IEC 61400-1

Edition 3.0 2005-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Wind turbines –
Part 1: Design requirements

Eoliennes –
Partie 1: Exigences de conception

IEC 61400-1:2005

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: 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 corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

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 It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:
Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

A propos de la CEI

La Commission Electrotechnique Internationale (CEI) est la première organisation mondiale qui élabore et publie des normes internationales pour tout ce qui a trait à l'électricité, à l'électronique et aux technologies apparentées.

A propos des publications CEI

Le contenu technique des publications de la CEI est constamment revu. Veuillez vous assurer que vous possédez l'édition la plus récente, un corrigendum ou amendement peut avoir été publié.

- Catalogue des publications de la CEI: www.iec.ch/searchpub/cur_fut-f.htm

Le Catalogue en-ligne de la CEI vous permet d'effectuer des recherches en utilisant différents critères (numéro de référence, texte, comité d'études,…). Il donne aussi des informations sur les projets et les publications retirées ou remplacées.

- Just Published CEI: www.iec.ch/online_news/justpub

Restez informé sur les nouvelles publications de la CEI. Just Published détaille deux fois par mois les nouvelles publications parues. Disponible en-ligne et aussi par email.

- Electropedia: www.electropedia.org

Le premier dictionnaire en ligne au monde de termes électroniques et électriques. Il contient plus de 20 000 termes et définitions en anglais et en français, ainsi que les termes équivalents dans les langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International en ligne.

- Service Clients: www.iec.ch/webstore/custserv/custserv_entry-f.htm

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions, visitez le FAQ du Service clients ou contactez-nous:
Email: csc@iec.ch
Tél.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC 61400-1

Edition 3.0 2005-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

Wind turbines – Part 1: Design requirements

Eoliennes – Partie 1: Exigences de conception

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

PRICE CODE XC
CODE PRIX

ICS 27.180

ISBN 2-8318-8161-7

CONTENTS

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.

This bilingual version, published in 2007-03, corresponds to the English version.

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.

The French version of this standard has not been voted upon.

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

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

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.

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.

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*

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)

3.7
complex terrain
surrounding terrain that features significant variations in topography and terrain obstacles that may cause flow distortion

3.8
control functions (wind turbines)
functions of the control and protection system that based on information about the condition of the wind turbine and/or its environment, adjust the turbine in order to maintain it within its operating limits

3.9
cut-in wind speed
V_{in}
lowest wind speed at hub height at which the wind turbine starts to produce power in the case of steady wind without turbulence

3.10
cut-out wind speed
V_{out}
highest wind speed at hub height at which the wind turbine is designed to produce power in the case of steady wind without turbulence

3.11
design limits
maximum or minimum values used in a design

3.12
dormant failure
failure of a component or system which remains undetected during normal operation

3.13
downwind
in the direction of the main wind vector

3.14
electrical power network
particular installations, substations, lines or cables for the transmission and distribution of electricity

NOTE The boundaries of the different parts of this network are defined by appropriate criteria, such as geographical situation, ownership, voltage, etc.

3.15
emergency shutdown (wind turbines)
rapid shutdown of the wind turbine triggered by a protection function or by manual intervention

3.16
environmental conditions
characteristics of the environment (wind, altitude, temperature, humidity, etc.) which may affect the wind turbine behaviour

3.17
external conditions (wind turbines)
factors affecting operation of a wind turbine, including the environmental conditions (temperature, snow, ice, etc.) and the electrical network conditions

3.18
extreme wind speed
value of the highest wind speed, averaged over t s, with an annual probability of exceedance of $1/N$ ("recurrence period": N years)

NOTE In this standard recurrence periods of N = 50 years and N = 1 year and averaging time intervals of t = 3 s and t = 10 min are used. In popular language, the less precise term survival wind speed is often used. In this standard, however, the turbine is designed using extreme wind speeds for design load cases.

3.19
fail-safe
design property of an item which prevents its failures from resulting in critical faults

3.20
gust
temporary change in the wind speed

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

3.21
horizontal axis wind turbine
wind turbine whose rotor axis is substantially horizontal

3.22
hub (wind turbines)
fixture for attaching the blades or blade assembly to the rotor shaft

3.23
hub height (wind turbines)
z_{hub}
height of the centre of the swept area of the wind turbine rotor above the terrain surface (see 3.51, swept area)

3.24
idling (wind turbines)
condition of a wind turbine that is rotating slowly and not producing power

3.25
inertial sub-range
frequency interval of the 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, 2 Hz to 1 kHz.

3.26
limit state
state of a structure and the loads acting upon it, beyond which the structure no longer satisfies the design requirement

[ISO 2394, modified]

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).

3.27
logarithmic wind shear law
see 3.62

3.28
mean wind speed
statistical mean of the instantaneous value of the wind speed averaged over a given time period which can vary from a few seconds to many years

3.29
nacelle
housing which contains the drive-train and other elements on top of a horizontal axis wind turbine tower

3.30
network connection point (wind turbines)
cable terminals of a single wind turbine or, for a wind power station, the connection point to the electrical bus of the site power collection system

3.31
network loss
loss of network for period exceeding any ride through provision in the turbine control system

3.32
normal shutdown (wind turbines)
shutdown in which all stages are under the control of the control system

3.33
operating limits
set of conditions defined by the wind turbine designer that govern the activation of the control and protection system

3.34
parked wind turbine
depending on the design of the wind turbine, parked refers to the turbine being either in a standstill or an idling condition