IEC 61400-12-5

Edition 1.0 2022-08

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Wind energy generation systems – Part 12-5: Power performance – Assessment of obstacles and terrain

Systèmes de génération d'énergie éolienne – Partie 12-5: Performance de puissance – Évaluation des obstacles et du terrain

IEC 61400-12-5:2022-08(en-fr)

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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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Wind energy generation systems – Part 12-5: Power performance – Assessment of obstacles and terrain

Systèmes de génération d'énergie éolienne – Partie 12-5: Performance de puissance – Évaluation des obstacles et du terrain

INTERNATIONAL ELECTROTECHNICAL COMMISSION

COMMISSION ELECTROTECHNIQUE INTERNATIONALE

ICS 27.180

ISBN 978-2-8322-5603-9

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WIND ENERGY GENERATION SYSTEMS –

Part 12-5: Power performance – Assessment of obstacles and terrain

FOREWORD

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IEC 61400-12-5 has been prepared by IEC technical committee 88: Wind energy generation systems. It is an International Standard.

This first edition of IEC 61400-12-5 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:

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Draft	Report on voting
88/825/CDV	88/870/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,
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INTRODUCTION

The purpose of this part of IEC 61400 is to describe procedures to determine a measurement sector that is not influenced by turbines or other obstacles for a specific wind turbine. The measurement sector is used to assess the terrain and determine if a site calibration is required. This measurement sector can be used to evaluate wind turbine power performance.

Clause 6 describes a procedure to determine one or more sectors which are not usable for a power performance measurement because the flow at the wind turbine under test and/or the flow at the position of the wind measurement equipment (WME: a meteorological mast or a remote sensing device) might be affected by an operating wind turbine and/or by an obstacle.

Clause 7 describes a procedure for establishing the measurement sector during the determination of the nacelle transfer function.

Clause 8 describes a procedure for establishing the measurement sector during the determination of the nacelle power curve.

Clause 9 describes a procedure to assess the terrain surrounding the site and to determine if it is sufficiently complex to require site calibration. The purpose of site calibration is generally to measure the change in the boundary layer as it follows the orography, which is generally attached flow, whereas obstacles often generate more turbulent wakes associated with them, which are affected by sharp edges and vertical surfaces that can trigger flow separation.

Clause 10 describes a procedure to classify the terrain in order to apply the nacelle transfer function for a nacelle power curve measurement. The classification is used to estimate the uncertainty of the nacelle transfer function (NTF) and nacelle power curve (NPC) and also to determine under what terrain condition the NTF can be used for the NPC.

The creation of this new standard was mandated with the restriction that no technical changes to the content copied from the source documents (IEC 61400-12-1 and IEC 61400-12-2) would be allowed. Therefore, in this first edition of the new standard IEC 61400-12-5, there are some obvious areas of technical disagreement (e.g. assessment of terrain in Clauses 9 and 10) where a choice needs to be made depending on whether the intended use case is as an input to a IEC 61400-12-1 or to a IEC 61400-12-2 power curve evaluation. It is recommended that future revisions of this document aim to harmonise the technical content.

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WIND ENERGY GENERATION SYSTEMS –

Part 12-5: Power performance – Assessment of obstacles and terrain

1 Scope

This part of IEC 61400 specifies the procedures for assessing the significance of obstacles and terrain variations on a proposed power performance measurement site and applies to the performance testing of wind turbines of all types and sizes connected to the electrical power network as described in other parts of the IEC 61400 series. The procedure applies to the performance evaluation of specific wind turbines at specific locations.

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 61400-12-1, *Wind energy generation systems – Part 12-1: Power performance measurements of electricity producing 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 61400-12-6, *Wind energy generation systems – Part 12-6: Measurement based nacelle transfer function of electricity producing wind turbines*

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
complex terrain
terrain surrounding the test site that features significant variations in topography and terrain obstacles (refer to 3.10) that may cause flow distortion

3.2
cut-in wind speed
lowest wind speed at which a wind turbine will begin to produce power

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3.3
data set
collection of data sampled over a continuous period

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

3.5
free stream wind speed
horizontal wind speed measured upstream of the rotor of the wind turbine generator that is unaffected by rotor aerodynamics

3.6
hub height
<of wind turbine> height of the centre of the swept area of the wind turbine rotor above the ground at the tower

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

3.7
measured power curve
table and graph that represent the measured, corrected and normalized net power output of a wind turbine as a function of measured wind speed, measured under a well-defined measurement procedure

3.8
measurement sector
sector of wind directions from which data are selected for the measured power curve

3.9
nacelle transfer function
NTF
transfer function applied to estimate the free stream wind speed from the nacelle anemometer wind speed

3.10
obstacle
obstruction that blocks and distorts the flow of the wind, such as a building or tree

3.11
power performance
measure of the capability of a wind turbine to produce electric power and energy

3.12
test site
location of the wind turbine under test and its surroundings

3.13
uncertainty in measurement
parameter, associated with the result of a measurement, which characterizes the dispersion of the values that could reasonably be attributed to the measurand

[SOURCE: IEC 60050-415:1999, 415-05-13]

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3.14
wind measurement equipment
meteorological mast or remote sensing device

4 Symbols, units and abbreviated terms

Symbol or abbreviated term	Description	Unit
D	rotor diameter	[m]
D_e	equivalent rotor diameter	[m]
D_n	rotor diameter of neighbouring and operating wind turbine	[m]
d_i	distance from turbine to point in terrain for worst case scenario of slope	[m]
H	hub height of wind turbine	[m]
h	height of obstacle	[m]
L	distance between the wind turbine and the wind measurement equipment	[m]
L_e	distance between the wind turbine or the wind measurement equipment and an obstacle	[m]
L_n	distance between the wind turbine or the wind measurement equipment and a neighbouring and operating wind turbine	[m]
l_h	height of obstacle	[m]
l_w	width of obstacle	[m]
RIX	Ruggedness index	
VP	wind speed evaluated from the power output	[m/s]
V_{free}	measured nacelle wind speed, corrected with nacelle transfer function	[m/s]
WME	wind measurement equipment	
z	height above ground	[m]
z_i	terrain elevation at point of the worst-case scenario for slope	[m]

5 General

For a power performance measurement carried out according to IEC 61400-12-1 or IEC 61400-12-2, the wind speed experienced at the measurement location and at the test turbine location can be influenced both by obstacles (e.g. buildings, forests, other turbines) in the surroundings and by the terrain (severity of terrain slopes and deviations within the terrain). The presence of such influences should be checked and the valid direction sector reduced accordingly in the case of obstacles or a site calibration (according to IEC 61400-12-3) carried out in the case of sufficiently complex terrain. Clause 6 and Clause 8 describe procedures to determine one or more sectors which are not usable for the test because the flow at the wind turbine under test and/or the flow at the position of the wind measurement equipment (WME: a meteorological mast or a remote sensing device) might be affected by an operating wind turbine and/or by an obstacle. Clause 9 describes the criteria to assess terrain to determine if a site can be considered flat (no site calibration required) or complex (site calibration required). Clause 10 describes the criteria to classify terrain as required for the application of an NTF.

As this method is closely related to both IEC 61400-12-1 and IEC 61400-12-2, both standards are referred to frequently in this document.

For this document, the interfaces are defined in Table 1 and Table 2; in order to facilitate the correct interpretation of the interfaces, a short description of the use of the interface has been added as well.

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Table 1 – Other International Standards which refer to this document

Interface description	References to this document in other International Standards	Short use description	Format
Measurement sector	IEC 61400-12-1:2022, Clause 6	Filtering the data set	From [degree] to [degree]
Measurement sector (NTF)	IEC 61400-12-2:2022, Clause 7	Filtering the data set	From [degree] to [degree]
Measurement sector (NPC)	IEC 61400-12-2:2022, Clause 8	Filtering the data set	From [degree] to [degree]
Terrain assessment	IEC 61400-12-1:2022, Clause 9	Determination of site calibration requirement	Complex or not complex
Terrain class	IEC 61400-12-2:2022, Clause 10 IEC 61400-12-6:2022, Clause 10	Reporting of the transfer function validity	Terrain class [1; 2; 3; 4; 5]

Table 2 – Interfaces from this document to other International Standards

Interface description	Relevant content in this document	Reference to other standards	Short use description	Format
Terrain assessment	Clause 9	IEC 61400-12-1:2022	Input to the wind speed measurement uncertainty calculation for the power curve	Operational characteristics of anemometer dependent on complexity of terrain or site-specific data
Terrain class	Clause 10	IEC 61400-12-2:2022	Input to the wind speed measurement uncertainty calculation for the nacelle transfer function (NTF)	Terrain class [1; 2; 3; 4; 5]

6 Measurement sector procedure to be used for power performance measurements according to IEC 61400-12-1

6.1 General

Clause 6 describes a procedure to determine one or more sectors which are not usable for the test because the flow at the wind turbine under test and/or the flow at the position of the wind measurement equipment (WME: a meteorological mast or a remote sensing device) might be affected by an operating wind turbine and/or by an obstacle.

The procedure consists of two steps, to be applied in the following order

a) Evaluation of influences caused by operating wind turbines (wind turbine under test, as well as neighbouring and operating wind turbines), as described in 6.2;

b) Evaluation of influences caused by obstacles, as described in 6.3 (under consideration of the special requirements for extended obstacles, as described in 6.5).

Step b) requires the preliminary measurement sector, which is the result of step a).

The valid sector which remains after this procedure shall be used for the terrain assessment according to Clause 9.

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The purpose of site calibration (refer to IEC 61400-12-3) is generally to measure the change in the boundary layer as it follows the orography, which is generally attached flow, whereas obstacles often generate more turbulent wakes associated with them, which are affected by sharp edges and vertical surfaces that may trigger flow separation. A site calibration does not typically work well for correcting the effects of flow separation. This should be considered when deciding whether to treat an object as an obstacle or as terrain as flow separation and highly turbulent wakes are to be avoided. With this in mind, it is recommended that an object (including orographic elements which satisfy the dimensional criteria) whose height is more than half of its width be treated as an obstacle.

6.2 Requirements regarding neighbouring operating wind turbines

The WME shall not be influenced by the wind turbine under test.

The wind turbine under test and the WME shall not be influenced by neighbouring operating wind turbines. If a neighbouring wind turbine is operated at any time during the power performance test, its wake shall be determined and accounted for as described in this document (using the calculation given in 6.4). Small wind turbines of total height less than (2/3)($H - D$/2) shall be treated as obstacles, and accounted for as described in Clause 8.

If a wind turbine is stopped at all times during the power performance test, it shall be considered as an obstacle and accounted for as described in Clause 8.

The minimum distance from the wind turbine under test and the neighbouring operating wind turbines is defined in IEC 61400-12-1. The minimum distance from the WME to any neighbouring operating wind turbine is also defined in IEC 61400-12-1. The sectors to exclude due to wakes from neighbouring operating wind turbines shall be taken from Figure 1. The dimensions to be taken into account are the actual distance L_n and the rotor diameter D_n of the neighbouring operating wind turbine. The sectors to be excluded shall be derived for both the wind turbine under test and the WME, and they shall be centred on the direction from the neighbouring operating wind turbine to the wind measurement equipment or the wind turbine. An example is shown in Figure 2.

6.3 Requirements regarding obstacles

Obstacles near the wind turbine under test or near the WME shall be evaluated. Each obstacle shall be evaluated either as part of the orography (as described in Clause 9), or – alternatively – according to the procedure which is described in this Subclause 6.3 as follows.

NOTE The consideration of an obstacle as part of the orography (as described in Clause 9) will typically increase mainly the terrain variation, whereas the effect on the slope can be very small (except for extended obstacles, e.g. forests).

No significant obstacles (e.g. buildings, trees, parked wind turbines) shall exist in the measurement sector within a reasonable distance from the wind turbine or from the WME. Only small buildings, connected to the wind turbine operation or the wind measurement equipment, are acceptable. Where significant obstacles are present then the measurement sector shall be reduced as described in 6.4 and 6.5.

The criterion for the significance of an obstacle (with respect to the wind turbine under test and/or with respect to the WME) is to exceed one or more of the limits given in Table 3, where Table 3 shall be applied for all locations:

a) for the evaluation of the surroundings of the wind turbine under test (i.e. using the centre of the wind turbine under test as centre of the 2L, 4L, 8L, and 16L circles);

b) for the evaluation of the surroundings of the WME (i.e. using the position(s) of the equipment as centre of the 2L, 4L, 8L, and 16L circles).

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Table 3 – Obstacle requirements: relevance of obstacles

Distance*	Sector**	Maximum obstacle height from terrain surface***
< 2L	360°	< 1/3 (H − 0,5 D)
≥ 2L and < 4L	Preliminary measurement sector	< 2/3 (H − 0,5 D)
≥ 4 L and < 8L	Preliminary measurement sector	< (H − 0,5 D)
≥ 8L and < 16L	Preliminary measurement sector	< 4/3 (H − 0,5 D)
≥ 2L and < 16L	Clearly outside preliminary measurement sector by 40° or more	No limit to height

* from obstacle to wind turbine under test, or from obstacle to WME – where L is the horizontal distance between wind turbine under test and wind measurement equipment.

** "Preliminary measurement sector" shall be understood here as the valid sector which remains after evaluation of neighbouring operating wind turbines (as described in 6.2, using the calculation described in 6.4), where all directions which are less than 40° outside shall also be considered.

*** H is the hub height and D is the rotor diameter of the wind turbine under test.

6.4 Method for calculation of sectors to exclude

The wind turbine under test shall always be evaluated according to Figure 1 with respect to its wake influence on the WME.

A neighbouring operating wind turbine shall always be evaluated according to Figure 1 with respect to its wake influence on the wind turbine under test and also with respect to its wake influence on the WME.

With respect to operating wind turbines, the dimensions to be taken into account are the actual distance L_n (from centre of wind turbine under test to the position of the WME) and the rotor diameter D_n of the wind turbine that causes the wake.

The influence of the turbine under test on the WME is evaluated by means of L (distance between turbine under test and wind measurement equipment) and D (rotor diameter of turbine under test).

An obstacle shall be evaluated according to Figure 1 with respect to its wake influence on the wind turbine under test if the obstacle is significant with respect to the wind turbine under test according to Table 3.

An obstacle shall be evaluated according to Figure 1 with respect to its wake influence on the WME if the obstacle is significant with respect to the WME according to Table 3.

With respect to obstacles, the dimensions to be taken into account are the actual horizontal distance L_e (from the centre of wind turbine under test or from the position of the WME as appropriate) and an equivalent rotor diameter D_e of the obstacle. A stopped neighbouring wind turbine may be treated as a cylinder with a diameter equal to the tower base diameter and a height equal to the upper tip height. The equivalent rotor diameter of the obstacle shall be defined as:

$$D_e = \frac{2 l_h l_w}{l_h + l_w} \tag{1}$$

where

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D_e is the equivalent rotor diameter;

l_h is the height of obstacle;

l_w is the width of obstacle as seen from the wind turbine under test or from the WME.

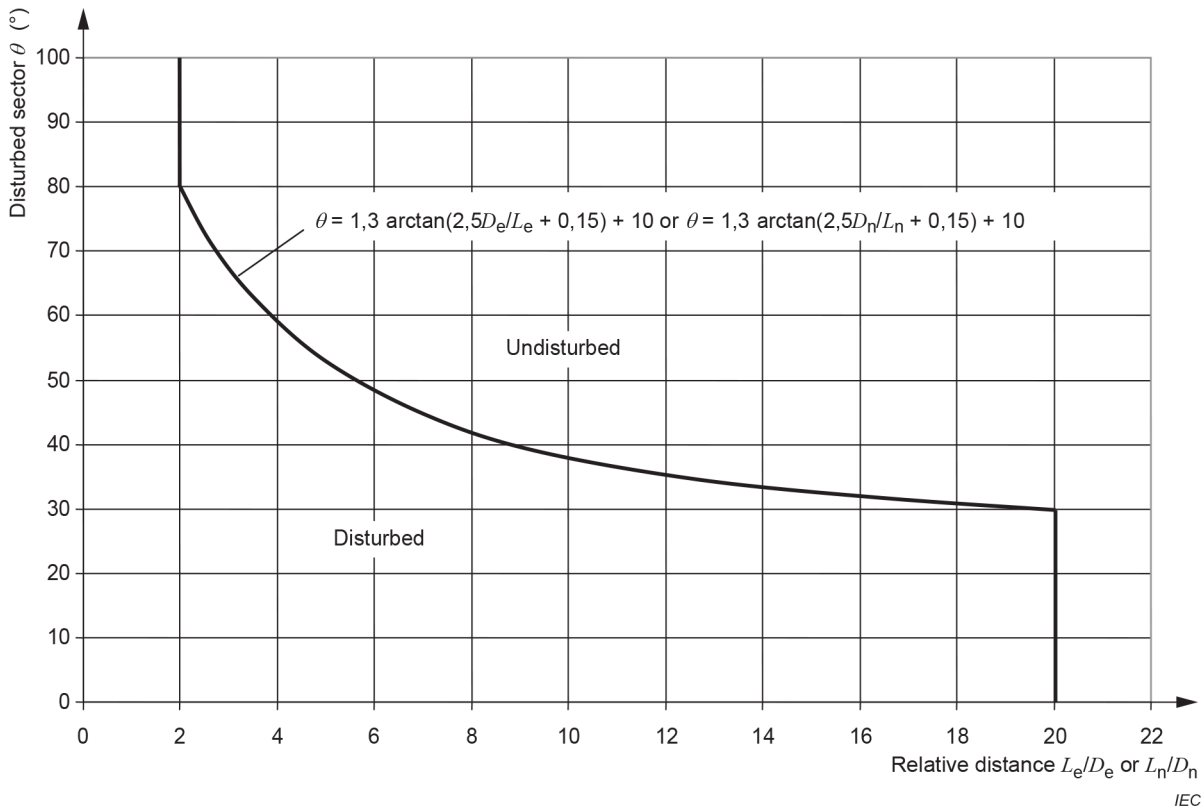

Figure 1 – Sectors to exclude due to wakes of neighbouring and operating wind turbines and significant obstacles

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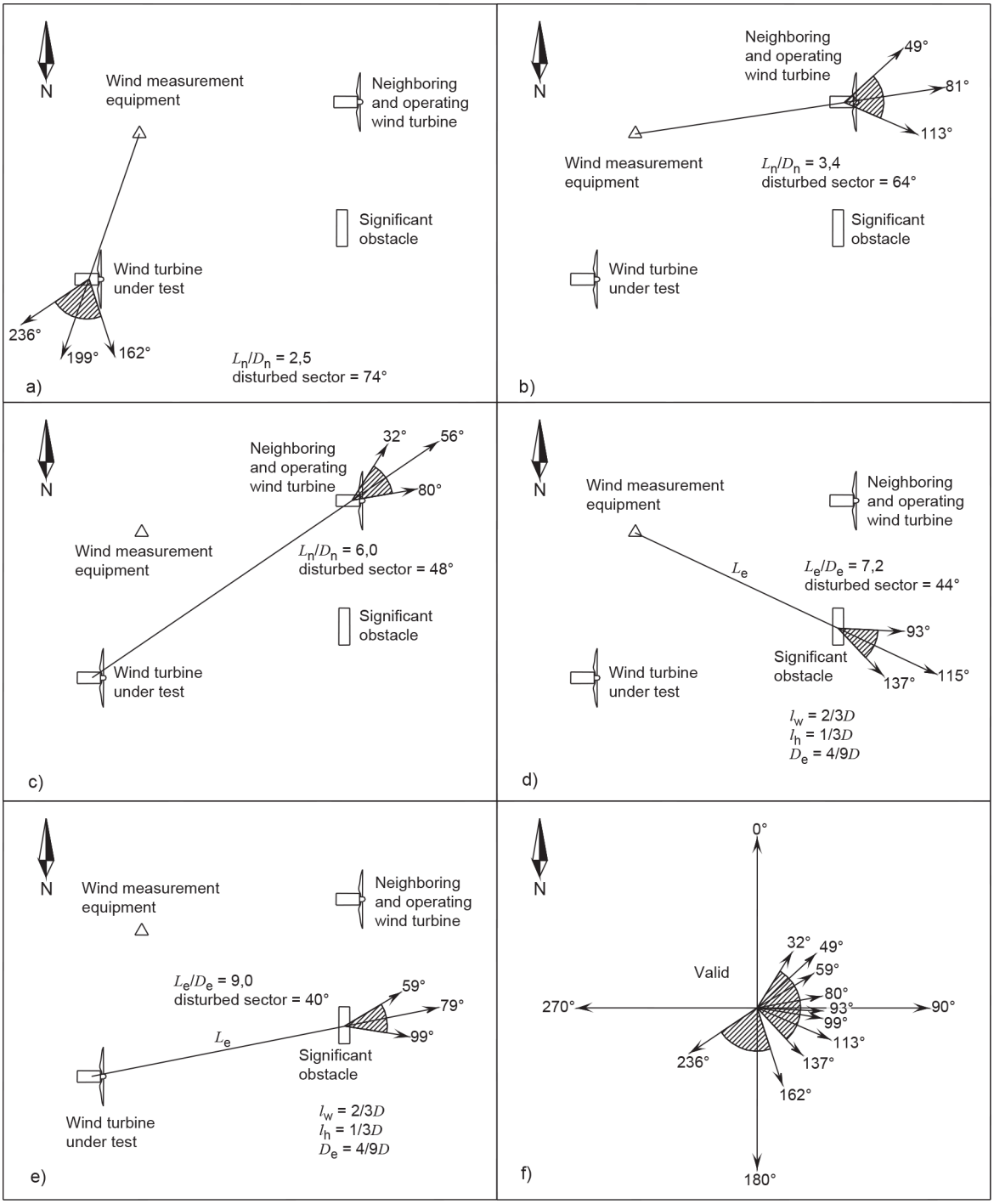

Figure 2 – An example of sectors to exclude due to wakes of the wind turbine under test, a neighbouring operating wind turbine and a significant obstacle

Figure 1 and Figure 2 show the sectors to exclude if:

a) the WME (meteorological mast or remote sensing device) is in the wake of the wind turbine under test;

b) the WME is in the wake of the neighbouring operating wind turbine;

c) the wind turbine under test is in the wake of the neighbouring operating wind turbine;

d) the WME is in the wake of the significant obstacle;

e) the wind turbine under test is in the wake of the significant obstacle;

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f) all of the above effects a) to e) are combined.

NOTE The example shown in Figure 2 is based on the assumption that the obstacle is significant (according to Table 3) with respect to the wind turbine under test and also significant with respect to the wind measurement equipment.

6.5 Special requirements for extended obstacles

Obstacles within a distance of less than $4L$ (from centre of the wind turbine under test or from the wind measurement equipment) which extend more than 50 m in any horizontal direction shall be divided into partial obstacles that do not extend more than 50 m in any horizontal direction and that extend exactly 50 m in any dimension that is more than 50 m. These partial obstacles may overlap one another. The combination of these partial obstacles shall at least cover the original obstacle completely.

For practical purposes, it makes sense to create partial obstacles which all have the same shape (e.g. squares of 50 m × 50 m). This is a conservative approach and therefore permitted (in this case, the set union of all partial obstacles covers a larger area than the original obstacle).

Each partial obstacle shall be evaluated separately. The significance of each partial obstacle shall be assessed, and if it is found to be significant, the sector to be excluded shall be determined. For example:

a) An obstacle 90 m by 90 m is divided into 4 partial obstacles 50 m by 50 m each. These partial obstacles are chosen such that they overlap one another by 10 m so that the set union of the 4 partial obstacles is identical to the original obstacle.
b) An obstacle 70 m by 10 m is divided into 2 partial obstacles 50 m by 10 m each. These partial obstacles are chosen such that they overlap one another by 30 m so that the set union of the 2 partial obstacles is identical to the original obstacle.

A grouping of trees or forest shall be treated in this way.

7 Measurement sector procedure to be used during the determination of the nacelle transfer function (NTF) between free wind speed and nacelle anemometer wind speed

For the determination of the NTF, the measurement sector is defined according to the requirements in Clause 8.

8 Measurement sector procedure to be used during the determination of the nacelle power curve (NPC)

NOTE: NTF has already been determined.

8.1 General

Neighbouring wind turbines, obstacles and terrain can influence the power performance assessment of a wind turbine. In the case of power performance analysis by means of nacelle wind speed measurements, the anemometer is positioned at the location where the power is extracted from the wind, so that the effect of wind turbines, obstacles and terrain lies in a non-uniform distribution of the wind over the rotor plane.

The choice of suitable measurement sectors for the NPC should be based on the key requirement that the wind speed, as measured by the nacelle anemometer in combination with the NTF, results in a wind speed which is representative for the wind speed incident onto the rotor of the wind turbine.

The wind direction measurement in a nacelle power curve contains two uncertainty components, namely the uncertainty of the yaw angle and the uncertainty of the wind direction measurement.

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