IEC 61400-12-1

Edition 3.0 2022-09

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Wind energy generation systems –
Part 12-1: Power performance measurements of electricity producing wind turbines

Systèmes de génération d'énergie éolienne –
Partie 12-1: Mesurages de performance de puissance des éoliennes de production d'électricité

IEC 61400-12-1:2022-09(en-fr)

IEC Secretariat
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
info@iec.ch
www.iec.ch

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FOREWORD

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IEC 61400-12-1 has been prepared by IEC technical committee 88: Wind energy generation systems. It is an International Standard.

This third edition of IEC 61400-12-1 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
88/822/CDV	88/867/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.

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INTRODUCTION

IEC TC 88 has made this third edition in order to reduce the complexity of the previous edition. Wind measurement procedures have been extracted from the performance standard, recognizing that wind measurements need to be referenced from other standards, such as in loads, noise and resource assessment measurements. IEC TC 88 recommends that the restructured standards gradually take over the previous standards before Maintenance Cycle Reports are written on the restructured standards introducing new technical requirements. Revision of the restructured documents should be proposed at the same time to incorporate such technical changes, recommendations, clarifications and simplifications.

The purpose of the IEC 61400-12 series is to provide a uniform methodology that will ensure consistency, accuracy and reproducibility in the measurement and analysis of power performance by wind turbines. This document has been prepared with the anticipation that it would be applied by:

a) a wind turbine manufacturer striving to meet well-defined power performance requirements and/or a possible declaration system;

b) a wind turbine purchaser in specifying such performance requirements;

c) a wind turbine operator who can be required to verify that stated, or required, power performance specifications are met for new or refurbished units;

d) a wind turbine planner or regulator who needs to be able to accurately and fairly define power performance characteristics of wind turbines in response to regulations or permit requirements for new or modified installations.

This document provides guidance in the measurement, analysis, and reporting of power performance testing for wind turbines. This document will benefit those parties involved in the manufacture, installation planning and permitting, operation, utilization, and regulation of wind turbines. 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 wind turbine performance. 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. 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 the power performance measurements.

The wind turbine power performance characteristics are determined by the measured power curve and the estimated annual energy production (AEP). The measured power curve, defined as the relationship between the wind speed and the wind turbine power output, is determined by collecting simultaneous measurements of meteorological variables (including wind speed), as well as wind turbine signals (including power output) at the test site 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 AEP is calculated by applying the measured power curve to reference wind speed frequency distributions, assuming 100 % availability.

A key element of power performance testing is the measurement of wind speed. This document specifies the use of cup or sonic anemometers or remote sensing devices (RSD) in conjunction with anemometers to measure wind. Even though suitable procedures for calibration, validation and classification are adhered to, the nature of the measurement principle of these devices can potentially cause them to perform differently. These instruments are robust and have been regarded as suitable for this kind of test with the limitation of some of them to certain classes of terrain.

Recognizing that, as wind turbines become ever larger, a wind speed measured at a single height is increasingly unlikely to accurately represent the wind speed through the entire turbine rotor, this document introduces an additional definition of wind speed. Whereas previously wind speed was defined as that measured at hub height only, this can now be supplemented with a

so-called rotor equivalent wind speed (REWS) defined by an arithmetic combination of simultaneous measurements of wind speed at a number of heights spanning the complete rotor diameter between lower tip and upper tip. The power curves defined by hub height wind speed and REWS are not the same and indeed the wind speed distributions defined by hub height wind speed and REWS are also not the same such that the annual energy production (AEP) is defined by the combination of a measured power curve and wind speed distribution, both of which are based on an identical definition of wind speed.

The technical requirements in this document have been extracted from and are identical to those in IEC 61400-12-1:2017. The corrections in IEC 61400-12-1:2017/Cor.1:2019, IEC 61400-12-1:2017/Cor.2:2020 and IEC 61400-12-1:2017/Cor.3:2021 have been incorporated in this document. Specifically, technical corrections have been applied to Equations (E.8), (E.44) and (E.17). A further technical correction to Equation (E.45) has been made to correct inconsistent units in the components of the summation. Refer to IEC 61400-12:2022 for an overview of the re-structuring of the IEC 61400-12 series and the relationships between different parts of the standard.

Procedures for calibration, classification and uncertainty of cup anemometers and ultrasonic anemometers are given in IEC 61400-50-1. Procedures for calibration, classification and uncertainty of remote sensing devices are given in IEC 61400-50-2. Special care should be taken in the selection of the instruments chosen to measure the wind speed because it can influence the result of the test.

WIND ENERGY GENERATION SYSTEMS –

Part 12-1: Power performance measurements of electricity producing wind turbines

1 Scope

This part of IEC 61400 specifies a procedure for measuring the power performance characteristics of a single wind turbine and applies to the testing of wind turbines of all types and sizes connected to the electrical power network. In addition, this document defines a procedure to be used to determine the power performance characteristics of small wind turbines (as defined in IEC 61400-2) when connected to either the electric power network or a battery bank. The procedure can be used for performance evaluation of specific wind turbines at specific locations, but equally the methodology can be used to make generic comparisons between different wind turbine models or different wind turbine settings when site-specific conditions and data filtering influences are taken into account.

Considerations which can be of relevance to the assessment of uncertainty of power performance tests on multiple turbines are presented in Annex R on an informative basis.

This document defines a measurement methodology that requires the measured power curve and derived energy production figures to be supplemented by an assessment of uncertainty sources and their combined effects. Uncertainty sources of wind measurements are assessed from procedures described in the relevant wind measurement equipment standards while uncertainty of the power curve and annual energy production are assessed by procedures in this document.

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 61400-2, *Wind turbines – Part 2: Small wind turbines*

IEC 61400-12-2, *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, *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*

IEC 61400-50-2, *Wind energy generation systems – Part 50-2: Wind measurement – Application of ground mounted remote sensing technology*

IEC 61869-1, *Instrument transformers – Part 1: General requirements*

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, *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
annual energy production
AEP
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
atmospheric stability
measure of tendency of the wind to encourage or suppress vertical mixing

Note 1 to entry: Stable atmosphere is characterized by a high temperature gradient with altitude, high wind shear, possible wind veer and low turbulence relative to unstable conditions. Neutral and unstable atmosphere generally result in lower temperature gradients and low wind shear.

3.4
complex terrain
terrain surrounding the test site that features significant variations in topography and terrain obstacles (3.18) that can cause flow distortion

3.5
cut-in wind speed
lowest wind speed at which a wind turbine will begin to produce power

3.6
cut-out wind speed
wind speed at which a wind turbine cuts out from the grid due to high wind speed

3.7
data set
collection of data sampled over a continuous period