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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Wind turbines –
Part 3: Design requirements for offshore wind turbines

Eoliennes –
Partie 3: Exigences de conception des éoliennes en pleine mer

IEC 61400-3:2009

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WIND TURBINES –

Part 3: Design requirements for offshore wind turbines

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 61400-3 has been prepared by IEC technical committee 88: Wind turbines.

This part is to be read in conjunction with IEC 61400-1:2005, *Wind turbines – Part 1: Design requirements.*

The text of this standard is based on the following documents:

FDIS	Report on voting
88/329/FDIS	88/338/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of IEC 61400 series, published under the general title *Wind turbines*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

This part of IEC 61400 outlines minimum design requirements for offshore wind turbines and is not intended for use as a complete design specification or instruction manual.

Several different parties may be responsible for undertaking the various elements of the design, manufacture, assembly, installation, erection, commissioning, operation and maintenance of an offshore wind turbine and for ensuring that the requirements of this standard are met. The division of responsibility between these parties is a contractual matter and is outside the scope of this standard.

Any of the requirements of this standard may be altered if it can be suitably demonstrated that the safety of the system is not compromised. Compliance with this standard does not relieve any person, organization, or corporation from the responsibility of observing other applicable regulations.

WIND TURBINES –

Part 3: Design requirements for offshore wind turbines

1 Scope

This part of IEC 61400 specifies additional requirements for assessment of the external conditions at an offshore wind turbine site and it specifies essential design requirements to ensure the engineering integrity of offshore wind turbines. Its purpose is to provide an appropriate level of protection against damage from all hazards during the planned lifetime.

This standard focuses on the engineering integrity of the structural components of an offshore wind turbine but is also concerned with subsystems such as control and protection mechanisms, internal electrical systems and mechanical systems.

A wind turbine shall be considered as an offshore wind turbine if the support structure is subject to hydrodynamic loading. The design requirements specified in this standard are not necessarily sufficient to ensure the engineering integrity of floating offshore wind turbines.

This standard should be used together with the appropriate IEC and ISO standards mentioned in Clause 2. In particular, this standard is fully consistent with the requirements of IEC 61400-1. The safety level of the offshore wind turbine designed according to this standard shall be at or exceed the level inherent in IEC 61400-1. In some clauses, where a comprehensive statement of requirements aids clarity, replication of text from IEC 61400-1 is included.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60721-2-1:1982, *Classification of environmental conditions – Part 2-1: Environmental conditions appearing in nature. Temperature and humidity*
Amendment 1:1987

IEC 61400-1:2005, *Wind turbines – Part 1: Design requirements*

IEC 62305-3:2006, *Protection against lightning – Part 3: Physical damage to structures and life hazard*

IEC 62305-4:2006, *Protection against lightning – Part 4: Electrical and electronic systems within structures*

ISO 2394:1998, *General principles on reliability for structures*

ISO 2533:1975, *Standard Atmosphere*

ISO 9001:2000, *Quality management systems – Requirements*

ISO 19900:2002, *Petroleum and natural gas industries – General requirements for offshore structures*

ISO 19901-1:2005, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 1: Metocean design and operating conditions*

ISO 19901-4:2003, *Petroleum and natural gas industries – Specific requirements for offshore structures – Part 4: Geotechnical and foundation design considerations*

ISO 19902, *Petroleum and natural gas industries – Fixed steel offshore structures*

ISO 19903: 2006, *Petroleum and natural gas industries – Fixed concrete offshore structures*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply in addition to those stated in IEC 61400-1.

3.1
co-directional (wind and waves)
acting in the same direction

3.2
current
flow of water past a fixed location usually described in terms of a current speed and direction

3.3
design wave
deterministic wave with a defined height, period and direction, used for the design of an offshore structure. A design wave may be accompanied by a requirement for the use of a particular periodic wave theory

3.4
designer
party or parties responsible for the design of an offshore wind turbine

3.5
environmental conditions
characteristics of the environment (wind, waves, sea currents, water level, sea ice, marine growth, scour and overall seabed movement, etc.) which may affect the wind turbine behaviour

3.6
external conditions (wind turbines)
factors affecting operation of an offshore wind turbine, including the environmental conditions, the electrical network conditions, and other climatic factors (temperature, snow, ice, etc.)

3.7
extreme significant wave height
expected value of the highest significant wave height, averaged over 3 h, with an annual probability of exceedance of 1/N ("recurrence period": N years)

3.8
extreme wave height
expected value of the highest individual wave height (generally the zero up-crossing wave height) with an annual probability of exceedance of 1/N ("recurrence period": N years)

3.9
fast ice cover
rigid continuous cover of ice not in motion

3.10
fetch
distance over which the wind blows constantly over the sea with approximately constant wind speed and direction

3.11
foundation
part of an offshore wind turbine support structure which transfers the loads acting on the structure into the seabed. Different foundation concepts are shown in Figure 1 together with the other parts of an offshore wind turbine

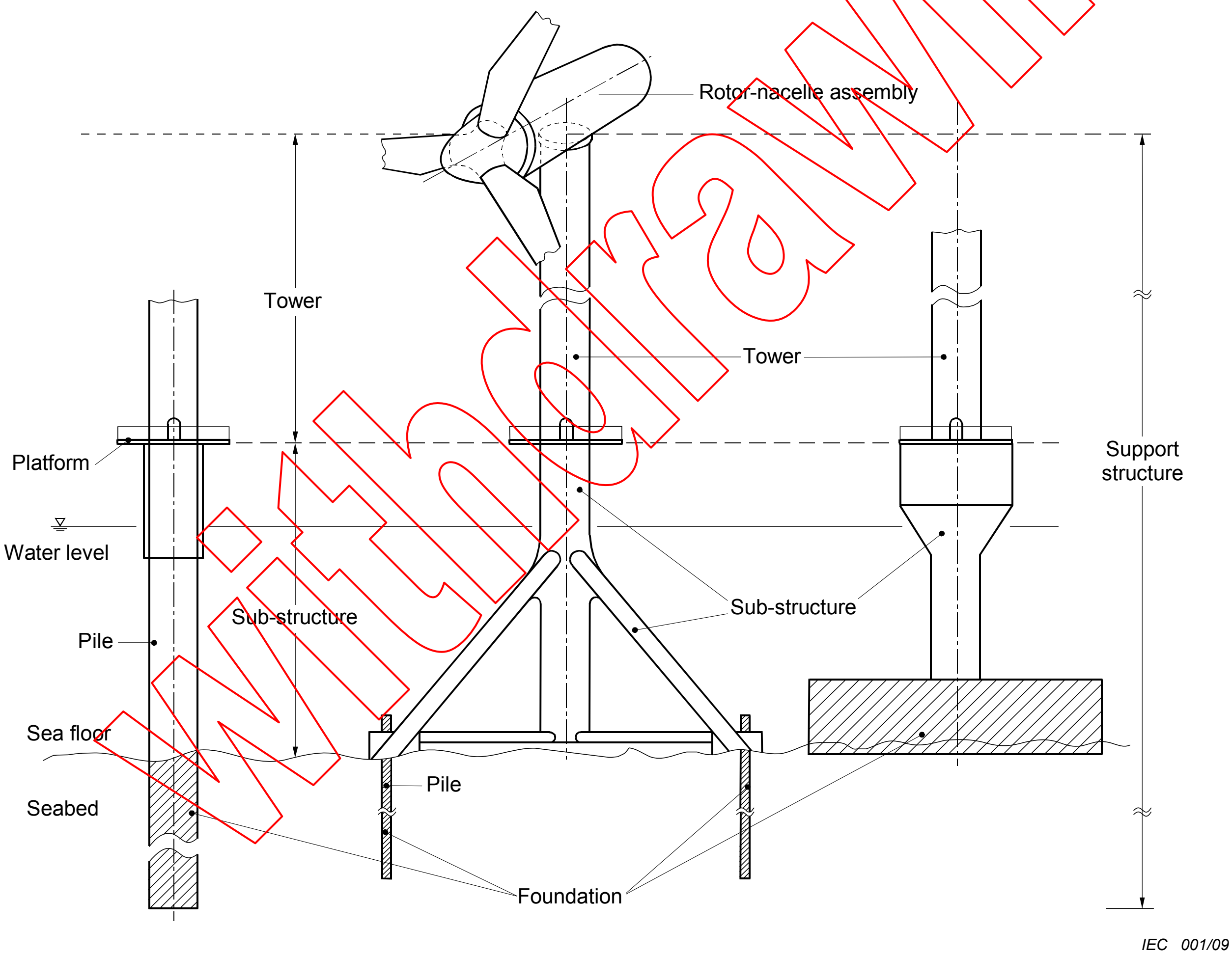

Figure 1 – Parts of an offshore wind turbine

3.12
highest astronomical tide
highest still water level that can be expected to occur under any combination of astronomical conditions and under average meteorological conditions. Storm surges, which are meteorologically generated and essentially irregular, are superimposed on the tidal variations, so that a total still water level above highest astronomical tide may occur

3.13
hindcasting
method of simulating historical (metocean) data for a region through numerical modelling

3.14
hub height (wind turbines)
height of the centre of the swept area of the wind turbine rotor above the mean sea level

3.15
hummocked ice
crushed ice and ice floes piled up into ridges when large ice floes meet with each other or with a rigid obstacle, for example an offshore wind turbine support structure

3.16
ice floe
sheet of ice in size from metres to several kilometres, not rigidly frozen to a shore, still or in motion

3.17
icing
build-up of a cover of ice or frost on parts of an offshore wind turbine that can result in added loads and/or changed properties

3.18
land-locked waters
waters almost or entirely surrounded by land

3.19
load effect
effect of a single load or combination of loads on a structural component or system, for example internal force, stress, strain, motion, etc.

3.20
lowest astronomical tide
lowest still water level that can be expected to occur under any combination of astronomical conditions and under average meteorological conditions. Storm surges, which are meteorologically generated and essentially irregular, are superimposed on the tidal variations, so that a total still water level below lowest astronomical tide may occur

3.21
manufacturer
party or parties responsible for the manufacture and construction of an offshore wind turbine

3.22
marine conditions
characteristics of the marine environment (waves, sea currents, water level, sea ice, marine growth, seabed movement and scour, etc.) which may affect the wind turbine behaviour

3.23
marine growth
surface coating on structural components caused by plants, animals and bacteria

3.24
mean sea level
average level of the sea over a period of time long enough to remove variations due to waves, tides and storm surges

3.25
mean zero crossing period
average period of the zero-crossing (up or down) waves in a sea state

3.26
metocean
abbreviation of meteorological and oceanographic

3.27
multi-directional (wind and/or wave)
distribution of directions

3.28
offshore wind turbine
wind turbine with a support structure which is subject to hydrodynamic loading

3.29
offshore wind turbine site
the location or intended location of an individual offshore wind turbine either alone or within a wind farm

3.30
pile penetration
vertical distance from the sea floor to the bottom of the pile

3.31
power collection system (wind turbines)
electric system that collects the power from one or more wind turbines. It includes all electrical equipment connected between the wind turbine terminals and the network connection point. For offshore wind farms, the power collection system may include the connection to shore

3.32
reference period
period during which stationarity is assumed for a given stochastic process, for example wind speed, sea elevation or response

3.33
refraction
process by which wave energy is redistributed as a result of changes in the wave propagation velocity due to variations in water depth and/or current velocity

3.34
residual currents
components of a current other than tidal current. The most important is often the storm surge current

3.35
rotor – nacelle assembly
part of an offshore wind turbine carried by the support structure, refer to Figure 1

3.36
sea floor
interface between the sea and the seabed

3.37
sea floor slope
local gradient of the sea floor, for example associated with a beach

3.38
sea state
condition of the sea in which its statistics remain stationary

3.39
seabed
materials below the sea floor in which a support structure is founded

3.40
seabed movement
movement of the seabed due to natural geological processes

3.41
scour
removal of seabed soils by currents and waves or caused by structural elements interrupting the natural flow regime above the sea floor

3.42
significant wave height
statistical measure of the height of waves in a sea state, defined as $4 \times \sigma_\eta$ where σ_η is the standard deviation of the sea surface elevation. In sea states with only a narrow band of wave frequencies, the significant wave height is approximately equal to the mean height of the highest third of the zero up-crossing waves

3.43
splash zone
external region of support structure that is frequently wetted due to waves and tidal variations. This shall be defined as the zone between

– the highest still water level with a recurrence period of 1 year increased by the crest height of a wave with height equal to the significant wave height with a return period of 1 year, and
– the lowest still water level with a recurrence period of 1 year reduced by the trough depth of a wave with height equal to the significant wave height with a return period of 1 year

3.44
still water level
abstract water level calculated by including the effects of tides and storm surge but excluding variations due to waves. Still water level can be above, at, or below mean sea level

3.45
storm surge
irregular movement of the sea brought about by wind and atmospheric pressure variations

3.46
sub-structure
part of an offshore wind turbine support structure which extends upwards from the seabed and connects the foundation to the tower, refer to Figure 1

3.47
support structure
part of an offshore wind turbine consisting of the tower, sub-structure and foundation, refer to Figure 1

3.48
swell
sea state in which waves generated by winds remote from the site have travelled to the site, rather than being locally generated

3.49
tidal current
current resulting from tides

3.50
tidal range
distance between the highest astronomical tide and the lowest astronomical tide

3.51
tides
regular and predictable movements of the sea generated by astronomical forces

3.52
tower
part of an offshore wind turbine support structure which connects the sub-structure to the rotor – nacelle assembly, refer to Figure 1

3.53
tsunami
long period sea waves caused by rapid vertical movements of the sea floor

3.54
uni-directional (wind and/or waves)
acting in a single direction

3.55
water depth
vertical distance between the sea floor and the still water level

NOTE As there are several options for the still water level (see 3.44) there can be several water depth values.

3.56
wave crest elevation
vertical distance between the crest of a wave and the still water level

3.57
wave direction
mean direction from which the wave is travelling

3.58
wave height
vertical distance between the highest and lowest points on the water surface of an individual zero up-crossing wave

3.59
wave period
time interval between the two zero up-crossings which bound a zero up-crossing wave

3.60
wave spectral peak frequency
frequency of the peak energy in the wave spectrum

3.61
wave spectrum
frequency domain description of the sea surface elevation in a sea state

3.62
wave steepness
ratio of the wave height to the wave length

3.63
weather downtime
one or more intervals of time during which the environmental conditions are too severe to allow for execution of a specified marine operation

3.64
weather window
interval of time during which the environmental conditions allow for execution of a specified marine operation

3.65
wind profile – wind shear law
mathematical expression for assumed wind speed variation with height above still water level

NOTE Commonly used profiles are the logarithmic profile (equation 1) and the power law profile (equation 2).

$$V(z) = V(z_r) \cdot \frac{\ln(z/z_0)}{\ln(z_r/z_0)} \quad (1)$$

$$V(z) = V(z_r) \cdot \left(\frac{z}{z_r}\right)^{\alpha} \quad (2)$$

where

$V(z)$ is the wind speed at height z;

z is the height above the still water level;

z_r is a reference height above the still water level used for fitting the profile;

z_0 is the roughness length;

α is the wind shear (or power law) exponent.

3.66
zero up-crossing wave
portion of a time history of wave elevation between zero up-crossings. A zero up-crossing occurs when the sea surface rises (rather than falls) through the still water level

4 Symbols and abbreviated terms

For the purposes of this document, the following symbols and abbreviated terms apply in addition to those stated in IEC 61400-1:

4.1 Symbols and units

A_C	Charnock's constant	[-]
d	water depth	[m]
f_p	wave spectral peak frequency	[s^{-1}]
g	acceleration due to gravity	[m/s^2]