Technical regulation 3.2.5

for wind power plants above 11 kW

REV.	DESCRIPTION	PREPARED	CHECKED	REVIEWED	APPROVED	
4.1	Published UK edition	30.06.2016	22.07.2016	22.07.2016	22.07.2016	DATE
		KDJ	FBN	BJA	APJ	NAME

13/96336-43

Revision view

Section no.	Text	Rev.	Date
Section 5.2.2	Editorial change made to figure 10 to match the published Danish version.	4.1	13.01.2017
All sections	The regulation was updated following public consultation. Editorial errors were corrected. Corrections were made to ensure consistency with the wording of other technical regulations.	4	22.07.2016
 All sections Figures 18, 19, 20, 21 Sections 4.4.2.1, 4.4.3.1, 4.5.2.1, 4.5.3.3, 4.6.2.1, 4.6.3.1, 4.7.2.1, 4.7.3.1 Section 5.8 Sections 7.4, 7.5 Section 8 Appendix 1	Public consultation document: Editorial errors were corrected in several sections of the document. Errors in the text on the Y and X axes in figures 18, 19, 20 and 21 corrected. Section 4.4.2.1 – Requirements added for category A2 Section 4.4.3.1 – Requirements added for category A2 Section 4.5.2.1 – Requirements added for category A2 Section 4.5.3.3 – Requirements added for category A2 Section 4.6.2.1 – Requirements added for category A2 Section 4.6.3.1 – Requirements added for category A2 Section 4.7.2.1 – Requirements added for category A2 Section 4.7.3.1 – Requirements added for category A2 Section 5.8 – note on type approval removed due to frequent misunderstandings. Sections 7.4 and 7.5 – specification of parameter set-up options. Section 8 adjusted to reflect the change in responsibilities concerning the *positive lists*. Appendix 1 corrected, dividing documentation requirements for *plant category* A2 into two groups – one with *plant components* on the *positive list*, and one with *plant components* not on the *positive list*.	3	07.06.2016
All sections	Editorial corrections. Table numbering adjusted.	2	12.06.2015
Sections 2.2, 2.6, 2.8	Text amended based on comments from the Danish Energy Regulatory Authority.	1	09.03.2015
	New document, final edition	0	15.12.2014

Table of contents

List of figures and tables

List of figures:

List of tables:

Reading instructions

This regulation contains the technical and functional minimum requirements which *wind power plants* with a *rated power* above 11 kW must comply with if they are to be *connected* to the Danish grid.

The regulation is structured such that section 1 contains the terminology and definitions used; section 2 describes the regulatory provisions and relevant references, while sections 3 up to and including section 7 contain the technical and functional minimum requirements for *wind power plants* in Denmark. Section 8 contains the documentation requirements, and section 9 contains the requirements for the electrical simulation model for the different *wind power plant categories*.

The technical requirements of the regulation are divided into four *plant categories* as described in sections 1.2.21 and 2.2.

The regulation makes extensive use of terminology and definitions. The most important terminology and definitions are found in section 1. In this regulation, terminology and definitions are written in *italics*.

The regulation is also published in English. In case of doubt, the Danish version applies.

The *transmission system operator publishes the* regulation and it is available on the website www.energinet.dk.

1. Terminology, abbreviations and definitions

1.1 Abbreviations

This section contains the abbreviations used in the document.

1.1.1 c_f

The *flicker* coefficient must be indicated by c_f.

1.1.2 Ψ_k

Ψ_k is used as an abbreviation for the short circuit angle in the *Point of Connection. Flicker* values are calculated for each *electricity-generating unit* using the Ψ_k parameter.

1.1.3 d(%)

d(%) denotes *rapid voltage changes* in % of U_n. See section 1.2.38 for a more detailed description.

1.1.4 df/dt

df/dt denotes the frequency change as a function of time. See section 1.2.6 for a more detailed description.

1.1.5 $f_<$

$f_<$ denotes the operational setting for underfrequency in the relay protection. See section 6 for a more detailed description.

1.1.6 $f_>$

$f_>$ denotes the operational setting for overfrequency in the relay protection. See section 6 for a more detailed description.

1.1.7 f_R

f_R denotes the frequency at which a *wind power plant* is to begin downward regulation with the agreed *droop*. See section 5.2.1 for a more detailed description.

1.1.8 f_x

f_x, where x may be 1 to 7 or minimum and maximum, are points used for frequency control and described in more detail in section 5.2.2.

1.1.9 G_{lt}

G_{lt} denotes the planning value of the *flicker* emission from a *plant*.

1.1.10 I_h

I_h denotes the sum of the individual harmonic currents.

1.1.11 I_k

I_k denotes the *short circuit current*. See section 1.2.44 for more detail.

1.1.12 I_n

The rated current I_n is the maximum continuous current that a *wind power plant* or a *wind turbine* is designed to deliver. See section 1.2.39 for a more detailed description.

1.1.13 I_Q
The reactive current delivered or absorbed by a *plant* is referred to as I_Q.

1.1.14 k_u
The voltage change factor is denoted by k_U. The voltage change factor is calculated as a function of Ψ_k.

1.1.15 $P_{current}$
$P_{current}$ denotes the current level of active power.

1.1.16 P_{delta}
P_{delta} denotes a rolling reserve. See section 5.2.2 for a more detailed description.

1.1.17 P_{lt}
P_{lt} denotes the long-term *flicker* emission from a *plant*. P_{lt} stands for 'long-term' and is assessed over a period of two hours. See IEC 61000-3-7 [ref. 32] for a more detailed definition.

1.1.18 P_M
P_M indicates the active power which can be generated under the given circumstances.

1.1.19 P_{min}
P_{min} denotes the lower limit for active power control.

1.1.20 P_n
P_n denotes the *rated power* of a *plant*. See section 1.2.41 for a more detailed description.

1.1.21 P_{st}
P_{st} denotes the short-term *flicker* emission from a *plant*. P_{st} stands for 'short term' and is assessed over a period of 10 minutes. See IEC 61000-3-7 [ref. 32] for a more detailed definition.

1.1.22 $P_{available}$
$P_{available}$ denotes the available active power.

1.1.23 PCC
This is the *Point of Common Coupling (PCC)*. See section 1.2.26 for a more detailed description.

1.1.24 PCI
Point of Connection in Installation (PCI). *PCI* is the point in the installation where the *plant* is connected and where consumption is connected. See section 1.2.29 for a more detailed definition.

1.1.25 PCOM
Point of Communication (*PCOM*). See section 1.2.27 for a more detailed definition.

1.1.26 PF
Power Factor (*PF*). See section 1.2.32 for a more detailed description.

1.1.27 PGC
Point of Generator Connection (*PGC*). *PGC* is the point which the supplier of a *wind turbine* or a *wind power plant* defines as the terminals of a *wind turbine* or *wind power plant*. See section 1.2.30 for a more detailed description.

1.1.28 POC
Point of Connection (*POC*). See section 1.2.28 for a more detailed definition.

1.1.29 PWHD
This is *Partial Weighted Harmonic Distortion*. See section 1.2.19 for a more detailed description.

1.1.30 Q_{max}
Q_{max} denotes the maximum level of reactive power at a *Power Factor* of 0.95 lagging that a *plant* can deliver.

1.1.31 Q_{min}
Q_{min} denotes the minimum level of reactive power at a *Power Factor* of 0.95 leading that a *plant* can absorb.

1.1.32 Q_n
Q_n denotes the reactive *rated power* of a *wind turbine* or a *wind power plant*.

1.1.33 S_i
S_i denotes the apparent power of an *electricity-generating unit* no. i. See section 1.2.42 for a more detailed description.

1.1.34 S_k
S_k denotes the *short circuit power*. See section 1.2.45 for a more detailed description.

1.1.35 S_{last}
S_{last} denotes the apparent power for the total radial load.

1.1.36 S_n
S_n denotes the nominal apparent power of *a plant*.

1.1.37 S_{out}
S_{out} denotes the apparent power for the total radial output.

1.1.38 SCR
Short Circuit Ratio (SCR) is the abbreviation used for the *short circuit ratio* of the *Point of Connection*.

1.1.39 THD
The abbreviation used for *Total Harmonic Distortion*. See section 1.2.47 for a more detailed description.

1.1.40 U_c
U_C denotes the *normal operating voltage*. See section 1.2.17 for a more detailed description.

1.1.41 U_h

U_h denotes the sum of the harmonic voltages.

1.1.42 U_{max}

U_{max} denotes the maximum value of the *nominal voltage* U_n that an *electricity-generating unit* may be exposed to.

1.1.43 U_{min}

U_{min} denotes the minimum value of the *nominal voltage* U_n that an *electricity-generating unit* may be exposed to.

1.1.44 U_n

U_n denotes the *nominal voltage*. This voltage is measured phase to phase. See section 1.2.16 for a more detailed description.

1.1.45 U_{PGC}

U_{PGC} denotes the voltage measured on the *wind turbine's* terminals. See section 1.2.30 for a more detailed description.

1.1.46 U_{POC}

U_{POC} denotes the *normal operating voltage* in the *POC*. See section 1.2.28 for a more detailed description.

1.1.47 U_x

U_x where x indicates the relay configuration for undervoltage steps 1 (<) or 2 (<<) as well as overvoltage steps 1 (>), 2 (>>) or 3 (>>>). See section 6 for a more detailed description.

1.1.48 UTC

UTC is an abbreviation of Coordinated Universal Time (Universal Time, Coordinated).

1.1.49 v_a

This is average annual velocity and denoted by v_a.

1.2 Definitions

This section contains the definitions used in the document. Several of the definitions are derived from IEC 60050-415:1999 [ref. 27], but have been modified as needed in this regulation.

1.2.1 Absolute power constraint

Adjustment of active power to a maximum level is indicated by a set point. The set point adjustment's +/- tolerance is referred to as the *absolute power constraint.* See section 5.2.3.1 for a more detailed description.

1.2.2 Balance-responsible party for production

A *balance-responsible party for production* is financially accountable to the *transmission system operator*.

The *balance-responsible party for production* holds the balance responsibility for a given *plant* vis-à-vis the *transmission system operator*.

1.2.3 COMTRADE

COMTRADE (Common Format for Transient Data) is a standardised file format specified in IEEE C37.111-2013 [ref. 43]. The format is designed for exchange of information about transient phenomena in connection with faults and switching in electricity systems.

The standard includes a description of the required file types and the sources of transient data such as protective relays, fault recorders and simulation programs. The standard also defines sample rates, filters and the conversion of transient data to be exchanged.

1.2.4 Cut-out wind speed

The *cut-out wind speed* is the maximum wind speed at hub height at which a *wind turbine* is designed to generate power, see IEC 60050-415-03-06 [ref. 27].

1.2.5 Delta power constraint

The control of active power with a set point-defined deviation (delta) between potential and actual power is called d*elta power constraint*. See section 5.2.3.2 for a more detailed description.

1.2.6 df/dt

df/dt denotes frequency change as a function of time.

Note 1:
The frequency change, *df/dt*, is calculated according to the principle below or an equivalent principle. The frequency measurement used to calculate the frequency change is based on an 80-100 ms measuring period when the mean value is calculated. Frequency measurements must be carried out continuously, so that a new value is calculated for every 20 ms. *df/dt* must be calculated as the difference between the frequency calculation just carried out and the frequency calculation carried out 80-100 ms ago.

Note 2:
The *df/dt* function is used in decentralised generation facilities to detect situations of island operation where island operation occurs without any prior voltage dip.

1.2.7 Droop
Droop is the trajectory of a curve which a control function must follow.

1.2.8 Electricity supply undertaking
The *electricity supply undertaking* is the enterprise to whose grid a *plant* is electrically connected. Responsibilities in the *public electricity supply grid* are distributed onto several grid companies and one transmission enterprise.

The grid company is the company licensed to operate the *public electricity supply grid of* **up to** 100 kV.

The transmission enterprise is the enterprise licensed to operate the *public electricity supply grid* **above** 100 kV.

1.2.9 Electricity-generating unit
An e*lectricity-generating unit* is a unit which generates electricity, and which is directly or indirectly connected to the *public electricity supply grid.* In a wind power context, the term *wind turbine* is often used for an *electricity-generating unit*. *Wind turbine* is defined in more detail in section 1.2.54.

1.2.10 Flicker
Flicker is a visual perception of light flickering caused by voltage fluctuations. *Flicker* occurs if the luminance or the spectral distribution of light fluctuates with time. *Flicker* becomes an irritant to the eye at a certain intensity.

Flicker is measured as described in IEC 61000-4-15 [ref. 11].

1.2.11 Frequency control
The frequency control function controls active power with the aim of stabilising the grid frequency. See section 5.2.2 for a more detailed description.

1.2.12 Frequency response
Frequency response is the automatic downward regulation of active power as a function of grid frequencies above a certain frequency f_R with a view to stabilising the grid frequency. See section 5.2.1 for a more detailed description.

1.2.13 Generator convention
The sign for active/reactive power indicates the power flow seen from the generator. The consumption/import of active/reactive power is indicated by a negative sign, while the generation/export of active/reactive power is indicated by a positive sign.

The sign of the *Power Factor* set point is used to determine whether control should take place in the first or the fourth quadrant. For *Power Factor* set points, two pieces of information are thus combined into a single signal: a set point value and the choice of control quadrant.

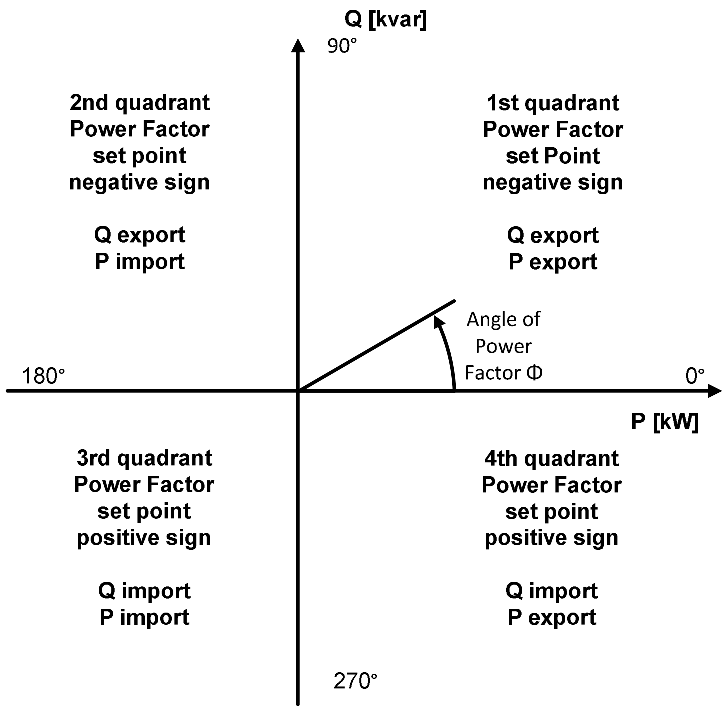

*Figure 1 Definition of signs for active and reactive power and Power Factor set points [*ref*. 24, 25 and 26].*

1.2.14 Harmonic distortions

Harmonic distortions are defined as electrical disturbances caused by overharmonic currents and voltages. *Harmonic distortions* are also referred to as overtones, overharmonic tones, overharmonic distortion or simply harmonics. See section 4.6 for a more detailed description.

1.2.15 Interconnected electricity supply system

The *public electricity supply grids* and associated *plants* in a larger area which are interconnected for the purpose of joint operation are referred to as an *interconnected electricity supply system*.

1.2.16 Nominal voltage (U_n)

The voltage level at the *POC* for which a grid is defined and to which operational characteristics refer. Voltage is measured phase to phase. *Nominal voltage* is denoted by U_n.

The internationally standardised voltage levels are shown in Table 1.

1.2.17 Normal operating voltage (U_c)

Normal operating voltage indicates the voltage range within which an *electricity-generating unit* must be able to continuously generate the specified *rated power*, see sections 3.1 and 3.2. *Normal operating voltage* is denoted by U_c. *Normal operating voltage* is determined by the *electricity supply undertaking* and is used to determine the *normal production* range.

1.2.18 Normal production

Normal production indicates the voltage/frequency range within which a *wind power plant* must be able to continuously generate the specified *rated power*, see sections 3.1 and 3.2.

1.2.19 Partial Weighted Harmonic Distortion (PWHD)

The partial weighted *harmonic distortions* are defined as the ratio between the root-mean-square (RMS) value of the current I_h or the voltage U_h for the h'th harmonic of a selected group of higher harmonics (h: 14th-40th harmonic) and the root-mean-square (RMS) value of the current I_1 from the fundamental frequency. The general formula for *PWHD* is as follows:

$$PWHD = \sqrt{\sum_{h=14}^{h=40} h * \left(\frac{X_h}{X_1}\right)^2}$$ See IEC 61000-3-12 [ref. 34] for a more detailed specification,

where:
X represents either current or voltage
X_1 is the RMS value of the fundamental component
h is the harmonic order
X_h is the RMS value of the harmonic component of the h order.

1.2.20 Plant

A *plant* is one or more *electricity-generating units,* which are defined in more detail in section 1.2.9. For wind power, the term *wind power plant,* defined in more detail in section 1.2.52, is often used for a *plant*.

1.2.21 Plant categories

Plant categories in relation to the total *rated power* in the *Point of Connection*:

- A2. *Plants* above 11 kW up to and including 50 kW
- B. *Plants* above 50 kW up to and including 1.5 MW
- C. *Plants* above 1.5 MW up to and including 25 MW
- D. *Plants* above 25 MW or connected to over 100 kV.

1.2.22 Plant component

A *plant component* is a component or subsystem which is part of an overall *plant*.

1.2.23 Plant infrastructure

Plant infrastructure is the electrical infrastructure between the *Point of Generator (PGC)* of the individual *electricity-generating units (wind turbines)* in a *plant (wind power plant)* and up to the *Point of Connection (POC).*

1.2.24 Plant operator

The *plant operator* is the enterprise responsible for the operation of the *wind power plant*, either through ownership or contractual obligations.

1.2.25 Plant owner

The *plant owner* is the entity that legally owns the *wind power plant*. In certain situations, the term company is used instead of *plant owner*. The *plant owner* can hand over the operational responsibility to a *wind turbine operator*.

1.2.26 Point of Common Coupling (PCC)

The *Point of Common Coupling (PCC)* is the point in the *public electricity supply grid*, where consumers are or can be connected.
The *Point of Common Coupling* and the *Point of Connection* may coincide electrically. The *Point of Common Coupling (PCC)* is always located the farthest into the *public electricity supply grid,* i.e. the farthest away from the *plant*, see Figure 2 and Figure 3.

The *electricity supply undertaking* determines the *point of common coupling*.

1.2.27 Point of Communication (PCOM)

The *Point of Communication (PCOM)* is the point in a *plant*, where the data communication properties specified in section 7 must be made available and verified.

1.2.28 Point of Connection (POC)

The *Point of Connection (POC)* is the point in the *public electricity supply grid* where the *wind power plant* is or can be connected; see Figure 2 and Figure 3 for the typical location.

All requirements specified in this regulation apply to the *Point of Connection*. By agreement with the *electricity supply undertaking*, reactive compensation at no load can be placed elsewhere in the *public electricity supply grid*. The *electricity supply undertaking* determines the *Point of Connection*.

Figure 2 shows a typical installation connection of one or more *small wind turbines,* indicating the typical location of the *Point of Generator Connection (PGC)*, *Point of Connection (POC), Point of Connection in installation (PCI)* and *Point of Common Coupling (PCC)*. In the example below, the *Point of Common Coupling (PCC)* and the *Point of Connection (POC)* coincide.

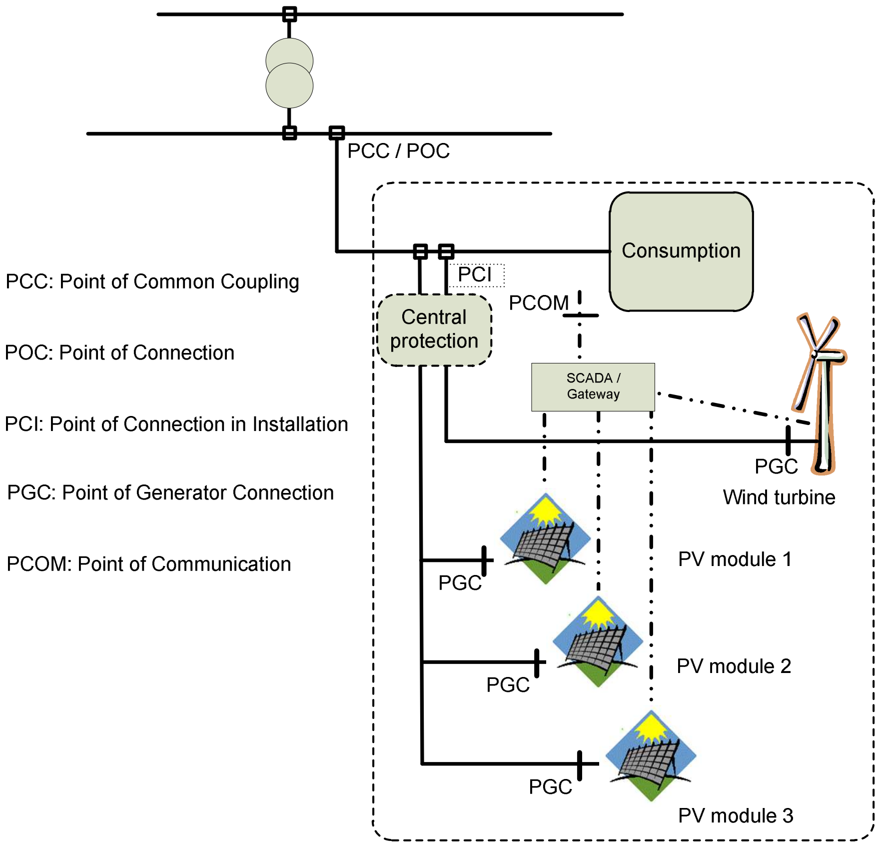

Figure 2 Example of installation connection of a small wind turbine.

Figure 3 shows a typical grid connection of several *wind power plants,* indicating where the *Point of Generator Connection (PGC)*, *Point of Connection (POC), Point of Common Coupling (PCC)* and the *voltage reference point* can be located. The *voltage reference point* is either in the *Point of Connection (POC)*, the *Point of Common Coupling (PCC)* or a point in between.

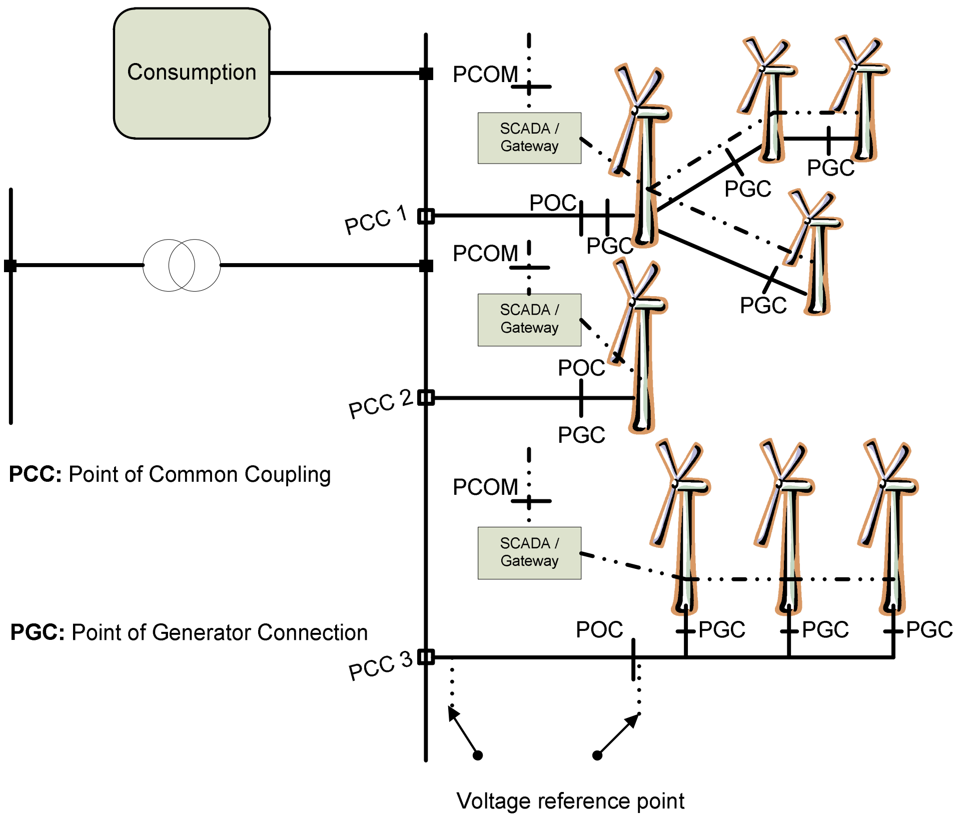

Figure 3 Example of grid connection of wind power plants.

1.2.29 Point of Connection in Installation (PCI)

The *Point of Connection in installation* (*PCI*) is the point in the installation where *electricity-generating units* in the installation are connected or can be connected, see Figure 2 for the typical location.

1.2.30 Point of Generator Connection (PGC)

The *Point of Generator Connection* is the point in the *plant infrastructure*, where the terminals/generator terminals for the *electricity-generating unit* are located. For the *electricity-generating unit,* the *Point of Generator Connection* is the point defined by the *wind turbine* manufacturer as the *wind turbine's* terminals.

1.2.31 Positive list

A so-called *positive list* has been prepared to facilitate the technical approval process for grid connection of a category A2 *plant*. The list contains *plant components* deemed to comply with the specific property and functionality requirements under the relevant technical regulations.

This *positive list* is available at the Danish Energy Association's website: www.danskenergi.dk/positivlister.

1.2.32 Power Factor (PF)

The *Power Factor*, cosine φ*,* for AC voltage systems indicates the ratio of active power P to apparent power S, where P = S*cosine φ. Likewise, reactive power Q = S*sine φ. The angle between current and voltage is denoted by φ.

1.2.33 Power factor control

Power factor control is the control of reactive power proportionately to active power generated. See section 5.3.2 for a more detailed description.

1.2.34 Power infrastructure

The *power infrastructure* is the part of the *public electricity supply grid* that connects the *POC* and *PCC*.

1.2.35 Public electricity supply grid

Transmission and distribution grids that serve to transmit electricity for an indefinite group of electricity suppliers and consumers on terms laid down by public authorities.

The distribution grid is defined as the *public electricity supply grid* with a **maximum** *nominal voltage* of 100 kV.

The transmission grid is defined as the *public electricity supply grid* with a *nominal voltage* **above** 100 kV.

1.2.36 Q control

Q control is the control of reactive power independent of active power generated.

1.2.37 Ramp rate constraint

A *ramp rate constraint* controls the interval of active power with a set point-defined maximum increase/reduction (ramp rate) of the active power. See section 5.2.3.3 for a more detailed description.

1.2.38 Rapid voltage changes

Rapid voltage change is defined as a brief isolated voltage change (RMS). *Rapid voltage changes* are expressed as a percentage of *normal operating voltage*.

1.2.39 Rated current (I_n)

Rated current I_n is defined as the maximum continuous current that a *wind power plant* is designed to provide under normal operating conditions, see DSF/CLC/FprTS 50549-1:2014 [ref. 38] and DSF/CLC/FprTS 50549-2:2014 [ref. 39]. *Rated current* is denoted by I_n.

1.2.40 Rated power of a wind power plant (P_n)

The *rated power* (P_n) of a *wind power plant* is the highest active power that the *wind power plant* is designed to continuously provide and that appears from the type approval, see IEC 61400-1 [ref. 9] and Danish Executive Order no. 73 of 25 January 2013 [ref. 18]. *Rated power* is denoted by P_n.

1.2.41 Rated power of a wind turbine (P_n)

The *rated power* of a *wind turbine* is the highest active power that the *wind turbine* is designed to continuously provide and that appears from the type approval. *Rated power* is denoted by P_n.

1.2.42 Rated value for the apparent power (S_n)

The *rated value for the apparent power* S_n is the highest power consisting of both the active and reactive component which a *wind turbine* or a *wind power plant* is designed to continuously deliver.

1.2.43 Rated wind speed

The *rated wind speed* is the wind speed at which a *wind turbine* achieves its *rated power*, see IEC 60050-415-03-04 [ref. 27].

1.2.44 Short circuit current (I_k)

The *short circuit current* (I_k) is the amount of power [kA] that the *wind power plant* can deliver to the *Point of Connection* in the event of a short circuit at the *wind power plant's* terminals.

1.2.45 Short circuit power (S_k)

The *short circuit power* S_k is the amount of three-phase *short circuit power* in the *Point of Connection*.

1.2.46 Short circuit ratio (SCR)

The *short circuit ratio (SCR)* is the ratio between the *short circuit power* in the *Point of Connection* S_k and the *plant's* nominal apparent power S_n.

1.2.47 Total Harmonic Distortion (THD)

The *Total Harmonic Distortion* is defined as the ratio between the root-mean-square value (RMS) of the current I_h or the voltage U_h for the h'th (h: 2-40) harmonic and the root-mean-square value (RMS) of the current I_1 from the fundamental frequency. The general formula for *THD* is as follows:

$THD_I = \sqrt{\sum_{h=2}^{h=H}\left(\frac{X_h}{X_1}\right)^2}$ See IEC 61000-3-16 [ref. 31] for a more detailed specification,

where:
X represents either current or voltage
X_1 is the RMS value of the fundamental component
h is the harmonic order
X_h is the RMS value of the harmonic component of the h order
H is generally 40 or 50 depending on use.

1.2.48 Transmission system operator

Enterprise entrusted with the overall responsibility for maintaining security of supply and ensuring effective utilisation of an *interconnected electricity supply system*.

1.2.49 Voltage control

Voltage control is the control of reactive power with the configured *droop* to achieve the desired voltage in the *voltage reference point*.

1.2.50 Voltage fluctuation

V*oltage fluctuation* is a series of *rapid voltage changes* or a periodic variation of the root-mean-square (RMS) value of the voltage.

1.2.51 Voltage reference point

A metering point used for *voltage control*. The *voltage reference point* is either in the *Point of Connection*, the *Point of Common Coupling* or a point in between.

The *electric supply undertaking* chooses the location of the *voltage reference point*, see Figure 3.

1.2.52 Wind power plant

A *wind power plant* is one or several *wind turbines* with a total *rated power* above 11 kW which are connected to the *public electricity supply grid*, see IEC 61400-1 [ref. 9] and IEC 61400-2 [ref. 10]. The term *wind power plant* is equivalent to the term *plant*. *Wind turbine* is defined in more detail in section 1.2.54.

A *wind power plant* comprises all necessary power supply and auxiliary equipment, and it is therefore the entire *wind power plant* that must comply with the technical minimum requirements specified in this regulation.

A *wind power plant* has only one *Point of Connection*.

1.2.53 Wind power plant controller

A *wind power plant controller* is a set of control functions that make it possible to control the services provided by a *wind power plant* as a single *plant* in the *Point of Connection*. The set of control functions must be part of the *wind power plant* in a communicative context. This means that if the communication to a *wind power plant* is interrupted, the *plant* must be able to continue providing services as scheduled or carry out a controlled shutdown. See section 6.2 for more detail.

1.2.54 Wind turbine

A *wind turbine* is a system which converts the wind's kinetic energy into electrical power, see IEC 60050-415-01-02 [ref. 27]. In a wind power context, a *wind turbine* is an *electricity-generating unit*. *Electricity-generating unit* is defined in more detail in section 1.2.9.

1.2.55 Wind turbine operator

The *wind turbine operator* is the enterprise responsible for the operation of the *wind power plant*, either through ownership or contractual obligations.

2. Objective, scope of application and regulatory provisions

2.1 Objective

The objective of technical regulation TR 3.2.5 is to specify the minimum technical and functional requirements that a *wind power plant* with a *rated power* above 11 kW must comply with in the *Point of Connection* when the *wind power plant* is connected to the *public electricity supply grid*.

The regulation is issued pursuant to Section 7(1)(i), (iii) and (iv) of Danish Executive Order no. 891 of 17 August 2011 (Executive Order on transmission system operation and the use of the electricity transmission grid, etc. (Systemansvarsbekendtgørelsen)). Under Section 7(1) of the Executive Order on transmission system operation and the use of the electricity transmission grid, etc., this regulation has been prepared following discussions with parties and grid companies. It has also been subject to public consultation before being registered with the Danish Energy Regulatory Authority.

This regulation is effective within the framework of the Danish Electricity Supply Act (Elforsyningsloven), see Consolidated Act no. 1329 of 25 November 2013 as amended.

A *wind power plant* must comply with Danish legislation, including the Danish Heavy Current Regulation (Stærkstrømsbekendtgørelsen) [ref. 4], [ref. 5], the Joint Regulation [ref. 3], the Machinery Directive [ref. 6], [ref. 7] and the grid connection and grid use agreement.

In areas which are not subject to Danish legislation, CENELEC standards (EN), IEC standards, CENELEC or IEC technical specifications apply.

2.2 Scope of application

Throughout its lifetime, any *wind power plant* connected to the *public electricity supply grid* must comply with the provisions of this regulation.

The technical requirements of the regulation are divided into the following categories based on the total *rated power* in the *Point of Connection*:

A2. *Plants* above 11 kW up to and including 50 kW **)
B. *Plants* above 50 kW up to and including 1.5 MW
C. *Plants* above 1.5 MW up to and including 25 MW
D. *Plants* above 25 MW or connected to over 100 kV.

**) *Plant components* used in this *plant category* may be included in the *positive list* of *plant components* or *plants* which may be installed in Denmark.

All requirements in this regulation respect the *plants'* design framework and properties that the current wind power technology offers, including properties at different wind conditions.

For planning and grid expansion reasons, t*he electricity supply undertaking* has the right to reject grid connection for non-three phase *plants*.

2.2.1 New wind power plants

This regulation applies to all *wind power plants* with *rated power* above 11 kW connected to the *public electricity supply grid* and commissioned as of the effective date of this regulation.

2.2.2 Existing wind power plants

A *wind power plant* with *rated power* above 11 kW which was connected to the *public electricity supply grid* before the effective date of this regulation must comply with the regulation in force at the time of commissioning.

2.2.3 Modifications to existing wind power plants

If substantial functional modifications are made to an existing *wind power plant,* the *plant* must comply with the provisions of this regulation relating to such modifications. In case of doubt, the *transmission system operator* decides whether a specific modification is substantial.

A substantial modification is one that changes one or more vital *plant components*, which may alter the properties of the *wind power plant*.

The documentation described in section 8 must be updated and submitted in a version showing any modifications made.

2.3 Delimitation

This technical regulation is part of the complete set of technical regulations issued by the Danish *transmission system operator*, Energinet.dk.

The technical regulations contain the technical minimum requirements that apply to the *plant owner*, *wind turbine operator* and *electricity supply undertaking* regarding connection to the *public electricity supply grid*.

Together with the market regulations, the technical regulations, including the system operation regulations, constitute the set of rules to be complied with by *plant owners, wind turbine operators* and *electricity supply undertakings* with regard to the operation of *wind power plants.*

- Technical regulation TR 5.8.1 'Metering data for system operation purposes' [ref. 19]
- Technical regulation TR 5.9.1 'Ancillary services' [ref. 20]
- Regulation D1 'Settlement metering' [ref. 21]
- Regulation D2 'Technical requirements for electricity metering' [ref. 22]
- Technical regulation 3.2.5 'Wind power plants above 11 kW'.

In addition, special contractual conditions may apply to the compensation for downward regulation of an offshore wind farm. In such cases, the following regulation applies:

- Regulation E – appendix 'Compensation for offshore wind farms ordered to perform downward regulation' [ref. 23].

In case of any discrepancy between the requirements of the individual regulations, the *transmission system operator* decides which requirements should apply.

Current versions of the above-mentioned documents are available on Energinet.dk's website www.energinet.dk.

Operational matters will be agreed between the *plant owner* and the *electricity supply undertaking* within the framework set by the *transmission system operator*.

Any supply of ancillary services must be agreed between the *plant owner* and the *balance-responsible party for production*.

This regulation does not deal with the financial aspects of using control capabilities, settlement metering or technical settlement metering requirements.

The *plant owner* must safeguard the *wind power plant* against possible damaging impacts due to a lack of electricity supply from the *public electricity supply grid* for short or long periods of time, among other things safeguard *wind turbines* and other *plant components* against condensation in the event of a lack of electricity supply.

2.4 Statutory authority

This regulation is issued pursuant to:

- Section 26(1) of Consolidated Act no. 1329 of 25 November 2013 concerning the Danish Electricity Supply Act
- Section 7(1), (i), (iii) and (iv) of Danish Executive Order no. 891 of 17 August 2011 (Executive Order on transmission system operation and the use of the electricity transmission grid, etc.)

2.5 Effective date

This regulation comes into force on **22 July 2016** and replaces

- Technical regulation 3.2.5 for wind power plants with a power output above 11 kW, Revision 2, effective from 12 June 2015.

Please direct questions and requests for additional information on this technical regulation to Energinet.dk. Contact information is available at http://energinet.dk/EN/El/Forskrifter/Technical-regulations/Sider/Regulations-for-grid-connection.aspx.

The regulation was registered with the Danish Energy Regulatory Authority pursuant to the provisions of section 26 of the Danish Electricity Supply Act (Elforsyningsloven)
and section 7 of the Danish executive order on transmission system operation and the use of the electricity transmission grid, etc. (Systemansvarsbekendtgørelsen).

As regards *wind power plants*, the construction of which was definitively ordered in a binding written order before the regulation was registered with the Danish Energy Regulatory Authority, but which are scheduled to be commissioned after this regulation becomes effective, an exemption can be applied for in accordance with section 2.9, enclosing any relevant documentation.

2.6 Complaints

Complaints in respect of this regulation may be lodged with the Danish Energy Regulatory Authority, www.energitilsynet.dk.

Complaints about the *transmission system operator's* enforcement of the provisions of the regulation can also be lodged with the Danish Energy Regulatory Authority.

Complaints about how the individual *electricity supply undertaking* enforces the provisions of the regulation can be lodged with the *transmission system operator*.

2.7 Breach

The *plant owner* shall ensure that the provisions of this regulation are complied with throughout the life of the *wind power plant*.

The *wind power plant* must be subjected to regular maintenance checks to ensure that the provisions of this regulation are complied with.

The *plant owner* must pay any expenses incurred to ensure compliance with the provisions of this regulation.

2.8 Sanctions

If a *wind power plant* does not comply with the provisions of section 3 and onwards of this regulation, the *electricity supply undertaking* is entitled to cut off the grid connection to the *wind power plant* as a last resort subject to the decision made by Energinet.dk, until the provisions are complied with.

2.9 Exemptions and unforeseen events

The *transmission system operator* may grant exemption from specific requirements in this regulation.

An exemption can only be granted if:

- special conditions exist, for instance of a local nature
- the deviation does not impair the technical quality and balance of the *public electricity supply grid*
- the deviation is not inappropriate from a socio-economic viewpoint.

To obtain an exemption, a written application must be submitted to the *electricity supply undertaking*, stating which provisions the exemption concerns and the reason for the exemption.

The *electricity supply undertaking* has the right to comment on the application before it is submitted to the *transmission system operator*.

If events not foreseen in this technical regulation occur, the *transmission system operator* must consult the parties involved to agree on a course of action.

If an agreement cannot be reached, the *transmission system operator* must decide on a course of action. The decision must be based on what is reasonable, where possible taking the views of the parties involved into consideration.

Complaints against the decision of the *transmission system operator* can be lodged with the Danish Energy Regulatory Authority, see section 2.6.

2.10 References

The mentioned International Standards (IS), European Standards (EN), Technical Reports (TR) and Technical Specifications (TS) are only to be used within the topics mentioned in connection with the references in this regulation.

2.10.1 Normative references

1. **DS/EN 50160:2010**: Voltage characteristics of electricity supplied by public distribution networks.
2. **DS/EN 60038:2011**: CENELEC standard voltages.
3. **Joint Regulation 2014:** 'Connection of electrical equipment and utility products'.
4. **Section 6 of the Danish Heavy Current Regulation:** 'Electrical installations', 2003.
5. **Section 2 of the Danish Heavy Current Regulation:** 'Design of electricity supply systems', 2003.
6. **DS/EN 60204-1:2006**: Danish Heavy Current Regulation Safety of machines – Electrical equipment of machines.
7. **DS/EN 60204-11:2002**: Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1000 V a.c. or 1500 V d.c. and not exceeding 36 kV.
8. **IEC-60870-5-104:2006**: Telecontrol equipment and systems, Part 5-104.
9. **IEC 61400-1:2005**: Wind Turbines – Part 1: Design requirements.
10. **IEC 61400-2:2013**: Wind Turbines – Part 2: Design requirements for small wind turbines.
11. **IEC 61000-4-15:2010**: Testing and measurement techniques – Section 15: Flicker metre – Functional and design specifications.
12. **IEC 61400-21:2008**: Measurement and assessment of power quality characteristics of grid connected wind turbines.
13. **IEC 61400-22:2010:** Conformity testing and certification.
14. **IEC 61400-25-1:2006**: Communications for monitoring and control of wind power plants – overall description of principles and models.
15. **IEC 61400-25-2:2006**: Communications for monitoring and control of wind power plants – information models.
16. **IEC 61400-25-3:2006**: Communications for monitoring and control of wind power plants – information exchange services.
17. **IEC 61400-25-4:2008**: Communications for monitoring and control of wind power plants – mapping to communication protocol stacks.
18. **Danish Executive Order no. 73 of 25 January 2013**: Executive Order on the technical certification scheme for wind turbines.
19. **Technical regulation TR 5.8.1:** 'Måledata til systemdriftsformål' (Metering data for system operation purposes), dated 28 June 2011, Rev. 3.0, document no. 17792/10 (= new doc. no. 13/89692-218).
20. **Technical regulation TR 5.9.1:** 'Systemtjenester' (Ancillary services), dated 5 July 2012, Rev. 1.1, document no. 91470-11 (new doc. no. 13/89692-225).
21. **Regulation D1:** 'Settlement metering', March 2016, version 4.11, document no. 16/04092-1.
22. **Regulation D2:** 'Technical requirements for electricity metering', May 2007, Rev. 1, document no. 171964-07 (new doc. no. 13/91893-11).

23. **Regulation E – Appendix:** 'Compensation for offshore wind farms ordered to perform downward regulation', version 2.0, 2 June 2014, document no. 13/91893-57.
24. **IEC 61850-7-4 Ed2.0:2012**: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes
25. **IEC 61850-90-7 Ed1.0:2013**: Object models for power converters in distributed energy resources (DER) systems.
26. **IEEE 1459:2010**: Standard definitions for the measurement of electrical power quantities under sinusoidal, non-sinusoidal, balanced or unbalanced conditions.
27. **IEC 60050-415:1999**: International Electrotechnical Vocabulary – Part 415: Wind turbine generator systems.
28. **IEC 60071-1:2006**: Insulation co-ordination – Part 1: Definitions, principles and rules.
29. **DS/EN TR 61000-3-2:2014**: Limit values – Limit values for harmonic current emissions (equipment input current up to and including 16A per phase).
30. **DS/EN TR 61000-3-3:13**: Limit values – Limitation of *voltage fluctuations* and flicker in public low-voltage supply systems, from equipment with a rated current <= 16A per phase which is not subject to conditional connection rules.
31. **IEC/TR 61000-3-6:2008**: EMC limits. Limitation of emissions of harmonic currents for equipment connected to medium and high voltage power supply systems.
32. **IEC/TR 61000-3-7:2008**: EMC limits. Limitation of voltage fluctuations and flicker for equipment connected to medium and high voltage power supply systems.
33. **DS/EN 61000-3-11:2001**: Electromagnetic compatibility (EMC): Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with a rated current up to and including 75A which is subject to conditional connection.
34. **DS/EN 61000-3-12:2012**: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16A and ≤ 75A per phase.
35. **IEC/TR 61000-3-13:2008**: Electromagnetic compatibility (EMC): Limits – Assessment of emission limits for the connection of unbalanced installations to MV, HV and EHV power systems.
36. **IEC/TR 61000-3-14:2011**: Electromagnetic compatibility (EMC): Assessment of emission limits for harmonics, interharmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems.
37. **IEC/TR 61000-3-15 Ed. 1.0:2011**: Limits – Assessment of low frequency electromagnetic immunity and emission requirements for dispersed generation systems in LV network.
38. **DS/CLC/TS 50549-1:2014**: Requirements for generating plants to be connected in parallel with a distribution network – Part 1: Generating plants larger than 16A per phase to be connected with a low voltage network.
39. **DS/CLC/TS 50549-2:2014**: Requirements for generating plants to be connected in parallel with a distribution network – Part 2: Generating plants to be connected with a medium voltage network.

2.10.2 Informative references

40. **Research Association of the Danish Electric Utilities (DEFU) report RA-557:** 'Guidelines on grid connection of wind power plants with a power output above 11 kW'.
41. **Research Association of the Danish Electric Utilities recommendation no. 16**: Voltage quality in low-voltage grids, 2nd edition, June 2001.
42. **Research Association of the Danish Electric Utilities recommendation no. 21**: Voltage quality in medium-voltage grids, February 1995.
43. **IEEE C37.111-24:2013** Measuring relays and protection equipment – Part 24: Common format for transient data exchange (COMTRADE) for power systems.
44. **Guidelines on the calculation of power quality parameters – TR 3.2.5**, document no. 13/96336-14.
45. **Guidelines on signal lists – TR 3.2.5**, document no. 13/96336-12.
46. **Guidelines on verification report – TR 3.2.5**, document no. 13/96336-13.

3. Tolerance of frequency and voltage deviations

A *wind power plant* must be able to withstand frequency and voltage deviations in the *Point of Connection* under normal and abnormal operating conditions while reducing active power as little as possible.

All requirements outlined in the following sections are to be considered minimum requirements.

Normal operating conditions are described in section 3.2, and abnormal operating conditions are described in section 3.3.

For the sake of planning and grid expansion *the electricity supply undertaking* has the right to reject grid connection for non-three phase *plants*.

3.1 Determination of voltage level

The *electricity supply undertaking* determines the voltage level for the *wind power plant's Point of Connection* within the voltage limits stated in Table 1.

Normal operating voltage may differ from location to location, and the *electricity supply undertaking* must therefore state the *normal operating voltage* U_c for the *Point of Connection*.

The *electricity supply undertaking* must ensure that the maximum voltage stated in Table 1 is never exceeded.

If *normal operating voltage* range U_c ±10% is lower than the minimum voltage indicated in Table 1, the requirements for production in the event of frequency/voltage variations must be adjusted so as not to overload the *wind power plant.*

Voltage level descriptions	Nominal voltage U_n [kV]	Minimum voltage U_{min} [kV]	Maximum voltage U_{max} [kV]
Extra high voltage (EH)	400	320	420
	220	-	245
High voltage (HV)	150	135	170
	132	119	145
	60	54.0	72.5
	50	45.0	60.0
Medium voltage (MV)	33	30.0	36.0
	30	27.0	36.0
	20	18.0	24.0
	15	13.5	17.5
	10	9.00	12.0
Low voltage (LV)	0.69	0.62	0.76
	0.40	0.36	0.44

Table 1 Definition of voltage levels applied in this regulation.

Maximum (U_{max}) and minimum (U_{min}) voltage limits are determined using the standards DS/EN 50160 (10-minute mean values) [ref. 1] and DS/EN 60038 [ref. 2].

The *wind power plant* must be able to briefly withstand voltages exceeding the maximum voltages within the required protective settings specified in section 6.

3.2 Normal operating conditions

Within the *normal production* range, a *wind power plant* must be designed start and generate power continuously within the design specifications(for example with proper wind conditions), restricted only by the settings of the protective function as described in section 6 and/or other functions impacting the *plant's* output.

Within the *normal production* range, the *normal operating voltage* is U_c ±10%, see section 3.1, and the frequency range is 49.50 to 50.20 Hz.

Automatic connection of a *wind power plant* can take place no earlier than three minutes after the voltage and frequency have come within the *normal production* range.

Frequency limit settings are determined by *the transmission system operator*.

3.2.1 Category A2 wind power plants

The overall requirements for active power production that a *wind power plant* must comply with in the event of frequency and voltage deviations are shown in Figure 4.

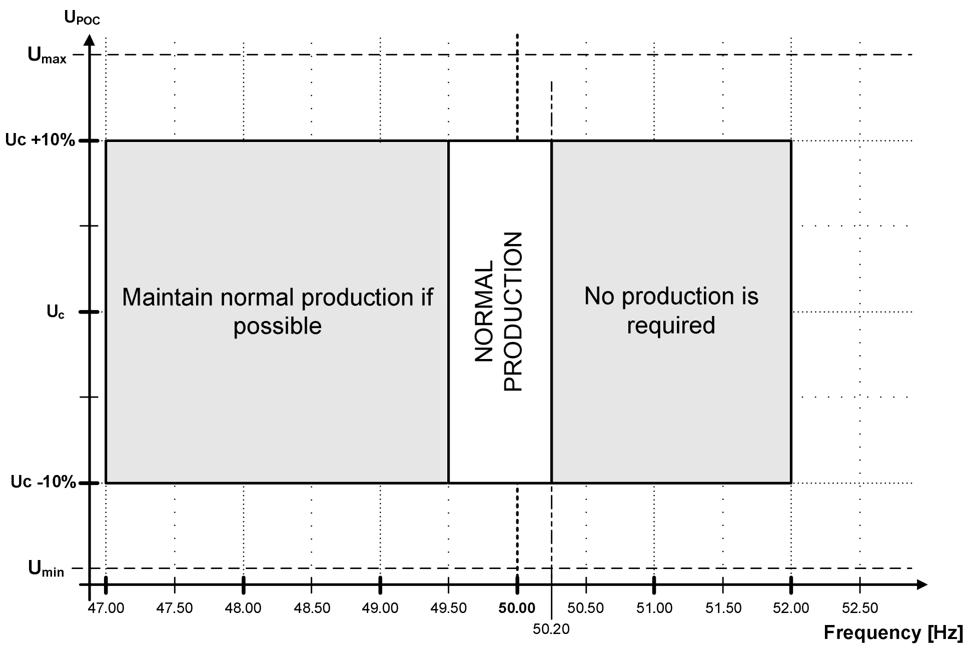

Figure 4 Active power requirements in the event of frequency and voltage fluctuations for category A2 wind power plants.

There are no requirements for active power production outside the *normal production* range, but the *wind power plant* must remain connected to the *public electricity supply grid* in accordance with the required settings for protective functions as specified in section 6.

3.2.2 Category B, C and D wind power plants

The overall requirements for active power production that *category B, C and D wind power plants* must comply with in the event of frequency and voltage deviations are shown in Figure 5.

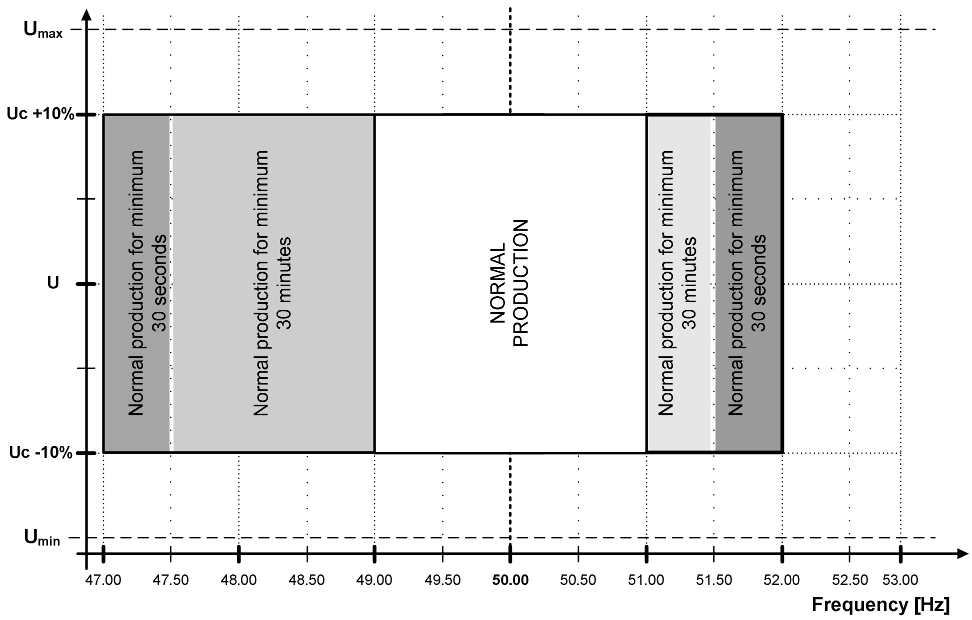

Figure 5 Active power requirements in the event of frequency and voltage fluctuations for category B, C and D wind power plants.

The *wind power plant* must remain connected to the *public electricity supply grid* in accordance with the required settings for protective functions as specified in section 6.

3.3 Abnormal operating conditions

The following requirements apply to category C and D *wind power plants*.

The *wind power plant* must be designed to withstand transitory (80-100 ms) phase jumps of up to 20° in the *Point of Connection (POC)* without disrupting or reducing its output.

After a transient start-up period, the *wind power plant* must deliver *normal production* no later than five seconds after the operating conditions in the *Point of Connection* have reverted to the *normal production* range.

The *wind power plant* must be designed to withstand voltage dips as shown in Figure 6 and during fault sequences supply added reactive current as shown in Figure 7 without disrupting or reducing its output.

After a settling period, the *wind power plant* must be capable of delivering *normal production* no later than five seconds after the operating conditions in the *Point of Connection* have reverted to the *normal production* range.

Irrespective of the requirements outlined in the following sections, the protective settings must be as specified in section 6.

Documentation proving that the *wind power plant* complies with the specified requirements must be as stated in section 8.

The *wind power plant* must be protected against damage caused by out-of-phase reclosing and against disconnections in non-critical situations.

3.3.1 Voltage dip tolerance

In the *Point of Connection*, a *wind power plant* must be designed to withstand voltage dips down to 20% of the voltage in the *Point of Connection* over a period of minimum 0.5 seconds, as shown in Figure 6, without disconnecting. In the figure below, the Y-axis indicates the smallest line-to-line voltage for the 50 Hz component.

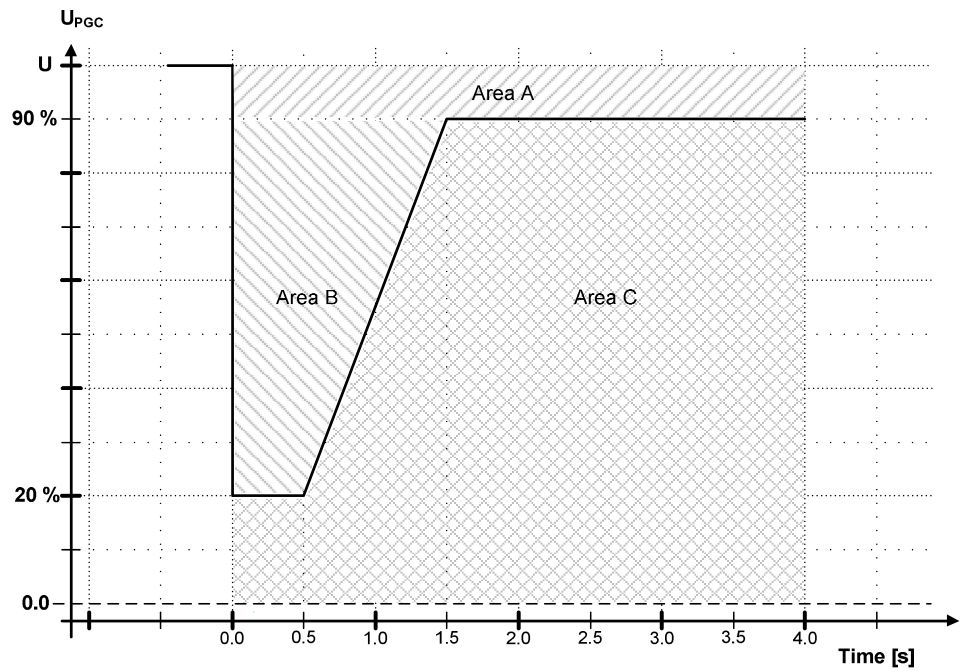

Figure 6 Voltage dip tolerance requirements for category C and D wind power plants.

The following requirements must be complied with in the event of symmetrical and asymmetrical faults, i.e. the requirements apply in case of faults in one, two or three phases:

- Area A: The *wind power plant* must stay connected to the grid and maintain *normal production*.
- Area B: The *wind power plant* must stay connected to the grid. The *wind power plant* must provide maximum voltage support by supplying an added amount of controlled reactive current so as to ensure that the *wind power*

plant helps to stabilise voltage within the design framework offered by the current *wind power plant* technology, see Figure 6.
- Area C: Disconnecting the *wind power plant* is allowed.

If the voltage U_{POC} reverts to area A after 1.5 seconds during a fault sequence, a subsequent voltage dip will be regarded as a new fault situation, see section 3.3.2.

If several successive fault sequences occur within area B, progressing time-wise into area C, disconnection is allowed.

In connection with fault sequences in area B, the *wind power plant* must have a control function capable of controlling the synchronous component of the reactive current as specified in Figure 7.

The terminal voltage measurement for the individual *wind turbine* may be used to control the reactive current during a voltage dip.

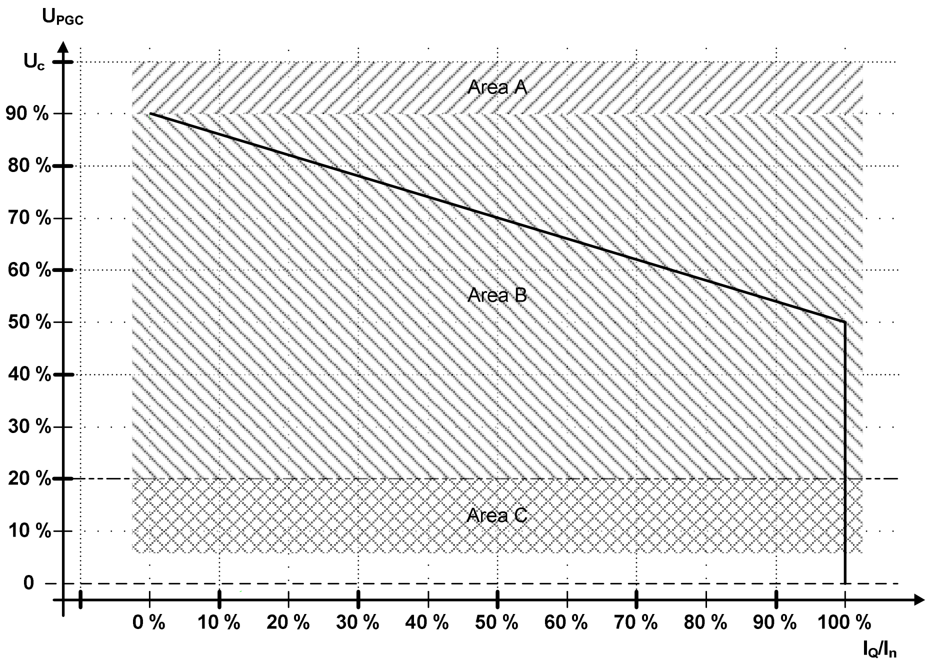

Figure 7 Requirements for the delivery of added reactive current I_Q during voltage dips for category C and D wind power plants.

The reactive current control must follow Figure 7, so that the added reactive current (synchronous component) after 100 ms follows the characteristic with a tolerance of ± 20% within the *wind power plant's* design limitations. In Figure 7, the Y-axis indicates the applied control voltage for the 50 Hz component.

With regard to the control concept for the delivery of added reactive current during a voltage dip, it is up to the *wind turbine* supplier to specify which control voltage is used. This may be the minimum or maximum line-to-line voltage or phase voltage. Alternatively, the synchronous voltage component may be used as long as the characteristic shown in Figure 7 can be observed in the event of three-phase faults and after disconnection of all types of asymmetrical faults.

If necessary, total reactive current can be limited to 1 p.u. of the *plant's* nominal output.

If necessary, added reactive current can be reduced relative to the maximum recorded phase voltage to avoid overvoltage.

In area B, the delivery of reactive current takes first priority, while the delivery of active power takes second priority.

If possible, active power must be maintained during voltage dips, but a reduction in active power within the *wind power plant's* design limitations is acceptable, however.

3.3.2 Recurring faults in the public electricity supply grid

The *wind power plant* and any compensation equipment must stay connected during and after faults have occurred in the *public electricity supply grid* as specified in Table 2.

These requirements apply to the *Point of Connection*, but the fault sequence is at a random point in the *public electricity supply grid*.

To further ensure compliance with the voltage dip requirements as stated in section 3.3.1, the requirements in Table 2 must be verified by documenting that the *wind power plant* is designed to withstand the specified recurring faults.

Type	Duration of fault
Three-phase short circuit	Short circuit for 150 ms
Phase-to-phase-to-earth short circuit/phase-to-phase short circuit	Short circuit for 150 ms followed by a new short circuit 0.5 to 3 seconds later, also with a duration of 150 ms½
Phase-to-earth short circuit	Phase-to-earth fault for 150 ms followed by a new phase-to-earth fault 0.5 to 3 seconds later, also with a duration of 150 ms

Table 2 Fault types and duration in the public electricity supply grid.

The energy reserves provided by auxiliary equipment such as emergency supply equipment, and the hydraulic and pneumatic systems should be sufficient for the *wind power plant* to meet the requirements in Table 2 in the event of at least two independent faults of the specified types occurring within two minutes.

The energy reserves provided by auxiliary equipment such as emergency supply equipment, and the hydraulic and pneumatic systems should be sufficient for the *wind power plant* to meet the specified requirements in the event of at least six independent faults of the types specified in Table 2 occurring at five-minute intervals.

4. Power quality

4.1 General

When assessing a *wind power plant's* impact on power quality in the *public electricity supply grid*, the various power quality parameters in the *Point of Connection* must be documented.

The table below lists the distortion requirements in the individual *plant categories*.

Requirements / **Category**	**A2**	**B**	**C**	**D**
DC content (4.2)	X	X	X	X
Asymmetry (4.3)	X	X	X	X
Rapid voltage changes (4.4)	X	X	X	X
Flicker (4.5)	X	X	X	X
Harmonic distortions (4.6)	X	X	X	X
Interharmonic distortions (4.7)	-	X	X	X
Distortions 2-9 kHz (4.8)	-	X	X	X

Bracketed numbers indicate the sections that specify the respective requirements.

Table 3 Overview of power quality requirements for plant categories.

For each of these distortion types, the following is specified:

- Data used for calculations
- Emission limit values – *plant* requirements
- Methods for verifying compliance with limit values.

Applied power quality terminology and calculation methods are described in the following international standards: DS/EN TR 61000-3-2:2014 [ref. 29], DS/EN 61000-3-3:2013 [ref. 30], IEC/TR 61000-3-6:2008 DS/EN 61000-3-12 [ref. 34], [ref. 31], IEC/TR 61000-3-7:2008 [ref. 32], DS/EN 61000-3-11 [ref. 33], DS/EN 61000-3-12 [ref. 34], DS/EN 61000-3-13 [ref. 35], DS/EN 61000-3-14 [ref. 36] and DS/EN 61000-3-15 [ref. 37] and national recommendations in the Research Association of the Danish Electric Utilities recommendation no. 16 [ref. 41] and the Research Association of the Danish Electric Utilities recommendation no. 21 [ref. 42].

The *electricity supply undertaking* is responsible for setting emission limits in the *Point of Connection*.

The *electricity supply undertaking* must agree on a schedule for determining emission limits with grid connection applicants.

Generally, the *plant owner* must ensure that the *wind power plant* is designed, constructed and configured in compliance with the specified emission limits.

The *plant owner* may purchase supplementary services from the *electricity supply undertaking* as agreed to ensure compliance with the specified limit values.

The *plant owner* must verify compliance with the emission limits in the *Point of Connection.*

4.1.1 Data basis

Data for the *wind power plant* as well as the *public electricity supply grid* will be used to assess a *wind power plant's* impact on power quality.

The *plant owner* must provide data as specified in IEC 61400-21 [ref. 12] to determine emission of *flicker* and high-frequency distortions for the *wind power plant.*

The *plant owner* must choose one of the following methods for the determination of the emission of *flicker* and high-frequency distortions.

1. The *plant owner* uses the results of the type test for each of the *electricity-generating units* that make up the *wind power plant*. The type test must be performed in accordance with the relevant parts of IEC 61400-21 [ref. 12].

   The *plant owner* calculates the total emissions as the sum of the contributions from each of the *electricity-generating units* that make up the *plant*.

2. The *plant owner* develops an emission model for the *wind power plant*. The *plant owner* must thus document that this emission model can be used to determine the emission of high-frequency distortions from the entire *plant*.

   The *plant* emission model must include emission models for the *electricity-generating units* and *plant infrastructure* in the *Point of Connection* for the relevant frequency range.

   The *transmission system operator* must approve the emission model.

The *electricity supply undertaking* supplies data for the *public electricity supply grid* in the *Point of Connection*. As regards the calculation of *voltage fluctuations*, see current international standards, the *public electricity supply grid* can be defined by the minimum, typical and maximum *short circuit power* S_k and the corresponding grid impedance angle ψ_k in the *Point of Connection*.

The *electricity supply undertaking* must state the maximum, minimum and typical S_k for the *Point of Connection*.

4.1.2 Limit values

The *electricity supply undertaking* is responsible for supplying limit values for the emission of various types of distortions coming from the *wind power plant* in the *Point of Connection* to ensure that the limit values for power quality in the *public electricity supply grid* are not exceeded.

The limit values specified in this regulation have been determined on the basis of the specifications in the Research Association of the Danish Electric Utilities recommendation no. 21 [ref. 42], IEC/TR 61000-3-6 [ref. 31], IEC/TR 61000-3-7 [ref. 32], DS/EN 61000-3-12 [ref. 34] and DS/EN 61000-3-11 [ref. 33].

4.1.3 Verification

The *plant owner* must use calculations, simulations or measurements to verify that the *wind power plant* complies with the limits defined in the *Point of Connection*. The *electricity supply undertaking* must approve the *plant owner's* verification.

4.2 DC content

For all *plant categories*, the DC content of the supplied AC current in the *plant's Point of Connection (POC)* may not exceed 0.5% of the nominal current, see IEC/TS 61000-3-15, section 7.5 [ref. 37].

4.3 Asymmetry

For all *plant categories*, asymmetry between phases at normal operation or in the event of faults in the *electricity-generating unit* may not exceed 16A.

If the *plant* consists of multiple single-phase units, the necessary communication must be established to ensure that the above limit is not exceeded.

4.4 Rapid voltage changes

4.4.1 Data basis

The *plant owner* must use data for the voltage change factor $k_{U,i}$ (ψ_k) for each *wind turbine, I,* during connections, as specified by the type test, see IEC 61400-21 [ref. 12].

The type test specifies k_U (ψ_k) for the short circuit angle ψ_k = 30, 50, 70 and 85 degrees for different types of connections. The type test also specifies the location of the metering point.

4.4.2 Limit values

4.4.2.1 Requirements for category A2 wind power plants

The connection of a *wind turbine* in the *wind power plant* must not give rise to *rapid voltage changes d* (%) exceeding the limit values indicated in the table below, see DS/EN 61000-3-11, section 5 [ref.33].

Voltage level	d (%)
$U_n \leq 35$ kV	4%

Table 4 Limit values for rapid voltage changes d (%) – category A2

4.4.2.2 Requirements for category B, C and D wind power plants

The connection of a *wind turbine* in the *wind power plant* must not give rise to *rapid voltage changes d* (%) exceeding the limit values indicated in the table below.

Voltage level	d (%)
$U_n \leq 35$ kV	4%
$U_n > 35$ kV	3%

Table 5 Limit values for rapid voltage changes d (%) – category B, C and D.

Excepted are rare voltage changes such as voltage dips resulting from the energising of the *plant infrastructure* with connected *wind turbine* transformers.

4.4.3 Verification

The voltage change factor k_U is determined for the *public electricity supply grid* in the *Point of Connection* for each type of *wind turbine* and for each of the different types of connections by simple interpolation between the values for ψ_k indicated in the type approval. Subsequently, $k_{U,i}(\psi_k)$ is determined as the largest voltage change factor among the different types of connections for each *wind turbine* indicated by *i*.

The voltage change d_i(%) is then determined for each *wind turbine*:

$$d_i(\%) = 100\% \cdot k_{u,i}(\psi_k) \cdot \frac{S_{n,i}}{S_k}$$

Subsequently, d(%) is determined as the highest value of d_i(%). Finally, it must be verified that the calculated voltage change, i.e. d(%), is below the limit values stated in Table 5.

4.4.3.1 Category A2 wind power plants

It must be verified that the calculated *rapid voltage change* for the entire *wind power plant* is below the limit values stated in Table 4.

4.4.3.2 Category B, C and D wind power plants

It must be verified that the calculated *rapid voltage change* for the entire *wind power plant* is below the limit values stated in Table 5.

4.5 Flicker

4.5.1 Data basis

The *flicker* emission must be documented for continuous operation and for connections. The flicker level is documented using data from type tests or emission models.

When calculating the *flicker* contribution at continuous operation, use the *flicker* coefficient $c_{f,i}(\psi_k, v_{a,i})$ data that appear from the type test.

The type test specifies $c_{f,i}(\psi_k)$ for ψ_k = 30, 50, 70 and 85 degrees and v_a = 6.0 m/s, 7.5 m/s, 8.5 m/s and 10.0 m/s for the average velocities.

Use the annual average velocity v_a for the *wind power plant* for the calculation.

Use data for the *flicker* step factor $k_{f,i}(\psi_k)$ as specified in the type test for connections.

The type test specifies $k_{f,i}(\psi_k)$ for ψ_k = 30, 50, 70 and 85 degrees for different types of connections. In addition, use the maximum number of each type of connection within 10 min. P_{st} (short-term *flicker*) and 120 min. P_{lt} (long-term *flicker*).

4.5.2 Limit values

The *wind power plant's* total *flicker* contribution must meet the requirements in the following sections in the *Point of Connection*.

4.5.2.1 Requirements for category A2 wind power plants

The limit values for *plants* in this category are stated in the table below for emissions from the individual *wind power plant*, see DS/EN 61000-3-11, section 5 [ref. 33].

Voltage level	P_{st}	P_{lt}
$U_n \leq 1$ kV	1.0	0.65

Table 6 Limit values for short-term flicker P_{st} and long-term flicker P_{lt}.

4.5.2.2 Requirements for category B wind power plants

If the connected *rated power* is lower than 0.4% of S_k, the *wind power plant* can be connected without further checks.

Otherwise, the limit values in the table below apply to emissions from the individual *wind power plant,* see DS/EN 61000-3-11, section 5 [ref. 33].

Voltage level	P_{st}	P_{lt}
$U_n \leq 1$ kV	0.35/0.45/0.55*)	0.25/0.30/0.40*)
$U_n > 1$ kV	0.30	0.20

*) The limit values apply if any 4/2/1 generation facility is already connected under the same substation.

Table 7 Limit values for short-term flicker P_{st} and long-term flicker P_{lt}.

4.5.2.3 Requirements for category C and D wind power plants

The *electricity supply undertaking* determines the *flicker* emission limits in the *Point of Connection*, so that the maximum allowed *flicker* level G_{lt} and G_{st} at the same voltage level and under the same substation is not exceeded.

4.5.3 Verification

Verify that the *flicker* emission from continuous operation of the *wind power plant* and from connections is lower than the limit value for the *Point of Connection*.

Determine the *flicker* coefficient on the basis of the current ψ_k for the *electricity-generating unit* by simple interpolation between the values for ψ_k specified in the type test.

4.5.3.1 Continuous operation

Determine the *flicker* coefficient for the *public electricity supply grid* in the *Point of Connection* and the current location of the *wind power plant* by simple interpolation between the values for ψ_k and v_a specified in the type approval.

The *flicker* emission for each *electricity-generating unit i* that make up the *wind power plant* is calculated as:

$$P_{st,i} = c_i(\psi_k, v_{a,i}) \cdot \frac{S_{n,i}}{S_k}$$

The emission from the entire *wind power plant* is then calculated as:

$$P_{st} = P_{lt} = \sqrt[3]{\sum_i (P_{st,i})^3}$$

Alternatively, the approved emission model is used to verify that limit values are met.

4.5.3.2 Connections

The *flicker* step factor is determined for each of the different types of connection for the *public electricity supply grid* in the *Point of Connection* by simple interpolation between the values for ψ_k specified in the type approval. Subsequently, $k_{f,i}(\psi_k)$ is determined as the largest *flicker* step factor among the different types of connection.

The *flicker* emission is then determined for each of the *wind turbines i* that make up the *wind power plant* by using the *flicker* step factor $k_{f,i}(\psi k)$, see IEC 61400-21, Ed2, section 8 [ref. 12]:

$$P_{st,i} = 18 \cdot N_{10\min,i}^{0,31} \cdot k_{f,i}(\psi_k) \cdot \frac{S_{n,i}}{S_k}$$

$$P_{lt,i} = 8 \cdot N_{120\min,i}^{0,31} \cdot k_{f,i}(\psi_k) \cdot \frac{S_{n,i}}{S_k}$$

The emission from the entire *wind power plant* is then calculated as:

$$P_{st} = \sqrt[3]{\sum_i (P_{st,i})^3}$$

$$P_{lt} = \sqrt[3]{\sum_i (P_{lt,i})^3}$$

It must be checked that the calculated values are below the limit values.

4.5.3.3 Category A2, B, C and D wind power plants

It must be verified that the *flicker* emission from continuous operation and connections is below the limit value in the *Point of Connection*.

4.6 Harmonic distortions

Emission of *harmonic distortions* must be documented for the entire *wind power plant*.

4.6.1 Data basis

Data from type tests or emission models are used to document the emission level.

The type test specifies measured mean values for 2-50 harmonic contributions for 11 levels of generated active power from 0% to 100% of the *rated power* and with a *Power Factor* of 1. Measured mean values are stated as percentages of the *rated current*.

4.6.2 Limit values

The *wind power plant* is not allowed to emit *harmonic distortions* exceeding the limit values specified in this section.

For *wind power plants* which are electrically connected far from other consumers, the emission limits may, however, be changed to values higher than the standard emission limits following approval from *the electricity supply undertaking*.

In addition to limit values for the individual *harmonic distortions*, limit values for *THD* and *PWHD* are used.

4.6.2.1 Requirements for category A2 wind power plants

The limit values for harmonic current emissions for different orders *h* are listed in the table below, see DS/EN 61000-3-12, table 3 [ref. 34]. The requirements below presuppose that *SCR* is less than 33. If the *short circuit ratio* is different, reference is made to table 3 of the above standard.

Harmonic	**Odd harmonic order h (not a multiple of 3)**					**Even harmonic order h**		
	5	7	11	13	17≤h≤39	2	4	8≤h≤40
Limit value [%]	10.7	7.2	3.1	2	-	-	-	-

Table 8 Limit values for harmonic current I_h/I_n (% of I_n) – A2.

Limit values for emission of total harmonic current distortion are listed in the table below.

Voltage level	**SCR**	**THD**	**PWHD**
U_c ≤ 1 kV	<33	13	22
U_c > 1 kV	-	No requirements	No requirements

Table 9 Limit values for total harmonic current distortion (% of I_h) – A2.

4.6.2.2 Requirements for category B wind power plants

Limit values for harmonic current emissions for different orders *h* are listed in the table below, see DS/EN 61000-3-12, table 3 [ref. 34].

Voltage level	SCR	Odd harmonic order *h* (not a multiple of 3)					Even harmonic order *h*		
		5	7	11	13	17≤*h*≤39	2	4	8≤*h*≤40
U_c ≤ 1 kV	<33	3.6	2.5	1.0	0.7	-	-	-	-
	≥33	4.1	2.8	1.1	0.8	-	-	-	-
	≥66	5.3	3.5	1.7	1.2	-	-	-	-
	≥120	7.2	4.6	2.6	1.6	-	-	-	-
	≥250	11.7	7.5	4.4	3.0	-	-	-	-
	≥350	15.2	9.6	5.9	4.1	-	-	-	-
U_c > 1 kV	-	4.0	4.0	2.0	2.0	$\frac{400}{h^2}$ *)	0.8	0.2	0.1

*) Minimum 0.1%.
Note: Interpolation between table values is done for *SCR* ≥33.

Table 10 Limit values for harmonic current I_h/I_n (%) – B.

Limit values for total harmonic current distortion emissions are listed in the table below.

Voltage level	SCR	THD_I	$PWHD_I$
U_c ≤ 1 kV	<25	4.5	7.9
	≥33	4.9	8.1
	≥66	6.0	9.0
	≥120	8.3	10.5
	≥250	13.9	14.3
	≥350	18.0	17.3
U_c > 1 kV		No requirements	No requirements

Table 11 Limit values for total harmonic current distortion (% of I_h) – B.

4.6.2.3 Requirements for category C and D wind power plants

The *electricity supply undertaking* determines the emission limits for *harmonic distortions* in the *Point of Connection*.

For category C and D *plants*, limit values for the *harmonic distortions* are determined as voltage distortions in order to take into account local variations in the grid impedance. Account is also taken of the size of the *plant* relative to the grid capacity.

The emission limits must ensure that the total permissible noise levels of the individual *harmonic distortions* and THD_U are not exceeded in the *Point of Connection*.

4.6.3 Verification

It must be verified that *plant* emissions are below the limit value in the *Point of Connection*.

Therefore, the value from the level of generated active power at which the individual harmonic current is the greatest is used to verify observance of the harmonic current limit values for the individual harmonic currents *h*. The current values are used to calculate THD_I and $PWHD_I$ for the respective levels of generated active power to verify compliance with the limit values for THD_I and $PWHD_I$.

For current harmonic I_h, THD_I and $PWHD_I$ are defined as:

$$THD_I = \sqrt{\sum_{h=2}^{h=40} \left(\frac{I_h}{I_1} \right)^2} \text{ [ref. 31] and } PWHD_I = \sqrt{\sum_{h=14}^{h=40} h * \left(\frac{I_h}{I_1} \right)^2} \text{ [ref. 34]}$$

For voltage harmonic U_h, THD_U is defined as follows:

$$THD_U = \sqrt{\sum_{h=2}^{h=40} \left(\frac{U_h}{U_1} \right)^2}$$

For *wind power plants* consisting of multiple *electricity-generating units*, contributions from individual *units* may be summarised in accordance with the general summation law, see IEC/TR 61000-3-6 [ref. 31] and DS/EN 61000-3-11 [ref. 29].

$$I_h = \sqrt[\alpha]{\sum_i I_{h,i}^{\alpha}}$$

Values for the exponent α are listed in the table below.

Harmonic order	**α (alpha)**
$h < 5$	1
$5 \le h \le 10$	1.4
$h > 10$	2
$h > 40$	3

Table 12 Values for the exponent α.

Calculation examples are found in 'Guidelines on the calculation of power quality parameters – TR 3.2.5' [ref. 44].

Alternatively, the approved emission model is used to verify that limit values are met.

4.6.3.1 Category A2 and B wind power plants

It must be verified that limit values are observed for all levels of generated active power.

4.6.3.2 Category C and D wind power plants

It must be verified that limit values are observed for all levels of generated active power.

The sum of the individual harmonic currents I_h is translated into harmonic voltages by multiplying individual harmonic currents by the numerical value of grid impedance at the individual frequencies as stated by the *electricity supply undertaking*.

THD_U is determined by using the formulas in section 4.6.3.

Unless otherwise stated by the *electricity supply undertaking*, use the model found in 'Guidelines on the calculation of power quality parameters – TR 3.2.5' [ref. 44] – section: Approximate model for the frequency dependence of the grid impedance.

Calculations of emission limits are described with examples in 'Guidelines on the calculation of power quality parameters – TR 3.2.5' [ref. 44].

Alternatively, the approved emission model is used to verify that limit values are met.

4.7 Interharmonic distortions

Emission of interharmonic distortions must be documented for the entire *wind power plant*.

4.7.1 Data basis

The type test specifies measured mean values for interharmonic distortions in the 75 Hz to 1975 Hz frequency range for 11 levels of generated active power from 0% to 100% of the *rated power* $P_{n,i}$ with a *Power Factor* of 1.

Measured mean values are stated as percentages of the *rated current* I_n.

4.7.2 Limit values

The *wind power plant* is not allowed to emit interharmonic distortions that exceed the limit values specified in this section.

4.7.2.1 Requirements for category A2 wind power plants

There are no requirements for interharmonic distortions for this category.

4.7.2.2 Requirements for category B wind power plants

Limit values for interharmonic distortion emissions are listed in the table below which is based on RA557 [ref. 40] and scaling according to the specifications in DS/EN 61000-3-12 [ref. 34].

Voltage level	SCR	Frequency (Hz)		
		75 Hz	125 Hz	>175 Hz
$U_C \leq$ 1kV	<33	0.4	0.6	$\frac{75}{f}$ *)
	≥33	0.5	0.7	$\frac{83}{f}$ *)
	≥66	0.6	0.8	$\frac{104}{f}$ *)
	≥120	0.7	1.1	$\frac{139}{f}$ *)
	≥250	1.2	1.8	$\frac{224}{f}$ *)
	≥350	1.5	2.3	$\frac{289}{f}$ *)
$U_C >$ 1kV	-	0.44	0.66	$\frac{83}{f}$ *)

*) Minimum 0.1%.

Table 13 Limit values for interharmonic distortion emissions – B.

4.7.2.3 Requirements for category C and D wind power plants

The *electricity supply undertaking* determines emission limits for interharmonic distortions from the *wind power plant* in the *Point of Connection*.

The emission limits are to ensure that the *electricity supply undertaking's* planning limits for the individual interharmonic distortions are not exceeded in the *Point of Connection*.

4.7.3 Verification

4.7.3.1 Category A2 wind power plants

There are verification requirements for this category.

4.7.3.2 Category B, C and D wind power plants

It must be verified that the *wind power plant* complies with the limit values for interharmonic distortion emissions in the same way as for *harmonic distortion* emissions, see section 4.6.3.1. The exponent α=3 must, however, be used if summation rules are used.

Alternatively, the approved emission model is used to verify that limit values are met.

4.8 Distortions in the 2-9 kHz frequency range

Distortion emission in the 2-9 kHz frequency range must be documented for the entire *wind power plant*.

4.8.1 Data basis

The type test specifies measured mean values for frequency components of the current in groups of 200 Hz width from 2.1 kHz to 8.9 kHz for 11 levels of generated active power from 0% to 100% of the *rated power* $P_{n,i}$ and a *Power Factor* of 1.

Measured mean values are stated as percentages of the *rated current* I_n.

4.8.2 Limit values

4.8.2.1 Requirements for category A2 wind power plants

There are no requirements for distortions above 2 kHz.

4.8.2.2 Requirements for category B wind power plants

The emission of currents with frequencies higher than 2 kHz must not exceed 0.2% of *rated current* in any frequency group measured.

4.8.2.3 Requirements for category C and D wind power plants

The *electricity supply undertaking* determines emission limits for voltages from the *wind power plant* in the *Point of Connection*.

The emission limits are to ensure that the *electricity supply undertaking's* planning limits for the individual frequency groups are not exceeded in the *Point of Connection*.

4.8.3 Verification

4.8.3.1 Category A2 wind power plants

There are no verification requirements for this category.

4.8.3.2 Category B, C and D wind power plants

It must be verified that the *wind power plant* complies with limit values for the emission of distortion above 2 kHz in the same way as for *harmonic distortion* emissions. The exponent α=3 must, however, be used if summation rules are used.

Alternatively, the approved emission model is used to verify that limit values are complied with.

5. Control and regulation

5.1 General requirements

All control functions mentioned in the following sections refer to the *Point of Connection.*

It must be possible to activate/deactivate all control functions and set them using external signals as described in section 7.

The currently activated functions and parameter settings must be agreed with the *electricity supply undertaking* within the framework laid down by the *transmission system operator* before the *wind power plant* can be connected to the *public electricity supply grid*.

In order to ensure the security of supply, the *transmission system operator* must be able to activate or deactivate the specified control functions and, by further agreement with the *plant owner*, be able to change current function settings via for example set points and activation commands.

All setting values for frequency parameters are determined by the *transmission system operator*.

For all active power and reactive power control functions, the accuracy of a completed control operation over a period of 1 minute may not deviate by more than 2% of P_n and Q_n, respectively.

The signs used in all figures follow the *generator convention*.

Required MW and MVAr power will be reduced on a pro-rata basis relative to the number of *wind turbines* in operation in the *wind power plant*.

Table 14 below specifies the minimum control functionality requirements for a *wind power plant* in the four *plant categories*, see section 1.2.21.

Section 7.2 lists required activation signals and related parameters.

Control function \ Category	A2	B	C	D
Frequency response (5.2.1)	X	X	X	X
Frequency control (5.2.2)*	-	-	-	X
Absolute power constraint (5.2.3.1)	X	X	X	X
Delta power constraint (5.2.3.2)	-	-	-	X
Ramp rate constraint (5.2.3.3)	X	X	X	X
Q control (5.3.1)*	X	X	X	X
Power factor control (5.3.2)*	X	X	X	X
Voltage control (5.3.3)*	-	-	-	X
System protection (5.4)	-	-	X	X

Bracketed numbers indicate the sections that describe the respective functions.
*) A *plant* must not perform *frequency control, Q control, Power Factor control* or *voltage control* without prior specific agreement with the *transmission system operator*.

Table 14 Overview of control functions required for wind power plants.

After a *wind power plant* has been disconnected due to a fault in the *public electricity supply grid*, the *wind power plant* must automatically reconnect no earlier than three minutes after the voltage and frequency are once again within the limits stated in sections 3.1 and 3.2.

A *wind power plant* which was disconnected by an external signal prior to a fault in the *public electricity supply grid* must not be reconnected until the external signal has been eliminated, and the voltage and frequency are once again within the limits stated in sections 3.1 and 3.2.

Wind power plants must be equipped with the control functions specified in Table 14.

The purpose of the various control functions is to ensure overall control and monitoring of the *wind power plant's* output.

The various control functions may be implemented in an individual *wind turbine,* combined into a single *wind turbine plant controller* or be a combination thereof, provided there is only one communication interface as shown in Figure 8.

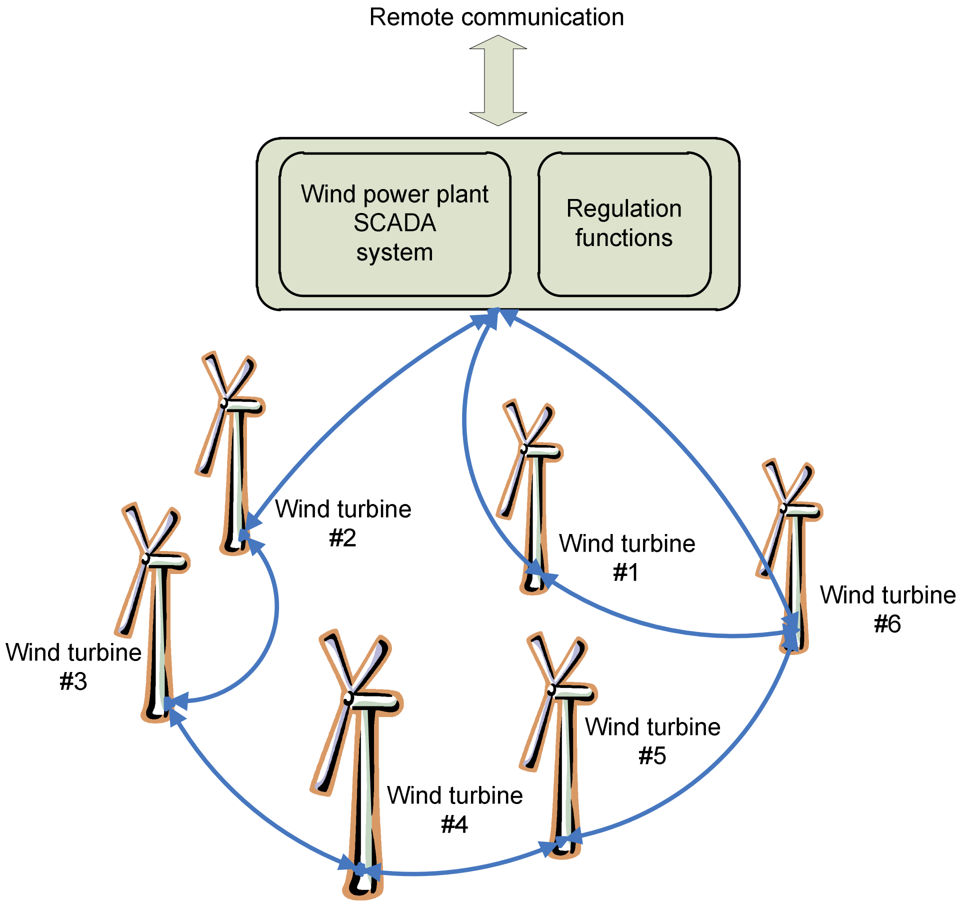

Figure 8 Drawing of a wind power plant controller.

All set point changes must be registered with an identification of the party requesting the change.

All set point changes or orders for output changes must be time stamped with a maximum accuracy of 10 ms and refer to *UTC*.

5.2 Active power control functions

A *wind power plant* must be equipped with active power control functions capable of controlling the active power supplied by a *wind power plant* in the *Point of Connection* using activation orders with set points.

It must be possible to indicate set points for active power with a 1kW or resolution or higher.

Current parameter settings for activated active power control functions are determined by the *electricity supply undertaking* in collaboration with the *transmission system operator* before commissioning.

In addition to fulfilling the general requirements in section 5.1, active power control functions must comply with the requirements outlined in the following sections.

5.2.1 Frequency response

In the event of frequency deviations in the *public electricity supply grid*, the *wind power plant* must contribute to grid stability by automatically reducing active power at grid frequencies above f_R. This is referred to as *frequency response.*

Frequency measurements must be carried out with an accuracy of ± 10 mHz or higher and with a standard deviation (1σ) of ±5 mHz or better.

It must be possible to set the *frequency response* function for the frequency points in Figure 9.

It must be possible to set the frequency f_R to any value in the 50.00-52.00[1] Hz range with an accuracy of 10 mHz or higher. The standard f_R value is 50.20 Hz. The f_R setting is determined by the *transmission system operator*.

It must be possible to set the *droop* for the downward regulation to any value in the range 2-12% of P_n and this must be effected with an accuracy of ±10% of P_n. The standard value for *droop* is 4% of P_n. In this context, *droop* is the change in active power as a function of the grid frequency. *Droop* is stated as a percentage of the *plant's* nominal output.

The *frequency response* control must start no later than two seconds after a frequency change is detected and must be completed within 15 seconds.

The *electricity supply undertaking* in whose grid the *plant* is connected can coordinate initiation of *frequency response* in relation to the trip time of island operation mode detection and thereby ensure optimal island operation mode detection functionality.

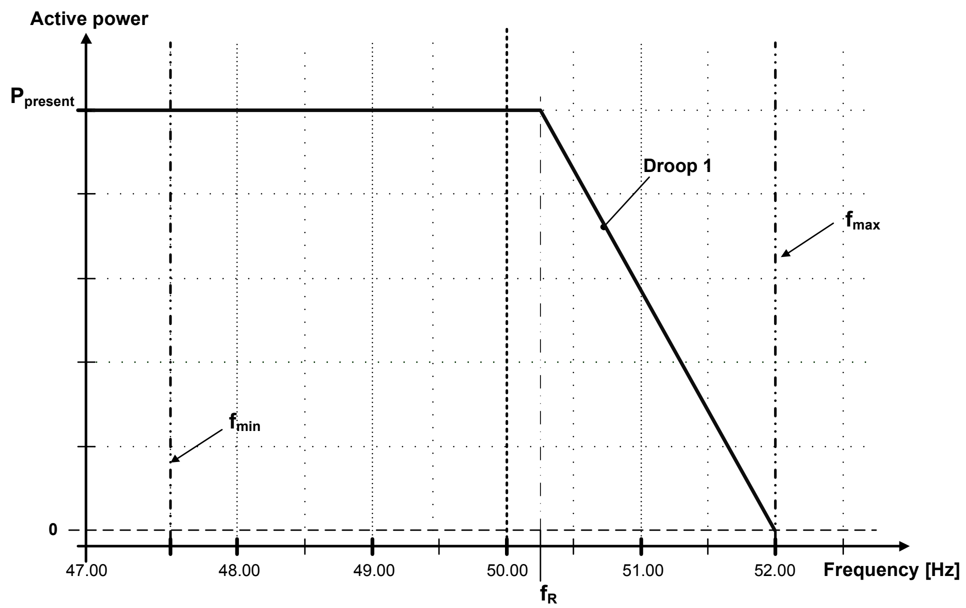

Figure 9 Frequency response for a wind power plant.

[1] The function is deactivated if f_R is set to 52 Hz.

5.2.2 Frequency control

In case of frequency deviations in the *public electricity supply grid*, the *wind power plant* must be able to provide *frequency control* to stabilise the grid frequency (50.00 Hz).

Frequency measurements must be carried out with an accuracy of ± 10 mHz or higher and with a standard deviation (1σ) of ±5 mHz or better.

It must be possible to set the *frequency control* function for all frequency points shown in
Figure 10, just as it must be possible to set the frequencies f_{min}, f_{max} and f_1 to f_7 to any value in the 47.00 Hz to 52.00 Hz range with an accuracy of 10 mHz.

The purpose of frequency points f_1 to f_4 is to be able to produce different *frequency response* curves in line with the delivery requirements for the 'critical power frequency' ancillary service, see TR 5.9.1 [ref. 20].

The *droop* required to perform control between the various frequency points is illustrated in
Figure 10 and specified in the signal list in section 7.

In this context, *droop* is the change in active power as a function of the grid frequency. *Droop* is stated as a percentage of the *plant's* nominal output.

P_{Delta} is the set point that current active power has been reduced to in order to possibly provide frequency stabilisation (upward regulation) in the event of falling grid frequency.
Figure 10 and Figure 11 show two different P_{Delta} values with the same *droop* (*droops* 1, 2, 3 and 4).

Control must start no later than 2 seconds after a frequency change is detected and must be completed within 15 seconds.

When regulating the *wind power plant's* active power downward below P_{min}, the shutdown of individual *wind turbines* is allowed.

When regulating the *wind power plant's* active power upward, it is accepted that design limitations may increase the regulation time if the upward regulation exceeds 10% of P_n.

In case of grid frequencies above f_5, upward regulation of the *wind power plant* cannot be commenced until the grid frequency is lower than f_7.

The purpose of the *frequency control* function is to reduce active power at grid frequencies above f_1 as shown in
Figure 10 and Figure 11.

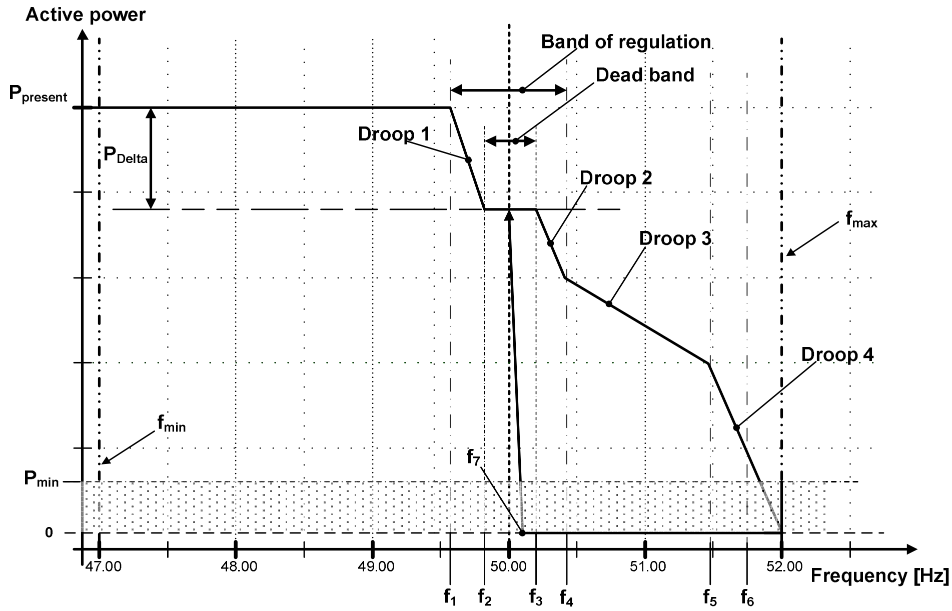

Figure 10 *Frequency control for wind power plants shown with a small downward regulation P_{Delta}.*

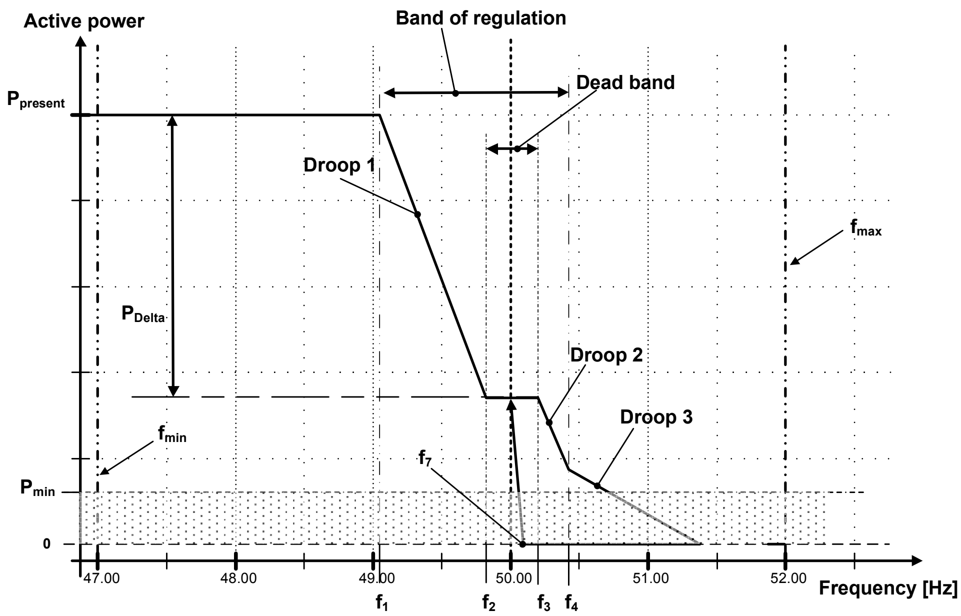

Figure 11 *Frequency control for wind power plants shown with a large downward regulation P_{Delta}.*

It must be possible to activate the *frequency control* function in the f_{min} to f_{max} range.

Frequency control using a new parameter set must be possible no later than 10 seconds from receipt of the order to change this parameter.

5.2.3 Constraint functions

A *wind power plant* must be equipped with constraint functions, i.e. supplementary active power control functions. Constraint functions are used to avoid instability or overloading of the *public electricity supply grid* in connection with switching in the *public electricity supply grid*, in fault situations or the like.

The required constraint functions are specified in the sections below.

5.2.3.1 Absolute power constraint

An a*bsolute power constraint* is used to limit active power from a *wind power plant* to a set point-defined maximum power limit in the *Point of Connection*.

An *absolute power constraint* is mainly used to protect the *public electricity supply grid* against overload in critical situations.

Control using a new parameter for the *absolute power constraint* must be commenced within two seconds and completed no later than 10 seconds after receipt of the order to change the parameter.

5.2.3.2 Delta power constraint (spinning reserve)

A *delta power constrain*t is used to constrain the active power from a *wind power plant* to a required constant value in proportion to the possible active power.

A *delta power constraint* is typically used to establish a regulating reserve for upward regulation purposes in connection with *frequency control*.

Control using a new parameter for the *delta power constraint* must be commenced within two seconds and completed no later than 10 seconds after receipt of an order to change the parameter.

5.2.3.3 Ramp rate constraint

A *ramp rate constraint* is used to limit the maximum speed by which the active power can be changed in the event of changes in wind speed or active power set points.

A *ramp rate constraint* is normally used for reasons of system operation to prevent the changes in active power from adversely impacting the stability of the *public electricity supply grid*.

Control using a new parameter for the active power *ramp rate constraint* must be commenced within two seconds and completed no later than 10 seconds after receipt of an order to change the parameter.

The maximum standard value for the *ramp rate constraint* is 100 kW/s.

Figure 12 shows an overview of active power constraint functions.

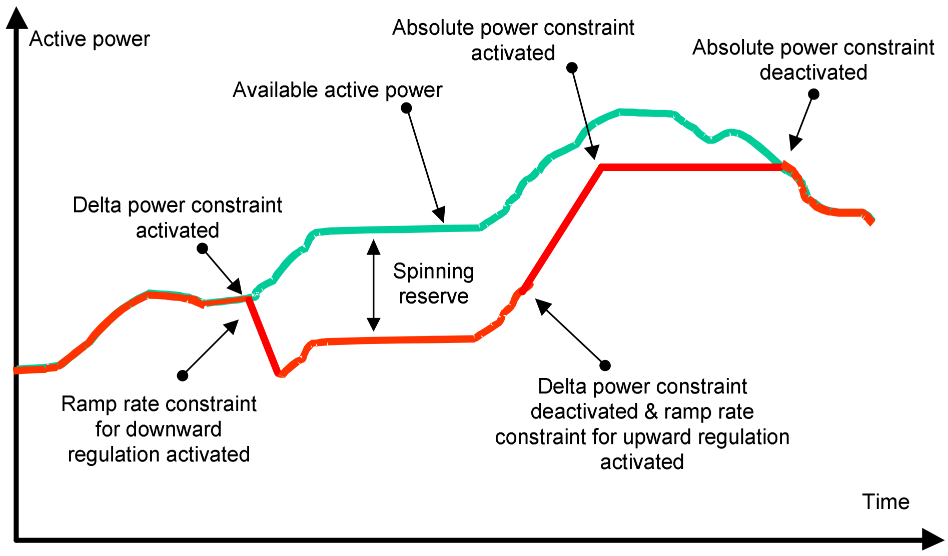

Figure 12 Drawing of constraint functions for active power.

5.3 Reactive power and voltage control functions

A *wind power plant* must be equipped with reactive power and voltage control functions capable of controlling the reactive power supplied by a *wind power plant* in the *Point of Connection* and with a control function capable of controlling the voltage in the *voltage reference point* via activation orders containing set points for the specified parameters.

The control functions for the supply of a specific reactive power (Q), *Power Factor* and *voltage control* are mutually exclusive, which means that only one of the three functions can be activated at a time.

It must be possible to set the *ramp rate* for reactive power control via set points. By default, the control *ramp rate* must be 10 MVAr/s.

Before commissioning, current parameter settings for reactive power and voltage control functions must be determined by the *electricity supply undertaking* in collaboration with the *transmission system operator*.

In addition to fulfilling the general requirements in section 5.1, the reactive power control, *Power Factor control* and *voltage control* functions must comply with the requirements in the following sections.

5.3.1 Q control

The Q control function controls reactive power independently of the active power in the *Point of Connection*.

This control function is shown as a horizontal line in the figure below.

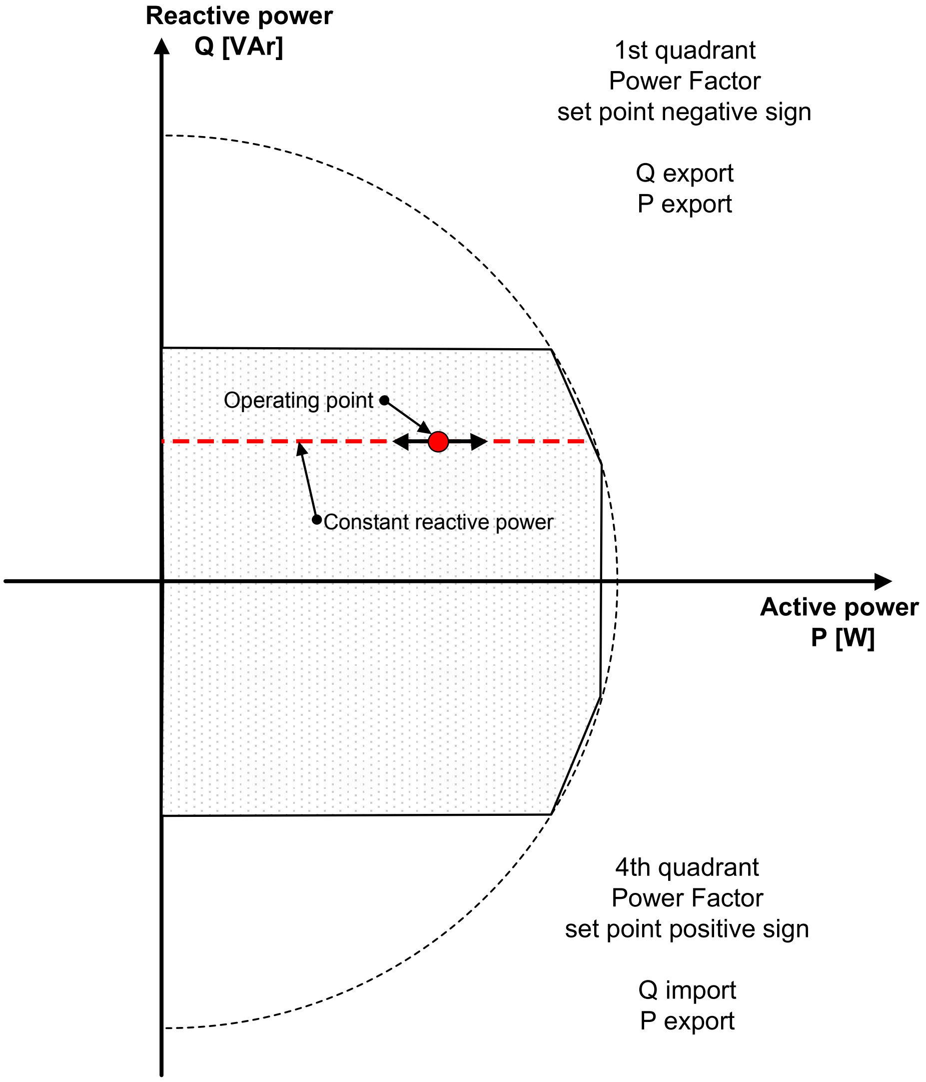

Figure 13 Reactive power control functions for a wind power plant, Q control.

Any change to the Q control set point must be commenced within two seconds and completed no later than 30 seconds after receipt of an order to change the set point.

The *wind power plant* must be able to receive a Q set point with an accuracy of 1 kVAr.

5.3.2 Power factor control

The *Power Factor control* controls the reactive power proportionately to the active power in the *Point of Connection*, which is shown by a line with a constant gradient in Figure 14.

The *wind power plant* must be able to receive a *Power Factor* set point with a resolution of 0.01.

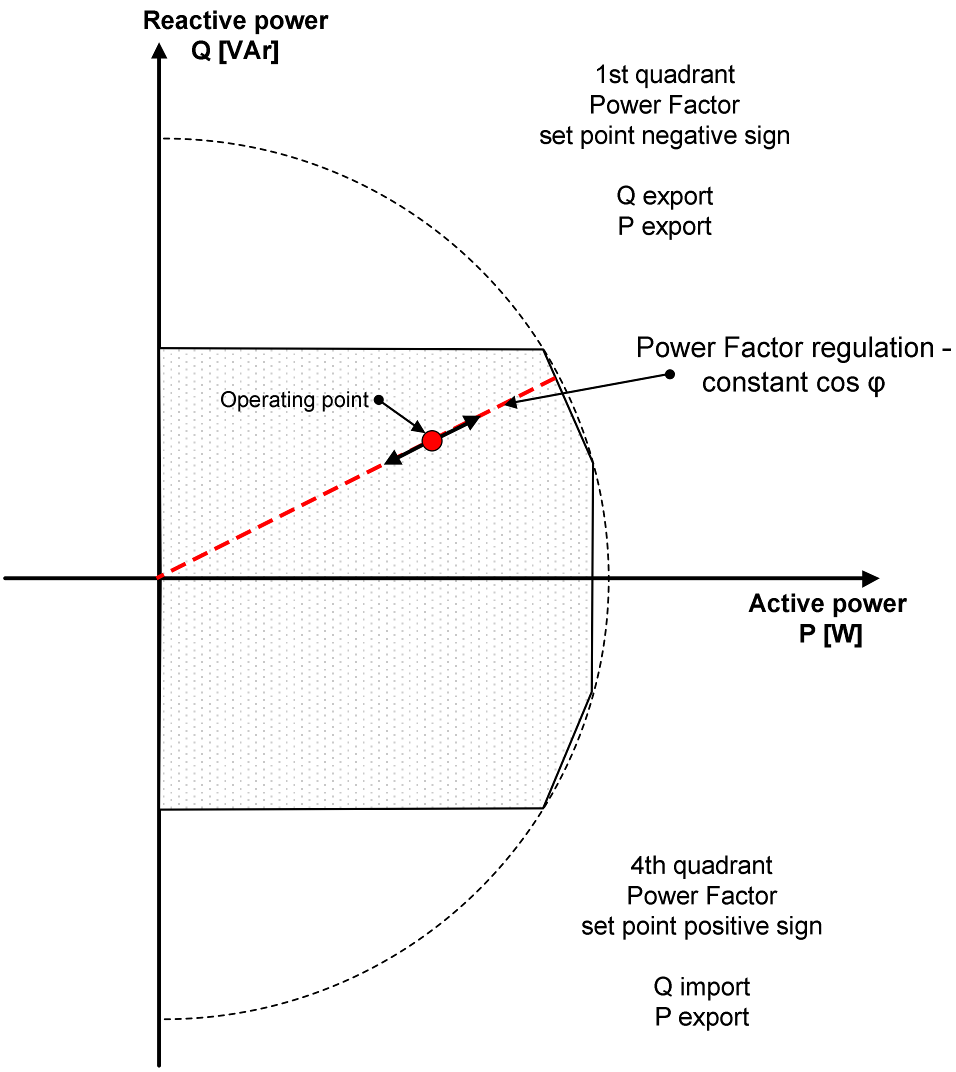

Figure 14 *Reactive power control functions for a wind power plant, Power Factor control.*

Any change to the *Power Factor* set point must be commenced within two seconds and completed no later than 30 seconds after receipt of an order to change the set point.

For the control function, the accuracy of a completed control operation over a period of 1 minute may not deviate by more than 2% of Q_n.

5.3.3 Voltage control

The *voltage control* function stabilises the voltage in the *voltage reference point*. *Voltage control* must have a setting range for minimum to maximum voltage as stated in Table 1 with an accuracy of 0.5% or higher of the *nominal voltage*.

Any change to the voltage set point must be commenced within two seconds and completed no later than 10 seconds after receipt of an order to change the set point.

For the control function, the accuracy of a completed control operation over a period of 1 minute may not deviate by more than 2% of Q_n.

The individual *wind power plant* must be capable of performing the control within its dynamic range and voltage limits with the *droop* configured.

A drawing of such a control is shown in Figure 15.

The *voltage control* reference point is the *voltage reference point*.

When the *voltage control* has reached the *wind power plant's* dynamic design limits, the control function must await a possible overall control from the tap changer or other *voltage control* functions.

Overall voltage coordination is managed by the *electricity supply undertaking* in collaboration with the *transmission system operator*.

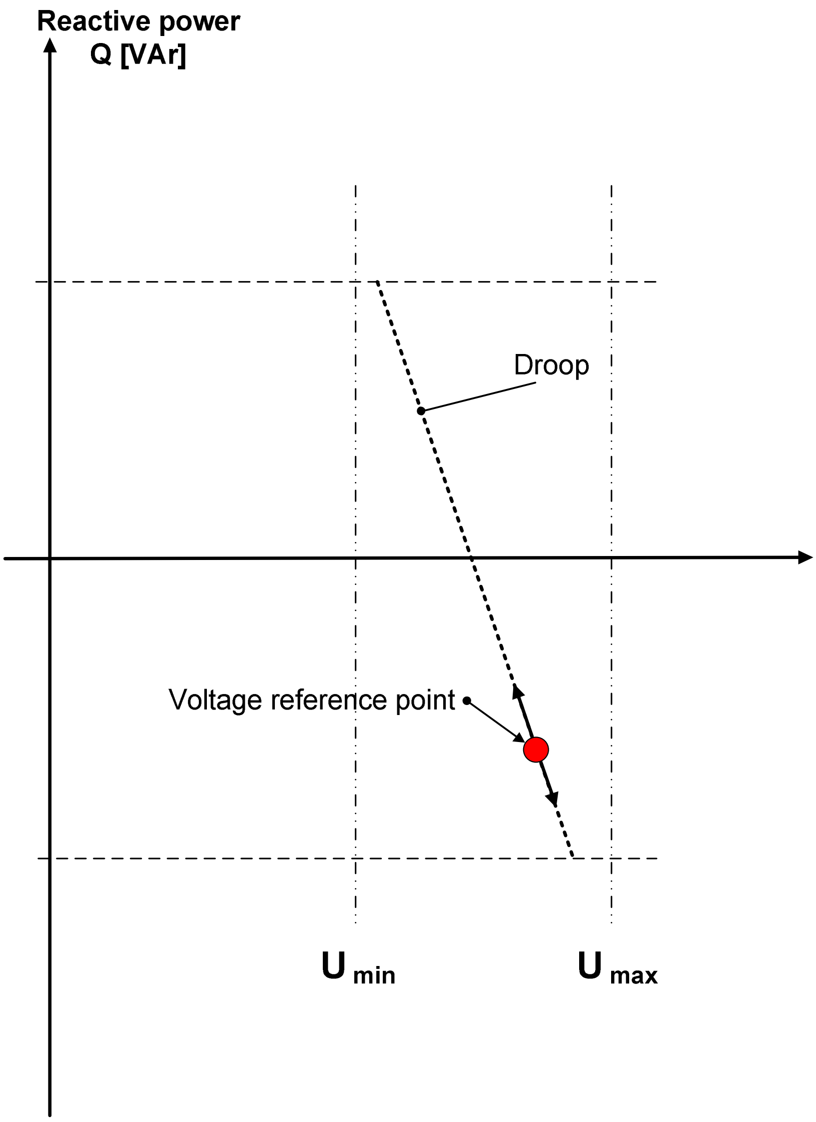

Figure 15 Voltage control for a wind power plant.

5.4 System protection

A *wind power plant* must be equipped with system protection – a control function which must be capable of very quickly regulating the active power supplied by a *wind power plant* to one or more predefined set points based on a downward regulation order. Set points are determined by *the electricity supply undertaking* upon commissioning within the framework laid down by the *transmission system operator*.

The *wind power plant* must have at least five different configurable regulation step options.

The following regulation steps are recommended as default values:

1. Up to 70% of *rated power*
2. Up to 50% of *rated power*
3. Up to 40% of *rated power*
4. Up to 25% of *rated power*
5. Up to 0% of *rated power*, i.e. the plant is shut down, but not disconnected from the grid.

When performing downward regulation, the shut-down of individual *wind turbines* is allowed.

Regulation must be commenced within one second and completed no later than 10 seconds after receipt of a downward regulation order.

If upward regulation is ordered for the system protection, e.g. from step 4 (25%) to 3 (40%), an increased order completion time is acceptable if caused by the design limitations of the *plant's wind turbines* or other *plant components.*

5.5 Order of priority for control functions

The individual control functions of a *wind power plant* must be ranked in order of priority. A priority 1 control function takes precedence over a priority 2 control function and so forth.

The recommended prioritisation between the functions of a *wind power plant* is as follows:

1. Protective functions, see section 6.
2. System protection, see section 5.4
3. *Frequency control,* see section 5.2.2
4. Constraint functions, see section 5.2.3.

5.6 Active power control requirements

Table 15 specifies the minimum requirements for control functionality for active power in the four *plant categories*, see section 1.2.21.

Control function \ Category	A2	B	C	D
Frequency response (5.2.1)*)	X	X	X	X
Frequency control (5.2.2)*)	-	-	-	X
Absolute power constraint (5.2.3.1)	X	X	X	X
Delta power constraint (5.2.3.2)	-	-	-	X
Ramp rate constraint (5.2.3.3)	X	X	X	X
System protection (5.4)	-	-	X	X

Bracketed numbers indicate the sections that describe the respective functions.
*) By default, a *wind power plant* must be configured with the *frequency response* function activated. Other methods of *frequency control* must be agreed with the *transmission system operator*.

Table 15 Active power control functions.

5.6.1 Category A2 wind power plants

In addition to fulfilling the general requirements in section 5.1 and the *normal production* requirements in section 3.2, category A2 *wind power plants* must as a minimum be equipped with the control functions specified in Table 15.

A *wind power plant* in this category must be prepared for the possible exchange of the information specified in sections 7.1.1 and 7.2.1.

5.6.2 Category B wind power plants

In addition to fulfilling the general requirements in section 5.1 and the *normal production* requirements in section 3.2, category B *wind power plants* must as a minimum be equipped with the control functions specified in Table 15.

A *wind power plant* in this category must be prepared for the possible exchange of the information specified in sections 7.1.2 and 7.2.2.

5.6.3 Category C wind power plants

In addition to fulfilling the general requirements in section 5.1 and the *normal production* requirements in section 3.2, category C *wind power plants* must as a minimum be equipped with the control functions specified in Table 15.

A *wind power plant* in this category must be prepared for the possible exchange of the information specified in sections 7.1.3 and 7.2.3.

Wind power plants in this category must as a minimum be able to reduce active power from the *wind power plant* continuously to a random value in the interval from 100% to a maximum of 40% of *rated power*.

A *wind power plant* in this category must be able to reduce active power generated in the event of high wind speeds, before the *wind turbines'* built-in protective function is activated (*cut-out wind speed*).

This is because the stability of the *public electricity supply grid* must be maintained during extreme weather conditions, including high wind speeds. As a minimum, the *wind power plant* must be equipped with an automatic downward regulation function that makes it possible to avoid a transitory interruption of the active power production at wind speeds exceeding the cut-out wind speed of the *wind turbines*.

It must be possible to activate/deactivate the control function using orders.

Downward regulation can be performed as continuous or discrete regulation. Discrete regulation must have a step size of maximum 25% of *rated power* within the hatched area shown in Figure 16. When performing downward regulation, the shutdown of individual *wind turbines* is allowed.

The downward regulation band must be agreed with the *transmission system operator* upon commissioning of the *wind power plant*. The width of the downward regulation band may depend on local wind conditions.

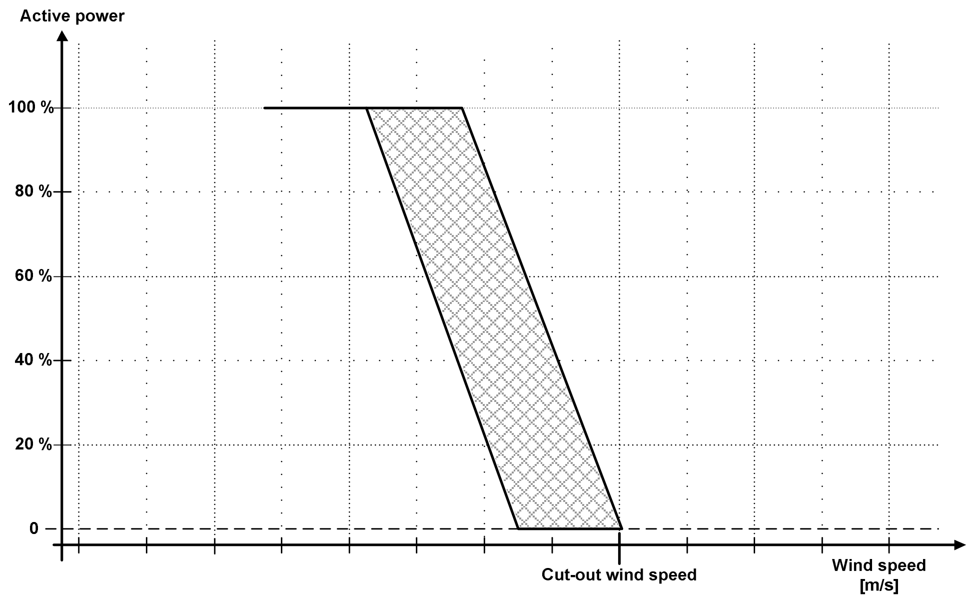

Figure 16 Downward regulation of active power at high wind speeds.

5.6.4 Category D wind power plants

In addition to fulfilling the requirements in section 5.6.3, category D *wind power plants* must as a minimum be equipped with the control functions specified in Table 15.

A *wind power plant* in this category must be capable of continuously regulating active power to a random value in the interval from 100% to a maximum of 20% of *rated power*.

A *wind power plant* in this category must be prepared for the possible exchange of the information specified in sections 7.1.3 and 7.2.4.

5.7 Calculation of non-provided active power

For *wind power plants* subject to compensation legislation in connection with downward regulation orders – see market regulation E – appendix: 'Compensation for offshore wind farms ordered to perform downward regulation' [ref. 23], the *wind power plant operator* must as a minimum provide the required information specified in the above-mentioned market regulation.

5.8 Reactive power control requirements

As a minimum, *wind power plants* in the four *plant categories*, see section 1.2.21, must be equipped with the reactive power control functions specified in Table 16.

Category / **Control function**	**A2**	**B**	**C**	**D**
Q control (5.3.1)*)	X	X	X	X
Power factor control (5.3.2)*	X	X	X	X
Voltage control (5.3.3)*)	-	-	-	X

Bracketed numbers indicate the sections that describe the respective functions.
*) By default, a *plant* must be configured with *Q control* and with a set point of 0 VAr. Other methods of reactive power control must be agreed with the *electricity supply undertaking*.

Table 16 Reactive power control functions

5.8.1 Category A2 wind power plants

In addition to fulfilling the general requirements in section 5.1 and the *normal production* requirements in section 3.2, *wind power plants* in this category must as a minimum be equipped with the control functions specified in Table 16.

The *wind power plant* must be designed in such a way that the *Power Factor* interval 0.95 < *Power Factor* < 1.0 is observed at output of more than 20% of *rated power*.

5.8.2 Category B wind power plants

In addition to fulfilling the general requirements in section 5.1 and the *normal production* requirements in section 3.2, *wind power plants* in this category must as a minimum be equipped with the control functions specified in Table 16.

The *wind power plant* must be designed in such a way that the operating point is always within the hatched area shown in Figure 17.

When the *wind power plant* is disconnected or not producing any active power, no compensation is required for the reactive power from the *plant infrastructure*.

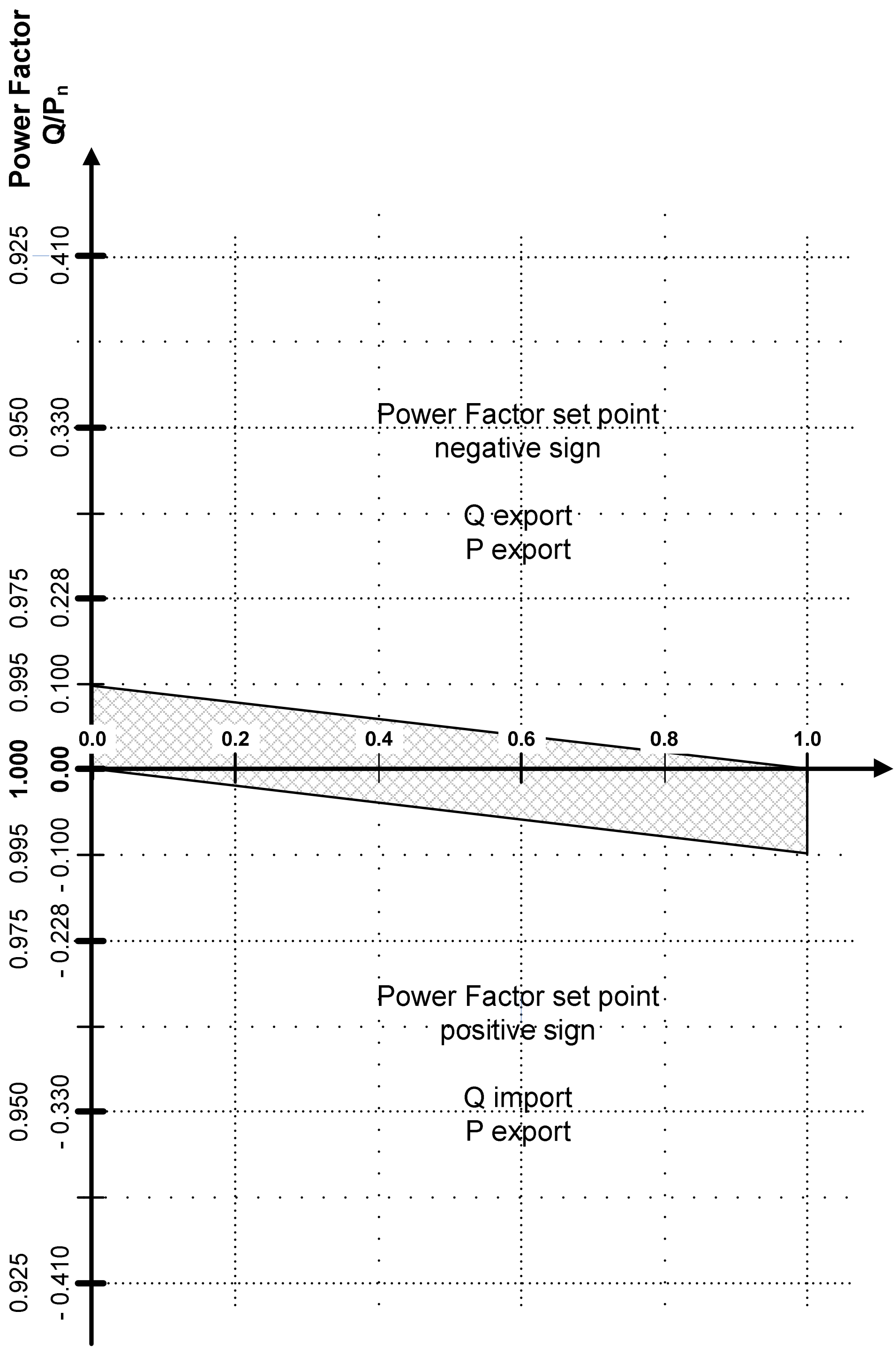

Figure 17 Requirements for the delivery of reactive power in relation to the active power level at U_C for category B wind power plants.

5.8.3 Category C wind power plants

In addition to fulfilling the general requirements in section 5.1 and the *normal production* requirements in section 3.2, *wind power plants* in this category must as a minimum be equipped with the control functions specified in Table 16.

The *wind power plant* must be designed in such a way that the operating point for delivery of reactive power can lie anywhere within the hatched area in Figure 18.

Control method and settings must be agreed with the *electricity supply undertaking* within the framework laid down by the *transmission system operator*.

The *plant owner* must compensate for the *plant infrastructure's* reactive power in situations where the *wind power plant* is disconnected or not generating active power. Compensation may take place in the electricity system by agreement with the *electricity supply undertaking*.

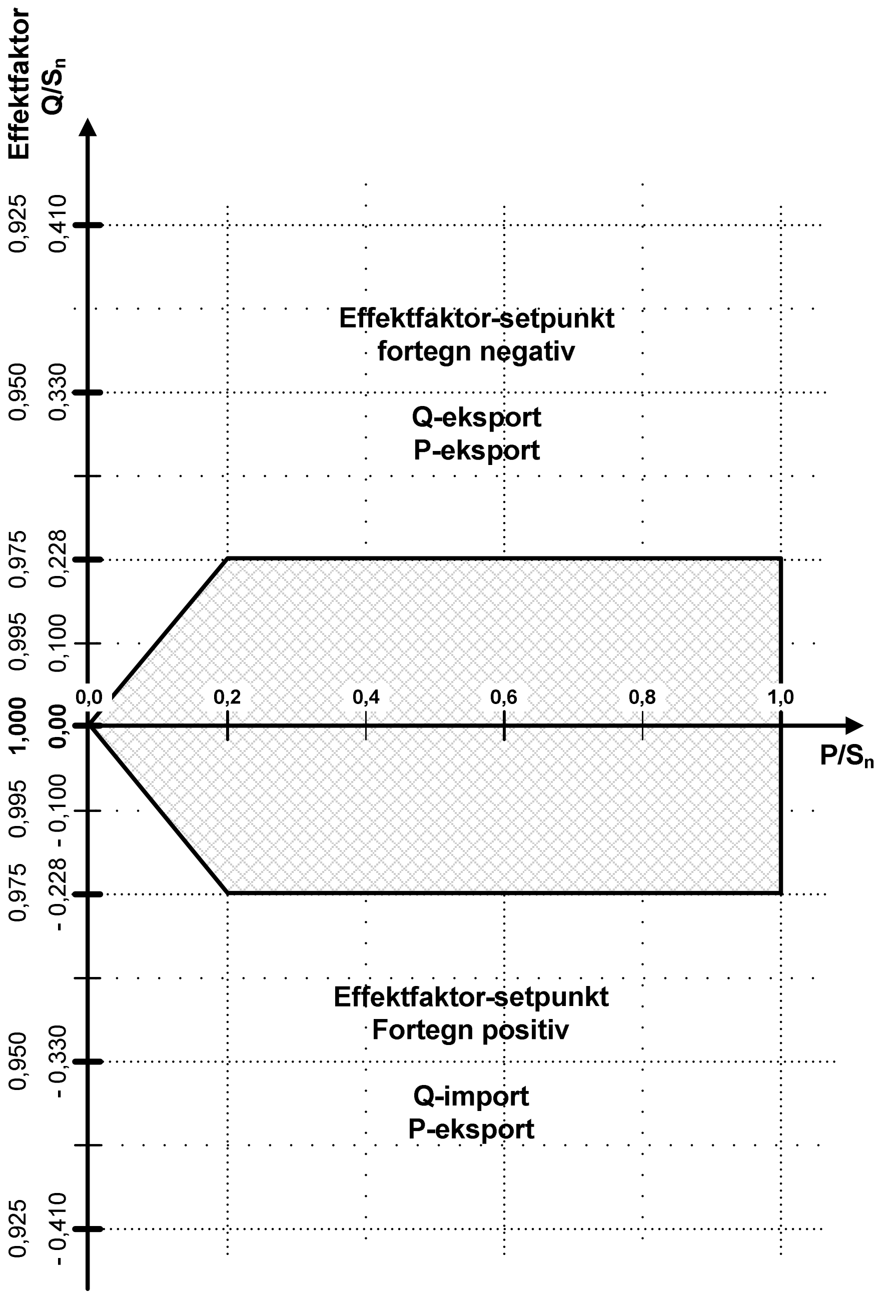

Figure 18 Requirements for the delivery of reactive power in relation to the active power level at U_c for category C wind power plants.

Figure 19 shows in which U_C area the delivery of reactive power is required for category C *wind power plants*.

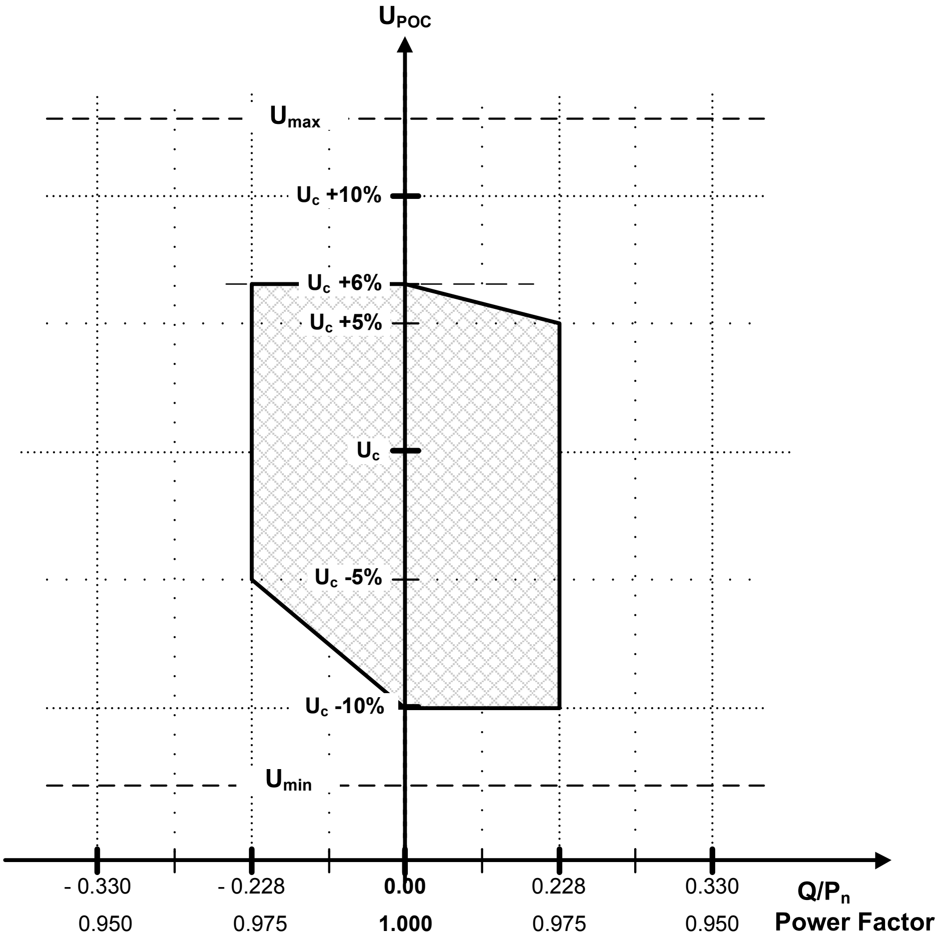

Figure 19 Requirements for the delivery of reactive power in relation to U_C for category C wind power plants.

5.8.4 Category D wind power plants

In addition to fulfilling the general requirements in section 5.1 and the *normal production* requirements in section 3.2, *wind power plants* in this category must as a minimum be equipped with the control functions specified in Table 16.

The *wind power plant* must be designed in such a way that the operating point for the delivery of reactive power can lie anywhere within the hatched area in Figure 20.

Control method and settings must be agreed with the *electricity supply undertaking* within the framework laid down by the *transmission system operator*.

The *plant owner* must compensate for the *plant infrastructure's* reactive power in situations where the *wind power plant* is disconnected or not generating active power.

Compensation may take place in the electricity system by agreement with the *electricity supply undertaking*.

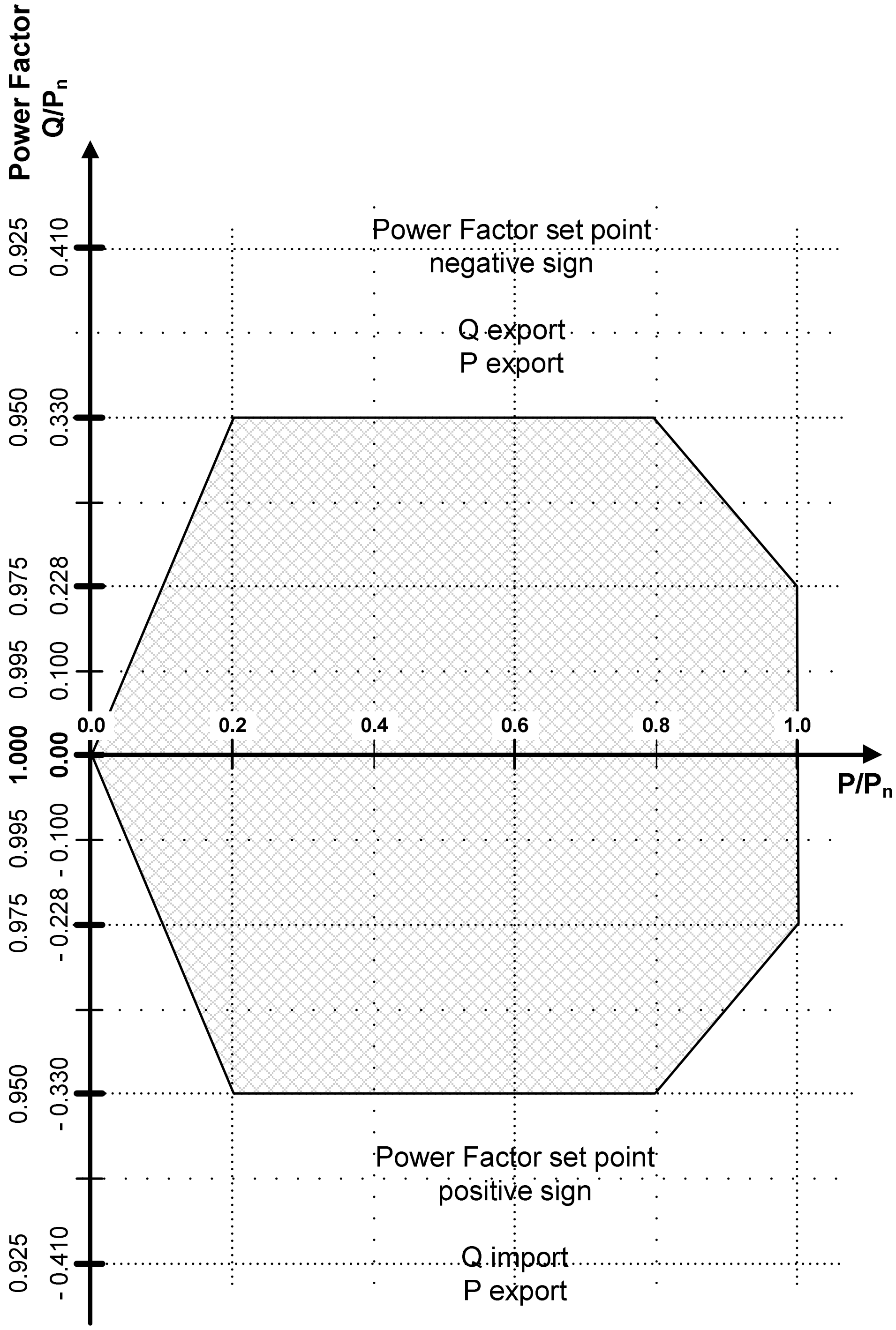

Figure 20 Requirements for the delivery of reactive power in relation to the active power level at U_c for category D wind power plants.

Figure 21 shows in which U_C area the delivery of reactive power is required for category D *wind power plants*.

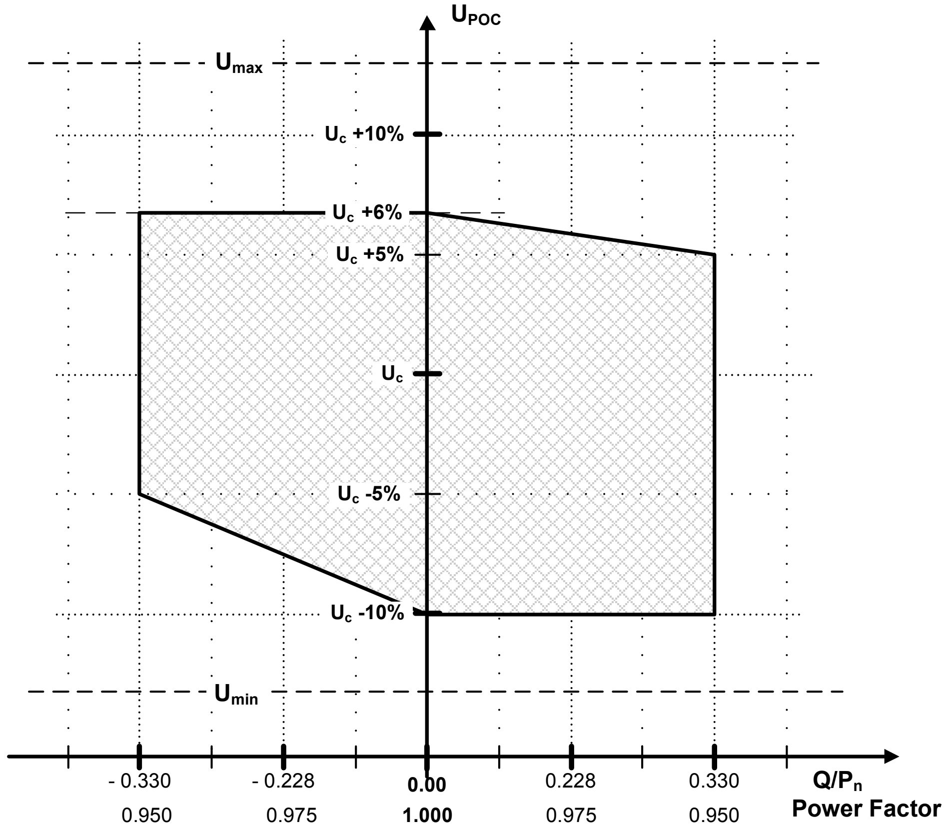

Figure 21 Requirements for the delivery of reactive power in relation to U_c for category D wind power plants.

6. Protection

6.1 General

The purpose of the *wind power plant's* protective functions is to protect the *wind power plant* and to ensure a stable *public electricity supply grid.*

The *plant owner* is responsible for ensuring that the *wind power plant* is dimensioned and equipped with the necessary protective functions so that the *wind power plant*:

- is protected against damage due to faults and incidents in the *public electricity supply grid*
- is protected against damage due to out-of-phase reclosing
- is protected against disconnections in non-critical situations for the *wind power plant*.

The *electricity supply undertaking* or the *transmission system operator* is entitled to demand that the setting values for protective functions be changed following commissioning if this is found to be of importance to the operation of the *public electricity supply grid*.

However, such change must not result in the *wind power plant* being exposed to impacts outside of the design requirements, as specified in section 3, from the *public electricity supply grid*.

After a *wind power plant* has been disconnected due to a fault in the *public electricity supply grid*, the *wind power plant* must be automatically reconnected no earlier than three minutes after the voltage and frequency are once again within the normal operating conditions stated in section 3.2.

A *wind power plant* which was disconnected by an external signal prior to a fault occurring in the *public electricity supply grid* must not be reconnected until the external signal has been eliminated, and the voltage and frequency are once again within the normal operating conditions stated in section 3.2.

At the *plant owner's* request, the *electricity supply undertaking* must state the highest and lowest *short circuit current* that can be expected in the *Point of Connection* as well as any other information about the *public electricity supply grid* that are necessary to determine the *wind power plant's* protective functions.

6.2 Protective setting requirements

The *wind power plant's* protective functions and associated settings must be as specified in the following subsections. Settings that deviate from the stated setting values, in the event of, for example, problems with local overvoltages, may only be used with the *electricity supply undertaking's* permission.

All settings are stated as root-mean-square (RMS) values.

The *wind power plant* must be disconnected or shut down if a measuring signal deviates more from its nominal value than the setting.

The trip time stated is the measuring period during which the trip condition must constantly be fulfilled for the protective function to release a trip signal.

The use of vector jump relays as protection against island operation/loss of mains is not allowed.

Recording of frequency must take place simultaneously on the phases used.

The *wind power plant* must not disconnect at a transitory phase jump of up to 20° in the *Point of Connection*.

6.2.1 Category A2 wind power plants

Protective functions with associated operating settings and trip times must be as shown in the table below.

Protective function	Symbol	Setting		Trip time		Standard value
Overvoltage (step 2)	$U_{>>}$	$1.15 \cdot U_n$	V	200	ms	200 ms
Overvoltage (step 1)	$U_{>}$	$1.10 \cdot U_n$	V	60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.85 \cdot U_n$	V	10…60	s	50 s
Undervoltage (step 2) ***)	U<<	$0.80 \cdot U_n$	V	100...200	ms	100 ms
Overfrequency	$f_{>}$	52.0	Hz	200	ms	200 ms
Underfrequency	$f_{<}$	47.0	Hz	200	ms	200 ms
Change of frequency ***)	*df/dt*	±2.5	Hz/s	50…100	ms	80 ms

***) One of the specified functions must be implemented.

Table 17 Requirements for category A2 wind power plants.

6.2.2 Category B wind power plants

Protective functions with associated operating settings and trip times must be as shown in the table below.

Protective function	Symbol	Setting		Trip time		Standard value
Overvoltage (step 2)	$U_{>>}$	$1.15 \cdot U_n$	V	200	ms	200 ms
Overvoltage (step 1)	$U_{>}$	$1.10 \cdot U_n$	V	60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.90 \cdot U_n$	V	10…60	s	10 s
Overfrequency	$f_{>}$	52	Hz	200	ms	200 ms
Underfrequency	$f_{<}$	47	Hz	200	ms	200 ms
Change of frequency	*df/dt*	±2.5	Hz/s	50…100	ms	80 ms

Table 18 Requirements for category B wind power plants.

6.2.3 Category C wind power plants

Protective functions with associated operating settings and trip times must be as shown in the table below.

Protective function	Symbol	Setting		Trip time		Standard value
Overvoltage (step 3)	$U_{>>>}$	1.20 · U_n	V	0…100	ms	100 ms
Overvoltage (step 2)	$U_{>>}$	1.15 · U_n	V	100…200	ms	200 ms
Overvoltage (step 1)	$U_{>}$	1.10 · U_n	V	60	s	60 s
Undervoltage (step 1)	$U_{<}$	0.90 · U_n	V	10…60	s	10 s
Overfrequency	$f_{>}$	52	Hz	200	ms	200 ms
Underfrequency	$f_{<}$	47	Hz	200	ms	200 ms
Change of frequency	*df/dt*	±2.5	Hz/s	50…100	ms	80 ms

Table 19 Requirements for category C wind power plants.

6.2.4 Category D wind power plants

Protective functions with associated operating settings and trip time must be as shown in the table below.

Protective function	Symbol	Setting		Trip time		Standard value
Overvoltage (step 3)	$U_{>>>}$	1.20 · U_n	V	0…100	ms	100 ms
Overvoltage (step 2)	$U_{>>}$	1.15 · U_n	V	100…200	ms	200 ms
Overvoltage (step 1)	$U_{>}$	1.10 · U_n	V	60	s	60 s
Undervoltage (step 1)	$U_{<}$	0.90 · U_n	V	10…60	s	10 s
Overfrequency	$f_{>}$	52	Hz	200	ms	200 ms
Underfrequency	$f_{<}$	47	Hz	200	ms	200 ms
Change of frequency	*df/dt*	±2.5	Hz/s	50…100	ms	80 ms

Table 20 Requirements for category D wind power plants.

7. Exchange of signals and data communication

7.1 Data communication requirements

To ensure the operation of the *public electricity supply grid*, the *plant* must be prepared for data communication between the *wind turbine operator* and the *transmission system operator* as well as the *electricity supply undertaking* in the *plant's* communication interface in line with this regulation.

7.1.1 Category A2 wind power plants

Category A2 *wind power plants* must be prepared to receive an external start signal ('released for start') and an external stop signal. The external signals are expected to be pulse signals.

This requirement is regarded as having been met if the normal stop circuit can be controlled by the external stop signal and the 'released for start' signal via a terminal strip.

7.1.2 Category B wind power plants

Category B *wind power plants* must be prepared to receive an external start signal ('released for start') and an external stop signal.

These signals must be accessible via a terminal strip or in the *PCOM* interface via commands as specified in section 7.2.

7.1.3 Category C and D wind power plants

Category C and D *wind power plants* must be capable of exchanging the information in the *PCOM* interface specified in sections 7.2.3 and 7.2.4.

Signals must be accessible in the *PCOM* interface via commands as specified in section 7.2.

It must be possible to obtain correct measurements and maintain data communication in all situations, including when *wind power plants* are shut down and the grid is dead.

Local back-up supply must as a minimum ensure the logging of relevant measurements and data and ensure the controlled shutdown of the *wind power plant's* control and monitoring system. Logging in connection with a shutdown must be performed at minute level.

All measurements and data relevant to recording and analysis must be logged with time stamps and an accuracy that ensures that such measurements and data can be correlated with each other and with similar recordings in the *public electricity supply grid*. Time stamping must refer to *UTC* with 10 ms accuracy and 1 ms precision or higher.

7.2 Data communication

Information for a *wind power plant* must be referred to, modelled and grouped as specified in the IEC 61400-25 standard series, IEC 61400-25-1 [ref. 14], IEC 61400-25-2 [ref. 15] and IEC 61400-25-3 [ref. 16].

For a *wind power plant,* information exchange must be implemented with a protocol stack as specified in IEC 61400-25-4 [ref. 17] and IEC 60870-5-104 [ref. 8].

The protocol stack must be configured so that the *wind power plant* as a minimum can communicate with two master units.

The final solution must be agreed with the *transmission system operator*.

Data communication with the *plant* must be available to the *transmission system operator* and the *electricity supply undertaking* in the *plant's* communication interface referred to as *PCOM* as shown in Figure 3.

Information, measuring signals and activation options specified in this section must be established and available to the respective parties as indicated for the individual *plant* sizes in the following sections.

Activation of the individual functions in the *plants* and configuration of the specific parameters must fulfil the requirements stated in Technical regulation 5.8.1 [ref. 19].

The specific requirements for the amount of information and signals are specified in the following sections for the individual *plant categories*.

7.2.1 Category A2 wind power plants

No online communication is required for category A2 *wind power plants.*

Wind power plants in this category must as a minimum be able to exchange the following signals:

Signal #	Signal description
A1.1	Stop signal
A1.2	Holding signal – 'Released for start'

Table 21 Requirements for information exchange with a category A2 wind power plant.

The requirements are regarded as having been complied with if the normal stop circuit can be controlled by the external signals (A1.1 and A1.2) via a terminal strip.

As a minimum, it must be possible to activate/deactivate and configure parameters for the *frequency response* function as well as the active and reactive power control functions via a control panel, relay switches or external signals. Parameters are listed in table below.

A1.3	Active power control – *ramp rate constraint*
A1.4	Active power control – ramp rate for upward regulation of active power
A1.5	Active power control – ramp rate for downward regulation of active power
A1.6	Active power control – *absolute power constraint*

A1.7	Active power control – desired maximum active power
A1.8	Reactive power control – Q control
A1.9	Reactive power control – Power Factor control
A1.10	Reactive power control – automatic Power Factor control
A1.11	*Frequency response – droop* for downward regulation from f_R
A1.12	*Frequency response* – initial frequency for *frequency response* – f_R

Table 22 Requirements for control function parameters – A2.

7.2.2 Category B wind power plants

Online communication is required for category B *wind power plants.*

Wind power plants in this category must as a minimum be able to exchange the following signals in accordance with the specifications in section 7.2:

Signal #	**Signal description**
B1.1	Switch gear status in the *plant's Point of Connection*
B1.2	Active power kW – measured in the *Point of Connection*
B1.3	Active power kW – set point for active power
B1.4	Reactive power MVAr – measured in the *Point of Connection*
B1.5	Stop signal
B1.6	Holding signal – 'Released for start'

Table 23 Requirements for information exchange with a category B wind power plant.

As a minimum, it must be possible to activate/deactivate and configure parameters for the *frequency response* function as well as the active and reactive power control functions via a control panel or external signals. Parameters are listed in table below.

B1.7	Active power control – *ramp rate constraint*
B1.8	Active power control – ramp rate for upward regulation of active power
B1.9	Active power control – ramp rate for downward regulation of active power
B1.10	Active power control – *absolute power constraint*
B1.11	Active power control – desired maximum active power
B1.12	Reactive power control – Q control
B1.13	Reactive power control – Power Factor control
B1.14	*Frequency response – droop* for downward regulation from f_R
B1.15	*Frequency response* – initial frequency for *frequency response* – f_R

Table 24 Requirements for control function parameters – B.

7.2.3 Category C wind power plants

Online communication is required for category C *wind power plants.*

Wind power plants in this category must as a minimum be able to exchange the following signals in accordance with the specifications in section 7.2:

Signal #	Signal description
C1.1	Switch gear status in the *Point of Connection*
C1.2	Active power kW – measured in the *Point of Connection*
C1.3	Active power control – *ramp rate constraint*
C1.4	Active power control – ramp rate for upward regulation of active power
C1.5	Active power control – ramp rate for downward regulation of active power
C1.6	Active power control – *absolute power constraint*
C1.7	Active power control – desired maximum active power
C1.8	Active power control – *delta power constraint*
C1.9	Active power control – desired regulating reserve – P_{delta}
C1.10	Reactive power MVAr – measured in the *Point of Connection*
C1.11	*Power factor* – calculated on the basis of measurements in the *Point of Connection*
C1.12	*Power factor* set point – desired *Power Factor* in the *Point of Connection*
C1.13	Reactive power control – activated/deactivated
C1.14	Reactive power control – desired reactive power in the *Point of Connection*
C1.15	Voltage – voltage measured in the *voltage reference point*
C1.16	System protection
C1.17	Stop signal
C1.18	Holding signal – 'Released for start'
C1.19	Overspeed protection – activated/deactivated

Table 25 Requirements for information exchange with a category C wind power plant.

A more detailed description of the signals can be found in 'Guidelines on signal list – TR 3.2.5' [ref. 45] which is available electronically at www.energinet.dk.

To ensure the security of supply, the *transmission system operator* must at all times be able to activate or deactivate the required control functions, also by using set points and activation commands to change current function settings.

7.2.4 Category D wind power plants

Online communication is required for category D *wind power plants.*

Wind power plants in this category must as a minimum be able to exchange the following signals in accordance with the specifications in section 7.2:

Signal #	Signal description
D1.1	Switch gear status in the *Point of Connection*
D1.2	Active power kW – measured in the *Point of Connection*
D1.3	Active power control – *ramp rate constraint*
D1.4	Active power control – ramp rate for upward regulation of active power
D1.5	Active power control – ramp rate for downward regulation of active power
D1.6	Active power control – *absolute power constraint*
D1.7	Active power control – desired maximum active power

D1.8	Active power control – *delta power constraint*
D1.9	Active power control – desired regulating reserve – P_{delta}
D1.10	Reactive power MVAr – measured in the *Point of Connection*
D1.11	*Power factor* – calculated on the basis of measurements in the *Point of Connection*
D1.12	*Power factor* set point – desired *Power Factor* in the *Point of Connection*
D1.13	Reactive power control – activated/deactivated
D1.14	Reactive power control – desired reactive power in the *Point of Connection*
D1.15	Voltage – voltage measured in the *voltage reference point*
D1.16	*Voltage control* – activated/deactivated
D1.17	*Voltage control* – voltage measured in the *Point of Connection*
D1.18	*Voltage control – voltage control droop*
D1.19	*Voltage control* – desired voltage in the *voltage reference point*
D1.20	*Frequency response – droop* for downward regulation from f_R
D1.21	*Frequency response* – initial frequency for *frequency response* – f_R
D1.22	*Frequency control* – frequency measured in the *Point of Connection*
D1.23	*Frequency control* – activated/deactivated
D1.24	Reference frequency – desired frequency in *PCC* – f_{ref}
D1.25	*Frequency control* – control limit – low – f_{min}
D1.26	*Frequency control* – control limit – high – f_{max}
D1.27	*Frequency control* – initial frequency for control band and *frequency response* – f_1
D1.28	*Frequency control* – initial frequency for dead band – f_2
D1.29	*Frequency control* – final frequency for dead band – f_3
D1.30	*Frequency control* – final frequency for control band – f_4
D1.31	*Frequency control* – final frequency for control up to f_5
D1.32	*Frequency control* – final frequency for control up to f_6
D1.33	*Frequency control – droop* 1 for control from f_1 to f_2
D1.34	*Frequency control – droop* 2 for control from f_3 to f_4
D1.35	*Frequency control – droop* 3 for control from f_4 to f_5
D1.36	*Frequency control – droop* 4 for control from f_5 to f_6
D1.37	*Frequency control* – frequency limit for reconnection – f_7
D1.38	System protection
D1.39	Stop signal
D1.40	Holding signal – 'Released for start'
D1.41	Overspeed protection – activated/deactivated

Table 26 Requirements for information exchange with a category D wind power plant.

A more detailed description of the signals can be found in 'Guidelines on signal list – TR 3.2.5' [ref. 45] which is available electronically at www.energinet.dk.

In order to ensure the security of supply, the *transmission system operator* must at all times be able to activate or deactivate the required control functions, also by using set points and activation commands to change the current function settings.

7.3 Fault incident recording

The requirements for recording fault incidents in the *public electricity supply grid* apply to category D *wind power plants*.

Logging must be performed using electronic equipment that as a minimum can be configured to log relevant incidents for the signals below in the *Point of Connection* in case of faults in the *public electricity supply grid*.

In the *Point of Connection*, the *plant owner* must install logging equipment capable of recording as a minimum:

- Voltage for each phase for the *wind power plant*
- Current for each phase for the *wind power plant*
- Active power for the *wind power plant* (can be computed values)
- Reactive power for the *wind power plant* (can be computed values)
- Frequency for the *wind power plant.*

Logging must be performed as correlated time series of measuring values from 10 seconds before the incident until 60 seconds after the incident.

Minimum sample frequency for all fault logs must be 1 kHz.

The specific settings for incident-based logging must be agreed with the *transmission system operator* upon commissioning of the *wind power plant*.

All measurements and data to be collected in accordance with Technical regulation 5.8.1 [ref. 19] must be logged with time stamps and an accuracy that ensures that such measurements and data can be correlated with each other and with similar recordings in the *public electricity supply grid*.

Time stamping of incidents and data must refer to *UTC* with a 10 ms accuracy or higher.

Logs must be filed for at least three months from the time of the fault situation. However, the maximum number of incidents to be recorded is 100.

Upon request, the *electricity supply undertaking* and the *transmission system operator* must be granted access to logged and relevant recorded information in *COMTRADE* format [ref. 43].

7.4 Requesting metered data and documentation

The requirements in this section apply to category D *wind power plants*.

The *electricity supply undertaking* and the *transmission system operator* are entitled to request relevant information about a *wind power plant* at any time. Expenses relating to such requests must be paid by the *plant owner*.

The *transmission system operator* may request metered data and fault recorder data collected for the *wind power plant* for a period of up to three months back in time.

At any time, the *electricity supply undertaking* and the *transmission system operator* are entitled to request that a *wind power plant* verify and document its compliance with the provisions of this regulation. Such request must be based on metered data and/or calculations specified by the *electricity supply undertaking* or the *transmission system operator*.

8. Verification and documentation

The *plant owner* is responsible for ensuring that the *wind power plant* complies with this technical regulation and for documenting that the requirements are met.

The *electricity supply undertaking* and the *transmission system operator* are entitled to request at any time verification and documentation that a *wind power plant* complies with the provisions of this regulation.

The standard procedure regarding the approval and issue of a final grid connection permit for a *wind power plant* is as follows:

1. Appendix 1 must be completed and submitted electronically to the *electricity supply undertaking*.

2. The *electricity supply undertaking* reviews and approves the documentation and determines whether any information is missing.

3. Once the documentation has been approved, a final grid connection permit can be issued.

8.1 Documentation requirements

Required documentation to be submitted for the different *plant categories* is stated in the table below.

Category / **Documentation**	**A2****)**	**B**	**C**	**D**
Protective functions	X	X	X	X
Single-line representation	X	X	X	X
Power quality	X	X	X	X
Voltage dip	-	X	X	X
PQ diagram	-	-	X	X
Signal list	-	-	X	X
Dynamic simulation model	-	X	X	X
Verification report	-	-	X	X

X: Documentation must be submitted.
**) May be included on the *positive list.*

Table 27 Documentation requirements for all plant categories.

8.1.1 Protective functions

Documentation of protective functions is a list of the relay configurations applicable at the time of commissioning. These values must be stated in the documentation.

8.1.2 Single-line representation

A single-line representation is a drawing showing the main components of the *plant* and their electrical interconnections. As a minimum, the location of protective functions and metering points must be indicated in the diagram.

8.1.3 Power quality

Power quality is a collection of parameters characterising the quality of the power delivered. The verification report must document how the requirements in section 4 have been met. The document 'Guidelines on the calculation of power quality parameters – TR 3.2.5' [ref. 44] contains examples and guidance on how the individual power quality parameters can be calculated.

8.1.4 Voltage dip

Voltage dip is the *plant's* ability to stay connected to the electricity system during a voltage dip. The *plant's* ability to stay connected to the grid must be documented using the electrical simulation model provided. Alternatively, type test data is supplied, demonstrating that the requirements have been met. Model simulations must show that the requirements in section 3.3.1 have been met.

8.1.5 PQ diagram

A PQ diagram is a figure illustrating the *plant's* properties and ability to deliver reactive power as a function of the *plant's* ability to deliver active power. Measurements must show that the requirements in section 5.3 have been met. Alternatively, type test data is supplied, demonstrating that the requirements have been met.

8.1.6 Signal list

The signal list is a list of the signals/information that needs to be exchanged between the parties that control and monitor a *plant*. Documentation proving that the signals specified in section 7.1 are present in the *PCOM* interface must be supplied as part of the verification report. The document 'Guidelines on signal list – TR 3.3.2' [ref. 45] contains a detailed description of the individual signals.

8.1.7 Dynamic simulation model

A 'dynamic simulation model' is a model of a *plant's* electrical properties and constraints. The electrical simulation model must comply with the requirements specified in section 9.1.

8.1.8 Verification report

A 'verification report' is a report on/documentation of completed tests, demonstrating that the required functions, see section 5, have been implemented and work as intended with the configured parameters. The document 'Guidelines on verification reports – TR 3.2.5' [ref. 46] may be used for inspiration.

8.2 Documentation requirements – category A2 wind power plants

The documentation requirements for *plant category* A2 are divided into the following two sections.

8.2.1 Documentation for plants not included on the *positive list*

If the *plant* or *plant components* are not included on the *positive list*, the following documentation must be submitted to *the electricity supply undertaking* for approval no later than three months before the date of commissioning.

Appendix 1 (B1.1.), duly completed and supplemented with the following documents:

1. CE declaration of conformity
2. Technical documentation proving that answers given in Appendix 1 (B1.1.) are correct.

8.2.2 Documentation for plants included on the positive list

The supplier of a *plant* will often have had the *plant components* used added to the *positive list,* making the technical processing easier.

If the *plant* or *plant components* are included on the *positive list*, the following documentation must be submitted to *the electricity supply undertaking* for approval.

Appendix 1 (B1.2.), duly completed.

8.3 Procedure for inclusion of plants and plant components on the positive list

To request that a *plant* or *plant components* be included on the *positive list*, the following documentation must be submitted to *positivlister@danskenergi.dk*:

Appendix 1 (B1.1.), duly completed and supplemented with the following documents:

1. CE declaration of conformity
2. Technical documentation proving that answers given in Appendix 1 (B1.1.) are correct.

The process for inclusion on the *positive list* is explained on the Danish Energy Association's website: www.danskenergi.dk/positivlister

8.4 Documentation requirements – category B wind power plants

The following documentation is required for the *plant*:

a. Protective functions
b. Single-line representation
c. Power quality
d. Voltage dip
e. Dynamic simulation model.

Appendix for the documentation can be found in section B1.3. .

8.5 Documentation requirements – category C wind power plants

The documentation to be provided must be in the form of preliminary data for the *wind power plant* which must be sent to the *electricity supply undertaking* no later than three months **before** the date of commissioning.

The documentation must be filled in with specific data for the entire *wind power plant* and sent to the *electricity supply undertaking* no later than three months **after** the date of commissioning. The required documentation comprises the following:

a. Protective functions
b. Single-line representation
c. Power quality
d. Voltage dip
e. PQ diagram
f. Signal list
g. Dynamic simulation model
h. Verification report.

Appendix for the documentation can be found in section B1.4.

8.6 Documentation requirements – category D wind power plants

The documentation to be provided must be in the form of preliminary data for the *wind power plant* which must be sent to the *electricity supply undertaking* no later than three months **before** the date of commissioning.

The documentation must be filled in with specific data for the entire *wind power plant* and sent to the *electricity supply undertaking* no later than three months **after** the date of commissioning. The required documentation comprises the following:

a. Protective functions
b. Single-line representation
c. Power quality
d. Voltage dip
e. PQ diagram
f. Signal list
g. Dynamic simulation model
h. Verification report.

Appendix for the documentation can be found in section B1.5.

9. Electrical simulation model

The requirements in this section apply to all category B, C and D *wind power plants*.

For the purposes of analysing the *public electricity supply grid*, the *transmission system operator* regularly maintains and expands the simulation models as new *wind power plants* are connected to the grid.

The simulation models are used to analyse the dynamic properties of the transmission and distribution grids, including stability.

From the design phase to the verification phase, the *plant owner* must keep the *transmission system operator* informed if the preliminary data can no longer be regarded as being indicative of the finally commissioned *wind power plant*.

The *plant owner* must provide the *transmission system operator* with the simulation models specified.

In pursuance of Section 84a of the Danish Electricity Supply Act, the *transmission system operator* is bound by a duty of confidentiality where commercially sensitive information is concerned.

Simulation models may be sent directly from the *wind turbine* manufacturer to the *transmission system operator*.

The *plant owner* is responsible for ensuring that the correct amount of data is submitted at the right time.

9.1 Simulation model requirements

The simulation model for the entire *wind power plant* must dynamically describe the electrical properties seen from the *public electricity supply grid*.

The simulation model must be supplied in the form of block diagrams which by means of mainly logical and mathematical functions, primarily transfer functions in the Laplace/z domain, describe the properties of the *wind power plant*.

The simulation model must be accompanied by model descriptions which as a minimum comprise function descriptions of the main elements of the model and detailed descriptions of the individual model components and associated model parameters.

A simulation model consisting of compiled code is acceptable provided the source code is included.

A simulation model with encrypted parts will not be accepted, as the *transmission system operator* needs to be able to include the *plant* model in the modelling of the *public electricity supply grid*.

The simulation model must comprise all control functions as required in section 5.

The simulation model must include all protective functions that can be activated during all relevant incidents and faults in the *public electricity supply grid* as required in section 6.

It must be possible to use the simulation model to simulate RMS values in the synchronous system (positive sequence).

It must be possible to use the simulation model to simulate RSM values in the individual phases during asymmetrical incidents and faults *in the public electricity supply grid.*

As a minimum, it must be possible to use the simulation model in the 47-53 Hz frequency range and in the 0.0 to 1.4 pu voltage range.

The simulation model must be able to describe the dynamic reply from a *wind power plant* for at least 30 seconds after any incident and fault in the *public electricity supply grid*.

It must be possible to initialise the simulation model directly on the basis of a load-flow solution without subsequent iterations.

The simulation model must be numerically stable and capable of utilising numerical equation solvers with variable sample lengths.

9.2 Verification of simulation model

If the model is not verified by an accredited institute, the *plant owner* must no later than three months after final commissioning of the *wind power plant* submit measurements that the *transmission system operator* can use to verify the simulation model for the entire *plant*.

The simulation model for the entire *wind power plant* must be verified for all control types as required in section 5.

The practical performance of verification tests must be determined no later than three months before the final commissioning of the *wind power plant* on the basis of the *plant owner's* proposal and in collaboration with the *transmission system operator*.

The *plant owner* is responsible for performing all verification tests and is also responsible for measuring equipment, data loggers and staff.

Measurements used to verify the simulation model for the entire *wind power plant* must be documented by the *plant owner* in a report containing detailed descriptions of each individual test.

The time-series measurements used to verify the simulation model must be enclosed with the verification report in *COMTRADE* format [ref. 43].

9.3 Simulation model requirements – category A2 wind power plants

No simulation model is required for category A2 *wind turbines* or *wind power plants.*

9.4 Simulation model requirements – category B wind power plants

The *transmission system operator* needs to be able to develop a dynamic simulation model for the *public electricity supply grid*, and to this end, the *transmission system operator* needs to know the simulation model for the *wind turbines* used.

The *plant owner* must submit a simulation model for the *wind turbines* used no later than three months after commissioning.

9.5 Simulation model requirements – category C wind power plants

The *transmission system operator* requires a dynamic simulation model for the entire *wind power plant*.

The *plant owner* must submit a simulation model for the entire *wind power plant*, including the *wind power plant controller*, if any, no later than three months after commissioning.

The content and level of detail of the simulation models for the *wind power plant controller* and the individual *wind turbines* must be such that they can be readily integrated and subsequently appear as a single fully functional simulation model as required in section 9.1.

The simulation model must be verified as specified in section 9.2.

The *plant owner* must supply *plant infrastructure* data upon request.

9.6 Simulation model requirements – category D wind power plants

The *transmission system operator* requires a dynamic simulation model for the entire *wind power plant*.

The *plant owner* must submit a simulation model for the entire *wind power plant*, including the *wind power plant controller* and *plant infrastructure* no later than three months after commissioning.

The content and level of detail of the simulation models for the *wind power plant controller* and the individual *wind turbines* must be such that they can be readily integrated and subsequently appear as a single fully functional simulation model as required in section 9.1.

The scope and level of detail of data for components and parts that form part of the *plant infrastructure* must also enable the construction of a single fully operational simulation model as required in section 9.1.

The simulation model must be verified as specified in section 9.2.

Appendix 1 Documentation

Appendix 1 specifies the documentation requirements for the four *plant categories*, see section 1.2.21*.*

The documentation (see the specifications in section 8) must be sent electronically to the *electricity supply undertaking*.

The technical documentation must include configuration parameters and configuration data applicable to the *wind power plant* at the time of commissioning.

All subsections in the appendix must be filled in for the *plant* in question.

If information is changed after the time of commissioning, updated documentation must be submitted as required in section 2.2.

A template for Appendix 1 for the different *plant categories* is available on the website www.energinet.dk.

B1.1. Appendix 1 for plant category A2 not included on the positive list

Please fill in the documentation form with data for the *wind power plant* at the time of commissioning and send it to the electricity *supply undertaking.*

B1.1.1. Identification

Plant	Description of the *plant*:
GSRN number	
Plant owner name and address	
Plant owner tel. no.	
Plant owner e-mail	
Type/model	
Voltage (nominal)	
Rated power (data sheet)	

B1.1.2. Power quality

Please state how each power quality parameter result was achieved.

B1.1.2.1. Voltage changes

Are the voltage changes for the entire *wind power plant* below the limit value? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.1.2.2. DC content

Does the DC content at normal operation exceed 0.5% of the *rated current*? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.1.2.3. Asymmetry

Does the asymmetry at normal operation and during faults exceed 16A? Where to find documentation that this requirement has been met?	Yes ☐ No ☐
In case of a *wind power plant* made up of single-phase *electricity-generating units*, have you taken measures to ensure that the above limit is not exceeded? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.1.2.4. Flicker

Is the *flicker* contribution for the entire *wind power plant* below the limit value? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.1.2.5. Harmonic distortions

Are all the *harmonic distortions* for the entire *wind power plant* below the limit values? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.1.3. Connection and synchronisation

Can the *wind power plant* be started and generate power continuously within the *normal production* range limited only by the protective settings? Where to find documentation that this requirement has been met?	Yes ☐ No ☐
Do connection and synchronisation occur three minutes, at the earliest, after voltage and frequency have come within the *normal production* range? Where to find documentation that these requirements have been met?	Yes ☐ No ☐

B1.1.4. Active power control at overfrequency

Is the *wind power plant* equipped with a *frequency response* function? Is the function activated? Where to find documentation that these requirements have been met?	Yes ☐ No ☐ Yes ☐ No ☐

B1.1.5. Absolute power constraint function

Is the *wind power plant* equipped with an *absolute power constraint* function? Is the function activated? Where to find documentation that these requirements have been met?	Yes ☐ No ☐ Yes ☐ No ☐

B1.1.6. Ramp rate constraint function

Is the *wind power plant* equipped with a *ramp rate constraint* function? Is the function activated? Where to find documentation that these requirements have been met?	Yes ☐ No ☐ Yes ☐ No ☐

B1.1.7. Reactive power control

Reactive power can be controlled by means of	*Q control* ☐ *Power factor control* ☐ *Voltage control* ☐

B1.1.8. Q control

Is the control function activated with a set point of ______ VAr? (Value may not differ from 0 VAr unless agreed with the *electricity supply undertaking*). Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.1.9. Power factor control

Is the control function deactivated? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.1.10. Voltage control

Is the control function deactivated? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.1.11. Protection against electricity system faults

B1.1.11.1. Relay settings

Please state current values at the time of commissioning in the table below.

Protective function	Symbol	Setting		Trip time	
Overvoltage (step 2)	$U_{>>}$		V		ms
Overvoltage (step 1)	$U_{>}$		V		s
Undervoltage (step 1)	$U_{<}$		V		s
Undervoltage (step 2)	$U_{<<}$		V		ms
Overfrequency	$f_{>}$		Hz		ms
Underfrequency	$f_{<}$		Hz		ms
Change of frequency	df/dt		Hz/s		ms

B1.1.12. Signature

Date of commissioning	
Company	
Person responsible for commissioning	
Signature	

B1.2. Appendix 1 for plant category A2 included on the positive list

Please fill in the documentation form with data for the *wind power plant* at the time of commissioning and send it to the electricity *supply undertaking.*

B1.2.1. Identification

Plant	Description of the *plant*:
GSRN number	
Plant owner name and address	
Plant owner tel. no.	
Plant owner e-mail	
Type/model	
Voltage (nominal)	
Rated power (data sheet)	

B1.2.2. Active power control at overfrequency

Is the *wind power plant* equipped with a *frequency response* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.2.3. Absolute power constraint function

Is the *wind power plant* equipped with an *absolute power constraint* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.2.4. Reactive power control

Reactive power can be controlled by means of	*Q control* ☐ *Power factor control* ☐ *Voltage control* ☐

B1.2.5. Q control

Is the control function activated with a set point of ______ VAr? (Value may not differ from 0 VAr unless agreed with the *electricity supply undertaking*).	Yes ☐ No ☐

B1.2.6. Power factor control

Is the control function deactivated?	Yes ☐ No ☐

B1.2.7. Voltage control

Is the control function deactivated?	Yes ☐ No ☐

B1.2.8. Protection against electricity system faults

B1.2.8.1. Relay settings

Please state current values at the time of commissioning in the table below.

Protective function	Symbol	Setting		Trip time	
Overvoltage (step 2)	$U_{>>}$		V		ms
Overvoltage (step 1)	$U_{>}$		V		s
Undervoltage (step 1)	$U_{<}$		V		s
Undervoltage (step 2)	$U_{<<}$		V		ms
Overfrequency	$f_{>}$		Hz		ms
Underfrequency	$f_{<}$		Hz		ms
Change of frequency	df/dt		Hz/s		ms

B1.2.9. Signature

Date of commissioning	
Company	
Person responsible for commissioning	
Signature	

B1.3. Appendix 1 for plant category B

Please fill in the documentation form with data for the *wind power plant* at the time of commissioning and send it to the electricity *supply undertaking.*

B1.3.1. Identification

Plant	Description of the *plant*:
GSRN number	
Plant owner name and address	
Plant owner tel. no.	
Plant owner e-mail	
Type/model	
Voltage (nominal)	
Rated power (data sheet)	

B1.3.2. Voltage dip tolerances

Will the *wind power plant* remain connected to the *public electricity supply grid* during voltage dips as specified in section 3.3.1 of TR 3.2.5?	Yes ☐ No ☐
Is a simulation enclosed, documenting that the Low Voltage Fault Ride Through (LVFRT) requirements have been met? If No, how is compliance then documented?	Yes ☐ No ☐

B1.3.3. Voltage quality

Please state how each power quality parameter result was achieved.

Were the values calculated?	Yes ☐ No ☐
Were the values measured?	Yes ☐ No ☐
Is a report enclosed, documenting that the calculations or measurements meet emission requirements? If No, how are calculations or measurements documented?	Yes ☐ No ☐

B1.3.3.1. DC content

Does the DC content at normal operation exceed 0.5% of the *rated current*?	Yes ☐ No ☐

B1.3.3.2. Asymmetry

Does asymmetry at normal operation and during faults exceed 16A?	Yes ☐ No ☐
In case of a *wind power plant* made up of single-phase *electricity-generating units*, have you taken measures to ensure that the above limit is not exceeded?	Yes ☐ No ☐

B1.3.3.3. Flicker

Is the *flicker* contribution for the entire *wind power plant* below the limit value?	Yes ☐ No ☐

B1.3.3.4. Harmonic distortions

Are all *harmonic distortions* for the entire *wind power plant* below the limit values?	Yes ☐ No ☐

B1.3.3.5. Interharmonic distortions

Are all the interharmonic distortions for the entire *wind power plant* below the limit values?	Yes ☐ No ☐

B1.3.3.6. Distortions from 2-9 kHz

Is the emission of distortions with frequencies in the 2-9 kHz range lower than 0.2% of the *rated current* I_n?	Yes ☐ No ☐

B1.3.4. Connection and synchronisation

Can the *wind power plant* be started and generate power continuously within the *normal production* range limited only by the protective settings?	Yes ☐ No ☐
Do connection and synchronisation occur three minutes, at the earliest, after voltage and frequency have come within the *normal production* range?	Yes ☐ No ☐

B1.3.5. Active power control at overfrequency

Is the *wind power plant* equipped with a *frequency response* function?	Yes ☐ No ☐

B1.3.6. Absolute power constraint function

Is the *wind power plant* equipped with an *absolute power constraint* function? Is the function activated?	Yes ☐ No ☐ Yes ☐ No ☐

B1.3.7. Ramp rate constraint function

Is the *wind power plant* equipped with a *ramp rate constraint* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.3.8. Reactive power control

Reactive power can be controlled by means of	*Q control* ☐ *Power factor control* ☐ *Voltage control* ☐

B1.3.9. Q control

Is the control function activated with a set point of ______ VAr? (Value may not differ from 0 VAr unless agreed with the *electricity supply undertaking*).	Yes ☐ No ☐

B1.3.10. Power factor control

Is the control function deactivated?	Yes ☐ No ☐

B1.3.11. Voltage control

Is the control function deactivated?	Yes ☐ No ☐

B1.3.12. Protection against electricity system faults

B1.3.12.1. Relay settings

Please state current values at the time of commissioning in the table below.

Protective function	Symbol	Setting		Trip time	
Overvoltage (step 2)	$U_{>>}$		V		ms
Overvoltage (step 1)	$U_{>}$		V		s
Undervoltage (step 1)	$U_{<}$		V		s
Overfrequency	$f_{>}$		Hz		ms
Underfrequency	$f_{<}$		Hz		ms
Change of frequency	df/dt		Hz/s		ms

B1.3.13. Single-line representation

Is a single-line representation for the *wind power plant* enclosed with the documentation? If No, when will the final single-line representation be provided?	Yes ☐ No ☐

B1.3.14. Signature

Date of commissioning	
Company	
Person responsible for commissioning	
Signature	

B1.4. Appendix 1 for plant category C

Please fill in the documentation form with preliminary data for the *wind power plant* and send it to the electricity *supply undertaking* no later than three months **before** the date of commissioning.

Please fill in the documentation form with specific data for the entire *wind power plant* and send it to the electricity *supply undertaking* no later than three months **after** the date of commissioning.

The required documentation comprises the following:
The required documentation comprises the following:

B1.4.1. Identification

Plant	Description of the *plant*:
GSRN number	
Plant owner name and address	
Plant owner tel. no.	
Plant owner e-mail	
Type/model	
Voltage (nominal)	
Rated power (data sheet)	

B1.4.2. Voltage dip tolerances

Will the *wind power plant* remain connected to the *public electricity supply grid* during voltage dips as specified in section 3.3.1?	Yes ☐ No ☐
Is a simulation enclosed, documenting that the Low Voltage Fault Ride Through (LVFRT) requirements have been met? If No, how is compliance then documented?	Yes ☐ No ☐

B1.4.3. Voltage quality

Please state how each power quality parameter result was achieved.

Were the values calculated?	Yes ☐ No ☐
Were the values measured?	Yes ☐ No ☐
Is a report enclosed, documenting that calculations or measurements meet emission requirements? If No, how are calculations or measurements documented?	Yes ☐ No ☐

B1.4.3.1. DC content

Does the DC content at normal operation exceed 0.5% of *rated current*?	Yes ☐ No ☐

B1.4.3.2. Asymmetry

Does the asymmetry at normal operation and during faults exceed 16A?	Yes ☐ No ☐
In case of a *wind power plant* made up of single-phase *electricity-generating units*, have you taken measures to ensure that the above limit is not exceeded?	Yes ☐ No ☐

B1.4.3.3. Flicker

Is the *flicker* contribution for the *wind power plant* below the limit value?	Yes ☐ No ☐

B1.4.3.4. Harmonic distortions

Are all *harmonic distortions* for the *wind power plant* below the limit values?	Yes ☐ No ☐

B1.4.3.5. Interharmonic distortions

Are all interharmonic distortions for the *wind power plant* below the limit values?	Yes ☐ No ☐

B1.4.3.6. Distortions from 2-9 kHz

Emission of distortions with frequencies in the 2-9 kHz range is determined by the *electricity supply undertaking*. Is the requirement met?	Yes ☐ No ☐

B1.4.4. Connection and synchronisation

Can the *wind power plant* be started and generate power continuously within the *normal production* range, limited only by the protective settings?	Yes ☐ No ☐
Do connection and synchronisation occur three minutes, at the earliest, after voltage and frequency have come within the *normal production* range?	Yes ☐ No ☐

B1.4.5. Active power control at overfrequency

Is the *wind power plant* equipped with a *frequency response* function?	Yes ☐ No ☐

B1.4.6. Frequency control

Is the *wind power plant* equipped with a *frequency control* function as specified in section 5.2.2?	Yes ☐ No ☐

B1.4.7. Absolute power constraint function

Is the *wind power plant* equipped with an *absolute power constraint* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.4.8. Delta power constraint function

Is the *wind power plant* equipped with a *delta power constraint* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.4.9. Ramp rate constraint function

Is the *wind power plant* equipped with a *ramp rate constraint* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.4.10. System protection

Is the *wind power plant* equipped with a system protection function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.4.11. Reactive power control

Reactive power can be controlled by means of	*Q control* ☐ *Power factor control* ☐ *Voltage control* ☐

B1.4.12. Q control

Is the control function activated with a set point of ______ VAr? (Value may not differ from 0 VAr unless agreed with the *electricity supply undertaking*).	Yes ☐ No ☐

B1.4.13. Power factor control

Is the control function deactivated?	Yes ☐ No ☐

B1.4.14. Voltage control

Is the *wind power plant* equipped with a *voltage control* function as specified in section 5.3.3?	Yes ☐ No ☐

B1.4.15. Protection against electricity system faults

B1.4.15.1. Relay settings

Please state current values at the time of commissioning in the table below.

Protective function	Symbol	Setting		Trip time	
Overvoltage (step 3)	$U_{>>>}$		V		ms
Overvoltage (step 2)	$U_{>>}$		V		ms
Overvoltage (step 1)	$U_{>}$		V		s
Undervoltage (step 1)	$U_{<}$		V		s
Overfrequency	$f_{>}$		Hz		ms
Underfrequency	$f_{<}$		Hz		ms
Change of frequency	*df/dt*		Hz/s		ms

B1.4.16. Single-line representation

Is a single-line representation for the *wind power plant* enclosed with the documentation? If No, when will the final single-line representation be provided?	Yes ☐ No ☐

B1.4.17. PQ diagram

Has the final PQ diagram been submitted to the *electricity supply undertaking*? If No, when will the final PQ diagram be provided?	Yes ☐ No ☐

B1.4.18. Signal list

Has the final signal list been submitted to the *electricity supply undertaking*? If No, when will the final signal list be provided?	Yes ☐ No ☐

B1.4.19. Simulation model

Has the electrical simulation model for the *wind power plant* been submitted to the *electricity supply undertaking*? If No, when will the final simulation model be provided?	Yes ☐ No ☐

B1.4.20. Verification report

Has the verification report been submitted to the *electricity supply undertaking*? If No, when will the verification report be provided?	Yes ☐ No ☐

B1.4.21. Signature

Date of commissioning	
Company	
Person responsible for commissioning	
Signature	

B1.5. Appendix 1 for plant category D

Please fill in the documentation form with preliminary data for the *wind power plant* and send it to the electricity *supply undertaking* no later than three months **before** the date of commissioning.

Please fill in the documentation form with specific data for the entire *wind power plant* and send it to the electricity *supply undertaking* no later than three months **after** the date of commissioning.

The required documentation comprises the following:

B1.5.1. Identification

Plant	Description of the *plant*:
GSRN number	
Plant owner name and address	
Plant owner tel. no.	
Plant owner e-mail	
Type/model	
Voltage (nominal)	
Rated power (data sheet)	

B1.5.2. Voltage dip tolerances

Will the *wind power plant* remain connected to the *public electricity supply grid* during voltage dips as specified in section 3.3.1?	Yes ☐ No ☐
Is a simulation enclosed, documenting that the Low Voltage Fault Ride Through (LVFRT) requirements have been met? If No, how is compliance then documented?	Yes ☐ No ☐

B1.5.3. Voltage quality

Please state how each power quality parameter result was achieved.

Were the values calculated?	Yes ☐ No ☐
Were the values measured?	Yes ☐ No ☐
Is a report enclosed, documenting that the calculations or measurements meet the emission requirements? If No, how are the calculations or measurements documented?	Yes ☐ No ☐

B1.5.3.1. DC content

Does the DC content at normal operation exceed 0.5% of the *rated current*?	Yes ☐ No ☐

B1.5.3.2. Asymmetry

Does the asymmetry at normal operation and during faults exceed 16A?	Yes ☐ No ☐
In case of a *wind power plant* made up of single-phase *electricity-generating units*, have you taken measures to ensure that the above limit is not exceeded?	Yes ☐ No ☐

B1.5.3.3. Flicker

Is the *flicker* contribution for the *wind power plant* below the limit value?	Yes ☐ No ☐

B1.5.3.4. Harmonic distortions

Are all *harmonic distortions* for the *wind power plant* below the limit values?	Yes ☐ No ☐

B1.5.3.5. Interharmonic distortions

Are all *interharmonic distortions* for the *wind power plant* below the limit values?	Yes ☐ No ☐

B1.5.3.6. Distortions from 2-9 kHz

Emission of distortions with frequencies in the 2-9 kHz range is determined by the *electricity supply undertaking*. Is the requirement met?	Yes ☐ No ☐

B1.5.4. Connection and synchronisation

Can the *wind power plant* be started and generate power continuously within the *normal production* range limited only by the protective settings?	Yes ☐ No ☐
Do connection and synchronisation occur three minutes, at the earliest, after voltage and frequency have come within the *normal production* range?	Yes ☐ No ☐

B1.5.5. Active power control at overfrequency

Is the *wind power plant* equipped with a *frequency response* function?	Yes ☐ No ☐

B1.5.6. Frequency control

Is the *wind power plant* equipped with a *frequency control* function as specified in section 5.2.2?	Yes ☐ No ☐

B1.5.7. Absolute power constraint function

Is the *wind power plant* equipped with an *absolute power constraint* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.5.8. Delta power constraint function

Is the *wind power plant* equipped with a *delta power constraint* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.5.9. Ramp rate constraint function

Is the *wind power plant* equipped with a *ramp rate constraint* function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.5.10. System protection

Is the *wind power plant* equipped with a system protection function?	Yes ☐ No ☐
Is the function activated?	Yes ☐ No ☐

B1.5.11. Reactive power control

Reactive power can be controlled by means of	*Q control* ☐ *Power factor control* ☐ *Voltage control* ☐

B1.5.12. Q control

Is the control function activated with a set point of ______ VAr? (Value may not differ from 0 VAr, unless agreed with the *electricity supply undertaking*).	Yes ☐ No ☐

B1.5.13. Power factor control

Is the control function deactivated?	Yes ☐ No ☐

B1.5.14. Voltage control

Is the *wind power plant* equipped with a *voltage control* function as specified in section 5.3.3?	Yes ☐ No ☐

B1.5.15. Protection against electricity system faults

B1.5.15.1. Relay settings

Please state current values at the time of commissioning in the table below.

Protective function	Symbol	Setting		Trip time	
Overvoltage (step 3)	$U_{>>>}$		V		ms
Overvoltage (step 2)	$U_{>>}$		V		ms
Overvoltage (step 1)	$U_{>}$		V		s
Undervoltage (step 1)	$U_{<}$		V		s
Overfrequency	$f_{>}$		Hz		ms
Underfrequency	$f_{<}$		Hz		ms
Change of frequency	*df/dt*		Hz/s		ms

B1.5.16. Single-line representation

Is a single-line representation for the *wind power plant* enclosed with the documentation? If No, when will the final single-line representation be provided?	Yes ☐ No ☐

B1.5.17. PQ diagram

Has the final PQ diagram been submitted to the *electricity supply undertaking*? If No, when will the final PQ diagram be provided?	Yes ☐ No ☐

B1.5.18. Signal list

Has the final signal list been submitted to the *electricity supply undertaking*? If No, when will the final signal list be provided?	Yes ☐ No ☐

B1.5.19. Simulation model

Has the electrical simulation model for the *wind power plant* been submitted to the *electricity supply undertaking*? If No, when will the final simulation model be provided?	Yes ☐ No ☐

B1.5.20. Verification report

Has the verification report been submitted to the *electricity supply undertaking*? If No, when will the verification report be provided?	Yes ☐ No ☐

B1.5.21. Signature

Date of commissioning	
Company	
Person responsible for commissioning	
Signature	