INTERNATIONAL STANDARD

IEC 61400-21

First edition
2001-12

Wind turbine generator systems –

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

*This **English-language** version is derived from the original **bilingual** publication by leaving out all French-language pages. Missing page numbers correspond to the French-language pages.*

Reference number
IEC 61400-21:2001(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.

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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 X

For price, see current catalogue

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND TURBINE GENERATOR SYSTEMS –

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

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the 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, the IEC publishes International Standards. 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. The 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 the 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 National Committees.
3) The documents produced have the form of recommendations for international use and are published in the form of standards, technical specifications, technical reports or guides and they are accepted by the National Committees in that sense.
4) In order to promote international unification, IEC National Committees undertake to apply IEC International Standards transparently to the maximum extent possible in their national and regional standards. Any divergence between the IEC Standard and the corresponding national or regional standard shall be clearly indicated in the latter.
5) The IEC provides no marking procedure to indicate its approval and cannot be rendered responsible for any equipment declared to be in conformity with one of its standards.
6) Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. The 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 turbine systems.

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

FDIS	Report on voting
88/144/FDIS	88/150/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 3.

Annexes A and B are for information only.

The committee has decided that the contents of this publication will remain unchanged until 2005. 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 measurement and assessment of power quality characteristics of grid connected wind turbines (WTs). In this respect the term power quality includes those electric characteristics of the WT that influence the voltage quality of the grid to which the WT is connected. The standard 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 must 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 must be able to determine the grid connection required for a WT.

This standard provides recommendations for preparing the measurements and assessment of power quality characteristics of grid connected WTs. The standard will benefit those parties involved in the manufacture, installation planning, obtaining of permission, operation, utilization, testing and regulation of WTs. The measurement and analysis techniques recommended in this standard 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 standard presents measurement and analysis procedures expected to provide consistent results that can be replicated by others.

WIND TURBINE GENERATOR SYSTEMS –

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, and as long as the wind turbine is not operated to actively control the frequency or voltage at any location in the network. The measurement procedures are valid for any size of wind turbine, though this standard only requires wind turbine types intended for PCC at MV or HV to be tested and characterized as specified in this standard.

The measured characteristics are valid for the specific configuration of the assessed wind turbine 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 ±1 Hz, and sufficient active and reactive power regulation capabilities and sufficient load to absorb the wind power production. In other cases, the principles for assessing compliance with power quality requirements may still be used as a guide.

NOTE 1 This standard uses the following terms for system voltage:

– low voltage (LV) refers to $U_n \leq 1$ kV;

– medium voltage (MV) refers to 1 kV < $U_n \leq 35$ kV;

– high voltage (HV) refers to $U_n > 35$ kV.

NOTE 2 The issue of interharmonics is not addressed in this standard, though it is under consideration awaiting proper measurement and assessment procedures to be established by the appropriate IEC committee.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 61400. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this part of IEC 61400 are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of IEC and ISO maintain registers of currently valid International Standards.

IEC 60034-1, *Rotating electrical machines – Part 1: Rating and performance*

IEC 60044-1, *Instrument transformers – Part 1: Current transformers*

IEC 60050(161), *International Electrotechnical Vocabulary (IEV) – Chapter 161: Electromagnetic compatibility*

IEC 60050(393), *International Electrotechnical Vocabulary (IEV) – Chapter 393: Nuclear instrumentation: Physical phenomena and basic concepts*

IEC 60050(415), *International Electrotechnical Vocabulary (IEV) – Chapter 415: Wind turbine generator systems*

IEC 60186, *Voltage transformers*
Amendment 1 (1988)
Amendment 2 (1995)

IEC 60688, *Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals*

IEC 61000-4-7, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 7: General guide on harmonics and interharmonics measurements and instrumentation, for power supply systems and equipment connected thereto*

IEC 61000-4-15, *Electromagnetic compatibility (EMC) – Part 4: Testing and measurement techniques – Section 15: Flickermeter – Functional and design specifications*

IEC 61800-3, *Adjustable speed electrical power drive systems – Part 3: EMC product standard including specific test methods*

3 Definitions

For the purpose of this part of IEC 61400, the following definitions apply.

3.1
continuous operation (for wind turbines)
normal operation of the wind turbine excluding start-up and shutdown operations

3.2
cut-in wind speed (for wind turbines)
lowest wind speed at hub height at which the wind turbine starts to produce power

[IEV 415-03-05]

3.3
flicker coefficient for continuous operation (for wind turbines)
a normalized measure of the flicker emission during continuous operation of the wind turbine:

$$c(\psi_k) = P_{st,fic} \cdot \frac{S_{k,fic}}{S_n}$$

where

$P_{st,fic}$ is the flicker emission from the wind turbine on the fictitious grid;

S_n is the rated apparent power of the wind turbine;

$S_{k,fic}$ is the short-circuit apparent power of the fictitious grid.

NOTE The flicker coefficient for continuous operation is the same for a short-term (10 min) and long-term period (2 h).

3.4
flicker step factor (for wind turbines)
a normalized measure of the flicker emission due to a single switching operation of the wind turbine:

$$k_f(\psi_k) = \frac{1}{130} \cdot \frac{S_{k,fic}}{S_n} \cdot P_{st,fic} \cdot T_p^{0,31}$$

where

T_p is the measurement period, long enough to ensure that the transient of the switching operation has abated, though limited to exclude possible power fluctuations due to turbulence;

$P_{st,fic}$ is the flicker emission from the wind turbine on the fictitious grid;

S_n is the rated apparent power of the wind turbine;

$S_{k,fic}$ is the short-circuit apparent power of the fictitious grid.

3.5
maximum permitted power (for wind turbines)
the 10 min average power from the wind turbine that must not be exceeded irrespective of weather and grid conditions

3.6
maximum measured power (for wind turbines)
that power (with a specified averaging time) which is observed during continuous operation of the wind turbine

3.7
network impedance phase angle
phase angle of network short-circuit impedance:

$$\psi_k = \arctan(X_k / R_k)$$

where

X_k is the network short-circuit reactance;

R_k is the network short-circuit resistance.

3.8
normal operation (for wind turbines)
fault free operation complying with the description in the wind turbine manual

[IEV 393-08-12, modified]

3.9
output power (for wind turbines)
electric active power delivered by the wind turbine at its terminals

[IEV 415-04-02, modified]

3.10
point of common coupling (PCC)
point of a power supply network, electrically nearest to a particular load, at which other loads are, or may be, connected

NOTE 1 These loads can be either devices, equipment or systems, or distinct customer's installations.

NOTE 2 In some applications, the term “point of common coupling” is restricted to public networks.

[IEV 161-07-15, modified]

3.11
power collection system (for wind turbines)
electrical system that collects the power from a wind turbine and feeds it into an electrical supply network

[IEV 415-04-06, modified]

3.12
rated apparent power (for wind turbines)
the apparent power from the wind turbine while operating at rated power and nominal voltage and frequency:

$$S_n = \sqrt{P_n^2 + Q_n^2}$$

where

P_n is the rated power;

Q_n is the corresponding reactive power.

3.13
rated current (for wind turbines)
the current from the wind turbine while operating at rated power and nominal voltage and frequency

3.14
rated power (for wind turbines)
maximum continuous electric output power which a wind turbine is designed to achieve under normal operating conditions

[IEV 415-04-03, modified]

3.15
rated wind speed (for wind turbines)
wind speed at which a wind turbine’s rated power is achieved

[IEV 415-03-04, modified]

3.16
rated reactive power (for wind turbines)
the reactive power from the wind turbine while operating at rated power and nominal voltage and frequency

3.17
standstill (for wind turbines)
condition of a wind turbine that is stopped

[IEV 415-01-15, modified]

3.18
start-up (for wind turbines)
transitional state of a wind turbine between standstill and power production

3.19
switching operation (for wind turbines)
start-up or switching between generators

3.20
turbulence intensity
ratio of the wind speed standard deviation to the mean wind speed, determined from the same set of measured data samples of wind speed, and taken over a specified period of time

[IEV 415-03-25]

3.21
voltage change factor (for wind turbines)
a normalized measure of the voltage change due to a switching operation of the wind turbine:

$$k_u(\psi_k) = \sqrt{3} \cdot \frac{U_{fic,max} - U_{fic,min}}{U_n} \cdot \frac{S_{k,fic}}{S_n}$$

where

$U_{fic,min}$ and $U_{fic,max}$ are the minimum and maximum one period RMS value of the phase-to-neutral voltage on the fictitious grid during the switching operation;

U_n is the nominal phase-to-phase voltage;

S_n is the rated apparent power of the wind turbine;

$S_{k,fic}$ is the short-circuit apparent power of the fictitious grid.

NOTE The voltage change factor k_u is similar to k_i being the ratio between the maximum inrush current and the rated current, though k_u is a function of the network impedance phase angle. The highest value of k_u will be numerically close to k_i.

3.22
wind turbine (WT)
system which converts kinetic wind energy into electric energy

3.23
wind turbine terminals
a point being a part of the WT and identified by the WT supplier at which the WT may be connected to the power collection system