APPENDIX 1.E – REQUIREMENTS FOR VOLTAGE QUALITY FOR TRANSMISSION-CONNECTED DISTRIBUTION SYSTEMS AND DEMAND FACILITIES

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	Changes made as a result of the Danish Utility Regulator's public consultation – categories specified and category 2 removed.	1	18.01.2019

Please note that this is a translation of the original Danish text.
In case of inconsistencies, the Danish version shall apply.

Contents

Figures

Reading instructions

This specification of requirements contains all general and specific requirements for voltage quality for transmission-connected *distribution systems* and transmission-connected *demand facilities*.

The various *power quality* parameters in *the grid connection point* must be documented when assessing the different types of transmission connections defined below, These parameters, as well as methods for their verification, are described in this specification of requirements.

The specification of requirements is structured as follows: Section 1 contains terminology and definitions used in the specification of requirements. In the text, definitions are written in italics.

The methods and requirements are specified in sections 3 to 8.

This specification of requirements is also published in English. If there are inconsistencies, the Danish version applies.

Present specification of requirements is published by Energinet and can be downloaded from Energinet's website, www.energinet.dk

1. Terminology and definitions

1.1 Definitions

This section contains the definitions used in this document.

1.1.1 Facility

Overall term for *demand facility* and *distribution systems*.

1.1.2 Facility owner

The *facility owner* is the legal owner of *the demand facility* or *distribution system*. The *facility owner* can transfer operational responsibility to a *demand facility operator* or *distribution system operator*.

1.1.3 Facility categories

A total of 6 different categories of transmission-connected distribution systems and demand facilities have been defined:

1. Distribution system - Category 1
2. Demand facility - Category 3
3. Demand facility - Category 4
4. Demand facility - Category 5
5. Demand facility - Category 6

1.1.4 Facility component

A *facility component* is a component or subsystem which is part of an overall *demand facility* or distribution system connection.

1.1.5 Harmonic background voltage distortion

The *harmonic voltage distortion* present in *the point of connection* before the *distribution system or demand facility* is connected.

1.1.6 Distribution system - category 1

A *distribution system*, which is characterized by one or more POCs to the transmission system and, in addition, depending on current operating conditions, has an electric interconnection - or the possibility of an electric interconnection - with one or more *distribution systems*.

The *distribution system* provides transport of electricity for customers connected to the *distribution system's* public high-voltage, medium-voltage and low-voltage grids.

If the electricity supply undertaking, when reviewing an application for grid connection, determines that there is a risk of significant challenges as regards voltage quality, the electricity supply undertaking must contact Energinet Elsystemansvar A/S, cf. the process in appendix 1.F.

1.1.7 Distribution system operator

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

1.1.8 Electricity supply undertaking

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

The *grid* enterprise is the enterprise licensed to operate the *public electricity supply grid* up to and including 100 kV.

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

1.1.9 Power quality

General term for the quality of the voltage that exists in the transmission grid. *Power quality* is defined on the basis of a number of *voltage quality parameters*.

1.1.10 Emission limits

Threshold values for the applicable *voltage quality parameters*.

1.1.11 Energinet Elsystemansvar A/S

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

1.1.12 Flicker

Flicker is rapid voltage fluctuations which for some types of light sources are identified by flicker being an irritant to the eye. *Flicker* is measured as described in DS/EN 61000-4-15 [1].

1.1.13 Flicker contribution

The *facility's* contribution of *flicker* to the transmission grid.

1.1.14 Demand facility - category 3

A *demand facility*, which, in connection with the completion of the grid connection process (EON, ION, FON) and issue of an FON, can document its maximum consumption relative to the assigned maximum power draw.

The assigned maximum power draw may, in specific instances, be limited if there is a predictable risk of lack of grid adequacy, lack of generation adequacy, and/or deterioration of the robustness of the transmission system. In such cases, the specific details will be stated in the grid connection agreement.

1.1.15 Demand facility - category 4

A *demand facility*, which, in connection with the completion of the grid connection process (EON, ION, FON) and issue of an FON, cannot document its maximum consumption relative to the assigned maximum power draw.

The *demand facility's* consumption may, by agreement with *Energinet Elsystemansvar A/S*, be increased to the maximum power draw assigned in a step-by-step expansion of the existing *demand facility*.

The assigned maximum power draw may, in specific instances, be limited if there is a predictable risk of lack of grid adequacy, lack of generation adequacy, and/or deterioration of the robustness of the transmission system. In such cases, the specific details will be stated in the grid connection agreement.

1.1.16 Demand facility - category 5

A *demand facility*, which, in connection with the completion of the grid connection process (EON, ION, FON) and issue of an FON, can document its maximum consumption relative to the assigned maximum power draw.

The *demand facility* is operational in peak-load situations for a maximum of 500 full-load equivalent hours a year.

The assigned maximum power draw may, in specific instances, be limited if there is a predictable risk of lack of grid adequacy, lack of generation adequacy, and/or deterioration of the robustness of the transmission system. In such cases, the specific details will be stated in the grid connection agreement.

1.1.17 Demand facility - category 6

Third rail current supply for electrical railway services, where the *facility's* supply and substations are connected to the transmission grid.

Supply and substations are connected to Banedanmark's overall third rail current system for electrical railway services.

This type of *demand facility* may differ significantly from other transmission-connected *demand facilities* with regard to connection and consumption characteristics.

1.1.18 Demand facility operator

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

1.1.19 Threshold value for harmonic voltage distortion contribution (LHD)

The limit set for the *harmonic voltage distortion contribution.*

1.1.20 Harmonic emission

The transmission-connected *facility* 's *emission* of *harmonics*, including the *harmonic voltage distortion* caused by harmonic voltages or currents from the transmission-connected facility (actively introduced distortion) and the amplification of existing *harmonic background voltage distortion* in *the point of connection* due to interaction between the *facility* and the transmission grid's *harmonic grid impedance* (passively introduced distortion).

1.1.21 Harmonic grid impedance

The frequency-dependent grid impedance, determined as positive sequence, negative sequence and zero sequence impedances, expressed either as a real and imaginary value or as a magnitude and angle.

1.1.22 Harmonic planning margin

The part of the *available harmonic distortion headroom* that is reserved for future *facilities* while also used as a safety measure in case of deviations.

1.1.23 Harmonic spectrum

An illustration of the Fourier coefficients (frequency components) resulting from a Fourier analysis of a given signal.

1.1.24 Harmonic voltage distortion

The distortion of grid voltage due to the presence of one or more higher order *harmonic voltage components*. Contribution may cover the full contribution in the form of *total harmonic voltage distortion* or be calculated per *harmonic voltage component*.

1.1.25 Harmonic voltage distortion contribution (HD)

The transmission-connected *facility's* contribution of *harmonic voltage distortion* to the transmission grid in *the point of connection*. The contribution may cover the full contribution in the form of *total harmonic voltage distortion* or be calculated per *harmonic voltage component*.

1.1.26 Harmonic voltage component

Fourier coefficients (frequency components) stemming from a Fourier analysis of a given voltage signal, wherein the frequency applicable to the Fourier coefficient is an integer multiple of the fundamental frequency.

1.1.27 Interharmonic

Fourier coefficients (frequency components) stemming from a Fourier analysis of a given voltage signal, wherein the frequency applicable to the Fourier coefficient is not an integer multiple of the fundamental frequency.

1.1.28 Interharmonic voltage distortion contribution

The *demand facility or distribution system's* contribution of interharmonic voltage distortion to the transmission grid in *the point of connection*. The contribution is set using *interharmonic subgroups.*

1.1.29 Interharmonic subgroup

Grouping of a series of *interharmonics*, executed as described in DS/EN 61000-4-7 [2].

1.1.30 Public electricity supply grid

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

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

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

1.1.31 Grid impedance polygons

Method for describing the transmission grid's frequency-dependent grid impedance in *the point of connection*.

1.1.32 Grid Connection Agreement

Terms and conditions entered into between the *electricity supply undertaking* and the *facility owner*, which includes relevant data and specific requirements and conditions.

1.1.33 Point of connection

The *point of connection (POC)* is the physical point in the *public electricity supply grid,* where the *demand facility or distribution system* is or can be connected.

All requirements specified in this specification of requirements apply to the *point of connection*. The *electricity supply undertaking* determines the *point of connection*.

1.1.34 Grid enterprise

The *grid* enterprise is the enterprise licensed to operate the *public electricity supply grid* up to and including 100 kV.

1.1.35 Planning level

The level of a specific *voltage quality parameter* according to which the transmission grid is coordinated.

1.1.36 Voltage unbalance

The negative sequence voltage content, calculated as a percentage of the positive sequence voltage.

1.1.37 Voltage unbalance contribution

The facility's contribution of *voltage unbalance* to the transmission grid in *the point of connection.*

1.1.38 Voltage unbalance vector

Voltage unbalance vector is defined as the ratio of inverse sequence and synchronous sequence voltage, both expressed as vectors.

1.1.39 Voltage quality parameters

The parameters that voltage quality is determined by. More specifically, *harmonic voltage distortion*, *interharmonic*, *flicker*, *voltage unbalance* and DC content are used.

1.1.40 System model defined by impedance polygons

Limited simulation model of the transmission grid around a *point of connection*.

1.1.41 Available harmonic distortion headroom

The headroom available after *harmonic background voltage distortion* has been deducted from *planning levels*.

1.1.42 Total harmonic voltage distortion

Total harmonic voltage distortion is calculated as:

$$THD_U = \sqrt{\sum_{h=2}^{50} U_h^2}$$

where U_h is the root-mean-square (RMS) value of the h-th *harmonic voltage overtone* expressed as a percentage of the root-mean-square value of the fundamental voltage.

1.1.43 Transmission company

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

2. Purpose, scope of application and administrative provisions

This document is appendix 1.E of the registered requirements which stipulate implementing measures under EU regulation 2016/1388 (DCC); this stipulates requirements for voltage quality.

3. Harmonic voltage distortion

Section 3 applies to *facility categories* 3 to 6.

Threshold values are set for the *facility's* maximum contribution *to harmonic voltage distortion* in the *point of connection*.

3.1 Planning level and definition of harmonic voltage distortion contribution

The *facility* is allocated threshold values in *the point of connection,* corresponding to the *facility's harmonic voltage distortion contribution*. *Energinet Elsystemansvar A/S* uses *planning levels* for high-voltage systems, specified in IEC 61000-3-6 Table 2 [3], and will coordinate the individual *facility's* contribution according to these levels.

Threshold values for the *facility* are determined as the threshold value *for harmonic voltage distortion contribution (THD)* and defined as the maximum *harmonic voltage distortion contribution (HD)*, which the *electricity generation facility* is permitted to introduce into the transmission grid.

The *facility's harmonic voltage distortion contribution* includes:

a) *harmonic voltage distortion* caused by *harmonic voltages* or currents from the *facility* (actively introduced distortion)
b) amplification of existing *harmonic background voltage distortion* in *the point of connection* due to interaction between the *facility* and the transmission grid's *harmonic grid impedance* (passively introduced distortion).

Contributions are illustrated graphically in Figure 1.

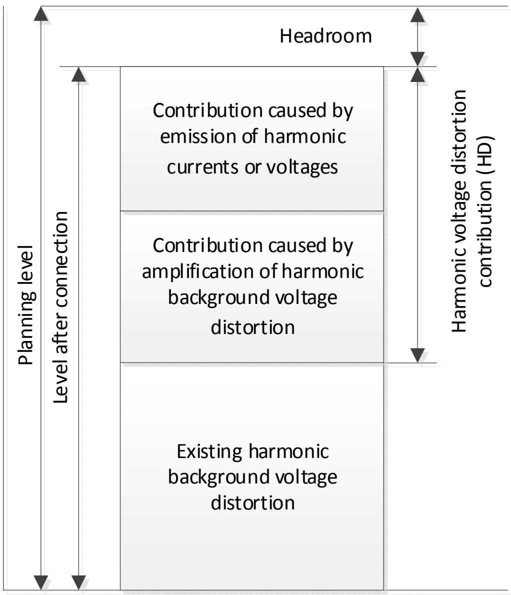

Figure 1 - Visual illustration of contributions to harmonic voltage distortion in the point of connection after commissioning of the facility.

Unique thresholds are defined per *harmonic voltage component* from the 2nd to the 50th order. These thresholds are determined as the root-mean-square value of the individual harmonic voltage component, expressed as a percentage of the root-mean-square value of the fundamental voltage. In addition to the threshold value per *harmonic voltage component*, a threshold for the *total harmonic voltage distortion* is set (THD_U). *Total harmonic voltage distortion* is calculated as:

$$THD_U = \sqrt{\sum_{h=2}^{50} U_h^2}$$

where U_h is the root-mean-square (RMS) value of the h-th *harmonic voltage component* expressed as a percentage of the root-mean-square value of the fundamental voltage.

All these *harmonic voltage components* are defined as 95% percentile levels, calculated on the basis of 10-minute aggregated values measured over a week. Aggregation is carried out as specified in DS/EN 61000-4-30 [4].

3.1.1.1 Establishing requirements for harmonic voltage distortion contribution

Requirements for *harmonic voltage distortion contribution* can be determined using one of the two methods described in sections 3.1.2 and 3.1.3.

The method is selected by the *facility owner* and approved by Energinet Elsystemansvar A/S.

3.1.2 Fixed harmonic voltage distortion contribution

The *facility's harmonic voltage distortion contribution* may make up maximum 10% of the *planning levels* stated in IEC 61000-3-6, Table 2 [3]; however, the threshold value must make up minimum 0.1% of the root-mean-square value of the fundamental voltage. A threshold value for the *total harmonic voltage distortion* is set at 0.2%.

3.1.3 Voltage distortion contribution based on background noise measurement

The *threshold value* of the *harmonic voltage distortion contribution* is set by *Energinet Elsystemansvar A/S*. The *threshold value* is set per *harmonic voltage component* based on the principle shown in Figure 2.

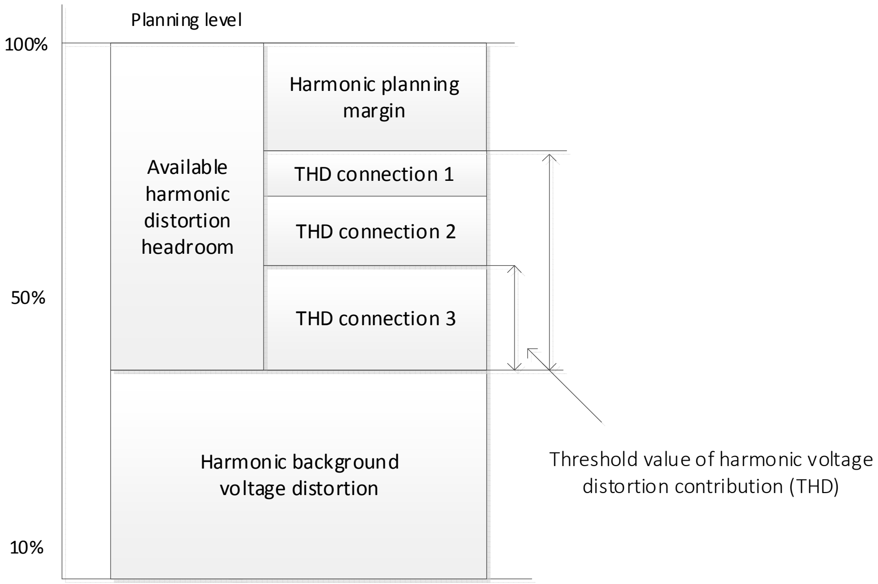

Figure 2 - Illustration of method used to set the threshold value for harmonic voltage distortion. contribution.

The method for determining the threshold is based on the fact that the levels of *harmonic background voltage distortion* in the *point of connection* are known for all relevant *harmonic voltage components*. Based on this, the *available harmonic distortion headroom is calculated*. This is shared between the planned *facilities* (generation or demand) that may connect in or near the *point of connection* of the *facility*. Part of the *available harmonic distortion headroom* is reserved for future facilities while also functioning as a safety buffer in the event of deviations. This reserved headroom is called the *harmonic planning margin.* The headroom is set by Energinet Elsystemansvar A/S and may vary from one connection point to another.

The *threshold value of the harmonic voltage distortion contribution* for facility number one is calculated by arithmetically subtracting the background level and the *harmonic planning margin* from the *planning level* of the relevant *harmonic voltage component*. In addition, thresholds allocated to other *facilities* that are not part of the *harmonic background voltage distortion* at the time of measurement are subtracted (see Figure 2):

$$U(h)_{GHF1} = U(h)_{PL} - U(h)_{bag} - U(h)_{PM} - U(h)_{GHF2} - \cdots - U(h)_{GHFn}$$

This means that the *facility owner* shall select an appropriate method for summation of the contributions from active *harmonic emission* and amplification of the existing *harmonic background distortion* (passive *harmonic emission*).

3.2 Verification of requirements for the harmonic voltage distortion contribution

The distortion contribution requirements for the *facility* can be verified by following one of two methods. The method described in section 3.2.1 presupposes that threshold values have been set in accordance with section 3.1.2. If threshold values have been set in accordance with section 3.1.3, the method described in section 3.2.2 is used.

3.2.1 Verification of requirements when allocating a fixed harmonic voltage distortion contribution

Observance of the requirements for the allocation of a fixed *harmonic voltage distortion contribution* is documented by presenting a written technical report, verifying that the contribution of the facility is negligible in the *point of connection* (*U(h)*<0.1%). The extent of underlying data for verification of the requirements described in section 3.2.3 can be reduced by using this approach. The extent must be agreed between the *facility owner* and *Energinet Elsystemansvar A/S*.

3.2.2 Verification of requirements for distortion contribution based on background noise measurement

To verify that the *facility* complies with the requirements for *harmonic voltage distortion* before energisation, the *facility owner* must complete a theoretical study that documents that the *facility*'s *harmonic distortion contribution* does not exceed the threshold stated. This must be verified for all operating configurations to be used to operate the *facility*, making the 95% percentile threshold of one week's 10-minute values relevant. This includes any temporary configurations used when commissioning the *facility*.

The *facility owner* must determine and account for the method used to summarise *harmonic emissions* from several *facilities*/units. The *facility owner* must also determine and account for the method used to summarise contributions of actively and passively introduced distortion (points a and b in section 3.1).

The method must be approved by *Energinet Elsystemansvar A/S*.

Sign-off on the requirements for the individual *voltage components* and THD_U is achieved when:

Verification criterion		
Harmonic distortion contribution (HD)	≤	Threshold value of harmonic distortion contribution (THD)

In addition to stating the *facility*'s *harmonic voltage distortion contribution*, the theoretical study must include the extent of contributions from active emissions as well as the amplification of existing *harmonic background voltage distortion* (passive emission) before summation (points a and b in section 3.1). The exact scope of the study and the calculation method is agreed on by the *facility owner* and *Energinet Elsystemansvar A/S,* before the study is performed. The *facility owner* must submit descriptions of study scope and method before the study is performed.

3.2.3 Underlying data for the verification of requirements for the harmonic voltage distortion contribution on calculation

Energinet Elsystemansvar A/S makes the following data available for verification of the requirements for the *facility's harmonic distortion contribution*:

1. The level of *harmonic background voltage distortion*

2. *Grid impedance polygons* in the *facility*'s point of connection or *system model defined by impedance polygons*

3.2.3.1 Harmonic background voltage distortion

Harmonic background voltage distortion is stated as the 95% percentile of 10-minute values, aggregated as described in DS/EN 61000-4-30 [4] and measured over a week. Typically, measurements are recorded for 6-12 months prior to connection, and the highest *harmonic voltage components* for the three phases, of all recorded weeks, are stated.

Please note that the stated *harmonic background distortion* is only to be used for the verification of operational requirements (THD). In respect of component design, design levels are set by the component manufacturer, under the prerequisite that the individual *harmonic component* must be able to take on *the planning levels* in the *point of connection*.

3.2.3.2 Grid impedance polygons in the *demand facility's point of connection* or the *system model* delimited by grid impedance polygons

Energinet Elsystemansvar A/S decides whether the transmission grid behind the *point of connection* of the *demand facility* is described using *impedance polygons,* or whether a *system model delimited by impendance polygons* is used. This decision is made by *Energinet Elsystemansvar A/S* prior to the start-up of analyses for verification of requirements.

3.2.3.2.1 Grid impedance polygons in the demand facility's point of connection

The transmission grid's g*rid impedance polygons* are defined in the R-X plane, seen from the *point of connection,* with the *facility* not connected. *The* g*rid impedance polygons* are calculated using a number of grid and system configurations, including unfavourable, but planned, component outages. The *harmonic spectrum* from 50 Hz to 2500 Hz is divided into a number of frequency intervals, each represented by a six-point polygon. The polygon corner points are illustrated in Figure 3.

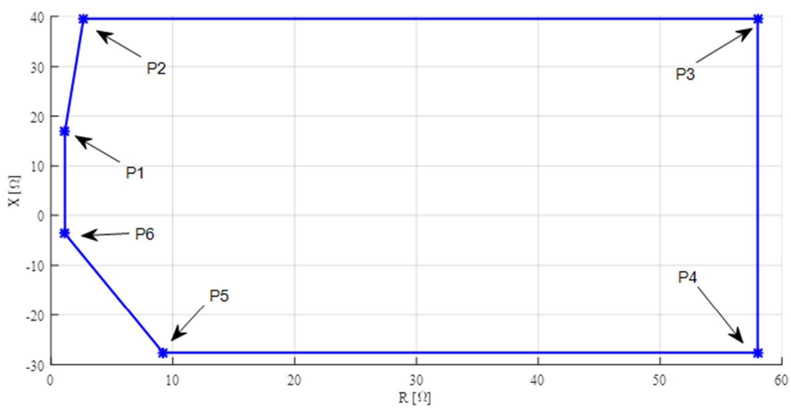

Figure 3 - Example of grid impedance polygon descriptive of grid impedance at the facility's point of connection.

The *facility owner* must verify that the *harmonic distortion contribution* does not exceed the allocated *threshold values for harmonic voltage distortion contribution* throughout the polygon area for each polygon stated. The calculation method using *grid impedance polygons* is determined by Energinet Elsystemansvar A/S in collaboration with the *facility owner*.

3.2.3.2.2 System model defined by grid impedance polygons

Energinet Elsystemansvar A/S may opt to provide a system model to verify *threshold values for harmonic voltage distortion contribution*. This option is relevant if the complexity of the system makes a system model either more representative due to mutual impact between parts of the system, or if it facilitates the *facility owner's* verification of requirements. If a system model option is selected, details of the process and method is agreed between Energinet Elsystemansvar A/S and the *facility owner* prior to the start-up of relevant studies.

3.2.4 Verification of requirements by measurement

The method for verification of requirements by measurement is determined jointly by Energinet Elsystemansvar A/S and the *facility owner*. Verification is done by *Energinet Elsystemansvar A/S*. This may be both immediately after commissioning before a final *grid connection agreement* is signed, and at any time during the *facility*'s service life. Should the *facility* fail to comply with requirements, the sanctions described in the Regulation will be imposed.

4. Interharmonics

Section 4 applies to *facility categories* 3 to 6.

4.1.1.1 Planning level and definition of interharmonic voltage distortion contribution

The *interharmonic planning level* for the transmission grid is determined as described in IEC 61000-3-6 [3] and measured as defined in IEC 61000-4-7 [2].

4.2 Specification of requirements for interharmonic voltage distortion contributions

Threshold values for *interharmonic voltage distortion contributions* are set as requirements for the *interharmonic subgroups.* Each *interharmonic subgroup* must be evaluated as described in DS/EN 61000-4-30 [4] and DS/EN 61000-4-7 [2]. The threshold value is fixed at 0.36% in the frequency range from 50 Hz up to 2.5 kHz in accordance with IEC 61000-3-6 [3]. This requirement applies for 95% percentile levels, calculated on the basis of 10-minute aggregated values measured over a week.

4.2.1.1 Verification of requirements

Documentation of compliance with requirements for interharmonics must be submitted to *Energinet Elsystemansvar A/S* no later than six months before commissioning of the *facility*. Verification is done using one of these two methods:

1) By submitting a written technical report showing that the *interharmonic voltage distortion contribution* of the *facility* is negligible in the *point of connection*
2) By running a worst-case operating condition simulation using a simulation model that includes sources of interharmonics.

If the option to verify requirements using method 2 is selected, *Energinet Elsystemansvar A/S* will forward relevant data describing the transmission grid in the *point of connection*. The amount of data will depend on the simulation method selected for verification, and is therefore determined following this selection.

The verification method and products must be approved by *Energinet Elsystemansvar A/S*.

Verification of requirements by measurement is done by *Energinet Elsystemansvar A/S*. This may be both immediately after commissioning before a final *grid connection agreement* is signed, and at any time during the *facility*'s service life. Should the *facility* fail to comply with requirements, the sanctions described in the Regulation will be imposed.

5. Voltage unbalance

Section 5 applies to *facility categories* 3 to 6. However, sections 5.2 and 5.4 only apply to *facility categories* 3 to 5, and sections 5.3 and 5.5 only apply to *facility category* 6.

A threshold for *voltage unbalance* originating from the *facility* is set in the *point of connection*.

5.1 Planning level and definition of voltage unbalance contributions

The *planning level* for *voltage unbalance* for the transmission grid is determined as described in IEC 61000-3-13, Table 2 [5]. Part of this *planning level* is allocated to the *facility* in *the point of connection*.

The v*oltage unbalance vector* is generally defined as:

$$\vec{u}_2 = \frac{\vec{U}_2}{\vec{U}_1}$$

where $\vec{U}_2$ is the negative sequence voltage, and $\vec{U}_1$ is the positive sequence voltage, both set as voltage vectors (described by magnitude and angle) and determined in the *facility's point of connection*.

The *voltage unbalance contribution,* stemming from the connection of the *facility* to the transmission grid, is defined as the size of the *voltage unbalance contribution vector* $\vec{u}_{2,bidrag}$. The v*oltage unbalance contribution vector* is the difference between the *voltage unbalance vectors,* determined in the *facility's point of connection* after and before the *facility* is connected:

$$\vec{u}_{2,bidrag} = \vec{u}_{2,efter} - \vec{u}_{2,før}$$

where $\vec{u}_{2,før}$ is the *voltage unbalance vector* before the *facility* is connected, and $\vec{u}_{2,efter}$ is the *voltage unbalance vector* after the *facility* is connected.

5.2 Setting requirements for voltage unbalance contributions - facility categories 3 to 5

The *facility* is allowed to have a maximum *voltage unbalance contribution* of 0.2% in the *point of connection*. This requirement applies for 95% percentile levels, calculated on the basis of 10-minute aggregated values measured over a week.

Connecting a *facility* may result in a reduced voltage unbalance in the *point of connection*. If this is the case, the *voltage unbalance contribution* is set equal to zero, and the requirement has been met.

Connecting a balanced *demand facility* may result in an increased unbalance level in *the point of connection* if the transmission grid is asymmetrical with a low short-circuit level. Such an increase is not the responsibility of the *facility owner*.

5.3 Setting requirements for voltage unbalance contributions - facility category 6

The *facility's voltage unbalance contribution* must not exceed 0.7% in the *point of connection*. This requirement applies to both the 95% percentile levels, calculated on the basis of 10-

minute aggregated values measured over a week, as well as the 99% percentile levels calculated on the basis of 3-second aggregated values measured over a day. Aggregation is carried out as specified in DS/EN 4-30 [4].

Connecting a *facility* may result in a reduced voltage unbalance in the *point of connection*. If this is the case, the *voltage unbalance contribution* is set equal to zero, and the requirement has been met.

Connecting a balanced *facility* may result in an increased unbalance level in *the point of connection* if the transmission grid is asymmetrical with a low short-circuit level. Such an increase is not the responsibility of the *facility owner*.

5.4 Verification of requirements for voltage unbalance - facility categories 3 to 5

Documentation of compliance with requirements for voltage unbalance must be submitted to *Energinet Elsystemansvar A/S* no later than six months before commissioning of the *facility*. Verification is done using one of the following two methods:

1) By submitting a written technical report showing that the *voltage unbalance contribution* of the *facility* is negligible in the *point of connection*
2) By running a worst-case operating condition simulation using a simulation model that includes sources of *voltage unbalance*.

If the option to verify requirements using method 2 is selected, *Energinet Elsystemansvar A/S* will forward relevant data describing the transmission grid in the *point of connection*. The amount of data will depend on the simulation method selected for verification, and is therefore determined following this selection.

The verification method and products must be approved by *Energinet Elsystemansvar A/S*.

Verification of requirements by measurement is done by *Energinet Elsystemansvar A/S*. This may be both immediately after commissioning before a final *grid connection agreement* is signed, and at any time during the *facility*'s service life. Should the *facility* fail to comply with requirements, the sanctions described in the Regulation will be imposed.

5.5 Verification of requirements for facility category 6

Documentation of compliance with requirements for voltage unbalance must be submitted to *Energinet Elsystemansvar A/S* no later than six months before commissioning of the *demand facility*. Verification is done using one of the following two methods:

1) By submitting a written technical report showing that the *voltage unbalance contribution* of the *facility* is negligible in the *point of connection*
2) By running a worst-case operating condition simulation using a simulation model that includes sources of *voltage unbalance*.

If the option to verify requirements using method 2 is selected, *Energinet Elsystemansvar A/S* will forward relevant data describing the transmission grid in the *point of connection*. The amount of data will depend on the simulation method selected for verification, and is therefore determined following this selection.

The verification method and products must be approved by *Energinet Elsystemansvar A/S*.

Verification of requirements by measurement is done by *Energinet Elsystemansvar A/S*. This may be both immediately after commissioning before a final *grid connection agreement* is signed, and at any time during the *facility*'s service life. Should the *facility* fail to comply with requirements, the sanctions described in the Regulation will be imposed.

6. Flicker

Section 6 applies to *facility categories* 3 to 6.

A threshold for *flicker* originating from the *facility* is set in the *point of connection*.

6.1.1.1 Planning level and definition of flicker contribution

The p*lanning level* for *flicker* for the transmission grid is determined as described in IEC 61000-3-7 [6] and measured as defined in DS/EN 61000-4-15 [1].

6.1.1.2 Setting requirements for flicker

The requirements for *flicker contribution* for the facility in *the point of connection* is shown in Table 1. These are defined as the minimum thresholds recommended, cf. IEC 61000-3-7[6].

Parameters	Limit
P_{st}	0.25
P_{lt}	0.35

Table 1 Threshold values for flicker caused by the demand facility.

P_{st} is short-term *flicker* intensity, and P_{lt} is long-term *flicker* intensity, both defined as described in DS/EN 61000-4-15 [1].

6.1.1.3 Verification of requirements

Documentation of compliance with requirements for flicker must be submitted to *Energinet Elsystemansvar A/S* no later than six months before commissioning of the *facility*. Verification is done using one of these two methods:

1) By submitting a written technical report showing that the *flicker contribution* of the *facility* is negligible in the *point of connection*
2) By running a worst-case operating condition simulation using a simulation model that includes sources of flicker.

If the option to verify requirements using method 2 is selected, *Energinet Elsystemansvar A/S* will forward relevant data describing the transmission grid in the *point of connection*. The amount of data will depend on the simulation method selected for verification and is therefore determined following this selection.

The verification method and products must be approved by *Energinet Elsystemansvar A/S*.

Verification of requirements by measurement is done by *Energinet Elsystemansvar A/S*. This may be both immediately after commissioning before a final *grid connection agreement* is signed, and at any time during the *facility*'s service life. Should the *facility* fail to comply with requirements, the sanctions described in the Regulation will be imposed.

7. DC content

Section 7 applies to *facility categories* 3 to 6.

A threshold for *DC content* in current supplied by the *facility* is set in the *point of connection*.

7.1.1.1 Setting requirements for DC content

DC content, measured in the AC current supplied by the *facility*, must not exceed 0.5% of the rated current in *the point of connection*.

7.1.1.2 Verification of requirements

Documentation of compliance with requirements for *DC content* must be submitted to *Energinet Elsystemansvar A/S* no later than six months before commissioning of the *facility*. Verification is done using one of these two methods:

1) By submitting a written technical report showing that the *DC content* originating from the *facility* is negligible in the *point of connection*
2) By running a worst-case operating condition simulation using a simulation model that includes sources of DC current or DC voltage.

If the option to verify requirements using method 2 is selected, *Energinet Elsystemansvar A/S* will forward relevant data describing the transmission grid in the *point of connection*. The amount of data will depend on the simulation method selected for verification and is therefore determined following this selection.

The verification method and products must be approved by *Energinet Elsystemansvar A/S*.

Verification of requirements by measurement is done by *Energinet Elsystemansvar A/S*. This may be both immediately after commissioning before a final *grid connection agreement* is signed, and at any time during the *facility*'s service life. Should the *facility* fail to comply with requirements, the sanctions described in the Regulation will be imposed.

8. Transmission-connected distribution systems – category 1

The *grid enterprise* and Energinet Elsystemansvar A/S are jointly responsible for ensuring that voltage quality in the *point of connection* complies with the *planning levels* specified by *Energinet Elsystemansvar A/S*. This applies particularly to *harmonic voltage distortion*, *interharmonic voltage distortion*, *voltage unbalance* and *flicker.* Each party has the right to carry out measurements of voltage quality in *the point of connection* at any time.

The requirement that the grid company follows the connection process for distribution connected systems, see. Appendix 1. F, whereby the grid operator and Energinet power system responsibility a/s enters into cooperation on the handling of the definition of requirements for voltage quality at the connection of distribution-connected facilities with significant impact on the transmission grid.

If a party discovers that levels are approaching - or exceed - *planning levels*, the other party must be notified. The parties must then enter into a mutually binding cooperation within 30 days to identify the source of any distortion as well as prepare a plan for corrective actions. If the source of distortion can be identified in all probability, costs incurred with corrective actions will be paid by the party who owns the grid in question.

9. References

[1] DS/EN 61000-4-15:2011 Elektromagnetisk kompatibilitet (EMC) - Del 4-15: Prøvnings- og måleteknikker - Flickermeter - Funktions- og designspecifikationer, Dansk Standard, 2011.

[2] IEC/TR 61000-3-14:2011 Electromagnetic compatibility (EMC) - Part 3-14: Assessment of emission limits for harmonics, interharmonics, voltage fluctuations and unbalance for the connection of disturbing installations to LV power systems, International Electrotechnical Commission, 2011.

[3] IEC TR 61000-3-6:2008 Electromagnetic compatibility (EMC) - Part 3-6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV Power systems, International Electrotechnical Commission, 2008-02.

[4] DS/EN 61000-4-30:2015 Elektromagnetisk kompatibilitet (EMC) - Del 4-30: Prøvnings- og måleteknikker - Metoder til måling af spændingskvaliteten; AC:2017, Dansk Standard, 2015.

[5] IEC/TR 61000-3-13:2008 Electromagnetic compatibility (EMC) - Part 3-13: Limits - Assessment of emission limits for the connection of unbalanced installations to MV, HV, 2008.

[6] IEC/TR 61000-3-7:2008 Electromagnetic compatibility (EMC) - Part 3-7: Limits - Assessment of emission limits for the connection of fluctuating installations to MV, HV and EHV power systems, International Electrotechnical Commission, 2008.

The international standards referenced (here: IEC) and European standards (EN) must only be used within the topics mentioned in connection with the references in this specification of requirements.