

Wind turbine generator systems —

Part 1: Safety requirements

The European Standard EN 61400-1:2004 has the status of a
British Standard

ICS 27.180

National foreword

This British Standard is the official English language version of EN 61400-1:2004. It was derived by CENELEC from IEC 61400-1:1999. It supersedes DD ENV 61400-1:1995 which will be withdrawn on 2006-11-01.

The CENELEC common modifications have been implemented at the appropriate places in the text and are indicated by tags (e.g [C] [CI].)

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CENELEC

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Foreword

The text of the International Standard IEC 61400-1:1999, prepared by IEC TC 88, Wind turbines, together with the common modifications prepared by the Technical Committee CENELEC TC 88, Wind turbine systems, was submitted to the formal vote and was approved by CENELEC as EN 61400-1 on 2003-11-01.

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Formulae which are additional to those in IEC 61400-1 are prefixed Z.

Endorsement notice

The text of the International Standard IEC 61400-1:1999 was approved by CENELEC as a European Standard with agreed common modifications.

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INTRODUCTION

Ⓒ The standard contains some requirements for a safe operation of wind turbine generator systems falling in the scope of Article 118a of the EC Treaty. Users of this Standard should, with the respect to these requirements, be aware that standards have no formal legal relationship with Directives which may have been made under Article 118a of the Treaty. In addition, national legislation in the Member states may contain more stringent requirements than the minimum requirements of a Directive based on Article 118a. Information on the relationship between the national legislation implementing Directives based on Article 118a and this Standard may be given in a national foreword of the national standard implementing this Standard. Ⓒ

Any of the requirements of this standard may be waived if it can be suitably demonstrated that the safety of the system is not compromised. Nevertheless this waiver does not apply to clause 6.

Compliance with this standard does not relieve any person, organization, or corporation from the responsibility of observing other applicable regulations.

WIND TURBINE GENERATOR SYSTEMS –

Part 1: Safety requirements

1 Scope and object

This part of IEC 61400 deals with safety philosophy, quality assurance and engineering integrity, and specifies requirements for the safety of Wind Turbine Generator Systems (WTGS), including design, installation, maintenance, and operation under specified environmental conditions. Its purpose is to provide the appropriate level of protection against damage from all hazards from these systems during their planned lifetime.

This standard is concerned with all subsystems of WTGS such as control and protection mechanisms, internal electrical systems, mechanical systems, support structures and the electrical interconnection equipment.

This standard applies to WTGS with a swept area equal to or larger than 40 m².

This standard should be used together with the appropriate IEC/ISO standards identified in clause 2.

ⓘ The standard contains requirements which directly address the operator of wind turbine generator systems. These requirements for a safe operation, however, constitute recommendations for the manufacturer, designed to support him in drafting the operation instruction handbook. ⓘ

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61400. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this part of IEC 61400 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

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 61000-3-2:1998, *Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤16 A per phase)*

IEC 61000-3-3:1994, *Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage fluctuations and flicker in low-voltage supply systems for equipment with rated current ≤16 A*

IEC 61000-4-2:1995, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test. Basic EMC publication*

IEC 61000-4-3:1995, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61000-4-4:1995, *Electromagnetic compatibility (EMC) – Part 4-4: Testing and measurement techniques – Electrical fast transient/burst immunity test. Basic EMC publication*

IEC 61000-4-5:1995, *Electromagnetic compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test*

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 principles*

ISO 2394:1986, *General principles on reliability for structures*

3 Terms and definitions

For the purpose of this International Standard, the following 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 shall be a whole number of years to average out non-stationary effects such as seasonality

3.2

annual average wind speed

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) 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

3.6

catastrophic failure (wind turbines)

disintegration or collapse of a component or structure, that results in loss of vital function which impairs safety

3.7

characteristic value (of a material property)

value having a prescribed probability of not being attained in a hypothetical unlimited test series

3.8

complex terrain

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

3.9

control system (wind turbines)

subsystem that receives information about the condition of the wind turbine and/or its environment and adjusts the turbine in order to maintain it within its operating limits

3.10

cut-in wind speed (V_{in})

lowest mean wind speed at hub-height at which the wind turbine starts to produce power (see 3.24, hub-height)

3.11

cut-out wind speed (V_{out})

highest mean wind speed at hub-height at which the wind turbine is designed to produce power (see 3.24, hub-height)

3.12

design limits

maximum or minimum values used in a design

3.13

dormant failure (also known as latent fault)

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

3.14

downwind

in the direction of the main wind vector

3.15

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.

3.16

emergency shutdown (wind turbines)

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

3.17

environmental conditions

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

3.18

external conditions (wind turbines)

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

3.19**extreme wind speed**

highest average wind speed, averaged over t s, that is likely to be experienced within a specified time period of N years ("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.

3.20**fail-safe**

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

3.21**gust**

temporary change in the wind speed

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

3.22**horizontal axis wind turbine**

wind turbine whose rotor axis is substantially parallel to the wind flow

3.23**hub (wind turbines)**

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

3.24**hub-height (wind turbines)**

height of the centre of the swept area of the wind turbine rotor above the terrain surface (see 3.55, swept area)

3.25**idling (wind turbines)**

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

3.26**inertial subrange**

frequency interval of the wind 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 subrange is roughly from 0,02 Hz to 2 kHz.

3.27**isolated operation**

stable and temporary operation of a discrete part of a power system after network splitting

3.28**limit state**

state of a structure and the loads acting upon it, beyond which the structure no longer satisfies the design requirement (ISO 2394)

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 (ISO 2394).

3.29**logarithmic wind shear law**

see wind profile

3.30

maximum power (wind turbines)

highest level of net electrical power delivered by a wind turbine in normal operation

3.31

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

3.32

nacelle

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

3.33

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

3.34

normal shutdown (wind turbines)

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

3.35

operating limits

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

3.36

parked wind turbine

depending on the construction of the wind turbine, parked refers to the turbine being either in a stand-still or an idling condition

3.37

power collection system (wind turbines)

electric connection system that collects the power from one or more wind turbines. It includes all electrical equipment connected between the WTGS terminals and the network connection point

3.38

power law for wind shear

see wind profile

3.39

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 WTGS.

3.40

protection system (wind turbine)

system which ensures that a WTGS remains within the design limits

3.41**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 WTGS is designed to achieve under normal operating conditions.

3.42**rated wind speed (V_r)**

specified wind speed at which a wind turbine's rated power is achieved

3.43**Rayleigh distribution**

probability distribution function, see 3.66 (wind speed distribution)

3.44**reference wind speed (V_{ref})**

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

NOTE – A turbine designed for a WTGS 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} .

3.45**resonance**

phenomenon appearing in an oscillating system, in which the period of a forced oscillation is very close to that of free oscillation

3.46**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.

3.47**rotor speed (wind turbines)**

rotational speed of a wind turbine rotor about its axis

3.48**roughness length**

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

3.49**safe life**

prescribed service life with a declared probability of catastrophic failure

3.50**scheduled maintenance**

preventive maintenance carried out in accordance with an established time schedule

3.51**serviceability limit state**

limit state which corresponds with criteria governing function related normal use (ISO 2394)

3.52

standstill

condition of a WTGS that is stopped

3.53

support structure (wind turbines)

part of a wind turbine comprising the tower and foundation

3.54

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 3.19).

3.55

swept area

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

3.56

turbulence intensity

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

3.57

turbulence scale parameter

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

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

3.58

ultimate limit state

limit states which generally correspond to maximum load carrying capacity (ISO 2394)

3.59

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

3.60

upwind

in the direction opposite to the main wind vector

3.61

vertical axis wind turbine

wind turbine whose rotor axis is vertical

3.62

Weibull distribution

probability distribution function, see 3.66 (wind speed distribution)

3.63

wind farm

see 3.64 (wind power station)

3.64

wind power station

group or groups of wind turbine generators, commonly called a wind farm

3.65**wind profile – wind shear law**

mathematical expression for assumed wind speed variation with height above ground

NOTE – Commonly used profiles are the logarithmic profile (1) or the power law profile (2).

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

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

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

3.66**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.

$$\begin{aligned} P_R(V_0) &= 1 - \exp[-\pi(V_0/2V_{ave})^2] \\ P_W(V_0) &= 1 - \exp[-(V_0/C)^k] \end{aligned} \quad (3)$$

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

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 yields the corresponding probability density functions.

3.67

wind shear

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

3.68

wind shear exponent

also commonly known as power law exponent, see 3.65 (wind profile – wind shear law)

3.69

wind speed

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

NOTE – The wind speed is also the magnitude of the local wind velocity (vector) (see 3.71, wind velocity).

3.70

wind turbine generator system (WTGS)

system which converts kinetic energy in the wind into electrical energy

3.71

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.

3.72

WTGS electrical system

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

3.73

WTGS terminals

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

3.74

yawing

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

3.75

yaw misalignment

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

4 Symbols and abbreviated terms

4.1 Symbols and units

a	slope parameter for turbulence standard deviation model	[-]
C	scale parameter of the Weibull distribution function	[m/s]
Coh	coherency 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_{15}	characteristic value of hub-height turbulence intensity at a 10 min average wind speed of 15 m/s	[-]
k	shape parameter of the Weibull distribution function	[-]
K	modified Bessel function	[-]
L	isotropic turbulence integral scale parameter	[m]
L_e	coherency scale parameter	[m]
L_k	velocity component integral scale parameter	[m]
n_i	counted number of fatigue cycles in load bin i	[-]
$N(.)$	is the number of cycles to failure as a function of the stress (or strain) indicated by the argument (i.e. the characteristic S-N curve)	[-]
N	recurrence period for extreme situations	[y]
p	survival probability	[-]
$P_R(V_0)$	Rayleigh probability distribution, i.e. the probability that $V < V_0$	[-]
$P_W(V_0)$	Weibull probability distribution	[-]
r	magnitude of separation vector projection	[m]
s_i	the stress (or strain) level associated with the counted number of cycles in bin i	[-]
$S_1(f)$	power spectral density function	[m ² /s ²]
S_k	single-sided velocity component spectrum	[m ² /s ²]
T	gust characteristic time	[s]
t	time	[s]
V	wind speed	[m/s]
$V(z)$	wind speed at height z	[m/s]
V_{ave}	annual average wind speed at hub-height	[m/s]
V_{cg}	extreme coherent gust magnitude over the whole rotor swept area	[m/s]
V_{eN}	expected extreme wind speed (averaged over 3 s), with a recurrence time interval of N years. V_{e1} and V_{e50} for 1 year and 50 years, respectively	[m/s]
V_{gustN}	largest gust magnitude with an expected recurrence period of N years.	[m/s]
V_{hub}	wind speed at hub-height averaged over 10 min	[m/s]
V_{in}	cut-in wind speed	[m/s]
V_0	limit wind speed in wind speed distribution model	[m/s]
V_{out}	cut-out wind speed	[m/s]
V_r	rated wind speed	[m/s]

V_{ref}	reference wind speed averaged over 10 min	[m/s]
$V(y,z,t)$	longitudinal wind velocity component to describe transient horizontal wind shear	[m/s]
$V(z,t)$	longitudinal wind velocity component to describe transient variation for extreme gust and shear conditions	[m/s]
x, y, z	coordinate system used for the wind field description; along wind (longitudinal), across wind (lateral) and height respectively	[m]
z_{hub}	hub-height of the wind turbine	[m]
z_r	reference height above ground	[m]
z_0	roughness length for the logarithmic wind profile	[m]
α	wind shear power law exponent	[-]
β	parameter for extreme direction change model	[-]
δ	coefficient of variation	[-]
Γ	gamma function	[-]
γ_f	partial safety factor for loads	[-]
γ_m	partial safety factor for materials	[-]
γ_n	partial safety factor for consequences of failure	[-]
$\theta(t)$	wind direction change transient	[°]
θ_{cg}	angle of maximum deviation from the direction of the average wind speed under gust conditions	[°]
θ_{eN}	extreme direction change with a recurrence period of N years	[°]
λ_1	turbulence scale parameter defined as the wave length where the non-dimensional, longitudinal power spectral density, $fS_1(f)/\sigma_1^2$, is equal to 0,05	[m]
σ_1	hub-height longitudinal wind velocity standard deviation	[m/s]
σ_k	k^{th} hub-height component wind velocity standard deviation ($k = 1, 2, \text{ or } 3$)	[m/s]

4.2 Abbreviations

A	Abnormal (for partial safety factors)
a.c.	Alternating current
C	Serviceability constraint
d.c.	Direct current
DLC	Design load case
ECD	Extreme coherent gust with direction change
ECG	Extreme coherent gust
EDC	Extreme wind direction change
EOG	Extreme operating gust
EWM	Extreme wind speed model
EWS	Extreme wind shear
F	Fatigue
HAWT	Horizontal axis wind turbine
N	Normal and extreme (for partial safety factors)
NWP	Normal wind profile model
NTM	Normal turbulence model
S	Special IEC WTGS class