

This document is a preview generated by EVS

Wind energy generation systems - Part 1: Design requirements (IEC 61400-1:2019 + IEC 61400-1:2019/AMD1:2025)

EESTI STANDARDI EESSÕNA**NATIONAL FOREWORD**

<p>See Eesti standard EVS-EN IEC 61400-1:2019+A1:2026 sisaldab Euroopa standardi EN IEC 61400-1:2019 ja selle muudatuse A1:2026 ja paranduse AC:2019 ingliskeelset teksti.</p>	<p>This Estonian standard EVS-EN IEC 61400-1:2019+A1:2026 consists of the English text of the European standard EN IEC 61400-1:2019 and its amendment A1:2026 and its corrigendum AC:2019.</p>
<p>Standard on jõustunud sellekohase teate avaldamisega EVS Teatajas.</p> <p>Euroopa standardimisorganisatsioonid on teinud Euroopa standardi rahvuslikele liikmetele kättesaadavaks 05.04.2019, muudatused A1 13.02.2026.</p>	<p>This standard has been endorsed with a notification published in the official bulletin of the Estonian Centre for Standardisation and Accreditation.</p> <p>Date of Availability of the European standard is 05.04.2019, for A1 13.02.2026.</p>
<p>Muudatusega A1 lisatud või muudetud teksti algus ja lõpp on tekstis tähistatud sümbolitega A1 A1.</p> <p>Parandusega AC lisatud või muudetud teksti algus ja lõpp on tekstis tähistatud sümbolitega AC AC.</p> <p>Standard on kättesaadav Eesti Standardimis-ja Akrediteerimiskeskusest.</p>	<p>The start and finish of text introduced or altered by amendment A1 is indicated in the text by tags A1 A1.</p> <p>The start and finish of text introduced or altered by corrigendum AC is indicated in the text by tags AC AC.</p> <p>The standard is available from the Estonian Centre for Standardisation and Accreditation.</p>

Tagasisidet standardi sisu kohta on võimalik edastada, kasutades EVS-i veebilehel asuvat tagasiside vormi või saates e-kirja meiliaadressile standardiosakond@evs.ee.

ICS 27.180

Standardite ja standardilaadsete dokumentide reprodutseerimise ja levitamise õigus kuulub Eesti Standardimis- ja Akrediteerimiskeskusele

Eesti standardid ja standardilaadsed dokumendid on Eesti Standardimis- ja Akrediteerimiskeskuse intellektuaalomand ning neid kasutatakse litsentsi alusel dokumentide kasutuslepingu tingimuste kohaselt.

Ilma Eesti Standardimis- ja Akrediteerimiskeskuse eelneva kirjaliku loata on keelatud standardite ja standardilaadsete dokumentide täielik või osaline reprodutseerimine, levitamine, muutmise või kasutamine mis tahes kujul ja viisil - sealhulgas kopeerimise, skaneerimise, salvestamise või jagamise teel digiplatvormidel (k.a masinõppe ja tehisintellekti rakendustes). Loata kasutamine väljaspool litsentsi tingimusi käsitletakse õigusrikkumisena.

Kui Teil on küsimusi standardite ja standardilaadsete dokumentide autoriõiguse kaitse kohta, võtke palun ühendust Eesti Standardimis- ja Akrediteerimiskeskusega:

Veebileht www.evs.ee; telefon +372 6055050; e-post info@evs.ee

The right to reproduce and distribute standards and standard-like documents belongs to the Estonian Centre for Standardisation and Accreditation

Estonian standards and standard-like documents are the intellectual property of the Estonian Centre for Standardisation and Accreditation and are made available under license in accordance with the terms and conditions of the document use agreement.

Without the prior written permission of the Estonian Centre for Standardisation and Accreditation, the full or partial reproduction, distribution, modification, or use of standards and standard-like documents in any form or by any means - including photocopying, scanning, storing, or sharing via digital platforms (incl. in machine learning and artificial intelligence applications) - is strictly prohibited. Any unauthorized use beyond the scope of the granted license is prohibited and may result in legal action.

If you have any questions about copyright, please contact Estonian Centre for Standardisation and Accreditation:

Homepage www.evs.ee; phone +372 605 5050; e-mail info@evs.ee

This document is a preview generated by EVS

English Version

**Wind energy generation systems - Part 1: Design requirements
(IEC 61400-1:2019 + IEC 61400-1:2019/AMD1:2025)**

Systèmes de génération d'énergie éolienne - Partie 1:
Exigences de conception
(IEC 61400-1:2019 + IEC 61400-1:2019/AMD1:2025)

Windenergieanlagen - Teil 1: Auslegungsanforderungen
(IEC 61400-1:2019 + IEC 61400-1:2019/AMD1:2025)

This European Standard was approved by CENELEC on 2019-03-15. Amendment A1 was approved by CENELEC on 2026-01-22. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard and its amendment 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 and its Amendment A1 exist 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, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Poland, Portugal, Republic of North Macedonia, Romania, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Türkiye and the United Kingdom.



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

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 88/696/FDIS, future edition 4 of IEC 61400-1, prepared by IEC/TC 88 "Wind energy generation systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61400-1:2019.

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) 2019-12-15
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2022-03-15

This document supersedes EN 61400-1:2005.

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

Endorsement notice

The text of the International Standard IEC 61400-1:2019 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 60146 (series)	NOTE	Harmonized as EN 60146 (series)
IEC 60269 (series)	NOTE	Harmonized as EN 60269 (series)
IEC 60898 (series)	NOTE	Harmonized as EN 60898 (series)
IEC 61000-6-1	NOTE	Harmonized as EN IEC 61000-6-1
IEC 61000-6-4	NOTE	Harmonized as EN 61000-6-4
IEC 61310-1:2007	NOTE	Harmonized as EN 61310-1:2008 (not modified)
IEC 61310-2:2007	NOTE	Harmonized as EN 61310-2:2008 (not modified)
IEC 61400-2	NOTE	Harmonized as EN 61400-2
IEC 61400-3-1 ¹	NOTE	Harmonized as EN IEC 61400-3-1 ²

¹ To be published. Stage at time of publication: IEC CDV 61400-3-1:2017

² To be published. Stage at time of publication: FprEN IEC 61400-3-1:2018

IEC 61400-6 ³	NOTE	Harmonized as EN IEC 61400-6 ⁴
IEC 61400-12-1	NOTE	Harmonized as EN 61400-12-1
IEC 61400-13	NOTE	Harmonized as EN 61400-13
IEC 61400-21	NOTE	Harmonized as EN 61400-21
IEC 61508 (series)	NOTE	Harmonized as EN 61508 (series)
IEC 61508-1:2010	NOTE	Harmonized as EN 61508-1:2010 (not modified)
IEC 61508-6	NOTE	Harmonized as EN 61508-6
IEC 62061:2005	NOTE	Harmonized as EN 62061:2005 (not modified)
IEC 62061:2005/AMD1:2012	NOTE	Harmonized as EN 62061:2005/A1:2013 (not modified)
IEC 62061:2005/AMD2:2015	NOTE	Harmonized as EN 62061:2005/A2:2015 (not modified)
IEC 62305-1	NOTE	Harmonized as EN 62305-1
ISO 12100:2010	NOTE	Harmonized as EN ISO 12100:2010 (not modified)
ISO 9001	NOTE	Harmonized as EN ISO 9001
ISO 13849-2	NOTE	Harmonized as EN ISO 13849-2

³ To be published. Stage at time of publication: IEC CDV 61400-6:2017

⁴ To be published. Stage at time of publication: pr EN IEC 61400-6:2017

A1 Amendment A1 European foreword

The text of document 88/1109/FDIS, future edition 4 of IEC 61400-1/AMD1, prepared by TC 88 "Wind energy generation systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61400-1:2019/A1:2026.

The following dates are fixed:

- latest date by which the document has to be implemented at national (dop) 2027-02-28 level by publication of an identical national standard or by endorsement
- latest date by which the national standards conflicting with the (dow) 2029-02-28 document have to be withdrawn

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

This document has been prepared under a standardization request addressed to CENELEC by the European Commission. The Standing Committee of the EFTA States subsequently approves these requests for its Member States.

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

Endorsement notice

The text of the International Standard IEC 61400-1:2019/AMD1:2025 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

CISPR 11:2024 NOTE Approved as EN IEC 55011:2025 (not modified)

A1

INTERNATIONAL STANDARD

CONSOLIDATED VERSION

**Wind energy generation systems -
Part 1: Design requirements**



THIS PUBLICATION IS COPYRIGHT PROTECTED
Copyright © 2025 IEC, Geneva, Switzerland

All rights reserved. Unless otherwise specified, no part of this publication may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying and microfilm, without permission in writing from either IEC or IEC's member National Committee in the country of the requester. If you have any questions about IEC copyright or have an enquiry about obtaining additional rights to this publication, please contact the address below or your local IEC member National Committee for further information.

IEC Secretariat
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

IEC publications search -

webstore.iec.ch/advsearchform

The advanced search enables to find IEC publications by a variety of criteria (reference number, text, technical committee, ...). It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

IEC Products & Services Portal - products.iec.ch

Discover our powerful search engine and read freely all the publications previews, graphical symbols and the glossary. With a subscription you will always have access to up to date content tailored to your needs.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22 500 terminological entries in English and French, with equivalent terms in 25 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

Warning! Make sure that you obtained this publication from an authorized distributor.

This document is a preview generated by EVS

CONTENTS

FOREWORD.....	10
▣ Amendment A1 FOREWORD ▣.....	12
INTRODUCTION.....	14
1 Scope.....	15
2 Normative references.....	15
3 Terms and definitions	17
4 Symbols and abbreviated terms	26
4.1 Symbols and units.....	26
4.2 Abbreviated terms.....	29
5 Principal elements.....	30
5.1 General.....	30
5.2 Design methods	30
5.3 Safety classes.....	31
5.4 Quality assurance	31
5.5 Wind turbine markings.....	31
6 External conditions	31
6.1 General.....	31
6.2 Wind turbine classes	32
6.3 Wind conditions.....	34
6.3.1 General	34
6.3.2 Normal wind conditions	35
6.3.3 Extreme wind conditions.....	37
6.4 Other environmental conditions	43
6.4.1 General	43
6.4.2 Normal other environmental conditions	44
6.4.3 Extreme other environmental conditions	44
6.5 Electrical power network conditions	45
7 Structural design	45
7.1 General.....	45
7.2 Design methodology.....	45
7.3 Loads	46
7.3.1 General	46
7.3.2 Gravitational and inertial loads	46
7.3.3 Aerodynamic loads.....	46
7.3.4 Actuation loads	46
7.3.5 Other loads.....	46
7.4 Design situations and load cases.....	46
7.4.1 General	46
7.4.2 Power production (DLC 1.1 to 1.5).....	49
7.4.3 Power production plus occurrence of fault or loss of electrical network connection (DLC 2.1 to 2.5).....	50
7.4.4 Start-up (DLC 3.1 to 3.3).....	52
7.4.5 Normal shutdown (DLC 4.1 to 4.2).....	52
7.4.6 Emergency stop (DLC 5.1)	53
7.4.7 Parked (standstill or idling) (DLC 6.1 to 6.4)	53

7.4.8	Parked plus fault conditions (DLC 7.1)	54
7.4.9	Transport, assembly, maintenance and repair (DLC 8.1 and 8.2)	54
7.5	Load calculations	54
7.6	Ultimate limit state analysis	56
7.6.1	Method	56
7.6.2	Ultimate strength analysis	58
7.6.3	Fatigue failure	62
7.6.4	Stability	63
7.6.5	Critical deflection analysis	63
7.6.6	Special partial safety factors	64
7.6.7	Evaluation of limit state through load comparison	64
8	Control system	65
8.1	General	65
8.2	Control functions	65
8.3	Protection functions	66
8.4	Control system failure analysis	66
8.4.1	General	66
8.4.2	Independence and common-cause failures	67
8.4.3	Fault exclusions	67
8.4.4	Failure mode return periods	67
8.4.5	Systematic failures	67
8.5	Manual operation	68
8.6	Emergency stop button function	68
8.7	Manual, automatic, and remote restart	68
8.8	Braking system	69
9	Mechanical systems	69
9.1	General	69
9.2	Errors of fitting	70
9.3	Hydraulic or pneumatic systems	70
9.4	Main gearbox	70
9.5	Yaw system	70
9.6	Pitch system	71
9.7	Protection function mechanical brakes	71
9.8	Rolling element bearings	72
9.8.1	General	72
9.8.2	Main shaft bearings	72
9.8.3	Generator bearings	72
9.8.4	Pitch and yaw bearings	72
10	Electrical system	72
10.1	General	72
10.2	General requirements for the electrical system	73
10.3	Internal environmental conditions	73
10.4	Protective devices	74
10.5	Disconnection from supply sources	74
10.6	Earth system	75
10.7	Lightning protection	75
10.8	Electrical cables	76
10.9	Self-excitation	76

10.10	Protection against lightning electromagnetic impulse.....	76
10.11	Power quality	76
10.12	A1 Electromagnetic compatibility (EMC) A1	76
A1	10.12.1 General.....	76
10.12.2	EMC design requirements A1	76
10.13	Power electronic converter systems and equipment	77
10.14	Twist/drip loop	77
10.15	Slip rings	78
10.16	Vertical power transmission conductors and components	78
10.17	Motor drives and converters	79
10.18	Electrical machines	79
10.19	Power transformers	79
10.20	Low voltage switchgear and controlgear	79
10.21	High voltage switchgear	79
10.22	Hubs.....	80
11	Assessment of a wind turbine for site-specific conditions	80
11.1	General.....	80
11.2	Assessment of the topographical complexity of the site and its effect on turbulence.....	81
11.2.1	Assessment of the topographical complexity	81
11.2.2	Assessment of turbulence structure at the site	84
11.3	Wind conditions required for assessment.....	85
11.3.1	General	85
11.3.2	Wind condition parameters	85
11.3.3	Measurement setup.....	86
11.3.4	Data evaluation	87
11.4	Assessment of wake effects from neighbouring wind turbines	87
11.5	Assessment of other environmental conditions.....	88
11.6	Assessment of earthquake conditions	88
11.7	Assessment of electrical network conditions	89
11.8	Assessment of soil conditions	89
11.9	Assessment of structural integrity by reference to wind data.....	89
11.9.1	General	89
11.9.2	Assessment of the fatigue load suitability by reference to wind data	90
11.9.3	Assessment of the ultimate load suitability by reference to wind data	91
11.10	Assessment of structural integrity by load calculations with reference to site-specific conditions.....	92
12	Assembly, installation and erection	93
12.1	General.....	93
12.2	Planning	94
12.3	Installation conditions.....	94
12.4	Site access	94
12.5	Environmental conditions	95
12.6	Documentation	95
12.7	Receiving, handling and storage	95
12.8	Foundation/anchor systems	95
12.9	Assembly of wind turbine.....	95
12.10	Erection of wind turbine	95

12.11	Fasteners and attachments	96
12.12	Cranes, hoists and lifting equipment	96
13	Commissioning, operation and maintenance	96
13.1	General.....	96
13.2	Design requirements for safe operation, inspection and maintenance	96
13.3	Instructions concerning commissioning	97
13.3.1	General	97
13.3.2	Energization.....	97
13.3.3	Commissioning tests	97
13.3.4	Records	98
13.3.5	Post commissioning activities	98
13.4	Operator's instruction manual	98
13.4.1	General	98
13.4.2	Instructions for operations and maintenance records.....	98
13.4.3	Instructions for unscheduled automatic shutdown	99
13.4.4	Instructions for diminished reliability	99
13.4.5	Work procedures plan	99
13.4.6	Emergency procedures plan	99
13.5	Maintenance manual	100
14	Cold climate	100
14.1	General.....	100
14.2	Low temperature and icing climate.....	100
14.3	External conditions for cold climate.....	101
14.3.1	General	101
14.3.2	Wind turbine class for cold climate	101
14.4	Structural design.....	101
14.5	Design situations and load cases.....	101
14.5.1	General	101
14.5.2	Load calculations	102
14.5.3	Selection of suitable materials	102
14.6	Control systems	102
14.7	Mechanical systems	103
14.8	Electrical systems	103
Annex A (normative)	Design parameters for external conditions	104
A.1	Design parameters for describing wind turbine class S	104
A.1.1	General	104
A.1.2	Machine parameters.....	104
A.1.3	Wind conditions	104
A.1.4	Electrical network conditions	104
A.1.5	Other environmental conditions (where taken into account).....	105
A.2	Additional design parameters for describing cold climate wind turbine class S (CC-S).....	105
Annex B (informative)	Design load cases for special class S wind turbine design or site suitability assessment	107
B.1	General.....	107
B.2	Power production (DLC 1.1 to 1.9).....	108
Annex C (informative)	Turbulence models	112
C.1	General.....	112

C.2	Mann [3] uniform shear turbulence model	112
C.3	Kaimal [1] spectrum and exponential coherence model	115
C.4	Reference documents	117
Annex D	(informative) Assessment of earthquake loading	118
D.1	General.....	118
D.2	Design response spectrum	118
D.3	Structure model.....	119
D.4	Seismic load evaluation.....	120
D.5	Additional load	121
D.6	Reference documents	122
Annex E	(informative) Wake and wind farm turbulence	123
E.1	Added wake turbulence method	123
E.2	Dynamic wake meandering model.....	125
E.2.1	General	125
E.2.2	Wake deficit.....	126
E.2.3	Meandering.....	127
E.2.4	Wake induced turbulence	128
E.2.5	Wake superposition.....	129
E.2.6	Model synthesis	129
E.3	Reference documents	129
Annex F	(informative) Prediction of wind distribution for wind turbine sites by measure-correlate-predict (MCP) methods	131
F.1	General.....	131
F.2	Measure-correlate-predict (MCP).....	131
F.3	Application to annual mean wind speed and distribution	131
F.4	Application to extreme wind speed.....	131
F.5	Reference documents	132
Annex G	(informative) Statistical extrapolation of loads for ultimate strength analysis	133
G.1	General.....	133
G.2	Data extraction for extrapolation	133
G.3	Load extrapolation methods.....	134
G.3.1	General	134
G.3.2	Global extremes.....	134
G.3.3	Local extremes	136
G.3.4	Long-term empirical distributions	136
G.4	Convergence criteria	137
G.4.1	General	137
G.4.2	Load fractile estimate	138
G.4.3	Confidence bounds	138
G.4.4	Confidence intervals based on bootstrapping	138
G.4.5	Confidence intervals based on the binomial distribution	139
G.5	Inverse first-order reliability method (IFORM).....	140
G.6	Reference documents	141
Annex H	(informative) Fatigue analysis using Miner's rule with load extrapolation	143
H.1	Fatigue analysis	143
H.2	Reference documents	147
Annex I	(informative) Contemporaneous loads.....	148

I.1	General.....	148
I.2	Scaling	149
I.3	Averaging	149
Annex J (informative) Prediction of the extreme wind speed of tropical cyclones by using Monte Carlo simulation method		150
J.1	General.....	150
J.2	Prediction of tropical cyclone induced extreme wind speeds	150
J.2.1	General	150
J.2.2	Evaluation of tropical cyclone parameters	150
J.2.3	Generation of synthetic tropical cyclones	151
J.2.4	Prediction of wind speeds in the tropical cyclone boundary	151
J.3	Prediction of extreme wind speed in mixed climate regions	152
J.3.1	General	152
J.3.2	Extreme wind distributions of extratropical cyclones by the MCP method	153
J.3.3	Extreme wind distributions of tropical cyclones by the MCS method	153
J.3.4	Determination of extreme wind speed in a mixed climate region	153
J.4	Reference documents	153
Annex K (informative) Calibration of structural material safety factors and structural design assisted by testing		155
K.1	Overview and field of application	155
K.2	Target reliability level	155
K.3	Safety formats.....	155
K.4	Reliability-based calibration.....	157
K.5	Calibration using the design value format	158
K.6	Partial safety factors for fatigue for welded details in steel structures	158
K.7	Types of tests for materials	160
K.8	Planning of tests	160
K.8.1	General	160
K.8.2	Objectives and scope	161
K.8.3	Prediction of test results.....	161
K.8.4	Specification of test specimen and sampling	161
K.8.5	Loading specifications.....	161
K.8.6	Testing arrangement.....	162
K.8.7	Measurements	162
K.8.8	Evaluation and reporting the test	162
K.9	General principles for statistical evaluations	162
K.10	Derivation of characteristic values	163
K.11	Statistical determination of characteristic value for a single property	163
K.12	Statistical determination of characteristic value for resistance models	165
K.12.1	General	165
K.12.2	Step 1: Develop a design model	165
K.12.3	Step 2: Compare experimental and theoretical values	166
K.12.4	Step 3: Estimate the mean value correction factor (bias) b	166
K.12.5	Step 4: Estimate the coefficient of variation of the errors.....	167
K.12.6	Step 5: Analyse compatibility.....	167
K.12.7	Step 6: Determine the coefficients of variation V_{Xi} of the basic variables.....	168
K.12.8	Step 7: Determine the characteristic value r_k of the resistance.....	168
K.13	Reference documents	169

Annex L (informative) Cold climate: assessment and effects of icing climate	170
L.1 Assessment of icing climate conditions	170
L.1.1 General	170
L.1.2 Icing climate	170
L.1.3 Rotor icing	171
L.1.4 Measurement methods	172
L.1.5 Profile coefficients modification for ice	172
L.2 Ice mass effects on wind turbine blades	173
L.3 Cold climate design situations and load case	174
L.3.1 General	174
L.3.2 Power production (DLC 1.1 to A_1 1.7 A_1)	174
L.3.3 Parked (standstill or idling) (DLC 6.1 to 6.5)	174
L.3.4 Parked and fault conditions (DLC 7.1)	175
L.4 Cold climate load calculations	175
L.5 Reference documents and bibliography	175
Annex M (informative) Medium wind turbines	177
M.1 Overview	177
M.2 External conditions	177
M.2.1 General	177
M.2.2 Wind shear	177
M.3 Assembly, installation and erection	177
12.6 Documentation	177
M.4 Commissioning, operation and maintenance	178
13.1 General	178
13.2 Design requirements for safe operation, inspection and maintenance	179
M.5 Documentation	179
Annex ZA (normative) Normative references to international publications with their corresponding European publications	181
Bibliography	184
Figure 1 – Turbulence standard deviation and turbulence intensity for the normal turbulence model (NTM)	37
Figure 2 – Example of extreme operating gust	39
Figure 3 – Example of extreme direction change magnitude	40
Figure 4 – Example of extreme direction change transient	40
Figure 5 – Example of extreme coherent gust amplitude for ECD	41
Figure 6 – Direction change for ECD	42
Figure 7 – Example of direction change transient	42
Figure 8 – Examples of extreme positive and negative vertical wind shear, wind profile before onset ($t = 0$, dashed line) and at maximum shear ($t = 6$ s, full line)	43
Figure 9 – Example of wind speeds at rotor top and bottom, respectively, which illustrate the transient positive wind shear	43
Figure 10 – Examples of 30° sectors for fitting the terrain data	82
Figure 11 – Terrain variation (Δz) and terrain slope (θ)	82
Figure 12 – Possible combinations of normalized mean wind speed and Weibull shape parameter k (shaded area)	90
Figure D.1 – Structure model for response spectrum method	120

Figure E.1 – Configuration – Inside a wind farm with more than 2 rows	125
Figure E.2 – The three fundamental parts of the DWM model	126
Figure K.1 – r_e - r_t diagram	166
Figure L.1 – Definition of meteorological icing and rotor icing	171
Figure L.2 – Representative ice affected rotor area as defined by rotor icing height	172
Figure L.3 – Iced airfoil lift and drag penalty factors	173
Table 1 – Basic parameters for wind turbine classes	33
Table 2 – Design load cases (DLC)	48
Table 3 – Partial safety factors for loads γ_f	60
Table 4 – Minimum safety factor $S_{H,min}$ and $S_{F,min}$ for the yaw gear system	71
Table 5 – Threshold values of the terrain complexity categories L, M and H	84
Table 6 – Values of lateral and vertical turbulence standard deviations relative to the longitudinal component depending on terrain complexity category L, M and H	84
Table 7 – Values of turbulence structure correction parameter depending on terrain complexity category L, M and H	85
Table A.1 – Design parameters for describing cold climate wind turbine class S (CC-S)	105
Table B.1 – Design load cases	108
Table C.1 – Turbulence spectral parameters for the Kaimal model	116
Table E.1 – Number (N) of neighbouring wind turbines	124
Table G.1 – Parameters needed to establish binomial-based confidence intervals	139
Table G.2 – Short-term load exceedance probabilities as a function of hub-height wind speed for different wind turbine classes for use with the IFORM procedure	141
Table I.1 – Extreme loading matrix	148
Table K.1 – Partial safety factor for model uncertainty, γ_δ	158
Table K.2 – Recommended values for partial safety factor for fatigue strength, γ_{Mf}	160
Table K.3 – Recommended partial safety factor for fatigue stresses, γ_{Ff}	160
Table K.4 – Values of k_n for the 5 % characteristic value	164
Table L.1 – Cold climate design load cases	174
Table L.2 – Blade ice mass and airfoil penalty factors used in different analysis types	175

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND ENERGY GENERATION SYSTEMS –

Part 1: Design requirements

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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

This fourth edition cancels and replaces the third edition published in 2005 and Amendment 1:2010. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) general update and clarification of references and requirements;
- b) extension of wind turbine classes to allow for tropical cyclones and high turbulence;
- c) Weibull distribution of turbulence standard deviation for normal turbulence model (NTM);
- d) updated design load cases (DLCs), in particular DLC 2.1 and 2.2;
- e) revision of partial safety factor specifications;
- f) major revision of Clauses 8, 10 and 11;

- g) introduction of cold climate requirements, Clause 14;
- h) new Annex B on design load cases for site-specific or special class S wind turbine design or site suitability assessment;
- i) new Annex J on prediction of the extreme wind speed of tropical cyclones by using Monte Carlo simulation method;
- j) new Annex K on calibration of structural material safety factors and structural design assisted by testing;
- k) new Annex L on assessment and effects of icing climate;
- l) new Annex M on medium wind turbines.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
88/696/FDIS	88/701/RVD

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

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

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

Future standards in this series will carry the new general title as cited above. Titles of existing standards in this series will be updated at the time of the next edition.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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

The contents of the corrigendum of September 2019 and the Interpretation Sheet 1 of February 2025 have been included in this copy.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

A1 Amendment A1 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.
- 2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
- 3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
- 4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
- 5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 6) All users should ensure that they have the latest edition of this publication.
- 7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
- 8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
- 9) IEC draws attention to the possibility that the implementation of this document may involve the use of (a) patent(s). IEC takes no position concerning the evidence, validity or applicability of any claimed patent rights in respect thereof. As of the date of publication of this document, IEC had not received notice of (a) patent(s), which may be required to implement this document. However, implementers are cautioned that this may not represent the latest information, which may be obtained from the patent database available at <https://patents.iec.ch>. IEC shall not be held responsible for identifying any or all such patent rights.

Amendment 1 to IEC 61400-1:2019 has been prepared by IEC technical committee 88: Wind energy generation systems.

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

Draft	Report on voting
88/1109/FDIS	88/1133/RVD

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

The language used for the development of this Amendment is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications/.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised. 

This document is a preview generated by EVS

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 document 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 document does not relieve any person, organization, or corporation from the responsibility of observing other applicable regulations.

This document is not intended to give requirements for wind turbines installed offshore, in particular for the support structure. For offshore installations, reference is made to the IEC 61400-3 series.

WIND ENERGY GENERATION SYSTEMS –

Part 1: Design requirements

1 Scope

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

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

This document applies to wind turbines of all sizes. For small wind turbines, IEC 61400-2 can be applied. IEC 61400-3-1 provides additional requirements to offshore wind turbine installations.

This document is intended to be used together with the appropriate IEC and ISO standards mentioned in Clause 2.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60034 (all parts), *Rotating electrical machines*

IEC 60038, *IEC standard voltages*

IEC 60071-1, *Insulation co-ordination – Part 1: Definitions, principles and rules*

IEC 60071-2, *Insulation co-ordination – Part 2: Application guidelines*

IEC 60076 (all parts), *Power transformers*

IEC 60204-1, *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 AC or 1 500 V DC and not exceeding 36 kV*

IEC 60364 (all parts), *Low voltage electrical installations*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

IEC 60664-1, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests*

EVS-EN IEC 61400-1:2019+A1:2026

IEC 60664-3, *Insulation coordination for equipment within low-voltage systems – Part 3: Use of coating, potting or moulding for protection against pollution*

IEC 60721 (all parts), *Classification of environmental conditions*

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

A1 deleted text **A1**

A1 IEC 61400-3-1, *Wind energy generation systems - Part 3-1: Design requirements for offshore wind turbines* **A1**

IEC 61400-4, *Wind Turbines – Part 4: Design requirements for wind turbine gearboxes*

A1 IEC 61400-6, *Wind energy generation systems - Part 6: Tower and foundation design requirements* **A1**

IEC 61400-24, *Wind turbines – Part 24: Lightning protection*

IEC 61439 (all parts), *Low-voltage switchgear and controlgear assemblies*

IEC 61800-4, *Adjustable speed electrical power drive systems – Part 4: General requirements – Rating specifications for AC power drive systems above 1 000 V AC and not exceeding 35 kV*

IEC 61800-5-1, *Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*

IEC 62271 (all parts), *High-voltage switchgear and controlgear*

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

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

IEC 62477-1:2012, *Safety requirements for power electronic converter systems and equipment – Part 1: General*

ISO 76, *Rolling bearings – Static load ratings*

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

ISO 2394, *General principles on reliability for structures*

ISO 2533, *Standard Atmosphere*

ISO 4354, *Wind actions on structures*

ISO 6336-2, *Calculation of load capacity of spur and helical gears – Part 2: Calculation of surface durability (pitting)*

ISO 6336-3:2006, *Calculation of load capacity of spur and helical gears – Part 3: Calculation of tooth bending strength*

ISO 12494:2001, *Atmospheric icing on structures*

ISO 13850, *Safety of machinery – Emergency stop function – Principles for design*

ISO/TS 16281, *Rolling bearings – Methods for calculating the modified reference rating life for universally loaded bearings*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

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 1 to entry: The averaging time interval should be a whole number of years (e.g. 10) 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 1 to entry: 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