Technical regulation 3.2.3 for thermal plants above 11 kW

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Revision view

Section no.	Text	Revision	Date
All	The regulation was updated following public consultation no. 2. Editorial errors were corrected. Changes were made to accommodate public consultation responses and include: Section 1.2 definitions updated and other sections updated with relevant text. Requirements clarified in sections 3.3.2.2, 3.3.2.3, 5.2.3.3, 5.3, 6.1.3 and 9.1. New figure 8, updated figures 3, 12, 14, 15, 16.	1	10.01.2017
All	Consultation document submitted for public consultation on 24 November 2016. Changes include: New definitions introduced in section 1.2. Asynchronous generator introduced in section 2.1. Plant type B introduced in section 3.3.1.2 Generator, step-up transformer, excitation system and PSS function combined in a new section 5.5. Text reworded and added to sections 6.1 and 6.1.1. 10 MW limit introduced in section 7.3 Corrections and clarifications made in sections 8 and 9. Corrections to ensure consistency made in Appendix 1.	0.a	24.11.2016
All	Consultation document submitted for public consultation on 26 July 2016. TR 3.2.3 and TR 3.2.4. merged into one technical regulation and layout harmonised with other technical regulations for grid connection. Section 2 updated and harmonised with other technical regulations. Plant category A2, B, C and D added. Section on emergency power units added. Change to frequency band made. Tolerance requirements for voltage dips between DK1 and DK2 harmonised. New signal list section added. New section with requirements for electrical simulation models added. New format for Appendix 1.	0	25.07.2016

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Reading instructions

This regulation contains the technical and functional minimum requirements which thermal *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 to 7 contain the technical and functional minimum requirements for thermal *plants* in Denmark. Section 8 contains documentation requirements, and section 9 contains requirements for the electrical simulation models for the different *plant* categories.

The technical requirements of the regulation are divided into four *plant categories* as described in sections 1.2.5 and 2.2.

The regulation makes extensive use of terminology and definitions. The key ones are found in section 1. In the 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 AVR

Abbreviation for automatic *voltage control.* See section 1.2.56 for a more detailed description.

1.1.2 $f_<$

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

1.1.3 $f_>$

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

1.1.4 f_R

f_R denotes the frequency at which a *plant* is to begin downward adjustment with the agreed *droop*. See section 5.1.1 for a more detailed description.

1.1.5 f_x

f_x, where x may be 1 to 4 or minimum and maximum, are points used for frequency control and described in more detail in section 5.1.2.

1.1.6 I_k

I_k denotes the *short circuit current*. See section 1.2.30 for a more detailed description.

1.1.7 I_n

I_n is the *rated current,* i.e. the maximum continuous current that a *plant* is designed to supply. See section 1.2.43 for a more detailed description.

1.1.8 $P_{current}$

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

1.1.9 P_{min}

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

1.1.10 P_n

P_n denotes the *rated power* of a *plant*.

1.1.11 PCC

Point of Common Coupling *(PCC).* See section 1.2.32 for a more detailed description.

1.1.12 PCI

Point of Connection in Installation (*PCI*) is the point in the installation where the *plant* is connected and where consumption is connected. See section 1.2.25 for a more detailed description.

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

1.1.14 PF
Power Factor (*PF*). See section 1.2.10 for a more detailed description.

1.1.15 PGC
Point of Generator Connection (*PGC*) is the point defined by the supplier of a *plant* as the *plant* terminals. See section 1.2.21 for a more detailed description.

1.1.16 POC
Point of Connection (*POC*). See section 1.2.39 for a more detailed description.

1.1.17 Q_{max}
Q_{max} denotes the maximum level of reactive power that the *plant* can supply.

1.1.18 Q_{min}
Q_{min} denotes the minimum level of reactive power that the *plant* can absorb.

1.1.19 Q_n
Q_n denotes the reactive *rated power.*

1.1.20 RMS
RMS is the abbreviation for Root-Mean-Square.

1.1.21 S_k
S_k denotes the *short circuit power*. See section 1.2.28 for a more detailed description.

1.1.22 S_n
S_n denotes the rated apparent power for a *plant*.

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

1.1.24 U_c
U_c denotes the *normal operating voltage*. See section 1.2.45 for a more detailed description.

1.1.25 U_{max}
U_{max} denotes the maximum value of the *rated voltage* U_n that the *plant* may be exposed to.

1.1.26 U_{min}
U_{min} denotes the minimum value of the *rated voltage* U_n that the *plant* may be exposed to.

1.1.27 U_n
U_n denotes the *rated voltage*. See section 1.2.42 for a more detailed description.

1.1.28 U_{PGC}

U_{PGC} denotes the voltage measured on the *generator's* terminals. See section 1.2.21 for a more detailed description.

1.1.29 U_{POC}

U_{POC} denotes the *normal operating voltage* in the *POC*. See section 1.2.39 for a more detailed description.

1.1.30 UTC

UTC is the abbreviation for Coordinated Universal Time (Universal Time, Coordinated).

1.2 Definitions

This section contains the definitions used in this document.

1.2.1 Plant

A unit which produces three-phase alternating current and where there is a direct functional correlation between the unit's main components.

In case of doubt, the *transmission system operator* decides whether a *plant* can be considered as consisting of one or more *plants* under the rules of this regulation.

1.2.2 Plant service life

The time that the *plant* is connected to the *public electricity supply grid* and has *plant* status category B: *Plant* in operation, see TR 5.1.2.

1.2.3 Plant owner

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

1.2.4 Plant infrastructure

Plant infrastructure is the electrical infrastructure connecting the *Point of Generator Connection (PGC)* for the given *generators* in a *plant* and the *Point of Connection (POC).*

1.2.5 Plant categories

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

- A1. *Plants* up to and including 11 kW
- 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.

1.2.6 Plant operator

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

1.2.7 House-load operation

Operating condition whereby a *plant* is operated in isolation from the *public electricity supply grid* and with its internal consumption as the only load.

1.2.8 COMTRADE

COMTRADE (Common Format for Transient Data) is a standardised file format specified in IEEE C37.111-2013 [ref. 27]. The format is designed for the exchange of information on transient phenomena occurring 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.

1.2.9 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 for which the mean value is calculated. Frequency measurements must be made continuously, so that a new value is calculated every 20 ms.

df/dt is calculated as the difference between the frequency calculation just carried out and the frequency calculation made 80-100 ms ago.

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

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

1.2.11 Power Factor control
Power Factor control is the control of reactive power proportionally to active power generated. See section 5.2.2 for a more detailed description.

1.2.12 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 across 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.

1.2.13 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.*

1.2.14 Frequency control
The *frequency control* function controls active power with the aim of stabilising the grid frequency. See section 5.1.2 for a more detailed description.

Note 1:
FSM, Frequency Sensitive Mode.
FSM is also used in connection with the frequency control state or the frequency control band.

1.2.15 Frequency response

Frequency response is the automatic upward or downward adjustment of active power as a function of grid frequencies below or above a certain frequency f_R with a view to stabilising the grid frequency. See section 5.1.1 for a more detailed description.

Note 1:
LFSM-O, Limited Frequency Sensitive Mode – Overfrequency.
The operational mode in which a plant reduces active power if the system frequency exceeds a set value.

LFSM-U, Limited Frequency Sensitive Mode – Underfrequency.
The operational mode in which a plant increases active power if the system power drops below a set value.

1.2.16 Full-load voltage range

Voltage range at the *POC* in which a *plant* can supply *rated power*.

1.2.17 Generator-remote faults

A *generator-remote fault* refers to a fault located at such a distance from the generator, that the share of AC of the initial *short-circuit current* (I_k) from the generator in the event of a three-phase short-circuit is less than 1.8 times the generator's *rated current*.

1.2.18 Generator feeder

Electrical connection that connects the generator/machine transformer to the *public electricity supply grid*.

1.2.19 Generator convention

The sign for active/reactive power indicates the power flow as 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.

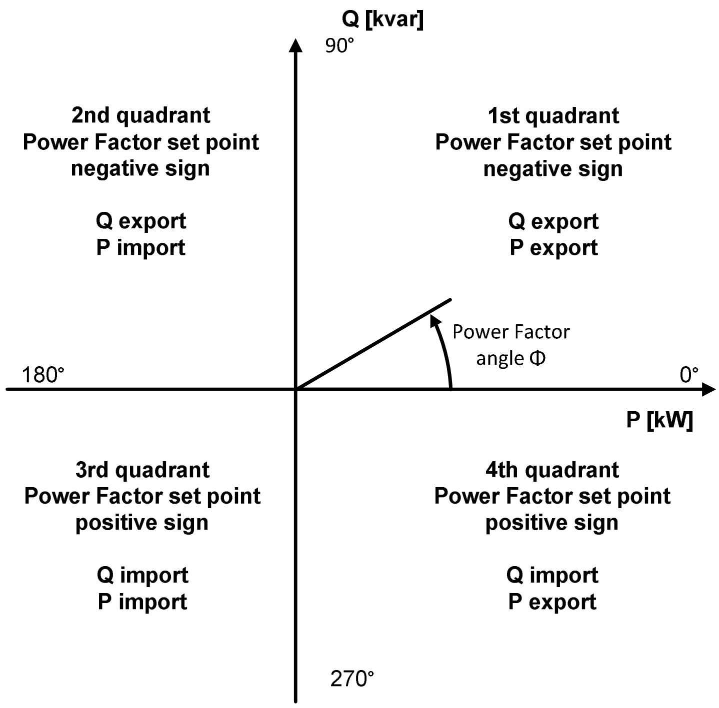

Figure 1 Definition of signs for active and reactive power and Power Factor set points [ref. 16 and 17].

1.2.20 Generator-near faults

A *generator-near fault* refers to a fault located at such a distance from the generator, that the share of AC of the *initial short-circuit current* (I_k) from the generator in the event of a three-phase short-circuit is at least 1.8 times the generator's *rated current*.

1.2.21 Point of Generator Connection (PGC)

The *Point of Generator Connection* is the point in the *plant infrastructure*, where the terminals/generator terminals for the *plant* are located.

1.2.22 Ramp rate limit (load limit)

Ramp rate limit refers to the control of the interval of active power using a set point-defined maximum increase/reduction (ramp rate) of active power. See section 5.1.3.2 for a more detailed description.

1.2.23 Rapid voltage changes

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

1.2.24 Installation connection

A *plant* is *installation connected* if the *plant* is connected to the *public electricity supply grid* via its own installation. This applies even if internal consumption accounts for the *plant's* entire electricity generation.

1.2.25 Point of Connection in Installation (PCI)

The *Point of Connection in Installation* (*PCI*) is the point in the installation where *the plant* in the installation is connected or can be connected, see Figure 3 for the typical location.

1.2.26 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** *rated voltage* of 100 kV.

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

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 Short-circuit power (S_k)
The *short-circuit power* (S_k) is the amount of power [VA] that the *public electricity supply grid* can supply at the *Point of Connection* in the event of a short-circuit of the *plant's* terminals.

1.2.29 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* rated apparent power S_n.

The *short-circuit ratio* definition is also used for generators, where it is the reciprocal of the saturated synchronous reactance in p.u.

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

1.2.31 Load regulator (absolute power limit)
Regulates active power to an arbitrary operating level specified by a set point. A *load regulator (absolute power limit)* can also be used to achieve part load. See section 5.1.3.1 for a more detailed description.

1.2.32 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 placed closest to the *public electricity supply grid*, see Figure 3.

The *electricity supply undertaking* determines the *Point of Common Coupling*.

1.2.33 'Local mode' power oscillations
'Local mode' power oscillations refer to low-frequency (approx. 0.7-2.0 Hz) power oscillations between the public electricity system and a generation facility.

1.2.34 Excitation control system
A feedback control system that encompasses the synchronous generator and its *excitation system*, see Figure 2.

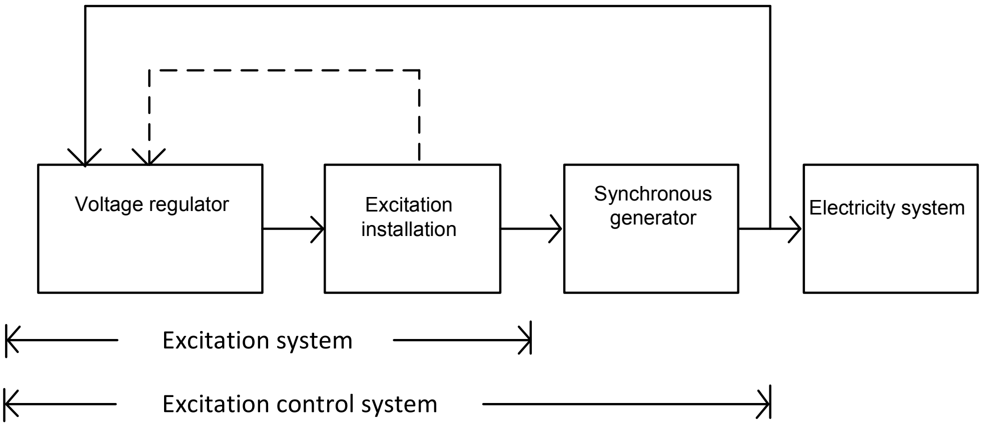

Figure 2 Excitation system

1.2.35 Excitation system
Equipment ensuring the necessary excitation of a synchronous generator, including excitation power, control and adjustment functions and limit functions, see Figure 2.

1.2.36 Minimum power
The minimum *effective power* which a *plant* can supply continuously in *normal operating mode* under the current external operating conditions and while observing the *full-load voltage-frequency range* at the *POCs*.

Minimum power varies with the external operating conditions and is therefore not a fixed value.

1.2.37 Metered data collector
The umbrella term metered data collector refers to the (monopoly) part of a transmission or distribution company responsible for ensuring the collection and distribution of required metered data.

Note: The metered data collector may choose to act as a metering point administrator directly, or to outsource the task to another enterprise.

1.2.38 Grid connection
A *plant* is *connected to the grid*, if the *plant* is connected directly to the *public electricity supply grid*.

1.2.39 Point of Connection (POC)
The *Point of Connection (POC)* is the point in the *public electricity supply grid,* where the *plant* is connected.

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*.

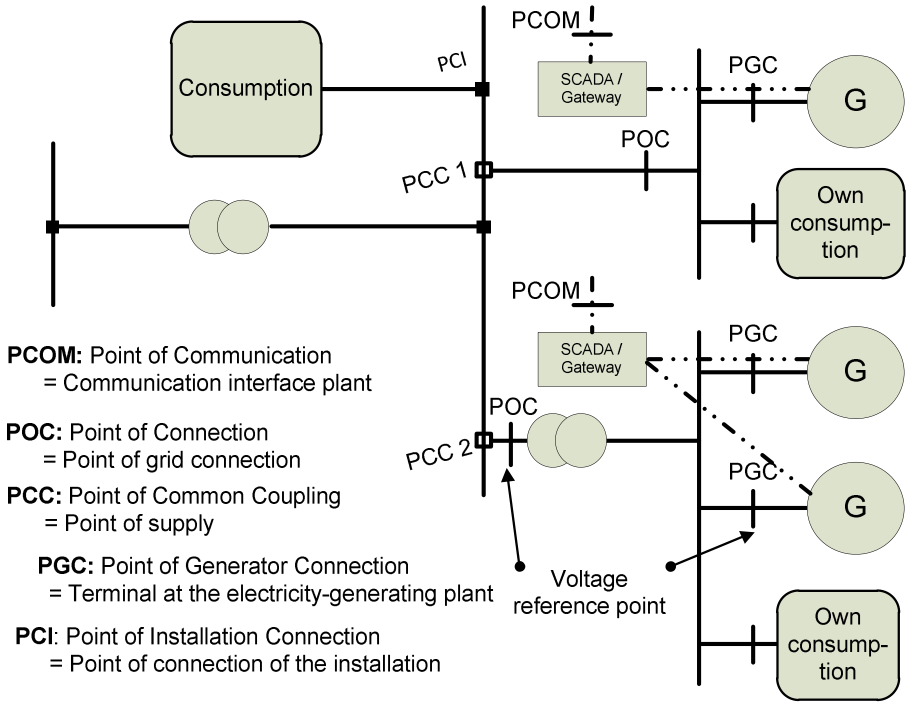

Figure 3 Example of plant grid connection with the aim of positioning defined interfaces.

1.2.40 Effective power

Effective power is the positive or negative sum of the active power which a *plant* exchanges with the grid at the *connection points*. The power flow direction from the *plant* to the *public electricity supply grid* is expressed with a positive value.

1.2.41 Rated power (P_n)

The *rated power* (P_n) of a *plant* is the highest active net power which the *plant* is approved to continuously supply at the *Point of Common Coupling* under normal operating conditions.

1.2.42 Rated voltage (U_n)

The voltage at the *POC* for which a grid is defined and to which operational characteristics refer. *Rated voltage* is denoted by U_n.

Internationally standardised voltage levels are shown in Table 1.

1.2.43 Rated current (I_n)

Rated current (I_n) is defined as the maximum continuous current a *plant* is designed to provide under normal operating conditions.

1.2.44 Rated value for apparent power (S_n)

The *rated value for apparent power* (S_n) is the highest output, consisting of both the active and reactive component, which a *plant* is designed to continuously supply.

1.2.45 Normal operating voltage (U_c)

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

1.2.46 Normal operating condition

The process, configuration and connection a *plant* has been designed for and in which a *plant* is normally operated.

The configuration of a *plant* may deviate from *normal operating condition*, for example when a fault occurs in parts of the *plant*, during start-up and shutdown, during house-load operation, or when the unit operates at overload.

There may be uncertainty about what constitutes the *normal operating condition*, for example if a *plant* under normal conditions will be operated both with and without heat production or using different fuels. In such cases, the transmission system operator must decide, in consultation with the *plant operator*, what is to be considered *normal operating condition* and may demand that the provisions in this regulation be met in several different operating conditions.

1.2.47 Normal production

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

1.2.48 Emergency power unit

An *emergency power unit* is a *plant* connected to an installation or part of an installation for the purpose of supplying electricity to the installation in situations where the *public electricity supply grid* is unable to supply electricity.

1.2.49 Isolated island operation

Operating state whereby a grid or part thereof is operated in isolation after being disconnected from the interconnected system, and where one or more *plants* supply the isolated grid area.

1.2.50 Power infrastructure

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

1.2.51 Overload capacity

Overload capacity is the *effective power* a *plant* can supply in addition to the rated power (P_n) for at least 1 hour under rated external operating conditions, while the *full-load voltage-frequency range* at the POCs is observed.

Overload capacity can be obtained, for example, by disconnecting heat production for a *plant* normally operated with heat production, or by disconnecting high-pressure preheaters in a steam power *plant*. The result of overload operation is often reduced efficiency, increased costs and/or reduced plant life.

1.2.52 PSS function

The *PSS function* (Power System Stabiliser) is a damper unit for the *excitation system* which aims to dampen the oscillations in the active power production from the *plant.*

1.2.53 Q control

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

1.2.54 Interconnected electricity supply system

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

1.2.55 Voltage reference point

Metering point used for *voltage control*. The *voltage reference point* is either in the *PGC*, the *POC,* or some point in between.

1.2.56 Voltage control

Voltage control is the control of reactive power with the configured *droop* for the purpose of achieving the desired voltage in the *voltage reference point*.

1.2.57 Droop

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

1.2.58 Transmission system operator (TSO)

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

1.2.59 Thermal plant

A *thermal plant* is a *plant* that produces 3-phase alternating current using a thermodynamic process.

1.2.60 Island operation

Mode of operation that comprises *house-load operation* and *isolated island operation*.

2. Objective, scope of application and regulatory provisions

2.1 Objective

The objective of technical regulation TR 3.2.3 is to specify the minimum technical and functional requirements that a thermal plant with a synchronous or asynchronous generator and rated power above 11 kW must comply with in the Point of Connection when the 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 market players 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 thermal plant must comply with Danish legislation, including the Danish Heavy Current Regulation (Stærkstrømsbekendtgørelsen) [ref. 4], [ref. 5], the Joint Regulation (Fællesregulativet) [ref. 3], the Machinery Directive (Maskindirektivet) [ref. 6], [ref. 7] and the grid connection and grid use agreement (nettilslutnings- og netbenyttelsesaftalen).

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

2.2 Scope of application

A *plant* connected to the *public electricity supply grid* must comply with the provisions of this regulation throughout the *plant's service life*.

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 on the *positive list* for *plant components* or *plants* when they are assessed to be in conformity with this regulation.

2.2.1 New plants

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

As regards *plants*, the construction of which was finally 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 comes into force, exemption can be applied for in accordance with section 2.9, and any relevant documentation should be enclosed.

2.2.2 Existing plants

A *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 plants

Existing *plants* to which substantial functional modifications are made must comply with the provisions of this regulation relating to such modifications. Before modifications are made, the *plant owner* must seek approval for modification of the *plant* from the *transmission system operator*.

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

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

In case of doubt, the *transmission system operator* decides whether a specific modification is substantial.

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*, *plant operator* and *electricity supply undertaking* regarding the connection of *plants* to the *public electricity supply grid*.

Together with the market regulations, the technical regulations (including the system operation regulations) constitute the set of rules which the *plant owner*, *plant operator* and *electricity supply undertaking* must comply with when operating a *plant:*

- Technical regulation TR 5.8.1 'Metering data for system operation purposes' [ref. 10]
- Technical regulation TR 5.9.1 'Ancillary services' [ref. 11]
- Regulation D1 'Settlement metering' [ref. 12]
- Regulation D2 'Technical requirements for electricity metering' [ref. 13]
- Regulation E 'Settlement of environmentally-friendly electricity generation' [ref. 14]
- Regulation E – (appendix) 'Guidelines for net settlement of autogenerators' [ref.15]

- Technical regulation TR 3.2.3 'Technical regulation 3.2.3 for thermal plants with a power output above 11 kW'

In case of discrepancies 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 at 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* or the *transmission system operator*.

This regulation does not set requirements for emergency power units as long as they are not operated in parallel with the public electricity supply grid for more than five minutes per month. Parallel operation in connection with unit maintenance or commissioning testing is not included in the five minutes.

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

The *plant owner* is responsible for deciding whether to safeguard the *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.

2.3.1 Exceptions from minimum requirements

The following functionalities are excepted from the minimum requirements:

- The system protection requirement has not been included as a minimum requirement to be fulfilled in order to be granted grid connection. See section 5.3.4 for further details.

- The start-up from dead grid requirement has not been included as a minimum requirement in order to be granted grid connection. See section 3.3.6 for further details.

2.4 Statutory authority

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 market players 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.

2.5 Effective date

This regulation comes into force on **10 January 2017** and replaces:

- Technical regulation 3.2.3 for thermal power station units of 1.5 MW or more, version 4.1, dated 1 October 2008.
- Technical regulation 3.2.4 for thermal power station units of 1.5 MW or more, version 4.1, dated 1 October 2008.

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 *plants*, the construction of which was finally 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 comes into force, an exemption can be applied for in accordance with section 2.9, and any relevant documentation should be enclosed.

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 Breaches

The *plant owner* must ensure that the provisions of this regulation are complied with throughout the *plant's service life.*

A *plant* must be regularly maintained 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 *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 *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

or

- the plant was ordered before the regulation was registered with the Danish Energy Regulatory Authority, see section 2.5.

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 – taking the views of the parties involved into consideration where possible.

Complaints about the decisions 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.
   DS/EN 50160/Corr.: **Dec. 2010:2011**
   DS/EN 50160:**2010/A1:2015**
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.
   DS/EN 60204-1/Corr.:2010
7. **DS/EN 60204-11:2002**: Safety of machinery – Electrical equipment of machines – Part 11: Requirements for HV equipment for voltages above 1000 VAC or 1500 VDC and not exceeding 36 kV.
   DS/EN 60204-11/AC:2010
8. **IEC-60870-5-104:2006**: Telecontrol equipment and systems, Part 5-104.
9. **IEC 61000-4-15:2010**: Testing and measurement techniques – Section 15: Flicker metre – Functional and design specifications.
10. **Technical regulation TR 5.8.1:** 'Metered data for system operation purposes', 28 June 2011, version 3, document no. 17792-11.
11. **Technical regulation TR 5.9.1:** 'Ancillary services', 6 July 2012, version 1.1 , document no. 91470-11.
12. **Regulation D1:** 'Settlement metering', March 2016, version 4.11, document no. 16-04092-1.
13. **Regulation D2:** 'Technical requirements for electricity metering', May 2007, version 1, document no. 263352-06.
14. **Regulation E:** 'Settlement of environmentally friendly electricity generation 2009', July 2009, rev. 1, document no. 255855-06.
15. **Regulation E – Appendix:** 'Availability of local CHP units', version 4, 25 June 2010, document no. 35139/10.
16. **IEC 61850-7-4 Ed2.0:2010**: Basic communication structure for substation and feeder equipment – Compatible logical node classes and data classes.
17. **IEEE 1459:2010**: Standard definitions for the measurement of electrical power quantities under sinusoidal, non-sinusoidal, balanced or unbalanced conditions.
18. **IEC 60071-1:2006**: Insulation co-ordination – Part 1: Definitions, principles and rules.
    DS/EN 60071-1/A1:2010: Insulation co-ordination – Part 1: Definitions, principles and rules
19. **DS/EN 60034-1:2004**: 'Rotating electrical machines – Part 1: Rating and performance'
20. **DS/EN60034-3:2008**: 'Rotating electrical machines, part 3: Specific requirements for turbine-type synchronous machines'.
21. **DS/EN 60034-16-1: 2011:** 'Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Chapter 1: Definitions',
22. **DS/CLC/TR 60034-16-3:2004:** 'Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Section 3: Dynamic performance'.
23. **IEC 61850-8-1:2004**: 'Communication networks and systems in substations – Part 8-1: Specific Communication Service Mapping (SCSM) – Mapping to MMS (ISO 9506-1 and 9506-2) and to ISO/IEC 8802-3'.
24. **IEEE 421.5-2016:** IEEE Recommended Practice for Excitation system Models for Power System Stability Studies

2.10.2 Informative references

25. **Research Association of the Danish Electric Utilities (DEFU) recommendation no. 16**: Voltage quality in low-voltage grids, 4th edition, August 2011.
26. **Research Association of the Danish Electric Utilities (DEFU) recommendation no. 21**: Voltage quality in medium-voltage grids, 3rd edition, August 2011.
27. **IEEE C37.111-24:2013:** Measuring relays and protection equipment – Part 24: Common format for transient data exchange (COMTRADE) for power systems.
28. **Research Association of the Danish Electric Utilities (DEFU) committee report 88**: Grid connection of local production facilities ('*Nettilslutning* af decentrale produktionsanlæg'), March 1991.
29. **Research Association of the Danish Electric Utilities (DEFU) technical report 293:** Relay protection for local production facilities with synchronous generators ('Relæbeskyttelse ved decentrale produktionsanlæg med synkrongeneratorer'), 2nd edition, June 1995.
30. **IEEE Std. 421.2-2014:** 'IEEE Guide for Identification, Testing and Evaluation of the Dynamic Performance of Excitation Control Systems'.
31. **Research Association of the Danish Electric Utilities (DEFU) technical report 303:** Relay protection of power plants' auxiliary supply facilities ('Relæbeskyttelse af kraftværkers egenforsyningsanlæg'), July 1992.
32. **DS/EN60076-1:2012:** 'Power transformers, part 1: General',
33. **DS/CLC/TS 50549-1:2015**: Requirements for generating plants connected in parallel with a distribution network – Part 1: Generating plants larger than 16A per phase connected to a low voltage network.
34. **DS/CLC/TS 50549-2:2015**: Requirements for generating plants connected in parallel with a distribution network – Part 2: Generating plants connected to a medium-voltage network.
35. **IEEE PES-TR1:2013**: Dynamic Models for Turbine-Governors in Power System Studies.

3. Tolerance of frequency and voltage deviations

A *plant* must be able to withstand frequency and voltage deviations in the *Point of Connection* under normal operating conditions while not reducing the active power.

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.

The *plant* must be able to start up with frequencies and voltages in the *Point of Connection* within the *normal production* range described in section 3.2.

3.1 Determination of voltage level

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

The *normal operating voltage*, U_c, 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*. For rated voltages up to 1 kV, $U_c = U_n$.

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

If the normal operating voltage range U_c - 10% is lower than the minimum voltage U_{min} indicated in Table 1, the requirements for production in the event of frequency/voltage variations may be adjusted so as not to overload the *plant*.

For the 400 kV voltage level, the *normal operating voltage* range is defined as U_c +5%, -10%.

Voltage level descriptions	**Rated 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 Rated, minimum and maximum voltage [ref. 1 and ref. 2]

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

The *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

The following requirements apply to *plant* category A2, B, C and D.

Within the *normal production* range, a *plant* must be able to start, synchronise and generate power continuously within the design specifications.

Within the *normal production* range, the *normal operating voltage* is U_c±10%, with the exception of 400 kV, see section 3.1, and the frequency range is 49.00 Hz to 51.00 Hz.

Note: Note that for the 400 kV voltage level, the *normal operating voltage range,* U_c, is defined as +5%, -10%.

The overall requirements for active power generation which *plants in category* A2, B, C and D must comply with in the event of frequency and voltage deviations are shown in Figure 4.

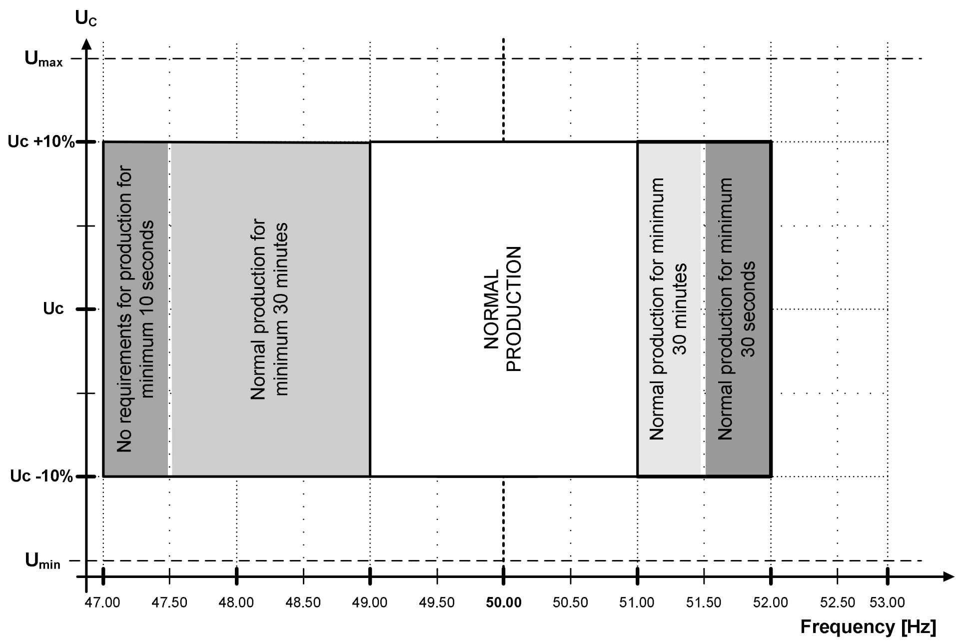

Figure 4 Active power requirements in the event of frequency and voltage fluctuations for plants in category A2, B, C and D.

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

3.3 Abnormal operating conditions

This section defines requirements for *plants* under abnormal operating conditions. The requirements not only contribute to stability in the public electricity supply grid, but also plant resilience in relation to various fault incidents. The following requirements will be differentiated for *plant category* A2, B, C and D.

The *plant* must be designed to withstand transitory (80-100 ms) phase jumps of up to 20° in the *Point of Connection* without outage.

3.3.1 Tolerance of frequency deviations

The *plant* must be able to withstand transient frequency gradients (*df/dt*) of up to ±2.5 Hz/s in the connecting point without disconnecting.

A reduction in active power is permitted in the frequency range from 49 Hz to 47.5 Hz. In this range, active power may be reduced by 6% of P_n per Hz.

3.3.2 Voltage dip tolerance

The *plant* must be designed to withstand a voltage dip without disconnection, as shown in Figure 5, Figure 6 or Figure 7. In the figures below, the Y-axis indicates the smallest line-to-line voltage for the 50 Hz component.

For areas I, II and III, shown in Figure 5, Figure 6 and Figure 7, the following applies:

- Area I: The *plant* must be able to remain connected and maintain *normal production*.
- Area II: The *plant* must be able to remain connected. The *plant* must provide maximum voltage support within the *plant's* design limits.
- Area III: *Plant* disconnection is permitted.

If the voltage U_{POC} reverts to area I after 1.5 seconds during a fault sequence, a subsequent voltage dip will be regarded as a new fault situation, see section 3.3.4. If several successive fault sequences occur within area II and evolve into area III, disconnection is allowed.

3.3.2.1 Category A2 plants

There are no plant tolerance requirements for voltage dips for category A2.

3.3.2.2 Category B and C plants

Figure 5 and Figure 6 illustrate plant tolerance requirements for voltage dips for plants in categories B and C.

Plants in category B or C must be designed in such a way that POCs with rated voltage up to 100 kV can withstand voltage dips to 50% of the rated voltage for one second in all three phases, and voltage dips to 0% voltage for one second in one phase. See Figure 5 and Figure 6.

The plant tolerance for voltage dips is specified at P_n and PF=1.

Plants in category B with rated output less than 200 kVA is exempted from the plant tolerance requirements for voltage dips.

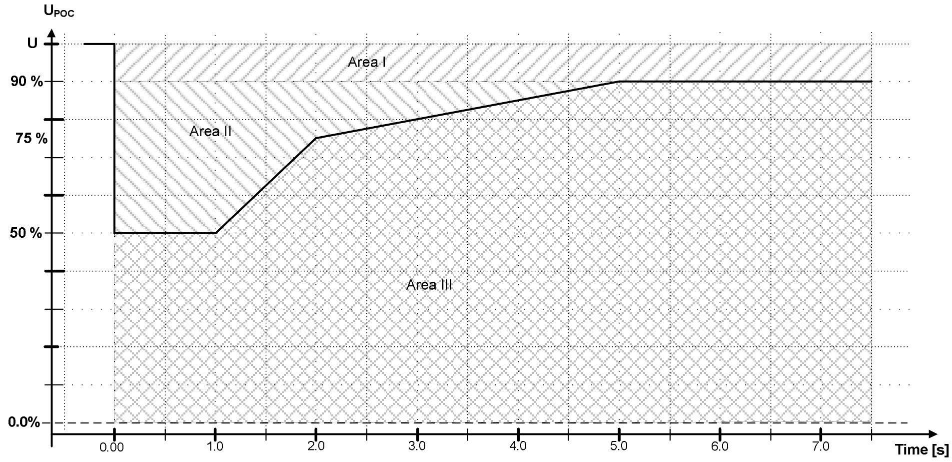

Figure 5 Tolerance requirements for three-phase voltage dips for plants in category B and C.

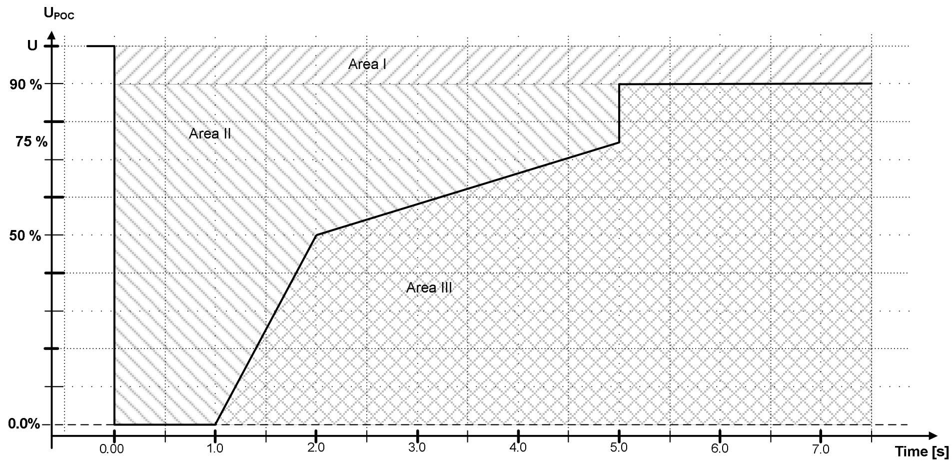

Figure 6 Tolerance requirement for single-phase voltage dips for plants in category B and C.

3.3.2.3 Category D plants

Figure 7 illustrates tolerance requirements for voltage dips for plants in category D. The requirement must be complied with in the event of symmetrical and asymmetrical faults. This means that the requirement applies in the event of faults in three, two or a single phase. The minimum time to withstand a voltage dip without disconnection is 150 ms for *plants* in Western Denmark (DK1) and Eastern Denmark (DK2).

The plant tolerance for voltage dips is specified at P_n and Q_{min}.

Plants in category D with a POC rated voltage above 100 kV must be able to withstand a one, two or three-phase *generator fault*, see section 1.2.17, of up to 5 seconds' duration.

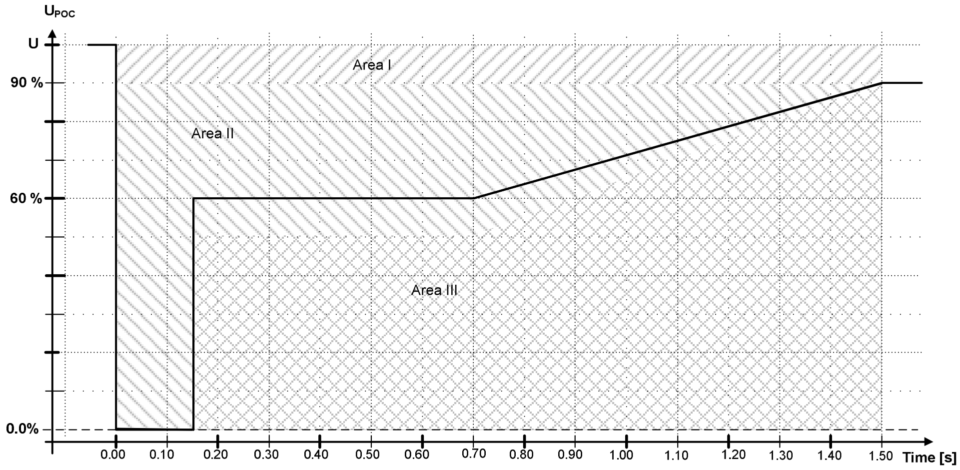

Figure 7 Tolerance requirement for voltage dips for category D plants.

3.3.3 Voltage support during voltage dips

In the event of faults in the public electricity supply grid, plants must provide voltage support to stabilise and raise the grid voltage.

3.3.3.1 Category A2, B and C plants

There are no voltage support requirements for voltage dips for category A2, B and C.

3.3.3.2 Category D plants

In the event of a fault sequence whereby the voltage in the *public electricity supply grid* moves into area II, *plants* in category D are required to provide voltage support.

3.3.4 Recurring voltage dips in the public electricity supply grid

The plant tolerance requirements for repeated voltage dips related to intentional or unintentional voltage dips in the public electricity supply grid are described in this section.

3.3.4.1 Category A2 and B plants

There are no tolerance requirements for repeated voltage dips for category A2 and B plants.

3.3.4.2 Category C and D plants

Plants in category C and D must remain connected after repeated voltage dips 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 any point in the *public electricity supply grid*.

In addition to the voltage dip requirements stated in section 3.3.2, *plants* must be designed to withstand repeated faults with the specifications stated in Table 2.

Type	**Duration of fault**
Three-phase short circuit	Short circuit for 150 ms
Phase-to-phase-to-earth short	Short circuit for 150 ms followed by a new

circuit/phase-to-phase short circuit	short circuit 0.3-0.8 seconds later, also with a duration of 150 ms
Phase-to-earth short circuit	Phase-to-earth fault for 150 ms followed by a new phase-to-earth fault 0.3-0.8 seconds later, also with a duration of 150 ms

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

The *plant* must have adequate energy reserves in auxiliary and process equipment to meet the requirements specified in Table 2.

The requirements in Table 2 are illustrated in Figure 2.

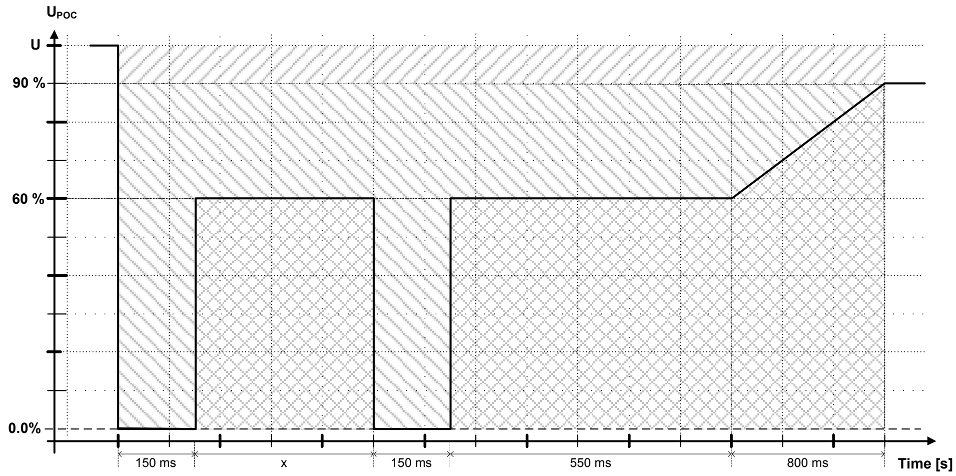

Figure 8 Tolerance for repeated faults

Phase voltage in affected phases during single-phase and two-phase voltage disturbances which must not lead to disconnection. The time interval, x, in the figure may vary between 300 and 800 ms.

3.3.5 Island operation

Plant requirements for *island operation* are specified in the following subsections.

3.3.5.1 House-load operation

House-load operation is a plant functionality that has impacted the public electricity supply grid. The requirement has been revised in this technical regulation and included as information.

3.3.5.1.1 Category A2, B, C and D plants

It is accepted that *plants* in category A2, B, C or D may be disconnected at frequencies and voltages outside the limits specified in sections 3 and 6, without switching from normal operation to *house-load operation*.

3.3.5.2 Island operation

A *plant* must be able to make the transition from *normal operation* to *island operation* directly, without stopping.

In the event of transition to *island operation*, a *plant* must be able to maintain the system frequency within the *normal production* range, unless this will result in the *effective power* becoming less than the *minimum power* or greater than P_n. This must be achieved during the transition to *island operation* by the *plant* performing *frequency control* in the same way as after a fault (LFSM-U and LFSM-O), and then immediately performing *frequency control* as during normal operation (FSM), in line with section 5.1.

Island operation must be maintained continuously, stably and safely, without the *plant* shutting down, as long as:

- the frequency and voltage ranges specified in section 3.2 are not exceeded
- there are no grid faults which exceed the voltage profiles and times during voltage dips specified in section 3.3
- the protective settings specified in section 6 are not exceeded.

The *plant* must be able to return to normal operation directly from *island operation* without stopping.

The transmission system operator's control centre reports changes in the electricity system's operational status.

3.3.5.2.1 Category A2, B and C plants

There is no requirement for *plants* in category A2 or B to be able to run in *island operation* mode.

A grid fault can cause unintentional *island operation*. Continuous operation of the *plan*t during unintentional *island operation* should be avoided as far as possible.

However, plants in category C must be able to supply an appropriate area during island operation based on a special operational supervisor agreement.

3.3.5.2.2 Category D plants

A *plant* in category D must be able to run island operation.

3.3.6 Start-up from a dead grid

For the purpose of re-establishing supply after a total system breakdown, it is necessary for a small number of *plants* in the *public electricity supply grid* to be able to start up from a dead grid.

Start-up from a dead grid is not a minimum requirement in order to be granted *grid connection* in the *public electricity supply grid*.

Fulfilment of this system requirement is handled by the *transmission system operator* by other means, such as via calls for tenders or negotiations.

4. Electricity quality

4.1 General

A *plant* must not give rise to inrush currents etc. at the *Point of Connection* of such a magnitude as to cause disruptive, temporary voltage changes.

4.2 Rapid voltage changes

4.2.1 Requirements for category A2, B, C and D plants

No switching in *a plant* may give rise to *rapid voltage changes d* (%) that exceed the limit values indicated in the table below.

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

Table 3 Limit values for rapid voltage changes d (%).

Rare voltage changes, such as voltage dips resulting from voltage restoration of *plant infrastructure* with connected step-up transformers, are excepted.

5. Control

The following requirements apply to *plant* category A2, B, C and D. All control functions mentioned in the following sections generally refer to the *Point of Connection*.

Before a *plant* can be connected to the public electricity supply grid, 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*.

In order to maintain security of supply, the *transmission system operator* must be able to activate or deactivate the specified control functions by agreement with the *plant owner and electricity supply undertaking.*

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

Table 4 below specifies the minimum control functionality requirements for *plants* in the four *plant categories*, see section 1.2.5.

Section 7 specifies the required signals for these control functions.

Category **Control function**	**A2**	**B**	**C**	**D**
Frequency response (5.1.1)	X	X	X	X
Frequency control (5.1.2)	-	-	X	X
Load regulator (absolute power limit) (5.1.3.1)	-	-	X	X
Ramp rate limit (5.1.3.2)	-	-	X	X
Q control (5.2.1)	X	X	X	X
Power Factor control (5.2.2)	X	X	X	X
Voltage control (5.2.3)	-	-	X	X
System protection (5.3.4) (not a minimum requirement)	-	-	X	X

Bracketed numbers in the various rows indicate the sections that describe the respective functions.

Table 4 Requirements for plant control functions.

The purpose of the various control functions is to ensure overall control and monitoring of the *plant's* output. External communication with one of the *plant's* control functions must be carried out through a single *communication interface,* as specified in section 7.

All set point changes specified in section 7 must be registered, along with identification of the party requesting the change. The registration is made by both the order initiator and the person who actively makes the change.

All set point changes or orders for output changes must be time stamped at intervals of no more than 5 minutes, referring to UTC.

5.1 Active power control functions

The following requirements apply to *plants* in category A2, B, C and D.

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

It must be possible to specify set points for active power with a resolution of 1% of P_n or higher.

It must be possible to set the frequency parameters in the active power control functions with a resolution of 10 mHz or less.

It must be possible to set the control *droops* with a resolution of 1% or less.

For all active power control functions, the accuracy of a completed or continuous control operation, including the accuracy at the set point, must not deviate by more than 2% of *P* over a period of 1 minute.

In addition to the general requirements in section 5, active power control functions must comply with the requirements outlined in the following sections.

5.1.1 Frequency response (LFSM-U and LFSM-O)

When frequency deviations occur in the *public electricity supply grid,* grid stability must be ensured by automatically increasing or decreasing active power when grid frequencies are above or below the reference frequency. This plant control function is referred to as *frequency response*. *Frequency response* is an autonomous function and the functionality requirement is differentiated based on plant size in the following subsections.

Frequency response must commence within 2 seconds after a frequency change is detected and active power must then be adjusted best possible.

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

Droops for controlling active power are illustrated in Figure 9 and Figure 10. In this context, *droop* is the change in active power as a function of the grid frequency. The *droop is* stated in per cent.

It must be possible to set the *droop* to a value in the range 2-8%.

It must be possible to set the f_{min} and f_{max} frequency points in Figure 9 and Figure 10 to any value in the 47.00-52.00 Hz range.

Frequency measurements must be carried out with a ± 10 mHz accuracy or higher.

The control function's sensitivity must be ± 10 mHz or higher.

5.1.1.1 Category A2 and B plants

In the event of overfrequency, a *frequency response* is required from *plants* in category A2 and B, which aims to reduce active power as a function of increasing frequency.

There is no requirement for A2 and B plants to ramp up active power in the event of underfrequency, LFSM-U.

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

It must be possible to set the f_{Rmax} frequency point to any value in the 50.10-52.00 Hz range. The standard value for f_{Rmax} is 50.20 Hz.

The f_{Rmax} setting is determined by the *transmission system operator*.

The standard value for *Droop 1* is 6%.

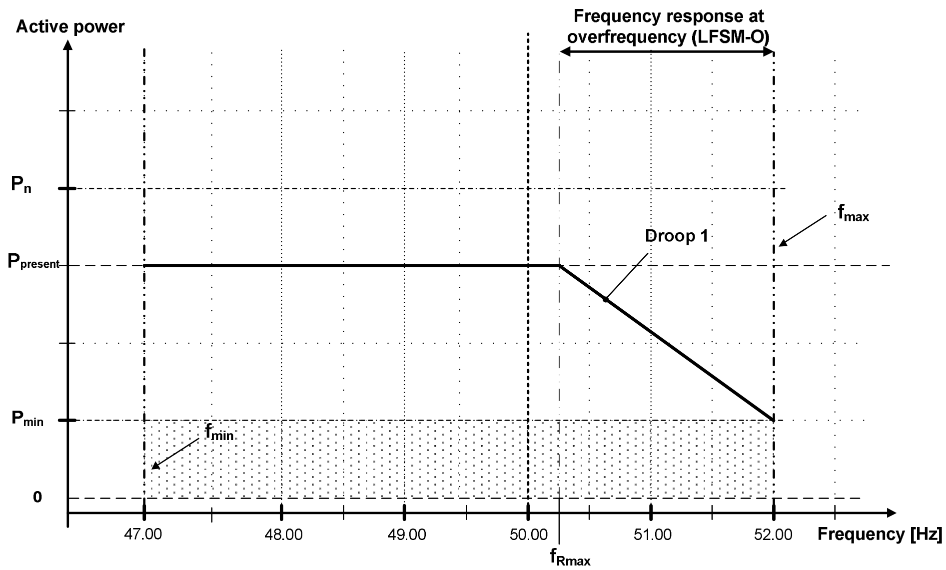

Figure 9 Frequency response in the event of overfrequency for category A2 and B plants.

5.1.1.2 Category C and D plants

In the event of overfrequency or underfrequency, a *frequency response* is required from *plants* in category C and D, which aims to reduce or increase the active power as a function of frequency.

It must be possible to set the *frequency control* function for all frequency points shown in Figure 10.

It must be possible to set the f_{Rmin} frequency point to any value in the 47.00-49.90 Hz range, and f_{Rmax} to any value in the 50.10-52.00 Hz range. The setting values for f_{Rmin} and f_{Rmax} are determined by the *transmission system operator*. The standard value for f_{Rmin} is 49.80 Hz and for f_{Rmax} it is 50.20 Hz.

The standard value for *Droop* 1 and 2 is 6%.

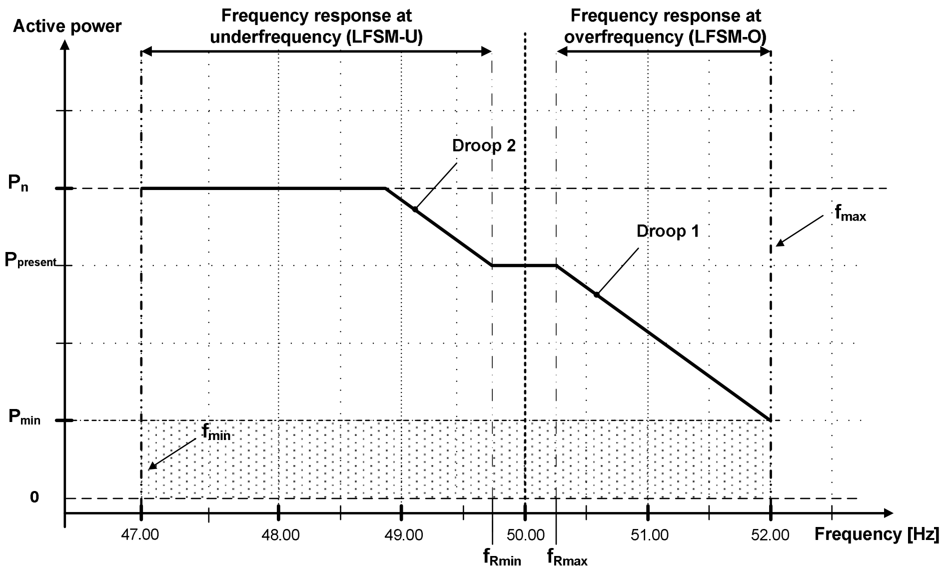

Figure 10 Frequency response in the event of underfrequency or overfrequency for plants in category C and D.

5.1.2 *Frequency control* (FSM)

In case of frequency deviations in the *public electricity supply grid*, the *plant* must have control functions that can provide *frequency control* in order to stabilise or restore the grid frequency (50.00 Hz).

5.1.2.1 Category A2 and B plants

There are no *frequency control* requirements for *plants* in category A2 and B.

5.1.2.2 Category C and D plants

Plants in category C and D must have control functions that can provide *frequency control*.

Figure 11 shows a general example of a *control* function. The specific parameters for frequency points, *droops*, control times etc., can vary depending on which services the *plant owner* wants the *plant* to supply and the geographic location of the *plant*. The specific settings for the various services are stated in the specifications for ancillary services.

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

Control according to a new parameter set for *frequency control* must be possible no later than 10 seconds from receipt of an order to change the parameters.

Frequency measurements must be carried out with a ± 10 mHz accuracy or higher. The control function's sensitivity must be ± 10 mHz or higher.

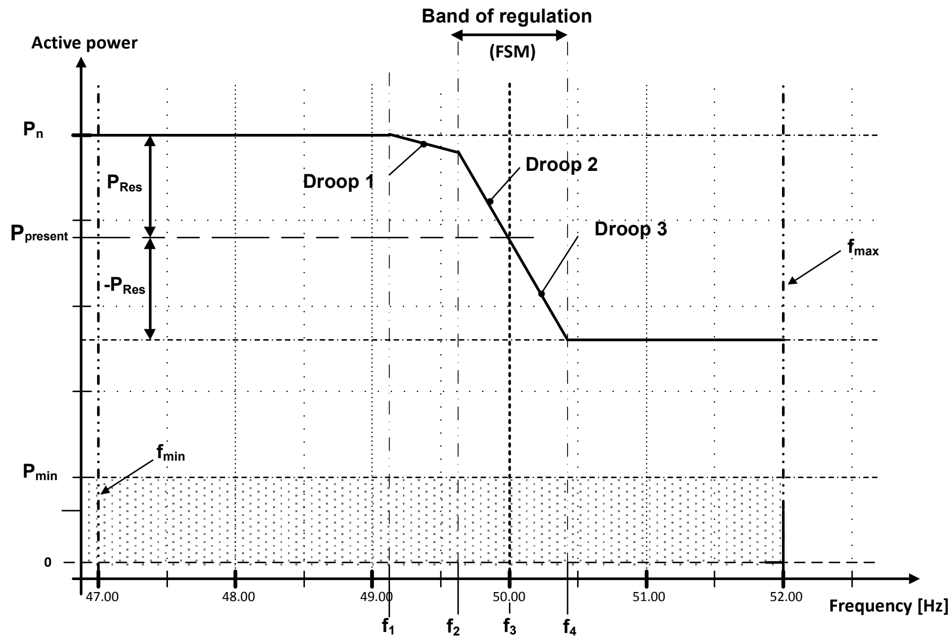

Figure 11 General frequency control principle for a plant.

5.1.3 Power limit – active power control

A *plant* must be equipped with control functions (limit functions) to control active power to ensure stable operation based on a selected operating point. Examples of the use of these control functions are load control based on a power schedule and secondary control based on centrally commanded control (FRR-a, FRR-m).

Control using a new power limit set point must commence within 2 seconds.

The required limit functions are specified in later sections.

5.1.3.1 Load regulator (absolute power limit)

A *load regulator (absolute power limit)* is used to limit the active power from a *plant* to a set point-defined value in the *Point of Connection*, for example to achieve part load.

5.1.3.1.1 Category A2 and B plants

Category A2 and B *plants* are not required to have a *load regulator* (*absolute power limit*) functionality.

5.1.3.1.2 Category C and D plants

Plants in category C and D must have a *load regulator (absolute power limit)* functionality.

5.1.3.2 Ramp rate limit (load ramp rate)

A *ramp rate limit* is used to limit the maximum speed by which the active power can be changed in the event of changes to active power set points. A *ramp rate limit* is typically used for reasons of system operation to prevent the changes in active power from adversely impacting the stability of the *public electricity supply grid*.

It must be possible to set the ramp rate to any value between 10 and 300 kW/s.

5.1.3.2.1 Category A2 and B plants
Plants in category A2 and B are not required to have a *ramp rate limit* functionality.

5.1.3.2.2 Category C and D plants
A *ramp rate limit* is used to limit the maximum speed by which the active power can be changed in the event of changes to active power set points.

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

Plants in category C and D must have a *ramp rate limit* functionality.

5.2 Reactive power control functions
The following requirements for reactive power and voltage control functions apply to *plants* in category A2, B, C and D.

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

The current control functions and parameter settings for these must be determined before commissioning by the *electricity supply undertaking* in collaboration with the *transmission system operator*.

Table 4 shows the control function requirements for each plant category. The relevant plants must be able to perform *Q control, Power Factor control* or *voltage control* within the U-PQ characteristics described for each *plant category* in section 5.3.

In addition to fulfilling the general requirements in section 5, the *Q control*, *Power Factor control* and *voltage control* functions must comply with the requirements in the following sections.

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

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

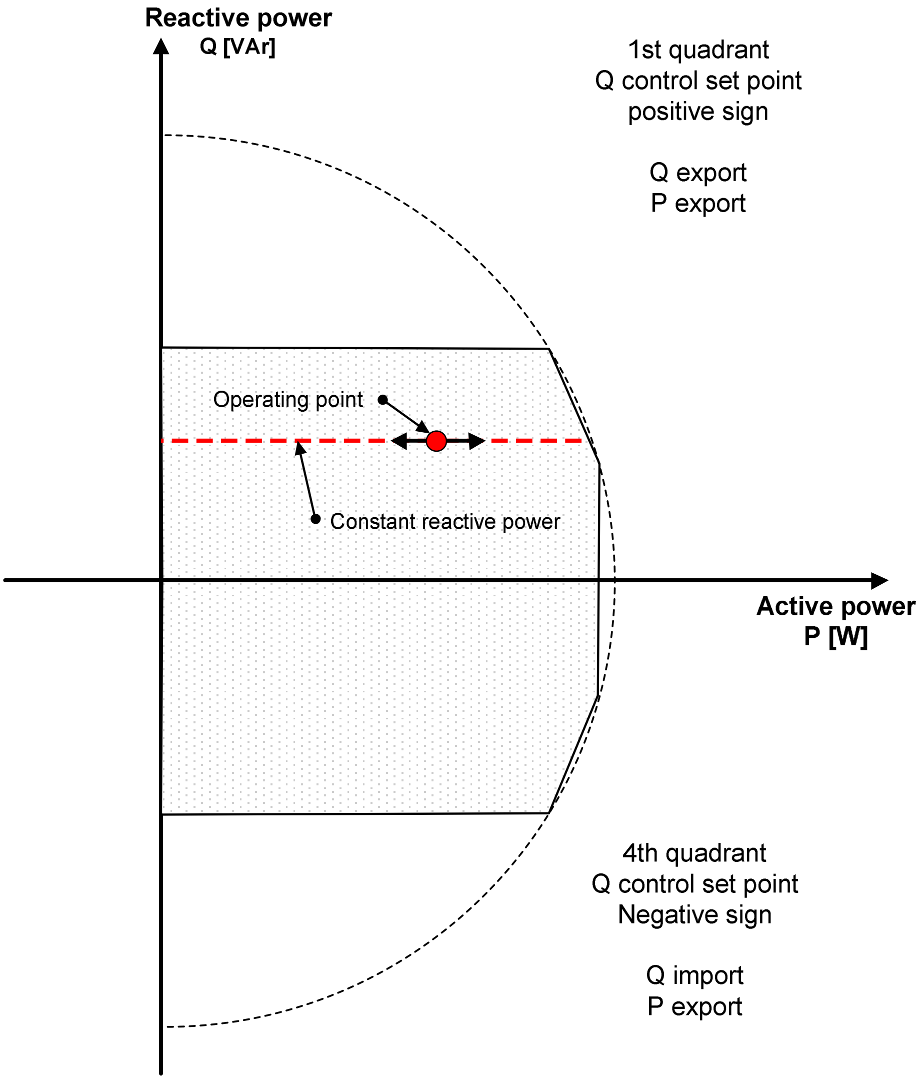

Figure 12 Reactive power control function for a plant (Q control).

Any change to the Q control set point must be commenced within 2 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 or continuous control operation, including the accuracy at the set point, must not deviate by more than 1% of Q_n over a period of 1 minute.

5.2.1.1 Plants in category A2 and B

For *plants* in category A2 and B, the *Q control* function option is required.

Plants must be able to receive a Q set point with an accuracy of 1 kVAr.

5.2.1.2 Plants in category C and D

For *plants* in category C and D, the *Q control* function option is required.

Plants must be able to receive a Q set point with an accuracy of 100 kVAr.

5.2.2 Power factor control

Power factor control is a control function that controls reactive power proportionately to active power in the *Point of Connection*.

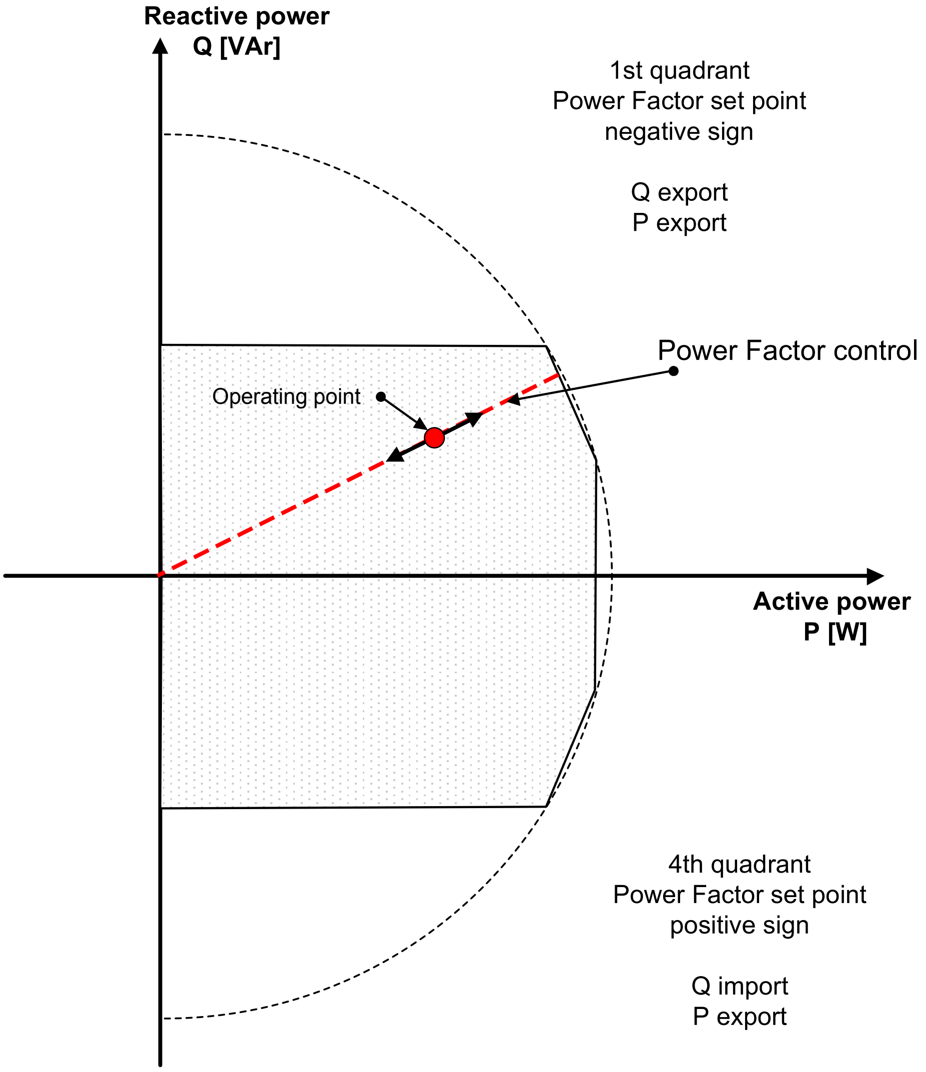

Figure 13 Reactive power control function for a plant (Power Factor control).

Any change to the *Power Factor* 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.

For the control function, the accuracy of a completed adjustment to the resulting reactive power, including the accuracy at the set point, may not deviate by more than 0.01% of the set point for *Power Factor* over a period of 1 minute

Plants must be able to receive a *Power Factor* set point with a resolution of 0.01.

5.2.2.1 Category A2, B, C and D plants

For *plants* in category A2, B, C and D, the *Power Factor* control function option is required.

5.2.3 Voltage control

Automatic *voltage control* (AVR) is a control function that automatically controls the voltage in the *voltage reference point*.

Any change to the voltage set point must be commenced within 2 seconds and completed no later than 10 seconds after receipt of the order to change the set point.

It must be possible to set the *droop* for the *voltage control* to a value in the range 2-8%.

The specific *droop* setting must be agreed between the *plant owner* and electricity supply undertaking in cooperation with the transmission system operator. The standard value for the setting is 4%.

5.2.3.1 Category A2 and B plants

There is no requirement for *voltage control* for *plants* in category A2 and B.

5.2.3.2 Category C plants

For *plants* in category C, the *voltage control* function option is required.

For *plants* in category C, the *voltage reference point* must be set in the *Point of Generator Connection*.

5.2.3.3 Category D plants

For *plant* in category D, the *voltage control* function option is required.

For *plants* in category D, the *voltage reference point* must be set at a point between the *Point of Generator Connection* and *Point of Connection*.

The *transmission system operator* specifies the set point location.

5.3 Requirements for U-PQ characteristics

The following requirements apply to *plants* in category A2, B, C and D.

This section defines the requirement for a *plant's* U-PQ area.

The U-PQ characteristics define the reactive power range *plants* can be operated within at a varying voltage of U_c +5% -5% and active power generation of P_n for plants in category A, B and C, and U_c +5% -10% and active power generation of P_n for plants in category D.

The reactive power control functions described in section 5.2 must be able to regulate within the U-PQ areas defined in the following sections.

Plants must stably and continuously be able to supply any part load between *minimum power* and P_n, subject to the technological limitations arising from the *plants'* process.

5.3.1 Category A2 and B plants

In addition to complying with the general requirements in section 5.1 and the requirements for *normal production* in section 3.2, a *plant* must be equipped with the control functions specified in Table 4.

Figure 14 shows the requirements for U-QP characteristics for *plants* in category A2 and B.

Plants in category A2 or B must be capable of operating at any operating point within the hatched area in Figure 14.

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

Figure 14 indicates at which voltages the supply of reactive power is required for *plants* in *category A2* and B.

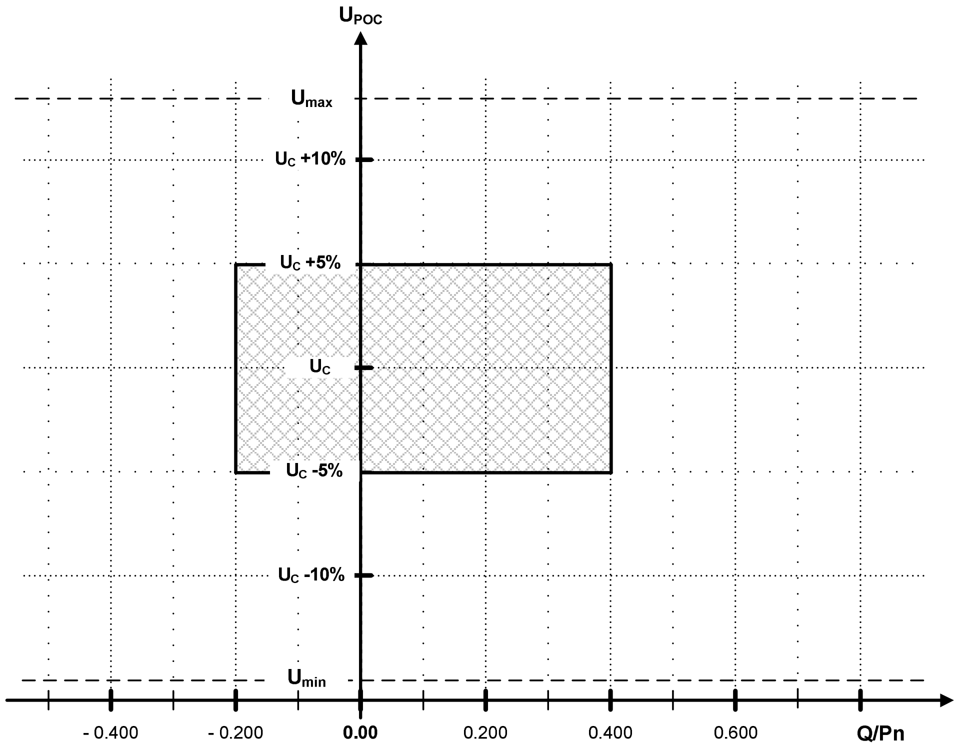

Figure 14 Requirements for delivery of reactive power in relation to U_c for category A2 or B plants.

5.3.2 Category C plants

In addition to complying with the general requirements in section 5.1 and the requirements for *normal production* in section 3.2, a *plant* must be equipped with the control functions specified in Table 4.

Figure 15 shows the requirements for U-QP characteristics for *plants* in category C.

Plants in category C must be capable of operating at any operating point within the hatched area in Figure 15.

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

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

Figure 15 indicates at which voltages the supply of reactive power is required for *plants* in *category* C.

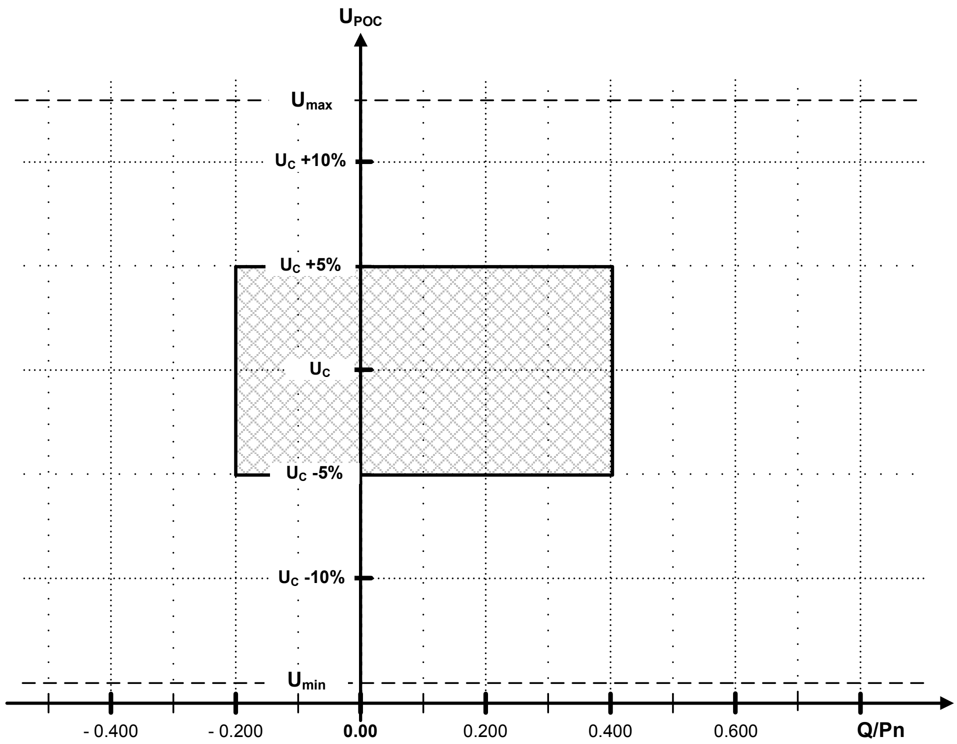

Figure 15 Requirements for delivery of reactive power in relation to U_c for category C plants.

5.3.3 Category D plants

In addition to complying with the general requirements in section 5.1 and the requirements for *normal production* in section 3.2, a *plant* must be equipped with the control functions specified in Table 4.

Figure 16 shows the requirements for U-QP characteristics for *plants* in category D.

Plants in category D must be capable of operating at any operating point within the hatched area in Figure 16.

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

Figure 16 indicates at which voltages the supply of reactive power is required for *plants* in *category* D.

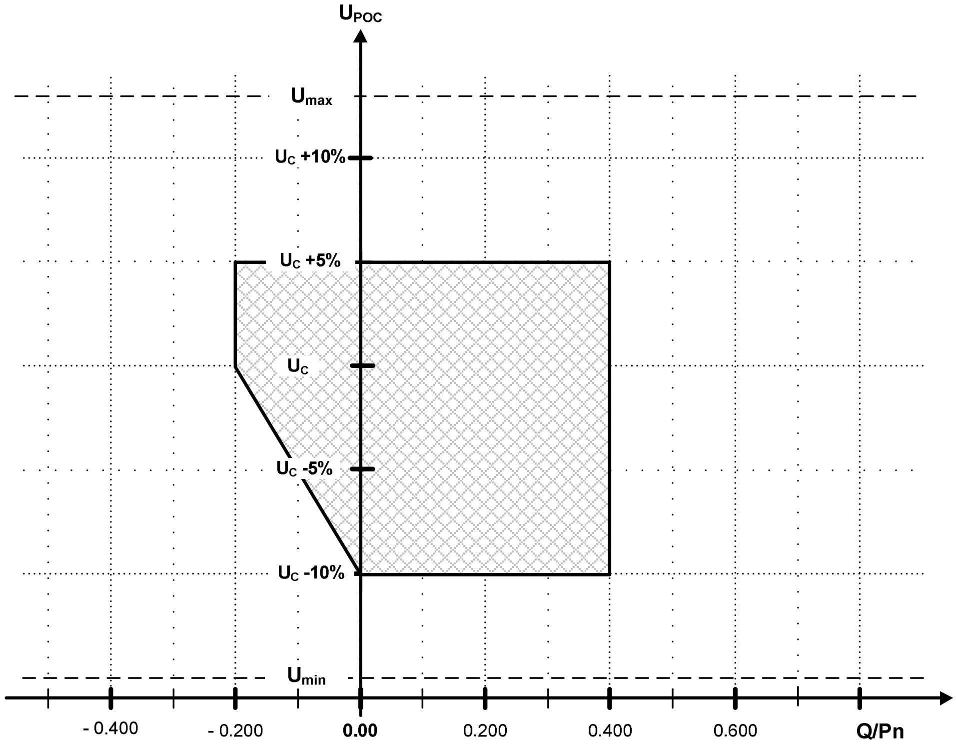

Figure 16 Requirements for delivery of reactive power in relation to U_c for category D plants.

5.3.4 System protection

System protection is not a minimum requirement for *grid connection* to the *public electricity supply grid,* but a requirement a *plant* can have imposed by the *transmission system operator*, depending on the location of the Point of Connection in the *public electricity supply grid* and/or the size of a *plant*. *The electricity supply undertaking* – in cooperation with the *transmission system operator* – must state whether there is a requirement to establish system protection in connection with deciding on the *POC*.

System protection is an auxiliary function in connection with maintaining the system and security of supply and is therefore not a normal operation control function.
System protection is a *plant* functionality, which, based on an order received from the transmission system operator or an autonomous signal from one or more protective relays installed in the *public electricity supply grid*, must very quickly (varying from 0.1-4 seconds) be able to initiate adjustment to the active power supplied by a *plant* to one or several predefined set points.

5.3.4.1 Category A2 and B plants

There are no *system protection* requirements for *plants* in category A2 and B.

5.3.4.2 Category C and D plants

Plants in category C and D can be equipped with system protection which can adjust the active power supplied from the *plant* to one or more predefined set points. The set points are determined by the *electricity supply undertaking* upon commissioning.

The *plant* must have at least five different configurable adjustment range options.

The following adjustment ranges are recommended as default values:

1. Up to 70% of *rated output*
2. Up to 50% of *rated output*
3. Up to 40% of *rated output*
4. Up to 25% of *rated output*
5. Up to 0% of *rated output*, i.e. the *plant* is shut down.

5.4 Priorities for protection and control functions for active power

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

The required prioritisation between the functions of a *plant* is as follows:

1. Protective functions, see section 6
2. *Frequency response*, see section 5.1.1 and *frequency control*, see section 5.1.2
3. Limit functions, see section 5.1.3

5.5 Plant components

A *plant* must be equipped with one or more generators supplying the generated electricity to the *public electricity supply grid,* possibly via a generator transformer.

This section specifies general stability requirements for a generator and generator transformer for a *plant*.

5.5.1 Generator

The *plant's* generator(s) must comply with the relevant parts of the specifications of the European standards EN 60034-1: 2004, 'Rotating electrical machines – Part 1: Rating and performance' [ref. 19] and EN 60034-3, 'Rotating electrical machines, part 3: Specific requirements for turbine-type synchronous machines', [ref. 20], but in pursuance of the following requirements.

The reactances of *electricity-generating units* in a *plant* must be as low as possible, taking the technical and financial consequences hereof into account, with the aim of contributing to the stability of the *public electricity supply grid* and reactive power control.

5.5.1.1 Category A2, B and C plants

Generator(s) for *plants* in category A2, B, or C must have a *short-circuit ratio* of at least 0.45 and a transient reactance of less than 0.35 p.u.

5.5.1.2 Category D plants

For *plants* in category D, the *short-circuit ratio* and transient reactance requirements are set in cooperation with the *transmission system operator*, based on plant design studies and stability analyses, to ensure compliance with section 3.3.2.

5.5.2 Generator transformer

The connection between a *plant's* generators and the *Point of Common Coupling*, including the generator transformer and *generator feeder*, must have a reactance that is as low as possible, taking into account the technical and financial consequences involved, with the aim of contributing to the stability of the *public electricity supply grid* and *voltage control*.

5.5.2.1 Category A2, B and C plants

The generator transformer(s) for *plants* in category A2, B, or C must have a short-circuit impedance as defined in DS/EN 60076-1 [ref. 18] of less than e_z:

$$e_z = 0.07 \cdot S_n^{0.15} \text{ p.u.}$$

where:
e_z is the limit value for the short-circuit impedance, and
S_n is the rated apparent power for the transformer measured in MVA.

5.5.2.2 Category D plants

For *plants* in category D, the maximum permissible value for the grid transformer's short-circuit reactance, as defined in DS/EN 60076-1 [Ref. 18], is set in cooperation with the *transmission system operator*, based on plant design studies and stability analyses, to ensure compliance with section 3.3.2.

5.5.3 Excitation system

A *plant* must be equipped with a continuously functioning automatic *excitation system*. The purpose is to ensure stable operation of the plant, and allow it to contribute to regulating voltage and/or the reactive power balance in the *public electricity supply grid*, see section 5.2.

The *excitation system* must be designed in conformity with European standard DS/EN 60034-16-1:2011 'Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Chapter 1: Definitions', [Ref. 21] and DS/CLC/TR 60034-16-3:2004 'Rotating electrical machines - Part 16: Excitation systems for synchronous machines – Section 3: Dynamic performance' [ref. 22].

The *excitation system's* frequency response (open-loop) must not have an amplification of more than 20 dB in the frequency range 0.2-1.5 Hz.

In the event of grid disturbances resulting in voltage reduction, it must be possible to overexcite the generator for at least 10 seconds to 1.6 times the excitation at rated output and $tg\varphi = 0.4$ and rated operating voltage.

The *generator's* overexcitation protection and other types of protection must be designed and set so that the generator's capacity for temporary overload can be utilised without overriding the generator's thermal limits.

The *excitation system's* limit functions must be selective with the *plant's* protective functions, as specified in section 6, and thereby permit the brief utilisation of overload characteristics without the *plant* being disconnected. Coordination between limit functions and protection functions must be documented in a P/Q diagram for static and dynamic characteristics, containing trip times and activation levels.

The *excitation system's* time response (measured at the generator terminals) during idling (generator disconnected from the grid and operated at rated RPM) for a momentary 10% change to the reference voltage must be non-oscillatory and have a maximum rise time, as defined in DS/EN 60034-16-1 [ref. 21], of 0.3 seconds for a static *excitation system*. For a rotating *excitation system* ('rotating exciter'), a time response of up to 0.5 seconds for a positive 10% change to the reference voltage is permitted, and correspondingly, up to 0.8 seconds for a negative 10% change to the reference voltage.

The *excitation system's* overshoot, measured at the generator terminals, as defined in DS/EN 60034-16-1, must not exceed 15% during a momentary 10% change in the reference voltage.

Verification of the above functional requirements for the excitation equipment must be attached as documentation. Simulations carried out, relevant measurements from the commissioning process, function descriptions and the final setting values must be attached as part of the total plant documentation.

5.5.3.1 Category A2 and B plants

There are no *excitation system* requirements for *plants* in category A2 and B.

5.5.3.2 Category C and D plants

Type C and D plants must meet the *excitation system* requirements.

5.5.3.3 PSS function

A *PSS function* (Power System Stabiliser), see section 1.2.52, is a damper unit for the *excitation system* which aims to dampen the oscillations in the active power production from the *plant.*

The *PSS function* must use input from rotor speed/grid frequency and active power (dual input) to derive the stability signal, where damping equipment of type IEEE PSS2B, see IEEE 421.5 [ref. 24] is normative.

The *PSS function* must be adjusted to achieve a significant damping in the 0.2-0.7 Hz frequency range.

The phase of the supplied damping signal produced by the *PSS function* must be in phase with the change in speed for the generator rotor in the 0.2-0.7 Hz frequency range. Deviations of up to -30 degrees (under-compensated) are acceptable.

With the *PSS function* activated, damping of the plant's power oscillations (exponentially declining function) must be faster than 1 second at all operating points and for any distortion.

The plant's natural damping of 'local mode' power oscillations must not be adversely affected by the *PSS function*.

The *PSS function* must be set so that changes to the plant's operating point (active power) during normal operation, or in the event of a fault in for example a turbine regulator, boiler plant, feedwater plant or other auxiliary power plant must not cause the voltage on the high-voltage side of the generator transformer to change by more than 1%.

The PSS output signal must be limited so that activation of the *PSS function* does not lead to a change in generator voltage greater than +/- 5% of the generator's rated voltage. Limits may be automatically and dynamically reduced by the voltage regulator, for example when the *excitation system's* limit functions are activated.

The *PSS function* must be deactivated automatically when generated active power is less than 20% of rated output.

It must be possible to connect and disconnect the *PSS function*. When the *PSS function* is disconnected, an alarm must be set off.

The *PSS function* must also meet the other specifications as regards control facilities and actual settings laid down by the *transmission system operator* in collaboration with the *plant operator*.

Simulation and analysis must be used to document that the setting values used give the *PSS function* and the entire *excitation system* satisfactory dynamic characteristics. The simulations performed must include the test scenarios below. With the exception of Test 6, these must be simulated both with the *PSS function* activated and deactivated:

1. Verification of the frequency characteristic, including correct phase compensation for the entire excitation system, in the form of Bode plots for amplification and phase.
2. Step response to a momentary +/- 5% change to the reference voltage. Simulations must be performed at various operating levels, e.g. 25%, 50%, 80% and 100% of the *plant's rated power*.
3. *Generator-near* short-circuit, see sections 1.2.20 and Figure 7.
4. *Generator-remote* short-circuit, see section 1.2.17.
5. Disconnection of a line, where the public electricity supply grid changes from the strongest grid configuration to the weakest grid configuration (short-circuit power)
6. A change to the generator's supplied mechanical power from the drive system in relation to the functions below (PSS device must be active):

   - Sine function, P(t) $= A \cdot Sin(\omega \cdot t),\ = 0.1\,pu,\ \omega = 2 \cdot \pi \cdot \frac{1}{60}\ rad$
   - Ramp function, P(t) $= \begin{cases} 0\ pu\ hvor\ t < 0sec \\ 0.25 \cdot t\ pu\ hvor\ 0\ sec < t \leq 4\ sec \\ 1\ pu\ hvor\ t > 4\ sec \end{cases}$

Compliance with the above functional requirements for the *PSS function* must be attached as documentation. Simulations carried out, relevant measurements from the commissioning process, function descriptions and the final setting values must be attached as part of the total plant documentation.

5.5.3.4 Category A2, B or C plants

There are no *PSS function* requirements for *plants* in category A2, B and C.

5.5.3.5 Category D plants

Plant in category D must be equipped with *PSS functions.*

6. Protection

The following requirements apply to *plants* in category A2, B, C and D.

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

Relay settings must not prevent specified plant functionality from functioning correctly.

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

- the *plant* is protected against damage due to faults and incidents in the *public electricity supply grid*
- the *plant* is protected against disconnection in non-critical situations for the *plant*.
- the *public electricity supply grid* to the widest possible extent is protected against unwanted impacts from the 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 *plant* being exposed to impacts outside of the design requirements, as specified in section 3, from the *public electricity supply grid.*

A *plant* which has been 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 voltage and frequency are once again within the normal operating range specified in section 3.2.

At the request of the *plant owner*, 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* as may be necessary to establish the *plant's* protective functions.

Apart from the relay protection mentioned in Table 5 and Table 6, relay protection can be established targeting faults in the *plant*, including short-circuits, overspeed, excitation monitoring, reverse power, etc. Such relays must not trip the unit in the event of short-circuits or grid rerouting.

In case of internal short-circuiting in the *plant*, relay protection must be selective with the grid protection, i.e. short-circuits in the plant must be disconnected within 100 ms.

6.1 Protective setting requirements

The *plant's* protective functions and associated settings must be as specified in the following subsections. Settings deviating from the recommended 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 *plant* must be disconnected or shut down if a measuring signal deviates more from its rated value than the setting.

The trip time stated is the measuring period during which the trip condition must constantly be met in order 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.

A positive-sequence undervoltage relay is only a requirement in cases where out-of-phase reclosing by automatic reclosing can occur.

Regarding the settings for the positive-sequence undervoltage relay:

- these must be calculated by the *electricity supply undertaking* in whose grid the *plant* is connected, using the principles in the Research Association of the Danish Electric Utilities (DEFU) technical report 293, 2nd edition, 'Relay protection for local production synchronous generators', June 1995.

the *df/dt* relay settings must be approved by the *transmission system operator*.

If a *plant* is isolated with a part of the *public electricity supply grid*, the *plant* must not give rise to temporary overvoltages that may damage the *plant* or the *public electricity supply grid*.

6.1.1 Category A2 and B 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 setting**
Positive-sequence undervoltage*	-	$0.7 \cdot U_n$	V	≤ 50	ms	50 ms
Overvoltage (step 2)	$U_{>>}$	$1.10 \cdot U_n$	V	< 50 ms	ms	< 50 ms
Overvoltage (step 1)	$U_{>}$	$1.06 \cdot U_n$	V	30-60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.90 \cdot U_n$	V	2…10	s	10 s
Overfrequency	$f_{>}$	52	Hz	300	ms	300 ms
Underfrequency	$f_{<}$	47	Hz	300	ms	300 ms
Change of frequency	*df/dt*	±2.5	Hz/s	80-100	ms	80 ms
Overcurrent*	$I_{>}$	$\geq \frac{U_N/\sqrt{3}}{X''_d + X_{k,G}}$	A	50	ms	50 ms
Overcurrent – positive-sequence undervoltage relay is not used	$I_{>}$	**	A		ms	

Table 5 Requirements for plants in category A2 and B.

U_N is the generator's *rated voltage* (outer value in V)
X_d'' is the generator's subtransient reactance (phase value in Ω).

$X_{K,G}$ is the grid's short-circuit impedance at the generator terminals in Ω per phase.
* If a positive-sequence undervoltage relay is used.
Positive-sequence undervoltage relay: the setting depends on the local generator and grid data. 70% is only a typical value. The actual setting is calculated by the *electricity supply undertaking*.
** Set based on the generator manufacturer's maximum value, where the generator only just has protection.

In connection with the use of an asynchronous generator, overload current and overspeed protection are used. The actual settings must be agreed with the electricity supply undertaking, as they have an impact on grid stability

6.1.2 Category C plants

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

Protective function	**Symbol**	**Setting**		**Trip time**		**Standard setting**
Positive-sequence undervoltage*	-	$0.7 \cdot U_n$	V	≤ 50	ms	50 ms
Overvoltage (step 2)	$U_{>>}$	$1.10 \cdot U_n$	V	< 50 ms	ms	< 50 ms
Overvoltage (step 1)	$U_{>}$	$1.06 \cdot U_n$	V	30-60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.90 \cdot U_n$	V	2…10	s	10 s
Overfrequency	$f_{>}$	52	Hz	300	ms	300 ms
Underfrequency	$f_{<}$	47	Hz	300	ms	300 ms
Change of frequency	df/dt	±2.5	Hz/s	80-100	ms	80 ms
Overcurrent*	$I_{>}$	$\geq \frac{U_N/\sqrt{3}}{X''_d + X_{k,G}}$	A	50	ms	50 ms
Overcurrent – positive-sequence undervoltage relay is not used	$I_{>}$	***	A		ms	

Table 6 Requirements for plants in category C

U_N is the generator's *rated voltage* (outer value in V)
X_d" is the generator's subtransient reactance (phase value in Ω).
$X_{K,G}$ is the grid's short-circuit impedance at the generator terminals in Ω per phase.
* If a positive-sequence undervoltage relay is used.
Positive-sequence undervoltage relay: the setting depends on the local generator and grid data. 70% is only a typical value. The actual setting is calculated by the *electricity supply undertaking*.
*** Calculated based on the requirements for plant tolerance for voltage dips, see 3.3

For plants in category C, the *plant owner is* responsible for ensuring that stability and selectivity studies are carried out with the aim of determining the *plant's* protective functions.

The studies must ensure that the *plant* fulfils the requirements specified in section 6, and that the protection does not prevent the *plant* from fulfilling the additional requirements of this regulation.

The set protection functions and associated setting values that are important to the operation of the *public electricity supply grid* must be approved by the *electricity supply undertaking* in whose grid *the plant* is connected.

6.1.3 Category D plants

For plants in category D, the *plant owner* is responsible for ensuring stability and selectivity studies are carried out with the aim of determining the plant's protective functions.

A positive-sequence undervoltage relay must not be used for plants in category D.

The studies must ensure that the *plant* fulfils the requirements specified in section 6, and that the protection does not prevent the *plant* from fulfilling the additional requirements of this regulation.

The set protection functions and associated setting values that are important to the operation of the *public electricity supply grid* must be approved by the *transmission system operator* and the *electricity supply undertaking* in whose grid *the plant* is connected.

7. Exchange of signals and data communication

7.1 Measurement requirements

The following requirements apply to *plants* in category A2, B, C and D.

Specific requirements for installed measuring equipment and measuring accuracy that must be available in order for a *plant* to be connected to the *public electricity supply grid* are specified in the following regulations:

1. Regulation D1 'Settlement metering' [ref. 12]
2. Regulation D2 'Technical requirements for electricity metering' [ref. 13]
3. Technical regulation 5.8.1 'Metering regulation for system operation purposes' [ref. 10].

Compliance with the above regulations must be verified by the *meter operator* as part of the checks and tests that form the basis for a final approval of the *grid connection*. The latest version of the applicable regulations can be found on the *transmission system operator's* website, www.energinet.dk.

7.2 Data communication

The following requirements apply to *plants* in category A2, B, C and D.

To ensure the operation of the *public electricity supply grid*, the communication interface (PCOM) must be prepared for data communication between the *plant operator* and market players in the *public electricity supply grid* in line with this regulation.

Information for a *plant* must be referred to, modelled and grouped as specified in the IEC 61850 standard series.

Information exchange for a *plant* must be implemented using an IEC 60870-5-104 [ref. 8] or IEC 61850-8-1 [ref. 23] protocol stack.

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

The final solution must be agreed with the *transmission system operator* and the *electricity supply undertaking.*

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

Specific requirements for the extent of information and signals are specified in the following sections for the individual *plant* categories.

7.2.1 Category A2 and B plants

As a minimum, *plants* in category A2 or B must be able to exchange the following signals:

Signal #	Signal description
Set point	Stop signal
Set point	Released for start

Table 7 Requirements for information exchange with plants in category A2 and B.

The signals must be accessible via a terminal strip or in the *PCOM* interface via commands.

7.2.2 Category C and D plants

It must be possible to obtain correct measurements and maintain data communication in all situations, including when the *plant* is 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 shut-down of the *plant's* control and monitoring system. Logging in connection with a shut-down 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 a 10 ms resolution and ±1 ms precision or higher.

As a minimum, *plants* in category C or D must be able to exchange the following signals in accordance with the specifications in section 7.2.

Signal type	Signal description
Status	Switch gear status in the *POC*
Measurement	Active power supplied at the *POC.*
Measurement	Reactive power – import/export at the *POC*
Measurement (calculation)	*Power Factor* – calculated at the *POC.*
Measurement	Voltage in the *voltage reference point*
Set point	Active power control – *frequency response* – LFSM-O – activate/deactivate
Status	Active power control – *frequency response* – LFSM-O – activated/not activated
Set point	Active power control – *frequency response* – LFSM-O – setting value – f_{Rmax}
Status	Active power control – *frequency response* – LFSM-O – value – f_{Rmax}
Set point	Active power control – *frequency response* – LFSM-O – setting value – *droop 1*
Status	Active power control – *frequency response* – LFSM-O – value – *droop 1*
Set point	Active power control – *frequency response* – LFSM-U – activate/deactivate
Status	Active power control – *frequency response* – LFSM-U – activated/not activated
Set point	Active power control – *frequency response* – LFSM-U – setting value – f_{Rmin}
Status	Active power control – *frequency response* – LFSM-U – value – f_{Rmin}
Set point	Active power control – *frequency response* – LFSM-U – setting value – *droop* 2
Status	Active power control – *frequency response* – LFSM-U – value – *droop* 2

Set point	Active power control – *frequency control* – activate/deactivate
Status	Active power control – *frequency control* – activated/not activated
Set point	Active power control – *frequency control* – setting value – f1
Status	Active power control – *frequency control* – value – f1
Set point	Active power control – *frequency control* – setting value – *droop* 3
Status	Active power control – *frequency control* – value – *droop* 3
Set point	Active power control – *frequency control* – setting value – f2
Status	Active power control – *frequency control* – value – f2
Set point	Active power control – *frequency control* – setting value – *droop* 4
Status	Active power control – *frequency control* – value – *droop* 4
Set point	Active power control – *frequency control* – setting value – f3
Status	Active power control – *frequency control* – value – f3
Set point	Active power control – *frequency control* – setting value – *droop* 5
Status	Active power control – *frequency control* – value – *droop* 5
Set point	Active power control – *frequency control* – setting value – f4
Status	Active power control – *frequency control* – value – f4
Set point	Active power control – *load regulator (absolute power limit)* – activate/deactivate
Status	Active power control – *load regulator (absolute power limit)* – activated/not activated
Set point	Active power control – *load regulator (absolute power limit)* – desired active power at the POC
Status	Active power control – *load regulator (absolute power limit)* – desired active power at the POC
Set point	Active power control – *ramp rate limit* – activate/deactivate
Status	Active power control – *ramp rate limit* – activated/not activated
Set point	Active power control – *ramp rate limit* – ramp rate for upward/downward adjustment
Status	Active power control – *ramp rate limit* – ramp rate for upward/downward adjustment
Set point	Active power control – system protection – activate/deactivate
Status	Active power control – system protection – activated/not activated
Set point	Active power control – system protection – set point
Set point	Reactive power control – *Q control* – activate/deactivate
Status	Reactive power control – *Q control* – activated/not activated
Set point	Reactive power control – *Q control* – setting value – desired reactive power at the *POC*
Status	Reactive power control – *Q control* – value – desired reactive power at the *POC*
Set point	Reactive power control – *Power Factor control* – activate/deactivate
Status	Reactive power control – *Power Factor control* – activated/not activated
Set point	Reactive power control – *Power Factor control* – setting value – desired *Power Factor* at the *POC*
Status	Reactive power control – *Power Factor control* – value – desired *Power Factor* at the *POC*
Set point	Reactive power control – *voltage control* – activate/deactivate
Status	Reactive power control – *voltage control* – activated/not activated

Set point	Reactive power control – *voltage control* – setting value – desired voltage in *voltage reference point*
Status	Reactive power control – *voltage control* – value – desired voltage in *voltage reference point*
Set point	Stop signal
Set point	Released for start

Table 8 Requirements for information exchange with plants in category C and D.

Online communication is required for category C and D *plants.*

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 agreement with the *plant owner* – change the current function settings, for example via set points and activation commands.

7.3 Fault incident recording

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

Plants in category C with a *rated output* of less than 10 MW are excluded.

Logging must be performed using electronic equipment that can be configured, as a minimum, 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 (fault recorder) which records, as a minimum:

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

Specific measurement requirements are described in the grid connection agreement.

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 *plant*.

All measurements and data to be collected in accordance with TR 5.8.1 [ref. 10] must be logged with a time stamp and an accuracy ensuring that such measurements and data can be correlated with each other and with similar recordings in the *public electricity supply grid*.

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.

7.4 Requesting metered data and documentation

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

The *electricity supply undertaking* and the *transmission system operator* are entitled to request relevant plant information in relation to grid stability and operation, and specific measurement requirements described in the grid connection agreement, at any time.

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

The *electricity supply undertaking* and the *transmission system operator* are entitled to request at any time verification and documentation that a *plant* complies with the provisions of this regulation. Such requests 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 *plant* complies with this technical regulation and for documenting that the requirements are met.

The *plant* documentation to be provided is specified in the following sections, which have been divided based on the total *rated power* in the *Point of Connection*.

The documentation must be submitted to *the electricity supply undertaking*.

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

Category A2 and B *plants*:

1. The *electricity supply undertaking* assigns the *plant owner* a *POC* and ROW (right-of-way) for installation.

2. Documentation must be submitted electronically to the *electricity supply undertaking*.

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

4. Once the documentation has been approved, a final operating permit can be issued.

Category C and D plants:

1. The *electricity supply undertaking* assigns the *plant owner* a *POC* and ROW (right-of-way) for installation. In connection with assigning the *POC,* the *electricity supply undertaking* informs the *transmission system operator* about the expected grid connection.

2. Documentation must be submitted electronically to the *electricity supply undertaking*.

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

4. The *electricity supply undertaking* sends the documentation electronically to the *transmission system operator*.

5. The *transmission system operator* reviews and approves the documentation for the *plant*.

   The *transmission system operator* issues a written approval of the documentation for the *plant.*

6. Once the documentation has been approved, a final operating permit can be issued.

For a *plant*, documentation must be supplied in accordance with Appendix 1.

8.1 Requirements for plant documentation

8.1.1 Category A2 plants

The type and function of *electricity-generating units* used in the *plant* must be approved in compliance with the technical code, and no additional documentation is therefore required.

Appendix 1 for *plant* category A2, see form B1.1.

8.1.2 Category B plants

Appendix 1 for *plant* category B, see form B1.2.

8.1.3 Category C plants

The documentation must be filled in with preliminary data for the *plant* and sent to the *electricity supply undertaking* no later than:

- twelve months **before** the date of commissioning for rated output ≥ 10 MW
- three months **before** the date of commissioning for rated output < 10 MW

From the design phase to the verification phase, the *plant owner* must inform the electricity supply undertaking if the preliminary *plant* data can no longer be regarded as representative for the final commissioned *plant*.

No later than three months **after** the date of commissioning, documentation must be provided in the form of specific data for the entire *plant,* which must be sent to the *electricity supply undertaking*. Required documentation comprises the following:

Appendix 1 for *plant* category C, see form B1.3.

8.1.4 Category D plants

The documentation form must be filled in with preliminary data for the *plant* and sent to the *electricity supply undertaking* no later than twelve months **before** the date of commissioning.

From the design phase to the verification phase, the *plant owner* must inform the *transmission system operator* if the preliminary *plant* data can no longer be regarded as representative for the final commissioned *plant*.

No later than three months **after** the date of commissioning, documentation must be provided in the form of specific data for the entire *plant,* which must be sent to the *electricity supply undertaking*. Required documentation comprises the following:

Appendix 1 for *plant* category D, see form **Fejl! Henvisningskilde ikke fundet.**

8.2 Positive list – category A2 plants

The documentation requirements for *plant category* A2 in relation to the positive list 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 the 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 *plant components* used added to the *positive list,* making the technical case 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 1.1 with B1.1.1. , B1.1.2. and B1.1.19. completed.

8.2.3 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 the answers given in Appendix 1 (B1.1.) are correct.

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

9. Electrical simulation model

For the purposes of analysing the *public electricity supply grid*, the *transmission system operator* regularly maintains and expands the complete system model, including simulation models for production facilities.

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

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

From the design phase to the verification phase, the *plant owner* must inform the *transmission system operator* if the preliminary *plant* data can no longer be regarded as representative for the final commissioned *plant*.

In pursuance of Section 84 a 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 *plant* supplier to the *transmission system operator*.

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

9.1 Simulation model requirements

The simulation model for the entire *plant* must describe the plant's fixed and dynamic electrical properties, as seen from the *public electricity supply grid*.

The electrical simulation model must:

- be supported by model descriptions which contain, as a minimum, Laplace domain transfer functions, function descriptions of the model’s main modules and detailed descriptions of the various model components and associated model parameters, including set-up and initialisation of the simulation model and any limitations on its application.

- contain all control functions, as required in section 5. Models for voltage regulators, damping equipment (PSS) and any excitation system must observe the latest version of IEEE 421.5 [Ref. 24].

- include power/speed regulators and the drive system in accordance with the relevant standard models, such as IEEE PES-TR1 [Ref. 35].

- include oscillation mass models for relevant plant components (such as generator plant, turbine group, excitation system)

- include details on stator over and underexcitation limit functions in block diagram format and show transfer functions for the individual elements.

- 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.

- allow simulation of RMS values in the synchronous system (positive sequence).

- allow simulation of RMS values in the individual phases during asymmetrical incidents and faults in the *public electricity supply grid*.

- as a minimum, cover the 47.00-52.00 Hz frequency range and the 0.0-1.4 pu voltage range.

- be able to describe the dynamic response from a *plant* for at least 30 seconds after any incident or fault in the *public electricity supply grid*.

- be numerically stable and capable of utilising numerical equation solvers with variable sample lengths.

- not use sample lengths less than 1 ms.

9.2 Verification of simulation model

The simulation model must be verified by the *plant owner* for the entire *plant,* including all forms of control, as required in section 5.

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

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

Measurements used to verify the simulation model for the entire *plant* must be documented by the *plant owner* in a report containing detailed descriptions of each test. Measurement results must be compared with the corresponding simulated results and documented in a verification report.

The time series measurements used to verify the simulation model must be enclosed with the verification report in IEEE *COMTRADE* format.

The time resolution for the measurement signals used must be 1 ms or higher.

9.3 Category A2 and B plants

No simulation model is required for category A2 or B *plants*.

9.4 Category C and D plants

A dynamic simulation model for the entire category C or D *plant* must be submitted to the transmission system operator.

Plants in category C with rated output of less than 10 MW are excluded.

The *plant owner* must submit an updated simulation model for the complete *plant* no later than three months after commissioning.

The content and level of detail of the simulation models for the *plant* and the individual *plant unit(s)* 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 1.2.5.

The documentation, as specified in section 8, must be sent electronically to the *electricity supply undertaking*.

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

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

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

Templates for the various *plant categories* are available on the website www.energinet.dk.

B1.1. Appendix 1 for plant category A2

Please fill in the documentation form with data for the *plant*, valid at the time of commissioning, and submit it to the *electricity supply undertaking.*

B1.1.1. Identification

Plant name:	
Plant owner's name and address:	
Plant owner's tel. no.:	
Plant owner's email address:	
Date of commissioning:	
GSRN number (all numbers must be provided for the *plant*):	
Name of *electricity supply undertaking*:	
Name of nearest 30-60 kV substation:	
Name of nearest 132-150 kV substation:	
Name and location of the *Point of Connection* (*POC*):	
Voltage at the *POC* (rated):	______ kV
Name and location of *Point of Common Coupling* (*PCC*):	
Voltage at the *PCC* (rated):	______ kV
Are there other connection points to the *public electricity supply grid*? Description of other connection points:	Yes ☐ No ☐

B1.1.2. Description of the plant

Type *Describe the type:	Steam turbine ☐ Gas turbine ☐ Combined-cycle unit ☐ Gas engine ☐ Diesel engine ☐ Other* ☐
Specification of fuel:	
Rated output (P_n)	______ kW
Minimum power (P_{min})	______ kW
Overload capacity ($P_{overload}$)	______ kW
Rated mechanical shaft power for drive system (P_{mech})	______ kW
Is a flowchart for the *plant* available? Reference to document:	Yes ☐ No ☐
Is a line diagram available showing settlement metering, online metering, ownership boundaries and operation manager boundaries? Reference to document:	Yes ☐ No ☐

B1.1.3. Determination of voltage level

What is the *normal operating voltage* (*Uc*) at the *POC*?	______ kV

B1.1.4. Normal operating conditions

Within the *normal production* area, see Figure 4, can the *plant* be started and generate continuously?	Yes ☐ No ☐
Will the *plant* remain connected in the event of frequency and voltage deviations at the *POC,* in line with Figure 4? Reference to type test/study or protection philosophy that verifies the above:	Yes ☐ No ☐

B1.1.5. Abnormal operating conditions

Will the *plant* remain connected in the event of phase jumps of 20° at the *POC*? Reference to type test/study that verifies the above:	Yes ☐ No ☐
Will the *plant* remain connected in the event of transient frequency gradients of 2.5 Hz/s at the *POC*? Reference to type test/study or protection philosophy that verifies the above:	Yes ☐ No ☐

B1.1.6. Power quality

When the *plant* is connected, do *rapid voltage changes* greater than the permissible levels (see Table 3) occur? Reference to calculation/study that verifies the above:	Yes ☐ No ☐

B1.1.7. Control functions

Which of the following control functions are active in the *plant*?	*Frequency response* – LFSM-O ☐ *Q control* ☐ *PF control* ☐

B1.1.8. Frequency response (LFSM-U and LFSM-O)

Is the *plant* designed with a *frequency response* system that can control active power as a function of frequency deviations from the reference frequency? Reference to type test/data sheet that verifies the above:	Yes ☐ No ☐
In the event of a frequency deviation, is the *frequency response* activated within 2 seconds?	Yes ☐ No ☐
Is it possible to adjust the *frequency response droop* to a value in the 2-8% range of P_n?	Yes ☐ No ☐
Is the *droop* set to 6%?	Yes ☐ No ☐
Is it possible to set the *frequency response* limit frequency (f_{min} and f_{max}) to a value in the 47-52 Hz range?	Yes ☐ No ☐
Is it possible to set the *frequency response* activation frequency (f_{Rmax}) to a value in the 50.1-52 Hz range?	Yes ☐ No ☐
Is f_{Rmax} set to 50.2 Hz? If 'no', what is the setting?	Yes ☐ No ☐
Is frequency measurement accuracy higher than 10 mHz and the control function sensitivity higher than +/-10 mHz?	Yes ☐ No ☐

B1.1.9. Frequency control

Does the *plant* have to provide ancillary services? If 'yes', which?	Yes ☐ No ☐ FCR – power frequency control ☐ FCR – FNR ☐ FCR – FDR ☐ FRR-a ☐ FRR-m ☐
Is the *plant's* turbine governor set with the specific parameter settings for the ancillary service(s) to be delivered, in line with the specifications for ancillary services?	Yes ☐ No ☐

B1.1.10. Reactive power control functions

Where is the reference point for the reactive power control functions located? *Describe where:	*PGC* ☐ *POC* ☐ *PCC* ☐ Elsewhere* ☐

B1.1.11. Requirements for reactive power control area

Can the generator *plant* supply reactive power at P_n and varying operating voltages, as specified in Figure 14? Reference to study/type test that verifies the above:	Yes ☐ No ☐
Is the generator's PQ diagram available? Reference to data sheet:	Yes ☐ No ☐

B1.1.12. Generator

Manufacturer:	
Type:	
Is there a data sheet for the generator? Reference to data sheet:	Yes ☐ No ☐
Does the generator comply with relevant parts of the following European Standards: - DS/EN60034-1, 'Rotating electrical machines – Part 1: Rating and performance', 2004 - DS/EN60034-3, 'Rotating electrical machines – Part 3: Specific requirements for turbine-type synchronous machines', 1995	Yes ☐ No ☐
Does the generator have a *short-circuit ratio* of 0.45 or higher?	Yes ☐ No ☐
Does the generator have a transient reactance (X'_d) of less than 0.35 pu?	Yes ☐ No ☐

B1.1.13. Generator data

Description	Symbol	Unit	Value
Rated apparent power (1 p.u.):	S_n	MVA	
Rated voltage (1 p.u.):	U_n	kV	
Rated frequency:	f_n	Hz	
Rated *Power Factor* (cosφ):	$\cos\varphi_n$	-	
Rated minimum reactive power generation from PQ diagram:	$Q_{min,n}$	Mvar	
Rated maximum reactive power generation from PQ diagram:	$Q_{max,n}$	Mvar	
Synchronous speed:	n_n	Rpm	

Total moment of inertia for rotating mass (generator, drive system, etc.):	J_{tot}	kg·m^2	
Total moment of inertia for generator:	J_G	kg·m^2	
Total moment of inertia for drive system:	J_D	kg·m^2	
Rotor type:	-	-	Salient poles ☐ Distinct poles ☐
Stator resistance per phase:	R_a	p.u.	
Temperature for resistance:	T_R	ºC	
Stator dispersion reactance per phase:	X_{ad}	p.u.	
Positive-sequence reactance, d axis:	X_d	p.u.	
Transient reactance, d axis:	X'_d	p.u.	
Subtransient reactance, d axis:	X''_d	p.u.	
Saturated positive-sequence reactance, d axis:	$X_{d,sat}$	p.u.	
Saturated subtransient positive-sequence reactance, d axis:	$X''_{d,sat}$	p.u.	
Positive-sequence reactance, q axis:	X_q	p.u.	
Transient reactance, q axis:	X'_q	p.u.	
Subtransient reactance, q axis:	X''_q	p.u.	
Transient open circuit time constant, d axis:	T'_{d0}	s	
Subtransient open circuit time constant, d axis:	T'_{d0}	s	
Transient open circuit time constant, q axis:	T'_{q0}	s	
Subtransient open circuit time constant, q axis:	T''_{q0}	s	
Potier reactance:	X_p	p.u.	
Saturation point at 1.0 p.u. voltage:	$SG_{1.0}$	p.u.	

Saturation point at 1.2 p.u. voltage:	$SG_{1.2}$	p.u.	
Reactance, inverse-component:	X_2	p.u.	
Resistance, inverse-component:	R_2	p.u.	
Reactance, zero-component:	X_0	p.u.	
Resistance, zero-component:	R_0	p.u.	
Is the generator star point earthed?	-	-	Yes ☐ No ☐
If yes, ground reactance:	X_e	Ohm	
If yes, ground resistance:	R_e	Ohm	
Generator's *short-circuit ratio* (Rated):	K_c	p.u.	

B1.1.14. Excitation system

What type of *excitation system* is used? *Describe the type:	Rotating ☐ Static ☐ Other* ☐
Is there a data sheet for the AVR? Reference to data sheet:	Yes ☐ No ☐

B1.1.15. Protection

Is a positive-sequence undervoltage relay used as protection against out-of-phase reclosing? If 'yes', reference to study justifying use of the relay:	Yes ☐ No ☐

B1.1.16. Protective functions and settings

Protective function	Symbol	Setting		Trip time		Standard setting
Positive-sequence undervoltage*		$0.7 \cdot U_n$	V	≤ 50	ms	50 ms
Overvoltage (step 2)	$U_{>>}$	$1.10 \cdot U_n$	V	< 50 ms	ms	< 50 ms
Overvoltage (step 1)	$U_{>}$	$1.06 \cdot U_n$	V	30-60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.90 \cdot U_n$	V	2…10	s	10 s
Overfrequency	$f_{>}$	52	Hz	300	ms	300 ms
Underfrequency	$f_{<}$	47	Hz	300	ms	300 ms
Change of frequency	*df/dt*	±2.5	Hz/s	80-100	ms	80 ms
Overcurrent*	$I_{>}$	$\geq \frac{U_N / \sqrt{3}}{X''_d + X_{k,G}}$	A	50	ms	50 ms
Overcurrent – positive-sequence undervoltage relay is not used	$I_{>}$	**	A		ms	

B1.1.17. Measurement requirements

Has settlement metering been implemented in line with market regulation D1 and D2?	Yes ☐ No ☐
Have online measurements and signals been implemented in line with ancillary services to be supplied in Denmark – specifications? (only relevant if the *plant* will provide ancillary services) Reference to signal list that verifies the above:	Yes ☐ No ☐

B1.1.18. Scope of signals

Signal #	**Signal description**
Set point	Stop signal
Set point	'Released for start'

B1.1.19. Signature

Date of commissioning	
Company	
Person responsible for commissioning	
Signature	

B1.2. Appendix 1 for plant category B

Please fill in the documentation form with data for the *plant*, valid at the time of commissioning, and submit it to the *electricity supply undertaking.*

B1.2.1. Identification

Plant name:	
Plant owner's name and address:	
Plant owner's tel. no.:	
Plant owner's email address:	
Date of commissioning:	
GSRN number (all numbers must be provided for *plant*):	
Name of *electricity supply under-taking*:	
Name of nearest 30-60 kV substa-tion:	
Name of nearest 132-150 kV sub-station:	
Name and location of the *Point of Connection* (*POC*):	
Voltage at the *POC* (rated):	______ kV
Name and location of *Point of Common Coupling* (*PCC*):	
Voltage at the *PCC* (rated):	______ kV
Are there other connection points to the *public electricity supply grid*? Description of other connection points:	Yes ☐ No ☐

B1.2.2. Description of the plant

Type *Describe the type:	Steam turbine ☐ Gas turbine ☐ Combined-cycle unit ☐ Gas engine ☐ Diesel engine ☐ Other* ☐
Specification of fuel:	
Rated output (P_n)	______ kW
Minimum power (P_{min})	______ kW
Overload capacity ($P_{overload}$)	______ kW
Rated mechanical shaft power for drive system (P_{mech})	______ kW
Is a flowchart for the *plant* available? Reference to document:	Yes ☐ No ☐
Is a line diagram available showing settlement metering, online metering, ownership boundaries and operation manager boundaries? Reference to document:	Yes ☐ No ☐

B1.2.3. Determination of voltage level

What is the *normal operating voltage* (*Uc*) at the *POC*?	______ kV

B1.2.4. Normal operating conditions

Within the *normal production* area, see Figure 4, can the *plant* be started and generate continuously?	Yes ☐ No ☐
Will the *plant* remain connected in the event of frequency and voltage deviations at the *POC,* in line with Figure 4? Reference to type test/study or protection philosophy that verifies the above:	Yes ☐ No ☐

B1.2.5. Abnormal operating conditions

Will the *plant* remain connected in the event of phase jumps of 20° at the *POC*? Reference to type test/study that verifies the above:	Yes ☐ No ☐
Will the *plant* remain connected in the event of transient frequency gradients of 2.5 Hz/s at the *POC*? Reference to type test/study or protection philosophy that verifies the above:	Yes ☐ No ☐

B1.2.6. Voltage dip tolerances

(Apply only to category B plants above 200 kW)

Will the *plant* remain connected in the event of voltage dips at the *POC*, see Figure 5 and Figure 6? Reference to type test/study or manufacturer declaration that verifies the above:	Yes ☐ No ☐

B1.2.7. Power quality

When the plant is connected, do *rapid voltage changes* greater than the permissible levels (see Table 3) occur? Reference to calculation/study that verifies the above:	Yes ☐ No ☐

B1.2.8. Control functions

Which of the following control functions are active in the *plant*?	*Frequency response* – LFSM-O ☐ *Q control* ☐ *PF control* ☐

B1.2.9. Frequency response (LFSM-U and LFSM-O)

Is the *plant* designed with a *frequency response* system that can control active power as a function of frequency deviations from the reference frequency? Reference to type test/data sheet that verifies the above:	Yes ☐ No ☐
In the event of a frequency deviation, is the *frequency response* activated within 2 seconds?	Yes ☐ No ☐
Is it possible to adjust the *frequency response droop* to a value in the 2-8% range of P_n?	Yes ☐ No ☐
Is the *droop* set to 6%?	Yes ☐ No ☐
Is it possible to set the *frequency response* limit frequency (f_{min} and f_{max}) to a value in the 47-52 Hz range?	Yes ☐ No ☐
Is it possible to set the *frequency response* activation frequency (f_{Rmax}) to a value in the 50.1-52 Hz range?	Yes ☐ No ☐
Is f_{Rmax} set to 50.2 Hz? If 'no', what is the setting?	Yes ☐ No ☐
Is frequency measurement accuracy higher than 10 mHz and the control function sensitivity higher than +/-10 mHz?	Yes ☐ No ☐

B1.2.10. Frequency control

Does the *plant* have to provide ancillary services? If 'yes', which?	Yes ☐ No ☐ FCR – power frequency control ☐ FCR – FNR ☐ FCR – FDR ☐ FRR-a ☐ FRR-m ☐
Is the *plant's* turbine governor set with the specific parameter settings for the ancillary service(s) to be delivered, in line with the specifications for ancillary services?	Yes ☐ No ☐
Is it possible to change the parameter settings within 10 seconds?	Yes ☐ No ☐

B1.2.11. Reactive power control functions

Where is the reference point for the reactive power control functions located? *Describe where:	*PGC* ☐ *POC* ☐ *PCC* ☐ Elsewhere* ☐

B1.2.12. Requirements for reactive power control area

Can the generator *plant* supply reactive power at P_n and varying operating voltages, as specified in Figure 14? Reference to study/type test that verifies the above:	Yes ☐ No ☐
Is the generator's PQ diagram available? Reference to data sheet:	Yes ☐ No ☐

B1.2.13. Generator

Manufacturer:	
Type:	
Is there a data sheet for the generator? Reference to data sheet:	Yes ☐ No ☐
Does the generator comply with relevant parts of the following European Standards: - DS/EN60034-1, 'Rotating electrical machines – Part 1: Rating and performance', 2004 - DS/EN60034-3, 'Rotating electrical machines – Part 3: Specific requirements for turbine-type synchronous machines', 1995	Yes ☐ No ☐
Does the generator have a *short-circuit ratio* of 0.45 or higher?	Yes ☐ No ☐
Does the generator have a transient reactance (X'_d) of less than 0.35 pu?	Yes ☐ No ☐

B1.2.14. Generator data

Description	Symbol	Unit	Value
Rated apparent power (1 p.u.):	S_n	MVA	
Rated voltage (1 p.u.):	U_n	kV	
Rated frequency:	f_n	Hz	
Rated *Power Factor* (cosφ):	$\cos\varphi_n$	-	
Rated minimum reactive power generation from PQ diagram:	$Q_{min,n}$	Mvar	
Rated maximum reactive power generation from PQ diagram:	$Q_{max,n}$	Mvar	
Synchronous speed:	n_n	Rpm	
Total moment of inertia for rotating mass (generator, drive system, etc.):	J_{tot}	$kg \cdot m^2$	
Total moment of inertia for generator:	J_G	$kg \cdot m^2$	
Total moment of inertia for drive system:	J_D	$kg \cdot m^2$	
Rotor type:	-	-	Salient poles ☐ Distinct poles ☐
Stator resistance per phase:	R_a	p.u.	
Temperature for resistance:	T_R	ºC	
Stator dispersion reactance per phase:	X_{ad}	p.u.	
Positive-sequence reactance, d axis:	X_d	p.u.	
Transient reactance, d axis:	X'_d	p.u.	
Subtransient reactance, d axis:	X''_d	p.u.	
Saturated positive-sequence reactance, d axis:	$X_{d,sat}$	p.u.	
Saturated subtransient positive-sequence reactance, d axis:	$X''_{d,sat}$	p.u.	
Positive-sequence reactance, q axis:	X_q	p.u.	
Transient reactance, q axis:	X'_q	p.u.	

Subtransient reactance, q axis:	X''_q	p.u.	
Transient open circuit time constant, d axis:	T'_{d0}	s	
Subtransient open circuit time constant, d axis:	T'_{d0}	s	
Transient open circuit time constant, q axis:	T'_{q0}	s	
Subtransient open circuit time constant, q axis:	T''_{q0}	s	
Potier reactance:	X_p	p.u.	
Saturation point at 1.0 p.u. voltage:	$SG_{1.0}$	p.u.	
Saturation point at 1.2 p.u. voltage:	$SG_{1.2}$	p.u.	
Reactance, inverse-component:	X_2	p.u.	
Resistance, inverse-component:	R_2	p.u.	
Reactance, zero-component:	X_0	p.u.	
Resistance, zero-component:	R_0	p.u.	
Is the generator star point earthed?	-	-	Yes ☐ No ☐
If yes, ground reactance:	X_e	Ohm	
If yes, ground resistance:	R_e	Ohm	
Generator's *short-circuit ratio* (Rated):	K_c	p.u.	

B1.2.15. Excitation system

What type of *excitation system* is used? *Describe the type:	Rotating ☐ Static ☐ Other* ☐
Is there a data sheet for the AVR? Reference to data sheet:	Yes ☐ No ☐

B1.2.16. Protection

Is a positive-sequence undervoltage relay used as protection against out-of-phase reclosing? If 'yes', reference to study justifying use of the relay:	Yes ☐ No ☐

B1.2.17. Protective functions and settings

Protective function	Symbol	Setting		Trip time		Standard setting
Positive-sequence undervoltage*		$0.7 \cdot U_n$	V	≤ 50	ms	50 ms
Overvoltage (step 2)	$U_{>>}$	$1.10 \cdot U_n$	V	< 50 ms	ms	< 50 ms
Overvoltage (step 1)	$U_{>}$	$1.06 \cdot U_n$	V	30-60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.90 \cdot U_n$	V	2…10	s	10 s
Overfrequency	$f_{>}$	52	Hz	300	ms	300 ms
Underfrequency	$f_{<}$	47	Hz	300	ms	300 ms
Change of frequency	*df/dt*	±2.5	Hz/s	80-100	ms	80 ms
Overcurrent*	$I_{>}$	$\geq \frac{U_N/\sqrt{3}}{X''_d + X_{k,G}}$	A	50	ms	50 ms
Overcurrent – positive-sequence undervoltage relay is not used	$I_{>}$	**	A		ms	

B1.2.18. Measurement requirements

Has settlement metering been implemented in line with market regulation D1 and D2?	Yes ☐ No ☐
Have online measurements and signals been implemented in line with ancillary services to be supplied in Denmark – specifications? (only relevant if the *plant* will provide ancillary services) Reference to signal list that verifies the above:	Yes ☐ No ☐

B1.2.19. Scope of signals

Signal #	**Signal description**
Set point	Stop signal
Set point	Released for start

B1.2.20. Signature

Date of commissioning	
Company	
Person responsible for commissioning	
Signature	

B1.3. Appendix 1 for plant category C

The documentation must be filled in with preliminary data for the *plant* and sent to the *electricity supply undertaking* no later than:

- twelve months **before** the date of commissioning for rated output ≥ 10 MW
- three months **before** the date of commissioning for rated output < 10 MW

No later than three months **after** the date of commissioning, documentation must be provided in the form of specific data for the entire *plant,* which must be sent to the *electricity supply undertaking*.

Required documentation comprises the following:

B1.3.1. Identification

Plant name:	
Plant owner's name and address:	
Plant owner's tel. no.:	
Plant owner's email address:	
Date of commissioning:	
GSRN number (all numbers must be provided for *plant*):	
Name of *electricity supply under-taking*:	
Name of nearest 30-60 kV substa-tion:	
Name of nearest 132-150 kV sub-station:	
Name and location of the *Point of Connection* (*POC*):	
Voltage at the *POC* (rated):	______ kV
Name and location of *Point of Common Coupling* (*PCC*):	
Voltage at the *PCC* (rated):	______ kV

Are there other connection points to the *public electricity supply grid*? Description of other connection points:	Yes ☐ No ☐

B1.3.2. Description of the plant

Type *Describe the type:	Steam turbine ☐ Gas turbine ☐ Combined-cycle unit ☐ Gas engine ☐ Diesel engine ☐ Other* ☐
Specification of fuel:	
Rated output (P_n)	______ MW
Minimum power (P_{min})	______ MW
Overload capacity ($P_{overload}$)	______ MW
Rated mechanical shaft power for drive system (P_{mech})	______ MW
Is a flowchart for the *plant* availa-ble? Reference to document:	Yes ☐ No ☐
Is a line diagram available showing settlement metering, online meter-ing, ownership boundaries and operation manager boundaries? Reference to document:	Yes ☐ No ☐

B1.3.3. Determination of voltage level

What is the *normal operating voltage* (*Uc*) at the *POC*?	______ kV

B1.3.4. Normal operating conditions

Within the *normal production* area, see Figure 4, can the *plant* be started and generate continuously?	Yes ☐ No ☐
Will the *plant* remain connected in the event of frequency and voltage deviations at the *POC,* in line with Figure 4? Reference to type test/study/protection philosophy that verifies the above:	Yes ☐ No ☐

B1.3.5. Abnormal operating conditions

Will the *plant* remain connected in the event of phase jumps of 20° at the *POC*? Reference to type test/study that verifies the above:	Yes ☐ No ☐
Will the *plant* remain connected in the event of transient frequency gradients of 2.5 Hz/s at the *POC*? Reference to type test/study or protection philosophy that verifies the above:	Yes ☐ No ☐

B1.3.6. Voltage dip tolerances

Will the *generator plant* remain connected in the event of voltage dips at the *POC, see* Figure 5 and Figure 6? Reference to type test/study or manufacturer declaration that verifies the above:	Yes ☐ No ☐
Do auxiliary supply and auxiliary facilities remain connected in the event of voltage dips at the *POC,* see Figure 5 and Figure 6? Reference to type test/study/design philosophy or manufacturer declaration that verifies the above:	Yes ☐ No ☐

B1.3.7. Voltage support during voltage dips

Does the *plant* provide voltage support during voltage dips? Reference to type test/study/data sheet or manufacturer declaration that verifies the above:	Yes ☐ No ☐

B1.3.8. Recurring voltage dips in the public electricity supply grid

Does the *generator plant* remain connected in the event of repeated voltage dips at the *POC, see* Table 2? Reference to type test/study or manufacturer declaration that verifies the above:	Yes ☐ No ☐

B1.3.9. Power quality

When the plant is connected, do *rapid voltage changes* greater than the permissible levels (see Table 3) occur? Reference to calculation/study that verifies the above:	Yes ☐ No ☐

B1.3.10. Control functions

Which of the following control functions are active in the *plant*?	*Frequency response* – LFSM-O ☐ *Frequency response* – LFSM-U ☐ *Q control* ☐ *PF control* ☐ Voltage control☐
Are all set point changes recorded with a 5-minute time stamp (*UTC*)?	Yes ☐ No ☐

B1.3.11. Active power control functions

Can a set point be set with a resolution of 1% of P_n or higher?	Yes ☐ No ☐
Can parameters in control functions be set with a resolution of 10 mHz or higher?	Yes ☐ No ☐
Can control function *droops* be set with a resolution of 1% or higher?	Yes ☐ No ☐
Do set points and effected control values deviate by more than 2% of P_n over a period of 1 minute?	Yes ☐ No ☐

B1.3.12. Frequency response (LFSM-U and LFSM-O)

Is the *plant* designed with a *frequency response* system that can control active power as a function of frequency deviations from the reference frequency? Reference to type test/data sheet that verifies the above:	Yes ☐ No ☐
In the event of a frequency deviation, is the *frequency response* activated within 2 seconds?	Yes ☐ No ☐
Is it possible to adjust the *frequency response droop* to a value in the 2-8% range of P_n?	Yes ☐ No ☐
Is the *droop* set to 6%?	Yes ☐ No ☐
Is it possible to set the *frequency response* limit frequency (f_{min} and f_{max}) to a value in the 47-52 Hz range?	Yes ☐ No ☐
Is it possible to set the *frequency response* activation frequency (f_{Rmax} and f_{Rmin}) to a value in the 50.1-52 Hz range for f_{Rmax} and 47-49.9 Hz range for f_{Rmin}?	Yes ☐ No ☐
Is f_{Rmax} set to 50.2 Hz and f_{Rmin} to 49.8 Hz? If 'no', what are the settings?	Yes ☐ No ☐
Is frequency measurement accuracy higher than 10 mHz and the control function sensitivity higher than +/-10 mHz?	Yes ☐ No ☐

B1.3.13. Frequency control

Does the *plant* have to provide ancillary services? If 'yes', which?	Yes ☐ No ☐ FCR – power frequency control ☐ FCR – FNR ☐ FCR – FDR ☐ FRR-a ☐ FRR-m ☐
Is the *plant's* turbine governor set with the specific parameter settings for the ancillary service(s) to be delivered, in line with the specifications for ancillary services?	Yes ☐ No ☐
Is it possible to change the parameter settings within 10 seconds?	Yes ☐ No ☐

B1.3.14. Reactive power control functions

Where is the reference point for the reactive power control functions located? *Describe where:	*PGC* ☐ *POC* ☐ *PCC* ☐ Elsewhere* ☐

B1.3.15. Q control

Does the *plant* begin adjustment to a new set point after 2 seconds and complete the adjustment within 30 seconds after receiving a new set point?	Yes ☐ No ☐
Do set points and effected control values deviate by more than 1% of Q_N over a period of 1 minute?	Yes ☐ No ☐
Is it possible to set a set point with a resolution of 100 kVAr or higher?	Yes ☐ No ☐

B1.3.16. Power Factor control

Does the *plant* begin adjustment to a new set point after 2 seconds and complete the adjustment within 30 seconds after receiving a new set point?	Yes ☐ No ☐
Do set points and effected control values deviate by more than 1% of the set point for *Power Factor* over a period of 1 minute?	Yes ☐ No ☐
Is it possible to set a set point with a resolution of 0.01 or higher?	Yes ☐ No ☐

B1.3.17. Voltage control

Does the *plant* begin adjustment to a new set point after 2 seconds and complete the adjustment within 10 seconds after receiving a new set point?	Yes ☐ No ☐
Can the *droop* for the voltage controller be set in the 2-8% range?	Yes ☐ No ☐
Is the *droop* for the voltage controller set to 4%?	Yes ☐ No ☐

B1.3.18. Reactive power control requirements

Can the *plant* supply reactive power at P_n and varying operating voltages, as specified in Figure 15? Reference to study/type test that verifies the above:	Yes ☐ No ☐
Is the generator's PQ diagram available? Reference to data sheet:	Yes ☐ No ☐

B1.3.19. System protection

Can the generator *plant* adjust active power down to five predefined power levels (70%, 50%, 40%, 25% and 0%)? Reference to live test that verifies the above:	Yes ☐ No ☐
When system protection is activated, does adjustment begin after 1 second and is it completed after 10 seconds?	Yes ☐ No ☐

B1.3.20. Generator

Manufacturer:	
Type:	
Is there a data sheet for the generator? Reference to data sheet:	Yes ☐ No ☐
Does the generator comply with relevant parts of the following European Standards: - DS/EN60034-1, 'Rotating electrical machines – Part 1: Rating and performance', 2004 - DS/EN60034-3, 'Rotating electrical machines – Part 3: Specific requirements for turbine-type synchronous machines', 1995	Yes ☐ No ☐
Does the generator have a *short-circuit ratio* of 0.45 or higher?	Yes ☐ No ☐
Does the generator have a transient reactance (X'_d) of less than 0.35 pu?	Yes ☐ No ☐

B1.3.21. Generator data

Description	Symbol	Unit	Value
Rated apparent power (1 p.u.):	S_n	MVA	
Rated voltage (1 p.u.):	U_n	kV	
Rated frequency:	f_n	Hz	
Rated *Power Factor* (cosφ):	$\cos\varphi_n$	-	
Rated minimum reactive power generation from PQ diagram:	$Q_{min,n}$	Mvar	
Rated maximum reactive power generation from PQ diagram:	$Q_{max,n}$	Mvar	
Synchronous speed:	n_n	Rpm	
Total moment of inertia for rotating mass (generator, drive system, etc.):	J_{tot}	$kg{\cdot}m^2$	
Total moment of inertia for generator:	J_G	$kg{\cdot}m^2$	
Total moment of inertia for drive system:	J_D	$kg{\cdot}m^2$	
Rotor type:	-	-	Salient poles ☐ Distinct poles ☐
Stator resistance per phase:	R_a	p.u.	
Temperature for resistance:	T_R	ºC	
Stator dispersion reactance per phase:	X_{ad}	p.u.	
Positive-sequence reactance, d axis:	X_d	p.u.	
Transient reactance, d axis:	X'_d	p.u.	
Subtransient reactance, d axis:	X''_d	p.u.	
Saturated positive-sequence reactance, d axis:	$X_{d,sat}$	p.u.	
Saturated subtransient positive-sequence reactance, d axis:	$X''_{d,sat}$	p.u.	
Positive-sequence reactance, q axis:	X_q	p.u.	
Transient reactance, q axis:	X'_q	p.u.	
Subtransient reactance, q axis:	X''_q	p.u.	

Transient open circuit time constant, d axis:	T'_{d0}	s	
Subtransient open circuit time constant, d axis:	T'_{d0}	s	
Transient open circuit time constant, q axis:	T'_{q0}	s	
Subtransient open circuit time constant, q axis:	T''_{q0}	s	
Potier reactance:	X_p	p.u.	
Saturation point at 1.0 p.u. voltage:	$SG_{1.0}$	p.u.	
Saturation point at 1.2 p.u. voltage:	$SG_{1.2}$	p.u.	
Reactance, inverse-component:	X_2	p.u.	
Resistance, inverse-component:	R_2	p.u.	
Reactance, zero-component:	X_0	p.u.	
Resistance, zero-component:	R_0	p.u.	
Is the generator star point earthed?	-	-	Yes ☐ No ☐
If yes, ground reactance:	X_e	Ohm	
If yes, ground resistance:	R_e	Ohm	
Generator's *short-circuit ratio* (Rated):	K_c	p.u.	

B1.3.22. Generator transformer

Manufacturer:	
Type:	
Is there a data sheet for the transformer? Reference to data sheet:	Yes ☐ No ☐
Is the generator transformer designed with short-circuit impedance less than the calculated value, see section 5.5.2.1?	Yes ☐ No ☐

Reference to calculation that verifies the above:	

B1.3.23. Transformer data

Description	Symbol	Unit	Value
Rated apparent power (1 p.u.):	S_n	MVA	
Rated primary voltage (1 p.u.):	U_p	kV	
Rated secondary voltage:	U_s	kV	
Coupling designation, e.g. Dyn11:	-	-	
Step switch location:	-	-	Primary side ☐ Secondary side ☐
Step switch, additional voltage per step:	du_{tp}	%/step	
Step switch, phase angle of additional voltage per step:	phi_{tp}	degree/step	
Step switch, lowest position:	n_{tpmin}	-	
Step switch, highest position:	n_{tpmax}	-	
Step switch, neutral position:	n_{tp0}	-	
Short-circuit voltage, synchronous:	u_k	%	
Copper loss:	P_{cu}	kW	
Short-circuit voltage, zero system:	u_{k0}	%	
Resistive short-circuit voltage, zero-sequence system:	u_{kr0}	%	
No-load current:	I_0	%	
No-load loss:	P_0	%	
Short-circuit impedance:	e_z	p.u.	

B1.3.24. Excitation system

What type of *excitation system* is used? *Describe the type:	Rotating ☐ Static ☐ Other* ☐
Is there a data sheet for the AVR? Reference to data sheet:	Yes ☐ No ☐
Is the *excitation system* in conformity with the following European Standards: - EN60034-16-1 'Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Chapter 1: Definitions' - IEC technical report IEC 60034-16-3 'Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Section 3: Dynamic performance'	Yes ☐ No ☐
Is the *excitation system's* open-loop *frequency response* amplification less than 20 dB in the 0.2-1.5 Hz frequency range?	Yes ☐ No ☐
Can the generator be overexcited to 1.6 times the excitation at rated output and tgφ = 0.4 and rated operating voltage for at least 10 seconds? Reference to type test/study or data sheet that verifies the above:	Yes ☐ No ☐
Are limit functions in the *excitation system* selective with protective functions?	Yes ☐ No ☐

Reference to study/data sheet or live test that verifies the above:	
Is the *excitation system* response time for a positive 10% voltage change no greater than 0.3 seconds for a static excitation system, and 0.5 seconds for a rotating excitation system? Reference to type test/study or live test that verifies the above:	Yes ☐ No ☐
Is the *excitation system* response time for a negative 10% voltage change no greater than 0.8 seconds for a rotating *excitation system*? Reference to type test/study/live test that verifies the above:	Yes ☐ No ☐
Is the *excitation system* response to a momentary ±10% voltage change non-oscillatory? Reference to type test/study or live test that verifies the above:	Yes ☐ No ☐
Does overshooting of no more than 15% occur in connection with ±10% voltage changes? Reference to type test/study or live test that verifies the above:	Yes ☐ No ☐

B1.3.25. Protection

Is a positive-sequence under-voltage relay used as protection against out-of-phase reclosing? If 'yes', reference to study justifying use of the relay:	Yes ☐ No ☐

B1.3.26. Protective functions and settings

Protective function	Symbol	Setting		Trip time		Standard setting
Positive-sequence undervoltage*		$0.7 \cdot U_n$	V	≤ 50	ms	50 ms
Overvoltage (step 2)	$U_{>>}$	$1.10 \cdot U_n$	V	< 50 ms	ms	< 50 ms
Overvoltage (step 1)	$U_{>}$	$1.06 \cdot U_n$	V	30-60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.90 \cdot U_n$	V	2…10	s	10 s
Overfrequency	$f_{>}$	52	Hz	300	ms	300 ms
Underfrequency	$f_{<}$	47	Hz	300	ms	300 ms
Change of frequency	df/dt	±2.5	Hz/s	80-100	ms	80 ms
Overcurrent*	$I_{>}$	$\geq \frac{U_N / \sqrt{3}}{X''_d + X_{k,G}}$	A	50	ms	50 ms
Overcurrent – positive-sequence undervoltage relay is not used	$I_{>}$	***	A		ms	

B1.3.27. Measurement requirements

Has settlement metering been implemented in line with market regulation D1 and D2?	Yes ☐ No ☐
Have online measurements been established in line with TR 5.8.1? Reference to signal list that verifies the above:	Yes ☐ No ☐
Have online measurements and signals been implemented in line with ancillary services to be supplied in Denmark – specifications? (only relevant if the *plant* will provide ancillary services) Reference to signal list that verifies the above:	Yes ☐ No ☐

B1.3.28. Scope of signals

Signal type	Signal description
M	Switch gear status in the *POC* Switch gear status in the collection radials
M	Active power supplied at the *POC.*
M	Reactive power – import/export at *POC*
M	*Power Factor* – calculated at *POC*
M	Voltage in the *voltage reference point*
Set point	Active power control – *frequency response* – LFSM-O – activate/deactivate
Status	Active power control – *frequency response* – LFSM-O – activated/not activated
Set point	Active power control – *frequency response* – LFSM-O – setting value – f_{Rmax}
Status	Active power control – *frequency response* – LFSM-O – value – f_{Rmax}
Set point	Active power control – *frequency response* – LFSM-O – setting value – *Droop 1*
Status	Active power control – *frequency response* – LFSM-O – value – *Droop 1*
Set point	Active power control – *frequency response* – LFSM-U – activate/deactivate
Status	Active power control – *frequency response* – LFSM-U – activated/not activated
Set point	Active power control – *frequency response* – LFSM-U – setting value – f_{Rmin}
Status	Active power control – *frequency response* – LFSM-U – value – f_{Rmin}
Set point	Active power control – *frequency response* – LFSM-U – setting value – *Droop* 2
Status	Active power control – *frequency response* – LFSM-U – value – *Droop* 2

Set point	Active power control – *frequency control* – activate/deactivate
Status	Active power control – *frequency control* – activated/not activated
Set point	Active power control – *frequency control* – setting value – f1
Status	Active power control – *frequency control* – value – f1
Set point	Active power control – *frequency control* – setting value – *Droop* 3
Status	Active power control – *frequency control* – value – *Droop* 3
Set point	Active power control – *frequency control* – setting value – f2
Status	Active power control – *frequency control* – value – f2
Set point	Active power control – *frequency control* – setting value – *Droop* 4
Status	Active power control – *frequency control* – value – *Droop* 4
Set point	Active power control – *frequency control* – setting value – f3
Status	Active power control – *frequency control* – value – f3
Set point	Active power control – *frequency control* – setting value – *Droop* 5
Status	Active power control – *frequency control* – value – *Droop* 5
Set point	Active power control – *frequency control* – setting value – f4
Status	Active power control – *frequency control* – value – f4
Set point	Active power control – *load regulator (absolute power limit)* – activate/deactivate
Status	Active power control – *load regulator (absolute power limit)* – activated/not activated
Set point	Active power control – *load regulator (absolute power limit)* – desired active power at POC
Status	Active power control – *load regulator (absolute power limit)* – desired active power at POC
Set point	Active power control – *ramp rate limit* – activate/deactivate
Status	Active power control – *ramp rate limit* – activated/not activated
Set point	Active power control – *ramp rate limit* – ramp rate for upward/downward adjustment
Status	Active power control – *ramp rate limit* – ramp rate for upward/downward adjustment
Set point	Active power control – system protection – activate/deactivate
Status	Active power control – system protection – activated/not activated
Set point	Active power control – system protection – Set point
Set point	Reactive power control – *Q control* – activate/deactivate
Status	Reactive power control – *Q control* – activated/not activated
Set point	Reactive power control – *Q control* – setting value – desired reactive power at *POC*
Status	Reactive power control – *Q control* – value – desired reactive power at *POC*
Set point	Reactive power control – *Power Factor control* – activate/deactivate
Status	Reactive power control – *Power Factor control* – activated/not activated
Set point	Reactive power control – *Power Factor control* – setting value – desired *Power Factor* at *POC*
Status	Reactive power control – *Power Factor control* – value – desired *Power Factor* at *POC*
Set point	Reactive power control – *voltage control* – activate/deactivate
Status	Reactive power control – *voltage control* – activated/not activated
Status	Reactive power control – *voltage control* – value – desired *droop* for *voltage control*
Status	Reactive power control – *voltage control* – value – desired voltage in *voltage reference point*

Set point	Stop signal
Set point	Released for start

B1.3.29. Fault incident recording

(Apply only to category C plants above 10 MW)

Is logging equipment installed at the *POC* to monitor the following parameters, as a minimum, in connection with incidents (faults, etc.) in the *public electricity supply grid*: - Voltage for each phase for the *plant* - Current for each phase for the *plant* - Active power for the *plant* (can be computed values) - Reactive power for the *plant* (can be computed values) - Frequency for the *plant*	Yes ☐ No ☐
Is logging performed as correlated time series of measuring values from 10 seconds before the incident until 60 seconds after the incident?	Yes ☐ No ☐
Is logging equipment designed with a minimum 1 KHz sample rate for all fault logging?	Yes ☐ No ☐
Has it been agreed with the transmission system operator which incidents should be logged? If 'yes', which?	Yes ☐ No ☐
Are incidents kept in the log for a minimum of three months after a fault situation?	Yes ☐ No ☐

B1.3.30. Simulation model requirements

(Apply only to category C plants above 10 MW)

Are simulation models available with associated parameters in line with IEEE 421.5 for the complete *excitation system,* including: - Excitation system - Limit functions - Voltage regulator - Q controller - *PF* controller Reference to document/study or model package that verifies the above:	Yes ☐ No ☐
Are simulation models available with associated parameters in line with IEEE PES-TR1 for the pow-er/speed controller: Reference to document/study or model package that verifies the above:	Yes ☐ No ☐
Are simulation models available with associated parameters in line with IEEE PES-TR1 for the com-plete drive system: Reference to document/study or model package that verifies the above:	Yes ☐ No ☐
Does the model include all protec-tive functions that can be activated in the event of incidents or faults in the public electricity supply grid? Reference to document/study or model package that verifies the above:	Yes ☐ No ☐
Are the above models supported by model descriptions?	Yes ☐ No ☐

Reference to document/study that verifies the above:	

B1.3.31. Verification of simulation model

(Apply only to category C plants above 10 MW)

Have all simulation models been verified or will these be verified in connection with the commissioning test? Reference to study that verifies the above:	Yes ☐ No ☐

B1.3.32. Signature

Date of commissioning:	
Company:	
Person responsible for commissioning:	
Signature:	

B1.4. Appendix 1 for plant category D

The documentation form must be filled in with preliminary data for the *plant* and sent to the *electricity supply undertaking* no later than twelve months **before** the date of commissioning.

No later than three months **after** the date of commissioning, documentation must be provided in the form of specific data for the entire *plant,* which must be sent to the *electricity supply undertaking*.

Required documentation comprises the following:

B1.4.1. Identification

Plant name:	
Plant owner's name and address:	
Plant owner's tel. no.:	
Plant owner's email address:	
Date of commissioning:	
GSRN number (all numbers must be provided for *plant*):	
Name of *electricity supply under-taking*:	
Name of nearest 30-60 kV substa-tion:	
Name of nearest 132-150 kV sub-station:	
Name and location of the *Point of Connection* (*POC*):	
Voltage at the *POC* (rated):	______ kV
Name and location of *Point of Common Coupling* (*PCC*):	
Voltage at the *PCC* (rated):	______ kV

Are there other connection points to the *public electricity supply grid*? Description of other connection points:	Yes ☐ No ☐

B1.4.2. Description of the plant

Type *Describe the type:	Steam turbine ☐ Gas turbine ☐ Combined-cycle unit ☐ Gas engine ☐ Diesel engine ☐ Other* ☐
Specification of fuel:	
Rated output (P_n)	______ MW
Minimum power (P_{min})	______ MW
Overload capacity ($P_{overload}$)	______ MW
Rated mechanical shaft power for drive system (P_{mech})	______ MW
Is a flowchart for the *plant* availa-ble? Reference to document:	Yes ☐ No ☐
Is a line diagram available showing settlement metering, online meter-ing, ownership boundaries and operation manager boundaries? Reference to document:	Yes ☐ No ☐

B1.4.3. Determination of voltage level

What is the *normal operating voltage* (*Uc*) at the *POC*?	______ kV

B1.4.4. Normal operating conditions

Within the *normal production* area, see Figure 4, can the *plant* be started and generate continuously?	Yes ☐ No ☐
Will the *plant* remain connected in the event of frequency and voltage deviations at the *POC,* in line with Figure 4? Reference to type test/study or protection philosophy that verifies the above:	Yes ☐ No ☐

B1.4.5. Abnormal operating conditions

Will the *plant* remain connected in the event of phase jumps of 20° at the *POC*? Reference to type test/study that verifies the above:	Yes ☐ No ☐
Will the *plant* remain connected in the event of transient frequency gradients of 2.5 Hz/s at the *POC*? Reference to type test/study or protection philosophy that verifies the above:	Yes ☐ No ☐

B1.4.6. Voltage dip tolerances

Will the *generator plant* remain connected in the event of voltage dips at the *POC*, see Figure 7? Reference to type test/study that verifies the above:	Yes ☐ No ☐
Will auxiliary supply and auxiliary facilities remain connected in the event of voltage dips at the *POC,* see Figure 7? Reference to type test/study or design philosophy that verifies the above:	Yes ☐ No ☐

B1.4.7. Voltage support during voltage dips

Does the *plant* provide voltage support during voltage dips? Reference to type test/study that verifies the above:	Yes ☐ No ☐

B1.4.8. Recurring voltage dips in the public electricity supply grid

Does the *generator plant* remain connected in the event of repeated voltage dips at the *POC*, see Table 2? Reference to type test/study that verifies the above:	Yes ☐ No ☐

B1.4.9. Island operation

Can the *plant* be switched over to *house-load operation*?	Yes ☐ No ☐
Is the time during which the *plant* can run in *house-load operation* limited? If 'yes', for how long?	Yes ☐ No ☐
Can the *plant* be switched over to *house-load operation*, as specified in 3.3.5.2?	Yes ☐ No ☐
Is start-up from a dead grid (black start) possible?	Yes ☐ No ☐

B1.4.10. Power quality

When the plant is connected, do *rapid voltage changes* greater than the permissible levels (see Table 3) occur? Reference to calculation/study that verifies the above:	Yes ☐ No ☐

B1.4.11. Control functions

Which of the following control functions are active in the *plant*?	*Frequency response* – LFSM-O ☐ *Frequency response* – LFSM-U ☐ *Q control* ☐ *PF control* ☐ *Voltage control* ☐
Are all set point changes recorded with a 5-minute time stamp (*UTC*)?	Yes ☐ No ☐

B1.4.12. Active power and frequency control functions

Can a set point be set with a resolution of 1% of P_n or higher?	Yes ☐ No ☐
Can parameters in control functions be set with a resolution of 10 mHz or higher?	Yes ☐ No ☐
Can control function *droops* be set with a resolution of 1% or higher?	Yes ☐ No ☐
Do set points and effected control values deviate by more than 2% of P_n over a period of 1 minute?	Yes ☐ No ☐

B1.4.13. Frequency response (LFSM-U and LFSM-O)

Is the *plant* designed with a *frequency response* system that can control active power as a function of frequency deviations from the reference frequency? Reference to type test/data sheet that verifies the above:	Yes ☐ No ☐
In the event of a frequency deviation, is the *frequency response* activated within 2 seconds?	Yes ☐ No ☐
Is it possible to adjust the *frequency response droop* to a value in the 2-8% range of P_n?	Yes ☐ No ☐
Is the *droop* set to 6%?	Yes ☐ No ☐
Is it possible to set the *frequency response* limit frequency (f_{min} and f_{max}) to a value in the 47-52 Hz range?	Yes ☐ No ☐
Is it possible to set the *frequency response* activation frequency (f_{Rmax} and f_{Rmin}) to a value in the 50.1-52 Hz range for f_{Rmax} and 47-49.9 Hz range for f_{Rmin}?	Yes ☐ No ☐

Is f_{Rmax} set to 50.2 Hz and f_{Rmin} to 49.8 Hz? If 'no', what are the settings?	Yes ☐ No ☐
Is frequency measurement accuracy higher than 10 mHz and the control function sensitivity higher than +/-10 mHz?	Yes ☐ No ☐

B1.4.14. Frequency control

Does the *plant* have to provide ancillary services? If 'yes', which?	Yes ☐ No ☐ FCR – power frequency control ☐ FCR – FNR ☐ FCR – FDR ☐ FRR-a ☐ FRR-m ☐
Is the *plant's* turbine governor set with the specific parameter settings for the ancillary service(s) to be delivered, in line with the specifications for ancillary services?	Yes ☐ No ☐
Is it possible to change the parameter settings within 10 seconds?	Yes ☐ No ☐

B1.4.15. Reactive power control functions

Where is the reference point for the reactive power control functions located? *Describe where:	*PGC* ☐ *POC* ☐ *PCC* ☐ Elsewhere* ☐

B1.4.16. Q control

Does the *plant* begin adjustment to a new set point after 2 seconds	Yes ☐

and complete the adjustment within 30 seconds after receiving a new set point?	No ☐
Do set points and effected control values deviate by more than 1% of Q_N over a period of 1 minute?	Yes ☐ No ☐
Is it possible to set a set point with a resolution of 100 kVAr or higher?	Yes ☐ No ☐

B1.4.17. Power Factor control

Does the *plant* begin adjustment to a new set point after 2 seconds and complete the adjustment within 30 seconds after receiving a new set point?	Yes ☐ No ☐
Do set points and effected control values deviate by more than 1% of the set point for *Power Factor* over a period of 1 minute?	Yes ☐ No ☐
Is it possible to set a set point with a resolution of 0.01 or higher?	Yes ☐ No ☐

B1.4.18. Voltage control

Does the *plant* begin adjustment to a new set point after 2 seconds and complete the adjustment within 10 seconds after receiving a new set point?	Yes ☐ No ☐
Can the *droop* for the voltage controller be set in the 2-8% range?	Yes ☐ No ☐
Is the *droop* for the voltage controller set to 4%?	Yes ☐ No ☐

B1.4.19. Reactive power control requirements

Can the *plant* supply reactive power at P_n and varying operating voltages, as specified in Figure 16? Reference to study/type test that verifies the above:	Yes ☐ No ☐
Is the generator's PQ diagram available? Reference to data sheet:	Yes ☐ No ☐

B1.4.20. System protection

Can the generator *plant* adjust active power down to five predefined power levels (70%, 50%, 40%, 25% and 0%)? Reference to live test that verifies the above:	Yes ☐ No ☐
When system protection is activated, does adjustment begin after 1 second and is it completed after 10 seconds?	Yes ☐ No ☐

B1.4.21. Generator

Manufacturer:	
Type:	
Is there a data sheet for the generator? Reference to data sheet:	Yes ☐ No ☐
Does the generator comply with relevant parts of the following European Standards: - DS/EN60034-1, 'Rotating electrical machines – Part 1: Rating and performance', 2004 - DS/EN60034-3, 'Rotating electrical machines – Part 3: Specific requirements for turbine-type synchronous machines', 1995	Yes ☐ No ☐
Does the generator have a *short-circuit ratio* greater than the value specified by the transmission system operator?	Yes ☐ No ☐
Does the generator have a transient reactance (X'_d) greater than the value specified by the transmission system operator?	Yes ☐ No ☐

B1.4.22. Generator data

Description	**Symbol**	**Unit**	**Value**
Rated apparent power (1 p.u.):	S_n	MVA	
Rated voltage (1 p.u.):	U_n	kV	
Rated frequency:	f_n	Hz	
Rated *Power Factor* (cosφ):	$\cos\varphi_n$	-	
Rated minimum reactive power generation from PQ diagram:	$Q_{min,n}$	Mvar	
Rated maximum reactive power generation from PQ diagram:	$Q_{max,n}$	Mvar	

Synchronous speed:	n_n	Rpm	
Total moment of inertia for rotating mass (generator, drive system, etc.):	J_{tot}	$kg{\cdot}m^2$	
Total moment of inertia for generator:	J_G	$kg{\cdot}m^2$	
Total moment of inertia for drive system:	J_D	$kg{\cdot}m^2$	
Rotor type:	-	-	Salient poles ☐ Distinct poles ☐
Stator resistance per phase:	R_a	p.u.	
Temperature for resistance:	T_R	ºC	
Stator dispersion reactance per phase:	X_{ad}	p.u.	
Positive-sequence reactance, d axis:	X_d	p.u.	
Transient reactance, d axis:	X'_d	p.u.	
Subtransient reactance, d axis:	X''_d	p.u.	
Saturated positive-sequence reactance, d axis:	$X_{d,sat}$	p.u.	
Saturated subtransient positive-sequence reactance, d axis:	$X''_{d,sat}$	p.u.	
Positive-sequence reactance, q axis:	X_q	p.u.	
Transient reactance, q axis:	X'_q	p.u.	
Subtransient reactance, q axis:	X''_q	p.u.	
Transient open circuit time constant, d axis:	T'_{d0}	s	
Subtransient open circuit time constant, d axis:	T'_{d0}	s	
Transient open circuit time constant, q axis:	T'_{q0}	s	
Subtransient open circuit time constant, q axis:	T''_{q0}	s	
Potier reactance:	X_p	p.u.	
Saturation point at 1.0 p.u. voltage:	$SG_{1.0}$	p.u.	
Saturation point at 1.2 p.u. voltage:	$SG_{1.2}$	p.u.	

Reactance, inverse-component:	X_2	p.u.	
Resistance, inverse-component:	R_2	p.u.	
Reactance, zero-component:	X_0	p.u.	
Resistance, zero-component:	R_0	p.u.	
Is the generator star point earthed?	-	-	Yes ☐ No ☐
If yes, ground reactance:	X_e	Ohm	
If yes, ground resistance:	R_e	Ohm	
Generator's *short-circuit ratio* (Rated):	K_c	p.u.	

B1.4.23. Generator transformer

Manufacturer:	
Type:	
Is there a data sheet for the transformer? Reference to data sheet:	Yes ☐ No ☐
Has the generator transformer been designed with a short-circuit impedance less than that specified by the transmission system operator? Reference to calculation that verifies the above:	Yes ☐ No ☐

B1.4.24. Transformer data

Description	**Symbol**	**Unit**	**Value**
Rated apparent power (1 p.u.):	S_n	MVA	
Rated primary voltage (1 p.u.):	U_p	kV	
Rated secondary voltage:	U_s	kV	
Coupling designation, e.g. Dyn11:	-	-	
Step switch location:	-	-	Primary side ☐ Secondary side ☐
Step switch, additional voltage per step:	du_{tp}	%/step	
Step switch, phase angle of additional voltage per step:	phi_{tp}	degree/step	
Step switch, lowest position:	n_{tpmin}	-	
Step switch, highest position:	n_{tpmax}	-	
Step switch, neutral position:	n_{tp0}	-	
Short-circuit voltage, synchro-nous:	u_k	%	
Copper loss:	P_{cu}	kW	
Short-circuit voltage, zero sys-tem:	u_{k0}	%	
Resistive short-circuit voltage, zero-sequence system:	u_{kr0}	%	
No-load current:	I_0	%	
No-load loss:	P_0	%	
Short-circuit impedance:	e_z	p.u.	

B1.4.25. Excitation system

What type of *excitation system* is used? *Describe the type:	Rotating ☐ Static ☐ Other* ☐
Is there a data sheet for the AVR?	Yes ☐ No ☐

Reference to data sheet:	
Is the *excitation system* in conformity with the following European Standards: - DS/EN60034-16-1, 'Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Chapter 1: Definitions' - IEC technical report DS/CLC/TR 60034-16-3 'Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Section 3: Dynamic performance'	Yes ☐ No ☐
Is the *excitation system's* open-loop *frequency response* amplification less than 20 dB in the 0.2-1.5 Hz frequency range?	Yes ☐ No ☐
Can the generator be overexcited to 1.6 times the excitation at rated output and tgφ = 0.4 and rated operating voltage for at least 10 seconds? Reference to type test/study or data sheet that verifies the above:	Yes ☐ No ☐
Are limit functions in the *excitation system* selective with protective functions? Reference to study/data sheet or live test that verifies the above:	Yes ☐ No ☐
Is the *excitation system* response time for a positive 10% voltage change no greater than 0.3 seconds for a static *excitation system*, and 0.5 seconds for a rotating *excitation system*? Reference to type test/study or	Yes ☐ No ☐

live test that verifies the above:	
Is the *excitation system* response time for a negative 10% voltage change no greater than 0.8 seconds for a rotating *excitation system*? Reference to type test/study or live test that verifies the above:	Yes ☐ No ☐
Is the *excitation system* response to a momentary ±10% voltage change non-oscillatory? Reference to type test/study or live test that verifies the above:	Yes ☐ No ☐
Does overshooting of no more than 15% occur in connection with ±10% voltage changes? Reference to type test/study or live test that verifies the above:	Yes ☐ No ☐

B1.4.26. PSS function

Is the *PSS function* of type IEEE PSS2B, see IEEE 421.5? Reference to model that verifies the above:	Yes ☐ No ☐
Is the *PSS function* set so that it contributes to a significant attenuation in the 0.2-0.7 Hz frequency range? Reference to study that verifies the above:	Yes ☐ No ☐

Is the phase of the added damping signal in phase with speed changes in the 2-2 Hz frequency range? Reference to study that verifies the above:	Yes ☐ No ☐
Is damping of the plant's power oscillations faster than 1 second in all load situations and disruptions? Reference to study that verifies the above:	Yes ☐ No ☐
Has the *PSS function* been set so that no voltage change on the high-voltage side of the generator transformer greater than 1 % occurs during any power change? Reference to study that verifies the above:	Yes ☐ No ☐
Is the output signal limit for the *PSS function* set to ±5% of the generator's rated voltage (U_n)? Reference to study or simulation model that verifies the above:	Yes ☐ No ☐
Is the *PSS function* automatically deactivated when power production from the *plant* is less than 20% of P_n?	Yes ☐ No ☐
Is it possible to activate and deactivate the *PSS function*?	Yes ☐ No ☐

B1.4.27. Protection

Is a positive-sequence undervoltage relay used as protection against out-of-phase reclosing? If 'yes', reference to study justifying use of the relay:	Yes ☐ No ☐

B1.4.28. Protective functions and settings

Are studies on the scope and settings of protective functions available? Reference to study:	Yes ☐ No ☐

B1.4.29. Measurement requirements

Has settlement metering been implemented in line with market regulation D1 and D2?	Yes ☐ No ☐
Have online measurements been established in line with TR 5.8.1? Reference to signal list that verifies the above:	Yes ☐ No ☐
Have signals been implemented in line with TR 5.3.4.2? Reference to signal list that verifies the above:	Yes ☐ No ☐
Have online measurements and signals been implemented in line with ancillary services to be supplied in Denmark – specifications? (only relevant if the *plant* will provide ancillary services) Reference to signal list that verifies the above:	Yes ☐ No ☐

B1.4.30. Data communication

Have data communication protocols and data security factors been implemented as specified in section 7?	Yes ☐ No ☐
Are the signals specified in section 7 available in the *PCOM* interface?	Yes ☐ No ☐

B1.4.31. Scope of signals

Signal type	Signal description
M	Switch gear status in the *POC* Switch gear status in the collection radials
M	Active power supplied at the *POC.*
M	Reactive power – import/export at *POC*
M	*Power Factor* – calculated at *POC*
M	Voltage in the *voltage reference point*
Set point	Active power control – *frequency response* – LFSM-O – activate/deactivate
Status	Active power control – *frequency response* – LFSM-O – activated/not activated
Set point	Active power control – *frequency response* – LFSM-O – setting value – f_{Rmax}
Status	Active power control – *frequency response* – LFSM-O – value – f_{Rmax}
Set point	Active power control – *frequency response* – LFSM-O – setting value – *Droop 1*
Status	Active power control – *frequency response* – LFSM-O – value – *Droop 1*
Set point	Active power control – *frequency response* – LFSM-U – activate/deactivate
Status	Active power control – *frequency response* – LFSM-U – activated/not activated
Set point	Active power control – *frequency response* – LFSM-U – setting value – f_{Rmin}
Status	Active power control – *frequency response* – LFSM-U – value – f_{Rmin}
Set point	Active power control – *frequency response* – LFSM-U – setting value – *Droop* 2
Status	Active power control – *frequency response* – LFSM-U – value – *Droop* 2
Set point	Active power control – *frequency control* – activate/deactivate
Status	Active power control – *frequency control* – activated/not activated
Set point	Active power control – *frequency control* – setting value – f1
Status	Active power control – *frequency control* – value – f1
Set point	Active power control – *frequency control* – setting value – *Droop* 3
Status	Active power control – *frequency control* – value – *Droop* 3
Set point	Active power control – *frequency control* – setting value – f2
Status	Active power control – *frequency control* – value – f2
Set point	Active power control – *frequency control* – setting value – *Droop* 4
Status	Active power control – *frequency control* – value – *Droop* 4
Set point	Active power control – *frequency control* – setting value – f3
Status	Active power control – *frequency control* – value – f3

Set point	Active power control – *frequency control* – setting value – *Droop* 5
Status	Active power control – *frequency control* – value – *Droop* 5
Set point	Active power control – *frequency control* – setting value – f4
Status	Active power control – *frequency control* – value – f4
Set point	Active power control – *load regulator (absolute power limit)* – activate/deactivate
Status	Active power control – *load regulator (absolute power limit)* – activated/not activated
Set point	Active power control – *load regulator (absolute power limit)* – desired active power at POC
Status	Active power control – *load regulator (absolute power limit)* – desired active power at POC
Set point	Active power control – *ramp rate limit* – activate/deactivate
Status	Active power control – *ramp rate limit* – activated/not activated
Set point	Active power control – *ramp rate limit* – ramp rate for upward/downward adjustment
Status	Active power control – *ramp rate limit* – ramp rate for upward/downward adjustment
Set point	Active power control – system protection – activate/deactivate
Status	Active power control – system protection – activated/not activated
Set point	Active power control – system protection – set point
Set point	Reactive power control – *Q control* – activate/deactivate
Status	Reactive power control – *Q control* – activated/not activated
Set point	Reactive power control – *Q control* – setting value – desired reactive power at *POC*
Status	Reactive power control – *Q control* – value – desired reactive power at *POC*
Set point	Reactive power control – *Power Factor control* – activate/deactivate
Status	Reactive power control – *Power Factor control* – activated/not activated
Set point	Reactive power control – *Power Factor control* – setting value – desired *Power Factor* at *POC*
Status	Reactive power control – *Power Factor control* – value – desired *Power Factor* at *POC*
Set point	Reactive power control – *voltage control* – activate/deactivate
Status	Reactive power control – *voltage control* – activated/not activated
Status	Reactive power control – *voltage control* – value – desired *droop* for *voltage control*
Status	Reactive power control – *voltage control* – value – desired voltage in *voltage reference point*
Set point	Stop signal
Set point	Released for start

B1.4.32. Fault incident recording

Is logging equipment installed at the *POC* to monitor the following parameters, as a minimum, in connection with incidents (faults, etc.) in the *public electricity supply grid*: - Voltage for each phase for the *plant* - Current for each phase for the *plant* - Active power for the *plant* (can be computed values) - Reactive power for the *plant* (can be computed values) - Frequency for the *plant*	Yes ☐ No ☐
Is logging performed as correlated time series of measuring values from 10 seconds before the incident until 60 seconds after the incident?	Yes ☐ No ☐
Is logging equipment designed with a minimum 1 KHz sample rate for all fault logging?	Yes ☐ No ☐
Has it been agreed with the transmission system operator which incidents should be logged? If 'yes', which?	Yes ☐ No ☐
Are incidents kept in the log for a minimum of three months after a fault situation?	Yes ☐ No ☐

B1.4.33. Simulation model requirements

Are simulation models available with associated parameters in line with IEEE 421.5 for the complete *excitation system,* including: - Excitation system - Limit functions - Voltage regulator - Q controller - *PF* controller Reference to document/study or model package that verifies the above:	Yes ☐ No ☐
Are simulation models available with associated parameters in line with IEEE PES-TR1 for the power/speed controller: Reference to document/study or model package that verifies the above:	Yes ☐ No ☐
Are simulation models available with associated parameters in line with IEEE PES-TR1 for the complete drive system: Reference to document/study or model package that verifies the above:	Yes ☐ No ☐
Does the model include all protective functions that can be activated in the event of incidents or faults in the public electricity supply grid? Reference to document/study or model package that verifies the above:	Yes ☐ No ☐
Are the above models supported by model descriptions?	Yes ☐ No ☐

Reference to document or study that verifies the above:	

B1.4.34. Verification of simulation model

Have all simulation models been verified or will these be verified in connection with the commissioning test? Reference to study that verifies the above:	Yes ☐ No ☐

B1.4.35. Signature

Date of commissioning:	
Company:	
Person responsible for commissioning:	
Signature:	