} and 0.7 times of the reference wind speed v_{ref} . The joint probability distribution of the characteristic wave height, peak spectral period and the 10 min mean wind speed at the hub height shall be considered. The normal water level range (NWLR) or the level higher than the mean seal level (MSL) shall be taken, and it shall be considered that wind and waves propagate in the same, multiple directions. No consideration of the effects of current speed is necessary;

⑤ DLC6.5 refers to the transient condition in which the status of an integrated mooring system transfers to the status with one broken mooring line. Such condition can be ignored if the mooring system is non-redundant. The wind field model, wind speed, sea state, current speed, water level, wind-wave directions and other aspects are consistent with DLC6.1;

⑥ DLC6.6 refers to the condition in which the new balance is fulfilled after one mooring line is broken. Such condition can be ignored for non-redundant mooring systems. The wind field model, wind speed, sea state, current speed, water level, wind-wave direction and other aspects are consistent with DLC6.1;

⑦ DLC6.7 refers to the condition in which the compartment of the buoyant structure i is damaged and flooded. The wind field model, wind speed, sea state, current speed, water level, wind-wave direction and other aspects are consistent with DLC6.3.

(7) Parked conditions with failures (DLC7.1–7.2) refer to the conditions of parked with failures in electrical networks or the WTGS. At least the failures of the braking, pitch and yaw systems and the like shall be considered.

① For DLC7.1, the combination of the extreme wind speed model (EWM) with a one-year return period under the parked condition with failures and the extreme sea state with a one-year return period shall be considered. The wind speed v_1 with a one-year return period shall be taken as the 10 min mean wind speed v_{hub} at the hub height. The characteristic wave height $H_{s,1}$ with a one-year return period, ultimate current speed with a one-year return period and the normal water level range (NWLR) shall be considered. It shall be considered that wind and waves propagate in different, multiple directions;

② DLC7.2 refers to the fatigue condition caused by parked plus failures. The normal turbulent model (NTM) and normal sea state (NSS) are adopted, and the 10 min mean wind speed at the hub height is v_{hub} , which is smaller than the cut-out wind speed v_{out} . The joint probability distribution of the characteristic wave height, peak spectral period and the 10 min mean wind speed at the hub height shall be considered. The normal water level range (NWLR) or the level higher than the mean seal level (MSL) shall be taken, and it shall be considered that wind and waves propagate in the same, multiple directions. No consideration of the effects of current speed is necessary.

(8) The conditions of transportation, installation, maintenance and repair (DLC8.1–8.4) refer to the conditions at the stages of transportation, installation, maintenance and repair of the FOWT.

① DLC8.1 refers to the ultimate strength analysis condition determined by the builder or owner during transportation, installation, maintenance and repair;

② DLC8.2 refers to the ultimate strength analysis condition defined when transportation, installation, maintenance and repair last over one week. When the extreme wind speed model (EWM) is adopted, the combination of the wind speed v_1 with a one-year return period, the characteristic wave height with a one-year return period $H_{s,1}$ and the current speed with a one-year return period shall be considered, and the normal water level range (NWLR) shall be taken. It shall also be considered that wind and waves propagate in the same, single direction;

③ DLC8.3 refers to the fatigue analysis condition during transportation, installation, maintenance and repair and when the electrical network is not connected with. The normal turbulent model (NTM) and normal sea state (NSS) are adopted, and the 10 min mean wind speed v_{hub} at the hub height is smaller than 0.7 times of the reference wind speed v_{ref} . The joint probability distribution of the characteristic wave height, peak spectral period and the 10 min mean wind speed at the hub height shall be considered. The normal water level range (NWLR) or the level higher than the mean seal level (MSL) shall be taken, and it shall be considered that wind and waves propagate in the same, multiple directions. No consideration of the effects of current speed is necessary;

④ DLC8.4 refers to the fatigue analysis condition determined by the builder or owner during transportation, installation, maintenance and repair.

Section 4 ANALYSIS OF GLOBAL PERFORMANCE

2.4.1 General requirements

2.4.1.1 The global performance and loads can be predicted through numerical calculation or model test.

2.4.1.2 The target of the global performance prediction is to determine the overall response of the FOWT installation under environmental loads.

2.4.1.3 The prediction of the global performance and loads shall cover the design conditions in Section 3 of this chapter, and the following contents shall be predicted:

(1) The six-degree-of-freedom motion responses of FOWT installations — for different types of FOWT installations, the relevant factors shall be considered based on the characteristics of these installations;

(2) The peak gap between the extreme wave peak and the lower edge of the lowest structure of the main structure of the deck (if applicable), which shall meet the relevant requirements of *CCS Rules for Mobile Offshore Units*;

(3) The tension of the mooring line and dynamic cable, including the maximum and minimum tension response as well as the fatigue load used for design;

(4) The hydrodynamic load used for structural analysis;

(5) The load at the tower bottom that is used for structural analysis, for which the inertia force of the RNA and the tower shall be considered;

(6) The acceleration used for determining the inertia load;

(7) The acceleration at the tower top that is used for the design and selection of the RNA, etc.

2.4.2 Analysis method

2.4.2.1 General requirements

(1) The global performance shall be obtained by the method of time-domain analysis, and the method of frequency-domain analysis can be used as the program for earlier stages through completion and selection;

(2) The effects of the RNA and tower on the global performance of the FOWT installation shall be considered;

(3) The interference and collision among dynamic cables, mooring structures and floating structures shall be considered;

(4) Both business software and internal software can be used for the analysis of the global performance; however, the internal software shall be verified thoroughly using model test or widely accepted by the industry.

2.4.2.2 Method of frequency-domain analysis

(1) The frequency-domain analysis shall include the six-degree-of-freedom wave frequency analysis of the FOWT installation, and special consideration shall be given to the FOWT installations of different types, e.g. the second-order low-frequency and high-frequency motion;

(2) The damping in the calculation analysis shall be determined based on existing engineering experience or model test, and shall be provided specifically in calculation reports.

2.4.2.3 Method of time-domain analysis

(1) For the method of time-domain analysis, the coupling effects between the aerodynamic

load, hydrodynamic load, driving load and the FOWT installation shall be considered;

(2) The time for time-domain simulation shall be long enough to obtain stable statistical peaks; the random number of seeds of irregular waves in time-domain simulation shall accurately simulate actual sea state as far as possible.

(3) Generally, the random number of seeds calculated and analyzed based on mean values shall not be less than 5. When the statistical analysis is conducted based on the ultimate value analysis models, the random number of seeds shall not be less than 10.

CHAPTER 3 STRUCTURE

Section 1 GENERAL PROVISIONS

3.1.1 Application

3.1.1.1 The provisions in this chapter apply to the main structure and accessory structure of the FOWT installation. The structures of the RNA and the FOWT tower are not within the applicable range of this chapter.

3.1.1.2 The provisions and requirements of the structural design described in this chapter mainly apply to the FOWT installations of the following types:

- (1) Column-stabilized (semi-submersible) installations;
- (2) Surface-type (barge-type) installations;
- (3) Tension leg platform (TLP);
- (4) Deep draft single-spar installations (SPAR).

For the floating wind turbine installations of novel structural types other than those mentioned above, structural design can be conducted by adopting the technical standards generally accepted by the industry based on the structural types, load-bearing characteristics and other aspects of the installations; however, the adopted structural design methods and relevant technical standards, technical basis and the like shall be specified in design documents and accepted by CCS.

3.1.2 Material and welding

3.1.2.1 The general requirements of materials and welding of FOWT installations shall meet the relevant requirements of *CCS Rules for Materials and Welding*.

3.1.2.1 For the steel FOWT installations, the following provisions shall be met:

(1) The steel used for the installation structure shall meet the relevant requirements of Chapter 3, PART ONE, in *CCS Rules for Materials and Welding*. For the selection of the steel used for the installation structure, the relevant requirements of Sections 4 and 6, Chapter 1, PART TWO, in *CCS Rules for Mobile Offshore Units* can also be referred to.

(2) The welding of the installation structure shall meet the relevant requirements of Chapter 6, PART THREE, in *CCS Rules for Materials and Welding*. For the weld design of the installation structure, the relevant requirements of Sections 5, Chapter 1, PART TWO, in *CCS Rules for Mobile Offshore Units* can be referred to.

3.1.2.3 For the FOWT installations mainly adopting concrete materials, the following provisions shall be met:

(1) The concrete materials shall conform to the relevant requirements of Chapter 6, PART TWO, of *CCS Rules for Materials and Welding*, and be approved by CCS.

(2) The relevant requirements of the concrete materials used for the installation structure can also be implemented based on the technical standards generally accepted by the marine industry at home and abroad. However, those standards shall be specified in the documents of design and construction, and shall be accepted by CCS.

3.1.3 Structure arrangement

3.1.3.1 For the structure arrangement of the FOWT installation, the requirements directly related to the global performance and safety of the installation shall be considered mainly (e.g. stability).

3.1.3.2 For the structure arrangement involving the channel arrangement, compartment partition, personnel protection, etc., the relevant requirements of Section 8, Chapter 1, PART TWO, in *CCS Rules for Mobile Offshore Units* can be referred to. During design, after considering the personnel attending, intelligent installation operation and other conditions, the equivalence or exemption of the arrangement requirements shall be indicated in the design documents, and shall be accepted by CCS.

3.1.4 Structure monitoring

3.1.4.1 The structure monitoring system of the FOWT installation shall generally meet the following requirements:

- (1) It shall be able to fulfill continuous monitoring of the structure;
- (2) The monitored data shall be able to be transmitted to the data center on land in a real-time manner. If local storage for the installation is adopted, there shall be measures to ensure the security of monitored data.

3.1.4.2 Arrangement of necessary protection shall be considered for the monitoring devices, signal transmission cables and other items within the wave affected areas, e.g. the protection structure against wave slamming.

Section 2 STRUCTURAL DESIGN

3.2.1 General requirements

3.2.1.1 The requirements of this section mainly apply to the structural design of the steel FOWT installation. The structural design of the concrete installation can be implemented in accordance with the rules and technical standards generally accepted by the industry, and shall be accepted by CCS.

3.2.1.2 The FOWT structural design can be implemented in accordance with the following design methods:

- (1) Working stress design (WSD);
- (2) Load and resistance factor design (LRFD).

3.2.1.3 The design life of the FOWT installation shall not be shorter than the design life of the offshore wind turbine. For the FOWT installation for demonstration and verification, the design life can be appropriately reduced, which, however, shall be specified in design documents and accepted by CCS.

3.2.2 Design load

3.2.2.1 For the selection of design load conditions, the relevant requirements of Section 3, Chapter 2, of the Guidelines shall be referred to.

3.2.2.2 The ultimate load effects generated by the combined action of the upper wind turbine loads and environmental loads shall be considered thoroughly. When the method of coupling analysis of the WTGS and installation integration is adopted to obtain ultimate loads, it shall be ensured that the effects of combined action of the wind loads on the WTGS and the environmental loads on the installation have been considered thoroughly in the integration analysis.

3.2.2.3 For the surface-type (barge-type) installation with insufficient freeboard, the effects of the wave slamming loads on the main deck and the accessory structures above it shall be considered.

3.2.3 Member size

3.2.3.1 The member size shall ensure that the global strength of the floating wind turbine installation shall meet the requirements of rules. If the size of the member is determined by adopting the rule-based method, the relevant requirements of Section 2, Chapter 3, PART TWO, of *CCS Rules for Mobile Offshore Units* can be referred to.

3.2.3.2 If the member size of the installation is determined by adopting direct finite element calculation, it shall be ensured that the structure strength under all design conditions shall meet requirements, and acceptance of CCS shall be obtained.

3.2.4 Structural analysis

3.2.4.1 The structural analysis of the FOWT shall generally include the analysis of structural strength and fatigue analysis.

3.2.4.2 The structural analysis methods shall be generally based on the linear elastic theory. Any plastic method adopted for analysis shall be indicted in design documents and accepted by CCS.

3.2.4.3 Structural calculation shall be conducted generally by adopting the accepted

finite-element structure analysis program; otherwise, the relevant description documents of procedures shall be provided, including the data about the mechanics principle on which the program is based, the calculation methods for the solution of the program and the relevant software verification.

3.2.4.4 In strength analysis, the structural high-stress area of the connection between the wind turbine tower and installation structure shall be paid special attention on. If the method of direct finite element calculation is adopted, the relevant provisions in 3.4.2, Chapter 3, PART TWO, in *CCS Rules for Mobile Offshore Units* shall be referred to.

3.2.4.5 In fatigue analysis, the time-domain characteristics of fatigue loads of the WTGS under various conditions and the frequency-domain characteristics of wave loads on the installation shall be considered thoroughly.

3.2.5 Strength verification

3.2.5.1 When working stress design (WSD) is adopted for the verification of structural strength, the following provisions shall be met.

(1) The criteria of structural strength verification shall be conducted by referring to the provisions in Section 4, Chapter 3, PART TWO, of *CCS Rules for Offshore Floating Installations*. For the definitions related to “static load condition” and “combined condition”, 3.3.2, Section 3, Chapter 3, PART TWO, in *CCS Rules for Offshore Floating Installations* shall be referred to;

(2) The load factor of the design condition (referring to Section 3, Chapter 2, in the Guidelines) of FOWT installations shall be 1.0;

(3) The buckling strength verification of the structure shall also be conducted by referring to *CCS Guidelines for Buckling Strength Assessment of Offshore Engineering Structures*.

3.2.5.2 When the load and resistance factor design (LRFD) method is adopted for the verification of structural strength, the following provisions shall be met:

(1) The load of the design condition of the offshore wind turbine (refer to Section 3, Chapter 2, of the Guidelines) shall be considered as the environmental load (refer to 2.2.4, Section 2, Chapter 2, of the Guidelines). Its partial load factor shall be taken in accordance with Table 3.2.5.2;

Type of operating condition	Normal/N	Abnormal/A
Partial load factor	1.35	1.1

Note: See Table 2.3.1, Section 3, Chapter 2, of the Guidelines for details of “Normal/N” and “Abnormal/A” in the definitions of the above condition types.

(2) The partial load factor of the fixed load and variable load (refer to 2.2.2 and 2.2.3 of Section 2, Chapter 2, of the Guidelines) can be 1.0. However, when the fixed load and variable load have favorable effects on the structure, the partial load factor shall be 0.9;

(3) The verification criteria of structural strength can be implemented by referring to the provisions of the technical standards generally accepted at home and abroad. The partial factor of the material shall be based on the provisions of the regulations and standards used. In case of lack of specific provisions, the factor can be 1.05.

3.2.6 Fatigue verification

3.2.6.1 The design fatigue life of the structure of the FOWT installation shall not be shorter than the design life of the WTGS.

3.2.6.2 The fatigue verification of the installation structure shall be conducted by referring to *CCS Guidelines for Fatigue Strength Assessment of Offshore Engineering Structures*.

3.2.6.3 When the LRFD method is adopted for fatigue verification, the load factor of all load conditions can be 1.0.

Section 3 CORROSION PROTECTION

3.3.1 General requirements

3.3.1.1 In order to prevent the overall damage caused by corrosion, effective protection shall

be arranged for the steel structure of the main hull, and necessary protection for other accessory steel structures can be implemented based on actual conditions. Effective protection systems generally include coating, metal coating, cathodic protection, increasing corrosion allowance or other acceptable methods. For the design of the corrosion protection system, the design life of the protected structure locations and the maintainability of devices in the protection system shall be paid special attention on.

3.3.1.2 Except for the size of the bulkhead's member, which has included the corrosion allowance specified in rules as specified in 3.2.3 of this chapter, all member sizes determined by adopting the calculation in rules as specified in 3.2.3 of this chapter shall not include corrosion allowance. Appropriate corrosion allowances shall be considered based on locations, environmental conditions and the anti-corrosion measures adopted. For the selection of corrosion allowances, the relevant provisions of Section 5, Chapter 3, PART TWO, of CCS *Rules for Offshore Floating Installations* shall be referred to. The increased corrosion allowances shall be indicated in design plans and documents.

3.3.1.3 For the installation adopting novel anti-corrosion methods or means, its anti-corrosion system shall be able to provide the installation with the protection equivalent to regular anti-corrosion methods or means, and necessary design data of anti-corrosion system, such as instructions of principles and methods and description documents of system design, shall be provided.

Chapter 4 STABILITY, SUBDIVISION AND LOAD LINES

Section 1 GENERAL PROVISIONS

4.1.1 General requirements

4.1.1.1 For the requirements of stability of FOWT installations, including the stability of the transit process, installation process and in-position status, see the relevant requirements of Section 2 of this chapter for details.

4.1.1.2 The stability of the FOWT installation is divided into intact stability and damage stability. The intact stability of the installation refers to the floating installation's capability of relying on its own righting moment after inclining to resist against the external capsizing moment. Damage stability refers to the installation's capability of relying on its own after-inclining righting moment after damage to prevent further flooding under specified external action of wind force.

Section 2 STABILITY

4.2.1 Inclining test

4.2.1.1 Inclining test shall be conducted for the FOWT installation that is newly constructed or subjected to major modification to determine the weight of the lightweight and center of gravity. Inclining test shall be conducted in the time possibly closest to completion, and CCS Surveyors shall be present at the site. The test procedures and the results obtained for the inclining test shall be submitted to CCS for review.

4.2.1.2 If inclining test for the installation cannot be conducted timely due to the special layout pattern and/or installation process, it can be considered to use alternative methods to determine the installation weight and center of gravity. If it is inconvenient to measure the center of gravity, conservative methods can be adopted for estimation. In alternative methods, the certified weighing sensor can be used to measure the weights of the installation and its assemblies. The final results of the weight and center of gravity and the whole process shall be agreed by CCS.

4.2.2 Stability verification

4.2.2.1 The intact stability in basic conditions of the FOWT installation shall be verified:

(1) Transit condition. The transit condition refers to the condition in which the FOWT installation is wet towed from the port (wharf) to the location in the sea area of the installation. The minimum wind speed for the verification of intact stability shall be 36 m/s (70 kn), and relevant requirements of competent authorities shall be met;

(2) Installation condition. The installation condition refers to the condition in which the transit condition of the FOWT installation arriving at the installation location is adjusted to the in-position status. During installation and commissioning, the positive metacentric height of the floating wind turbine installation shall be always maintained. The return period of the wind speed for stability verification shall not be less than one year;

(3) In-position condition. The in-position condition refers to the condition when the FOWT installation is in its service. For intact stability analysis, the quasi-static effect (equivalent capsizing moment that is required by the table of design load conditions, i.e. Table 2.3.1 and generated under any normal operating or extreme design conditions) of the RNA under various operation conditions shall be considered. During the calculation of the capsizing moment, the condition of the maximum equivalent capsizing moment that is listed in Table 2.3.1 shall be considered, and at least typical conditions, such as the conditions of power generation, parked and parked with failures, shall be included. For the condition of power generation, the wind speed (generally the rated wind speed) that enables the wind turbine blade to rotate and generate the maximum thrust, between the cut-in and cut-out wind speeds, shall be adopted to calculate the capsizing moment.

For the calculation of the capsizing moment, the effects of the worst loads of the wind turbine, the operating conditions of the RNA, the control strategies for the wind turbine and other aspects shall be considered. When the calculation of the capsizing moment for different inclination angle under the condition of power generation is conducted, if the inclination angle exceeds a certain value, there shall be control strategies leading to shutdown, and the discontinuity of the capsizing moment at the location of the inclination angle shall be noted (as shown in Figure 4.2.2.1).

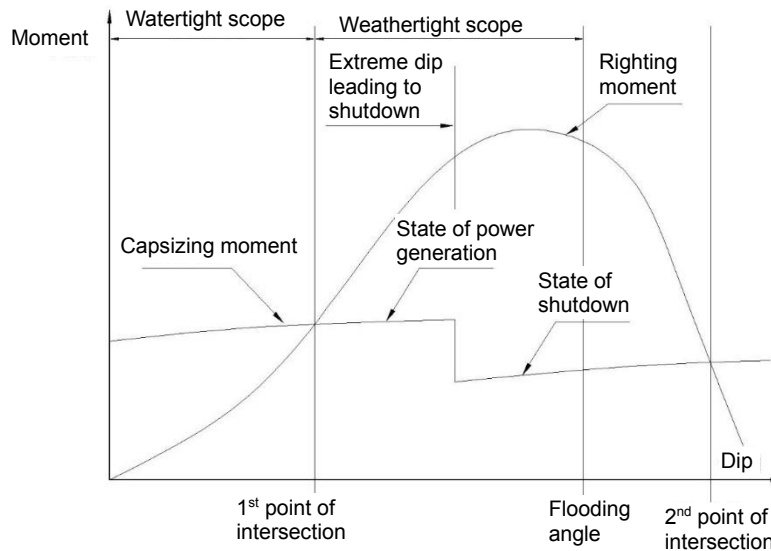


Figure 4.2.2.1 Hydrostatic curve plan of intact status under typical power generation condition

4.2.2.2 For damage stability, the transit condition and in-position condition shall be verified:

(1) For the transit condition, the minimum wind speed for the analysis of damage stability shall be 25.8 m/s (50 kn). If the installation is unattended during wet towing, and no damage threat will be caused to marine environment and the adjacent offshore structures during towing, the analysis of damage stability can be exempted;

(2) When the damage stability under the in-position condition is calculated, the DLC 1.9 and DLC 6.7 listed in Table 2.3.1 shall be used as the design condition and load condition;

(3) For the analysis of damage stability, the condition of flooding in whole or partial of single watertight compartments below the water line shall be considered. These compartments can be pump rooms, the compartments equipped with sea water cooling systems and machinery or the compartments adjacent to sea water. For the tension leg platform (TLP), any single tendon compartment shall be included.

4.2.2.3 For the calculation of wind loads, the relevant requirements of 2.2.4.2 of the Guidelines shall be referred to. The arm of acting force of wind loads shall be the vertical distance between the pressure center of the wind area and the lateral drag center of the underwater part of the installation.

4.2.2.4 Righting moment curves and wind heeling moment curves corresponding to the most critical axis shall be calculated and plotted in a sufficient number within the draft ranges of all floating conditions. For the calculation of the righting moment, the maximum deck load and equipment in the most unfavorable position as applicable and the free level of liquids in tanks shall be taken into account. For the purpose of calculation, it shall be assumed that the FOWT installation is floating free of mooring restraints. However, the possible detrimental effects of mooring restraints shall be considered.

4.2.2.5 The wind heeling moment results obtained from the wind tunnel test of representative floating wind turbine installation models can be substituted for the calculated values required in Section 4.2.2.4. Such heeling moment determination shall include lift effects at various applicable heel angles, as well as drag effects.

4.2.2.6 The intact stability criteria of afloat surface-type and column-stabilized FOWT installations shall meet the relevant requirements in Section 3, Chapter 2, PART THREE, in *CCS Rules for Mobile Offshore Units*.

4.2.2.7 The damage stability criteria and damage scope of afloat surface-type FOWT installations shall meet the relevant requirements in Section 4, Chapter 2, PART THREE, in *CCS Rules for Mobile Offshore Units*.

4.2.2.8 The damage stability criteria of afloat column-stabilized FOWT installations after the flooding of a single compartment shall meet the relevant requirements in Section 4, Chapter 2, PART THREE, in *CCS Rules for Mobile Offshore Units*.

4.2.2.9 The intact stability of the afloat tension-leg FOWT installation and the damage stability after the flooding of a single compartment shall meet the relevant requirements of Section 2, Chapter 2, of *CCS Rules for Classification of Tension Leg Platform*.

4.2.2.10 The stability criteria of deep draft single-spar (SPAR) FOWT installations shall meet the relevant requirements in Chapter 3, PART NINE, in *CCS Rules for Offshore Floating Installations*.

Section 3 LOAD LINES

4.3.1 General requirements

4.3.1.1 The surface-type and column-stabilized FOWT installations shall meet the relevant requirements in Chapter 3, PART THREE, in *CCS Rules for Mobile Offshore Units*.

4.3.1.2 The tension-leg FOWT installations shall meet the relevant requirements in Chapter 3, PART THREE, in *CCS Rules for Offshore Floating Installations*.

4.3.1.3 The deep draft single-spar (SPAR) FOWT installations shall meet the relevant requirements in Chapter 3, PART NINE, in *CCS Rules for Offshore Floating Installations*.

Section 4 WATERTIGHT AND WEATHERTIGHT INTEGRITY

4.4.1 General requirements

4.4.1.1 The surface-type and column-stabilized FOWT installations shall meet the relevant requirements in Chapter 4, PART THREE, in *CCS Rules for Mobile Offshore Units*.

4.4.1.2 The tension-leg FOWT installations shall meet the relevant requirements in Section 4, PART TWO, in *CCS Rules for Classification of Tension Leg Platform*.

4.4.1.3 The deep draft single-spar (SPAR) FOWT installations shall meet the relevant requirements in Chapter 3, PART NINE, in *CCS Rules for Offshore Floating Installations*.

Section 5 OTHERS

4.5.1 General requirements

4.5.1.1 Special consideration shall be given by CCS to the stability, subdivision and load lines of the FOWT installations of novel design types.

Chapter 5 POSITION MOORING SYSTEM

Section 1 GENERAL PROVISIONS

5.1.1 General requirements

5.1.1.1 This chapter applies to the FOWT installation equipped with position mooring systems. Position systems can be the spread-type mooring systems, tension-type mooring system, single-point mooring systems, etc.

5.1.1.2 The results of the analysis of position mooring systems can be obtained through calculation and analysis or by means of model test.

5.1.1.3 If the analysis method that is different from those specified in this chapter is adopted to calculate the environmental load, there shall be sufficient model tests or measured results for description.

Section 2 ENVIROMENTAL CONDITIONS AND ENVIROMENTAL LOADS

5.2.1 General requirements

5.2.1.1 The owner/designer shall consider the operating condition (condition of power generation) and survival condition (extreme sea state) during the design of the position mooring system of the floating wind turbine installation. For the selection of the corresponding design environmental conditions and parameters, the relevant requirements of Section 3, Chapter 2, of the Guidelines shall be referred to.

5.2.1.2 When the model test is adopted to determine the environmental loads and the motion of the moored FOWT installation, the above-water or underwater shape of the test model shall be able to characterize the actual floating structures, and the effects of other accessories shall be considered appropriately. The flowing characteristics of the model test shall be the same with the actual FOWT installation, and the procedure and method of model test shall be determined through the negotiation with CCS.

5.2.2 Design requirements of position mooring system

5.2.2.1 The state of the redundant position mooring system shall include the intact mooring state, damage mooring state and instantaneous damage mooring state. For its definition and applicable scope, the related requirements of Section 3, Chapter 8, PART EIGHT, of CCS *Rules for Mobile Offshore Units* can be referred to.

5.2.2.2 The non-redundant mooring system refers to the position mooring system of which the damage mooring state will cause the FOWT installation's failure in meeting the design requirements of mooring line design criteria; however, its intact mooring status can lead to higher safety factors.

5.2.3 Extreme water level

5.2.3.1 The water level changes caused by tides will affect the pretension, mooring stiffness and other aspects of the mooring system of the FOWT installation to some extent. The effects of the extreme water level shall be assessed in the design of shallow mooring positioning.

5.2.4 Design life

5.2.4.1 The design life of the position mooring system shall be consistent with the design life of the offshore floating wind turbine installation.

5.2.5 Environmental loads

5.2.5.1 For the environmental load calculation and direction combination of the FOWT installation, the relevant requirements of Section 2, Chapter 6, PART NINE, of *CCS Rules for Offshore Floating Installations* can be referred to.

Section 3 INSTALLATION OFFSET AND MOORING LINE TENSION

5.3.1 General requirements

5.3.1.1 The requirement of this section only involves the motion offset and mooring line tension of the floating wind turbine installations that are caused by the action of wind, waves and currents.

5.3.1.2 The motion offset and mooring line tension of the floating wind turbine can be obtained through numerical simulation analysis and/or by model test methods.

5.3.2 Analysis method of mooring

5.3.2.1 For the analysis method of the mooring system, it is recommended to refer to the relevant requirements of Sections 2 and 3, Chapter 6, PART NINE, in *CCS Rules for Offshore Floating Installations*.

5.3.3 Fiber cable

5.3.3.1 If the design program of fiber cables is adopted, the determination method of the stiffness shall be agreed by CCS.

Section 4 DESIGN CRITERIA OF MOORING SYSTEM

5.4.1 General requirements

5.4.1.1 The contents of this section mainly apply to the position mooring system of the FOWT installation using mooring lines for mooring.

5.4.1.2 For the position mooring system of the FOWT installation containing multiple mooring lines in design, it is generally designed that any sudden failure of any mooring line will cause no successive failure of other mooring lines; otherwise, the design shall be conducted based on non-redundant position systems.

5.4.2 Design condition

5.4.2.1 For the determination of the design condition of the position mooring system, the relevant requirements of Section 3, Chapter 8, PART EIGHT, of *CCS Rules for Mobile Offshore Units* can be referred to.

5.4.2.2 Considering the operating characteristics of the FOWT installation, the operating condition of the mooring position system shall at least include the maximum wind turbine load condition and the maximum operating environment conditions.

5.4.3 Design criteria

5.4.3.1 For the verification of the redundant position mooring system of the FOWT, the relevant requirements of Section 3, Chapter 8, PART EIGHT, of *CCS Rules for Mobile Offshore Units* can be referred to.

5.4.3.2 The non-abundant position mooring system shall be calculated using the dynamic analysis method. The safety factor of its mooring line shall not be less than 1.2 times of the minimum safety factor of the corresponding intact condition in Section 3, Chapter 8, PART EIGHT, in *CCS Rules for Mobile Offshore Units*.

Section 5 MOORING EQUIPMENT

5.5.1 General requirements

5.5.1.1 The materials, design, manufacturing, test and other aspects of anchors, mooring lines and their accessories, fairleads and chain/wire stoppers shall meet the relevant requirements of Chapter 10, PART ONE, in *CCS Rules for Materials and Welding*, or the relevant requirements of accepted national or international standards.

5.5.2 Anchors and mooring lines

5.5.2.1 Anchors and mooring lines shall meet the relevant requirements of Sections 3 and 4, Chapter 8, PART EIGHT, in *CCS Rules for Mobile Offshore Units*.

5.5.3 Fairleads and chain/wire stoppers

5.5.3.1 Fairleads and chain/wire stoppers shall meet the relevant requirements of Sections 4, Chapter 8, PART EIGHT, in *CCS Rules for Mobile Offshore Units*.

Chapter 6 INSTALLATION SYSTEM AND EQUIPMENT

Section 1 GENERAL PROVISIONS

6.1.1 General requirements

6.1.1.1 This chapter applies to the electromechanical system, safety system and communication and signal system on the attendant FOWT installation.

6.1.1.2 The contents of this chapter do not apply to the system and equipment in the RNA and tower.

6.1.1.3 The relevant systems and equipment in this chapter shall be independent of the wind turbine electrically and functionally. At least it shall be ensured that the failures of relevant systems or equipment of the wind turbine will not affect the safety of the installation.

Section 2 ELECTRICAL INSTALLATIONS

6.2.1 General requirements

6.2.1.1 For the electric control system of the column-stabilized FOWT installations, the relevant requirements in PART FIVE and PART SIX in *CCS Rules for Mobile Offshore Units* shall be referred to.

6.2.1.2 For the electric control system of other types of FOWT installations, the relevant requirements in PART SIX and PART SEVEN in *CCS Rules for Offshore Floating Installations*

shall be referred to.

6.2.2 Main power supply

6.2.2.1 The power obtained by transforming the power generated by the wind turbine can be the main power supply for the FOWT installation.

6.2.3 Emergency power supply

6.2.3.1 The FOWT shall be equipped with the emergency power supply to ensure the emergency lighting, signal equipment, safety system and other components of the installation can operate in emergency.

6.2.3.2 The emergency power supply can be power generators or battery packs, and shall be installed on the installation.

6.2.3.3 The power supply duration for navigation aiding lights and aviation obstruction light shall be 96 hours, and the duration of all other emergency power supply shall be at least 1.5 hours.

Section 3 COMMUNICATIONS AND SIGNALS

6.3.1 General requirements

6.3.1.1 The communication equipment required in this chapter is the lowest requirement for the communication system of the FOWT installations. The communication equipment of other forms can be added based on actual conditions provided that the functions of the lowest configuration will not be affected.

6.3.1.2 The FOWT installation shall be equipped with clear navigation aiding signs and signal equipment. The signal sign shall meet the relevant regulations of competent authorities of the sea area.

6.3.1.3 When the offshore wind farm is equipped with safeguard measures for navigation as a whole, e.g. the electric fence system, the arrangement of the signal system on a single FOWT can be exempted.

6.3.1.4 When the offshore wind farm is equipped with peripheral navigation aiding lights as a whole, the arrangement of any navigation aiding light for a single FOWT can be exempted, while aviation obstruction lights shall be provided.

6.3.2 Communication system

6.3.2.1 The arrangement of the communication system for the unattended FOWT installation can be exempted. However, the personnel embarking on the installation shall carry reliable portable external radio communication equipment.

6.3.3 Signal equipment

6.3.3.1 The arrangement requirements of navigation aiding lights: the synchronously lighting navigation aiding lights providing white light at nights shall be installed at the four corners of the FOWT installation. The quantity and installation locations of those lights shall ensure that the ships approaching the installation from any direction can see the light from at least one location. The flash characteristic of the navigation aiding light is the Morse signal “U” (··—), with the maximum period of 15 sec. The Morse signal “U” shall meet the requirements of Table 6.3.3.

Morse signal of lights, “U”

Table 6.3.3

Short, bright (point)	0.5 sec
Dark	0.5 sec
Short, bright (point)	0.5 sec
Dark	0.5 sec
Long-time bright (line)	1.5 sec
Stop	8.5 sec or 11.5 sec
Light period	12 sec or 15 sec

6.3.3.2 Arrangement requirements for aviation obstruction lights: red obstruction lights shall be provided at the top of the WTGS of the FOWT installation, the arrangement of which shall

meet the requirements of aviation conditions.

6.3.3.3 Arrangement requirements of fog horns: the main fog horn and standby fog horns shall be arranged for the FOWT installations, and the structures and locations of which shall ensure that the ships approaching the installation from any direction can hear the sound. When the general listening range in any direction is smaller than 0.5 nm due to complete or partial failure of the main fog horn, the standby fog horns shall be able to be put into operation immediately. The main and standby fog horns shall be automatic (or can be started up remotely).

6.3.4 Requirement of power supply

6.3.4.1 The navigation aiding signs and signal equipment shall be able to get connected automatically to emergency power supplies in case of any failure in the main power supply.

Section 4 UTILITY SYSTEM

6.4.1 General requirements

6.4.1.1 For the utility system, the relevant requirements of PART FOUR of CCS *Rules for Mobile Offshore Units* or PART FIVE of CCS *Rules for Offshore Floating Installations* shall be referred to.

6.4.1.2 Considering the demand of the specific operation modes of the FOWT, on condition that the safety of operators is ensured, the utility system required in 6.4.1.1 of the Guidelines shall be provided appropriately for the FOWT installation, and shall be accepted by CCS.

6.4.2 Ballast system

6.4.2.1 For the ballast system of the column-stabilized FOWT installation, the relevant requirements in PART FOUR in CCS *Rules for Mobile Offshore Units* shall be referred to.

6.4.2.2 For the ballast system of other types of FOWT installations, the relevant requirements in PART FIVE in CCS *Rules for Offshore Floating Installations* shall be referred to.

6.4.2.3 If the design of the FOWT installation can ensure that no draft adjustment is needed, or no pumping in or discharging of ballast water from the outboard is needed, under the operating and survival conditions, the arrangement of fixed ballast system and the water level detection system for the ballast tank is not necessary.

6.4.3 Open drain system

6.4.3.1 On condition that the compliance with draining requirements is confirmed, the rainwater on the FOWT installation can be drained directly to the sea.

6.4.4 Ventilation system

6.4.4.1 For the pump room for fixed ballast and other spaces with seldom personnel accessing, continuous ventilation is not necessary; however, there shall be safety measures for the accessing personnel.

Section 5 FIRE PROTECTION SYSTEM

6.5.1 General requirements

6.5.1.1 For unattended FOWT installation, safety systems generally include the fire/gas detection and alarm, emergency shutdown and fire protection system.

6.5.1.2 For the fire protection system of the column-stabilized FOWT installation, the relevant requirements in Chapter 3, PART FIVE, in CCS *Rules for Mobile Offshore Units* shall be referred to. For the fire protection system of other types of installations, the relevant requirements in PART SEVEN in CCS *Rules for Offshore Floating Installations* shall be referred to.

6.5.1.3 Considering the demand of the specific operation modes of the FOWT, on condition that the safety of operators is ensured, the fire protection system required in 6.5.1.2 of the Guidelines shall be provided appropriately for the FOWT installation, and shall be accepted by

CCS.

6.5.2 Fire/gas detection and alarm system

6.5.2.1 If power generator rooms, power distribution rooms and battery rooms are arranged, necessary fire/gas detection and alarm systems shall be arranged based on actual conditions.

6.5.2.2 The fire alarm signals shall be indicated in the control station onshore.

6.5.3 Fire protection system

6.5.3.1 If fire protection systems are arranged, the relevant requirements of PART SEVEN of *CCS Rules for Mobile Offshore Units* shall be referred to.

Section 6 LIFE-SAVING APPLIANCES

6.6.1 General requirements

6.6.1.1 Life appliances shall be able to be put into use immediately and effectively in emergency.

6.6.1.2 All life appliances shall be tagged with the name of the FOWT installation and stored appropriately as specified. The storage locations shall be indicated on the general layout of the installation.

6.6.1.3 Life appliances shall be able to be stored within the temperature range of the sea area where the FOWT installation is located, without any damage, and shall also be able to be used normally within the water temperature range of the sea area.

6.6.1.4 The life-saving appliances shall be tagged with the applicable life or the date of mandatory replacement.

6.6.1.5 The life-saving appliances shall be surveyed and accepted by CCS.

6.6.2 Requirement of arrangement

6.6.2.1 The arrangement of lifeboats, rescue boats and life rafts for the FOWT installation is not required.

6.6.2.1 Sufficient lifebuoys shall be provided for the FOWT installation, and at least a half of the total lifebuoys shall have built-in self-igniting lights, and at least 2 lifebuoys shall be provided with the function of self-activating smoke signals.

6.6.2.3 The lifejackets for 12 persons shall be provided for the FOWT installation, or all persons embarking on the installation shall carry a lifejacket each.

6.6.2.4 For the FOWT installation for the operation of cold regions, the lifejackets for 12 persons shall also be provided, or all persons embarking on the installation shall carry a lifejacket each.

6.6.2.5 If the number of the related persons embarking on the FOWT installation possibly exceeds 12, the life-saving equipment shall be arranged as required in this section and based on the actual number of personnel.

6.6.3 Arrangement requirement of distress signals

6.6.3.1 At least 12 rocket parachute flare signals and 2 buoyant smoke signals shall be provided for the FOWT installation.

6.6.3.2 The above distress signals shall be stored in easily accessible places and away from any passing heat source.

6.6.4 Arrangement requirement of line-throwing appliance

6.6.4.1 One line-throwing appliance shall be provided for the FOWT installation.

6.6.4.2 The line-throwing appliance shall be stored in easily accessible places, and shall be ready for immediate use.

6.6.5 Arrangement requirement of first-aid equipment

6.6.5.1 Commonly used drugs, first aid kits, stretchers and other appliances should be

provided for the FOWT installation.