

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE



**Wind energy generation systems –  
Part 50-3: Use of nacelle-mounted lidars for wind measurements**

**Systèmes de génération d'énergie éolienne –  
Partie 50-3: Utilisation de lidars montés sur nacelle pour le mesurage du vent**

IEC 61400-50-3:2022

<https://standards.iteh.ai/catalog/standards/sist/40acb18d-c13d-49c8-8d0f-e628448b0f09/iec-61400-50-3-2022>





## THIS PUBLICATION IS COPYRIGHT PROTECTED

Copyright © 2022 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 Secretariat  
3, rue de Varembé  
CH-1211 Geneva 20  
Switzerland

Tel.: +41 22 919 02 11  
[info@iec.ch](mailto:info@iec.ch)  
[www.iec.ch](http://www.iec.ch)

### About the IEC

The International Electrotechnical Commission (IEC) is the leading global organization that prepares and publishes International Standards for all electrical, electronic and related technologies.

### About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigendum or an amendment might have been published.

#### IEC publications search - [webstore.iec.ch/advsearchform](http://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](http://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](http://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](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Discover our powerful search engine and read freely all the publications previews. With a subscription you will always have access to up to date content tailored to your needs.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

The world's leading online dictionary on electrotechnology, containing more than 22 300 terminological entries in English and French, with equivalent terms in 19 additional languages. Also known as the International Electrotechnical Vocabulary (IEV) online.

### 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](http://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](http://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](http://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](mailto:sales@iec.ch).

#### IEC Products & Services Portal - [products.iec.ch](http://products.iec.ch)

Découvrez notre puissant moteur de recherche et consultez gratuitement tous les aperçus des publications. Avec un abonnement, vous aurez toujours accès à un contenu à jour adapté à vos besoins.

#### Electropedia - [www.electropedia.org](http://www.electropedia.org)

Le premier dictionnaire d'électrotechnologie en ligne au monde, avec plus de 22 300 articles terminologiques en anglais et en français, ainsi que les termes équivalents dans 19 langues additionnelles. Egalement appelé Vocabulaire Electrotechnique International (IEV) en ligne.



IEC 61400-50-3

Edition 1.0 2022-01

# INTERNATIONAL STANDARD

## NORME INTERNATIONALE



**Wind energy generation systems –  
Part 50-3: Use of nacelle-mounted lidars for wind measurements**

**Systèmes de génération d'énergie éolienne –  
Partie 50-3: Utilisation de lidars montés sur nacelle pour le mesurage du vent**

[IEC 61400-50-3:2022](https://standards.iteh.ai/catalog/standards/sist/40acb18d-c13d-49c8-8d0f-e628448b0f09/iec-61400-50-3-2022)

<https://standards.iteh.ai/catalog/standards/sist/40acb18d-c13d-49c8-8d0f-e628448b0f09/iec-61400-50-3-2022>

INTERNATIONAL  
ELECTROTECHNICAL  
COMMISSION

COMMISSION  
ELECTROTECHNIQUE  
INTERNATIONALE

ICS 27.180

ISBN 978-2-8322-1063-9

**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.....	6
1 Scope.....	8
2 Normative references .....	8
3 Terms and definitions .....	9
4 Symbols and abbreviated terms.....	14
5 Overview .....	18
5.1 General.....	18
5.2 Measurement methodology overview .....	19
5.3 Document overview.....	20
6 Lidar requirements.....	20
6.1 Functional requirements.....	20
6.2 Documentary requirements .....	21
6.2.1 Technical documentation .....	21
6.2.2 Installation and operation documentation.....	22
7 Calibration and uncertainty of nacelle lidar intermediate values .....	22
7.1 Calibration method overview .....	22
7.2 Verification of beam trajectory/geometry .....	23
7.2.1 Static position uncertainty.....	23
7.2.2 Dynamic position uncertainty .....	24
7.3 Inclinometer calibration.....	24
7.4 Verification of the measurement range.....	24
7.5 LOS speed calibration.....	25
7.5.1 Method overview .....	25
7.5.2 Calibration site requirements .....	26
7.5.3 Setup requirements .....	28
7.5.4 Calibration range .....	30
7.5.5 Calibration data requirements and filtering.....	30
7.5.6 Determination of LOS .....	31
7.5.7 Binning of data and database requirements .....	33
7.6 Uncertainty of the LOS speed measurement .....	33
7.6.1 General .....	33
7.6.2 Uncertainty of $V_{ref}$ .....	34
7.6.3 Flow inclination uncertainty.....	37
7.6.4 Uncertainty of the LOS speed measurement .....	37
7.7 Calibration results.....	38
7.8 Calibration reporting requirements .....	39
7.8.1 Report content.....	39
7.8.2 General lidar information .....	40
7.8.3 Verification of beam geometry/trajectory (according to 7.2).....	40
7.8.4 Inclinometer calibration (according to 7.3) .....	40
7.8.5 Verification of the sensing range (according to 7.4) .....	40
7.8.6 LOS speed calibration (for each LOS).....	40
8 Uncertainty due to changes in environmental conditions .....	41
8.1 General.....	41
8.2 Intermediate value uncertainty due to changes in environmental conditions .....	41
8.2.1 Documentation .....	41

8.2.2	Method .....	41
8.2.3	List of environmental variables to be considered .....	42
8.2.4	Significance of uncertainty contribution .....	42
8.3	Evidence-base supporting the adequacy of the WFR .....	42
8.4	Requirements for reporting .....	43
9	Uncertainty of reconstructed wind parameters .....	44
9.1	Horizontal wind speed uncertainty .....	44
9.2	Uncertainty propagation through WFR algorithm .....	45
9.2.1	Propagation of intermediate value uncertainties $u_{\langle V \rangle, WFR}$ .....	45
9.2.2	Uncertainties of other WFR parameters $u_{WFR, par}$ .....	46
9.3	Uncertainty associated with the WFR algorithm $u_{ope, lidar}$ .....	46
9.4	Uncertainty due to varying measurement height $u_{\langle \Delta V \rangle, measHeight}$ .....	46
9.5	Uncertainty due to lidar measurement inconsistency .....	46
9.6	Combining uncertainties .....	47
10	Preparation for specific measurement campaign .....	47
10.1	Overview of procedure .....	47
10.2	Pre-campaign check list .....	47
10.3	Measurement set up .....	48
10.3.1	Lidar installation .....	48
10.3.2	Other sensors .....	48
10.3.3	Nacelle position calibration .....	49
10.4	Measurement sector .....	49
10.4.1	General .....	49
10.4.2	Assessment of influence from surrounding WTGs and obstacles .....	49
10.4.3	Terrain assessment .....	52
11	Measurement procedure .....	53
11.1	General .....	53
11.2	WTG operation .....	53
11.3	Consistency check of valid measurement sector .....	54
11.4	Data collection .....	55
11.5	Data rejection .....	56
11.6	Database .....	56
11.7	Application of WFR algorithm .....	56
11.8	Measurement height variations .....	57
11.9	Lidar measurement monitoring .....	57
12	Reporting format – relevant tables and figures specific to nacelle-mounted lidars .....	57
12.1	General .....	57
12.2	Specific measurement campaign site description .....	57
12.3	Nacelle lidar information .....	58
12.4	WTG information .....	58
12.5	Database .....	58
12.6	Plots .....	59
12.7	Uncertainties .....	59
Annex A	(informative) Example calculation of uncertainty of reconstructed parameters for WFR with two lines of sight .....	60
A.1	Introduction to example case .....	60
A.2	Uncertainty propagation through WFR algorithm .....	61
A.3	Operational uncertainty of the lidar and WFR algorithm .....	63

A.4	Uncertainty contributions from variation of measurement height.....	63
A.5	Wind speed consistency check.....	64
A.6	Combined uncertainty .....	64
Annex B (informative)	Suggested method for the measurement of tilt and roll angles.....	65
Annex C (informative)	Recommendation for installation of lidars on the nacelle .....	68
C.1	Positioning of lidar optical head on the nacelle.....	68
C.2	Lidar optical head pre-tilt for fixed beam lidars.....	69
C.3	Attachment points for the lidar .....	70
Annex D (informative)	Assessing the Influence of nacelle-mounted lidar on turbine behaviour.....	71
D.1	General.....	71
D.2	Recommended consistency checks methods.....	71
D.2.1	General .....	71
D.2.2	Documentation-based approach .....	71
D.2.3	Data-based approach using neighbouring WTG .....	72
D.2.4	Data-based approach using only the WTG being assessed.....	74
Bibliography	.....	78
Figure 1	– Example of opening angle $\beta$ between two beams .....	23
Figure 2	– Side elevation sketch of calibration setup.....	26
Figure 3	– Plan view sketch of sensing and inflow areas .....	27
Figure 4	– Sketch of a calibration setup .....	30
Figure 5	– Example of lidar response to the wind direction and cosine fit.....	32
Figure 6	– Example of LOS evaluation using the RSS process: RSS vs $\theta_{proj}$ .....	33
Figure 7	– High level process for horizontal wind speed uncertainty propagation .....	45
Figure 8	– Procedure flow chart .....	47
Figure 9	– Plan view sketch of NML beams upstream of WTG being assessed and neighbouring turbine wake .....	49
Figure 10	– Sectors to exclude due to wakes of neighbouring and operating WTGs and significant obstacles .....	51
Figure 11	– Example of sectors to exclude due to wakes of a neighbouring turbine and a significant obstacle .....	52
Figure 12	– Example of full directional sector discretization .....	53
Figure 13	– Lidar relative wind direction vs turbine yaw for a two-beam nacelle lidar [Wagner R, 2013].....	54
Figure 14	– Example of LOS turbulence intensity vs turbine yaw, for a two-beam nacelle lidar .....	55
Figure B.1	– Pair of tilted and rolled lidar beams (red) shown in relation to the reference position (grey).....	65
Figure B.2	– Opening angle between two beams symmetric with respect to the horizontal plane( $\gamma$ ) and its projection onto the vertical plane of symmetry of the lidar ( $\gamma_V$ ) .....	67
Figure C.1	– Example of a good (left) and bad (right) position for a 2-beam lidar .....	68
Figure C.2	– Example of a good (left) and bad (right) position for a 4-beam lidar .....	68
Figure C.3	– Sketch of lidar optical head pre-tilted downwards to measure at hub height (example for a two beam lidar) .....	70
Figure D.1	– Example of reporting the side-by-side comparison .....	73

Figure D.2 – Example of the power ratio between two neighbouring turbines ..... 74

Figure D.3 – General process outline ..... 74

Figure D.4 – Example of binned  $\Delta Dir_{Nac}$  function for a setting where the lidar has not significantly influenced the two nacelle wind direction sensors' reported signals ..... 77

Table 1 – Summary of calibration uncertainty components ..... 38

Table 2 – Calibration table example ..... 39

Table 3 – Calibration table example (n=1...N; N is the total number of lines of sight calibrated) ..... 39

Table A.1 – Uncertainty components and their correlations between different LOSs for this example ..... 62

**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[IEC 61400-50-3:2022](#)

<https://standards.iteh.ai/catalog/standards/sist/40acb18d-c13d-49c8-8d0f-e628448b0f09/iec-61400-50-3-2022>

## INTERNATIONAL ELECTROTECHNICAL COMMISSION

## WIND ENERGY GENERATION SYSTEMS –

## Part 50-3: Use of nacelle-mounted lidars for wind measurements

## 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 61400-50-3 has been prepared by IEC technical committee TC 88: Wind energy generation systems.

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

Draft	Report on voting
88/845/FDIS	88/853/RVD

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](http://www.iec.ch/members_experts/refdocs). The main document types developed by IEC are described in greater detail at [www.iec.ch/standardsdev/publications](http://www.iec.ch/standardsdev/publications).



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](https://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 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.**

**iTeh Standards**  
**(<https://standards.iteh.ai>)**  
**Document Preview**

[IEC 61400-50-3:2022](https://standards.iteh.ai/catalog/standards/sist/40acb18d-c13d-49c8-8d0f-e628448b0f09/iec-61400-50-3-2022)

<https://standards.iteh.ai/catalog/standards/sist/40acb18d-c13d-49c8-8d0f-e628448b0f09/iec-61400-50-3-2022>

## WIND ENERGY GENERATION SYSTEMS –

### Part 50-3: Use of nacelle-mounted lidars for wind measurements

#### 1 Scope

The purpose of this part of IEC 61400 is to describe procedures and methods that ensure that wind measurements using nacelle-mounted wind lidars are carried out and reported consistently and according to best practice. This document does not prescribe the purpose or use case of the wind measurements. However, as this document forms part of the IEC 61400 series of standards, it is anticipated that the wind measurements will be used in relation to some form of wind energy test or resource assessment.

The scope of this document is limited to forward-looking nacelle-mounted wind lidars (i.e. the measurement volume is located upstream of the turbine rotor).

This document aims to be applicable to any type and make of nacelle-mounted wind lidar. The method and requirements provided in this document are independent of the model and type of instrument, and also of the measurement principle and should allow application to new types of nacelle-mounted lidar.

This document aims to describe wind measurements using nacelle-mounted wind lidar with sufficient quality for the use case of power performance testing (according to IEC 61400-12-1:2017). Readers of this document should consider that other use cases may have other specific requirements.

This document only provides guidance for measurements in flat terrain and offshore as defined in IEC 61400-12-1:2017, Annex B. Application to complex terrain has been excluded from the scope due to limited experience at the time of writing this document.

Corrections for induction zone or blockage effects are not included in the scope of this document. However, such correction or uncertainty estimation due to blockage effects may be applied if required by the use case, under the responsibility of the user.

The purpose of this document is to provide guidance for wind measurements. HSE requirements (e.g. laser operation) are out of the scope of this document although they are important.

#### 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.

ISO/IEC 61400-12-1:2017, *Wind energy generation systems – Part 12-1: Power performance measurements of electricity producing wind turbines*

ISO/IEC 61400-12-2:2013, *Wind energy generation systems – Part 12-2: Power performance of electricity-producing wind turbines based on nacelle anemometry*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61400-12-1:2017 and the following apply. ISO and IEC maintain terminological databases for use in standardization at the following addresses:

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

#### 3.1

##### **carrier-to-noise ratio**

CNR

measure of signal quality for a pulsed lidar defined as the ratio between the heterodyne current power and the total noise power in the detection bandwidth

Note 1 to entry: By default, CNR is CNR wide band ( $CNR_{wb}$ ). We can also define CNR narrow band ( $CNR_{nb}$ ) as the ratio between the heterodyne current power and the noise power in the Doppler peak bandwidth. This does not depend on spectral signal processing. CNR is different from Signal-to-Noise Ratio (SNR). SNR is the ratio between the Doppler peak power and the noise power standard deviation.

Note 2 to entry:  $SNR = CNR_{nb}\sqrt{n}$ , with  $n$ : number of averaged pulses.

#### 3.2

##### **continuous wave lidar**

CW lidar

a lidar transmitting a laser signal of constant amplitude and frequency and receiving backscattered light at the same time

#### 3.3

##### **correlated uncertainties**

a pair of uncertainty components in which an unknown error on one of the components is correlated to some degree to the error on the other component

Note 1 to entry: The value of the correlation coefficient can vary between -1 and 1.

[SOURCE: JCGM 100:2008; 5.2]

#### 3.4

##### **data availability**

ratio between the number of measurement points accepted on the basis of a predefined data quality and the maximum number of measurement points that can be acquired during a given measurement period

#### 3.5

##### **final values**

values provided by the nacelle lidar system for use in wind energy assessment applications such as WTG power performance testing

Note 1 to entry: Therefore, the accuracy of the final value is the key consideration when using nacelle lidar in wind energy applications. Examples of final values include (but are not limited to) horizontal wind speed and wind direction.

#### 3.6

##### **free wind speed**

wind speed that would be present at the turbine location if the turbine was not there

**3.7****homodyne detection**

measurement technique in which the received signal is mixed with a signal of the same frequency as that of the transmitted signal

Note 1 to entry: The mixing product at the difference frequency contains information on the magnitude of the Doppler shift induced in the received signal, but not whether that Doppler shift is positive or negative.

**3.8****heterodyne detection**

measurement technique in which the received signal is mixed with a signal of a different frequency to that of the transmitted signal

Note 1 to entry: The mixing product at the difference frequency contains information on both the magnitude and the sign of the Doppler shift induced in the received signal.

**3.9****intermediate values**

inputs to the wind field reconstruction (WFR) model or algorithm, which delivers final values as output

Note 1 to entry: Examples of intermediate values include (but are not limited to) line of sight (LOS) speeds.

**3.10****line of sight**

LOS

direction originating at the laser source and oriented along the axis of the transmitted laser beam, corresponding to the beam propagation path

**3.11****line of sight speed**

LOS speed

magnitude of the component of the wind velocity in the LOS

<https://standards.iteh.ai/catalog/standards/sist/40acb18d-c13d-49c8-8d0f-e628448b0f09/iec-61400-50-3-2022>

<https://standards.iteh.ai/catalog/standards/sist/40acb18d-c13d-49c8-8d0f-e628448b0f09/iec-61400-50-3-2022>

**3.12****LOS speed turbulence intensity**

ratio of the LOS speed standard deviation to the mean LOS speed, determined from the set of measurement data samples of LOS speed, and taken over a specified period of time

Note 1 to entry: See Clause 6 for the characteristics of turbulence measured with lidar.

**3.13****measurement**

process of experimentally obtaining one or more quantity values that can reasonably be attributed to a measurand

[SOURCE: JCGM\_200\_2012; 2.1]

**3.14****measurement accuracy**

closeness of agreement between a measured quantity value and a true quantity value of a measurand

[SOURCE: JCGM\_200\_2012; 2.13]

**3.15****measurement bias**

estimate of a systematic measurement error

[SOURCE: JCGM\_200\_2012; 2.18]

**3.16****measurement period**

interval of time between the first and last measurements

[SOURCE: ISO 28902-1:2012, 3.10]

**3.17****measurement uncertainty**

non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

[SOURCE: JCGM\_200\_2012; 2.26]

**3.18****nacelle-mounted lidar**

NML

wind lidar mounted on the nacelle of a WTG generator

EXAMPLE A lidar placed in the spinner of a WTG is not considered nacelle-mounted in the case where it follows the spinner's rotation about the rotor axis.

Note 1 to entry: A wind lidar can only be considered as nacelle-mounted if the lidar is fixed in the frame of reference of the nacelle (but not the rotor frame of reference).

**3.19****probe length**

measure of the radial extent of the lidar probe volume, which can be defined in terms of the distance between the two points at which the radial sensitivity of the lidar is half of its maximum value: the full-width at half-maximum (FWHM) sensitivity

- For pulsed coherent lidars: The probe length is the distance between the FWHM levels of the Velocity Range Weighting Function (VRWF).
- For pulsed incoherent lidars (direct detection lidars): The probe length is the distance between the FWHM levels of the laser pulse. (assuming no range averaging).
- For CW coherent Lidars: The probe length is the distance between the FWHM levels of the Lorentzian weighting function.

Note 1 to entry: The Velocity Range Weighting Function describes the relative efficiency of collecting velocity information as a function of distance around the nominal range. An ideal weighting function would be a Dirac function at 0 (the wind speed is measured at one point). The integral of the weighting function (from minus to plus infinity) is equal to 1. The VRWF is the normalized convolution of the range gate profile with the pulse amplitude profile.

**3.20****probe volume**

volume located along the laser beam propagation path in which particles scattering light back to the lidar system contribute significantly to the received signal

**3.21****pulsed lidar**

lidar transmitting a laser signal during a short time period (the pulse) at regular intervals and receiving backscattered light between the pulses

**3.22****remote sensing**

technique for wind measurement where the instrument is distant from the locations where the wind vector is sensed

### 3.23 roll angle

angle of rotation of the lidar about the roll axis, with respect to the design orientation of the lidar defined as horizontal

Note 1 to entry: The roll axis passes through the origin of the lidar coordinate system in a direction representative of the average measurement direction of the lidar. The exact definition of the roll axis shall be documented by the lidar manufacturer. For a scanning lidar it is suggested that the roll axis is defined as the unit vector with the same direction as the average of the unit vectors describing the beam's trajectory. For a fixed beam lidar it is suggested that the roll axis is defined as the unit vector with the same direction as the average of the unit vectors describing the lidar's fixed beams.

### 3.24 scalar average

scalar number found by dividing the sum of scalar data by the number of items in the data set

### 3.25 scanning lidar

lidar in which the direction of a single transmitted beam is scanned

Note 1 to entry: In this document, two types of scanning lidars are considered:

- 1) Fixed-pattern-scanning lidar: the beam is scanned following a fixed, predefined trajectory (this trajectory is typically planar or conical)
- 2) Programmable-scanning lidars: the beam is scanned in a programmable manner.

In contrast, a fixed-beam-geometry lidar is a lidar in which the laser beam is transmitted in a number of different, but fixed, directions that are addressed sequentially or simultaneously.

### 3.26 specific measurement campaign SMC

an implementation of a use case

### 3.27 tilt angle

angle of rotation of the lidar about the tilt axis, with respect to the design orientation of the lidar defined as horizontal

Note 1 to entry: The tilt axis passes through the origin of the lidar coordinate system, is perpendicular to the roll axis, and is horizontal when the lidar is in the design orientation defined as horizontal.

### 3.28 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

[SOURCE: IEC 61400-1:2019, 3.58]

### 3.29 use case

combination of the following three elements:

- Data requirements: objectives arising from the application and independent of instrument capabilities.
- Measurement method: lidar technique selected to fulfil the data requirements. The scope of this guidance is restricted to methods using nacelle-mounted lidar and evaluation of their accuracy under the operational conditions described.
- Operational conditions: circumstances that may influence measurement accuracy.

[SOURCE: CLIFTON, A. et al., 2018]

**3.30****vector average**

vector found by dividing the sum of vectors by the number of items in the dataset

**3.31****wind direction**

direction of the horizontal component of the wind velocity

**3.32****wind field reconstruction**

WFR

process of combining intermediate values, such as the LOS speeds associated with multiple LOSs, to retrieve the final values relevant to the use case

**3.33****wind lidar**

remote sensing device that transmits energy from a laser source into the atmosphere and analyses the signal reflected from particles being carried by the wind to measure the characteristics of the wind

Note 1 to entry: The word "lidar" is used for wind lidar throughout this document.

Note 2 to entry: Most wind lidars working principles rely on the Doppler effect, where the frequency of the light backscattered by particles moving with the wind is Doppler shifted.

**3.34****wind measurement equipment**

WME

meteorological mast or remote sensing device

[SOURCE: IEC 61400-12-1:2017,3.29]

**3.35****wind shear**

change of horizontal wind speed with height

Note 1 to entry: In this document, the focus is on the change of wind speed with height across the turbine rotor span.

**3.36****wind shear exponent**

exponent of the power law model of the variation of horizontal wind speed with height above the ground

Note 1 to entry: The power law formula is

$$v_{z2} = v_{z1} \left( \frac{z_2}{z_1} \right)^\alpha \quad (1)$$

where

$v_{zi}$  is the horizontal wind speed at height  $z_i$ ;

$\alpha$  is the wind shear exponent.

**3.37****wind speed**

magnitude of the local wind velocity