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

**Systèmes de génération d'énergie éolienne
Partie 50-1: Mesurages du vent – Application d'instruments météorologiques montés sur mât, nacelle et nez de rotor**

IEC 61400-50-1:2022-11(en-fr)

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WIND ENERGY GENERATION SYSTEMS –

Part 50-1: Wind measurement – Application of meteorological mast, nacelle and spinner mounted instruments

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IEC 61400-50-1 has been prepared by IEC technical committee 88: Wind energy generation systems. It is an International Standard.

This first edition of IEC 61400-50-1 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
88/902/FDIS	88/916/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.

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

This part of IEC 61400 specifies procedures and methods which ensure that wind measurements using cup or sonic anemometers mounted on meteorological masts or wind turbine nacelles/spinners are carried out and reported consistently and in accordance with best practice. This document does not define 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 carried out in accordance with this standard will be used in relation to some form of wind energy testing or resource assessment.

The main clauses of this document are not mutually dependent. Therefore, it is possible that a user will refer to only certain of the main clauses rather than all clauses to adapt this document to their specific use case. However, the main clauses are presented in a logical sequence that could be applied in practice.

The technical content of this document could previously be found in IEC 61400-12-1:2017 and IEC 61400-12-2:2013.

NOTE A technical correction to the value of the tolerance of the anemometer mounting tube has been made in 10.2.

Due to the increasing complexity of these source documents, IEC TC 88 decided that a re-structuring of the IEC 61400-12 series of standards into a number of more specific parts would allow more efficient management and maintenance going forward. This document has been created as part of that re-structuring process. The requirements on wind measurement specific to the use cases described in IEC 61400-12-1:2017 and IEC 61400-12-2:2013 (for example, the required location of the meteorological mast relative to the test turbine and the height of wind measurement relative to hub height) remain within the new editions of IEC 61400-12-1 and IEC 61400-12-2.

WIND ENERGY GENERATION SYSTEMS –

Part 50-1: Wind measurement – Application of meteorological mast, nacelle and spinner mounted instruments

1 Scope

IEC 61400-50 specifies methods and requirements for the application of instruments to measure wind speed (and related parameters, e.g. wind direction, turbulence intensity). Such measurements are required as an input to some of the evaluation and testing procedures for wind energy and wind turbine technology (e.g. resource evaluation and turbine performance testing) described by other standards in the IEC 61400 series. This document is applicable specifically to the use of wind measurement instruments mounted on meteorological masts, turbine nacelles or turbine spinners which measure the wind at the location at which the instruments are mounted. This document excludes remote sensing devices which measure the wind at some location distant from the location at which the instrument is mounted (e.g. vertical profile or forward facing lidars). This document specifies the following:

a) the classification parameters for cup and sonic anemometers such that the uncertainty in wind speed measurement for a specific type and model of anemometer exposed to a certain class of environmental conditions can be assessed;

b) the procedure and requirements for classifying cup and sonic anemometers as, for example, part of the type testing of a specific anemometer model and type;

c) the procedures and requirements for wind tunnel calibration of anemometers;

d) an additional or alternative method of checking the consistency of the calibration of an anemometer in the field by carrying out an in-situ comparison with another anemometer;

e) the requirements for the mounting of anemometers and other instruments on meteorological masts;

f) the assessment of wind speed measurement uncertainty;

g) reporting requirements.

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 2533:1975, *Standard atmosphere*

ISO 3966, *Measurement of fluid flow in closed conduits – Velocity area method using Pitot static tubes*

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 https://www.electropedia.org/
- ISO Online browsing platform: available at https://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
data set
collection of data sampled over a continuous period

3.3
distance constant
indication of the response time of an anemometer, defined as the length of air that shall pass the instrument for it to indicate 63 % of the final value for a step input in wind speed

3.4
flow distortion
change in air flow caused by obstacles, topographical variations, or other wind turbines that results in the wind speed at the measurement location being different from the wind speed at the wind turbine location

3.5
hub height
<of a wind turbine> height of the centre of the swept area of the wind turbine rotor above the ground at the tower

Note 1 to entry: For a vertical axis wind turbine the hub height is defined as the height of the centroid of the swept area of the rotor above the ground at the tower.

3.6
measurement period
period during which a statistically significant database has been collected for the use case

Note 1 to entry: A power performance test is an example of a use case.

3.7
measurement sector
sector of wind directions from which data are selected for the use case

Note 1 to entry: A measured power curve is an example of a use case.

3.8
obstacle
obstruction that blocks the wind and creates distortion of the flow

Note 1 to entry: Buildings and trees are examples of obstacles.

3.9
power performance
measure of the capability of a wind turbine to produce electric power and energy

3.10
standard uncertainty
uncertainty of the result of a measurement expressed as a standard deviation

3.11
wind measurement equipment
meteorological mast-mounted instruments or remote sensing device

3.12
wind shear
change of wind speed with height

3.13
wind shear exponent
α
exponent of the power law defining the variation of wind speed with height

Note 1 to entry: This parameter is used as a measure of the magnitude of wind shear and can be otherwise useful. The power law equation is:

$$v_{zi} = v_h \left(\frac{z_i}{H} \right)^{\alpha} \tag{1}$$

where

v_h is the hub height wind speed;

H is the hub height (m);

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

α is the wind shear exponent.

4 Symbols, units and abbreviated terms

Symbol	Description	Unit
A	swept area of the wind turbine rotor	m^2
B	barometric pressure	Pa
$B_{10\text{min}}$	measured air pressure averaged over 10 min	Pa
C_h	pitot tube head coefficient	
C_{QA}	generalized aerodynamic torque coefficient	
C_T	thrust coefficient	
c	sensitivity factor of 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_index	sensitivity factor of index parameter	
$c_{k,i}$	sensitivity factor of component k in bin i	
$c_{T,i}$	sensitivity factor of air temperature in bin i	W/K
$c_{V,i}$	sensitivity factor of wind speed in bin i	Ws/m
$c_{\rho,i}$	sensitivity factor of air density correction in bin i	Wm^3/kg

Symbol	Description	Unit
d	meteorological mast diameter	m
e	eccentricity	
$F(V)$	Rayleigh cumulative probability distribution function for wind speed	
$F_{\alpha,\gamma}(\alpha,\gamma,\lvert\vec{U}\rvert)$	tilt and yaw response function for the sonic anemometer	
$f\left(k_{\mathrm{b}},k_{\mathrm{i}},k_{\mathrm{p}},\overline{v}_{\mathrm{p}},..\right)$	correction function due to interference between the anemometer including its mounting tube and the wind tunnel flow	
H	hub height of wind turbine	m
h	height of obstacle	m
I	inertia of cup anemometer rotor	kg·m^2
$K_{B,t}$	barometer sensitivity	N/m^{2}V
$K_{B,s}$	barometer gain	
$K_{B,d}$	barometer sampling conversion	
$K_{T,t}$	temperature transducer sensitivity	K/A
$K_{T,s}$	temperature transducer gain	A/V
$K_{T,d}$	temperature transducer sampling conversion	
$K_{p,t}$	pressure transducer sensitivity	
$K_{p,s}$	pressure transducer gain	
$K_{p,d}$	pressure transducer sampling conversion	
k	class number	
k_{b}	blockage correction factor	
k_{c}	wind tunnel calibration factor	
k_{f}	wind tunnel correction factor to other tunnels (only used in uncertainty estimate)	
k_{i}	correction factor due to interference between the anemometer (including mounting tube) and test section enclosure, also including flow effects due to mounting tubes extending through the enclosure	
k_n	class number of anemometer sample number n (n = 1, …, 5 or more)	
k_{p}	correction factor due to interference caused by the anemometer (including mounting tube) on the velocity measured by the pitot tube	
k_ρ	humidity correction to density	
L_{m}	distance between adjacent legs of lattice meteorological mast	m
L	distance between the wind turbine and the wind measurement equipment	m
M	number of uncertainty components in each bin	
M_{A}	number of category A uncertainty components	
M_{B}	number of category B uncertainty components	
m	slope of the regression relating V_{control} to $V_{\mathrm{primary\_est}}$	

Symbol	Description	Unit
m	slope of the regression between V_1 and V_2	
N	number of bins	
N_h	number of hours in one year ≈ 8 760	h
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	number of samples within sampling interval	
n_h	number of available measurement heights	
P_w	vapour pressure	Pa
p	axial run-out deviation	
Q_A	aerodynamic torque	N·m
Q_F	friction torque	N·m
R	rotor radius	m
r_a	effective radius of angle measurement	
R_0	gas constant of dry air (287,05)	J/kg·K
R_d	distance to meteorological mast centre	m
R_w	gas constant of water vapour (461,5)	J/kg·K
REWS	rotor equivalent wind speed	
RSD	remote sensing device	
r	correlation coefficient	
s	category A standard uncertainty component	
s_A	category A standard uncertainty of tunnel wind speed time series	
$s_{k,i}$	category A standard uncertainty of component k in bin i	
s_i	combined category A uncertainties in bin i	
S	meteorological mast solidity	
T	absolute temperature	K
TI	turbulence intensity	
T_10min	measured absolute air temperature averaged over 10 min	K
t	time	s
U	wind speed	m/s
U_d	centreline wind speed deficit	m/s
U_eq	equivalent horizontal wind speed	m/s
U_i	wind speed in bin i	m/s
U_j	wind speed in bin j	
U_sonic	sonic anemometer	
U_t	threshold wind speed	m/s
$\vec{U}$	instantaneous wind vector	
u	category B standard uncertainty component	