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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

IEC 61400-21:2008

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CONTENTS

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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.
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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 manufacture, 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 ±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 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*

IEC 60050-161, *International Electrotechnical Vocabulary – Part 161: Electromagnetic compatibility*

IEC 60050-415, *International Electrotechnical Vocabulary – Part 415: Wind turbine generator systems*

IEC 61000-4-7:2002, *Electromagnetic compatibility (EMC) – Part 4-7: Testing and measurement techniques – 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 61400-12-1, *Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines*

IEC 61800-3:2004, *Adjustable speed electrical power drive systems – Part 3: EMC requirements and specific test methods*

IEC 62008, *Performance characteristics and calibration methods for digital data acquisition systems and relevant software*

3 Terms and definitions

For purposes of this document, the following terms and 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)
normalized measure of the flicker emission during continuous operation of the wind turbine:

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

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:

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

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

NOTE The flicker coefficient $P_{st,fic}$ is here evaluated over the time period T_p.

3.5
maximum measured power (for wind turbines)
power (with a specified averaging time) which is observed during continuous operation of the wind turbine

3.6
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

3.7
normal operation (for wind turbines)
fault free operation complying with the description in the wind turbine manual

3.8
operational mode (for wind turbines)
operation according to control setting, for example voltage control mode, frequency control mode, reactive power control mode, active power control mode, etc.

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)
apparent power from the wind turbine while operating at rated current and nominal voltage and frequency:

$$S_n = \sqrt{3} U_n I_n$$

where

U_n is the nominal voltage;

I_n is the rated current

3.13
rated current (for wind turbines)
maximum continuous electric output current which a wind turbine is designed to achieve under normal operating conditions

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

[IEV 415-01-15, modified]

3.17
start-up (for wind turbines)
transitional state of a wind turbine between standstill and power production

3.18
switching operation (for wind turbines)
start-up or switching between generators

3.19
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]

3.20
voltage change factor (for wind turbines)
a normalized measure of the voltage change due to a switching operation of the wind turbine:

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

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.

3.21
wind turbine
WT
system which converts kinetic wind energy into electric energy

3.22
wind turbine terminals
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

4 Symbols and units

In this part of IEC 61400, the following symbols and units are used.

$\frac{\Delta U_{dyn}}{U_n}$	maximum permitted voltage change (%)
ψ_k	network impedance phase angle (°)
$\alpha_m(t)$	electrical angle of the fundamental of the measured voltage (°)
β	exponent associated with summation of harmonics
$c(\psi_k)$	flicker coefficient for continuous operation
d	relative voltage change (%)
E_{PIti}	long-term flicker emission limit
E_{Psti}	short-term flicker emission limit
f_g	nominal grid frequency (50 Hz or 60 Hz)
$f_{m,i}$	frequency of occurrence of flicker coefficient values within the i'th wind speed bin
f_{over}	over-frequency protection level
f_{under}	under-frequency protection level
$f_{y,i}$	frequency of occurrence of wind speeds within the i'th wind speed bin
h	harmonic order

$I_{h,i}$ h'th order harmonic current distortion of i'th wind turbine (A)

$i_m(t)$ measured instantaneous current (A)

I_n rated current (A)

$k_f(\psi_k)$ flicker step factor

k_i ratio of maximum inrush current and rated current

$k_u(\psi_k)$ voltage change factor

L_{fic} inductance of fictitious grid (H)

N_{10m} maximum number of one type of switching operations within a 10 min period

N_{120m} maximum number of one type of switching operations within a 120 min period

N_{bin} total number of wind speed bins between $v_{cut\text{-}in}$ and 15 m/s

n_i ratio of the transformer at the i'th wind turbine

N_m total number of measured flicker coefficient values

$N_{m,i}$ number of measured flicker coefficient values within the i'th wind speed bin

$N_{m,i,c<x}$ number of flicker coefficient values less than x within the i'th wind speed bin

N_{wt} number of wind turbines

P active power (W)

$P_{0,2}$ maximum measured active power (0,2 s average value) (W)

P_{60} maximum measured active power (60 s average value) (W)

P_{600} maximum measured active power (600 s average value) (W)

P_{lt} long-term flicker disturbance factor

P_n rated active power of wind turbine (W)

$Pr(c<x)$ accumulated distribution of c

P_{st} short-term flicker disturbance factor

$P_{st,fic}$ short-term flicker disturbance factor at fictitious grid

Q reactive power (var)

R_{fic} resistance of fictitious grid (Ω)