# IEC 61400-50-3

Edition 1.0 2022-01

# INTERNATIONAL STANDARD

# NORME INTERNATIONALE

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**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 61400-50-3:2022-01(en-fr)

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ICS 27.180 ISBN 978-2-8322-1063-9

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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. The main document types developed by IEC are described in greater detail at www.iec.ch/standardsdev/publications.

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# 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 ($CNR_{\mathrm{wb}}$). We can also define CNR narrow band ($CNR_{\mathrm{nb}}$) 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: $SNR = CNR_{\mathrm{nb}}\sqrt{n}$, 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



**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

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

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