GREEN POWER DENMARK

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Guide for grid connection of demand installations to the low-voltage grid (≤ 1 kV)

Version 1.1

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	Layout update.	18-11-2022

TABLE OF CONTENTS

1. INTRODUCTION

This guide describes the requirements for demand installations connected to the low-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 a demand installation are described in chapter 4. If the demand installation 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 response 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 that must be fulfilled by a demand installation that is – or is required to be – connected to the public low-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 installation 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 the event of doubt, the registered conditions will apply.

2.1.2. New installations and demand units

New demand installations 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 installations, cf. section 2.1.3, that are connected to the grid after this date are exempt from the requirements.

2.1.3. Existing installations and demand units

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

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

2.1.4. Changes to existing installations and demand units

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

A significant modification of an installation changes the electrical properties of the installation at the Point of Connection and may e.g. concern the replacement of vital components.

Before changes are made, the owner of the demand installation or demand unit delivering demand response must notify the electricity supply undertaking of the modification to the demand installation 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 an installation is an increase in the scope of delivery or any changes in the demand response delivered by the demand units in the installation. A change in a demand unit that delivers demand response, or a change in the demand response 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 installations or demand units delivering demand response.

If a demand installation concerns 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 installations 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 installation 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 installation, 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 installation(s) or demand units delivering demand response 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 61000-3-2: Electromagnetic compatibility (EMC) – Part 3-2: Limits – Limits for harmonic current emissions (equipment input current ≤16A per phase).
DS/EN 61000-3-3: Electromagnetic compatibility (EMC) – Part 3-3: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems, for equipment with rated current ≤16A per phase and not subject to conditional connection.
DS/EN 61000-3-11: Electromagnetic compatibility (EMC) – Part 3-11: Limits – Limitation of voltage changes, voltage fluctuations and flicker in public low-voltage supply systems – Equipment with rated current ≤75A and subject to conditional connection.
DS/EN 61000-3-12: Electromagnetic compatibility (EMC) – Part 3-12: Limits – Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current >16A and ≤75A per phase.
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 61000-3-14: Electromagnetic compatibility (EMC) – Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage fluctuations and imbalance for the connection of disturbing installations to LV power systems.

DEFU (Research Association of the Danish Electric Utilities) Report RA 557: "Maximum emission of voltage disturbance from wind power plants >11 kW", Dansk Energi, June 2010.

DEFU Report RA 599: 'Voltage disturbance in distribution grids and industrial environments, DK2 – Eastern Denmark', Dansk Energi, September 2015.

DEFU Recommendation no. 16: Voltage quality in low-voltage grids.

3. DEFINITIONS/TERMS

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 3.2.48.

3.1.4. DK2

Eastern Denmark. For a more detailed description, see 3.2.50.

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 3.2.33.

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 3.2.30.

3.1.10. P_{lt}

P_{lt} denotes long-term flicker emissions from a demand installation. 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 short-term flicker emissions from a demand installation. 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 3.2.28.

3.1.13. PCI

Abbreviation for Point of Connection in Installation. For a more detailed description, see 3.2.21.

3.1.14. PCOM

Abbreviation for Point of Communication. PCOM is defined in section 3.2.24.

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 3.2.29.

3.1.18. PWHD

Abbreviation for Partial Weighted Harmonic Distortion. For a more detailed description, see 3.2.37.

3.1.19. Q_n

Q_n denotes nominal reactive power. For a more detailed description, see section 3.2.31.

3.1.20. S_k

S_k denotes short-circuit power. For a more detailed description, see 3.2.25.

3.1.21. S_n

S_n denotes nominal apparent power. For a more detailed description, see 3.2.34.

3.1.22. SCR

Abbreviation for Short-Circuit Ratio. For a more detailed description, see 3.2.27.

3.1.23. THD

Abbreviation for Total Harmonic Distortion. For a more detailed description, see 3.2.46.

3.1.24. U_c

U_c denotes normal operating voltage. For a more detailed description, see 3.2.35.

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 3.2.32.

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 demand installation. 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 installation 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 company in whose grid an installation is connected electrically. 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** 100kV.

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

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 2-9kHz frequency range

Distortions in the 2-9kHz 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 installation 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 frequency in the public grid is 50 Hz. There are also other frequencies related to power quality. These frequencies are referred to as harmonic overtones, interharmonic overtones and disturbances in the 2 to 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 unit

A demand unit or device intended to convert electrical energy into another form of energy, e.g. light, movement or heat. A demand unit is e.g. a heat pump, electric stove, motor, vacuum cleaner or electric kettle.

3.2.13. Demand unit delivering demand response

A demand unit or device 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.

3.2.14. Demand installation

A demand installation is a demand unit or a collection of multiple demand units under a Point of Connection in the low-voltage grid. In a demand installation, there may be demand units that deliver demand response, as shown on figure 3.2.

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.

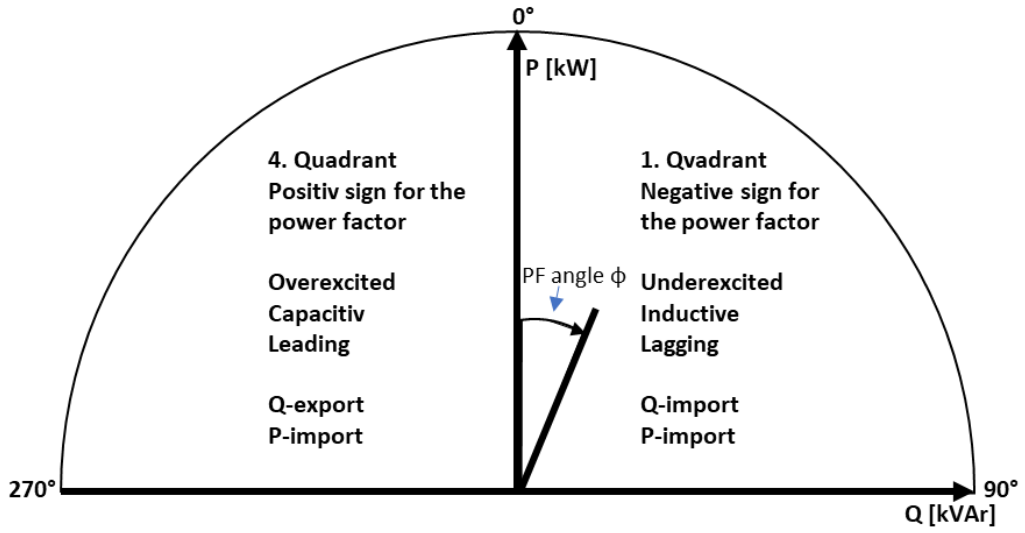

Figure 3.1 – Definition of signs for active and reactive power, Power Factor and reference for Power Factor angle.

3.2.16. Point of Demand Connection (PDC)

The location in the installation 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. See figure 3.2 and figure 3.3.

3.2.17. Harmonic overtones

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

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. Frequent current changes

Frequent current changes are major sudden current changes occurring more than a few times a day. Frequent current changes occur, for example, when a motor is started frequently, when there are frequent changes in a motor's load, or when a heater is frequently disconnected and disconnected.

3.2.20. Connection

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

3.2.21. Point of Connection in Installation (PCI)

The point in the demand installation where demand units that deliver demand response are connected or may be connected, see figure 3.2 and figure 3.3 for the typical location.

3.2.22. Interharmonic overtones

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

3.2.23. 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 **below** 100 kV.

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

3.2.24. Point of Communication (PCOM)

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

3.2.25. Short-circuit Power (S_k)

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

3.2.26. 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.

3.2.27. Short-Circuit Ratio (SCR)

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

$$SCR = \frac{S_{k,powerquality}}{S_n}$$

3.2.28. 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 installation, see figure 3.2 and figure 3.3.

The electricity supply undertaking determines the Point of Common Coupling.

3.2.29. Point of Connection (POC)

The point in the public electricity supply grid where a demand installation is or can be connected, see figure 3.2 and figure 3.3 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.

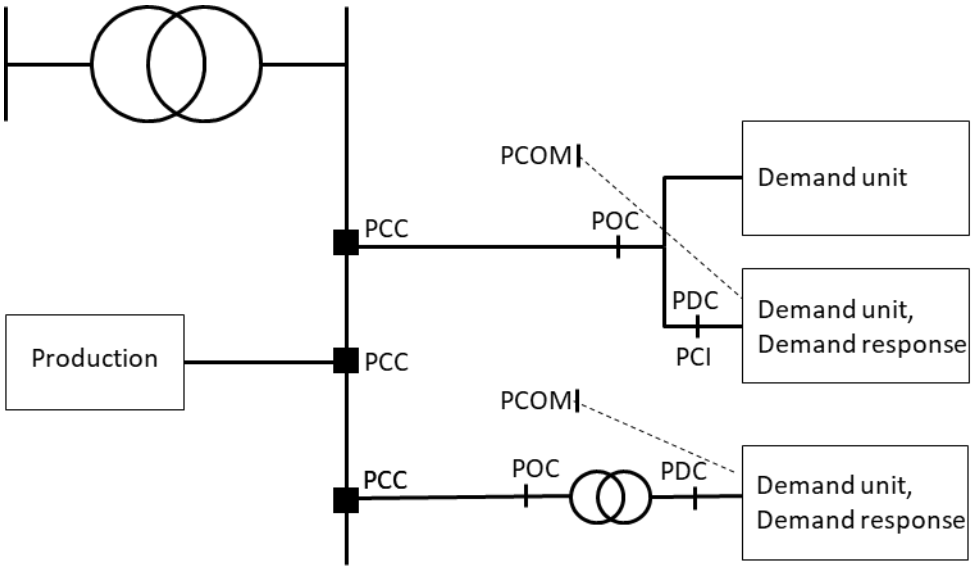

Figure 3.2 – Typical grid-connected consumption, specifying PDC, PCI, POC, PCC and PCOM.

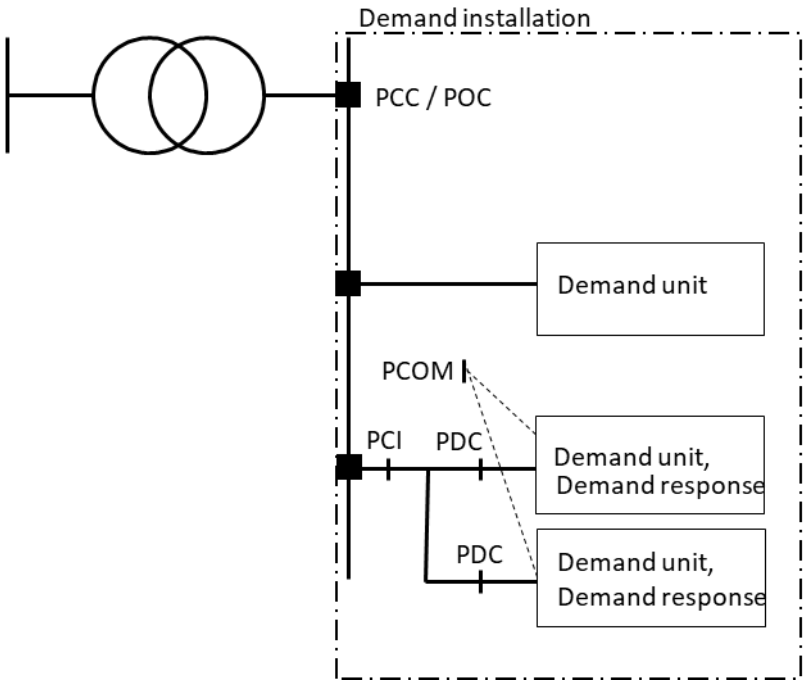

Figure 3.3 – Installation-connected demand units that deliver demand response.

figure 3.3 shows a typical installation connection of several demand units delivering demand response, indicating the typical location of the Point of Demand Connection (PDC), Point of Connection (POC), Point of Connection in Installation (PCI) and Point of Common Coupling (PCC). In the illustrated example, the Point of Common Coupling (PCC) coincides with the Point of Connection (POC).

3.2.30. Nominal active power/rated power (P_n)

The maximum active power that a demand installation 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.

3.2.31. Nominal reactive power (Q_n)

The maximum reactive power that a demand installation 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.

3.2.32. 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.

3.2.33. Nominal current/rated current (I_n)

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

3.2.34. Nominal apparent power (S_n)

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

3.2.35. 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.

3.2.36. Normal operation

The voltage and frequency range within which a demand installation 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.

3.2.37. 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 ($PWHD_U$).

3.2.38. Reactive power

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

3.2.39. Robustness

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

3.2.40. 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.

3.2.41. 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:

<table>
<tr><th>Designation of voltage level</th><th>Nominal voltage U_n [kV]</th><th>Electricity supply undertaking</th></tr>
<tr><td rowspan="2">Extra high voltage (EHV)</td><td>400</td><td rowspan="4">Transmission enterprise</td></tr>
<tr><td>220</td></tr>
<tr><td rowspan="4">High voltage (HV)</td><td>150</td></tr>
<tr><td>132</td></tr>
<tr><td>60</td><td rowspan="3">Grid company</td></tr>
<tr><td>50</td></tr>
<tr><td>Medium voltage (MV)</td><td>33</td></tr>
</table>

Designation of voltage level	Nominal voltage U_n [kV]	Electricity supply undertaking
	30	
	20	
	15	
	10	
Low voltage (LV)	0.4	
	0.23	

Table 3.1 – Definition of voltage levels.

3.2.42. 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.

3.2.43. Starting current

Starting current means that a short-term high current exceeding the nominal current is drawn from the electricity supply grid on the connection of the demand installation or a demand unit. This takes place, for example, on starting a motor or starting many LED bulbs at the same time.

3.2.44. Current imbalance

Condition in a multiphase system where the current amplitude and/or the angles between the successive phases are not the same.

3.2.45. 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.

3.2.46. 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).

3.2.47. Abnormal operation

Operating conditions with frequency or voltage deviations – i.e. operating outside the normal operating range (see section 3.2.36).

3.2.48. Western Denmark (DK1)

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

3.2.49. 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.

3.2.50. Eastern Denmark (DK2)

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

4. DEMAND INSTALLATIONS CONNECTED TO THE LOW-VOLTAGE GRID

4.1. TOLERANCE OF FREQUENCY AND VOLTAGE DEVIATIONS

A demand installation must comply with the following requirements concerning normal operation and abnormal operation.

4.1.1. Normal operation

The demand installation must be designed to maintain normal operation in the voltage range of +10% to -15% of U_n and in the frequency range of 49 Hz to 51 Hz at the Point of Connection.

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

4.1.2. Tolerance of frequency deviations

A demand installation 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 installation 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 installation must be designed to withstand voltage deviations which may occur in the Danish distribution grid during normal operation and abnormal operation. Damage means that the installation and components of the installation must be designed so as not to suffer permanent loss of functionality as a consequence of voltage deviations. The requirement will be considered to be fulfilled if the demand installation 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 installation 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 installation 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 installation, to assess how robust the installation should be towards voltage dips.

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

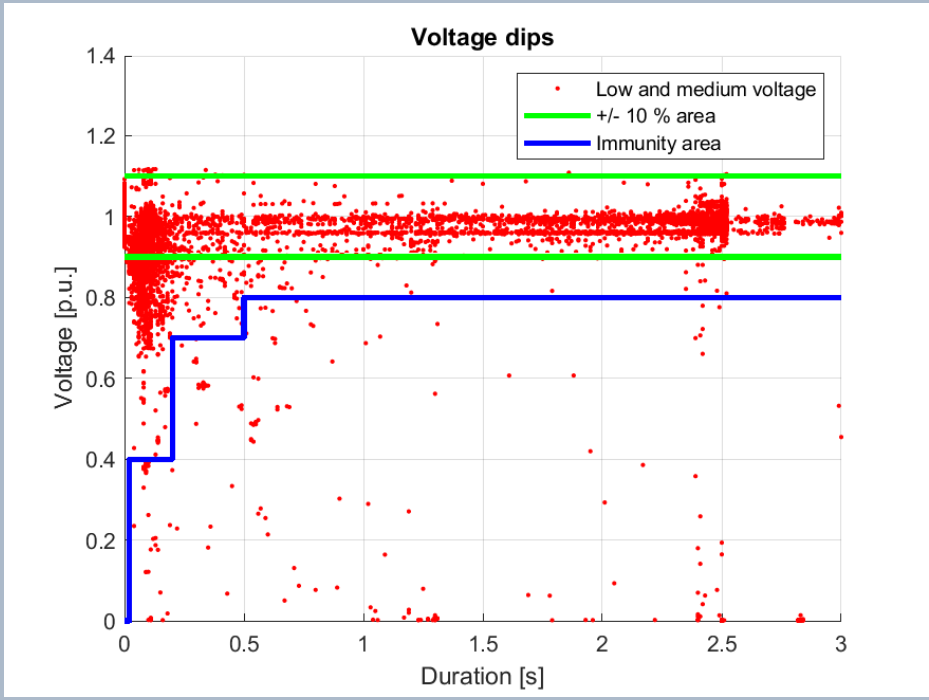

Figure 4.1 – Overview of the voltage dips occurring in the Danish electricity supply grid.

4.2. Connecting and starting up a demand installation

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

4.3. Active power control

No requirements are made of the control of active power for demand installations.

4.4. Requirements of reactive power

In a demand installation, the power factor must lie between 0.9 inductive 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 in the demand installation'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 whether there are specific earthing requirements.

In practice, the earthing agreement is made by the installer applying for the required type of earthing on registration.

Details of the short-circuit flow must always be obtained from the electricity supply undertaking in the case of connection directly to a transformer station, or connection to the public electricity supply grid of the following electricity supply undertakings:

- *Radius Elnet A/S (Frederiksberg and City)*
- *Elektrus A/S*

Concerning matters other than the aforementioned, unless otherwise disclosed by the electricity supply undertaking, the following assumptions are made concerning the short-circuit current at the Point of Connection:

- *The greatest short-circuit current is 16 kA at PF = 0.3 (inductive).*
- *The lowest short-circuit current is five times the nominal current of the service line fuse.*

4.6. POWER QUALITY

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

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

If the demand installation 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.

4.6.1. Limit values

Significant disturbance occurs if the demand installation exceeds the limit values set out in sections 4.6.1.1, 4.6.1.2 and 4.6.1.3.

In addition, significant disturbance may occur if:

- Demand units up to and including 50 kW do not fulfil the requirements for rapid voltage changes, flickers, harmonic overtones, interharmonic overtones and disturbance in the 2 to 9 kHz frequency range, which are set in relevant product standards or the DS/EN 61000-3 series.

- Demand units and demand installations above 50 kW do not fulfil the requirements concerning flicker, harmonic overtones, interharmonic overtones and disturbance in the 2 to 9 kHz frequency range set out in section 4.6.1.3 to section 4.6.1.7.

The limit values in sections 4.6.1.2 to 4.6.1.7 are based on the principles in DEFU Report RA 557 and IEC/TR 61000-3-14.

4.6.1.1. Current imbalance

A demand installation may not cause unacceptable current imbalance in the grid. In order to avoid this, demand must be distributed as evenly as possible among the phases. Phase imbalance may not exceed 20% of the delivery volume – although up to 16 A imbalance is always allowed and the phase imbalance may never exceed 300 A.

This means that for installations up to 55.2 kVA (80 A per phase), up to 16 A power imbalance is permitted

1 phase	2 phases	3 phases
Up to 3.68 kVA	Up to 7.36 kVA	Over 7.36 kVA

Table 4.1 – Overview of the minimum number of phases on which an installation of up to 55.2 kVA must be evenly distributed.

For installations exceeding 55.2 kVA, a power imbalance of up to 20% of the delivery volume is permitted, but maximum 300 A.

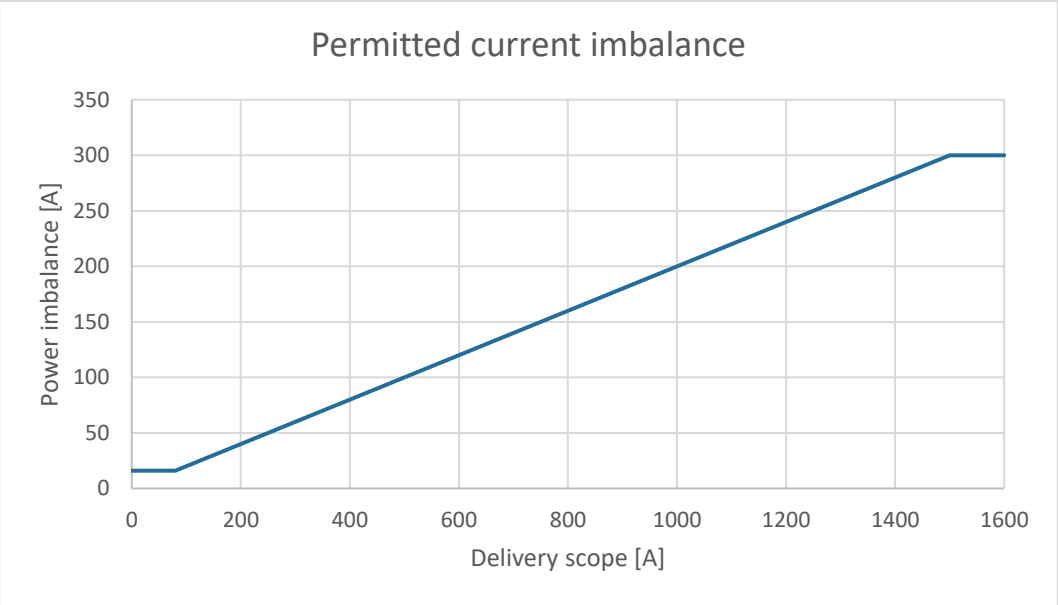

Figure 4.2 – Permitted power imbalance for installations.

Power imbalance is measured as 10 min. mean values, like the other elements of power quality, see section 4.6.3.

Example 1
A demand installation draws the following currents on the 3 phases:
L1: 20 A
L2: 35 A
L3: 25 A

The greatest difference in phase flow between 2 phases is 15 A (L2 – L1) and the installation fulfils the imbalance requirement.

Example 2
A demand installation draws the following currents on the 3 phases:
L1: 20 A
L2: 4 A
L3: 0 A

The greatest difference between 2 phases is 20 A (L1 – L3) and the installation does ***not*** *fulfil the imbalance requirement. The installation's load must be reallocated to the phases, so that the imbalance is reduced to less than 16 A, since the installation is 55.2 kVA, or less.*

The imbalance requirement is made because imbalance in phase voltages and phase currents is not required in the public electricity supply grid, since these may have adverse effects on the grid's operation and on the units connected to the public electricity supply grid.

The requirement is laid down on the basis of the Joint Regulations (Fællesregulativet) and international standards. In Denmark, it is permitted to connect single-phase units with a nominal current of up to 16 A, and many international standards use 16 A per phase as the limit value for the units covered by the standards.

The requirement for large demand installations (> 55.2 kVA) is laid down on the basis that there may not be excessive voltage imbalance, but that for large installations it will often not be possible to comply with 16 A current imbalance in practice, under all operating conditions.

International standards concerning imbalance consider the voltage imbalance. Since documenting compliance with the voltage imbalance requirements is more complicated, it has been chosen to exclusively make requirements of the current imbalance/kVA imbalance for demand installations connected to low voltage. It is easier to document compliance with requirements concerning current imbalance/kVA imbalance, among other things because they do not depend on the short-circuit power 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 installation may not cause rapid voltage changes exceeding the limit value specified in table 4.2.

Limit value for rapid voltage changes
d (%)
4% of Un

Table 4.2 – Limit values for rapid voltage changes.

The requirement of rapid voltage changes is made on the basis of DS/EN 61000-3-11 and the methods for determining limit values described in DEFU Report RA 557 and IEC/TR 61000-3-14.

Starting current

The attenuation of starting currents must take place on an equivalent basis at all operating phases of the demand unit.

If the starting current in an installation does not exceed the values specified in table 4.3, it is assessed that the requirement for rapid voltage changes is complied with.

Connection	Starting current
1 phase	35 A
3 phases	60 A

Table 4.3 – Maximum starting current for a demand installation.

The starting currents in table 4.3 are determined according to the general assumption that they do not occur more often than a few times a day. If frequent starting currents (frequent power changes) occur, this may give rise to flicker contributions or frequent power changes that exceed the limit values in section 4.6.1.3.

4.6.1.3. Flicker

A demand installation or demand unit above 50 kW may cause significant disturbance if it has a flicker contribution greater than the limit values for short-term and long-term flicker specified in table 4.4.

	Short-term flicker (P_{st})	Long-term flicker (P_{lt})
Limit value	0.40	0.30

Table 4.4 – Limit value for short-term and long-term flicker.

The limit value for flicker is set on the basis of DS/EN 61000-3-11 and the methods for determining limit values described in DEFU Report RA 557 and IEC/TR 61000-3-14.

Frequent current changes

If frequent current changes at the Point of Connection are no greater than the values in figure 4.3 and figure 4.4, it is assessed that the limit value for flicker is observed.

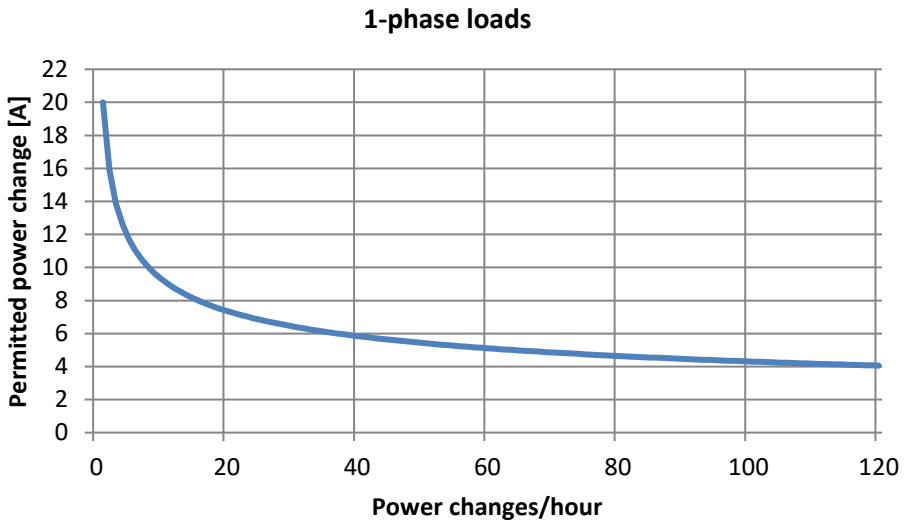

Figure 4.3 – Limit values for frequent power changes for 1-phase loads.

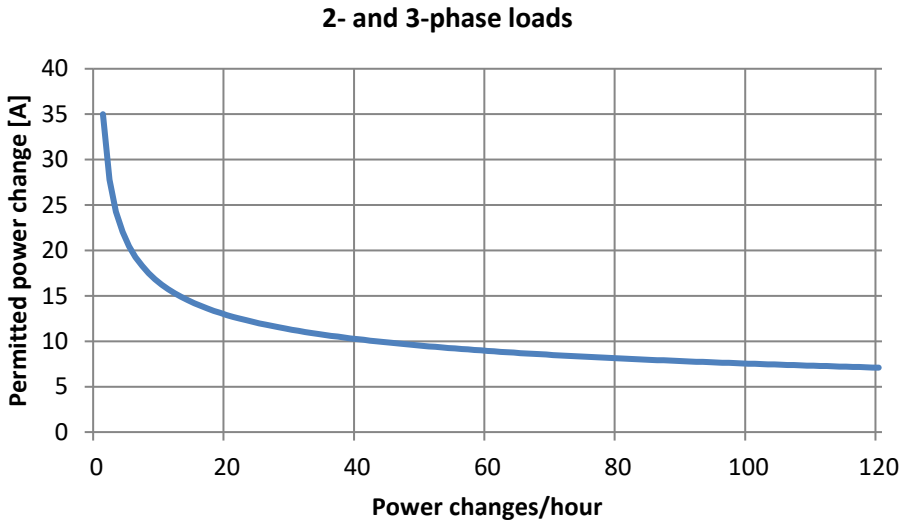

Figure 4.4 – Limit values for frequent power changes for 2- and 3-phase loads.

4.6.1.4. Harmonic disturbance

A demand installation or demand unit above 50 kW may cause significant disturbance if it emits harmonic currents greater than the limit values in table 4.5 for the individual harmonic overtones specified as a percentage of the installation's nominal current, (I_h/I_n (%)). The limit values depend on the ratio between a demand installation's nominal power and the short-circuit power at the demand installation's Point of Connection (SCR).

SCR	Odd-order harmonics h							Even-order harmonics h					
	3	5	7	9	11	13	15	2	4	6	8	10	12
<33	4.5	5.1	3.4	0.6	1.6	0.9	0.5	0.5	0.5	1.3	1.1	0.8	0.7
≥33	4.7	5.4	3.6	0.7	1.8	1.0	0.5	0.5	0.5	1.3	1.1	0.8	0.7
≥66	5.2	7.0	4.5	0.8	2.4	1.4	0.6	0.5	0.5	1.3	1.1	0.8	0.7
≥120	6.2	9.5	6.1	1.1	3.4	2.1	0.7	0.5	0.5	1.3	1.1	0.8	0.7
≥250	8.4	15.5	9.8	1.7	5.8	3.7	1.1	0.5	0.5	1.3	1.1	0.8	0.7
≥350	10.1	20.1	12.6	2.2	7.7	4.9	1.3	0.5	0.5	1.3	1.1	0.8	0.7

Table 4.5 – Limit values for harmonic currents I_h/I_n (% of I_n).

In addition to the limit values for the individual harmonic overtones, there are also limit values for total harmonics. These limit values for THD_I and $PWHD_I$ are specified in table 4.6.

SCR	THD_I	$PWHD_I$
<33	5.8	5.8
≥33	6.3	6.3
≥66	8.1	8.1
≥120	11.2	11.2
≥250	18.4	18.4
≥350	24.0	24.0

Table 4.6 – Limit values for THD_I and $PWHD_I$ in current (% of I_n).

The limit values for individual harmonics, THD_I and $PWHD_I$, are based on DS/EN 61000-3-12, Table 3, and the methods to determine limit values described in DEFU Report RA 557 and IEC/TR 61000-3-14.

The 2nd and 4th harmonics are reduced compared to the method in RA 557, because they may indicate DC content in the current drawn from the public electricity supply grid. Exceeding the limit values for the 2nd or 4th harmonics may indicate that the demand installation exceeds the DC content limit value.

Triple harmonics are added on the basis of their ratio for the limit values in DS/EN 50160.

4.6.1.5. Interharmonic disturbance

A demand installation or demand unit above 50 kW may cause significant disturbance if it emits interharmonic currents greater than the limit values in table 4.7 for the individual interharmonic overtones specified as a percentage of the installation's nominal current, (I_h/I_n (%)). The limit values depend on the ratio between a demand installation's nominal power and the short-circuit power at the demand installation's Point of Connection (SCR).

SCR	Frequency (Hz)		
	75Hz	125Hz	>175 Hz
<33	0.5	0.8	$\frac{100}{f}$*
≥33	0.6	0.9	$\frac{107}{f}$*
≥66	0.7	1.1	$\frac{137}{f}$*
≥120	1.0	1.5	$\frac{186}{f}$*
≥250	1.6	2.4	$\frac{305}{f}$*
≥350	2.1	3.2	$\frac{396}{f}$*
*However, not less than the measurement uncertainty.			

Table 4.7 – Limit values for interharmonic overtones in current (% of I_n).

The limit values for interharmonic overtones are set on the basis of the methods to determine limit values described in DEFU Report RA 557 and IEC/TR 61000-3-14.

The limit values set out in this section are deemed to be met if the limit values in section 4.6.1.4 are complied with, when measured with grouping (for further details of grouping, see section 4.6.3).

4.6.1.6. Disturbance in the 2-9 kHz frequency range

A demand installation or demand unit above 50 kW may cause significant disturbance if it does not comply with the limit value in table 4.8 for each 200 Hz frequency group between 2 and 9 Hz. The limit value is specified as current as a percentage of the installation's nominal current (I_h/I_n (%)).

The limit value for all frequencies in the range of 2 to 9 kHz
0.25%

Table 4.8 – Limit value in current stated as a percentage of I_n for all frequencies between 2 kHz and 9 kHz.

The limit value for disturbance in the 2-9 kHz frequency range is based on DEFU Report RA 557.

4.6.1.7. DC content

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

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 installation is designed, constructed and configured in such a way that installation does not cause significant disturbance of the public electricity supply grid that might have adverse consequences for other customers' installations.

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

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

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 installations, 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 demand response (higher short-circuit power or delivery scope) from the electricity supply undertaking in order to comply with the specified limit values.

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 $S_{k,\ powerquality}$ with associated short-circuit angle ψ_k at the Point of Connection.

In cases where the public electricity supply grid contributes to unacceptable disturbance of the public electricity supply grid, or adverse consequences for other customers' installations 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

No requirements are made concerning information exchange with the electricity supply undertaking.

4.8. Verification and documentation

As a general rule, no documentation of demand installations is required, unless the installation includes demand units that deliver demand response. If the installation includes demand units that deliver demand response, documentation must be provided, as described in section 5.7.

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

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

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 must be delivered within the general connection conditions described in chapter 4, as well as other terms, conditions and agreements applying to the demand installation.

5.1. IMMUNITY TO FREQUENCY AND VOLTAGE DEVIATIONS

5.1.1. Normal operating conditions

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

The voltage, U_n, at the Point of Connection (POC) is 230 V.

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 85% 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.

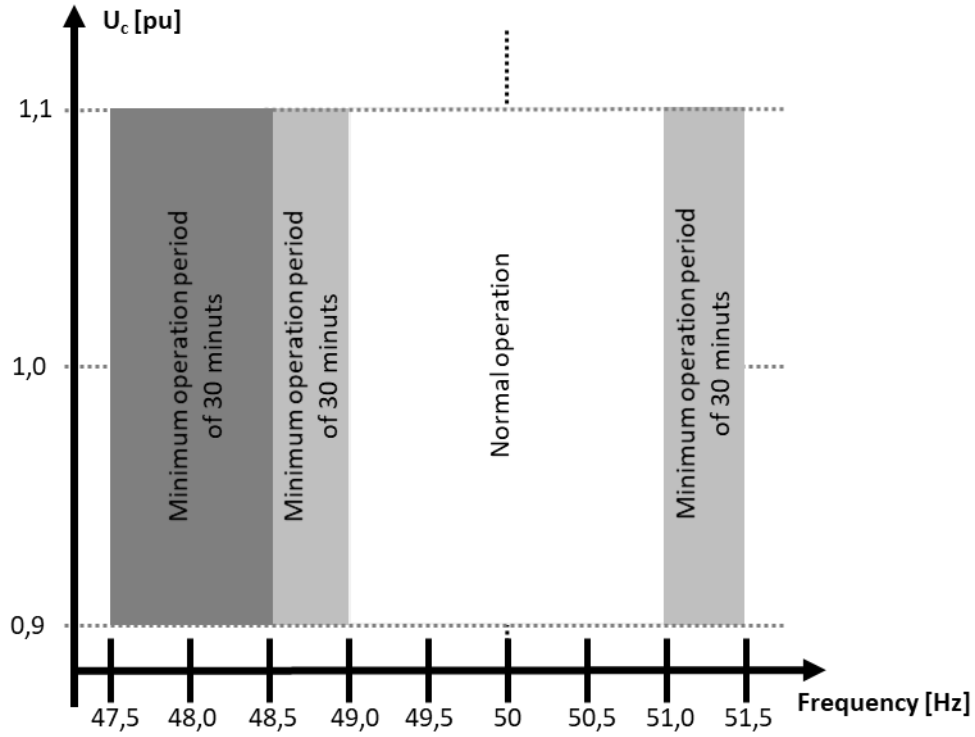

Figure 5.1 – Minimum periods of time during which a demand unit delivering demand response must be able to maintain operation at different frequencies without disconnecting from the grid.

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 grids 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.

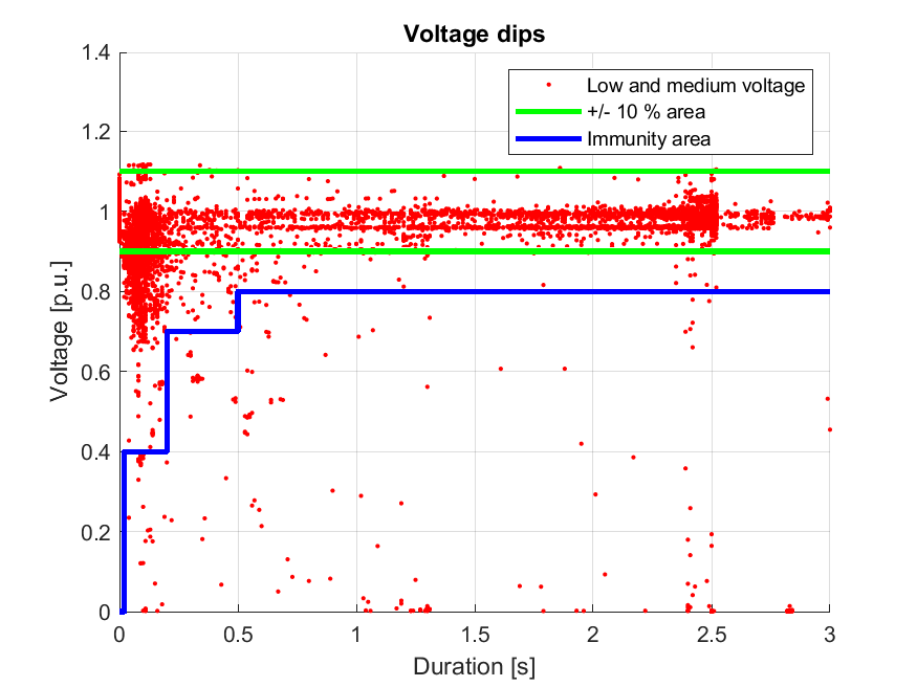

Figure 5.2 – Overview of the voltage dips occurring in the Danish electricity supply grid.

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 4.6.1.2.

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 demand installations have a contract must be notified of the change in capacity.

5.3.1. Demand response to grid companies

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

The only active power service used by the electricity supply undertaking is the limited grid access scheme. Deadlines for the delivery of demand response to the electricity supply undertaking are therefore set in the grid connection agreement, in which account is also taken of the electrical characteristics of the demand units.

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 demand response, 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 grid companies

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 grid company

For demand installations that include demand units which deliver demand response, separate documentation must be provided for the demand units that deliver demand response. The following documentation for the demand units must be delivered to the electricity supply undertaking:

- CE Declaration of Conformity
- Annex B1.1 completed with technical documentation in support of the answers given.

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

The plant owner must adhere to the transmission system operator’s documentation process and send documentation directly to the transmission system operator.

The documentation must be approved by the transmission system operator.

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

CE Declaration of Conformity

A CE Declaration of Conformity must be provided for the demand units in the demand installation used to deliver demand response. 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.

Completion of annexes

A completed annex B1.1 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 INSTALLATION DOCUMENT FOR DEMAND RESPONSE

B1.1. Documentation for demand units delivering demand response to the grid company

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

B1.1.1. Identification

Unit:	Description of the demand unit:
Installation number:	
Plant owner name and address:	
Plant owner tel. no.:	
Plant owner email address:	
Type/model:	
Rated power (P_n) in kW	
Voltage (U_n)	

B1.1.2. Demand response

What service will the demand unit deliver?

B1.1.3. Normal operating conditions

Can the demand unit be started and maintain continuous operation under normal operating conditions, as specified in section 5.1.1, only limited by the protection settings?	Yes ☐ No ☐

Where can documentation showing that the requirements are fulfilled be found?	

B1.1.4. Abnormal operating conditions

Can the demand unit maintain continuous operation during frequency deviations, as specified in section 5.1.2? Where can documentation showing that the requirements are fulfilled be found?	Yes ☐ No ☐

B1.1.5. Active power control

What has been agreed concerning active power control, cf. section 5.3?	

B1.1.6. Protection

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

B1.1.7. Information exchange

What has been agreed concerning information exchange, cf. section 5.6?	

B1.1.8. Signature

Date of commissioning:	
Company:	
Commissioning manager:	

Signature (Commissioning manager):	