



BSI Standards Publication

Wind energy generation systems

Part 12-6: Measurement based nacelle transfer function
of electricity producing wind turbines

National foreword

This British Standard is the UK implementation of EN IEC 61400-12-6:2022. It is identical to IEC 61400-12-6:2022. Together with BS EN IEC 61400-50-2:2022, BS EN IEC 61400-12-3:2022 and BS EN IEC 61400-12-5:2022, it supersedes BS EN IEC 61400-12-2:2013 which is withdrawn. Together with BS EN IEC 61400-12-5:2022, it supersedes BS EN IEC 61400-12-1:2017, which will be withdrawn on publication of BS EN IEC 61400-12-5:2022.

The UK participation in its preparation was entrusted to Technical Committee PEL/88, Wind turbines.

A list of organizations represented on this committee can be obtained on request to its committee manager.

Contractual and legal considerations

This publication has been prepared in good faith, however no representation, warranty, assurance or undertaking (express or implied) is or will be made, and no responsibility or liability is or will be accepted by BSI in relation to the adequacy, accuracy, completeness or reasonableness of this publication. All and any such responsibility and liability is expressly disclaimed to the full extent permitted by the law.

This publication is provided as is, and is to be used at the recipient's own risk.

The recipient is advised to consider seeking professional guidance with respect to its use of this publication.

This publication is not intended to constitute a contract. Users are responsible for its correct application.

This publication has been prepared under a mandate given to the European Standards Organizations by the European Commission and the European Free Trade Association. It is intended to support requirements of the EU legislation detailed in the European Foreword. A European Annex, usually Annex ZA or ZZ, describes how this publication relates to that EU legislation.

For the Great Britain market (England, Scotland and Wales), if UK Government has designated this publication for conformity with UKCA marking (or similar) legislation, it may contain an additional National Annex. Where such a National Annex exists, it shows the correlation between this publication and the relevant UK legislation. If there is no National Annex of this kind, the relevant Annex ZA or ZZ in the body of the European text will indicate the relationship to UK regulation applicable in Great Britain. References to EU legislation may need to be read in accordance with the UK designation and the applicable UK law. Further information on designated standards can be found at www.bsigroup.com/standardsandregulation.

For the Northern Ireland market, UK law will continue to implement relevant EU law subject to periodic confirmation. Therefore Annex ZA/ZZ in the European text, and references to EU legislation, are still valid for this market.

UK Government is responsible for legislation. For information on legislation and policies relating to that legislation, consult the relevant pages of www.gov.uk.

© The British Standards Institution 2022
Published by BSI Standards Limited 2022

ISBN 978 0 539 18336 8

ICS 27.180

Compliance with a British Standard cannot confer immunity from legal obligations.

This British Standard was published under the authority of the Standards Policy and Strategy Committee on 31 October 2022.

Amendments/corrigenda issued since publication

Date	Text affected
------	---------------

English Version

Wind energy generation systems - Part 12-6: Measurement
based nacelle transfer function of electricity producing wind
turbines
(IEC 61400-12-6:2022)

Systèmes de génération d'énergie éolienne - Partie 12-6:
Fonction de transfert de la nacelle fondée sur le mesurage
des éoliennes de production d'électricité
(IEC 61400-12-6:2022)

Windenergieanlagen - Teil 12-6: Messbasierte
Gondelübertragungsfunktion von stromerzeugenden
Windkraftanlagen
(IEC 61400-12-6:2022)

This European Standard was approved by CENELEC on 2022-10-04. 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 CEN-CENELEC Management Centre 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 CEN-CENELEC Management Centre has the same status as the official versions.

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



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

CEN-CENELEC Management Centre: Rue de la Science 23, B-1040 Brussels

European foreword

The text of document 88/826/CDV, future edition 1 of IEC 61400-12-6, prepared by IEC/TC 88 "Wind energy generation systems" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN IEC 61400-12-6:2022.

The following dates are fixed:

- latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2023-07-04
- latest date by which the national standards conflicting with the document have to be withdrawn (dow) 2025-10-04

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC shall not be held responsible for identifying any or all such patent rights.

Any feedback and questions on this document should be directed to the users' national committee. A complete listing of these bodies can be found on the CENELEC website.

Endorsement notice

The text of the International Standard IEC 61400-12-6:2022 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following note has to be added for the standard indicated:

IEC 61400-2 NOTE Harmonized as EN 61400-2

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

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.

NOTE 1 Where an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60688	-	Electrical measuring transducers for converting AC and DC electrical quantities to analogue or digital signals	EN 60688	-
IEC 61400-12-1	-	Wind energy generation systems - Part 12-1: Power performance measurement of electricity producing wind turbines	EN 61400-12-1	-
IEC 61400-12-2	2022	Wind energy generation systems - Part 12-2: Power performance of electricity producing wind turbines based on nacelle anemometry	EN IEC 61400-12-2	2022
IEC 61400-12-3	-	Wind energy generation systems - Part 12-3: Power performance - Measurement based site calibration	EN IEC 61400-12-3	-
IEC 61400-12-5	2022	Wind energy generation systems - Part 12-5: Power performance - Assessment of obstacles and terrain	EN IEC 61400-12-5	2022
IEC 61400-50-1	-	Wind energy generation systems - Part 50-1: Wind Measurement - Application of Meteorological Mast, Nacelle and Spinner Mounted Instruments	EN IEC 61400-50-1 ¹	-
ISO/IEC Guide 98-3 2008		Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-

¹ Under preparation. Stage at the time of publication: FprEN IEC 61400-50-1:2022.

This page is left deliberately blank.

CONTENTS

FOREWORD.....	5
INTRODUCTION.....	7
1 Scope.....	8
2 Normative references	8
3 Terms and definitions	9
4 Symbols, units and abbreviated terms	11
5 Overview of test method	15
6 Preparation for measurement of nacelle transfer function	15
6.1 General.....	15
6.2 Wind turbine	15
6.3 Test site.....	16
6.3.1 General	16
6.3.2 Terrain classification.....	17
6.4 Test plan.....	17
7 Test equipment.....	17
7.1 General.....	17
7.2 Data acquisition	18
8 Measurement procedure	19
8.1 General.....	19
8.2 Data system(s) synchronisation	19
8.3 Data collection	20
8.4 Data quality check	20
8.4.1 General	20
8.4.2 Measured signals are in range and available	20
8.4.3 Sensors are operating properly.....	20
8.4.4 Ensure data acquisition system(s) is(are) operating properly	21
8.4.5 Sector self-consistency check.....	21
8.5 Data rejection	21
8.6 Data correction	21
8.7 Database	22
9 Derived results	22
9.1 Overview of derived results.....	22
9.2 Determination of measured nacelle transfer function.....	23
9.3 Data quality check	24
9.3.1 General	24
9.3.2 Directional stability check	24
9.3.3 Self-consistency check for NTF, using the NPC	25
9.4 Uncertainty analysis.....	25
10 Reporting format.....	25
Annex A (informative) Nacelle instrument mounting	29
A.1 General.....	29
A.2 Preferred method of anemometer's mounting	29
A.3 Preferred position of anemometer	29
Annex B (normative) Evaluation of uncertainty in measurement	31
B.1 General.....	31

B.2	The measurands	31
B.3	Uncertainty components.....	31
B.4	Wind direction uncertainty.....	33
Annex C (normative) Theoretical basis for determining the uncertainty of measurement using the method of bins		34
C.1	General.....	34
C.2	Propagation of uncertainty through the stages of NTF/NPC measurement	35
C.3	Category A uncertainties	38
C.3.1	General	38
C.3.2	Category A uncertainty in electric power	38
C.4	Category B uncertainties	39
C.4.1	General	39
C.4.2	Category B uncertainties in climatic variations	40
C.5	Expanded uncertainty	40
Annex D (normative) NTF uncertainty estimates and calculation		41
D.1	Methods and assumptions.....	41
D.1.1	General	41
D.1.2	Site calibration.....	41
D.1.3	Nacelle transfer function uncertainty component estimates	43
D.1.4	Nacelle power curve uncertainty component estimates	45
D.1.5	Wind direction uncertainty	45
D.1.6	Contribution factors	47
D.2	Uncertainty example calculations	48
D.2.1	Example description	48
D.2.2	Example case – NTF uncertainty	49
D.2.3	Example case – NPC uncertainty	49
Annex E (normative) Allowable anemometry instrument types.....		51
E.1	General.....	51
E.2	Recalibration of sonic anemometers	51
E.3	Uncertainty of sonic and propeller anemometers.....	51
Annex F (informative) Organisation of test, safety and communication.....		52
F.1	General.....	52
F.2	Responsibility for test	52
F.3	Safety during test.....	52
F.4	Communication	52
F.5	Prior to test.....	52
F.6	During test.....	52
F.7	After test.....	53
Annex G (informative) NTF flowchart		54
Bibliography.....		55
Figure 1 – Presentation of example data: measured transfer function		27
Figure A.1 – Mounting of anemometer on top of nacelle.....		30
Figure G.1 – NTF flowchart.....		54
Table 1 – Example of presentation of a measured power curve based on data from the meteorological mast, for consistency check		28
Table B.1 – Uncertainty components in nacelle transfer function evaluation.....		32

Table B.2 – Uncertainty components in nacelle based absolute wind direction	33
Table C.1 – Example cancellation sources	36
Table C.2 – List of category A and B uncertainties for NTF	39
Table C.3 – Expanded uncertainties.....	40
Table D.1 – Estimates for uncertainty components from site calibration	42
Table D.2 – Estimates for uncertainty components from NTF measurement	44
Table D.3 – Estimates for uncertainty components for wind direction	46
Table D.4 – Estimates for contribution factors for site calibration	47
Table D.5 – Estimates for contribution factors for NTF	48

INTERNATIONAL ELECTROTECHNICAL COMMISSION

WIND ENERGY GENERATION SYSTEMS –

**Part 12-6: Measurement based nacelle transfer
function 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 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.

IEC 61400-12-6 has been prepared by IEC technical committee 88: Wind energy generation systems. It is an International Standard.

This first edition of IEC 61400-12-6 is part of a structural revision that cancels and replaces the performance standards IEC 61400-12-1:2017 and IEC 61400-12-2:2013. The structural revision contains no technical changes with respect to IEC 61400-12-1:2017 and IEC 61400-12-2:2013, but the parts that relate to wind measurements, measurement of site calibration and assessment of obstacle and terrain have been extracted into separate standards.

The purpose of the re-structure was to allow the future management and revision of the power performance standards to be carried out more efficiently in terms of time and cost and to provide a more logical division of the wind measurement requirements into a series of separate standards which could be referred to by other use case standards in the IEC 61400 series and subsequently maintained and developed by appropriate experts.

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

Draft	Report on voting
88/826/CDV	88/871/RVC

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this International Standard is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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 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.

IMPORTANT – The "colour inside" logo on the cover page of this document 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

The IEC 61400-12 series consists of the following parts, under the general title Wind energy generation systems:

IEC 61400-12:	<i>Power performance measurements of electricity producing wind turbines – Overview</i>
IEC 61400-12-1:	<i>Power performance measurement of electricity producing wind turbines</i>
IEC 61400-12-2:	<i>Power performance of electricity producing wind turbines based on nacelle anemometry</i>
IEC 61400-12-3:	<i>Power performance – Measurement based site calibration</i>
IEC 61400-12-4:	<i>Numerical site calibration</i>
IEC 61400-12-5:	<i>Power performance – Assessment of obstacles and terrain</i>
IEC 61400-12-6:	<i>Measurement based nacelle transfer function of electricity producing wind turbines</i>

The purpose of this document is to provide a uniform methodology of measurement, analysis, and reporting for the determination of a nacelle transfer function of electricity producing wind turbines utilising nacelle-anemometry methods. This document is intended to be applied only to horizontal axis wind turbines of sufficient size that the nacelle-mounted anemometer does not significantly affect the flow through the turbine's rotor and around the nacelle and hence does not affect the wind turbine's performance. The intent of this document is that the methods presented herein be utilised when applying the methodology described in IEC 61400-12-2 to determine the power performance of individual wind turbines. This will ensure that the results are as consistent, accurate, and reproducible as possible within the current state of the art for instrumentation and measurement techniques.

This procedure describes how to characterise a wind turbine's nacelle transfer function in terms of wind speeds measured on a meteorological mast as well as a wind speed measured on the hub or nacelle of a wind turbine. The anemometer that is placed on the turbine is measuring a wind speed that is strongly affected by the test turbine's rotor. This procedure includes methods for determining and applying appropriate corrections for this interference. Such a correction is termed a nacelle transfer function which relates the wind speed measured on the turbine to a free-stream wind speed as measured on a meteorological mast. The procedure also provides guidance on determination of measurement uncertainty including assessment of uncertainty sources and recommendations for combining them into uncertainties.

Even when anemometers are carefully calibrated in a quality wind tunnel, fluctuations in magnitude and direction of the wind vector can cause different anemometers to perform differently in the field. Further, the flow conditions close to a turbine nacelle are complex and variable. Therefore, special care should be taken in the selection and installation of the anemometer. These issues are addressed in this document.

This document will benefit those parties interested in power performance testing of wind turbines using IEC 61400-12-2 as well as parties involved in the installation, planning and execution of such tests. When and where appropriate, the technically accurate measurement and analysis techniques recommended in this document 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 document presents measurement and reporting procedures expected to provide accurate results that can be replicated by others.

Meanwhile, a user of this document should be aware of differences that arise from large variations in wind shear and turbulence intensity, 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 engaging in nacelle transfer function measurements.

WIND ENERGY GENERATION SYSTEMS –

Part 12-6: Measurement based nacelle transfer function of electricity producing wind turbines

1 Scope

This part of IEC 61400-12 specifies a procedure for measuring the nacelle transfer function of a single electricity-producing, horizontal axis wind turbine, which is not considered to be a small wind turbine in accordance with IEC 61400-2. It is expected that this document be used when a valid nacelle transfer function is needed to execute a power performance measurement according to IEC 61400-12-2.

A wind speed measured on the nacelle or hub of a wind turbine is affected by the turbine rotor (i.e. speeded up or slowed down wind speed). In IEC 61400-12-1, an anemometer is located on a meteorological tower that is located between two and four rotor diameters upwind of the test turbine. This location allows direct measurement of the "free" wind with minimum interference from the test turbine's rotor. In the procedure of this document, the anemometer is located on or near the test turbine's nacelle. In this location, the anemometer is measuring a wind speed that is strongly affected by the test turbine's rotor and the nacelle. The procedure in this document includes methods for determining and applying appropriate corrections for this interference. However, note that these corrections inherently increase the measurement uncertainty compared to a properly configured test conducted in accordance with IEC 61400-12-1.

This document specifies how to characterise a wind turbine's nacelle transfer function. The nacelle transfer function is determined by collecting simultaneous measurements of nacelle-measured wind speed and free stream wind speed (as measured on a meteorological mast) 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 procedure also provides guidance on determination of measurement uncertainty including assessment of uncertainty sources and recommendations for combining them.

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.

IEC 60688, *Electrical measuring transducers for converting AC and DC electrical quantities to analogue or digital signals*

IEC 61400-12-1, *Wind energy generation systems – Part 12-1: Power performance measurement of electricity producing wind turbines*

IEC 61400-12-2:2022, *Wind energy generation systems – Part 12-2: Power performance of electricity producing wind turbines based on nacelle anemometry*

IEC 61400-12-3, *Wind energy generation systems – Part 12-3: Power performance – Measurement based site calibration*

IEC 61400-12-5:2022, *Wind energy generation systems – Part 12-5: Power performance – Assessment of obstacles and terrain*

IEC 61400-50-1, *Wind energy generation systems – Part 50-1: Wind measurement – Application of meteorological mast, nacelle and spinner mounted instruments*

ISO/IEC GUIDE 98-3:2008, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

accuracy

closeness of the agreement between the result of a measurement and a true value of the measurand

3.2

complex terrain

terrain surrounding the test site that features significant variations in topography and terrain obstacles that may cause flow distortion

3.3

data set

collection of data sampled over a contiguous period

3.4

documentation

any information regarding the test which is kept in files or data, or both, but which is not necessarily presented in the final report

3.5

flow distortion

change in air flow caused by obstacles, topographical variations, turbine's rotor, turbine's nacelle or other wind turbines that results in a significant deviation of the measured wind speed from the free stream wind speed

3.6

free stream wind speed

horizontal wind speed measured upstream of the rotor of the wind turbine generator that is unaffected by rotor aerodynamics

3.7

turbulence intensity

ratio of the wind speed standard deviation to the mean wind speed, determined from the same set of measured data samples of horizontal wind speed, and taken over a specific period of time

3.8

hub height

<wind turbine> height of the centre of the swept area of the wind turbine rotor above the ground level at the tower base

3.9

measurement period

period during which a statistically significant database has been collected for the power performance test

3.10

measurement sector

sector of wind directions from which data are selected for the measured power curve or during the determination of the nacelle transfer function

3.11

measurement uncertainty

parameter, associated with the result of a measurement, which characterises the dispersion of the values that could reasonably be attributed to the measurand

3.12

method of bins

data reduction procedure that groups test data for a certain parameter into intervals (bins)

Note 1 to entry: The method of bins is normally used for wind speed bins but is also applicable to other parameters.

Note 2 to entry: For each bin, the number of data sets or samples and their sum are recorded, and the average parameter value within each bin is calculated.

3.13

nacelle

housing which contains the drive train and other elements on top of a horizontal axis wind turbine generator

3.14

NPC

nacelle power curve

measured power performance of a wind turbine expressed as net active electric power output from the wind turbine as a function of free stream wind speed

Note 1 to entry: For the NPC, the free stream wind speed is not directly measured, but rather the nacelle wind speed is measured and a nacelle transfer function is applied to arrive at the free stream wind speed.

3.15

nacelle wind speed

horizontal wind speed measured on top of or in front of the nacelle of a wind turbine

3.16

obstacle

object that blocks the wind and distorts the flow, such as a building or tree

3.17

pitch angle

angle between the chord line at a defined blade radial location (usually 100 % of the blade radius) and the rotor plane of rotation

3.18

report

any information regarding the test which is stated in the final report

3.19

roughness length

extrapolated height at which the mean wind speed becomes zero if the vertical wind profile is assumed to have a logarithmic variation with height

3.20**ruggedness index****RIX_{xx}**

measure of terrain, the ruggedness index of which is calculated as the percentage of altitude differences within a given direction sector that exceed an altitude difference of $xx \times (D + H)$

3.21**site calibration**

procedure that quantifies and potentially reduces the effects of terrain and obstacles by measuring the correlation over wind direction between the wind speed measured at a reference meteorological mast and the wind speed measured at the wind turbine position

3.22**standard uncertainty**

uncertainty of the result of a measurement expressed as a standard deviation

3.23**swept area**

for a horizontal-axis turbine, the projected area of the moving rotor upon a plane normal to axis of rotation

Note 1 to entry: For teetering rotors, it should be assumed that the rotor remains normal to the low-speed shaft.

3.24**test site**

location of the wind turbine under test and its surroundings

3.25**turbine online**

status of the wind turbine, during normal operation excluding cut-in or cut-out, but including any operation at rotor speed in normal operating range where the turbine briefly disconnects from the grid, e.g. switching between generators, generator stages, star/delta or similar

3.26**wind shear**

variation of wind speed across a plane perpendicular to the wind direction

4 Symbols, units and abbreviated terms

Symbol or abbreviated term	Description	Unit
A	swept area of the wind turbine rotor	[m ²]
AEP	annual energy production	
ASL	above sea level	[m]
B	barometric pressure	[Pa]
$B_{10\text{min}}$	measured air pressure averaged over 10 minutes	[Pa]
c	sensitivity factor on a parameter (the partial differential)	
$c_{B,i}$	sensitivity factor of air pressure in bin i	[W/Pa]
$c_{d,i}$	sensitivity factor of data acquisition system in bin i	
$c_{k,i}$	sensitivity factor of component k in bin i	
$c_{l,j}$	sensitivity factor of component l in bin j	
$c_{m,i}$	sensitivity factor of air density correction in bin i	[W/m ³ kg]

Symbol or abbreviated term	Description	Unit
$c_{m,k,i}$	sensitivity factor of component k in bin i on turbine m	
$c_{T,i}$	sensitivity factor of air temperature in bin i	[W/K]
$c_{V,i}$	sensitivity factor of wind speed in bin i	[W / ms ⁻¹]
D	rotor diameter	[m]
D_e	equivalent rotor diameter	[m]
D_n	rotor diameter of neighbouring and operating wind turbine	[m]
D_r	blade rotor diameter	[m]
Elevation	elevation above sea level	[m]
$F(V)$	the Rayleigh cumulative probability distribution function for wind speed	
f_i	relative occurrence of wind speed between $V_i - 1$ and V_i ($F(V_i) - F(V_i - 1)$) within bin i	
H	hub height of wind turbine	[m]
K	von Karman constant, 0,4	
NT	number of turbines	
L	distance between turbine and met mast (2,5D) in terms of rotor diameters	
L_x	contribution factor related to source x	
M	number of uncertainty components in each bin	
M_A	number of category A uncertainty components	
M_B	number of category B uncertainty components	
N	number of bins	
N_h	number of hours in one year $\approx 8\,760$	
N_i	number of 10-min data sets in wind speed bin i	
N_j	number of 10-min data sets in wind direction bin j	
N_k	is the number of 10-min data sets in bin k	
N_m	number of bins on turbine m	
N_n	number of bins on turbine n	
n_{Test}	number of turbines tested	
N	velocity profile exponent ($n = 0,14$)	
NPC	nacelle power curve	
NTF	nacelle transfer function	
P_i	normalised and averaged power output in bin i	[W]
P_n	normalised power output	[W]
$P_{n,i,j}$	normalised power output of data set j in bin i	[W]
$P_{10\text{min}}$	measured power averaged over 10 min	[W]
P_w	water vapour pressure	[Pa]
R_0	gas constant (= 287,05)	[J/(kg × K)]
R_w	gas constant of water vapour (= 461,5)	[J/(kg × K)]
RIX ₂₀	percentage of calculated slopes within a given direction sector that exceed 20 %	
$S_{sc,i}$	standard deviation of the wind speed ratios in bin i	
S	uncertainty component of category A	[W]

Symbol or abbreviated term	Description	Unit
$s_{k,i}$	category A standard uncertainty of component k in bin i	[W]
s_i	combined category A uncertainties in bin i	[W]
$s_{P,i}$	category A standard uncertainty of power in bin i	[W]
$s_{NTF,i}$	statistical uncertainty in captured dataset	
$s_{a,j}$	category A standard uncertainty of wind speed ratios in bin j	[W]
$Slope_i$	slope between adjacent elevation points	[°]
T	absolute temperature	[K]
TI	turbulence intensity	
T_{10min}	measured absolute air temperature averaged over 10 min	[K]
T	time	[s]
U	uncertainty component of category B	
U_i	Combined category B uncertainties in bin i	
u_{AEP}	combined standard uncertainty in the estimated annual energy production	[Wh]
$u_{AEP,AVG}$	uncertainty in the average AEP	[Wh]
$u_{AEP,k}$	uncertainty in AEP from category B component k	[Wh]
$u_{AEP,m,k}$	uncertainty in AEP from category B component k on turbine m	[Wh]
$u_{AEPRATIO}$	ratio of the uncertainty in the AEP	[Wh]
u_{ano_class}	uncertainty related to anemometer class	[W]
$u_{B,i}$	category B standard uncertainty of air pressure in bin i	[W]
$u_{c,i}$	combined standard uncertainty of the power in bin i	[W]
$u_{c,m,i}$	combined uncertainty in power in bin i on turbine m	[W]
$u_{dFS,i}$	uncertainty component for data acquisition system	
$u_{dP,i}$	uncertainty component for data acquisition of power in bin i	
$u_{dT,i}$	uncertainty component for data acquisition of temperature in bin i	
$u_{dV,i}$	uncertainty component for data acquisition of wind speed in bin i	
$u_{dWD,i}$	uncertainty component for data acquisition of wind direction in bin i	
u_{FS}	uncertainty component for free stream wind speed	[W]
U_i	combined category B uncertainties in bin i	
$u_{k,i}$	category B standard uncertainty of component k in bin i	[W]
$u_{m,k,i}$	standard uncertainty of component k in bin i on turbine m	[W][kg/m ³]
$u_{l,j}$	standard uncertainty of component l in bin j	[W]
$u_{m,i}$	category B standard uncertainty of air density correction in bin i	[kg/m ³]
u_N	uncertainty component for nacelle wind speed	
$u_{P,i}$	category B standard uncertainty of power in bin i	[W]
u_{sc}	category B standard uncertainty of power in bin i	[W]
$u_{sc,i,j}$	uncertainty component for site calibration in wind speed bin i and wind direction bin j	[W]
$u_{T,i}$	category B standard uncertainty of air temperature in bin i	[K]
$u_{V,i}$	category B standard uncertainty of wind speed in bin i	[W]