

BS EN 61400-2:2014



BSI Standards Publication

Wind turbines

Part 2: Small wind turbines

bsi.

...making excellence a habit.™

National foreword

This British Standard is the UK implementation of EN 61400-2:2014. It is identical to IEC 61400-2:2013. It supersedes BS EN 61400-2:2006 which is withdrawn.

The UK participation in its preparation was entrusted to Technical Committee PEL/88, Wind turbines.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

© The British Standards Institution 2014.
Published by BSI Standards Limited 2014

ISBN 978 0 580 75719 8
ICS 27.180

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2014.

Amendments issued since publication

Date	Text affected
-------------	----------------------

EUROPEAN STANDARD

EN 61400-2

NORME EUROPÉENNE

EUROPÄISCHE NORM

October 2014

ICS 27.180

Supersedes EN 61400-2:2006

English Version

**Wind turbines - Part 2: Small wind turbines
(IEC 61400-2:2013)**Eoliennes-- Partie 2: Petits aérogénérateurs
(CEI 61400-2:2013)Windenergieanlagen - Teil 2: Anforderungen für kleine
Windenergieanlagen
(IEC 61400-2:2013)

This European Standard was approved by CENELEC on 2014-01-16. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the CEN-CENELEC Management Centre or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the CEN-CENELEC Management Centre has the same status as the official versions.

CENELEC members are the national electrotechnical committees of Austria, Belgium, Bulgaria, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, Former Yugoslav Republic of Macedonia, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey and the United Kingdom.



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

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Foreword

The text of document 88/465/FDIS, future edition 3 of IEC 61400-2, prepared by IEC/TC 88 "Wind turbines" and ISO/TC 60 "Gears" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61400-2:2014.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2015-04-10
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2017-01-16

This document supersedes EN 61400-2:2006

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 61400-2:2013 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

IEC 60034 (Series)	NOTE	Harmonized as EN 60034 (Series).
IEC 60364 (Series)	NOTE	Harmonized as HD 60364 (Series).
IEC 60529:1989	NOTE	Harmonized as EN 60529:1991.
IEC 61400-1:2005	NOTE	Harmonized as EN 61400-1:2005.
IEC 61400-4	NOTE	Harmonized as EN 61400-4.
IEC 61400-21:2008	NOTE	Harmonized as EN 61400-21:2008.
IEC 61400-22:2010	NOTE	Harmonized as EN 61400-22:2011.
IEC 61400-24	NOTE	Harmonized as EN 61400-24.
ISO/IEC 17020:2012	NOTE	Harmonized as EN ISO/IEC 17020:2012.
ISO 9000 (Series)	NOTE	Harmonized as EN ISO 9000 (Series).
ISO 9001:2008	NOTE	Harmonized as EN ISO 9001:2008.

Annex ZA

(normative)

Normative references to international publications with their corresponding European publications

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

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 60038 (mod)	2009	IEC standard voltages	EN 60038	2011
IEC 60204-1 (mod)	2005	Safety of machinery - Electrical equipment of machines -- Part 1: General requirements	EN 60204-1 +prA11 +EN 60204-1:2006/corrigendum Feb. 2010	2006 2010
IEC 60364-5-54	-	Low-voltage electrical installations -- Part 5-54: Selection and erection of electrical equipment - Earthing arrangements and protective conductors	HD 60364-5-54 +FprAA	- 2011
IEC 60721-2-1	-	Classification of environmental conditions -- Part 2-1: Environmental conditions appearing in nature - Temperature and humidity	EN 60721-2-1	-
IEC 61400-1	2005	Wind turbines -- Part 1: Design requirements	EN 61400-1 +prA	2005
IEC 61400-11	-	Wind turbines -- Part 11: Acoustic noise measurement techniques	EN 61400-11	-
IEC 61400-12-1	2005	Wind turbines -- Part 12-1: Power performance measurements of electricity producing wind turbines	EN 61400-12-1	2006
IEC 61643-11 (mod)	2011	Low-voltage surge protective devices -- Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods	EN 61643-11	2012
ISO 2394	1998	General principles on reliability for structures-	-	-
IEC/TS 61400-13	-	Wind turbine generator systems - Part 13: Measurement of mechanical loads	-	-
IEC/TS 61400-23	2001	Wind turbine generator systems -- Part 23: Full-scale structural testing of rotor blades	-	-
ISO/IEC 17025	-	General requirements for the competence of testing and calibration laboratories	EN ISO/IEC 17025	-

CONTENTS

1	Scope	11
2	Normative references	11
3	Terms and definitions	12
4	Symbols and abbreviated terms	21
4.1	General	21
4.2	Symbols	21
4.3	Coordinate system	25
5	Principal elements	26
5.1	General	26
5.2	Design methods	27
5.3	Quality assurance	27
1	Design evaluation	29
6	External conditions	29
6.1	General	29
6.2	SWT classes	29
6.3	Wind conditions	30
6.3.1	General	30
6.3.2	Normal wind conditions	30
6.3.3	Extreme wind conditions	32
6.4	Other environmental conditions	36
6.4.1	General	36
6.4.2	Other normal environmental conditions	37
6.4.3	Other extreme environmental conditions	37
6.5	Controlled test conditions	38
6.6	Electrical load conditions	38
6.6.1	General	38
6.6.2	For turbines connected to the electrical power network	38
6.6.3	For turbines not connected to the electrical power network	38
7	Structural design	39
7.1	General	39
7.2	Design methodology	39
7.3	Loads and load cases	39
7.3.1	General	39
7.3.2	Vibration, inertial and gravitational loads	39
7.3.3	Aerodynamic loads	39
7.3.4	Operational loads	40
7.3.5	Other loads	40
7.3.6	Load cases	40
7.4	Simplified loads methodology	40
7.4.1	General	40
7.4.2	Load case A: normal operation	42
7.4.3	Load case B: yawing	43
7.4.4	Load case C: yaw error	44
7.4.5	Load case D: maximum thrust	44
7.4.6	Load case E: maximum rotational speed	44

7.4.7	Load case F: short at load connection	44
7.4.8	Load case G: shutdown (braking)	44
7.4.9	Load case H: extreme wind loading	45
7.4.10	Load case I: parked wind loading, maximum exposure.....	46
7.4.11	Load case J: transportation, assembly, maintenance and repair.....	47
7.5	Simulation modelling.....	47
7.5.1	General	47
7.5.2	Power production (DLC 1.1 to 1.5).....	48
7.5.3	Power production plus occurrence of fault (DLC 2.1 to 2.3).....	49
7.5.4	Normal shutdown (DLC 3.1 and 3.2)	49
7.5.5	Emergency or manual shutdown (DLC 4.1)	49
7.5.6	Extreme wind loading (stand-still or idling or spinning) (DLC 5.1 to 5.2).....	49
7.5.7	Parked plus fault conditions (DLC 6.1).....	50
7.5.8	Transportation, assembly, maintenance and repair (DLC 7.1).....	50
7.5.9	Load calculations.....	50
7.6	Load measurements.....	50
7.7	Stress calculation	50
7.8	Safety factors.....	51
7.8.1	Material factors and requirements.....	51
7.8.2	Partial safety factor for loads	52
7.9	Limit state analysis	52
7.9.1	Ultimate strength analysis.....	52
7.9.2	Fatigue failure	53
7.9.3	Critical deflection analysis	53
8	Protection and shutdown system	54
8.1	General.....	54
8.2	Functional requirements of the protection system	54
8.3	Manual shutdown.....	54
8.4	Shutdown for maintenance.....	55
9	Electrical system	55
9.1	General.....	55
9.2	Protective devices.....	55
9.3	Disconnect device.....	56
9.4	Earthing (grounding) systems	56
9.5	Lightning protection	56
9.6	Electrical conductors and cables.....	56
9.7	Electrical loads	56
9.7.1	General	56
9.7.2	Battery charging	56
9.7.3	Electrical power network (grid connected systems).....	57
9.7.4	Direct connect to electric motors (e.g. water pumping).....	57
9.7.5	Direct resistive load (e.g. heating)	57
9.8	Local requirements	57
10	Support structure.....	58
10.1	General.....	58
10.2	Dynamic requirements	58
10.3	Environmental factors	58

10.4	Earthing	58
10.5	Foundation.....	58
10.6	Turbine access design loads.....	58
11	Documentation requirements	58
11.1	General.....	58
11.2	Product manuals	59
11.2.1	General	59
11.2.2	Specification.....	59
11.2.3	Installation.....	60
11.2.4	Operation	60
11.2.5	Maintenance and routine inspection.....	61
11.3	Consumer label.....	62
12	Wind turbine markings	62
II	Type testing.....	63
13	Testing	63
13.1	General.....	63
13.2	Tests to verify design data	63
13.2.1	General	63
13.2.2	P_{design} , n_{design} , V_{design} and Q_{design}	63
13.2.3	Maximum yaw rate.....	64
13.2.4	Maximum rotational speed	64
13.3	Mechanical loads testing.....	64
13.4	Duration testing	65
13.4.1	General	65
13.4.2	Reliable operation	66
13.4.3	Dynamic behaviour	68
13.4.4	Reporting of duration test	69
13.5	Mechanical component testing	70
13.5.1	General	70
13.5.2	Blade test	70
13.5.3	Hub test.....	71
13.5.4	Nacelle frame test	71
13.5.5	Yaw mechanism test.....	71
13.5.6	Gearbox test.....	71
13.6	Safety and function	71
13.7	Environmental testing	72
13.8	Electrical.....	72
Annex A	(informative) Variants of small wind turbine systems	73
A.1	General.....	73
A.2	Example 1: power forms.....	73
A.3	Example 2: blades	73
A.4	Example 3: support structures.....	73
Annex B	(normative) Design parameters for describing SWT class S	75
Annex C	(informative) Stochastic turbulence models.....	76
C.1	General.....	76
C.2	Exponential coherency model	77
C.3	Von Karman isotropic turbulence model	77
Annex D	(informative) Deterministic turbulence description.....	79

Annex E (informative) Partial safety factors for materials	81
E.1 General.....	81
E.2 Symbols.....	81
E.3 Characteristic value versus design values.....	81
E.4 Material factors and requirements	82
E.4.1 General	82
E.4.2 Composites	83
E.4.3 Metals	85
E.4.4 Wood.....	85
E.5 Geometry effects	88
E.6 Reference documents	89
Annex F (informative) Development of the simplified loads methodology.....	90
F.1 Symbols used in this annex.....	90
F.2 General.....	91
F.3 Caution regarding use of simplified equations	91
F.4 General relationships	92
F.5 Reference documents	100
Annex G (informative) Example of test reporting formats	101
G.1 Overview.....	101
G.2 Duration test	101
G.2.1 General	101
G.2.2 Table summarizing the duration test results.....	101
G.2.3 Plot showing any potential power degradation	102
G.3 Power/energy performance	102
G.3.1 General	102
G.4 Acoustic noise test.....	105
Annex H (informative) EMC measurements.....	106
H.1 Overview.....	106
H.2 Measurement for radiated emissions.....	106
H.3 Measurements of conducted emissions.....	108
H.4 Reference documents	108
Annex I (normative) Natural frequency analysis	110
Annex J (informative) Extreme environmental conditions	112
J.1 Overview.....	112
J.2 Extreme conditions	112
J.3 Low temperature	112
J.4 Ice	112
J.5 High temperature	113
J.6 Marine	113
Annex K (informative) Extreme wind conditions of tropical cyclones.....	114
K.1 General.....	114
K.2 Using SWT classes in tropical cyclone areas	114
K.3 Extreme wind conditions	114
K.3.1 Definition of tropical cyclones	114
K.3.2 General features of tropical cyclones	114
K.3.3 Extreme wind conditions	115
K.4 Stochastic simulation (Monte Carlo simulation)	116
K.5 Reference documents	117

Annex L (informative) Other wind conditions	120
L.1 General.....	120
L.2 Typical situations	120
L.3 Directionally dependent flow	120
L.4 Inclined flow.....	120
L.5 Turbulence.....	122
L.6 Extreme wind direction changes.....	125
L.7 Gust factors	126
L.8 Reference documents	127
Annex M (informative) Consumer label	128
M.1 General.....	128
M.2 Administration.....	128
M.2.1 General	128
M.2.2 Test summary report.....	128
M.2.3 Publication of labels	129
M.2.4 Wind turbine variants.....	129
M.3 Tests for labelling	129
M.3.1 General	129
M.3.2 Duration test.....	129
M.3.3 Power curve and reference annual energy	130
M.3.4 Acoustic noise test	130
M.4 Label layout.....	130
M.5 Reference documents	130
Bibliography.....	133
Figure 1 – Definition of the system of axes for HAWT	25
Figure 2 – Definition of the system of axes for VAWT	26
Figure 3 – IEC 61400-2 decision path	28
Figure 4 – Characteristic wind turbulence	32
Figure 5 – Example of extreme operating gust ($N=1$, $V_{hub} = 25$ m/s)	33
Figure 6 – Example of extreme direction change magnitude ($N = 50$, $D = 5$ m, $z_{hub} = 20$ m).....	35
Figure 7 – Example of extreme direction change transient ($N = 50$, $V_{hub} = 25$ m/s)	35
Figure 8 – Extreme coherent gust ($V_{hub} = 25$ m/s) (ECG).....	35
Figure 9 – The direction change for ECD	36
Figure 10 – Time development of direction change for $V_{hub} = 25$ m/s.....	36
Figure E.1 – Normal and Weibull distribution	82
Figure E.2 – Typical S-N diagram for fatigue of glass fibre composites (Figure 41 from reference [E.2]).....	84
Figure E.3 – Typical environmental effects on glass fibre composites (Figure 25 from reference [E.2]).....	84
Figure E.4 – Fatigue strain diagram for large tow unidirectional 0° carbon fibre/vinyl ester composites, $R = 0,1$ and 10 (Figure 107 from reference [E.2])	84
Figure E.5 – S-N curves for fatigue of typical metals	85
Figure E.6 – Fatigue life data for jointed softwood (from reference [E.5])	86
Figure E.7 – Typical S-N curve for wood (from reference [E.5]).....	86

Figure E.8 – Effect of moisture content on compressive strength of lumber parallel to grain (Figure 4-13 from reference [E.6])	87
Figure E.9 – Effect of moisture content on wood strength properties (Figure 4-11 from reference [E.6])	87
Figure E.10 – Effect of grain angle on mechanical property of clear wood according to Hankinson-type formula (Figure 4-4 from reference [E.6])	88
Figure G.1 – Example power degradation plot	102
Figure G.2 – Example binned sea level normalized power curve	103
Figure G.3 – Example scatter plot of measured power and wind speed	104
Figure G.4 – Example immission noise map	105
Figure H.1 – Measurement setup of radiated emissions (set up type A)	107
Figure H.2 – Measurement setup of radiated emissions (set up type B)	107
Figure H.3 – Measurement setup of conducted emissions (setup type A)	108
Figure H.4 – Measurement setup of conducted emissions (setup type B)	108
Figure I.1 – Example of a Campbell diagram	111
Figure K.1 – Comparison of predicted and observed extreme winds in a mixed climate region (after Isihara, T. and Yamaguchi, A.)	117
Figure K.2 – Tropical cyclone tracks between 1945 and 2006	119
Figure L.1 – Simulation showing inclined flow on a building (courtesy Sander Mertens)	121
Figure L.2 – Example wind flow around a building	122
Figure L.3 – Turbulence intensity and wind speed distribution, 5 m above treetops in a forest north of Uppsala, Sweden, during Jan-Dec 2009	123
Figure L.4 – Turbulence intensity and wind speed distribution, 69 m above treetops in a forest north of Uppsala, Sweden, during 2009 (limited data for high wind speeds)	123
Figure L.5 – Turbulence intensity and wind distribution, 2 m above rooftop in Melville, Western Australia, during Jan-Feb 2009, reference [L.4]	124
Figure L.6 – Turbulence intensity and wind speed distribution, 5,7 m above a rooftop in Port Kennedy, Western Australia, during Feb-Mar 2010, reference [L.4]	124
Figure L.7 – Example extreme direction changes; 1,5 m above a rooftop in Tokyo, Japan during three months February-May of 2007 (0,5 Hz data, reference [L.5])	125
Figure L.8 – Example extreme direction changes; 1,5 m above a rooftop in Tokyo, Japan during five months September 2010 to February 2011 (1,0 Hz data, reference [L.5])	126
Figure L.9 – Gust factor measurements during storm in Port Kennedy, Western Australia, during March 2010, measured 5 m above rooftop compared with 10-min average wind speed	126
Figure M.1 – Sample label in English	131
Figure M.2 – Sample bilingual label (English/French)	132
Table 1 – Basic parameters for SWT classes	30
Table 2 – Design load cases for the simplified load calculation method	42
Table 3 – Force coefficients (C_f)	47
Table 4 – Minimum set of design load cases (DLC) for simulation by aero-elastic models	48
Table 5 – Equivalent stresses	51
Table 6 – Partial safety factors for materials	52
Table 7 – Partial safety factors for loads	52

Table C.1 – Turbulence spectral parameters for Kaimal model.....	76
Table E.1 – Factors for different survival probabilities and variabilities.....	82
Table E.2 – Geometric discontinuities	89
Table G.1 – Example duration test result	101
Table G.2 – Example calculated annual energy production (AEP) table	104
Table K.1 – Top five average extreme wind speeds recorded at meteorological stations	115
Table K.2 – Extreme wind speeds recorded at meteorological stations	116

WIND TURBINES –

Part 2: Small wind turbines

1 Scope

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

This standard is concerned with all subsystems of SWTs such as protection mechanisms, internal electrical systems, mechanical systems, support structures, foundations and the electrical interconnection with the load. A small wind turbine system includes the wind turbine itself including support structures, the turbine controller, the charge controller / inverter (if required), wiring and disconnects, the installation and operation manual(s) and other documentation.

While this standard is similar to IEC 61400-1, it does simplify and make significant changes in order to be applicable to small wind turbines. Any of the requirements of this standard may be altered if it can be suitably demonstrated that the safety of the turbine 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, organisation, or corporation from the responsibility of observing other applicable regulations.

This standard applies to wind turbines with a rotor swept area smaller than or equal to 200 m², generating electricity at a voltage below 1 000 V a.c. or 1 500 V d.c. for both on-grid and off-grid applications.

This standard should be used together with the appropriate IEC and ISO standards (see Clause 2).

2 Normative references

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

IEC 60038:2009, *IEC standard voltages*

IEC 60204-1:2005, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

IEC 60364-5-54, *Low-voltage electrical installations – Part 5-54: Selection and erection of electrical equipment – Earthing arrangements and protective conductors*

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

IEC 61400-11, *Wind turbines – Part 11: Acoustic noise measurement techniques*