



BSI Standards Publication

Wind turbines

Part 12-2: Power performance of
electricity-producing wind turbines
based on nacelle anemometry
(IEC 61400-12-2:2013)

National foreword

This British Standard is the UK implementation of EN 61400-12-2:2013. It is identical to IEC 61400-12-2:2013, incorporating corrigendum September 2016.

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A list of organizations represented on this committee can be obtained on request to its secretary.

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**Wind turbines -
Part 12-2: Power performance of electricity-producing wind turbines
based on nacelle anemometry
(IEC 61400-12-2:2013)**

Eoliennes -
Partie 12-2: Performance de puissance
des éoliennes de production d'électricité
basée sur l'anémométrie de nacelle
(CEI 61400-12-2:2013)

Windenergieanlagen -
Teil 12-2: Messung des
Leistungsverhaltens von Elektrizität
erzeugenden Windturbinen basierend auf
Gondelanemometrie
(IEC 61400-12-2:2013)

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Management Centre: Avenue Marnix 17, B - 1000 Brussels

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Foreword

The text of document 88/442/FDIS, future edition 1 of IEC 61400-12-2, prepared by IEC/TC 88 "Wind turbines" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 61400-12-2:2013.

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Annex ZA (normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

<u>Publication</u>	<u>Year</u>	<u>Title</u>	<u>EN/HD</u>	<u>Year</u>
IEC 60688	1992	Electrical measuring transducers for	EN 60688	1992
+ A1 (mod)	1997	converting a.c. electrical quantities to	+ A1	1999
+ A2	2001	analogue or digital signals	+ A2	2001
IEC 61400-12-1	2005	Wind turbines - Part 12-1: Power performance measurements of electricity producing wind turbines	EN 61400-12-1	2006
IEC 61869-2	-	Instrument transformers - Part 2: Additional requirements for current transformers	EN 61869-2	-
IEC 61869-3	-	Instrument transformers - Part 3: Additional requirements for inductive voltage transformers	EN 61869-3	-
ISO/IEC 17025	-	General requirements for the competence of	EN ISO/IEC 17025	-
		testing and calibration laboratories		
ISO/IEC Guide 98-3	-	Uncertainty of measurement - Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)	-	-
ISO 2533	-	Standard atmosphere	-	-

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INTRODUCTION

The purpose of this part of IEC 61400-12 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 standard 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 standard is that the methods presented herein be utilised when the requirements set forth in IEC 61400-12-1:2005 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 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. This procedure includes methods for determining and applying appropriate corrections for this interference. However, it must be noted that these corrections inherently increase the measurement uncertainty compared to a properly-configured test conducted in accordance with IEC 61400-12-1:2005. The procedure also provides guidance on determination of measurement uncertainty including assessment of uncertainty sources and recommendations for combining them into uncertainties in reported power and AEP.

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 standard.

The standard 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 standard 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 standard presents measurement and reporting procedures expected to provide accurate results that can be replicated by others.

Meanwhile, a user of the standard 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 TURBINES –

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, which is not considered to be a small wind turbine per IEC 61400-2. It is expected that this standard will be used when the specific operational or contractual specifications may not comply with the requirements set forth in IEC 61400-12-1:2005. 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 wind turbine power performance characterised by the measured power curve and the estimated AEP based on nacelle-measured wind speed will be affected by the turbine rotor (i.e. speeded up or slowed down wind speed). The nacelle-measured wind speed shall be corrected for this flow distortion effect. Procedures for determining that correction will be included in the methodology. In IEC 61400-12-1:2005, an anemometer is located on a meteorological tower that is located between two and four rotor diameters upwind of the test turbine. This location allows direct measurement of the 'free' wind with minimum interference from the test turbine's rotor. In this IEC 61400-12-2 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 and the nacelle. This procedure includes methods for determining and applying appropriate corrections for this interference. However, it should be noted that these corrections inherently increase the measurement uncertainty compared to a properly-configured test conducted in accordance with IEC 61400-12-1:2005.

This IEC 61400-12-2 standard describes how to characterise a wind turbine's power performance in terms of a measured power curve and the estimated 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 and validate such a transfer function is presented herein. The AEP is calculated by applying the measured power curve to the reference wind speed frequency distributions, assuming 100 % availability. The procedure also provides guidance on determination of measurement uncertainty including assessment of uncertainty sources and recommendations for combining them into uncertainties in reported power and AEP.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC/TR 60688, *Electrical measuring transducers for converting a.c. electrical quantities to analogue or digital signals*

Amendment 1 (1997)

Amendment 2 (2001)

IEC 61400-12-1:2005, *Wind turbines – Part 12-1: Power performance measurements of electricity producing wind turbines*

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/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO/IEC Guide 98-3, *Uncertainty of measurement – Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 2533, *Standard atmosphere*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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 during 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

annual energy production – measured (AEP-measured)

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

annual energy production – extrapolated (AEP-extrapolated)

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 that was sampled over a contiguous period

3.7
documentation

any information regarding the test which is kept in files and/or data, but which may 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

a 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

EXAMPLE Replacements of hardware components, especially rotor blade, gearbox or generator; a change or update of the turbine software or its parameters, unplanned blade washing.

3.14
measured power curve

table and graph that represents 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

a sector of wind directions from which data are selected for the measured power curve or during the determination of 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). Normally used for wind speed bins but also applicable to other parameters.

Note 1 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

nacelle power curve (NPC)

the 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; 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, e.g. oil change, blade washing (if due anyway, independent from the power performance test)

3.24

obstacles

objects that block the wind and create distortion of the flow, such as buildings and trees

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 report

3.30

roughness length

extrapolated height at which the mean speed becomes zero if the vertical wind profile is assumed to have a logarithmic variation with height

3.31

ruggedness index

RIX_{xx}

a measure of terrain, the ruggedness index is calculated as the percentage of altitude differences within a given direction sector that exceed an altitude difference of $xx \times (D+H)$

3.32

site calibration

a 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

3.33

standard uncertainty

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

3.34

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

3.35

test site

location of the wind turbine under test and its surroundings

3.36

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

3.37

wind shear

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

4 Symbols and units

Symbol	Description	Unit
A	swept area of the wind turbine rotor	[m ²]
AEP	annual energy production	[Wh]
AEP_m	the measured AEP on turbine m	[Wh]
AEP_s	Sum of annual energy production	[Wh]
ASL	Above Sea Level	[m]
B	barometric pressure	[Pa]
B_{10min}	measured air pressure averaged over 10 minutes	[Pa]
C_p	power coefficient	
$C_{p,i}$	power coefficient in bin i	
c	sensitivity factor on 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	
$c_{k,i}$	sensitivity factor of component k in bin i	
$c_{l,j}$	sensitivity factor of component l in bin j	
$c_{m,i}$	sensitivity factor of air density correction in bin i	[W/m ³ kg]
$c_{m,k,i}$	sensitivity factor of component k in bin i on turbine m	
$c_{T,i}$	sensitivity factor of air temperature in bin i	[W/K]
$c_{V,i}$	sensitivity factor of wind speed in bin i	[W / ms ⁻¹]
D	rotor diameter	[m]
D_e	equivalent rotor diameter	[m]
D_n	rotor diameter of neighbouring and operating wind turbine	[m]
D_r	blade root diameter	[m]
Δz_i	Vertical distance between adjacent elevation points	[m]
<i>elevation</i>	elevation above sea level	[m]
$F(V)$	the Rayleigh cumulative probability distribution function for wind speed	
H	hub height of wind turbine	[m]
h	height of obstacle minus zero displacement	[m]
K	von Karman constant, 0,4	
NT	number of turbines	
L	distance between the turbine and met mast (2,5D) in terms of rotor diameters	
Le	distance between the wind turbine or the meteorological mast and an obstacle	[m]
Ln	actual distance between neighbouring and operating wind turbine or the meteorological mast and a neighbouring and operating wind turbine	[m]
Lh	actual height of obstacle	[m]
Lw	distance between the wind turbine or the meteorological mast and a neighbouring and operating wind turbine	[m]
M	number of uncertainty components in each bin	

Symbol	Description	Unit
MA	number of category A uncertainty components	
MB	number of category B uncertainty components	
N	number of bins	
Nh	number of hours in one year ≈ 8760	
N_i	number of 10-minute data sets in wind speed bin i	
N_j	number of 10-minute data sets in wind direction bin j	
N_m	number of bins on turbine m	
N_n	number of bins on turbine n	
N	number of samples within sampling interval	
n_{Test}	number of turbines tested	
n	velocity profile exponent ($n=0,14$)	
NPC	nacelle power curve	
NTF	nacelle transfer function	
P_i	normalised and averaged power output in bin i	[W]
P_0	porosity of obstacle (0: solid, 1: no obstacle)	
P_n	normalised power output	[W]
$P_{n,i,j}$	normalised power output of data set j in bin i	[W]
$P_{10\text{min}}$	measured power averaged over 10 minutes	[W]
P_w	the water vapour pressure	[Pa]
R	distance to mast centre	[m]
R_0	the gas constant ($=287,05$)	[J/(kg $\times$ K)]
Rw	the gas constant of water vapour ($=461,5$)	[J/(kg $\times$ K)]
RIX_{20}	the percentage of calculated slopes within a given direction sector that exceed 20 %	
$S_{sc,i}$	standard deviation of the wind speed ratios in bin i	
S	uncertainty component of category A	[W]
$s_{AEP,k}$	uncertainty in AEP from category A component k	[W]
$s_{AEP,m,k}$	uncertainty in AEP from category A component k on turbine m	[W]
$s_{k,i}$	category A standard uncertainty of component k in bin i	[W]
s_i	combined category A uncertainties in bin i	[W]
$s_{P,i}$	category A standard uncertainty of power in bin i	[W]
$s_{\alpha,j}$	category A standard uncertainty of wind speed ratios in bin j	[W]
se_{AEP}	standard error in the mean AEP of the sample	[Wh]
$slope_i$	slope between adjacent elevation points	[°]
T	absolute temperature	[K]
TI	turbulence intensity	
$T_{10\text{min}}$	measured absolute air temperature averaged over 10 minutes	[K]
T	time	[s]
U	horizontal wind speed component	[m/s]
U	uncertainty component of category B	

Symbol	Description	Unit
u_{AEP}	combined standard uncertainty in the estimated annual energy production	[Wh]
$u_{\text{AEP,AVG}}$	uncertainty in the average AEP	[Wh]
$u_{\text{AEP,k}}$	uncertainty in AEP from category B component k	[Wh]
$u_{\text{AEP,m,k}}$	uncertainty in AEP from category B component k on turbine m	[Wh]
$u_{\text{AEP,RATIO}}$	the ratio of the uncertainty in the AEP	[Wh]
$u_{\text{ano_class}}$	uncertainty related to anemometer class	[m/s]
$u_{\text{B,i}}$	category B standard uncertainty of air pressure in bin i	[Pa]
$u_{\text{c,i}}$	combined standard uncertainty of the power in bin i	[W]
u_{FS}	uncertainty component for free stream wind speed	[m/s]
u_{i}	combined category B uncertainties in bin i	
$u_{\text{k,i}}$	category B standard uncertainty of component k in bin i	
$u_{\text{m,k,i}}$	category B standard uncertainty of component k in bin i on turbine m	
$u_{\text{l,j}}$	standard uncertainty of component l in bin j	[W]
$u_{\text{m,i}}$	category B standard uncertainty of air density correction in bin i	[kg/m ³]
u_{N}	uncertainty component for nacelle wind speed	[m/s]
$u_{\text{NTFM,i}}$	a guess / estimate of the magnitude of the variation in results from a NTF measured at different times of the year using the same equipment	[W] [m/s]
$u_{\text{wind farm_AEP}}$	total uncertainty in wind farm AEP	[Wh]
$u_{\text{P,i}}$	category B standard uncertainty of power in bin i	[W]
$u_{\text{sc,i,j}}$	uncertainty component for site calibration in wind speed bin i and wind direction bin j	[W]
$u_{\text{V,i}}$	category B standard uncertainty of wind speed in bin i	[m/s]
u_{WD}	wind direction uncertainty	[°]
$u_{\text{WD,SENSOR}}$	wind direction uncertainty, nacelle measured	[°]
u_{YAW}	wind direction uncertainty, yaw component	[°]
$u_{\text{T,i}}$	category B standard uncertainty of air temperature in bin i	[K]
$u_{\alpha,i,j}$	combined standard uncertainty of site calibration in wind speed bin i and wind direction bin j	[m/s]
$u_{\text{c,m,i}}$	combined uncertainty in power in bin i on turbine m	[W]
V	wind speed	[m/s]
V_{ave}	annual average wind speed at hub height	[m/s]
V_{free}	measured nacelle wind speed, corrected with the nacelle transfer function	[m/s]
V_{i}	normalised and averaged wind speed in bin i	[m/s]
V_{n}	normalised wind speed	[m/s]
$V_{\text{n,i,j}}$	normalised wind speed of data set j in bin i	[m/s]
$V_{\text{met,i}}$	bin averages of the met-mast wind speed in bin i wind speed determined with the nacelle anemometer	[m/s]
V_{nacelle}	the measured value of the nacelle anemometer for which we want to estimate the free stream wind speed	[m/s]
$V_{\text{nacelle,i}}$	the bin average value of the nacelle anemometer for bin i	[m/s]



Symbol	Description	Unit
$V_{10\min}$	measured wind speed averaged over 10 minutes	[m/s]
v_P	wind speed evaluated from the power output	[m/s]
x	distance downstream obstacle to met mast or wind turbine	[m]
Z	height above ground	[m]
z_0	roughness length	[m]
α	disturbed sector	[°]
α_j	ratio of wind speeds in wind direction bin j (wind turbine position to meteorological mast position)	
ΔU_z	influence of an obstacle in wind speed difference	[m/s]
ρ	correlation coefficient	
$\rho_{k,l,i,j}$	correlation coefficient between uncertainty component k in bin i and uncertainty component l in bin j	
$\rho_{k,m,n}$	correlation coefficient between turbine m and turbine n for component k	
$\rho_{k,m,i,l,j,n}$	correlation coefficient between uncertainty component k in bin i on turbine m and uncertainty component l in bin j on turbine n	
ρ_0	reference air density	[kg/m ³]
$\rho_{10\min}$	derived air density averaged over 10 minutes	[kg/m ³]
$\rho_{ubi,m,n}$	correlation coefficient for pressure	
$\rho_{umi,m,n}$	correlation coefficient for method	
$\rho_{upi,m,n}$	correlation coefficient for electric power	
$\rho_{sp,m,n}$	statistical correlation coefficient	
$\rho_{uti,m,n}$	correlation coefficient for temperature	
$\rho_{uvi,m,n}$	correlation coefficient for wind speed	
$\sigma_{P,i}$	standard deviation of the normalised power data in bin i	[W]
$\sigma_{10\min}$	standard deviation of parameter averaged over 10 minutes	
$\sigma_u/\sigma_v/\sigma_w$	standard deviations of longitudinal/transversal/vertical wind speeds	[m/s]
Φ	relative humidity (range 0 to 1)	
Ω	angular speed	[s ⁻¹]

5 Overview of test method

This ‘nacelle-anemometry’ power performance measurement method is similar to the standard method described in IEC 61400-12-1:2005 in that data are obtained to characterise a wind turbine’s power curve – that is power as a function of free stream wind speed. In both methods free stream wind speed is the horizontal component of free stream wind that would exist at the position of the centre of the turbine’s rotor if the turbine were not present to obstruct the wind. In the IEC 61400-12-1:2005 method, an anemometer is placed on a meteorological tower between 2 and 4 rotor diameters distance to the turbine. In flat terrain, this position provides a reasonably good estimate of the wind speed that would be at the turbine if the turbine were not present. In complex terrain, a site calibration corrects for the distortion of wind speed between the meteorological tower and the position at the centre of the turbine’s rotor.

In this nacelle-anemometry method, wind is measured using an anemometer mounted on or in front of the turbine's nacelle. This position is relatively close to the centre of the turbine's rotor so surrounding terrain and obstacles have less potential to distort the wind between the desired and the actual measurement positions. However, the turbine's rotor and nacelle distort the wind significantly. Therefore it is necessary to quantify this distortion and to account for it in the test procedure. This method describes this distortion in terms of a nacelle transfer function (NTF) which is obtained experimentally as described in Annex D as well as defining criteria to determine if a transfer function is valid for a certain turbine.

Once the transfer function is obtained, the nacelle-anemometry method to establish a power curve (the nacelle power curve (NPC)) is similar to the IEC 61400-12-1:2005 method. In this document this part of the method is called the 'Performance Test'. Similar data to that required by the IEC 61400-12-1:2005 test are obtained on wind speed (nacelle based wind speeds rather than meteorological tower wind speeds), wind direction (through turbine yaw position and wind vane rather than use of a wind vane on a meteorological tower), electrical power, air temperature, air pressure, and other conditions. The transfer function is applied to the measured wind speed in a manner analogous to that used for site calibration corrections. Valid data are selected and binned and the NPC is presented in tabular and graphical formats. AEP and the measurement uncertainties are determined and reported.

The following points shall be duly noted when using the method described in this standard. The definition of the resulting power curve is not identical to that of the IEC 61400-12-1:2005, as the transfer function can only be established and applied when the rotor is extracting power from the wind (i.e. turbine online). As a consequence, the power curve determined according to this standard does not consider occurrences during which the wind turbine is not online while it is available (start-up, stand-by for internal check, hysteresis effects, etc.). In this respect, the power curve is similar to, but not coincident with, the power curve B of IEC 61400-12-1:2005. In extreme cases the mean power output given by the power curve determined according to this standard may be significantly larger, and the AEP overestimated, as compared to IEC 61400-12-1:2005.

Furthermore, this method is based on the assumption that the terrain effects can be separated from the rotor effects, i.e. the terrain effects are captured in the site calibration whereas the rotor effects are captured in the transfer function. The assumption that all terrain effects are captured in the site calibration also underlies the IEC 61400-12-1:2005. However, the validity of this assumption has a stronger effect in the IEC 61400-12-2 methodology. For that reason additional uncertainty contribution due to terrain effects are taken into account. Finally, this method is based on the assumption that the transfer function and resulting power curve are not seasonally dependent. There is sufficient evidence to doubt this assumption. Therefore the uncertainty assessment reflects seasonal dependency. The user of this standard is cautioned to be aware of these issues when applying this standard in practice.

Note that a site calibration is not relevant to the measurement of a nacelle power curve. However, a site calibration may be required to determine the NTF.

A graphical representation of the overall nacelle power curve test method can be seen in Figure 1 and more details can be seen in Annex L.

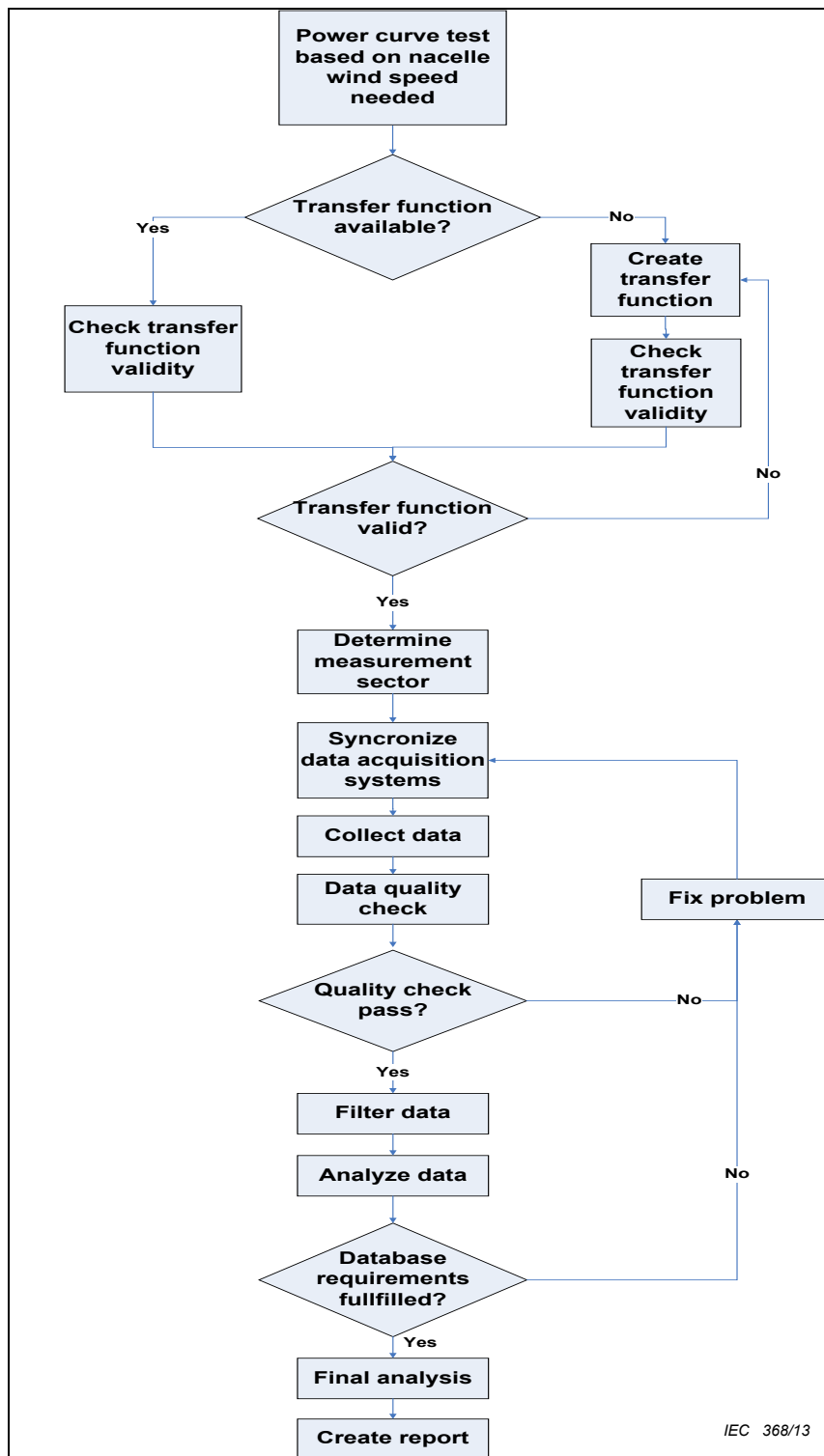


Figure 1 – Procedural overview

6 Preparation for performance test

6.1 General

The specific test conditions related to the power performance measurement of the wind turbine shall be well documented and reported, as detailed in Clause 10.

6.2 Wind turbine

As detailed in Clause 10, the wind turbine shall be assessed, described, and reported to uniquely identify the specific machine configuration that is tested.

The turbine configuration has significant influence on the measured nacelle power curve of the wind turbine. In particular, nacelle and rotor-based flow distortion effects will cause the wind speed as measured at the turbine nacelle to be different from, though correlated to, the free stream wind speed.

The turbine configuration shall be assessed for sources of influence on the NTF in order to:

- determine validity of a previously generated nacelle transfer function (Annex C);
- develop an appropriate nacelle transfer function (Annex D); and
- evaluate the uncertainty due to wind flow distortion (Annexes E, F and G).

All checks as per Annex C shall be done as part of the wind turbine assessment.

The turbine configuration shall be reported as detailed in Clause 10.

6.3 Test site

Conditions at the test site may significantly increase uncertainty in power performance measurements. Although the proximity of the nacelle anemometer to the desired measurement position (the rotor centre) reduces the distortion that exists between an anemometer that is mounted on a meteorological tower and the turbine rotor, topography and obstructions may still influence test results.

The test site shall be assessed for sources of wind flow distortion in order to:

- define a suitable measurement sector taking the location of obstacles and the terrain classification into consideration;
- evaluate the uncertainty in the power curve due to wind flow distortion.

The following factors shall be considered, in particular:

- topographical variations and reference roughness length (as defined in IEC 61400-12-1:2005);
- other wind turbines;
- turbulence as function of wind speed and wind direction;
- obstacles (buildings, trees, etc.).

Two factors are particularly important:

- First, other turbines or significant obstacles upwind of the test turbine produce wakes that influence both the test turbine's power production and the nacelle anemometer's measurements. There are currently no techniques available to minimise this interference with the measurement campaign. Therefore wakes shall be avoided.

- Second, topographical variations may change the vertical angle of the wind vector at the turbine. Depending on the position of the anemometer on the nacelle, the nacelle transfer function may be altered significantly by changes in the vertical angle of wind. Therefore, the relationship of local wind speed at the nacelle anemometer to vertical wind angle should be assessed. Based on this relationship and test site topology, certain wind directions may be excluded.

The measurement sector shall be determined using the procedure described in Annex B. It is strongly recommended that care is taken such that the average slopes of the 10° direction sectors making up the whole measurement sector have the same sign – i.e. the terrain in the measurement sector is either sloping down towards the turbine or sloping up towards the turbine. A measurement sector that mixes up and down slopes becomes difficult as the NTF is sensitive to this. Therefore, the measurement sector shall be restricted to slopes of the same sign and only an NTF derived for a slope of the same sign and satisfying the other terrain classification validity requirements (6.4) may be used.

The test site and the measurement sector shall be reported as detailed in Clause 10.

6.3.1 Terrain classification

Other conditions at the test site may adversely influence test results. These conditions can be accounted for by further exclusions of allowable wind directions if they are clearly reported in the test report. Wind directions that are not excluded for the reasons cited above are termed the 'measurement sector' even though the sector might not be contiguous.

Since local terrain may influence the NTF and NPC, a terrain classification is proposed in this section to allow an estimation of the uncertainty contribution of different types of terrain. This is done according based on similar variables as IEC 61400-12-1:2005, namely the average terrain slope as well as local terrain variations.

The terrain (incl. slope as defined in IEC 61400-12-1:2005) will be assessed from the turbine to 20 times the hub height in all directions. This information is used to determine if the site is 'flat' as defined in IEC 61400-12-1:2005.

6.3.2 RIX indices

In order to assess the terrain-related component of the uncertainty in the NTF from local terrain variations, a ruggedness index denoted by RIX shall be calculated for each 10° direction sector within the valid measurement sector (as defined in Annex B). The ruggedness index is calculated using the following method:

- 1) a topographic map¹ is digitised to a radius of 20 times the hub height from the test turbine;
- 2) in a given 10° direction sector, elevation points are determined every 30 metres along a line that extends through the centre of the direction sector;
- 3) the absolute difference in altitude Δz_i between adjacent elevation points is calculated as

$$\Delta z_i = |(\text{elevation}_i - \text{elevation}_{i-1})| \quad (1)$$

¹ The topographic map shall have a contour interval of 5 m or smaller. Alternatively the evaluation can be based on a digital terrain model based on a 30 m × 30 m grid or smaller and having a height accuracy for adjacent points of 1,0 m or 0,02 D, whichever is larger where D is the turbine diameter.

where:

- $\text{elevation}_{(i)}$ and $\text{elevation}_{(i-1)}$ are the elevations expressed in metres for adjacent elevation points; this is calculated for all elevation points up to 20 times the hub height;
- 4) the ruggedness index for the 10° sector is calculated as the percentage of calculated altitude differences within a given 10° sector that respectively exceed $0,04(D+H)$ (called $\text{RIX}_{0,04}$), $0,06(D+H)$ (called $\text{RIX}_{0,06}$) and $0,08(D+H)$ (called $\text{RIX}_{0,08}$). Note that points included in $\text{RIX}_{0,08}$ are necessarily also included in $\text{RIX}_{0,06}$ and $\text{RIX}_{0,04}$ and points included in $\text{RIX}_{0,06}$ and $\text{RIX}_{0,04}$ also included in $\text{RIX}_{0,08}$;
- 5) the ruggedness index for the measurement sector is calculated as the average of the ruggedness indices of 10 degree sectors that make up the measurement sector. The measurement sector is therefore characterised by three RIX indices.

6.3.3 Average slope

The average slope that will be used in the terrain classification is determined as follows:

- For each 10° sector calculate the slope from a radius of 5 times the hub height to the tower base.
- The average slope for the measurement sector is the average of the slopes for all 10° sectors that are part of the measurement sector.

For correct application of the nacelle transfer function it is important that we distinguish between positive and negative slopes. The transfer function will likely be different if the terrain drops by 20° when the wind flows to the turbine than if the terrain increases by 20° when the wind flows to the turbine.

6.3.4 Determine terrain class

The terrain class is evaluated by looking at average slope and the three RIX indices for the measurement sector. If the measurement sector contains both positive and negative slopes the test engineer should consider reducing the measurement sector as the results may be difficult to interpret and apply as it is likely that different transfer functions exists for positive and negative slopes.

The slope terrain class is defined in Table 1. The RIX terrain class is defined in Table 2.

Table 1 – Slope terrain classification

Absolute slope (%)	Slope terrain class
Compliant to IEC 61400-12-1:2005 Annex B (use $L = 2,5D$)	1
$0^\circ \leq \text{slope} < 10^\circ$, but not class 1	2
$10^\circ \leq \text{slope} < 15^\circ$	3
$15^\circ \leq \text{slope} < 20^\circ$	4
$20^\circ \leq \text{slope}$	5

Table 2 – RIX terrain classification

RIX (%)	RIX terrain class
Compliant to IEC 61400-12-1:2005 Annex B (use $L = 2,5D$)	0
$RIX_{0,04} < 16$ AND $RIX_{0,06} < 8$ AND $RIX_{0,08} < 4$ but not class 0	1
$RIX_{0,04} < 32$ AND $RIX_{0,06} < 16$ AND $RIX_{0,08} < 8$ but not class 1	2
$RIX_{0,04} < 48$ AND $RIX_{0,06} < 32$ AND $RIX_{0,08} < 16$ but not class 2	3
$RIX_{0,04} \geq 48$ OR $RIX_{0,06} \geq 32$ OR $RIX_{0,08} \geq 16$	4

The terrain class is the sum of the slope terrain class and the RIX terrain class with the understanding that the maximum terrain class is 5. If the sum of slope and RIX terrain class is higher than 5, then the terrain class is 5.

The final terrain class is shown in Table 3:

Table 3 – Final terrain class

	RIX terrain class				
Slope terrain class	0	1	2	3	4
1	1	2	3	4	5
2	2	3	4	5	5
3	3	4	5	5	5
4	4	5	5	5	5
5	5	5	5	5	5

6.3.5 Ridge formations

A ridge formation shall be treated differently as it possibly has only one point per 10° sector that is identified as complex terrain in the above procedure and could therefore be incorrectly classified as class 2. A ridge formation is defined as a step in terrain elevation where the step is larger than $0,08(H+D)$ between two adjacent elevated points. Additionally, such a step must be present in five adjacent 10° sectors or in all 10° sectors if the measurement sector contains less than five 10° sectors. The maximum ridge step is defined as the maximum elevation difference in meters of the points that make up the ridge. The maximum ridge step determines how the ridge affects the terrain class:

Table 4 – Maximum ridge step effects on terrain class

Maximum ridge step	Increase in terrain class
$0 \leq \text{maximum ridge step} < 0,08(H+D)$	0 (No ridge)
$0,08(H+D) \leq \text{maximum ridge step} < 2 \times 0,08(H+D)$	1
$2 \times 0,08(H+D) \leq \text{maximum ridge step} < 3 \times 0,08(H+D)$	2
$3 \times 0,08(H+D) \leq \text{maximum ridge step}$	3
where H = hub height and D = rotor diameter	

A ridge therefore increases the terrain complexity class depending on how steep the maximum slope is. The maximum terrain class is 5, so a ridge with a steep slope in terrain class 4 still gives a class 5 terrain class.

6.4 Nacelle wind speed transfer function

This method of determining power performance of a wind turbine requires a nacelle wind speed transfer function. This transfer function predicts what the free stream wind speed would be at the position of the centre of the turbine rotor if the turbine were not present using wind speed measured by a nacelle-mounted anemometer.

If a transfer function is not available then the nacelle wind speed transfer function must be measured in accordance with the procedure in Annex D. If a transfer function is available then it must be checked for validity using Annex C. If the transfer function is found to be valid then it can be used for the NPC, otherwise the nacelle wind speed transfer function must be measured in accordance with the procedure in Annex D.

If during an NPC measurement an NTF is used that has previously been measured in the same park it may be applied to turbines with a terrain classification differing maximum one terrain class from the terrain class during the NTF measurements; the terrain must also have the same sign of terrain slope in the measurement sector. (Please note that this may apply to a park where the park is built across a range of terrain classes).

If during an NPC measurement an NTF is used that has previously been measured in another park it may only be applied to turbines with a terrain classification that is the same as the terrain class during the NTF measurements; the terrain must also have the same sign of terrain slope in the measurement sector.

The terrain complexity is classified according to 6.3.

The uncertainty related to this NTF shall be evaluated as detailed in Annex E.

6.5 Test plan

A test plan shall be prepared prior to the test that addresses the information covered in Clause 10 of this standard to the extent that it can be determined prior to the tests. The guidelines in Annex K should also be considered regarding the organisation of the test, safety and communication.

7 Test equipment

7.1 Electric power

The net electric power of the wind turbine shall be measured using a power measurement device (e.g. power transducer) and based on measurements of current and voltage on each phase.

The class of the current transformers shall meet the requirements of IEC 61869-2 and the class of the voltage transformers, if used, shall meet the requirements of IEC 61869-3. They shall be class 0,5 or better.

The accuracy of the power measurement device, if it is a power transducer, shall meet the requirements of IEC 60688 and shall be class 0,5 or better. If the power measurement device is not a power transducer then the accuracy should be equivalent to class 0,5 power transducers. The operating range of the power measurement device shall be set to measure all positive and negative instantaneous power peaks generated by the wind turbine. As a guide, the full-scale range of the power measurement device should be set to –50 % to +200 % of the wind turbine rated power. All data shall be periodically reviewed during the test to ensure that the range limits of the power measurement device have not been exceeded. This also includes the possibility of in-situ verification. The power measurement device shall be mounted between the wind turbine and the electrical connection to ensure that only the net active electric power (i.e. reduced by self-consumption) is measured. It shall be stated

whether the measurements are made on the turbine side or the network side of the transformer.

The power measurement equipment (current transformer, voltage transformer, power measurement device) shall be calibrated traceable to national standards. Alternatively, an in-situ comparison may be done to a calibrated energy meter. The in-situ procedure used as well as the results must be documented.

7.2 Wind speed

Nacelle wind speed shall be measured with a nacelle- or spinner-mounted anemometer that meets the requirements in Annex H. The wind speed to be measured is defined as the average magnitude of the horizontal component of the instantaneous wind velocity vector, including only the longitudinal and lateral, but not the vertical, turbulence components. All reported wind speeds, and all uncertainties connected to operational characteristics shall be related to this wind speed definition.

The anemometer shall be of the same type, calibrated in the same wind tunnel and mounted in the same fashion as the anemometer used to measure the NTF, as described in Annex D.

The signal details shall be reported as described in Clause 10.

Before the measurement campaign, the anemometer shall be calibrated according to the procedure described in IEC 61400-12-1:2005 and/or Annex D. The mounting structure used for the calibration of the anemometer for wind speed measurement shall be the same as the mounting structure used for the measurement of the NTF. If this is not possible, differences should be kept small and shall be clearly documented. The mounting structure used during calibration of the NPC anemometer shall be the standard tubular mounting structure as used for the calibration of the anemometer for the NTF. The calibration is valid for one year of operation in the field. The anemometer shall either be post-test calibrated or two side by side mounted anemometers shall be used to ensure correct operation of the anemometers. Post-test calibration is recommended as it gives a more objective and accurate result. If an in-situ calibration is done, the procedure described in IEC 61400-12-1:2005 shall be used.

It is recommended that the anemometer be mounted as recommended in Annex A.

The uncertainty in wind speed measurement derives from five main sources (see Table E.2):

- the calibration of the instrument
- the operational characteristics of the anemometer
- flow distortion due to instrument mounting effects and nacelle
- the influence from the terrain
- the influence of the turbine rotor on the anemometer

Uncertainty in calibration shall be derived using a procedure similar to that described in IEC 61400-12-1:2005. Uncertainty due to operational characteristics shall be derived from IEC 61400-12-1:2005 on classification of anemometry. Uncertainty due to mounting effects shall be derived from Annex E. Uncertainty due to terrain influence shall be derived from Annex E. Uncertainty due to rotor influence shall be derived from Annex E.

7.3 Wind direction

7.3.1 Nacelle yaw position sensor

The turbine nacelle yaw position shall be measured. The signal from the wind turbine controller may be used for that purpose. The nacelle yaw position signal shall be verified in-situ to determine correct operation and establish the relation to True North. It is recommended

to do this verification by comparing the measured yaw position with known bearings to multiple known reference points, but other methods are also allowed.

It is recommended that a check be done to ensure that the nacelle position signal alignment has not changed during the power curve measurement.

7.3.2 Nacelle wind direction sensor

Nacelle wind direction shall be measured. The signal from the wind turbine controller may be used for that purpose. An instrument used for this purpose shall be mounted on a nacelle mounting structure, as described in Annex A. The nacelle wind direction signal shall be verified in-situ to determine correct operation and establish the relation relative to the nacelle's longitudinal axis such that this is zero or a constant value of degrees.

Apart from establishing an NTF to determine the rotor effect on wind speed, it is also possible to establish an NTF to determine rotor effect on wind direction, as briefly described in Annex D. The uncertainty due to flow distortion around the nacelle may be reduced by applying a wind direction transfer function determined using the data from the nacelle wind speed transfer function test. If a nacelle transfer function for wind direction is made, a site calibration for wind direction should also be assessed, using a similar methodology to the site calibration for wind speed.

The signal details shall be reported as detailed in Clause 10.

7.3.3 Wind direction

The measurement of wind direction on the nacelle of a wind turbine is influenced by the yaw position of the wind turbine. The wind vane gives a signal relative to the yaw position of the wind turbine. It is important to remember that the instantaneous wind direction is also influenced by the wake from the turbine rotor and the presence of the nacelle. The wind direction signal shall therefore be a combination of the instantaneous nacelle yaw position signal and the instantaneous wind vane signal. This addition cannot be done after the raw data have been averaged.

7.4 Air density

Air density shall be derived from the measurement of ambient air temperature and ambient absolute air pressure using equation (4) (See Clause 9). At high temperatures, it is also recommended that the ambient relative air humidity be measured and that the air density be corrected to account for the effect of the air humidity using formula (2).

$$\rho = \frac{1}{T} \left(\frac{B}{R_0} - \phi P_w \left(\frac{1}{R_0} - \frac{1}{R_w} \right) \right) \quad (2)$$

Where

- B is the barometric pressure [Pa];
- T is the absolute temperature [K];
- ϕ is the relative humidity (range 0 to 1);
- R_0 is the gas constant of dry air [287,05 J/kgK];
- R_w is the gas constant of water vapour [461,5 J/kgK];
- P_w is the vapour pressure [Pa];

$$P_w = 0,0000205e^{0,0631846T}$$

where vapour pressure P_w depends on mean air temperature.

Air temperature, pressure, and humidity measurements shall measure the ambient air conditions (i.e. not internal nacelle conditions). If the air pressure sensor is mounted on the turbine it shall be placed such that the measurement is not affected by the blades or by other equipment from the turbine such as the ventilation system.

The temperature sensor (and humidity sensor when used) shall be mounted within 10 metres of hub height, either on the turbine itself or on a local meteorological tower within a distance of four rotor diameters from the turbine. The temperature sensor shall measure the ambient outside air temperature without influence from the turbine equipment, e.g. ventilation or heating systems. If humidity is not measured and a correction for humidity at high temperatures is needed, then a value of $\phi=0,5$ shall be used in formula 2.

The air pressure shall be measured within 5 km from the turbine and shall be synchronised with the NPC measurement system to within 10 minutes. If the air pressure sensor is not mounted close to rotor centre altitude above sea-level (ASL), air pressure measurements shall be corrected to the rotor centre altitude ASL according to ISO 2533.

The combined uncertainty of the temperature signal shall be less than 3 °C. The combined uncertainty of the air pressure signal shall be less than 10 hPa.

7.5 Rotor speed

The turbine rotor speed should be measured or verified by checking that the relevant parameter settings of the turbine have not changed during the test duration. This measurement will be used to ensure the validity of the application of the NTF.

7.6 Pitch angle

The turbine blade pitch angles are recommended to be measured or verified by checking that the relevant parameter settings of the turbine have not changed during the test duration. This measurement will be utilised to ensure the validity of the application of the nacelle wind speed transfer function.

7.7 Wind turbine status

Sufficient status signals shall be identified, verified and monitored to allow the rejection criteria of Clause 8.6 to be applied. The status signal must identify curtailed situations such as noise reduced operation or power deregulation conditions. Typically, a generator grid connection status signal is sufficient. Obtaining these parameters from the turbine controller's data system, if available, is adequate. Obtaining an 'availability' status signal to ascertain the operational status of the wind turbine (available or not available) is recommended. The definition of each status signal shall be reported.

It is recommended to keep track of online and offline operation of the turbine as described in Table 1.

7.8 Data acquisition

A data acquisition system having a sampling rate per channel of at least 1 Hz shall be used to collect measurements and store pre-processed data.

The turbine controller data system (i.e. SCADA system) may be used for data acquisition as long as it fulfils the requirements and gives sufficient insight into the traceability of the signals and signal processing.

The calibration and accuracy of the data system chain (transmission, signal conditioning and data recording) shall be verified by injecting known signals at the transducer ends and

comparing these inputs against the recorded readings. This shall be done using instrumentation that is calibrated traceable to national standards. As a guideline, the uncertainty of the data acquisition system should be negligible compared with the uncertainty of the sensors.

Any influence or operation performed by the data acquisition system on the data shall be reported. The following checks shall be done:

- any averaging or filtering of the data by the data acquisition system shall be reported in such detail that its effect on the data and the uncertainty of the data can be established;
- any internal calibrations, applied offsets or corrections applied to the data shall be reported in such detail that the calibrations, applied offsets or corrections can be undone during data processing;
- the uncertainty of the whole signal chain shall be calculated for each signal;
- a correct treatment of the wind direction north jump (360° to 0° transition or vice versa) averaging shall be verified.

If the conditions in this paragraph cannot be fulfilled due to the fact that a turbine controller data system is used, a separate, independent data system that is capable to fulfil these requirements shall be installed and used instead.

8 Measurement procedure

8.1 General

The objective of the measurement procedure is to collect data that meet a set of clearly defined criteria to ensure that the data are of sufficient quantity and quality to accurately determine the power performance characteristics of the wind turbine. The measurement procedure shall be reported, as detailed in Clause 10, so that every procedural step and test condition can be reviewed and, if necessary, repeated.

Accuracy of the measurements shall be expressed in terms of measurement uncertainty, as described in Annex E. During the measurement period, data shall be periodically checked to ensure high quality and repeatability of the test results. These checks shall be reported. Test logs shall be maintained to document all important events during the power performance test.

8.2 Wind turbine operation

During the measurement period, the wind turbine shall be in normal operation, as prescribed in the wind turbine operations manual (or equivalent), and the machine configuration may not be changed. The operational status of the wind turbine shall be documented by the status signals as described in Clause 7 and it shall be stated in the report that the operational status has not changed throughout the test. Normal maintenance of the turbine shall be carried out throughout the measurement period, and such work shall be noted in the test log. Any special maintenance actions, such as frequent blade washing, which ensure good performance during the test shall in particular be noted. Such special maintenance actions shall by default not be made, unless agreed by contractual parties prior to commencement of the test.

8.3 Data system(s) synchronisation

If during one test the signals are measured with more than one data acquisition system, the synchronisation of all systems shall be ensured throughout the measurement period. The maximum synchronisation difference between any two data acquisition systems shall be less than 1 % of the averaging time. Any violation of this synchronisation requirement shall be reported. The pressure measurement is excluded from this criterion.

It is recommended to avoid synchronisation problems by measuring with one single measurement system. The recommended time convention is coordinated universal time (UTC).

or a reference to the UTC time base. The time correction applied for each update shall be logged. The selected time reference shall be reported.

8.4 Data collection

Data shall be collected continuously at a sampling rate of 1 Hz or faster. The data acquisition system should as a minimum store statistics of data sets of all signals as follows:

- 10-minute mean value;
- 10-minute standard deviation;
- 10-minute maximum value;
- 10-minute minimum value.

If the data collection system present in the turbine cannot do this for all signals, then 10-minute minimum, 10-minute maximum, 10-minute standard deviation and 10-minute mean must be stored for all wind speed and power signals. For the other signals storing a 10-minute mean signal will suffice.

Selected data sets shall be based on 10-minute periods derived from contiguous measured data. Data shall be collected until the requirements defined in 8.8 are satisfied.

The standard analysis will be based on the 10-minute statistics of the measured data. This has been chosen to keep the results closely linked to the IEC 61400-12-1:2005 standard.

It is important to note that the choice to use 10-minute statistics in itself influences the result of the power performance test, for instance through the effect of turbulence. Originally, the 10-minute period was selected, amongst other reasons, to allow for the time the wind needs to flow from mast to turbine and to ensure reasonable correlation between wind speed and power. In the case of nacelle anemometry, this is no longer needed and there are arguments to reduce the averaging time to a period less than 10 minutes.

In order to keep the link with the IEC 61400-12-1:2005 standard and at the same time not prevent more accurate reporting, the choice has been made to always report the standard result based on 10-minute statistics, but to allow analysis based on shorter averaging periods to be reported as well. The validity of the applied transfer function shall be checked when using shorter averaging periods.

8.5 Data quality check

To ensure the data included in the final valid database of results are accurate, quality control steps shall be performed on the data during, or prior to, the data reduction and analysis process. The following sections list examples of quality control methods, but do not include all methods that may be required. Data points that fail to meet the quality control criteria defined by the user shall be removed from the valid database. All data filtering methodology shall be reported thoroughly as required by Clause 10. These steps are in addition to the check/calibration of the measurement system as described in 6.2.

Measured signals are in range and available

Ensure that each data set in which a required signal is outside the signal range is excluded from the valid database. Similarly, exclude data sets in which one or more of the required signals are unavailable or not operating for one or more samples. These exclusions must be reported and described as per the requirements listed in Clause 10.

Sensors are operating properly

The individual data set average, max, min and standard deviation statistics of the measured signals must be checked periodically to ensure the values are consistent with the expected values (e.g. no significant signal noise; or data when the sensors are influenced by their mounting structure or other sensors). Manually interrogating time-series and/or sensor data

of a sub set of the measured data (database sampling) is suggested, in addition to automated techniques, in order to ensure all irregularities are identified. Additionally, compare like signals to each other (e.g. primary and control wind speed on meteorological tower; turbine-measured power and independent power signal; turbine yaw position to meteorological tower, or nearby wind direction measurement) to ensure the deviations are consistent with the expected values. Suspect data should be excluded from the valid database. These exclusions must be reported and described as per the requirements listed in Clause 10.

Ensure Data Acquisition System(s) is/are operating properly

Steps should be taken to verify that the data acquisition system operates properly throughout the measurement period. These steps include, but are not limited to:

- ensuring data records are not repeated;
- investigating the cause for any significant data gaps in measured signals;
- investigating any discontinuities in measured signals that do not correspond to data gaps.

If any issues are found, these findings shall be documented and reported. The checks themselves shall also be reported.

Sector self consistency check

Once a (draft) NPC is available the sector self-consistency check in B.2.2. shall be done.

8.6 Data rejection

Certain data sets shall be excluded from the database to ensure:

- analysis and results are commensurate with normal operating conditions of the turbine;
- corrupted and inaccurate data are excluded.

Data sets shall be excluded from the database under the following circumstances:

- external conditions other than wind speed are out of the operating range of the wind turbine;
- external conditions are out of the operating range of the test instruments;
- turbine is not online (except for turbines that temporarily go offline as part of normal operation, e.g. generator switching. These effects shall be captured in the power curve and the precise filter applied shall be reported);
- turbine is output-limited by external factors such as the power grid; this shall be documented in situ, for instance with a logbook or status-signal from the turbine;
- failure or degradation (e.g. due to icing) of test equipment;
- 10-minute average wind direction outside the measurement sector as defined in Annex B;
- blade icing events and snow cover on the nacelle;
- wind speed is out of the applicability range of the nacelle wind speed transfer function;
- data from time periods where the NTF is not valid shall be excluded (i.e. wrong parameter settings in the turbine);
- turbine cannot operate because of a turbine fault condition;
- turbine is manually shut down or in a test or maintenance operating mode.

Any other rejection criteria shall be clearly reported. All data rejected for these reasons shall be clearly documented and reported.

Subsets of the database collected under special operational conditions (e.g. high blade roughness due to dust, salt, insects, ice) or atmospheric conditions (e.g. precipitation, turbulence intensity, wind shear) that occur during the measurement period may be selected as special databases.

If it is to be expected that the grid frequency varies with more than 1 % during an average time of 600 seconds, the grid frequency shall be measured. Measurement data collected when the grid frequency is outside the nominal grid frequency ± 1 % shall be separately classified or shall be neglected.

8.7 Data correction

For the selected data sets the following data corrections shall be made to the following measurements:

- air pressure correction to rotor centre altitude ASL (if required by 7.4);
- the absolute wind direction shall be calculated from the nacelle yaw position and the nacelle vane signal;
- signal modifications applied by the wind turbine controller shall be taken into account to ensure correct final values;
- data may be corrected for any calibrations, applied offsets or corrections performed by the data acquisition system in order to ensure the highest data quality, as applicable and as long as clearly reported;
- nacelle wind speed shall be corrected to free stream wind speed using the transfer function determined in Annex D;
- any other corrections made to the data shall be reported clearly and in detail.

The data correction details shall be reported as detailed in Clause 10.

8.8 Database

After data normalisation (see 9.1) the selected data sets shall be sorted using the 'method of bins' procedure (see 9.2). The selected data sets shall at least cover a wind speed range extending from cut-in to 1,5 times the wind speed at 85 % of the rated power of the wind turbine. Alternatively, the wind speed range shall extend from cut-in to a wind speed at which 'AEP-measured' is greater than or equal to 95 % of 'AEP-extrapolated' (see 9.3). The report shall state which of the two definitions has been used to determine the range of the measured power curve. The wind speed range shall be divided into 0,5 m/s contiguous bins centred on multiples of 0,5 m/s.

The database shall be considered complete when it has met the following criteria:

- each bin includes a minimum of 30 minutes of sampled data;
- the database includes a minimum of 180 hours of sampled data.

Should a single incomplete bin be preventing completion of the test, then that bin value can be estimated by linear interpolation from the two adjacent complete bins.

In order to complete the power curve at high wind speeds the following procedure may be used. For wind speeds above 1,6 times the wind speed at 85 % of rated power the measurement sector can be opened.

The following condition shall be fulfilled when using the above two extended procedures: AEP-measured from extended procedures deviates less than 1 % from AEP-extrapolated up to the highest complete wind speed bin for the extended procedures (for the Rayleigh distribution in 9.3).

The database shall be presented in the test report as detailed in Clause 10.