

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Wind energy generation systems –
Part 21-1: Measurement and assessment of electrical characteristics – Wind
turbines**

IEC 61400-21-1:2019
**Systemes de generation d'energie eolienne –
Partie 21-1: Mesurage et evaluation des caracteristiques electriques – Eoliennes**





THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2019 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 l'IEC ou du Comité national de l'IEC du pays du demandeur. Si vous avez des questions sur le copyright de l'IEC ou si vous désirez obtenir des droits supplémentaires sur cette publication, utilisez les coordonnées ci-après ou contactez le Comité national de l'IEC de votre pays de résidence.

IEC Central Office
3, rue de Varembe
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
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 corrigendum or an amendment might have been published.

IEC publications search - webstore.iec.ch/advsearchform

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 It also gives information on projects, replaced and withdrawn publications.

IEC Just Published - webstore.iec.ch/justpublished

Stay up to date on all new IEC publications. Just Published details all new publications released. Available online and once a month by email.

IEC Customer Service Centre - webstore.iec.ch/csc

If you wish to give us your feedback on this publication or need further assistance, please contact the Customer Service Centre: sales@iec.ch.

Electropedia - www.electropedia.org

The world's leading online dictionary on electrotechnology, containing more than 22,000 terminological entries in English and French, with equivalent terms in 16 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

IEC Glossary - std.iec.ch/glossary

67,000 electrotechnical terminology entries in English and French extracted from the Terms and Definitions clause of IEC publications issued since 2002. Some entries have been collected from earlier publications of IEC TC 37, 77, 86 and CISPR.

A propos de l'IEC

La Commission Electrotechnique Internationale (IEC) 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 IEC

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

Recherche de publications IEC -

webstore.iec.ch/advsearchform

La recherche avancée permet de trouver des publications IEC en utilisant différents critères (numéro de référence, texte, comité d'études,...). Elle donne aussi des informations sur les projets et les publications remplacées ou retirées.

IEC Just Published - webstore.iec.ch/justpublished

Restez informé sur les nouvelles publications IEC. Just Published détaille les nouvelles publications parues. Disponible en ligne et une fois par mois par email.

Service Clients - webstore.iec.ch/csc

Si vous désirez nous donner des commentaires sur cette publication ou si vous avez des questions contactez-nous: sales@iec.ch.

Electropedia - www.electropedia.org

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 000 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 16 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.

Glossaire IEC - std.iec.ch/glossary

67 000 entrées terminologiques électrotechniques, en anglais et en français, extraites des articles Termes et Définitions des publications IEC parues depuis 2002. Plus certaines entrées antérieures extraites des publications des CE 37, 77, 86 et CISPR de l'IEC.



IEC 61400-21-1

Edition 1.0 2019-05

INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Wind energy generation systems –
Part 21-1: Measurement and assessment of electrical characteristics – Wind
turbines**

IEC 61400-21-1:2019
**Systemes de génération d'énergie éolienne –
Partie 21-1: Mesurage et évaluation des caractéristiques électriques – Éoliennes**

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

COMMISSION
ELECTROTECHNIQUE
INTERNATIONALE

ICS 27.180

ISBN 978-2-8322-6761-5

**Warning! Make sure that you obtained this publication from an authorized distributor.
Attention! Veuillez vous assurer que vous avez obtenu cette publication via un distributeur agréé.**

CONTENTS

FOREWORD.....	10
INTRODUCTION.....	12
1 Scope.....	13
2 Normative references	13
3 Terms and definitions	14
4 Symbols and units	25
5 Abbreviated terms	26
6 Wind turbine specification.....	27
7 Test conditions and test systems	27
7.1 General.....	27
7.2 Overview of required test levels	27
7.3 Test validity	28
7.4 Test conditions	29
7.5 Test equipment.....	30
8 Measurement and test of electrical characteristics.....	32
8.1 General.....	32
8.2 Power quality aspects	32
8.2.1 General.....	32
8.2.2 Flicker during continuous operation	32
8.2.3 Flicker and voltage change during switching operations.....	35
8.2.4 Harmonics, interharmonics and higher frequency components	38
8.3 Steady-state operation.....	40
8.3.1 General	40
8.3.2 Observation of active power against wind speed.....	40
8.3.3 Maximum power	42
8.3.4 Reactive power characteristic ($Q = 0$)	44
8.3.5 Reactive power capability	44
8.3.6 Voltage dependency of PQ diagram.....	45
8.3.7 Unbalance factor	46
8.4 Control performance	47
8.4.1 General	47
8.4.2 Active power control	47
8.4.3 Active power ramp rate limitation	50
8.4.4 Frequency control.....	52
8.4.5 Synthetic inertia.....	54
8.4.6 Reactive power control	55
8.5 Dynamic performance	58
8.5.1 General	58
8.5.2 Fault ride-through capability	58
8.6 Disconnection from grid	66
8.6.1 General	66
8.6.2 Grid protection.....	66
8.6.3 Test of rate of change of frequency RoCoF (df/dt) protection device	70
8.6.4 Reconnection test.....	71
Annex A (informative) Reporting	72
A.1 Overview.....	72

A.2	General.....	72
A.3	Power quality aspects	74
A.4	Steady-state operation	83
A.5	Dynamic performance (see 8.5)	101
A.6	Disconnection from grid (see 8.6)	106
Annex B (informative) Voltage fluctuations and flicker.....		110
B.1	Continuous operation.....	110
B.2	Switching operations.....	110
B.3	Verification test of the measurement procedure for flicker	111
B.3.1	General	111
B.3.2	Fictitious grid performance testing	112
B.3.3	Distorted $u_m(t)$ voltage with multiple zero crossings.....	113
B.3.4	Distorted $u_m(t)$ voltage with inter-harmonic modulation.....	113
B.3.5	Slow frequency changes	114
B.4	Deduction of definitions.....	114
B.4.1	Flicker coefficient	114
B.4.2	Flicker step factor	115
B.4.3	Voltage change factor.....	116
Annex C (normative) Measurement of active power, reactive power and voltage.....		117
C.1	General.....	117
C.2	Generator convention of the signs.....	117
C.3	Calculation of positive, negative and zero sequence quantities	118
C.3.1	Phasor calculations	118
C.3.2	Calculation of the positive sequence quantities using phasor components.....	121
C.3.3	Calculation of the negative sequence quantities using phasor components.....	122
C.3.4	Calculation of the zero sequence quantities using phasor components	123
Annex D (informative) Harmonic evaluation		125
D.1	General.....	125
D.2	General analysis methods.....	125
D.2.1	General	125
D.2.2	Harmonic voltages	125
D.2.3	Harmonic phase angles and magnitudes.....	125
D.2.4	Statistical analysis	129
D.2.5	Sample rate adjustment	129
D.2.6	Determination of background harmonic voltage distortion	129
D.2.7	Diurnal variations of the harmonic voltage and current.....	129
D.2.8	Shutting down neighbouring WT or loads.....	130
D.2.9	Harmonics of current and voltage over power	130
D.2.10	Filters switching.....	131
D.2.11	Measuring at a standard source.....	132
D.2.12	Harmonics power flow + voltage measurement, phase angle	132
D.2.13	Voltage harmonics with and without operation of the tested wind turbine	133
D.2.14	Measurements at different sites	134
D.2.15	Harmonic model.....	134
D.3	Determination of harmonic amplitude affected by space harmonics at DFAG systems	134

Annex E (informative) Assessment of power quality of wind turbines and wind power plants.....	136
E.1 General.....	136
E.2 Voltage fluctuations	136
E.2.1 General	136
E.2.2 Continuous operation.....	137
E.2.3 Switching operations	137
E.3 Current harmonics, interharmonics and higher frequency components	138
Annex F (informative) Guidelines for the transferability of test results to different turbine variants in the same product platform.....	140
Bibliography.....	144
Figure 1 – Example of step response	22
Figure 2 – Measurement system description including the most significant components.....	31
Figure 3 – Fictitious grid for simulation of fictitious voltage	33
Figure 4 – Active power as a function of the wind speed (example).....	41
Figure 5 – Number of measurements in power bins (example)	42
Figure 6 – Number of measurements in wind speed bins (example)	42
Figure 7 – Example of PQ capability diagram for a given voltage at WT level.....	45
Figure 8 – Adjustment of active power reference value.....	48
Figure 9 – Example of active power response step	48
Figure 10 – Example of available active power and active power in ramp rate limitation mode figure.....	51
Figure 11 – Example of an active power control function $P=f(f)$ with the different measurement points and related steps of frequency	52
Figure 12 – Synthetic inertia – definitions	55
Figure 13 – Test for static error.....	56
Figure 14 – Test of dynamic response (example)	57
Figure 15 – Example UVRT test equipment.....	59
Figure 16 – Tolerances of the positive sequence voltage for the undervoltage event with disconnected WT under test	60
Figure 17 – Tolerance of positive sequence overvoltage event.....	61
Figure 18 – Example OVRT capacitor test unit.....	62
Figure 19 – Example of an undervoltage test chart	63
Figure 20 – Example of an overvoltage capability curve	64
Figure 21 – Example of step ramp for overvoltage or frequency testing.....	68
Figure 22 – Example of pulse ramp for over voltage or frequency testing.....	69
Figure 23 – Example of the test levels to determine the release time	69
Figure A.1 – Voltage flicker P_{St} vs. active power	74
Figure A.2 – Flicker coefficient $c(30^\circ)$ vs. active power	74
Figure A.3 – Flicker coefficient $c(50^\circ)$ vs. active power	75
Figure A.4 – Flicker coefficient $c(70^\circ)$ vs. active power	75
Figure A.5 – Flicker coefficient $c(85^\circ)$ vs. active power	75
Figure A.6 – Time series of 3-phase voltages as RMS of start-up at the wind speed of ... m/s	76

Figure A.7 – Time series of 3-phase currents as RMS of start-up at the wind speed of ... m/s	76
Figure A.8 – Time series of active and reactive power of start-up at the wind speed of ... m/s	76
Figure A.9 – Time series of 3-phase voltages as RMS of start-up at the wind speed of ... m/s	77
Figure A.10 – Time series of 3-phase currents as RMS of start-up at the wind speed of ... m/s	77
Figure A.11 – Time series of active and reactive power of start-up at the wind speed of ... m/s	77
Figure A.12 – Time series of 3-phase voltages as RMS of change from generator stage 1 to stage 2.....	78
Figure A.13 – Time series of 3-phase currents as RMS of change from generator stage 1 to stage 2.....	78
Figure A.14 – Time series of active and reactive power of change from generator stage 1 to stage 2.....	78
Figure A.15 – Time series of 3-phase voltages as RMS of change from generator stage 2 to stage 1.....	78
Figure A.16 – Time series of 3-phase currents as RMS of change from generator stage 2 to stage 1.....	78
Figure A.17 – Time series of active and reactive power of change from generator stage 2 to stage 1.....	79
Figure A.18 – Max. of the 95 th percentiles of integer harmonic currents vs. harmonic order.....	83
Figure A.19 – Max. of the 95 th percentiles of interharmonic currents vs. frequency.....	83
Figure A.20 – Max. of the 95 th percentiles of higher frequency current components vs. frequency.....	83
Figure A.21 – Active power as a function of the wind speed	84
Figure A.22 – Reactive power vs. active power	85
Figure A.23 – PQ-Diagram.....	86
Figure A.24 – PQ-Diagram.....	87
Figure A.25 – PQ-Diagram.....	88
Figure A.26 – Mean 1-min current unbalance factor over active power.....	89
Figure A.27 – Time-series of active power reference values, available power and measured active power output during active power control for the evaluation of the static error	89
Figure A.28 – Time-series of measured wind speed during active power control during the test of the static error.....	89
Figure A.29 – Time-series of active power reference values, available power and measured active power output during active power control for the evaluation of the settling time	90
Figure A.30 – Time-series of available and measured active power output during ramp rate limitation.....	90
Figure A.31 – Time-series of measured wind speed during ramp rate limitation	91
Figure A.32 – Time-series of available and measured active power output during ramp rate limitation.....	91
Figure A.33 – Time-series of measured wind speed during ramp rate limitation	91
Figure A.34 – Time-series of available and measured active power output during ramp rate limitation.....	92

Figure A.35 – Time-series of measured wind speed during ramp rate limitation	92
Figure A.36 – Time-series of available and measured active power output during ramp rate limitation	93
Figure A.37 – Time-series of measured wind speed during ramp rate limitation	93
Figure A.38 – Time-series of available power, measured active power and reference value of the grid frequency change	94
Figure A.39 – Time-series of measured wind speed	94
Figure A.40 – Measured active power over frequency change	94
Figure A.41 – Time-series of available power, measured active power and reference value of the grid frequency change	95
Figure A.42 – Time-series of measured wind speed	95
Figure A.43 – Measured active power over frequency change	95
Figure A.44 – Test 1, time-series of available power, measured active power and reference value of the grid frequency for $0,25 \times P_n < P < 0,5 \times P_n$	96
Figure A.45 – Test 1, time-series of wind speed for $0,25 \times P_n < P < 0,5 \times P_n$	96
Figure A.46 – Test 2, time-series of available power, measured active power and reference value of the grid frequency for $0,25 \times P_n < P < 0,5 \times P_n$	97
Figure A.47 – Test 2, time-series of wind speed for $0,25 \times P_n < P < 0,5 \times P_n$	97
Figure A.48 – Test 3, time-series of available power, measured active power and reference values of the grid frequency for $P > 0,8 \times P_n$	97
Figure A.49 – Test 3, time-series of wind speed for $P > 0,8 \times P_n$	97
Figure A.50 – Test 4, time-series of available power, measured active power and reference value of the grid frequency for $P > 0,8 \times P_n$	97
Figure A.51 – Test 4, time-series of wind speed for $P > 0,8 \times P_n$	98
Figure A.52 – Test 5, time-series of available power, measured active power and reference value of the grid frequency for $v > v_n$	98
Figure A.53 – Test 5, time-series of wind speed for $v > v_n$	98
Figure A.54 – Test 6, time-series of available power, measured active power and reference value of the grid frequency for $v > v_n$	98
Figure A.55 – Test 6, time-series of wind speed for $v > v_n$	98
Figure A.56 – Time-series of reactive power reference values and measured reactive power during the test of reactive power control	99
Figure A.57 – Time-series of active power during the test of reactive power control	99
Figure A.58 – Time-series of reactive power reference values and measured reactive power during the test of reactive power dynamic response	100
Figure A.59 – Time-series of active power during the test of reactive power dynamic response	100
Figure A.60 – Wave shape of 3-phase voltages during entrance of voltage dip/swell when the WT under test is not connected	101
Figure A.61 – Wave shape of 3-phase voltages during clearance of voltage dip/swell when the WT under test is not connected	102
Figure A.62 – 3-phase voltages as RMS (1 line period) during the test when the WT under test is not connected	102
Figure A.63 – Positive sequence voltage during the test when the WT under test is not connected	102
Figure A.64 – Wave shape of 3-phase voltages during entrance of the voltage dip/swell when the WT under test is connected	104
Figure A.65 – Wave shape of 3-phase voltages during clearance of the voltage dip/swell when the WT under test is connected	104

Figure A.66 – 3-phase voltages as RMS (1 line period) during the test when the WT under test is connected	104
Figure A.67 – Positive and negative sequence fundamental voltage during the test when the WT under test is connected	104
Figure A.68 – 3-phase currents as RMS (1 line period) during the test when the WT under test is connected	104
Figure A.69 – Pos. and neg. sequence fundamental current during the test when the WT under test is connected	105
Figure A.70 – Pos. sequence fundamental active power during the test when the WT under test is connected	105
Figure A.71 – Pos. sequence fundamental reactive power during the test when the WT under test is connected	105
Figure A.72 – Pos. sequence fundamental active current during the test when the WT under test is connected	105
Figure A.73 – Pos. sequence fundamental reactive current during the test when the WT under test is connected	105
Figure A.74 – Wind speed or available power during the test when the WT under test is connected	106
Figure A.75 – Voltage during the reconnection test of 10 s	107
Figure A.76 – Active power during the reconnection test of 10 s, including the recovery	107
Figure A.77 – Time-series of measured wind speed during the reconnection test of 10 s	108
Figure A.78 – Voltage during the reconnection test of 60 s	108
Figure A.79 – Active power during the reconnection test of 60 s, including the recovery	108
Figure A.80 – Time-series of measured wind speed during the reconnection test of 60 s	108
Figure A.81 – Voltage during the reconnection test of 600 s	108
Figure A.82 – Active power during the reconnection test of 600 s including the recovery	109
Figure A.83 – Time-series of measured wind speed during the reconnection test of 600 s	109
Figure B.1 – Measurement procedure for flicker during continuous operation of the wind turbine	110
Figure B.2 – Measurement procedure for voltage changes and flicker during switching operations of the wind turbine	111
Figure C.1 – Positive directions of active power, reactive power, instantaneous phase voltages and instantaneous phase currents with generator convention	117
Figure C.2 – Examples of the power phasor diagrams of the generator convention in each quadrant with respective instantaneous phase voltage and current	118
Figure D.1 – Definition of the phase angles of the spectral line in generator convention – (5th harmonic with $\alpha_{15} = + 120^\circ$ and $\alpha_{U5} = + 170^\circ$ shown as an example, thus 5th harmonic phase angle is $\varphi_5 = + 170^\circ - 120^\circ = + 50^\circ$)	126
Figure D.2 – Comparison of harmonic amplitude aggregation (dotted) no aggregated amplitude directly from DFT with 10-cycle window, (dashed) 10-second aggregation	127
Figure D.3 – Comparison of the prevailing angle ratio (PAR)	128
Figure F.1 – Block diagram for generic wind turbine (source IEC 61400-27-1)	141
Table 1 – Overview of required test levels	28
Table 2 – Specification of requirements for measurement equipment	31
Table 3 – Number of 10-min time-series per wind speed bin	41
Table 4 – Number of measurements per power bin (10 min average)	41

Table 5 – Measured maximum active power values.....	43
Table 6 – Accuracy of the active power control values	49
Table 7 – Results from the active power reference test	49
Table 8 – Active power ramp rate calculation	51
Table 9 – Example of Settings for the frequency dependent active power function	53
Table 10 – Test for static error.....	58
Table 11 – Test for dynamic response	58
Table 12 – Example of undervoltage events.....	63
Table 13 – Example of overvoltage tests.....	65
Table 14 – Grid protection tests	67
Table A.1 – General report information	72
Table A.2 – General data	73
Table A.3 – Nominal data.....	73
Table A.4 – Test conditions.....	73
Table A.5 – Flicker coefficient per power bin (95 th percentile)	74
Table A.6 – Start-up at cut in wind speed.....	75
Table A.7 – Start-up at nominal active power	76
Table A.8 – Worst-case switching between generators	77
Table A.9 – General test information.....	79
Table A.10 – 95 th percentile of 10-min harmonic magnitudes per power bin	79
Table A.11 – 95 th percentile of 10-min harmonic magnitudes per power bin	81
Table A.12 – 95 th percentile of 10-min harmonic magnitudes per power bin	82
Table A.13 – Active power against wind speed (see 8.3.2).....	83
Table A.14 – Measurement data set.....	84
Table A.15 – Maximum active power.....	84
Table A.16 – Reactive power characteristic.....	85
Table A.17 – PQ-diagram.....	86
Table A.18 – PQ-diagram at maximum voltage.....	87
Table A.19 – PQ-diagram at minimum voltage	88
Table A.20 – P-IUF _i diagram.....	88
Table A.21 – General test information.....	89
Table A.22 – Static error	89
Table A.23 – Dynamic response	90
Table A.24 – General test information.....	90
Table A.25 – Active power ramp rate calculation at start-up	90
Table A.26 – General test information.....	91
Table A.27 – Active power ramp rate limitation at start-up.....	91
Table A.28 – General test information.....	92
Table A.29 – Active power ramp rate limitation at normal stop	92
Table A.30 – General test information.....	92
Table A.31 – Active power ramp rate limitation in normal operation	93
Table A.32 – General test information.....	93
Table A.33 – Test at $0,25 \times P_n < P < 0,5 \times P_n$	94

Table A.34 – Test at $P > 0,8 \times P_n$	95
Table A.35 – Synthetic inertia results.....	96
Table A.36 – General test information.....	99
Table A.37 – Static error.....	99
Table A.38 – Dynamic response.....	100
Table A.39 – Results for tests where the WT is not connected.....	101
Table A.40 – Results for tests where the WT is connected.....	103
Table A.41 – Voltage protection.....	106
Table A.42 – Frequency protection.....	106
Table A.43 – Complete trip circuit test.....	106
Table A.44 – RoCoF test results.....	107
Table A.45 – RoCoF test information.....	107
Table A.46 – Reconnection test results.....	107
Table B.1 – Nominal values of the wind turbine used in the verification tests.....	111
Table B.2 – Input relative current fluctuation, $\Delta I/I$, for flicker coefficient $c(\psi_k) = 2,00 \pm 5\%$ when $S_{k, \text{fic}} = 20 \cdot S_n$	112
Table B.3 – Input relative current fluctuation, $\Delta I/I$, for flicker coefficient $c(\psi_k) = 2,00 \pm 5\%$ when $S_{k, \text{fic}} = 50 \cdot S_n$	112
Table B.4 – Test specification for distorted voltage with multiple zero crossings.....	113
Table D.1 – Example of measurements results presentation.....	133
Table E.1– Specification of exponents in accordance with IEC TR 61000-3-6.....	139
Table F.1– Main components influencing the electrical characteristics of the WT.....	142

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND ENERGY GENERATION SYSTEMS –**Part 21-1: Measurement and assessment of electrical characteristics –
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 itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
- 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 61400-21-1 has been prepared by IEC technical committee 88: Wind energy generation systems.

This first edition cancels and replaces the second edition of 61400-21 published in 2008. This edition constitutes a technical revision.

This edition includes the following new items with respect to 61400-21:

- a) frequency control measurement;
- b) updated reactive power control and capability measurement, including voltage and $\cos \varphi$ control;
- c) inertia control response measurement;
- d) overvoltage ride through test procedure;
- e) updated undervoltage ride through test procedure based on Wind Turbine capability;

f) new methods for the harmonic assessment.

Parts of the assessments related to the wind power plant evaluation are moved to Annex E, as they will be replaced by IEC 61400-21-2, *Measurement and assessment of electrical characteristics – Wind power plants*.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
88/711/FDIS	88/716/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

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

A list of all parts in the IEC 61400 series, published under the general title *Wind energy generation systems*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

iTeh STANDARD PREVIEW
(standards.iteh.ai)
<https://standards.iteh.ai/catalog/standards/sist/beb9172c-9e20-41f3-8b23-532d6ec4f11d/iec-61400-21-1-2019>

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This part of IEC 61400 provides a uniform methodology that will ensure consistency and accuracy in reporting, testing and assessment of electrical characteristics of grid connected wind turbines (WTs). The electrical characteristics include wind turbine specifications and capabilities, voltage quality (emissions of flicker and harmonics), under- and overvoltage ride-through response, active power control, frequency control, voltage control, and reactive power control, 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 electrical characteristics;
- the WT purchaser, in specifying such electrical characteristics;
- the WT operator, who may be required to verify that stated, or required electrical 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 testing organization, in evaluating the electrical 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 electrical characteristics of grid connected WTs. This document will benefit those parties involved in the manufacture, installation planning, obtaining of permission, operation, usage, testing and regulation of WTs. The measurement and analysis techniques, recommended in this document, 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. Any selection of tests can be done and reported separately.

WIND ENERGY GENERATION SYSTEMS –

Part 21-1: Measurement and assessment of electrical characteristics – Wind turbines

1 Scope

This part of IEC 61400 includes:

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

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 connection to an electricity supply network 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 product platform. If a measured property is based on control parameters and the behavior of the wind turbine can be changed for this property, it is stated in the test report. Example: Grid protection, where the disconnect level is based on a parameter and the test only verifies the proper functioning of the protection, not the specific level.

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

This document is for the testing of wind turbines; all procedures, measurements and tests related to wind power plants are covered by IEC 61400-21-2.

The procedures for assessing electrical characteristics are valid for wind turbines with the connection to the PCC in power systems with stable grid frequency.

NOTE

For the purposes of this document, the following terms for system voltage apply:

- 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 $35 \text{ kV} < U_n \leq 220$ kV;
- Extra high voltage (EHV) refers to $U_n > 220$ kV.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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.