

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE

---

### Wind turbines –

**Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines**

### Eoliennes –

**Partie 21: Mesurage et évaluation des caractéristiques de qualité de puissance des éoliennes connectées au réseau**



## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2008 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.

Droits de reproduction réservés. Sauf indication contraire, aucune partie de cette publication ne peut être reproduite ni utilisée sous quelque forme que ce soit et par aucun procédé, électronique ou mécanique, y compris la photocopie et les microfilms, sans l'accord écrit de la CEI ou du Comité national de la CEI du pays du demandeur.

Si vous avez des questions sur le copyright de la CEI ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de la CEI de votre pays de résidence.

IEC Central Office  
3, rue de Varembe  
CH-1211 Geneva 20  
Switzerland  
Email: [inmail@iec.ch](mailto:inmail@iec.ch)  
Web: [www.iec.ch](http://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](http://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 It also gives information on projects, withdrawn and replaced publications.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](http://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](http://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](http://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](mailto: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 toute ce qui 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](http://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](http://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](http://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](http://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](mailto:csc@iec.ch)  
Tél.: +41 22 919 02 11  
Fax: +41 22 919 03 00



# INTERNATIONAL STANDARD

## NORME INTERNATIONALE

---

**Wind turbines –**

**Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines**

**Eoliennes –**

**Partie 21: Mesurage et évaluation des caractéristiques de qualité de puissance des éoliennes connectées au réseau**

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

PRICE CODE **XA**  
CODE PRIX

ICS 27.180

ISBN 2-8318-9938-9

## CONTENTS

FOREWORD.....	4
INTRODUCTION.....	6
1 Scope.....	7
2 Normative references.....	7
3 Terms and definitions.....	8
4 Symbols and units.....	11
5 Abbreviations.....	13
6 Wind turbine power quality characteristic parameters.....	14
6.1 General.....	14
6.2 Wind turbine specification.....	14
6.3 Voltage fluctuations.....	14
6.3.1 General.....	14
6.3.2 Continuous operation.....	14
6.3.3 Switching operations.....	15
6.4 Current harmonics, interharmonics and higher frequency components.....	15
6.5 Response to voltage drops.....	16
6.6 Active power.....	16
6.6.1 Maximum measured power.....	16
6.6.2 Ramp rate limitation.....	16
6.6.3 Set-point control.....	17
6.7 Reactive power.....	17
6.7.1 Reactive power capability.....	17
6.7.2 Set-point control.....	17
6.8 Grid protection.....	18
6.9 Reconnection time.....	18
7 Test procedures.....	18
7.1 General.....	18
7.1.1 Test validity.....	19
7.1.2 Test conditions.....	19
7.1.3 Test equipment.....	20
7.2 Wind turbine specification.....	21
7.3 Voltage fluctuations.....	21
7.3.1 General.....	21
7.3.2 Fictitious grid.....	21
7.3.3 Continuous operation.....	23
7.3.4 Switching operations.....	26
7.4 Current harmonics, interharmonics and higher frequency components.....	27
7.5 Response to temporary voltage drop.....	28
7.6 Active power.....	30
7.6.1 Maximum measured power.....	30
7.6.2 Ramp rate limitation.....	31
7.6.3 Set point control.....	31
7.7 Reactive power.....	31
7.7.1 Reactive power capability.....	31
7.7.2 Set point control.....	32
7.8 Grid protection.....	32

7.9	Reconnection time.....	33
8	Assessment of power quality .....	34
8.1	General.....	34
8.2	Voltage fluctuations.....	34
8.2.1	General .....	34
8.2.2	Continuous operation .....	35
8.2.3	Switching operations .....	35
8.3	Current harmonics, interharmonics and higher frequency components .....	36
Annex A (informative)	Sample report format.....	38
Annex B (informative)	Voltage fluctuations and flicker.....	48
Annex C (informative)	Measurement of active power, reactive power and voltage .....	53
	Bibliography.....	58
	Figure 1 – Adjustment of active power set-point.....	17
	Figure 2 – Adjustment of reactive power set-point.....	18
	Figure 3 – Assumed elements of measurement system.....	20
	Figure 4 – Fictitious grid for simulation of fictitious voltage .....	22
	Figure 5 – System with short circuit emulator for testing wind turbine response to temporary voltage drop.....	29
	Figure 6 – Tolerance of voltage drop .....	30
	Figure B.1 – Measurement and assessment procedures for flicker during continuous operation of the wind turbine.....	48
	Figure B.2 – Measurement and assessment procedure for voltage changes and flicker during switching operations of the wind turbine.....	49
	Figure B.3 – Flicker coefficient as a function of wind speed .....	50
	Table 1 – Specification of voltage drop. The specified magnitudes, duration and shape are for the voltage drop occurring when the wind turbine under test is not connected.....	16
	Table 2 – Specification of requirements for measurement equipment.....	21
	Table 3 – Specification of elements according to IEC 61000-3-6.....	37
	Table B.1 – Number of measurements $N_{m,i}$ and frequency of occurrence of $f_{m,i}$ and $f_{y,i}$ for each wind speed bin in the range from cut-in wind speed to 15 m/s .....	51
	Table B.2 – Weighting factor $w_i$ for each wind speed bin.....	51
	Table B.3 – Total sum of weighting factor multiplied by number of measurements for all wind speed bins .....	52
	Table B.4 – Weighted accumulated distribution of the flicker coefficients $Pr(c < x)$ for each wind speed distribution.....	52
	Table B.5 – Resulting flicker coefficient in continuous operation .....	53
	Table B.6 – Probabilities and percentiles for different wind speeds .....	53

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## WIND TURBINES –

**Part 21: Measurement and assessment of power quality characteristics of grid connected 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 Guidances (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 61400-21 has been prepared by IEC technical committee 88: Wind turbines.

This second edition cancels and replaces the first edition published in 2001. This edition constitutes a technical revision.

This edition includes the following new items with respect to the previous edition:

- Interharmonics and current distortions (<9 kHz)
- Response to voltage dips
- Active power ramp rate limitation and set-point control
- Reactive power capabilities and set-point control
- Grid protection and reconnection time after grid faults

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

FDIS	Report on voting
88/317/FDIS	88/326/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.

A list of all parts of the IEC 61400 series, under the general title *Wind turbines*, 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

The purpose of this part of IEC 61400 is to provide a uniform methodology that will ensure consistency and accuracy in the presentation, testing and assessment of power quality characteristics of grid connected wind turbines (WTs). The power quality characteristics here include wind turbine specifications, voltage quality (emissions of flicker and harmonics), voltage drop response, power control (control of active and reactive power), grid protection and reconnection time.

This part of IEC 61400 has been prepared with the anticipation that it would be applied by:

- the WT manufacturer striving to meet well-defined power quality characteristics;
- the WT purchaser in specifying such power quality characteristics;
- the WT operator who may be required to verify that stated, or required power quality characteristics are met;
- the WT planner or regulator who has to be able to accurately and fairly determine the impact of a WT on the voltage quality to ensure that the installation is designed so that voltage quality requirements are respected;
- the WT certification authority or component testing organization in evaluating the power quality characteristics of the wind turbine type;
- the planner or regulator of the electric network who has to be able to determine the grid connection required for a WT.

This part of IEC 61400 provides recommendations for preparing the measurements and assessment of power quality characteristics of grid connected WTs. This part of IEC 61400 will benefit those parties involved in the manufacturing, installation planning, obtaining of permission, operation, utilization, testing and regulation of WTs. The measurement and analysis techniques recommended in this part of IEC 61400 should be applied by all parties to ensure that the continuing development and operation of WTs are carried out in an atmosphere of consistent and accurate communication.

This part of IEC 61400 presents measurement and analysis procedures expected to provide consistent results that can be replicated by others.

## WIND TURBINES –

### Part 21: Measurement and assessment of power quality characteristics of grid connected wind turbines

#### 1 Scope

This part of IEC 61400 includes:

- definition and specification of the quantities to be determined for characterizing the power quality of a grid connected wind turbine;
- measurement procedures for quantifying the characteristics;
- procedures for assessing compliance with power quality requirements, including estimation of the power quality expected from the wind turbine type when deployed at a specific site, possibly in groups.

The measurement procedures are valid for single wind turbines with a three-phase grid connection. The measurement procedures are valid for any size of wind turbine, though this part of IEC 61400 only requires wind turbine types intended for PCC (Point of Common Coupling) at MV or HV to be tested and characterized as specified in this part of IEC 61400.

The measured characteristics are valid for the specific configuration and operational mode of the assessed wind turbine type only. Other configurations, including altered control parameters that cause the wind turbine to behave differently with respect to power quality, require separate assessment.

The measurement procedures are designed to be as non-site-specific as possible, so that power quality characteristics measured at, for example a test site can be considered valid also at other sites.

The procedures for assessing compliance with power quality requirements are valid for wind turbines with PCC at MV or HV in power systems with fixed frequency within  $\pm 1$  Hz, and sufficient active and reactive power regulation capabilities. In other cases, the principles for assessing compliance with power quality requirements may still be used as a guidance.

This part of IEC 61400 is for testing of wind turbines, though it contains information that may also be useful for testing of wind farms.

NOTE This part of IEC 61400 uses the following terms for system voltage:

- low voltage (LV) refers to  $U_n \leq 1$  kV;
- medium voltage (MV) refers to  $1 \text{ kV} < U_n \leq 35$  kV;
- high voltage (HV) refers to  $U_n > 35$  kV.

#### 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, *Instrument transformers – Part 1: Current transformers*

IEC 60044-2, *Instrument transformers – Part 2: Inductive voltage transformers*