

Wind turbine generator systems —

Part 1: Safety requirements

Committees responsible for this Draft for Development

The preparation of this Draft for Development was entrusted to Technical Committee PEL/88, Wind turbine systems, upon which the following bodies were represented:

- British Wind Energy Association
- Electricity Association
- Energy Industries Council
- Lloyds Register Engineering Services

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National foreword

This Draft for Development has been prepared by Technical Committee PEL/88 and is the English language version of European Prestandard ENV 61400-1:1995 *Wind turbine generator systems — Part 1: Safety requirements*, published by the European Committee for Electrotechnical Standardization (CENELEC). It is identical with IEC 1400-1:1994 published by the International Electrotechnical Commission (IEC).

This publication is not to be regarded as a British Standard.

It is being issued in the Draft for Development series of publications and is of a provisional nature. It should be applied on this provisional basis so that information and experience of its practical application may be obtained.

Comments arising from the use of this Draft for Development are requested so that UK experience can be reported to the European organization responsible for its conversion to a European Standard. A review of this publication will be initiated 2 years after its publication by the European organization so that a decision can be taken on its status at the end of its three-year life. The commencement of the review will be notified by an announcement in *BSI News*.

According to the replies received by the end of the review period, the responsible BSI Committee will decide whether to support the conversion into a European Standard, to extend the life of the prestandard or to withdraw it. Comments should be sent in writing to the Secretary of BSI Technical Committee PEL/88 at 389 Chiswick High Road, London W4 4AL giving the document reference and clause number and proposing, where possible, an appropriate revision of the text.

Cross-references

Publication referred to	Corresponding British Standard
HD 472 S1:1988 (IEC 38:1983)	BS 7697:1993 <i>Nominal voltages for low voltage public electricity supply systems</i>
EN 60529:1991 (IEC 529:1989)	BS EN 60529:1992 <i>Specification for degrees of protection provided by enclosures (IP code)</i> BS 7527 <i>Classification of environmental conditions</i> Part 2: <i>Environmental conditions appearing in nature</i>
HD 478.2.1 S1:1989 (IEC 721-2-1:1982)	Section 2.1:1991 <i>Temperature and humidity</i>
EN 61000 (IEC 1000)	BS EN 61000 <i>Electromagnetic compatibility (EMC)</i>

ISO 9001:1987, ISO 9002:1987 and ISO 9003:1987 have been superseded by ISO 9001:1994, ISO 9002:1994 and ISO 9003:1994, respectively, which are identical with BS EN ISO 9001:1994, BS EN ISO 9002:1994 and BS EN ISO 9003:1994, respectively.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, the ENV title page, pages 2 to 40, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

English version

Wind turbine generator systems Part 1: Safety requirements

(IEC 1400-1:1994)

Aérogénérateurs
Partie 1: Spécifications de sécurité
(CEI 1400-1:1994)

Windturbogeneratorsysteme
Teil 1: Sicherheitsanforderungen
(IEC 1400-1:1994)

This European Prestandard (ENV) was approved by CENELEC on 1994-10-24 as a prospective standard for provisional application. The period of validity of this ENV is limited initially to three years. After two years the members of CENELEC will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard (EN).

CENELEC members are required to announce the existence of this ENV in the same way as for an EN and to make the ENV available promptly at national level in an appropriate form. It is permissible to keep conflicting national standards in force (in parallel to the ENV) until the final decision about the possible conversion of the ENV into an EN is reached.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

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Foreword

The text of document 88(CO)5, future edition 1 of IEC 1400-1, prepared by IEC TC 88, Wind turbine generator systems, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as ENV 61400-1 on 1994-12-06.

The following date was fixed:

- latest date by which the existence of the ENV has to be announced at national level (dop) 1995-02-15

Annexes designated “normative” are part of the body of the standard. Annexes designated “informative” are given for information only. In this standard, Annex A, Annex B, Annex C, and Annex ZA are normative and Annex D is informative. Annex ZA has been added by CENELEC.

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1 General

1.1 Scope and object

This part of IEC 1400 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 applies to WTGS with swept area equal to or larger than 40 m². This standard is also concerned with all sub-systems of WTGS such as control and protection mechanisms, internal electrical systems, mechanical systems, support structures, foundations and the electrical interconnection equipment.

This standard should be used together with the appropriate IEC/ISO standards.

1.2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 1400. 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 1400 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 38:1983, *IEC standard voltages*.

IEC 227, *Polyvinyl chloride insulated cables of rated voltages up to and including 450/750 V*.

IEC 245, *Rubber insulated cables of rated voltages up to and including 450/750 V*.

IEC 287:1982, *Calculation of the continuous current rating of cables (100 % load factor)*.

IEC 364, *Electrical installations of buildings*.

IEC 364-5-54:1980, *Electrical installations of buildings — Part 5: Selection and erection of electrical equipment — Chapter 54: Earthing arrangements and protective conductors*.

IEC 529:1989, *Degrees of protection provided by enclosures (IP Code)*.

IEC 721-2-1:1982, *Classification of environmental conditions — Part 2: Environmental conditions appearing in nature — Temperature and humidity*.

IEC 1000, *Electromagnetic compatibility (EMC)*.

IEC 1024-1:1990, *Protection of structures against lightning — Part 1: General principles*.

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

ISO 9001:1987, *Quality systems — Model for quality assurance in design/development, production, installation and servicing*.

ISO 9002:1987, *Quality systems — Model for quality assurance in production and installation*.

ISO 9003:1987, *Quality systems — Model for quality assurance in final inspection and test*.

1.3 Definitions

For the purpose of this part of IEC 1400, the following definitions apply.

1.3.1

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

NOTE The time period should be a whole number of years to average out non-stationary effects such as seasonality.

1.3.2

annual average wind speed

wind speed averaged according to the definition of annual average

1.3.3

blocking (wind turbines)

use of a mechanical pin or other device to prevent movement, for instance, of the rotor shaft or yaw mechanism

1.3.4

brake (wind turbines)

device capable of reducing the rotor speed or stopping rotation

1.3.5

catastrophic failure (wind turbines)

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

1.3.6

control system (wind turbines)

sub-system 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

1.3.7

cut-in wind speed (V_{in})

lowest wind speed at hub height at which the wind turbine starts to produce useable power (see hub height)

1.3.8

cut-out wind speed (V_{out})

maximum wind speed at hub height at which the wind turbine is designed to produce useable power (see hub height)

1.3.9

design limits

maximum or minimum values used in a design

1.3.10

dormant failure

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

1.3.11

downwind

in the main wind direction

1.3.12

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.

1.3.13

emergency shutdown (wind turbines)

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

1.3.14

environmental conditions

those characteristics of the environment (altitude, temperature, humidity, etc.) which may affect performance

1.3.15

external conditions (wind turbines)

factors affecting the operation of wind turbine including the wind regime and other climatic factors, i.e. snow, ice etc.

1.3.16**extreme wind speed**

highest average wind speed, averaged over t s, that is likely to be experienced within a specified time period of T years (recurrence period: T years)

NOTE In this standard recurrence periods of $T = 50$ years and $T = 1$ year and averaging times 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 the extreme wind speed for design load cases.

1.3.17**fail-safe**

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

1.3.18**gust**

temporary change in the wind speed which may be characterized by its rise-time, its amplitude and its duration

1.3.19**horizontal axis wind turbine**

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

1.3.20**hub** (wind turbine)

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

1.3.21**hub height**

height of the centre of the wind turbine rotor above the terrain surface. For a vertical axis wind turbine, the hub height is the height of the equator plane

1.3.22**idling** (wind turbines)

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

1.3.23**inertial sub-range**

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 sub-range is roughly from 0,02 Hz to 2 kHz.

1.3.24**interconnection**

single or multiple transmission link between transmission systems enabling electricity to be exchanged between these systems by means of circuits and/or transformers

NOTE (wind turbines) Electrical connection between a wind turbine generator system and a network in which energy can be transferred from the wind turbine to the network and vice versa.

1.3.25**isolated operation**

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

1.3.26**limit state**

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

1.3.27**logarithmic wind shear law**

see wind profile

1.3.28

maximum power (wind turbines)

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

1.3.29

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

1.3.30

nacelle

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

1.3.31

network connection point (wind turbines)

low-voltage tap on the transformer of the wind turbine or the connection point to the electrical bus of the site facilities

1.3.32

parking brake (wind turbines)

brake capable of preventing rotor movement

1.3.33

power collection system (wind turbines)

electrical system that collects the power from a wind turbine, and feeds it into a network step-up transformer or into electrical loads

1.3.34

power law for wind shear

see wind profile

1.3.35

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.

1.3.36

protection system (wind turbines)

system which ensures that a WTGS remains within the design limits

1.3.37

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.

1.3.38

rated wind speed (V_r)

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

1.3.39

rayleigh distribution

see 1.3.63

1.3.40

reference wind speed (V_{ref})

basic extreme wind speed parameter used for defining wind turbine classes. Other design-related climatic parameters are derived from the reference wind speed and other basic class parameters (see clause 3)

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} .

1.3.41**resonance**

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

1.3.42**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.

1.3.43**rotor speed** (wind turbines)

rotational speed of a wind turbine rotor about its axis

1.3.44**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

1.3.45**safe life**

prescribed service life with a declared probability of catastrophic failure

1.3.46**scheduled maintenance**

preventive maintenance carried out in accordance with an established time schedule

1.3.47**serviceability limit states**

conditions relating to the boundaries of normal service criteria

1.3.48**shutdown** (wind turbines)

transitional state of a wind turbine between power production and standstill or idling

1.3.49**site electrical facilities**

all electrical and related equipment required to connect the wind turbines with the network

1.3.50**standstill**

condition of a WTGS that is stopped

1.3.51**support structure** (wind turbines)

part of a wind turbine comprising the tower and foundation

1.3.52**survival wind speed**

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

NOTE In this standard, this expression is not used. Design conditions instead refer to extreme wind speed (see 1.3.16).

1.3.53**swept area**

area of the projection, upon a plane perpendicular to the wind velocity vector, of the circle along which the rotor blade tips move during rotation

1.3.54

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

1.3.55

turbulence scale parameter

wave length where the non-dimensional, longitudinal power spectral density, $fS_l(f)/\sigma_1^2$, is equal to 0,05

1.3.56

ultimate limit state

limit state corresponding to the danger of failure, large displacements or strain which can be compared with failure

1.3.57

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

1.3.58

upwind

in the direction opposite to the main wind direction

1.3.59

vertical axis wind turbine

wind turbine whose rotor axis is vertical

1.3.60

weibull distribution

see 1.3.63

1.3.61

wind power station

group or groups of wind turbine generators

1.3.62

wind profile — wind shear law

mathematical expression for assumed wind speed variation with height above ground

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

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

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

where

V 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_o is the roughness length;

α is the power law exponent.

1.3.63

wind shear

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

1.3.64

wind shear exponent

see 1.3.62

1.3.65

wind speed

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

1.3.66

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, $P_R(V_o)$, and the Weibull, $P_w(V_o)$, functions.

$$P_R \{V < V_o\} = 1 - \exp \left[-\pi (V_o/2 V_{ave})^2 \right]$$

$$P_w \{V < V_o\} = 1 - \exp \left[- (V_o/C)^k \right]$$
(3)

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

where

- $P(V_o)$ is the cumulative probability function;
- V_o 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} satisfied the condition stated in equation (4) for $k = 2$.

The distribution functions express the cumulative probability that the wind speed is lower than V_o . Thus $(P\{V < V_1\} - P\{V < V_2\})$, 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.

1.3.67

wind turbine generator system (WTGS)

system which converts kinetic energy in the wind into electrical energy

1.3.68

wind velocity

vector pointing in the direction of motion of a minute amount of air surrounding the point of consideration

NOTE The length of the vector is equal to the speed of motion of this air parcel (i.e. the local wind speed). The vector at any point is thus the time derivative of the position vector of the air parcel moving through the point.

1.3.69

yawing

rotation of the rotor axis about a vertical axis

1.4 Symbols and units

1.4.1	C	scale parameter of the Weibull distribution function	[m/s]
1.4.2	D	rotor diameter	[m]
1.4.3	f	frequency	[s ⁻¹]
1.4.4	l_{ave}	annual average turbulence intensity at hub height	[-]
1.4.5	k	shape parameter of the Weibull distribution function	
1.4.6	$p(V)$	probability density function	[-]
1.4.7	$P(V)$	probability distribution	[-]
1.4.8	$S_1(f)$	power spectral density function	
1.4.9	T	gust duration time	[s]

1.4.10	t	time	[s]
1.4.11	V	wind speed	[m/s]
1.4.12	$V(z)$	wind speed at height z	[m/s]
1.4.13	V_{ave}	annual average wind speed at hub height	[m/s]
1.4.14	V_{cg}	maximum coherent gust over the whole rotor swept area	[m/s]
1.4.15	V_{e50}	expected extreme wind speed (averaged over 3 s), with a recurrence time interval of 50 years.	
		NOTE The calculation of the extreme wind speed shall consider factors accounting for the height above the terrain, expected level of exposure, terrain roughness, and topographic character at the intended site type.	[m/s]
1.4.16	V_{e1}	as V_{e50} , but with a recurrence time interval of 1 year	[m/s]
1.4.17	V_{gust50}	largest 50-year gust magnitude which starts within 2 m/s of a target starting hub-height wind speed and has an expected recurrence time interval equal to 50 years	[m/s]
1.4.18	V_{gust1}	as V_{gust50} , but with a recurrence time interval of 1 year	[m/s]
1.4.19	V_{hub}	10 min average wind speed at hub height	[m/s]
1.4.20	V_{in}	cut-in wind speed	[m/s]
1.4.21	V_{out}	cut-out wind speed	[m/s]
1.4.22	V_r	rated wind speed	[m/s]
1.4.23	V_{ref}	the reference wind speed for the turbine class selected	[m/s]
1.4.24	$V_1(y, z, t)$	longitudinal wind speed component to describe horizontal and vertical wind shear	[m/s]
1.4.25	$V_1(z, t)$	longitudinal wind speed component at height z and time t	[m/s]
1.4.26	z	height above ground	[m]
1.4.27	Z_{hub}	hub height (i.e. the height of the centre) of the wind turbine	[m]
1.4.28	z_r	reference height above ground	[m]
1.4.29	z_o	roughness length for the logarithmic wind profile	[m]
1.4.30	α	wind shear power law exponent	[-]
1.4.31	Γ	gamma function	[-]
1.4.32	γ_f	partial safety factor for loads	[-]
1.4.33	γ_m	partial safety factor for materials	[-]
1.4.34	$\theta(t)$	wind direction change transient	[-]
1.4.35	θ_{cg}	angle of deviation from the direction of the average wind speed under gust conditions	[°]
1.4.36	θ_{ext}	largest direction change which occurs while the average hub-height wind speed is within 2 m/s of the target hub-height wind speed at the beginning of the transient and has an expected recurrence interval equal to that used for the extreme wind conditions	[°]
1.4.37	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]
1.4.38	σ_1	hub-height longitudinal wind speed standard deviation	[m/s]
1.4.39	σ_2	hub-height lateral wind speed standard deviation	[m/s]
1.4.40	σ_3	hub-height vertical wind speed standard deviation	[m/s]