

INTERNATIONAL STANDARD

IEC
61400-1

Third edition
2005-08

Wind turbines –

**Part 1:
Design requirements**



Reference number
IEC 61400-1:2005(E)

Publication numbering

As from 1 January 1997 all IEC publications are issued with a designation in the 60000 series. For example, IEC 34-1 is now referred to as IEC 60034-1.

Consolidated editions

The IEC is now publishing consolidated versions of its publications. For example, edition numbers 1.0, 1.1 and 1.2 refer, respectively, to the base publication, the base publication incorporating amendment 1 and the base publication incorporating amendments 1 and 2.

Further information on IEC publications

The technical content of IEC publications is kept under constant review by the IEC, thus ensuring that the content reflects current technology. Information relating to this publication, including its validity, is available in the IEC Catalogue of publications (see below) in addition to new editions, amendments and corrigenda. Information on the subjects under consideration and work in progress undertaken by the technical committee which has prepared this publication, as well as the list of publications issued, is also available from the following:

- **IEC Web Site** (www.iec.ch)

- **Catalogue of IEC publications**

The on-line catalogue on the IEC web site (www.iec.ch/searchpub) enables you to search by a variety of criteria including text searches, technical committees and date of publication. On-line information is also available on recently issued publications, withdrawn and replaced publications, as well as corrigenda.

- **IEC Just Published**

This summary of recently issued publications (www.iec.ch/online_news/justpub) is also available by email. Please contact the Customer Service Centre (see below) for further information.

- **Customer Service Centre**

If you have any questions regarding this publication or need further assistance, please contact the Customer Service Centre:

Email: custserv@iec.ch
Tel: +41 22 919 02 11
Fax: +41 22 919 03 00

INTERNATIONAL STANDARD

IEC
61400-1

Third edition
2005-08

Wind turbines –

**Part 1:
Design requirements**

© IEC 2005 — Copyright - all rights reserved

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 the publisher.

International Electrotechnical Commission, 3, rue de Varembé, PO Box 131, CH-1211 Geneva 20, Switzerland
Telephone: +41 22 919 02 11 Telefax: +41 22 919 03 00 E-mail: inmail@iec.ch Web: www.iec.ch



Commission Electrotechnique Internationale
International Electrotechnical Commission
Международная Электротехническая Комиссия

PRICE CODE

XC

For price, see current catalogue

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references.....	8
3 Terms and definitions	9
4 Symbols and abbreviated terms	17
4.1 Symbols and units	17
4.2 Abbreviations.....	19
5 Principal elements	19
5.1 General	19
5.2 Design methods.....	19
5.3 Safety classes	20
5.4 Quality assurance.....	20
5.5 Wind turbine markings.....	20
6 External conditions	21
6.1 General	21
6.2 Wind turbine classes	21
6.3 Wind conditions	22
6.4 Other environmental conditions.....	31
6.5 Electrical power network conditions.....	32
7 Structural design.....	33
7.1 General	33
7.2 Design methodology	33
7.3 Loads	33
7.4 Design situations and load cases	34
7.5 Load calculations.....	39
7.6 Ultimate limit state analysis.....	39
8 Control and protection system.....	45
8.1 General	45
8.2 Control functions	45
8.3 Protection functions	46
8.4 Braking system.....	47
9 Mechanical systems.....	47
9.1 General	47
9.2 Errors of fitting.....	48
9.3 Hydraulic or pneumatic systems.....	48
9.4 Main gearbox.....	48
9.5 Yaw system	49
9.6 Pitch system.....	49
9.7 Protection function mechanical brakes	49
9.8 Rolling bearings.....	49

10	Electrical system.....	50
10.1	General	50
10.2	General requirements for the electrical system	50
10.3	Protective devices.....	50
10.4	Disconnect devices	50
10.5	Earth system.....	50
10.6	Lightning protection.....	51
10.7	Electrical cables.....	51
10.8	Self-excitation	51
10.9	Protection against lightning electromagnetic impulse	51
10.10	Power quality	51
10.11	Electromagnetic compatibility	51
11	Assessment of a wind turbine for site-specific conditions.....	52
11.1	General	52
11.2	Assessment of the topographical complexity of the site	52
11.3	Wind conditions required for assessment	52
11.4	Assessment of wake effects from neighbouring wind turbines.....	53
11.5	Assessment of other environmental conditions	54
11.6	Assessment of earthquake conditions	54
11.7	Assessment of electrical network conditions.....	55
11.8	Assessment of soil conditions	55
11.9	Assessment of structural integrity by reference to wind data	56
11.10	Assessment of structural integrity by load calculations with reference to site specific conditions	57
12	Assembly, installation and erection	57
12.1	General	57
12.2	Planning	58
12.3	Installation conditions.....	58
12.4	Site access	58
12.5	Environmental conditions	58
12.6	Documentation.....	59
12.7	Receiving, handling and storage.....	59
12.8	Foundation/anchor systems.....	59
12.9	Assembly of wind turbine	59
12.10	Erection of wind turbine.....	59
12.11	Fasteners and attachments	59
12.12	Cranes, hoists and lifting equipment.....	60
13	Commissioning, operation and maintenance	60
13.1	General	60
13.2	Design requirements for safe operation, inspection and maintenance	60
13.3	Instructions concerning commissioning	61
13.4	Operator's instruction manual.....	62
13.5	Maintenance manual	63

Annex A (normative) Design parameters for describing wind turbine class S	65
Annex B (informative) Turbulence models	66
Annex C (informative) Assessment of earthquake loading	72
Annex D (informative) Wake and wind farm turbulence	73
Annex E (informative) Prediction of wind distribution for wind turbine sites by measure-correlate-predict (MCP) methods	76
Annex F (informative) Statistical extrapolation of loads for ultimate strength analysis	78
Annex G (informative) Fatigue analysis using Miner's rule with load extrapolation	81
Bibliography	85
Figure 1a –Turbulence standard deviation for the Normal Turbulence Model (NTM)	25
Figure 1b – Turbulence intensity for the Normal Turbulence Model (NTM).....	25
Figure 2 – Example of extreme operating gust	27
Figure 3 – Example of extreme direction change magnitude	28
Figure 4 – Example of extreme direction change	28
Figure 5 – Example of extreme coherent gust amplitude for ECD	29
Figure 6 –Direction change for ECD	30
Figure 7 – Example of direction change transient.....	30
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).	31
Figure 9 – Example of wind speeds at rotor top and bottom, respectively, illustrate the transient positive wind shear	31
Figure D.1 – Configuration – Inside a wind farm with more than 2 rows	75
Figure F.1 – Exceedance probability for largest out-of-plane blade bending load in 10 min (normalized by mean bending load at rated wind speed).....	80
Table 1 – Basic parameters for wind turbine classes.....	22
Table 2 – Design load cases	35
Table 3 – Partial safety factors for loads γ_f	42
Table 4 – Terrain complexity indicators	52
Table B.1 – Turbulence spectral parameters for the Kaimal model.....	70

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND TURBINES –**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 provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with an IEC Publication.
- 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 turbines.

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

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

- the title has been changed to "Design requirements" in order to reflect that the standard presents safety requirements rather than requirements for safety or protection of personnel;
- wind turbine class designations have been adjusted and now refer to reference wind speed and expected value of turbulence intensities only;
- turbulence models have been expanded and include an extreme turbulence model;
- gust models have been adjusted and simplified;

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

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

FDIS	Report on voting
88/228/FDIS	88/232/RVD

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

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

IEC 61400 consists of the following parts under the general title *Wind turbine generator systems*:

- Part 1: Design requirements
- Part 2: Design requirements for small wind turbines
- Part 11: Acoustic noise measurement techniques
- Part 12: Wind turbine power performance testing
- Part 13: Measurement of mechanical loads
- Part 14: Declaration of apparent sound power level and tonality values
- Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines
- Part 23: Full-scale structural testing of rotor blades
- Part 24: Lightning protection

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

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

A bilingual version of this publication may be issued at a later date.

INTRODUCTION

This part of IEC 61400 outlines minimum design requirements for wind turbines and is not intended for use as a complete design specification or instruction manual.

Any of the requirements of this standard may be altered if it can be suitably demonstrated that the safety of the system is not compromised. This provision, however, does not apply to the classification and the associated definitions of external conditions in Clause 6. Compliance with this standard does not relieve any person, organization, or corporation from the responsibility of observing other applicable regulations.

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

This document is a preview generated by EVS

WIND TURBINES –

Part 1: Design requirements

1 Scope

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

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

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

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

2 Normative references

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

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

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

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

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

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

IEC 61000-6-2:1999, *Electromagnetic compatibility (EMC) – Part 6: Generic standards – Section 2: Immunity for industrial environments 15*

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

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

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

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

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

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

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

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

ISO 2533:1975, *Standard Atmosphere*

ISO 4354:1997, *Wind actions on structures*

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

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

3 Terms and definitions

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

3.1

annual average

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

3.2

annual average wind speed

V_{ave}

wind speed averaged according to the definition of annual average

3.3

auto-reclosing cycle

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

3.4

blocking (wind turbines)

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

3.5

brake (wind turbines)

device capable of reducing the rotor speed or stopping rotation

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

3.6

characteristic value

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