

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Wind turbines –
Part 1: Design requirements**

**Eoliennes –
Partie 1: Exigences de conception**

Withdrawn



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IEC 61400-1

Edition 3.0 2005-08

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**Wind turbines –
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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

PRICE CODE **XC**
CODE PRIX

ICS 27.180

ISBN 2-8318-8161-7

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND TURBINES –

Part 1: Design requirements

FOREWORD

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International Standard IEC 61400-1 has been prepared by IEC technical committee 88: Wind turbines.

This third edition cancels and replaces the second edition published in 1999. It constitutes a technical revision.

The main changes with respect to the previous edition are listed below:

- the title has been changed to “Design requirements” in order to reflect that the standard presents safety requirements rather than requirements for safety or protection of personnel;
- wind turbine class designations have been adjusted and now refer to reference wind speed and expected value of turbulence intensities only;

- turbulence models have been expanded and include an extreme turbulence model;
- gust models have been adjusted and simplified;
- design load cases have been rearranged and amended;
- the inclusion of turbulence simulations in the load calculations is emphasised and a scheme for extreme load extrapolation has been specified;
- the partial safety factors for loads have been adjusted and simplified;
- the partial safety factors for materials have been amended and specified in terms of material types and component classes;
- the requirements for the control and protection system have been amended and clarified in terms of functional characteristics;
- a new clause on assessment of structural and electrical compatibility has been introduced with detailed requirements for assessment, including information on complex terrain, earthquakes and wind farm wake effects.

This bilingual version, published in 2007-03, corresponds to the English version.

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

| FDIS | Report on voting |
|-------------|------------------|
| 88/228/FDIS | 88/232/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.

The French version of this standard has not been voted upon.

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

A list of all parts of IEC 61400 series, under the general title *Wind turbine generator systems*, 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 wind turbines and is not intended for use as a complete design specification or instruction manual.

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. This provision, however, does not apply to the classification and the associated definitions of external conditions in Clause 6. Compliance with this standard does not relieve any person, organization, or corporation from the responsibility of observing other applicable regulations.

The standard is not intended to give requirements for wind turbines installed offshore, in particular for the support structure. A future document dealing with offshore installations is under consideration.

Withdrawn

WIND TURBINES –

Part 1: Design requirements

1 Scope

This part of IEC 61400 specifies essential design requirements to ensure the engineering integrity of wind turbines. Its purpose is to provide an appropriate level of protection against damage from all hazards during the planned lifetime.

This standard is concerned with all subsystems of wind turbines such as control and protection mechanisms, internal electrical systems, mechanical systems and support structures.

This standard applies to wind turbines of all sizes. For small wind turbines IEC 61400-2 may be applied.

This standard should be used together with the appropriate IEC and ISO standards mentioned in Clause 2.

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 60204-1:1997, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60204-11:2000, *Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1 000 V a.c. or 1 500 V d.c. and not exceeding 36 kV*

IEC 60364 (all parts), *Electrical installations of buildings*

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

IEC 61000-6-1:1997, *Electromagnetic compatibility (EMC) – Part 6: Generic standards – Section 1: Immunity for residential, commercial and light-industrial environments*

IEC 61000-6-2:1999, *Electromagnetic compatibility (EMC) – Part 6: Generic standards – Section 2: Immunity for industrial environments*

IEC 61000-6-4:1997, *Electromagnetic compatibility (EMC) – Part 6: Generic standards – Section 4: Emission standard for industrial environments*

IEC 61024-1:1990, *Protection of structures against lightning – Part 1: General principles*

IEC 61312-1:1995, *Protection against lightning electromagnetic impulse – Part 1: General principle*

IEC 61400-21:2001, *Wind turbine generator systems – Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines*

IEC 61400-24: 2002, *Wind turbine generator systems – Part 24: Lightning protection*

ISO 76:1987, *Rolling bearings – Static load ratings*

ISO 281:1990, *Rolling bearings – Dynamic load ratings and rating life*

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

ISO 2533:1975, *Standard Atmosphere*

ISO 4354:1997, *Wind actions on structures*

ISO 6336 (all parts), *Calculation of load capacity of spur and helical gears*

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

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1

annual average

mean value of a set of measured data of sufficient size and duration to serve as an estimate of the expected value of the quantity. The averaging time interval should be a whole number of years to average out non-stationary effects such as seasonality

3.2

annual average wind speed

V_{ave}

wind speed averaged according to the definition of annual average

3.3

auto-reclosing cycle

event with a time period, varying from approximately 0,01 s to a few seconds, during which a breaker released after a grid fault is automatically reclosed and the line is reconnected to the network

3.4

blocking (wind turbines)

use of a mechanical pin or other device (other than the ordinary mechanical brake) that cannot be released accidentally to prevent movement, for instance of the rotor shaft or yaw mechanism

3.5

brake (wind turbines)

device capable of reducing the rotor speed or stopping rotation

NOTE The brake may operate on, for example, aerodynamic, mechanical or electrical principles.

3.6

characteristic value

value having a prescribed probability of not being attained (i.e. an exceedance probability of less than or equal to a prescribed amount)

3.7

complex terrain

surrounding terrain that features significant variations in topography and terrain obstacles that may cause flow distortion

3.8

control functions (wind turbines)

functions of the control and protection system that based on information about the condition of the wind turbine and/or its environment, adjust the turbine in order to maintain it within its operating limits

3.9

cut-in wind speed

V_{in}

lowest wind speed at hub height at which the wind turbine starts to produce power in the case of steady wind without turbulence

3.10

cut-out wind speed

V_{out}

highest wind speed at hub height at which the wind turbine is designed to produce power in the case of steady wind without turbulence

3.11

design limits

maximum or minimum values used in a design

3.12

dormant failure

failure of a component or system which remains undetected during normal operation

3.13

downwind

in the direction of the main wind vector

3.14

electrical power network

particular installations, substations, lines or cables for the transmission and distribution of electricity

NOTE The boundaries of the different parts of this network are defined by appropriate criteria, such as geographical situation, ownership, voltage, etc.

3.15**emergency shutdown (wind turbines)**

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

3.16**environmental conditions**

characteristics of the environment (wind, altitude, temperature, humidity, etc.) which may affect the wind turbine behaviour

3.17**external conditions (wind turbines)**

factors affecting operation of a wind turbine, including the environmental conditions (temperature, snow, ice, etc.) and the electrical network conditions

3.18**extreme wind speed**

value of the highest wind speed, averaged over t s, with an annual probability of exceedance of $1/N$ ("recurrence period": N years)

NOTE In this standard recurrence periods of $N = 50$ years and $N = 1$ year and averaging time intervals of $t = 3$ s and $t = 10$ min are used. In popular language, the less precise term survival wind speed is often used. In this standard, however, the turbine is designed using extreme wind speeds for design load cases.

3.19**fail-safe**

design property of an item which prevents its failures from resulting in critical faults

3.20**gust**

temporary change in the wind speed

NOTE A gust may be characterised by its rise-time, its magnitude and its duration.

3.21**horizontal axis wind turbine**

wind turbine whose rotor axis is substantially horizontal

3.22**hub (wind turbines)**

fixture for attaching the blades or blade assembly to the rotor shaft

3.23**hub height (wind turbines)**

z_{hub}

height of the centre of the swept area of the wind turbine rotor above the terrain surface (see 3.51, swept area)

3.24**idling (wind turbines)**

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

3.25

inertial sub-range

frequency interval of the turbulence spectrum, where eddies – after attaining isotropy – undergo successive break-up with negligible energy dissipation

NOTE At a typical 10 m/s wind speed, the inertial sub-range is roughly from 0, 2 Hz to 1 kHz.

3.26

limit state

state of a structure and the loads acting upon it, beyond which the structure no longer satisfies the design requirement

[ISO 2394, modified]

NOTE The purpose of design calculations (i.e. the design requirement for the limit state) is to keep the probability of a limit state being reached below a certain value prescribed for the type of structure in question (see ISO 2394).

3.27

logarithmic wind shear law

see 3.62

3.28

mean wind speed

statistical mean of the instantaneous value of the wind speed averaged over a given time period which can vary from a few seconds to many years

3.29

nacelle

housing which contains the drive-train and other elements on top of a horizontal axis wind turbine tower

3.30

network connection point (wind turbines)

cable terminals of a single wind turbine or, for a wind power station, the connection point to the electrical bus of the site power collection system

3.31

network loss

loss of network for period exceeding any ride through provision in the turbine control system

3.32

normal shutdown (wind turbines)

shutdown in which all stages are under the control of the control system

3.33

operating limits

set of conditions defined by the wind turbine designer that govern the activation of the control and protection system

3.34

parked wind turbine

depending on the design of the wind turbine, parked refers to the turbine being either in a standstill or an idling condition

3.35**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

3.36**power law for wind shear**

see 3.62

3.37**power output**

power delivered by a device in a specific form and for a specific purpose

NOTE (wind turbines) The electric power delivered by a wind turbine.

3.38**protection functions (wind turbine)**

functions of the control and protection system which ensure that a wind turbine remains within the design limits

3.39**rated power**

quantity of power assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment

NOTE (wind turbines) Maximum continuous electrical power output which a wind turbine is designed to achieve under normal operating and external conditions.

3.40**rated wind speed**

V_r

minimum wind speed at hub height at which a wind turbine's rated power is achieved in the case of steady wind without turbulence

3.41**Rayleigh distribution**

P_R

probability distribution function, see 3.63

3.42**reference wind speed**

V_{ref}

basic parameter for wind speed used for defining wind turbine classes. Other design related climatic parameters are derived from the reference wind speed and other basic wind turbine class parameters (see Clause 6)

NOTE A turbine designed for a wind turbine class with a reference wind speed V_{ref} , is designed to withstand climates for which the extreme 10 min average wind speed with a recurrence period of 50 years at turbine hub height is lower than or equal to V_{ref} .

3.43**rotationally sampled wind velocity**

wind velocity experienced at a fixed point of the rotating wind turbine rotor

NOTE The turbulence spectrum of a rotationally sampled wind velocity is distinctly different from the normal turbulence spectrum. While rotating, the blade cuts through a wind flow that varies in space. Therefore, the resulting turbulence spectrum will contain sizeable amounts of variance at the frequency of rotation and harmonics of the same.

3.44

rotor speed (wind turbines)

rotational speed of a wind turbine rotor about its axis

3.45

roughness length

z_0

extrapolated height at which the mean wind speed becomes zero if the vertical wind profile is assumed to have a logarithmic variation with height

3.46

scheduled maintenance

preventive maintenance carried out in accordance with an established time schedule

3.47

site data

environmental, seismic, soil and electrical network data for the wind turbine site. Wind data shall be the statistics of 10 min samples unless otherwise stated

3.48

standstill

condition of a wind turbine that is stopped

3.49

support structure (wind turbines)

part of a wind turbine comprising the tower and foundation

3.50

survival wind speed

popular name for the maximum wind speed that a construction is designed to withstand

NOTE In this standard, the expression is not used. Design conditions instead refer to extreme wind speed (see 3.18).

3.51

swept area

projected area perpendicular to the wind direction that a rotor will describe during one complete rotation

3.52

turbulence intensity

I

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

3.53

turbulence scale parameter

λ_1

wavelength where the non-dimensional, longitudinal power spectral density is equal to 0,05

NOTE The wavelength is thus defined as $\lambda_1 = V_{hub} / f_0$, where $f_0 S_1(f_0) / \sigma_1^2 = 0,05$.

3.54**turbulence standard deviation** σ_1

standard deviation of the longitudinal component of the turbulent wind velocity at hub height

3.55**ultimate limit state**

limit states which generally correspond to maximum load carrying capacity

[ISO 2394, modified]

3.56**unscheduled maintenance**

maintenance carried out, not in accordance with an established time schedule, but after reception of an indication regarding the state of an item

3.57**upwind**

in the direction opposite to the main wind vector

3.58**vertical axis wind turbine**

wind turbine whose rotor axis is vertical

3.59**Weibull distribution** P_w

probability distribution function, see 3.63

3.60**wind farm**

see 3.61

3.61**wind power station**

group or groups of wind turbines, commonly called a wind farm

3.62**wind profile – wind shear law**

mathematical expression for assumed wind speed variation with height above ground

NOTE Commonly used profiles are the logarithmic profile (equation 1) or 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 ground; z_r is a reference height above ground used for fitting the profile; z_0 is the roughness length;

α is the wind shear (or power law) exponent

3.63

wind speed distribution

probability distribution function, used to describe the distribution of wind speeds over an extended period of time

NOTE Often used distribution functions are the Rayleigh, $P_R(V_0)$, and the Weibull, $P_W(V_0)$, functions.

$$P_R(V_0) = 1 - \exp\left[-\pi(V_0/2V_{ave})^2\right] \quad (3)$$

$$P_W(V_0) = 1 - \exp\left[-(V_0/C)^k\right]$$

$$\text{with } V_{ave} = \begin{cases} C \Gamma(1 + \frac{1}{k}) \\ C \sqrt{\pi}/2, \text{ if } k = 2 \end{cases} \quad (4)$$

where

$P(V_0)$ is the cumulative probability function, i.e. the probability that $V < V_0$;

V_0 is the wind speed (limit);

V_{ave} is the average value of V ;

C is the scale parameter of the Weibull function;

k is the shape parameter of the Weibull function;

Γ is the gamma function.

Both C and k can be evaluated from real data. The Rayleigh function is identical to the Weibull function if $k = 2$ is chosen and C and V_{ave} satisfy the condition stated in (equation 4) for $k = 2$.

The distribution functions express the cumulative probability that the wind speed is lower than V_0 . Thus $(P(V_1) - P(V_2))$, if evaluated between the specified limits V_1 and V_2 , will indicate the fraction of time that the wind speed is within these limits. Differentiating the distribution functions yield the corresponding probability density functions

3.64

wind shear

variation of wind speed across a plane perpendicular to the wind direction

3.65

wind shear exponent

α

also commonly known as power law exponent, see 3.62

3.66

wind speed

V

at a specified point in space it is the speed of motion of a minute amount of air surrounding the specified point

NOTE It is also the magnitude of the local wind velocity (vector) (see 3.69).

3.67

wind turbine generator system (wind turbine)

system which converts kinetic energy in the wind into electrical energy

3.68**wind turbine site**

the location of an individual wind turbine either alone or within a wind farm

3.69**wind velocity**

vector pointing in the direction of motion of a minute amount of air surrounding the point of consideration, the magnitude of the vector being equal to the speed of motion of this air "parcel" (i.e. the local wind speed)

NOTE The vector at any point is thus the time derivative of the position vector of the air "parcel" moving through the point.

3.70**wind turbine electrical system**

all electrical equipment internal to the wind turbine, up to and including the wind turbine terminals, including equipment for earthing, bonding and communications. Conductors local to the wind turbine, which are intended to provide an earth termination network specifically for the wind turbine, are included

3.71**wind turbine terminals**

point or points identified by the wind turbine supplier at which the wind turbine may be connected to the power collection system. This includes connection for the purposes of transferring energy and communications

3.72**yawing**

rotation of the rotor axis about a vertical axis (for horizontal axis wind turbines only)

3.73**yaw misalignment**

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

4 Symbols and abbreviated terms**4.1 Symbols and units**

| | | |
|-----------|--|--------------------|
| C | scale parameter of the Weibull distribution function | [m/s] |
| C_{CT} | turbulence structure correction parameter | |
| C_T | thrust coefficient | |
| Coh | coherence function | |
| D | rotor diameter | [m] |
| f | frequency | [s ⁻¹] |
| f_d | design value for material strength | [-] |
| f_k | characteristic value for material strength | [-] |
| F_d | design value for loads | [-] |
| F_k | characteristic value for loads | [-] |
| I_{ref} | expected value of hub-height turbulence intensity at a 10 min average wind speed of 15 m/s | [-] |
| I_{eff} | effective turbulence intensity | [-] |