

Wind turbines Part 12-1: Power performance measurements of electricity producing wind turbines

Wind turbines Part 12-1: Power performance measurements of electricity producing wind turbines

EESTI STANDARDI EESSÕNA

NATIONAL FOREWORD

Käesolev Eesti standard EVS-EN 61400-12-1:2006 sisaldab Euroopa standardi EN 61400-12-1:2006 ingliskeelset teksti. Käesolev dokument on jõustatud 22.09.2006 ja selle kohta on avaldatud teade Eesti standardiorganisatsiooni ametlikus väljaandes. Standard on kättesaadav Eesti standardiorganisatsioonist.	This Estonian standard EVS-EN 61400-12-1:2006 consists of the English text of the European standard EN 61400-12-1:2006. This document is endorsed on 22.09.2006 with the notification being published in the official publication of the Estonian national standardisation organisation. The standard is available from Estonian standardisation organisation.
--	---

Käsitlusala: This part of IEC 61400 specifies a procedure for measuring the power performance characteristics of a single wind turbine and applies to the testing of wind turbines of all types and sizes connected to the electrical power network. In addition, this standard describes a procedure to be used to determine the power performance characteristics of small wind turbines (as defined in IEC 61400-2) when connected to either the electric power network or a battery bank.	Scope: This part of IEC 61400 specifies a procedure for measuring the power performance characteristics of a single wind turbine and applies to the testing of wind turbines of all types and sizes connected to the electrical power network. In addition, this standard describes a procedure to be used to determine the power performance characteristics of small wind turbines (as defined in IEC 61400-2) when connected to either the electric power network or a battery bank.
--	--

ICS 27.180

Võtmesõnad: electrical engineering, generators, power measurement (electric), rating tests, turbines, wind power stations, wind turbines

English version

Wind turbines
Part 12-1: Power performance measurements of
electricity producing wind turbines
(IEC 61400-12-1:2005)

Eoliennes
Partie 12-1: Mesures des performances
de puissance des éoliennes
de production d'électricité
(CEI 61400-12-1:2005)

Windenergieanlagen
Teil 12-1: Messung des
Leistungsverhaltens einer
Windenergieanlage
(IEC 61400-12-1:2005)

This European Standard was approved by CENELEC on 2006-05-01. 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 Central Secretariat 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 Central Secretariat has the same status as the official versions.

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

CENELEC

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

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Foreword

The text of document 88/244/FDIS, future edition 1 of IEC 61400-12-1, prepared by IEC TC 88, Wind turbines, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 61400-12-1 on 2006-05-01.

This European Standard supersedes EN 61400-12:1998.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2007-02-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2009-05-01

Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 61400-12-1:2005 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 60044-2 NOTE Harmonized as EN 60044-2:1999 +A1:2000 +A2:2003 (not modified).

IEC 61400-1 NOTE Harmonized as EN 61400-1:2005 (not modified).

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

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

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60044-1 (mod)	1996	Instrument transformers -	EN 60044-1	1999
+ A1	2000	Part 1: Current transformers	+ A1	2000
+ A2	2002		+ A2	2003
IEC 60688	1992	Electrical measuring transducers for	EN 60688	1992
+ A1 (mod)	1997	converting a.c. electrical quantities to	+ A1	1999
+ A2	2001	analogue or digital signals	+ A2	2001
IEC 61400-2	1996	Wind turbine generator systems -	EN 61400-2	1996
		Part 2: Safety of small wind turbines		
ISO 2533	1975	Standard atmosphere	-	-
ISO/IEC Guide Expres	1995	Guide to the expression of uncertainty in measurement (GUM)	-	-

INTERNATIONAL STANDARD

IEC
61400-12-1

First edition
2005-12

Wind turbines –

**Part 12-1:
Power performance measurements
of electricity producing wind turbines**



Reference number
IEC 61400-12-1:2005(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
61400-12-1

First edition
2005-12

Wind turbines –

Part 12-1: Power performance measurements of electricity producing wind turbines

© 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 units	11
5 Preparation for performance test	14
5.1 Wind turbine and electrical connection	14
5.2 Test site	14
6 Test equipment.....	16
6.1 Electric power	16
6.2 Wind speed	16
6.3 Wind direction	17
6.4 Air density	17
6.5 Rotational speed and pitch angle.....	17
6.6 Blade condition	17
6.7 Wind turbine control system	17
6.8 Data acquisition system.....	18
7 Measurement procedure.....	18
7.1 General	18
7.2 Wind turbine operation	18
7.3 Data collection	18
7.4 Data rejection.....	19
7.5 Data correction.....	19
7.6 Database.....	19
8 Derived results	20
8.1 Data normalization	20
8.2 Determination of the measured power curve.....	21
8.3 Annual energy production (<i>AEP</i>)	21
8.4 Power coefficient.....	22
9 Reporting format.....	23
Annex A (normative) Assessment of obstacles at the test site.....	33
Annex B (normative) Assessment of terrain at the test site	36
Annex C (normative) Site calibration procedure	37
Annex D (normative) Evaluation of uncertainty in measurement.....	39
Annex E (informative) Theoretical basis for determining the uncertainty of measurement using the method of bins.....	41
Annex G (normative) Mounting of instruments on the meteorological mast.....	66
Annex H (normative) Power performance testing of small wind turbines.....	74
Annex I (normative) Classification of anemometry.....	77
Annex J (informative) Assessment of cup anemometry	79
Annex K (informative) In situ comparison of anemometers	88
Bibliography.....	90

Figure 1 – Requirements as to distance of the meteorological mast and maximum allowed measurement sectors	15
Figure 2 – Presentation of example database A and B: power performance test scatter plots sampled at 1 Hz (mean values averaged over 10 min).....	26
Figure 3 – Presentation of example measured power curve for databases A and B	27
Figure 4 – Presentation of example C_p curve for databases A and B.....	28
Figure 5 – Presentation of example site calibration (only the sectors 20° to 30°, 40° to 60°, 160° to 210° and 330° to 350° are valid sectors).....	29
Figure A.1 – Sectors to exclude due to wakes of neighbouring and operating wind turbines and significant obstacles	34
Figure A.2 – An example of sectors to exclude due to wakes of the wind turbine under test, a neighbouring and operating wind turbine and a significant obstacle.....	35
Figure B.1 – Illustration of area to be assessed, top view.....	36
Figure G.1 – Example of a top-mounted anemometer and requirements for mounting	66
Figure G.2 – Example of alternative top-mounted primary and control anemometers positioned side-by-side and wind vane and other instruments on the boom.....	67
Figure G.3 – Example of a top-mounted anemometer and mounting of control anemometer, wind vane and other sensors on a boom.....	68
Figure G.4 – Example of top-mounted primary and control anemometers positioned side-by-side, wind vane and other instruments on the boom	69
Figure G.5 – Iso-speed plot of local flow speed around a cylindrical mast, normalised by free-field wind speed (from the left); analysis by 2 dimensional Navier-Stokes computations	70
Figure G.6 – Centre-line relative wind speed as a function of distance R from the centre of a tubular mast and mast diameter d	70
Figure G.7 – Representation of a three-legged lattice mast showing the centre-line wind speed deficit, the actuator disc representation of the mast with the leg distance L and distance R from the centre of the mast to the point of observation.....	71
Figure G.8 – Iso-speed plot of local flow speed around a triangular lattice mast with a C_T of 0,5 normalised by free-field wind speed (from the left); analysis by 2 dimensional Navier-Stokes computation and actuator disc theory	72
Figure G.9 – Centre-line relative wind speed as a function of distance R from the centre of a triangular lattice mast of face width L for various C_T values.....	72
Figure J.1 – Measured angular response of a cup anemometer compared to cosine response.....	79
Figure J.2 – Wind tunnel torque measurements on a cup anemometer at 8 m/s	80
Figure J.3 – Example of bearing friction torque measurements	81
Figure J.4 – Distribution of vertical wind speed components assuming a fixed ratio between horizontal and vertical standard deviation in wind speed.....	82
Figure J.5 – Calculation of the total deviation with respect to the cosine response.....	83
Figure J.6 – Probability distributions for three different average angles of inflow.....	84
Figure J.7 – Total deviation from cosine response for three different average angles of inflow over horizontal turbulence intensity.....	84
Figure J.8 – Example of an anemometer that does not fulfil the slope criterion	85
Figure J.9 – Example of deviations of a Class 2.0A cup anemometer.....	87

Table 1 – Example of presentation of a measured power curve for database A	30
Table 2 – Example of presentation of a measured power curve for database B	31
Table 3 – Example of presentation of estimated annual energy production (database A).....	32
Table 4 – Example of presentation of estimated annual energy production (database B).....	32
Table B.1 – Test site requirements: topographical variations	36
Table D.1 – List of uncertainty components	40
Table E.1 – Expanded uncertainties	43
Table E.2 – List of categories B and A uncertainties	45
Table E.3 – Uncertainties from site calibration	53
Table E.4 – Sensitivity factors (database A).....	54
Table E.5 – Sensitivity factors (database B).....	55
Table E.6 – Category B uncertainties (database A).....	56
Table E.7 – Category B uncertainties (database B).....	57
Table F.1 – Example of evaluation of anemometer calibration uncertainty.....	62
Table G.1 – Estimation method for C_T for various types of lattice tower.....	73
Table H.1 – Battery bank voltage settings	76
Table I.1 – Influence parameter ranges (based on 10 min averages) of Classes A and B.....	78

Preview generated by EVS

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND TURBINES –

**Part 12-1: Power performance measurements
of electricity producing wind turbines**

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 61400-12-1 has been prepared by IEC technical committee 88: Wind turbines.

This standard cancels and replaces IEC 61400-12 published in 1998. This first edition of IEC 61400-12-1 constitutes a technical revision. IEC 61400-12-2 and IEC 61400-12-3 are additions to IEC 61400-12-1.

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

FDIS	Report on voting
88/244/FDIS	88/251/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 61400-12 consists of the following parts, under the general title *Wind turbines*:

Part 12-1: Power performance measurements of electricity producing wind turbines

Part 12-2: Verification of power performance of individual wind turbines (under consideration)

Part 12-3: Wind farm power performance testing (under consideration)

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 standard may be issued at a later date.

INTRODUCTION

The purpose of this part of IEC 61400 is to provide a uniform methodology that will ensure consistency, accuracy and reproducibility in the measurement and analysis of power performance by wind turbines. The standard has been prepared with the anticipation that it would be applied by:

- a wind turbine manufacturer striving to meet well-defined power performance requirements and/or a possible declaration system;
- a wind turbine purchaser in specifying such performance requirements;
- a wind turbine operator who may be required to verify that stated, or required, power performance specifications are met for new or refurbished units;
- a wind turbine planner or regulator who must be able to accurately and fairly define power performance characteristics of wind turbines in response to regulations or permit requirements for new or modified installations.

This standard provides guidance in the measurement, analysis, and reporting of power performance testing for wind turbines. The standard will benefit those parties involved in the manufacture, installation planning and permitting, operation, utilization, and regulation of wind turbines. The technically accurate measurement and analysis techniques recommended in this standard should be applied by all parties to ensure that continuing development and operation of wind turbines is carried out in an atmosphere of consistent and accurate communication relative to environmental concerns. This standard presents measurement and reporting procedures expected to provide accurate results that can be replicated by others. Meanwhile, a user of the standard should be aware of differences that arise from large variations in wind shear and turbulence, and from the chosen criteria for data selection. Therefore, a user should consider the influence of these differences and the data selection criteria in relation to the purpose of the test before contracting the power performance measurements.

A key element of power performance testing is the measurement of wind speed. This standard prescribes the use of cup anemometers to measure the wind speed. This instrument is robust and has long been regarded as suitable for this kind of test. Even though suitable wind tunnel calibration procedures are adhered to, the field flow conditions associated with the fluctuating wind vector, both in magnitude and direction, will cause different instruments to potentially perform differently.

Tools and procedures to classify cup anemometers are given in Annexes I and J. However there will always be a possibility that the result of the test can be influenced by the selection of the wind speed instrument. Special care should therefore be taken in the selection of the instruments chosen to measure the wind speed.

WIND TURBINES –

Part 12-1: Power performance measurements of electricity producing wind turbines

1 Scope

This part of IEC 61400 specifies a procedure for measuring the power performance characteristics of a single wind turbine and applies to the testing of wind turbines of all types and sizes connected to the electrical power network. In addition, this standard describes a procedure to be used to determine the power performance characteristics of small wind turbines (as defined in IEC 61400-2) when connected to either the electric power network or a battery bank. The procedure can be used for performance evaluation of specific turbines at specific locations, but equally the methodology can be used to make generic comparisons between different turbine models or different turbine settings.

The wind turbine power performance characteristics are determined by the measured power curve and the estimated annual energy production (*AEP*). The measured power curve is determined by collecting simultaneous measurements of wind speed and power output at the test site for a period that is long enough to establish a statistically significant database over a range of wind speeds and under varying wind and atmospheric conditions. The *AEP* is calculated by applying the measured power curve to reference wind speed frequency distributions, assuming 100 % availability.

The standard describes a measurement methodology that requires the measured power curve and derived energy production figures to be supplemented by an assessment of uncertainty sources and their combined effects.

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 60044-1:1996, *Instrument transformers – Part 1: Current transformers*
Amendment 1 (2000)
Amendment 2 (2002)¹

IEC 60688:1992, *Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals*
Amendment 1 (1997)
Amendment 2 (2001)²

IEC 61400-2:1996, *Wind turbine generator systems – Part 1: Safety of small wind turbines*

ISO 2533:1975, *Standard atmosphere*

ISO Guide to the expression of uncertainty in measurement, 1995, ISBN 92-67-10188-9

¹ There exists a consolidated edition 1.2 (2003) that includes edition 1 and its amendments 1 and 2.