GREEN POWER DENMARK

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Guide to grid connection of demand facilities for the medium- and high-voltage grid (> 1 kV)

Version 1.2

VERSION LOG

Version	Change	Date
1.0	Created on the basis of the approved technical conditions from the grid companies and Energinet.	11-07-2019
1.1	Updating of annex.	26-02-2020
1.2	Layout update	18-11-2022

TABLE OF CONTENTS

1. INTRODUCTION

This guide describes requirements for demand facilities connected to the medium- or high-voltage grid. Chapter 2 contains the administrative provisions. The purpose, legal basis, sanctions, appeal process and exemptions are explained here. This section also presents a list of normative and informative references.

Definitions and abbreviations used in this guide can be found in chapter 3.

Requirements of demand facilities are described in chapter 4. If the demand facility includes demand units which deliver demand response to the public electricity supply grid, the requirements in chapter 5 must also be fulfilled. Chapter 5 describes the requirements to be fulfilled by each demand unit that delivers demand response. Demand units that deliver demand responses are distinguished by their active participation in the operation of the public electricity supply grid, either via a market or via bilateral agreements. Additional requirements are therefore made of these demand units.

Unless specified otherwise, all of the requirements specified in this guide apply at the Point of Connection.

There are several green text boxes in this guide. Such text boxes do not include requirements; they only contain supplementary information or recommendations for the reader.

2. PURPOSE AND ADMINISTRATIVE PROVISIONS

2.1. PURPOSE

The purpose of this guide is to describe the technical and functional requirements to be fulfilled by a demand facility that is – or is required to be – connected to the public medium- and high-voltage distribution grid. The guide also describes the technical and functional requirements for demand units which deliver demand response.

By adhering to this guide, the demand facility or demand unit will be assessed to be in compliance with applicable rules and terms for connection to the public electricity supply grid.

2.1.1. Legal framework and terms and conditions

This guide is based on the rules laid down under 'COMMISSION REGULATION (EU) 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection of consumption and distribution systems' and Section 26 of the Danish Electricity Supply Act, as well as terms laid down under Section 73a and Section 73b of the Electricity Supply Act.

In case of doubt, the registered conditions will prevail.

2.1.2. New facilities and demand units

New demand facilities or demand units delivering demand response that are connected to the grid as from 18 August 2019 must comply with the requirements set out in this guide. Existing facilities, see section 2.1.3, that are connected to the grid after this date are exempt from the requirements.

2.1.3. Existing facilities and demand units

A demand facility or a demand unit delivering demand response is considered to exist if the facility or unit was connected to the grid before 18 August 2019, or if the plant owner entered into a final and binding agreement for the purchase of the main plant before 6 September 2018.

Existing demand facilities or demand units delivering demand response must comply with the requirements in force on the grid connection date or on the date when the plant owner entered into a final and binding agreement for the purchase of the main plant.

2.1.4. Changes to existing facilities and demand units

An existing demand facility or demand unit which delivers demand response to which significant technical modifications are made must fulfil the technical and functional requirements set out in this guide.

A significant modification of a facility changes the electrical properties of the facility at the Point of Connection and may, for example, include replacement of vital components.

Before changes are made, the owner of the demand facility or demand unit delivering demand response must notify the electricity supply undertaking of the modification to the demand facility or demand unit. A third party may notify modifications on behalf of the plant owner, but the legal responsibility is held by the plant owner.

> *A significant modification of a facility is an increase in the scope of delivery, or any changes in the services delivered by the demand units in the facility. A change in a demand unit that delivers services, or a change in the services delivered by the unit, can be considered to be a significant modification.*

2.2. Delineation

This guide does not include economic aspects related to the establishment of settlement metering and grid connection of demand facilities or demand units delivering demand response.

If a demand facility comprises both demand and production, these will be evaluated separately.

2.3. Complaints concerning grid connection of consumption

Complaints about the electricity supply undertaking on the grid connection of demand facilities or demand units delivering demand response may be referred to the Danish Utility Regulator (*Forsyningstilsynet*).

2.4. Sanctions in the event of non-compliance

If a demand facility or a demand unit delivering demand response does not fulfil the rules and conditions, the electricity supply undertaking may ultimately withdraw the operational notification and disconnect the electrical connection to the demand facility until the requirements are fulfilled.

2.5. Exemption from grid connection requirements

It is possible to apply for an exemption from the requirements in these instructions under special circumstances.

The plant owner must send an exemption application to the electricity supply undertaking . Depending on the nature of the application, it will be forwarded to the Danish Utility Regulator, which will make a decision.

An exemption application must contain a detailed description, which at least includes:

- Identification of the plant owner, as well as a contact person.
- A description of the demand facility/facilities or demand units delivering demand responses for which an exemption is requested.
- Reference to the provisions from which exemption is requested, and a description of the requested exemption.

- A detailed description of the reasons for the requested exemption, supported by relevant documentation and a cost-benefit analysis.
- Documentation that the requested exemption does not have any adverse effect on open power trading.

2.6. Determination of voltage level and Point of Connection

The electricity supply undertaking determines the Point of Connection and associated voltage level in accordance with the provisions of the Electricity Supply Act.

All requirements apply at the Point of Connection, unless otherwise specified.

2.7. References

2.7.1. Normative

EU Regulation 2016/1388 (DCC)
The Danish Electricity Supply Act
DS/EN 50160: Voltage characteristics of electricity supplied by public distribution networks.
DS/EN 60038: IEC/CENELEC standard voltages.
DS/EN 61000-4-30: Electromagnetic compatibility (EMC) – Part 4-30: Testing and measurement techniques – Power quality measurement methods.
DS/EN 61000-6-1: Electromagnetic compatibility (EMC) – Part 6-1: Generic standards - Immunity for residential, commercial and light industrial environments.
DS/EN 61000-6-2: Electromagnetic Compatibility (EMC) - Part 6-2: Generic standards - Immunity standard for industrial environments.

2.7.2. Informative

IEC/TR 61000-3-6: Electromagnetic compatibility (EMC) – Part 3-6: Limits – Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems.
IEC/TR 61000-3-7: Electromagnetic compatibility (EMC) – Part 3-7: Limits – Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems.
Research Association of the Danish Electric Utilities (DEFU) Report RA 557: 'Maximum emission of voltage disturbance from wind power plants >11 kW', June 2010.
DEFU Report RA 599: 'Voltage disturbance in distribution grids and industrial environments, DK2 – Eastern Denmark', Dansk Energi, September 2015.

3. DEFINITIONER/TERMER

3.1. Abbreviations

3.1.1. ψ_k

ψ_k denotes the short-circuit angle at the Point of Connection.

3.1.2. d(%)

d(%) denotes rapid voltage changes. For a more detailed description, see 3.2.18.

3.1.3. DK1

Western Denmark. For a more detailed description, see 3.2.45.

3.1.4. DK2

Eastern Denmark. For a more detailed description, see 3.2.47.

3.1.5. df/dt

df/dt denotes frequency change. For a more detailed description, see section 3.2.11.

3.1.6. I_h

I_h denotes individual harmonic currents, where h denotes the harmonic order.

3.1.7. I_n

I_n denotes nominal current. For a more detailed description, see section 3.2.32.

3.1.8. $P_{current}$

$P_{current}$ is the designation of the current level of active power.

3.1.9. P_n

P_n denotes nominal active power. For a more detailed description, see section 3.2.29.

3.1.10. P_{lt}

P_{lt} denotes long-term flicker emissions from a demand facility. P_{lt} stands for 'long term' and is evaluated over a period of 2 hours. For a more detailed description, see IEC 61000-3-7.

3.1.11. P_{st}

P_{st} denotes long-term flicker emissions from a demand facility. P_{st} stands for 'short term' and is evaluated over a period of 10 minutes. For a more detailed description, see IEC 61000-3-7.

3.1.12. PCC

Abbreviation for Point of Common Coupling. For a more detailed description, see 3.2.27.

3.1.13. PCI

Abbreviation for Point of Connection in Installation. For a more detailed description, see 3.2.20.

3.1.14. PCOM
Abbreviation for Point of Communication. PCOM is defined in section 3.2.23.

3.1.15. PF
Abbreviation for Power Factor. For a more detailed description, see section 3.2.4.

3.1.16. PDC
Abbreviation for Point of Demand Connection. For a more detailed description, see section 3.2.16.

3.1.17. POC
Abbreviation for Point of Connection. POC is defined in section 3.2.28.

3.1.18. PWHD
Abbreviation for Partial Weighted Harmonic Distortion. For a more detailed description, see 3.2.36.

3.1.19. Q_n
Q_n denotes nominal reactive power. For a more detailed description, see section 3.2.30.

3.1.20. S_k
S_k denotes short-circuit power. For a more detailed description, see 3.2.24.

3.1.21. S_n
S_n denotes nominal apparent power. For a more detailed description, see 3.2.33.

3.1.22. SCR
Abbreviation for Short-Circuit Ratio. For a more detailed description, see 3.2.26.

3.1.23. THD
Abbreviation for Total Harmonic Distortion. For a more detailed description, see 3.2.43.

3.1.24. U_c
U_c denotes normal operating voltage. For a more detailed description, see 3.2.34.

3.1.25. U_h
U_h denotes individual harmonic voltages, where h denotes the harmonic order.

3.1.26. U_n
U_n denotes nominal voltage. For a more detailed description, see section 3.2.31.

3.1.27. UTC
Abbreviation for Universal Time, Coordinated.

3.1.28. $Z_{net,h}$
$Z_{net,h}$ denotes grid impedance of the harmonic order h.

3.2. DEFINITIONS

3.2.1. Plant owner

The legal owner of a plant. In some contexts, the term 'company' is used instead of 'plant owner'. The plant owner can transfer the operational responsibility to a plant operator.

3.2.2. Plant operator

The company which holds operational responsibility for the demand facility via ownership or contractual obligations.

3.2.3. DC content

A DC current which results in an AC offset, meaning that the AC current is asymmetric around zero at the Point of Connection.

3.2.4. Power Factor (PF)

The Power Factor $\cos\varphi$ for AC systems indicates the relationship between the active power P and the apparent power S, where $P = S \cdot \cos\varphi$. Similarly, the reactive power is $Q = S \cdot \sin\varphi$. The angle between current and voltage is denoted by ϕ.

3.2.5. Electricity supply undertaking

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

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

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

3.2.6. Flicker

A visual perception of light flickering caused by voltage fluctuations. Flicker occurs if the luminance or the spectral distribution of light fluctuates with time. At a certain intensity, flicker becomes an irritant to the eye.

3.2.7. Distortions in the 2-9 kHz frequency range

Distortions in the 2-9 kHz frequency range can be found in the public electricity supply grid. Such frequencies may interfere with other customers. Interference with other customers typically occurs when emissions in this frequency range interfere with one or more resonant frequencies in the public electricity supply grid.

3.2.8. Disconnect

When a demand facility or demand unit delivering demand response disconnects the electrical connection to the public electricity supply grid.

3.2.9. Frequency

Frequency is measured in Hertz (Hz). The grid frequency in the public electricity supply grid is 50Hz. There are also other frequencies related to power quality. Such frequencies are referred to as harmonics, interharmonic overtones and distortions in the 2-9 kHz frequency range. In connection with power quality, grid frequency is referred to as the fundamental frequency.

3.2.10. Frequency deviation

When the grid frequency lies outside the normal operating range.

3.2.11. Frequency change

A change of frequency, df/dt, is a change in the grid frequency in the public electricity supply grid over a period of time.

3.2.12. Demand facility

A demand unit or a collection of multiple demand units under a grid connection point in the medium- and high-voltage grid. In a demand facility, there may be demand units delivering services as shown in figure 3.2.

3.2.13. Demand unit

A demand unit intended to convert electrical energy into another form of energy, e.g. light, movement or heat. A demand unit is, for example, a motor (pumping system, heat pumps), an immersion boiler, a charging system (battery-driven ferries, large rapid charging systems), train systems and hydrogen electrolysis systems

3.2.14. Demand unit delivering demand response

A demand unit that can regulate its active or reactive power according to an external signal or local measurement, and which sells this regulation as a service to the public electricity supply grid. A demand unit delivering demand response is part of a market via the customer itself or third parties.

3.2.15. Demand convention

This guide applies the demand convention shown in figure 3.1.

The sign preceding active/reactive power indicates the power flow as seen from the demand unit. Consumption/import of active/reactive power is stated with a positive sign, while the production/export of active/reactive power is stated with a negative sign.

The desired Power Factor control is effected with a Power Factor set point, and the sign determines whether control is to be performed in the first or the fourth quadrant.

Power Factor set points thus combine two pieces of information in a single signal: a set point value and choice of control quadrant.

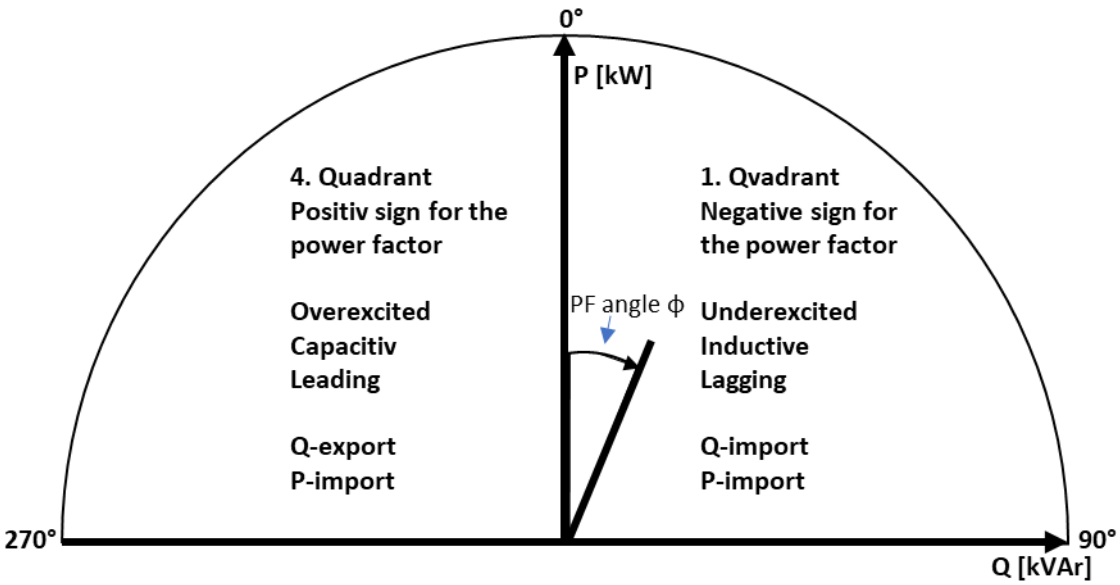

Figure 3.1 – Definition of signs for active and reactive power, Power Factor and reference for Power Factor angle.

3.2.16. Point of Demand Connection (PDC)

The place in the facility infrastructure where the terminals for a demand unit delivering demand response are located. For demand units delivering demand response, the Point of Demand Connection is the location defined by the manufacturer as the terminals of the demand unit. Se figure 3.2.

3.2.17. Harmonic overtones

Electrical disturbance caused by overharmonic currents or voltages. Harmonics are frequencies which are a whole multiple (h) of the fundamental frequency (50 Hz).

3.2.18. Rapid voltage change

A transient isolated change of the RMS voltage. A rapid voltage change expressed as a percentage of the normal operating voltage.

3.2.19. Connection

When a demand facility or demand unit is electrically connected to the public electricity supply grid, thereby becoming energised from the public electricity supply grid.

3.2.20. Point of Connection in Installation (PCI)

The point in the installation where demand units that deliver demand response are connected or may be connected, see figure 3.2 for the typical location.

3.2.21. Interharmonic overtones

Electrical disturbances caused by interharmonic currents or voltages. Interharmonic overtones are frequencies that are not a whole multiple of the fundamental frequency (50Hz). These frequencies are located between the harmonics.

3.2.22. The public electricity supply grid

Transmission and distribution grids operated on publicly regulated conditions with the purpose of transporting electricity between suppliers and consumers of electricity.

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

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

3.2.23. Point of Communication (PCOM)

The point where information is exchanged between the demand facility and other operators. The information that is exchanged comprises signals, such as measurements, status, set points and commands.

3.2.24. Short-circuit Power (S_k)

The size of the three-phase short-circuit power at the Point of Connection.

3.2.25. Short-circuit power quality ($S_{k,powerquality}$)

The size of the three-phase short-circuit power at the Point of Connection, which is used to calculate power quality.

3.2.26. Short-Circuit Ratio (SCR)

The ratio between the short-circuit power at the Point of Connection, $S_{k,power\ quality}$ and the demand facility's nominal apparent power, S_n.

$$SCR = \frac{S_{k,power\ quality}}{S_n}$$

3.2.27. Point of Common Coupling (PCC)

The point in the public electricity supply grid where consumers are or can be connected.

In electrical terms, the Point of Common Coupling and the Point of Connection may coincide. The Point of Common Coupling (PCC) is always the point furthest along the public electricity supply grid, i.e. furthest away from the facility, see figure 3.2.

The electricity supply undertaking determines the Point of Common Coupling.

3.2.28. Point of Connection (POC)

The point in the public electricity supply grid where a demand facility is or may be connected, see figure 3.2 for the typical location.

All requirements specified in this guide apply at the Point of Connection, unless otherwise specified.

The electricity supply undertaking indicates the Point of Connection.

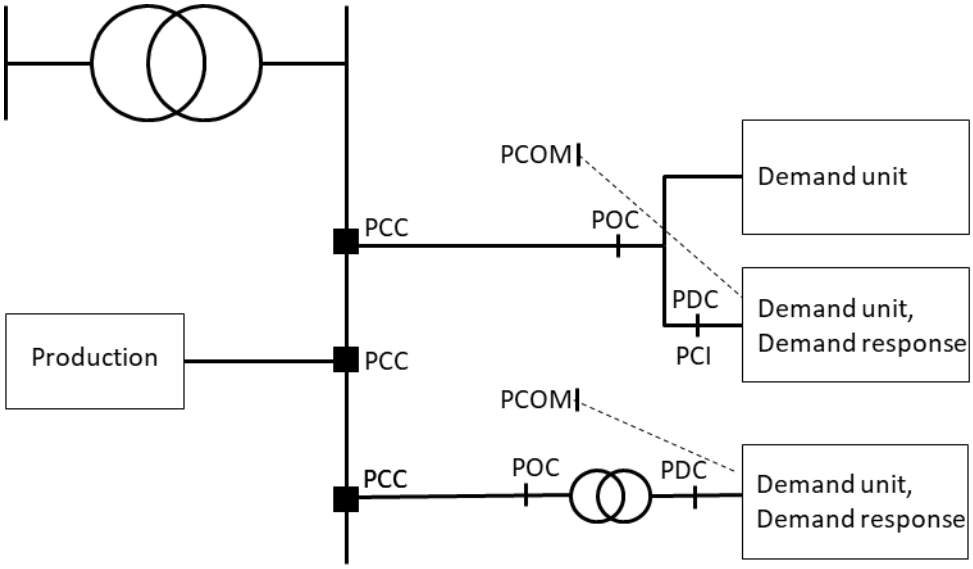

Figure 3.2 – Typical grid-connected consumption, specifying PDC, PCI, POC, PCC and PCOM.

3.2.29. Nominal active power/rated power (P_n)

The maximum active power that a demand facility or demand unit delivering demand response is designed to be able to take up continuously at the Point of Connection (POC). The rated power or nominal active power is denoted by P_n.

3.2.30. Nominal reactive power (Q_n)

The maximum reactive power that a demand facility or demand unit delivering demand response is designed to be able to take up continuously at the Point of Connection (POC). Nominal reactive power is denoted by Q_n.

3.2.31. Nominal voltage (U_n)

The voltage of a grid or component. The voltage is stated phase to phase for three-wire systems and phase to zero for four-wire systems. Nominal voltage is denoted by U_n.

3.2.32. Nominal current/rated current (I_n)

The maximum continuous power at the Point of Connection (POC) that a demand facility or demand unit delivering demand response is designed to take up in normal operating conditions. Rated current is denoted by I_n.

3.2.33. Nominal apparent power (S_n)

The maximum power, consisting of both the active and reactive components, that a demand facility is designed to be able to take up continuously at the Point of Connection (POC). Nominal apparent power is denoted by S_n.

3.2.34. Normal operating voltage (U_c)

The voltage at which the grid is operated, and thereby the voltage that can be expected at the Point of Connection (POC).
Normal operating voltage is denoted by U_c.

Normal operating voltage is determined by the electricity supply undertaking and is used to determine the normal operating range and protection. For low voltage, the normal operating voltage is equal to the nominal voltage.

3.2.35. Normal operation

The voltage and frequency range within which a demand facility or demand unit delivering demand response can be in continuous operation. For further information about normal operation, see sections 4.1.1 and 5.1.1.

3.2.36. Partial Weighted Harmonic Distortion (PWHD)

Square sum of the total harmonic distortion from a limited group of the higher harmonic orders (Y_h), weighted according to the individual order of harmonics (h). PWHD is calculated from and including the 14th harmonic order (h = 14) up to and including the 40th harmonic order (h = 40), calculated as a percentage of the fundamental frequency (h = 1).

$$PWHD_Y = \sqrt{\sum_{h=14}^{h=40} h \cdot \left(\frac{Y_h}{Y_1}\right)^2}$$

Where Y is either RMS currents ($PWHD_I$) or RMS voltages ($PWHD_U$).

3.2.37. Reactive power

The imaginary component of the apparent power, usually expressed in VAr or kVAr.

3.2.38. Robustness

Robustness towards voltage and frequency deviations, to ensure that a demand facility or demand unit delivering demand response does not disconnect from the public electricity supply grid, but instead maintains operation.

3.2.39. Voltage dip

Transient voltage change resulting in the effective value of the voltage at the Point of Connection (POC) being between 5% and 90% of normal operating voltage.

3.2.40. Voltage level

For the purpose of these instructions, the voltage levels in the distribution and transmission grids are defined according to the standard DS/EN/IEC 60038 and are as follows:

Designation of voltage level	Nominal voltage U_n [kV]	Electricity supply undertaking
Extra high voltage (EHV)	400	Transmission enterprise
	220	
High voltage (HV)	150	

Designation of voltage level	Nominal voltage U_n [kV]	Electricity supply undertaking
	132	
	60	Grid company
	50	
Medium voltage (MV)	33	
	30	
	20	
	15	
	10	
Low voltage (LV)	0.4	
	0.23	

Table 1 – Definition of voltage levels.

3.2.41. Voltage unbalance

Condition in a multiphase system where the effective values of the fundamental frequency of the outer voltages and/or the angles between the successive outer voltages are not identical.

3.2.42. Transmission system operator (TSO)

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

The transmission system operator in Denmark is Energinet.

3.2.43. Total Harmonic Distortion (THD)

Square sum of the total harmonic distortion of the individual harmonics (Y_h) from the second harmonic order (h = 2) up to and including the 40th harmonic order (h = 40), calculated as a percentage of the fundamental frequency (h = 1).

$$THD_Y = \sqrt{\sum_{h=2}^{h=40} \left(\frac{Y_h}{Y_1}\right)^2}$$

Where Y is either RMS currents (THD_I) or RMS voltages (THD_U).

3.2.44. Abnormal operation

Operating conditions with frequency or voltage deviations – i.e. operating outside the normal operating range (see section 3.2.35).

3.2.45. Western Denmark (DK1)

The part of the continental European synchronous area covering Denmark west of the Great Belt.

3.2.46. Demand response

Regulation of active or reactive power that is sold to the electricity supply undertaking or transmission system operator, in order to support system operation.

3.2.47. Eastern Denmark (DK2)

The part of the northern European synchronous area covering Denmark east of the Great Belt.

4. DEMAND FACILITIES CONNECTED TO THE MEDIUM- AND HIGH-VOLTAGE GRID

4.1. TOLERANCE OF FREQUENCY AND VOLTAGE DEVIATIONS

A demand facility must comply with the following requirements for normal operation and abnormal operation.

4.1.1. Normal operation

The demand facility must be designed to maintain normal operation in the voltage range of ±10% of U_c and in the frequency range of 49 Hz to 51 Hz at the Point of Connection.

The voltage, U_c, at the Point of Connection (POC) is disclosed by the electricity supply undertaking.

4.1.2. Tolerance of frequency deviations

The demand facility may not be damaged by the frequency deviations that may arise in the Danish electricity supply grid. Damage means that the installation and components of the facility must be designed so as not to sustain permanent loss of functionality due to frequency deviations between 47 Hz and 52 Hz, which can be expected in the Danish electricity supply grids, cf. DS/EN 50160.

4.1.3. Tolerance of voltage deviations

A demand facility must be designed to withstand voltage deviations which may occur in the Danish distribution grid during normal operation and abnormal operation. Withstand means that the facility and facility components must be designed to ensure that voltage deviations will not permanently damage their functionality. The requirement is considered to be fulfilled if the demand facility complies with the immunity requirements, cf. the relevant product standards or the DS/EN 61000-6 series.

In addition, it is recommended that a demand facility be designed so that it can maintain normal operation during the voltage dips that may occur in Danish distribution grids in the event of abnormal operation, see figure 4.1.

A demand facility or demand unit may lose its functionality briefly or restart on any voltage dip. It is up to the plant owner, in cooperation with the plant operator of the demand facility, to assess how robust the facility should be towards voltage dips.

figure 4.1 provides an overview of the voltage dips occurring in Danish distribution grids. [DEFU Report RA 599]

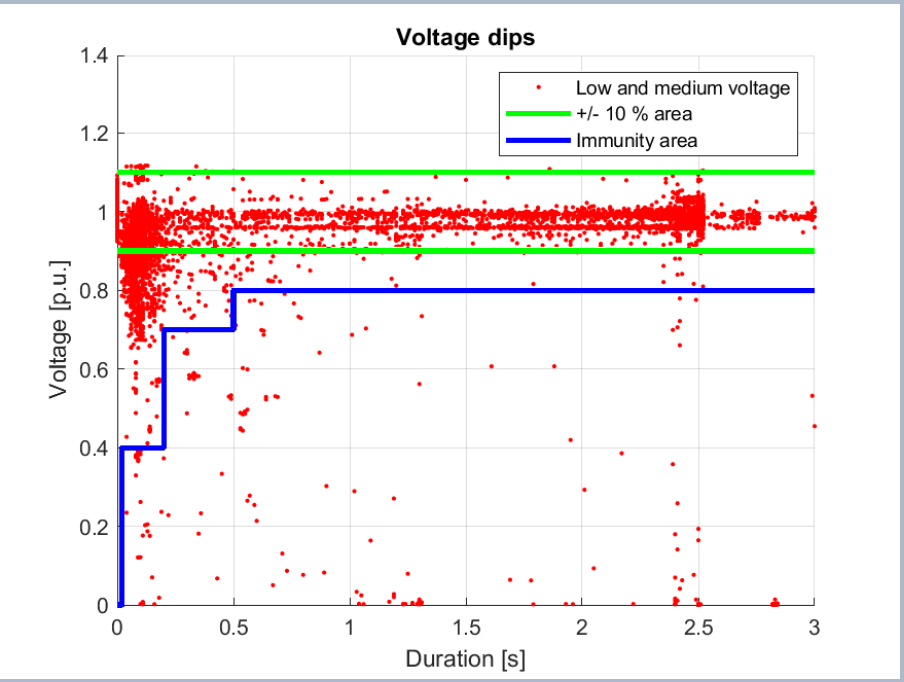

Figure 4.1 – Overview of voltage dips occurring in the Danish electricity supply grid.

4.2. Connection and start-up of a demand facility

Normal connections, including motor start-ups, must fulfil the requirements in section 4.6.1.2.

4.3. Active power control

Large variations in consumption can challenge system stability in terms of both frequency and voltage stability. It may therefore be necessary to limit the rate at which consumption changes.

As a general rule, there are no requirements for regulating the active power of demand facilities. However, there may be situations where such requirements are necessary for the sake of system stability. The plant owner must therefore engage in dialogue with the electricity supply undertaking, so that it can be clarified in consultation whether the intended mode of operation of the demand facility might present challenges in terms of system stability and whether any corrective action can be agreed in advance.

The power quality requirements entail implicit requirements for large and frequent changes in the active power. Large and frequent changes in demand will typically give rise to an elevated flicker level and exceed the limit value for rapid voltage changes.

4.4. Requirements of reactive power

In a demand facility, the power factor must lie between 0.95 and 1, calculated as a mean value measured over 15 minutes. The power factor must be complied with at the Point of Connection.

If the power factor cannot be complied with, phase-compensating equipment must be installed, dimensioned according to the power factor as a mean value measured over 15 minutes at the maximum apparent power.

No further requirements are made of the reactive power.

4.5. Grid protection

Grid protection and earthing must be agreed with the electricity supply undertaking.

Grid protection typically entails the coordination of short-circuit protection sizes via overcurrent relays or fuses at the demand facility's Point of Connection and the public electricity supply grid.

At the request of the plant owner, the electricity supply undertaking must state the greatest and smallest short-circuit current at the Point of Connection, and any earthing requirements.

4.6. Power quality

The power quality requirement is that a demand facility may not cause significant or unacceptable disturbance of the public electricity supply grid, which may be an adverse factor for other customers' facilities.

If the demand facility fulfils the provisions in section 4.6.1, the demand facility will not cause significant disturbance of the public electricity supply grid.

If the demand facility causes significant disturbance which jeopardises the technical quality of the public electricity supply grid, the electricity supply undertaking may require that the disturbance be brought below the level stipulated in section 4.6.1.

In special cases when a demand facility may have a significant impact on the public electricity supply grid (the distribution grid and/or the transmission grid), additional requirements may apply to a demand facility, see section 4.6.2.

A three-step procedure for power quality assessment is applied, which in brief comprises: :

1. *The Short-Circuit Ratio (SCR) ≥500.*
2. *A pre-evaluation of electricity quality by calculation.*
3. *Measurement of noise in the grid before and after connection of the demand facility.*
   Resolve the problem by mitigating the disturbance.

4.6.1. Limit values

Significant disturbance occurs if the demand installation exceeds the limit values set out in sections 4.6.1.1 to 4.6.1.7.

4.6.1.1. Voltage imbalance

Demand facilities may not cause unacceptable increases in voltage imbalance in the grid. In order to avoid this, consumption must be distributed as evenly as possible among the phases.

Requirements concerning imbalance are made because imbalance in phase voltages should be avoided in the public electricity supply grid, as this may have adverse effects on the grid's operation and on the units connected to the public electricity supply grid.

For technical reasons it is necessary to assess the acceptable voltage imbalance on a case-by-case basis. In some cases, even a small voltage imbalance from the demand facility will be unacceptable, while in other cases a greater voltage imbalance from the demand facility can be accepted, especially if the demand facility's voltage imbalance is contrary to the voltage imbalance already existing at the Point of Connection.

4.6.1.2. Rapid voltage changes

A rapid voltage change is a single, rapid change in the voltage's root-mean-square value from one level to another.

A demand facility may not cause rapid voltage changes exceeding the limit values specified in table 2.

Voltage level	d (%)
Medium voltage	4%
High voltage	3%

Table 2 – Limit values for rapid voltage changes.

Requirements concerning rapid voltage changes are based on IEC/TR 61000-3-7.

4.6.1.3. Flicker

A demand facility may cause significant disturbance if it exceeds the limit values for flicker calculated by the electricity supply undertaking. At the request of the plant owner, the electricity supply undertaking will state the limit values.

Limit values for flicker are determined on the basis of the methods described in IEC/TR 61000-3-7.

4.6.1.4. Harmonic disturbance

A demand facility may cause significant disturbance if it exceeds the limit values for harmonic disturbance calculated by the electricity supply undertaking. At the request of the plant owner, the electricity supply undertaking will state the limit values.

Limit values for harmonic disturbance are determined on the basis of the methods described in IEC/TR 61000-3-6.

4.6.1.5. Interharmonic disturbance

A demand facility may cause significant disturbance if it exceeds the limit values for interharmonic disturbance calculated by the electricity supply undertaking. At the request of the plant owner, the electricity supply undertaking will state the limit values.

Limit values for interharmonic disturbance are determined on the basis of the methods described in IEC/TR 61000-3-6.

4.6.1.6. Disturbance in the 2-9 kHz frequency range

A demand facility may cause significant disturbance if it exceeds the limit values for disturbance in the 2-9 kHz frequency range calculated by the electricity supply undertaking. At the request of the plant owner, the electricity supply undertaking will state the limit values.

Limit values for disturbance in the 2-9 kHz frequency range are determined on the basis of the methods described in IEC/TR 61000-3-6.

4.6.1.7. DC content

A demand facility may cause significant disturbance if it draws DC from the public electricity supply grid that are greater than 0.5% of the demand facility's nominal current.

If the facility is connected via a plant transformer (galvanic separation), the limit value is assumed to be complied with.

The limit value for DC content is set because DC currents are undesirable in the public electricity supply grid and may have an adverse effect on grid operation and protection. The limit value is set on the basis of equivalent requirements for production facilities.

4.6.2. Division of responsibilities

4.6.2.1. The plant owner's obligations

The plant owner must ensure that the demand facility is designed, constructed and configured in such a way that the facility does not cause significant disturbance of the public electricity supply grid that might have adverse consequences for other customers' facilities.

In cases where the demand facility contributes to unacceptable disturbance of the public electricity supply grid, or adverse consequences for other customers' facilities in the public electricity supply grid, the plant owner is obliged to contribute to a solution.

If there is any doubt as to whether the demand facility may cause significant or unacceptable disturbance of the public electricity supply grid, the plant owner will be obliged to contact the electricity supply undertaking.

If the demand facility has a significant impact on the public electricity supply network, the limit values for the demand facility must be complied with and the plant owner must verify that the limit values have been complied with.

The plant owner can verify that the emission limits at the Point of Connection are complied with, in accordance with the requirements set out in this guide.

If the plant owner wishes to calculate the power quality for demand facilities, the plant owner must contact the electricity supply undertaking for details of the short-circuit level, $S_{k,power\ quality}$, and the associated short-circuit angle ψ_k at the Point of Connection.

Subject to agreement, the plant owner can buy additional services (higher short-circuit power or delivery scope) from the electricity supply undertaking in order to comply with the specified limit values.

The grid company and the transmission enterprise will perform a joint assessment of whether a demand facility has a significant impact on the public electricity supply grid.

For demand facilities with a significant impact on the public electricity supply grid, the plant owner must also:

- Use frequency-dependent impedance polygons to calculate power quality.
- Verify that emission limits are also complied with regarding the transmission grid.
- Be able to deliver an impedance model for the demand facility, see section 4.8.

4.6.2.2. The electricity supply undertaking's obligations

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

At the request of the plant owner, the electricity supply undertaking must specify the short-circuit level $S_{k,\text{power quality}}$ with associated short-circuit angle ψ_k at the Point of Connection.

If it is impossible to calculate the actual $S_{k,\text{power quality}}$ for a connection point, $S_{k,\text{power quality}}$ is estimated as $(S_{k,\,min} + S_{k,\,max})/2$.

At the request of the plant owner, the electricity supply undertaking must also state the frequency-dependent grid impedance at the Point of Connection $Z_{net,h}$. The electricity supply undertaking may choose to state the grid impedance as a measured value or as an approximate model.

Using impedance polygons, the grid company passes on the impedance polygons from the transmission enterprise, adjusted according to any intermediate systems.

$Z_{net,h}$ is generally stated as an approximate model using the approximate model below. When it is deemed necessary with respect to the impact on the public electricity supply grid, frequency-dependent impedance polygons are stated instead.

For frequencies up to and including 2 kHz:

$$|Z_{net,h}| = \sqrt{R_{50}^2 + (h \cdot X_{50})^2}\ , for\ h = [1;40]$$

For frequencies above 2kHz:

$$|Z_{net,h}| = \sqrt{R_{50}^2 + (40 \cdot X_{50})^2}\ , for\ h > 40$$

R_{50} and X_{50} are resistance and reactance at 50 Hz. They are calculated on the basis of $S_{k,power\ quality}$ and the related short-circuit angle ψ_k.

In cases where the public electricity supply grid contributes to unacceptable disturbance of the public electricity supply grid, or adverse consequences for other customers' facilities in the public electricity supply grid, the electricity supply undertaking is obliged to contribute to a solution.

4.6.3. Measurement method

Measurements of the various power quality parameters must be performed in accordance with the European standard DS/EN 61000-4-30 (class A).

Measurement of harmonic distortion of voltage and current must be carried out as defined in IEC 61000-4-7 in accordance with the principles (harmonic subgroup) and with the accuracies specified for class I.

Measurement of interharmonic distortion up to 2kHz must be carried out as defined in IEC 61000-4-7 Annex A and must be measured as interharmonic subgroups.

Alternatively, it is permitted to measure harmonic distortion up to 2 kHz with grouping enabled (harmonic groups), as specified in IEC 61000-4-7 and with the accuracies specified for class I. If harmonic distortion up to 2 kHz is measured with grouping enabled, it is not required to measure interharmonic distortion up to 2 kHz separately.

Measurement of disturbance in the 2-9 kHz frequency range must be performed as defined in IEC 61000-4-7 Annex B and must be measured in 200 Hz windows with centre frequencies from 2100 Hz to 8900 Hz.

4.7. Information exchange

As a general rule, there are no requirements for the exchange of information for demand facilities.

For a demand facility, there may be a need for information exchange. The need is assessed by the electricity supply undertaking or the transmission system operator. The specific need depends on the active power dimension of the demand facility at the grid connection point.

4.8. Verification and documentation

As a general rule, no documentation is required for demand facilities unless the facility has a significant impact on the transmission grid or contains demand units delivering demand response. If the facility includes demand units delivering demand response, documentation must be provided, as described in section 5.7.

For demand facilities with a significant impact on the public electricity supply grid, the plant owner must provide a simulation model. Requirements of simulation models are coordinated with Energinet and reference is therefore made to Energinet's memorandum on simulation models [Requirements for Generators (RfG) - simulation model requirements].

The plant owner is responsible for compliance with the requirements described in this guide and for documenting such compliance.

The electricity supply undertaking may at any time request verification and documentation that the demand facility fulfils the requirements described in this guide.

5. DEMAND UNITS DELIVERING DEMAND RESPONSE

A demand unit that is to deliver demand response to the electricity supply undertaking or the transmission system operator must fulfil the requirements stated in this chapter.

Demand response will be delivered within the general connection conditions described in chapter 4, as well as other terms, conditions and agreements applying to the demand facility.

5.1. IMMUNITY TO FREQUENCY AND VOLTAGE DEVIATIONS

5.1.1. Normal operating conditions

The demand unit must be able to maintain continuous operation in the 49 Hz to 51 Hz frequency range..

The voltage, U_c, at the Point of Connection (POC) is disclosed by the electricity supply undertaking.

The demand unit must be able to maintain continuous operation when the voltage at the Point of Connection (POC) lies within the voltage range of 90% to 110% of nominal voltage.

A demand unit delivering demand response must maintain operation at different frequencies for the minimum periods of time specified in figure 5.1, without disconnecting from the grid.

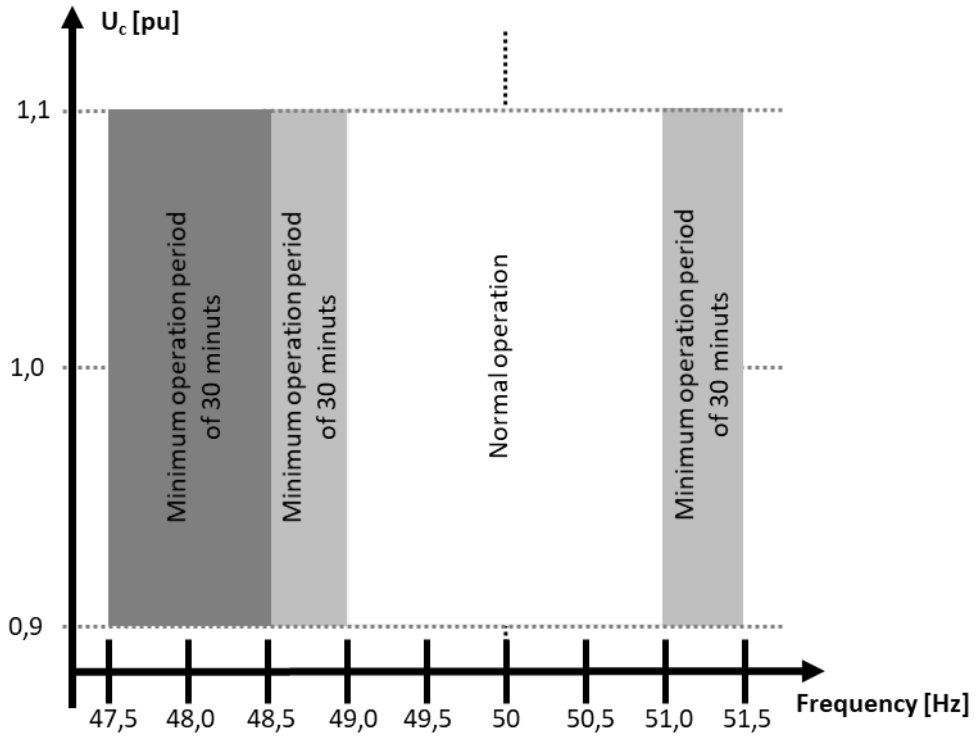

Figure 5.1 – Minimum periods during which a demand unit delivering demand response must be able to maintain operation at different frequencies without disconnecting from the grid.

5.1.2. Frequency deviations

Demand units delivering demand response may not be damaged by the frequency deviations that may arise in the Danish electricity supply grid. Damage means that demand units must be designed so as not to sustain permanent loss of functionality due to frequency deviations between 47 Hz and 52 Hz, which can be expected in the Danish electricity supply grid, cf. DS/EN 50160.

In addition, the demand unit must be able to remain connected to the grid in the event of frequency changes of up to 2.0 Hz/s.

5.1.3. Voltage deviations

Demand units delivering demand response must be designed to withstand voltage deviations which may occur in the Danish distribution grid during normal operation and abnormal operation. Damage means that demand units must be designed so as not to sustain permanent loss of functionality due to frequency deviations. The requirement is considered to be fulfilled if the demand unit complies with the immunity requirements, cf. the relevant product standards or the DS/EN 61000-6 series.

It is also recommended that the demand unit is designed so that it can maintain continuous operation in the voltage conditions that may occur in Danish distribution grids in the event of abnormal operating conditions in the electricity supply grid, see figure 5.2.

It is up to the owner, in cooperation with the operator of the demand unit, to assess the required degree of robustness towards voltage dips. A demand unit may lose its functionality briefly, or restart, after a voltage dip.

figure 5.2 provides an overview of the voltage dips occurring in Danish distribution grids.

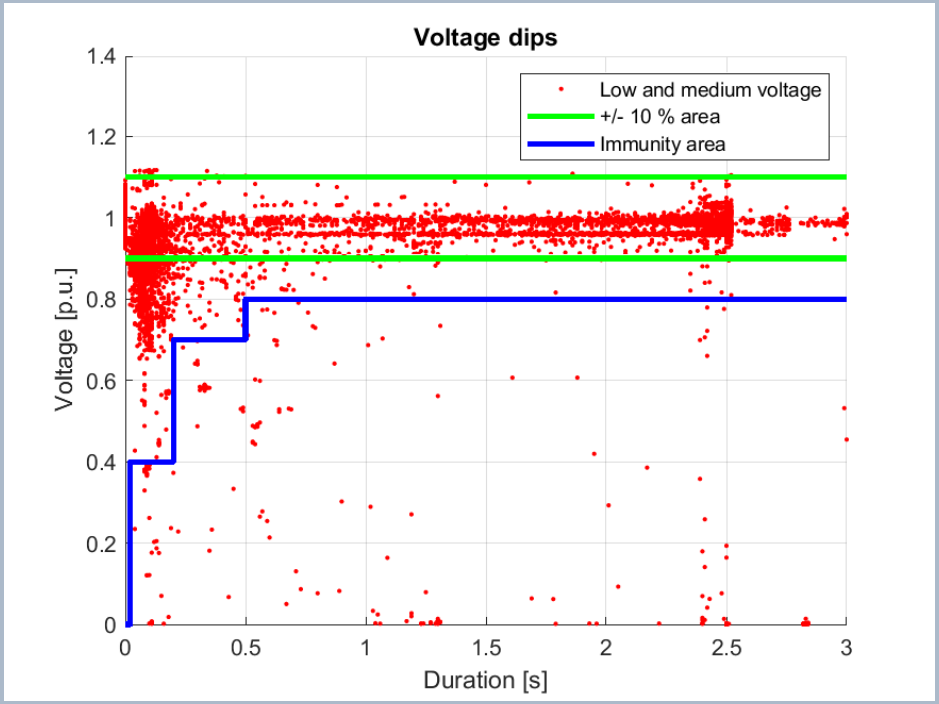

Figure 5.2 – Overview of the voltage dips occurring in the Danish electricity supply grid.

5.2. Connecting and starting up a demand unit that delivers demand response

Normal connections, including motor start-ups, must fulfil the requirements in section 4.2.

5.3. Active power control

Within the duration of the service, demand units that are in the process of delivering a service may not change their consumption unless so requested by the buyer of the service. For demand response delivered by a set of aggregated demand facilities, the buyer of the service will determine how the delivery is to be distributed among the aggregated demand units.

Demand units delivering demand response must be able to regulate their consumption within the agreed power range.

Demand units delivering demand response must notify the electricity supply undertaking if the capacity used for the delivery of demand response is changed. In addition, all purchasers of demand response with which the demand facility has a contract must be notified of the change in capacity.

5.3.1. Demand response to the electricity supply undertaking

A demand unit delivering demand response must be able to regulate its active power within the time limit agreed with the electricity supply undertaking.

5.3.2. Demand response to transmission system operator

The requirements are set by the transmission system operator in their tender specifications for system demand response.

5.4. Reactive power control

Electricity supply undertakings do not require reactive power demand response from demand units. No requirements are therefore set for reactive power demand response.

5.5. Grid protection

Grid protection must be agreed with the electricity supply undertaking.

> *There may be additional grid protection requirements for demand units delivering services, in addition to the requirements made of the demand installation.*

Demand units delivering demand response must be able to deliver the service in question to the full, limited only by the demand unit's agreed protection settings.

5.6. Information exchange

Demand units delivering demand response must fulfil the information exchange requirements described in this section.

Demand units delivering demand response must be able to receive commands either directly or indirectly via a third party.

5.6.1. Demand response to the electricity supply undertaking

A demand unit delivering demand response must be able to exchange the information, including signal list, communication protocol, etc. agreed with the electricity supply undertaking on grid connection.

5.6.2. Demand response to transmission system operator

The requirements are set by the transmission system operator in their tender specifications for system demand response.

5.7. VERIFICATION AND DOCUMENTATION

This section describes the documentation to be provided by the plant owner or a third party to the electricity supply undertaking in order to achieve operational notification.

The plant owner is responsible for compliance with the technical conditions and for documenting such compliance.

The electricity supply undertaking may at any time require verification and documentation that demand units delivering demand response fulfil the requirements described in these technical conditions.

5.7.1. Demand units delivering demand response to the electricity supply undertaking

For demand facilities which include demand units that deliver demand response, separate documentation must be provided for each demand unit that delivers demand response.

The following documentation for each demand unit must be delivered to the electricity supply undertaking:

- CE Declaration of Conformity
- Single-line representation
- Completed annex 1 with technical documentation in support of the answers given in the annex.

Product certificates issued by an approved certification body may also be used. The product certificates may cover some of the documentation requirements.

5.7.2. Demand units delivering demand response to transmission system operators

For demand facilities which include demand units that deliver demand response to transmission system operators, separate documentation must be provided for each demand unit that delivers demand response.

Documentation must be delivered to the electricity supply undertaking as described in section 5.7.1

For the transmission system operator, the plant owner must adhere to the transmission system operator's documentation process and send the necessary documentation directly to the transmission system operator.

5.7.2.1. Requirements for testing of demand units that deliver system demand response

The requirements for testing of demand units that deliver demand response can be found in Energinet's tender specifications for system demand response, and in the 'prequalification of installations and aggregated portfolios' document.

Product certificates issued by an approved certification body may also be used. The product certificates may cover some of the documentation requirements.

Definitions of demand response can be found in table 3 – definitions for frequency

Type of delivery	Where	Frequency range	Description of service
FCR	DK1	49.80 - 49.98 Hz and 50.02 - 50.20 Hz	Rapid-reaction frequency response
FCR-D	DK2	49.90 - 49.50 Hz	Rapid-reaction frequency response
FCR-N	DK2	49.90 - 50.10 Hz	Rapid-reaction frequency response
FRR	DK2	49.7 - 49.5 Hz	Rapid-reaction frequency response for large frequency outages with activation time from 1.3 to 0.7 seconds
aFRR	DK1 & DK2		Automatic upward and downward regulation reserve. Regulation takes place within 15 minutes in DK1 and 5 minutes in DK2
mFRR	DK1 & DK2		Automatic upward and downward regulation reserve. Regulation must be fully activated within 15 minutes.

Table 3 – Definitions for frequency demand response

CE Declaration of Conformity
A CE Declaration of Conformity must be provided for the demand units in the demand installation used to deliver services. The CE Declaration of Conformity must include a list of the relevant standards, codes of practice and directives with which the unit complies.

Protective functions
Documentation of protective functions means a list of all the relevant relay set-ups at the time of commissioning of the grid protection agreed with the electricity supply undertaking.

Single-line representation
A single-line representation is a drawing that shows the main components of the installation and how they are interconnected electrically, with specific focus on the demand unit that delivers services. In addition, the location of any protection and metering points is included in the representation.

Completion of annexes
A completed annex means that the annex in this guide must be completed, and that the technical documentation verifying the correctness of the answers given in the annex must be attached. The technical documentation may be a test report, product certificate, user manual, simulations, etc.

ANNEX 1 TECHNICAL DOCUMENTATION OF DEMAND UNITS DELIVERING DEMAND RESPONSE

The documentation is completed with data for the demand unit and sent to the electricity supply undertaking.

B1.1. Identification and plant data

Unit:	Description of the demand unit:
Installation number:	
Plant owner name and address:	
Plant owner tel. no.:	
Plant owner email address:	
Contact person at the plant:	
Voltage (rated):	
Nominal active power (P_n):	
Nominal current (I_n):	
Minimum active power (P_{min}):	
Maximum active power (P_{max}):	
Active power bid (P_{bid}):	

B1.2. Normal operating conditions

	Yes ☐ No ☐

Can the demand unit be started and maintain continuous operation under normal operating conditions, only limited by the protection settings? Where can documentation showing that the requirements are fulfilled be found?	

B1.3. Abnormal operating conditions

Can the demand unit maintain continuous operation in the operating conditions specified in section 5.1.2? Where can documentation showing that the requirements are fulfilled be found?	Yes ☐ No ☐

B1.4. Grid protection

What has been agreed concerning protection, cf. section 5.5?	

B1.5. Demand response to the electricity supply undertaking

(To be completed only if demand response are to be delivered to the electricity supply undertaking)

The demand unit will deliver the following demand response: *If other, describe the service:	Limited grid access ☐ Other* ☐

B1.6. Demand response to transmission system operator

(To be completed only if demand response are to be delivered to the transmission system operator)

The demand unit will deliver the following demand response: *If other, describe the service:	FCR ☐ FCR-N ☐ FCR-D ☐ FRR ☐ mFRR ☐ aFRR ☐ Other* ☐

B1.7. Maximum active power regulation ramp rates

What are the maximum upward and downward regulation ramp rates that the demand unit can deliver?	Upward regulation - P_n/min. _____% of P_n/___ Downward regulation - P_n/min. _____% of P_n/___

B1.8. Signature

Date of commissioning:	
Company:	
Commissioning manager:	
Signature (commissioning manager):	