IEC 61400-12-2

Edition 2.0 2022-09

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

Systèmes de génération d'énergie éolienne –
Partie 12-2: Performance de puissance des éoliennes de production d'électricité fondée sur l'anémométrie de nacelle

IEC 61400-12-2:2022-09(en-fr)

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CONTENTS

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WIND ENERGY GENERATION SYSTEMS –

Part 12-2: Power performance of electricity producing wind turbines based on nacelle anemometry

FOREWORD

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IEC 61400-12-2 has been prepared by IEC technical committee 88: Wind energy generation systems. It is an International Standard.

This second edition of IEC 61400-12-2 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
88/823/CDV	88/868/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

This second edition contains no technical changes with respect to the previous edition but the parts that relate to wind measurements, measurement of nacelle transfer functions and assessment of obstacles and terrain have been extracted into separate standards. The separated standards comprise:

– IEC 61400-50, *Wind measurements – Overview*

– IEC 61400-50-1, *Wind measurement – Application of meteorological mast, nacelle and spinner mounted instruments*

– IEC 61400-50-2, *Wind measurement – Application of ground-mounted remote sensing technology*

– IEC 61400-12, *Power performance measurements of electricity producing wind turbines – Overview*

– IEC 61400-12-1, *Power performance measurement of electricity producing wind turbines*

– IEC 61400-12-2, *Power performance of electricity producing turbines based on nacelle anemometry*

– IEC 61400-12-3, *Power performance – Measurement based site calibration*

– IEC 61400-12-5, *Power performance – Assessment of obstacles and terrain*

– IEC 61400-12-6, *Measurement based nacelle transfer function of electricity producing wind turbines.*

This procedure describes how to characterise a wind turbine's power performance characteristics in terms of a measured power curve and the estimated annual energy production (AEP) based on nacelle-anemometry. In this procedure, the anemometer is located on or near the test turbine's nacelle. In this location, the anemometer is measuring wind speed that is strongly affected by the test turbine's rotor. The procedure provides guidance on determination of measurement uncertainty including assessment of uncertainty sources and recommendations for combining them into uncertainties in reported power and AEP.

The measured power curve is determined by collecting simultaneous measurements of nacelle-measured wind speed and power output 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. In order to accurately measure the power curve, the nacelle-measured wind speed is adjusted using a transfer function to estimate the free stream wind speed. The procedure to measure such a transfer function is given in IEC 61400-12-6. The AEP is calculated by applying the measured power curve to the reference wind speed frequency distributions, assuming 100 % availability.

A key element of power performance testing is the measurement of wind speed. 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 involved in the manufacture, installation, planning and permitting, operation, utilisation and regulation of wind turbines. When 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 contracting power performance measurements.

WIND ENERGY GENERATION SYSTEMS –

Part 12-2: Power performance of electricity producing wind turbines based on nacelle anemometry

1 Scope

This part of IEC 61400-12 specifies a procedure for verifying the power performance characteristics of a single electricity-producing, horizontal axis wind turbine that is not considered to be a small wind turbine per IEC 61400-2. It is expected that this document be used when the specific operational or contractual specifications do not comply with the requirements set out in IEC 61400-12-1. The procedure can be used for power performance evaluation of specific turbines at specific locations, but equally the methodology can be used to make generic comparisons between different turbine models or different turbine settings.

The purpose of this document is to provide a uniform methodology of measurement, analysis, and reporting of power performance characteristics for individual 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 in this document be utilised when the requirements set out in IEC 61400-12-1 are not feasible. 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 document describes how to characterise a wind turbine's power performance in terms of a measured power curve and the estimated AEP. Guidance on uncertainty considerations relating to the power performance of the sample of turbines tested relative to the power performance of all turbines in a wind farm is provided. Guidance on the evaluation of the combined uncertainty for the case where multiple turbines are tested is also provided.

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 60688:2021, *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 measurements of electricity producing wind turbines*

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 61400-12-6, *Wind energy generation systems – Part 12-6: Measurement based nacelle transfer function of electricity producing wind turbines*

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

IEC 61869-2, *Instrument transformers – Part 2: Additional requirements for current transformers*

IEC 61869-3, *Instrument transformers – Part 3: Additional requirements for inductive voltage transformers*

ISO 2533:1975, *Standard atmosphere*

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
AEP
annual energy production
estimate of the total energy production of a wind turbine over a one-year period by applying the measured power curve to different reference wind speed frequency distributions at hub height, assuming 100 % availability

3.3
AEP-measured
measured annual energy production
estimate of the total energy production of a wind turbine during a one-year period by applying the measured power curve to different reference wind speed frequency distributions at hub height, assuming 100 % availability, without power curve extrapolation to higher wind speeds

3.4
AEP-extrapolated
extrapolated annual energy production
estimate of the total energy production of a wind turbine during a one-year period by applying the measured power curve to different reference wind speed frequency distributions at hub height, assuming 100 % availability, with power curve extrapolation to cut-out wind speed of the turbine

3.5
complex terrain
terrain surrounding the test site that features significant variations in topography and terrain obstacles that may cause flow distortion

3.6
data set
collection of data sampled over a contiguous period

3.7
documentation
any information regarding the test which is kept in files or data, or both, but which will not necessarily be presented in the final report

3.8
extrapolated power curve
extension of the measured power curve by estimating power output from the maximum measured wind speed to cut-out wind speed

3.9
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

3.10
free stream wind speed
horizontal wind speed measured upstream of the rotor of the wind turbine generator that is unaffected by rotor aerodynamics

3.11
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

3.12
hub height
<wind turbines> height of the centre of the swept area of the wind turbine rotor above the ground level at the tower base

3.13
machine configuration change
change to the turbine or intervention in the turbine operation which causes a significant change in the power performance of the turbine and which is not normal maintenance

Note 1 to entry: Examples of machine configuration change include replacements of hardware components, especially rotor blade, gearbox or generator; a change or update of the turbine software or its parameters; unplanned blade washing; turbine software updates.

3.14
measured power curve
table and graph that represent the measured, corrected and normalised net power output of a wind turbine as a function of measured free stream wind speed, measured under a well-defined measurement procedure

3.15
measurement period
period during which a statistically significant database has been collected for the power performance test

3.16
measurement sector
sector of wind directions from which data are selected for determination of:

i) the measured power curve

ii) the nacelle transfer function

3.17
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

3.18
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.

3.19
nacelle
housing which contains the drive train and other elements on top of a horizontal axis wind turbine generator

3.20
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.

3.21
nacelle wind speed
horizontal wind speed measured on top of or in front of the nacelle of a wind turbine

3.22
net active electric power
measure of the wind turbine electric power output that is delivered to the electrical power network

3.23
normal maintenance
any intervention which is done according to a defined regular maintenance program, independent from the fact that a power performance test is being done, for example, oil change, blade washing (if due anyway, independent from the power performance test) and any intervention which is outside of the scope of the regular maintenance program (e.g. repair of a failed component) and which is not a machine configuration change

3.24
obstacle
object that blocks and distorts the flow of the wind, such as a building or tree

3.25
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

3.26
power coefficient
ratio of the net electric power output of a wind turbine to the power available in the free stream wind over the rotor swept area

3.27
power performance
measure of the capability of a wind turbine to produce electric power and energy

3.28
rated power
quantity of power assigned, generally by a manufacturer, for a specified operating condition of a component, device or equipment

3.29
report
any information regarding the test which is stated in the final documentation

3.30
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

3.31
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

3.32
standard uncertainty
uncertainty of the result of a measurement expressed as a standard deviation

3.33
swept area
for a horizontal-axis turbine, the projected area of the moving rotor upon a plane normal to axis of rotation; for teetering rotors, it should be assumed that the rotor remains normal to the low-speed shaft

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

3.34
test site
location of the wind turbine under test and its surroundings

3.35
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

3.36
wind shear
variation of wind speed across a plane perpendicular to the wind direction