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All equipment shall be kept in good repair and be suitable for the task for which it is intended. Cranes, hoists and lifting equipment, including all slings, hooks and other apparatus, shall be adequate for safe lifting and approved.

Particular consideration should be given to installation of the offshore wind turbine under unusual conditions, such as hail, lightning, high winds, earthquake, icing, high waves, extreme tidal conditions, etc.

Installation procedures shall be such that, if necessary, work can be broken off without causing danger to personnel or unacceptable loads on the construction. In the case of a tower standing without a nacelle, appropriate measures shall be taken to avoid vortex-generated transverse vibrations, whether caused by wind or by currents. The critical wind speeds and precaution measures shall be included in the installation manual.

Prior to any construction activity at the site of an offshore wind turbine facility, any planned temporary or permanent structure considered to be an obstacle to marine navigation and aviation shall be promulgated with adequate advance notice and shall be indicated on relevant maps and databases providing position, extent and elevation. Obstacle lighting and marking shall comply with relevant national and international regulations and codes.

All aspects of helicopter operations relevant to the structural safety of landing platforms, clearance, fire protection, marking, etc. shall comply with relevant national and international regulations and codes.

ISO 29400 provides guidance for the planning and engineering of port and marine operations associated with the transport, installation and maintenance of fixed offshore wind turbines.

#### 12.2 Planning

The assembly, erection and installation of wind turbines and associated equipment shall be planned in order that the work is carried out safely and in accordance with local and national regulations. In addition to procedures for quality assurance, the planning shall include, where appropriate, consideration of the following:

- detailed drawings and specifications of the work and inspection plan;
- rules for safe execution of excavation work, blasting and other activities that have to do
  with foundation and underwater construction, for example pile driving, laying of scour
  protection and cable laying;
- rules for the proper handling of embedded items, such as foundations, bolts, anchors and reinforcement steel;
- rules for concrete composition, delivery, sampling, pouring, finishing and placement of conduits;
- procedures for installation of tower and other anchors;
- health, safety and environmental rules for offshore work, including safety rules for diving;
- evacuation procedures (including procedures for monitoring of wind conditions and sea states, and when evacuation is in order).

#### 12.3 Installation conditions

During the installation of an offshore wind turbine, the site shall be maintained in such a state that it does not present safety or navigation risks.

#### 12.4 Site access

Access to a site shall be safe and the following shall be taken into account:

• barriers and routes of travel;

- exclusion zones;
- traffic;
- access weight bearing capacity;
- movement of equipment at the site;
- ship-to-turbine access system;
- helicopter-to-turbine access system.

## 12.5 Environmental conditions

During installation, environmental limits specified by the manufacturer shall be observed. Items such as the following should be considered:

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- wind speed;
- snow and ice;
- ambient temperature;
- lightning;
- visibility;
- rain;
- wave height;
- insufficient water depth;
- currents;
- tides.

## 12.6 Documentation

The manufacturer of an offshore wind turbine shall provide drawings, specifications and instructions for assembly procedures, installation and erection of the offshore wind turbine. The manufacturer shall provide details of all loads, weights, lifting points and special tools and procedures necessary for the safe handling and installation of the offshore wind turbine. The manufacturer shall provide a risk assessment of all hazardous activities.

## 12.7 Receiving, handling and storage

Handling and transport of wind turbine generator equipment during installation shall be performed with equipment confirmed to be suitable to the task and in accordance with the manufacturer's recommended practice.

Where there is risk of movement caused by the wind and/or waves with risk of consequent damage, blades, nacelles, other aerodynamic parts and light crates shall be secured.

## 12.8 Support structure systems

Where specified by the manufacturer for safe installation or assembly, special tools, jigs and fixtures and other apparatus shall be used.

## 12.9 Assembly of offshore wind turbine

An offshore wind turbine shall be assembled according to the manufacturer's instructions. Inspection shall be carried out to confirm proper lubrication and pre-service conditioning of all components.

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#### 12.10 Erection of offshore wind turbine

An offshore wind turbine shall be erected by personnel trained and instructed in proper and safe offshore erection practices. Apart from specific training having to do with turbine installation, training shall include at least:

- first aid;
- procedures particular to offshore (for example the use of life rafts, life jackets, special suits, offshore survival);
- evacuation procedures, also of wounded or unconscious persons;
- use of boats, helicopters and offshore access systems (with special attention to safe transfer procedures at night).

All work shall be undertaken by at least 2 persons, equipped with suitable means of communication.

No part of an offshore wind turbine electrical system shall be energized during erection unless it is necessary for the erection process. In this case, the energization of such equipment shall be carried out in accordance with a written procedure provided by the wind turbine supplier.

All elements where motion (rotation or translation) may result in a potential hazard shall be secured from unintentional motion throughout the erection process.

#### **12.11 Fasteners and attachments**

Threaded fasteners and other attachment devices shall be installed according to the wind turbine manufacturer's recommended torque and/or other instructions. Fasteners identified as critical shall be checked and procedures for confirming installation torque and other requirements shall be obtained and used.

In particular, inspection shall be carried out to confirm the following:

- proper assembly and connection of guys, cables, turn buckles, gin poles and other apparatus and devices;
- proper attachment of lifting devices required for safe erection.

#### 12.12 Cranes, hoists and lifting equipment

Cranes, hoists and lifting equipment, including all hoisting slings, hooks and other apparatus required for safe erection, shall be adequate for safe lifting and final placement of the loads. Manufacturer's instructions and documentation with respect to erection and handling should provide information on expected loads and safe lifting points for components and/or assemblies. All hoisting equipment, slings and hooks shall be tested and certified for safe load.

## **13** Commissioning, operation and maintenance

#### 13.1 General

The commissioning, operation, inspection, and maintenance procedures shall be specified in the offshore wind turbine manual with due consideration of the safety of personnel.

The design shall incorporate provisions for safe access for inspection and maintenance of all components. The access system shall comply with relevant local, national and international regulations.

The requirements of Clause 10 also cover electrical measurement equipment temporarily installed in the offshore wind turbine for the purpose of measurements.

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When appropriate, operation and maintenance personnel shall use approved personal protective equipment, such as eye, foot, hearing and head protection. All personnel climbing towers, or working above ground or water level, shall be trained in such work and shall use approved safety belt, safety climbing aids. Other safety devices include life jackets, wetsuits and buoyancy aids.

#### 13.2 Design requirements for safe operation, inspection and maintenance

The normal operation of an offshore wind turbine by the operating personnel shall be possible at platform level. A tagged, local, manual override on the automatic/remote control system shall be provided.

External events detected as faults but not critical for the future safety of an offshore wind turbine, such as loss and reinstatement of the electrical load, may allow automatic return to normal operation after completion of the shutdown cycle.

Guards designed to protect personnel from accidental contact with moving components shall be fixed, unless frequent access is foreseen, where they may be movable.

Guards shall:

- be of robust construction;
- not be easy to bypass;
- where possible, enable essential maintenance work to be carried out without their dismantling.

Any walkway or platform mounted on the support structure of an offshore wind turbine shall be located above the splash zone. For safety, removal of marine growth should be considered. If there is a risk of icing at the site, the limitation of accessibility to ladders and platforms under icing conditions shall be considered. Consideration shall also be given to the risk of damage to structures from falling ice.

The design shall incorporate adequate minimum vertical clearance between a rotating blade tip and any walkway or platform used during operation of the wind turbine.

Provisions shall be made in the design for use of diagnostic fault finding equipment.

In order to ensure safety of the inspection and maintenance personnel, the design shall incorporate:

- safe access paths and working places for inspection and routine maintenance;
- adequate means to protect personnel from accidental contact with rotating components or moving parts;
- provision for securing lifelines and safety belts or other approved protection devices when climbing or working above platform level;
- provisions for blocking rotation of the rotor and yawing mechanism or other mechanical motion, such as blade pitching, during servicing according to wind conditions and design situations specified in DLC 8.1, as well as provisions for safe unblocking;
- warning signs for live conductors;
- suitable devices for the discharge of accumulated electricity;
- suitable fire protection for personnel;
- an alternative escape route from the nacelle;
- provision for an alternative escape route from the offshore wind turbine in case of emergency;

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- provisions for a stay of 1 week in an offshore wind turbine (food, water, heating, clothing/blankets);
- offshore safety equipment (such as: life jackets, life raft, lights, alarm pistol, flares).

Maintenance procedures shall require safety provisions for personnel entering any enclosed working space, such as hub or blade interior that ensures any dangerous situation will be known by standby personnel to immediately initiate rescue procedures, if necessary.

The operation of obstacle lighting and marking relevant to marine navigation and aviation shall comply with relevant national and international regulations and codes.

#### 13.3 Instructions concerning commissioning

#### 13.3.1 General

The manufacturer shall provide instructions for commissioning.

#### 13.3.2 Energization

The manufacturer's instructions shall include a procedure for initial energization of the wind turbine electrical system.

#### 13.3.3 Commissioning tests

The manufacturer's instructions shall include the procedures for testing of the offshore wind turbine after installation, to confirm proper, safe and functional operation of all devices, controls and apparatus. These shall include, but not be limited to

- safe start-up;
- safe shutdown;
- safe emergency shutdown;
- safe shutdown from overspeed or representative simulation thereof;
- function test of protection system.

#### 13.3.4 Records

The manufacturer's instructions shall include the information that proper records shall be kept, describing testing, commissioning, control parameters and results.

## 13.3.5 Post commissioning activities

At the completion of installation, and following operation for the manufacturer recommended running in period, the specific actions that may be required by the manufacturer shall be completed.

These can include, but are not limited to preloading of fasteners, changing of lubrication fluids, checking other components for proper setting and operation and proper adjustment of control parameters.

## **13.4** Operator's instruction manual

## 13.4.1 General

An operator's instruction manual shall be supplied by the offshore wind turbine manufacturer and augmented with information on special local conditions at the time of commissioning as appropriate. The manual shall be available to the operation and maintenance personnel in a language that can be read and understood by the operator. The manual shall include, but not be limited to

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- any requirements that the operation shall be performed by personnel suitably trained or instructed in this activity;
- safe operating limits and system descriptions;
- start-up and shut-down procedures;
- an alarms action list;
- emergency procedures plan;
- safe offshore access procedures;
- stated requirements that when appropriate:
  - approved personal protection equipment, such as life-jacket plus eye, foot, hearing and head protection shall be used,
  - when appropriate, all personnel climbing towers, or working above water level, shall be trained in such work and shall use approved safety belt, safety climbing aids or other safety devices.

## 13.4.2 Instructions for operations and maintenance record

The manual shall state that operations and maintenance records shall be kept and should include the following:

- wind turbine identification;
- energy produced;
- operating hours;
- shutdown hours;
- date and time of fault reported;
- date and time of service or repair;
- nature of fault or service;
- action taken;
- parts replaced.

## 13.4.3 Instructions for unscheduled automatic shutdown

The manual shall require that following any unscheduled automatic shutdown caused by a fault or malfunction, unless specified otherwise in the operations manual or instructions, the operator shall investigate the cause before an offshore wind turbine is restarted. All unscheduled automatic shutdowns should be recorded.

If the wind turbine is re-started after a period of more than three months of non-power production, special precautions shall be taken. Prior to re-start, all components and systems shall be thoroughly inspected and their engineering integrity assessed. Components and systems that are determined to no longer satisfy their design requirements because of the effects of the prolonged period of non-power production shall be repaired or replaced. The condition of critical components and systems shall be monitored after the turbine is re-started and brought back to a state of power production.

## 13.4.4 Instructions for diminished reliability

The manual shall require that action shall be taken to eliminate the root cause of any indication or warning of abnormality or diminished reliability.

## 13.4.5 Work procedures plan

The manual shall require that the offshore wind turbine shall be operated according to safe working procedures, taking into account the following:

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- electrical systems operation;
- co-ordination of operation and maintenance;
- utility clearance procedures;
- tower climbing procedures;
- equipment handling procedures;
- activity during bad weather;
- communications procedures and emergency plans;
- turbine access procedure.

#### 13.4.6 Emergency procedures plan

Possible emergency situations shall be identified in the operations manual and the required actions of the operating personnel prescribed.

The manual shall require that where there is a fire or apparent risk of structural damage to the wind turbine or its components, no one should approach the wind turbine unless the risk is specifically evaluated.

In preparing the emergency procedures plan, it shall be taken into account that the risk for structural damage may be increased by situations such as the following:

- overspeeding;
- icing conditions;
- lightning storms;
- earthquakes;
- broken or loose guy-cables;
- brake failure;
- rotor imbalance;
- loose fasteners;
- lubrication defects;
- fire, flooding;
- ship collision;
- other component failures.

#### 13.5 Maintenance manual

Each offshore wind turbine shall have a maintenance manual, which at a minimum consists of the maintenance requirements and emergency procedures specified by the wind turbine manufacturer. The manual shall also provide for unscheduled maintenance.

The maintenance manual shall identify parts subject to wear, damage, corrosion and build up of marine growth, and indicate criteria for replacement.

Subjects which should also be covered in the manual include:

- any requirement that the inspection and maintenance shall be carried out by personnel suitably trained or instructed in this activity, at the intervals specified in and in compliance with the instructions in the wind turbine maintenance manual;
- description of the subsystems of the offshore wind turbine and their operation;
- lubrication schedule prescribing frequency of lubrication and types of lubricants or any other special fluids;

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- recommissioning procedure;
- maintenance inspection periods and procedures;
- procedures for functional check of protection subsystems;
- complete wiring and interconnection diagram;
- guy-cable inspection and retensioning schedules and bolt inspection and preloading schedules, including tension and torque loadings;
- maintenance of the access system and repair procedures following its damage due, for example, to impact by the service vessel;
- diagnostic procedures and trouble-shooting guide;
- recommended spare parts list;
- set of field assembly and installation drawings;
- tooling list;
- inspection and possible removal of marine growth;
- maintenance of the scour protection system.

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# Annex A

## (informative)

# Key design parameters for an offshore wind turbine

## A.1 Offshore wind turbine identifiers

## A.1.1 General

For an offshore wind turbine, the following information should be given in a summary included in the design documentation:

- name and type of wind turbine (description);
- location coordinates.

## A.1.2 Rotor-nacelle assembly (machine) parameters

The following parameters should be given:

•	rated power	[kW]			
•	rotor diameter	[m]			
•	rotational speed range	[rpm]			
•	power regulation (stall/pitch)				
•	hub height (above MSL)	[m]			
•	hub height operating wind speed range $V_{in} - V_{out}$	[m/s]			
•	design life time	[y]			
•	operational weight (minimum, maximum)	[kg]			
•	corrosion protection of rotor-nacelle assembly (description)				
Α.	1.3 Support structure parameters				
Th	e following parameters should be given:				
•	description of foundation including scour protection (if any)				
•	design water depth	[m]			
•	bathymetry in the vicinity of the wind turbine				
•	soil conditions at turbine location (description, see 6.4.7)				
•	resonant frequencies of the support structure (minimum, maximum):				
	<ul> <li>at normal and extreme operating conditions</li> </ul>	[Hz]			
	<ul> <li>with and without the RNA installed</li> </ul>	[Hz]			
•	corrosion allowance	[mm]			
•	corrosion protection (description)				
•	height of access platform (above MSL)	[m]			
A.1.4 Wind conditions (based on a 10-min reference period and including wind farm wake effects where relevant)					
Th	e following information should be given:				
•	turbulence intensity as a function of mean wind speed used for the NTM and ETM				
•	annual average wind speed (at hub height)	[m/s]			

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•	average inclined flow	[º]				
•	wind speed distribution (Weibull, Rayleigh, measured, other)					
•	normal wind shear model and parameters					
•	turbulence model and parameters					
•	hub height extreme wind speeds $V_{a1}$ and $V_{a50}$	[m/s]				
•	extreme gust model and parameters					
•	extreme direction change model and parameters					
•	extreme coherent gust model and parameters					
•	extreme coherent gust with direction change model and parameters					
•	extreme wind shear model and parameters					
•	wind direction distribution (wind rose)					
Α.	.1.5 Marine conditions (based on a 3-hour reference period where relevant)					
Tł	ne following information should be given:					
•	tidal variation and/or storm surge (50-year return period)	[m]				
•	highest astronomical tide (HAT)	[m]				
•	lowest astronomical tide (LAT)	[m]				
•	highest still water level (HSWL)	[m]				
•	lowest still water level (LSWL)	[m]				
•	significant wave height for 1- and 50-vear return periods	[m]				
•	range of peak periods for 1- and 50-year return periods	[s]				
•	individual extreme wave height for 1- and 50-year return periods	[m]				
•	range of associated wave periods for 1- and 50-year return periods	[s]				
•	extreme crest height with a return period of 50 years	[m]				
•	extreme sea surface current for 1- and 50-year return periods	[m/s]				
•	wind and wave joint distribution ( $H_s$ , $T_n$ , V) including directionality					
•	wave spectrum and parameters					
•	deterministic wave model and parameters					
•	breaking wave model and parameters					
•	sea/lake ice conditions if applicable (description, see 6.4.4.5)					
•	tropical cyclone assumptions if applicable					
•	local and global scour or sum of both (maximum allowed)	[m]				
•	sea floor level variation (maximum allowed)	[m]				
•	marine growth profile and thickness	[mm]				
Α.	1.6 Electrical network conditions at turbine					
Tł	ne following information should be given:					
•	normal supply voltage and range	[V]				
•	normal supply frequency and range	[Hz]				
•	voltage imbalance	[V]				
•	maximum duration of electrical power network outages	[days]				
•	annual number of electrical network outages	[1/year]				

annual number of electrical network outages

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•	total lifetime duration of network outages auto-reclosing cycles (description) behaviour during symmetric and unsymm	etrical external faults	[h] (description)
Α.	2 Other environmental conditions		
Th	e following information should be given:		
•	normal and extreme air temperature rang	es	[°C]
•	normal and extreme sea temperature ran	ges	[°C]
•	air density		[kg/m <sup>3</sup> ]
•	water density		[kg/m <sup>3</sup> ]
•	solar radiation		[W/m <sup>2</sup> ]
•	humidity		[%]
•	rain, hail, snow and icing		
•	chemically active substances		
•	mechanically active particles		
•	description of lightning protection system		
•	earthquake model and parameters (descr	iption)	
•	salinity		[g/m <sup>3</sup> ]
•	duration and environmental conditions as	sumed for DLC 6.4	
•	duration and environmental conditions as	sumed for DLC 7.2	
•	duration and environmental conditions as	sumed for DLC 8.3	
Α.	3 Limiting conditions for transpor	t, erection and mai	ntenance
Th	e following information should be given:		
•	maximum wind speed		[m/s]
•	maximum significant wave height		[m]
•	maximum water level variation		[m]
•	permitted atmospheric temperature		[°C]

- maximum wind speed for maintenance [m/s]
- displacement of transport vessel
   [metric tons]