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TECHNICAL REGULATION 3.3.1 FOR ELECTRICAL ENERGY STORAGE FACILITIES

EFFECTIVE FROM 18 December 2019

Please note: This is a translation. In case of inconsistencies, the Danish version applies.

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All section 5.3.5 7	The regulation was updated following public consultation. This includes: - editorial errors being corrected. - changes being made in accordance with public consultation responses Updated with new requirements for facility properties as regards reactive power Updated communication requirements	1	23-06-2017
All sections	Public consultation document	0	14-02-2017

Contents

List of figures

List of tables

Reading instructions

This regulation contains all general and specific requirements that energy storage facilities included in the definition of electrical energy storage facilities must comply with when being connected to the electrical grid in Denmark.

The definition of an electrical energy storage facility and this regulation apply to inverter technology and therefore do not apply to synchronous generators.

The regulation is structured as follows: section 1 contains terminology and definitions used in the regulation. Please note that numbering matches the Danish version and is therefore not alphabetised.

Section 2 describes objective, scope and regulatory provisions.

Sections 3 to 7 contain technical and functional requirements.

Section 8 contains requirements for the exchange of signals and data communication, section 9 contains requirements for verification and documentation, section 0 contains requirements for electrical simulation models, while section 11 contains references.

Moreover, Table 1 is included to provide the reader with a consultative overview of requirements, differentiated on facility category, based on the facility's rated power and its grid connection point in the public electricity system.

In Table 1, the following energy storage facility categories are used :

- categories A-D
- category D * (specific transmission grid connection requirements deviating from general category D requirements)
- categories SA and SB (requirements for retrofitted electricity generation facilities)
- category T (two-way chargers).

This regulation is also published in Danish. If there are inconsistencies, the Danish version applies.

This regulation is published by Energinet and can be downloaded from www.energinet.dk.

Reference/requirements (explanation)	A	B	C	D	D*	SX	T
3.1.1/Information about storage medium, categories A, B, C, D	A	B	C	D			
3.2.1/Information about storage medium, category SX						SX	
3.4.1/Information about two-way chargers							T
4.2/Determination of voltage level	A	B	C	D	D*		T
4.3.1/Automatic connection and gradient for active power	A	B	C	D			T
4.3.2/Normal operating range, distribution system connection, category A	A						
4.3.3/Normal operating range, distribution system connection, categories B, C and D		B	C	D			
4.3.4/Normal operating range, transmission system connection					D*		
4.4.1/Phase jumps	A	B	C	D			
4.4.2/ROCOF	A	B	C	D			
4.4.3/Normal operation after voltage dips		B	C	D			
4.4.4/Tolerance of voltage dips, distribution system		B	C	D			
4.4.5/Tolerance of voltage dips, transmission system					D*		
5.1/Power quality, energy storage facilities categories A, B and T, connected to the distribution system	A	B					T
5.2/Power quality, energy storage facilities categories C, D and T, connected to the distribution system			C	D			T
5.3/Power quality, energy storage facilities connected to the transmission system					D*		
6.2.2.1/ LFSM-O, categories A, B, C and D	A	B	C	D			
6.2.2.3/ Category C and D facilities			C	D			
6.2.3.2/FSM, categories C and D			C	D			
6.2.4.1.1/Absolute power constraint, categories A, B, C and D	A	B	C	D			
6.2.4.2.1/Ramp rate constraint, categories A, B, C and D	A	B	C	D			
6.3.1.1/Q control, categories A, B, C and D	A	B	C	D			
6.3.2.1/Power factor control, categories A, B, C and D	A	B	C	D			
6.3.3.2/Voltage control, categories C and D			C	D			
6.3.4.1/Automatic power factor control, categories A	A	B					
6.3.5.1/Reactive power, categories A and B	A	B					
6.3.5.2/Reactive power, category B		B					
6.3.5.3/Reactive power, category C			C				
0/Reactive power, category D				D			
6.3.5.5/Reactive power, category D*					D*		
6.4.2/ System protection, categories C and D			C	D			
6.5/Order of priority for control functions	A	B	C	D	D*		T
7.2.1/Protective functions, category A	A						
7.2.2/Protective functions, category B		B					
7.2.3/Protective functions, category C and D			C	D			
7.2.4/Protective functions, transmission system connections					D*		
8.2.1/Information exchange, category A and B1	A	B1					
8.2.2/Information exchange, categories B2, C and D		B2	C	D			
8.3.2/Fault incident recording, category D				D			
8.4/Requesting metered data and documentation				D			
9.2/Documentation requirements	A	B	C	D	D*	SX	T
10.1/General simulation model requirements			C	D	D*		

*Table 1	Consultative requirement overview. See reading instructions for explanation of facility categories.*

1. Terminology, definitions and abbreviations

1.1 Introduction

This section contains the definitions used in this document. Several definitions are based on IEC 60050-415:1999 [1], but have been modified for the purpose.

Table 2 below presents terms, definitions and abbreviations used.

Absolute power constraint /1.1.1	Harmonic distortions /1.1.30	$P_{deliver}$ /1.1.53
Facility owner /1.1.2	Rapid voltage changes /1.1.31	P_{min} /1.1.54
Facility infrastructure /1.1.3	Point of connection in installation, PCI /1.1.32	Pnl /1.1.55
Facility category /1.1.4	Internal power infrastructure /1.1.33	Pno /1.1.56
Facility operator /1.1.5	Public electricity supply grid /1.1.34	P_{absorb} /1.1.57
COMTRADE /1.1.6	Point of communication, PCOM /1.1.35	Positive list /1.1.58
DK1 /1.1.7	Short-circuit power, S_k /1.1.36	Q control /1.1.59
DK2 /1.1.8	Short-circuit power electricity quality /1.1.37	Reactive current, Iq /1.1.60
Power factor, PF /1.1.9	Short-circuit ratio, SCR /1.1.38	ROCOF /1.1.61
Power Factor control /1.1.10	Short-circuit current, Ik /1.1.39	Integrated electricity supply system /1.1.62
Electricity supply undertaking /1.1.11	Point of common coupling, PCC /1.1.40	Voltage fluctuation /1.1.63
Electrical energy storage facility /1.1.12	LFSM-O /1.1.41	Voltage reference point /1.1.64
Energy storage facility controller /1.1.13	LFSM-U /1.1.42	Voltage control /1.1.65
Energinet Elsystemansvar A/S /1.1.14	Rated power, normalised conditions, P/Pn /1.1.43	Droop /1.1.66
F_0 /1.1.15	Rated reactive power delivery, Qnl /1.1.44	Sum of harmonic voltages /1.1.67
F_1 /1.1.16	Rated voltage, Un /1.1.45	Sum of individual harmonic currents, Ih /1.1.68
F_2 /1.1.17	Rated current, In /1.1.46	Point of connection, POC /1.1.69
F_4 /1.1.18	Rated reactive power absorbed, Qno /1.1.47	Connection terminals, PEC /1.1.70
F_5 /1.1.19	Rated value of apparent power, Sn /1.1.48	Apparent power, S /1.1.71
Flicker /1.1.20	Normal operating voltage, Uc /1.1.49	Total Harmonic Distortion, THD /1.1.72
fmax /1.1.21	Normal operating range /1.1.50	Two-way charger /1.1.73
fmin /1.1.22	$P_{current}$ /1.1.51	Umax /1.1.74
Frequency response /1.1.23	Partial Weighted Harmonic Distortion, PWHD /1.1.52	Umin /1.1.75
Frequency response insensitivity /1.1.24		Coordinated universal time, UTC /1.1.76
FSM /1.1.25		Ψk /1.1.77
FSM band /1.1.26		
Generator convention /1.1.27		
G_{it} /1.1.28		
Ramp rate constraint /1.1.29		

*Table 2	Definitions and abbreviations in numerical order.*

1.1.1 Absolute power constraint

Adjustment of active power to a maximum level is indicated by a set point. The +/- tolerance of the set point adjustment is referred to as the absolute power constraint.

See section 6.2.4.1 for a more detailed description.

1.1.2 Facility owner

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

1.1.3 Facility infrastructure

Facility infrastructure is the electrical infrastructure connecting the point(s) of generator connection (PEC) of the individual energy storage unit(s) in a facility to the point of connection (POC).

1.1.4 Facility category

Facility categories in relation to total rated power in the point of connection:

- A. Energy storage facilities up to 125 kW
- B. Energy storage facilities from and including 125 kW up to 3 MW
- C. Energy storage facilities from and including 3 MW up to 25 MW
- D. Energy storage facilities from and including 25 MW or connected at voltages above 100 kV
- SX. Category A or B energy storage facilities
- T. Temporarily connected energy storage facilities.

Note 1:
Category SX comprises existing generation facilities connected in accordance with technical regulation 3.2.1, technical regulation 3.2.2 or technical regulation 3.2.5 that are retrofitted with an energy storage solution.

Note 2:
In connection with requirements for the exchange of signals and data communication, facility category B is divided into categories B1 and B2:

- B1 from and including 125 kW up to 1 MW
- B2 from and including 1 MW up to 3 MW.

Note 3:
Simulation model requirements apply to categories C and up, however only starting at $P_n > 10$ MW.

1.1.5 Facility operator

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

1.1.6 COMTRADE

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

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

1.1.7 DK1

DK1 is used as the designation for Western Denmark, which is part of the synchronous area Continental Europe.

1.1.8 DK2

DK2 is used as the designation for Eastern Denmark, which is part of the Nordic synchronous area.

1.1.9 Power factor, PF

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

1.1.10 Power factor control

Power factor control is the control of reactive power proportionately to active power generated. See section 6.3.2 for a more detailed description.

1.1.11 Electricity supply undertaking

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

Grid enterprises are enterprises 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.

1.1.12 Electrical energy storage facilities (also referred to as energy storage facilities)

An electrical energy storage facility is a facility which can store and deliver electrical energy in one or more of the following ways or in combination with the following ways:

1. Absorb electrical energy from the public electricity supply grid and, at a given time, deliver it back in the point of connection
2. Absorb energy from the public electricity supply grid and, at a given time, deliver electrical energy back internally in the installation, i.e. not deliver it back in the point of connection
3. Absorb electrical energy directly generated in the installation (RE generation), i.e. not absorb electrical energy from the public electricity supply grid, and, at a given time,

deliver electrical energy back internally in the installation, i.e. not deliver it back in the point of connection.

4. Absorb electrical energy directly generated in the installation (RE generation), i.e. not absorb energy from the public electricity supply grid, and, at a given time, deliver electrical energy in the point of connection.

The definition of electrical energy storage facilities comprises permanent and temporarily connected energy storage facilities.

Permanently connected energy storage facilities comprise:

- Facilities designed so that one of the facility's original functions includes the storage of electrical energy (categories A, B, C, D).
- Generation facilities, which are converted (retrofitted) so that the facility has functions added that include the storage of electrical energy (category SX, where X may be category A or B in reference to the rated power supplied by the facility).

Temporarily connected energy storage facilities (category T) comprise:

- Two-way chargers (V2G), which are used by an electric vehicle or an electric vessel where the electrical energy is primarily used for propulsion, and where the electric vehicle must have a vehicle certificate issued by the Danish Motor Vehicle Agency, and the electric vessel must be used for the transport of passengers or goods, are covered by this technical regulation.

The definition of an electrical energy storage facility and this regulation apply to inverter technology and therefore do not apply to synchronous or asynchronous generator facilities.

For energy storage facilities that incorporate RE generation, master data for the respective RE generation facilities must also be submitted.

An energy storage facility may consist of several separate inverters and electrical energy stores (energy storage units).

The rated power of an energy storage facility when energy (P_{no}) is absorbed from or energy (P_{nl}) is delivered back to the public electricity supply grid, or internally in the installation, may differ.

UPS systems (emergency power supply systems with batteries), on condition that such systems are operated as such exclusively, are not defined as electrical energy storage facilities and therefore not subject to the requirements in this technical regulation, because the function of a UPS system is to maintain power supply locally in an installation or in part of an installation in case of public electricity supply grid disturbances or faults. If ancillary services are provided, excluding reduction of absorbed power or time coordination of absorbed active power, the facility is subject to this technical regulation.

A regenerative demand facility, i.e. a demand facility which, due to the facility design and operating pattern, can return an unspecified amount of energy to the point of connection, is not defined as an electrical energy storage facility and is therefore not subject to this technical regulation.

1.1.13 Electrical energy storage facility controller

An electrical energy storage facility controller is a set of control functions that make it possible to control several units as a single energy storage facility in the point of connection.

The set of control functions must be part of the energy storage facility in terms of communication. This means that if communication with an energy storage facility is interrupted, the energy storage facility must be able to continue operation as planned or carry out a controlled shutdown.

1.1.14 Energinet Elsystemansvar A/S

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

1.1.15 f_0

f_0 denotes the ideal base frequency of 50.00 Hz.

1.1.16 f_1

f_1 denotes the lower frequency threshold, which delimits the FSM band and is where the autonomous frequency response LFSM-U is initiated.

1.1.17 f_2

f_2 denotes the upper frequency threshold, which delimits the FSM band and is where the autonomous frequency response LFSM-O is initiated.

1.1.18 f_4

f_4 denotes the lower frequency threshold, which delimits FCR-N and marks the transition to FCR-D.

1.1.19 f_5

f_5 denotes the upper frequency threshold, which delimits FCR-N and marks the transition to FCR-D.

1.1.20 Flicker

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

Flicker is measured as described in DS/EN 61000-4-15 [2].

1.1.21 f_{max}

f_{Max} denotes the maximum frequency within the frequency band.

1.1.22 f_{min}

f_{min} denotes the minimum frequency within the frequency band.

1.1.23 Frequency response

Frequency response is the automatic upward or downward regulation of active power as a function of the grid frequency at grid frequencies above or below the reference frequency, f_1 and f_2, for the purpose of stabilising grid frequency. See section 6.2.1 for a more detailed description.

Frequency response is an autonomous function.

1.1.24 Frequency response insensitivity

A setting in the control system used in connection with frequency control, defined as the minimum value of the frequency change or input signal which triggers a change in the power output or output signal.

1.1.25 FSM

FSM, frequency sensitive mode, is a frequency control state which is an operational mode in which an energy storage facility controls active power so that it contributes to stabilising the base frequency; in other words, frequency control. See section 6.2.3 for a more detailed description.

1.1.26 FSM band

The frequency control band in which frequency control can be performed. The purpose of the frequency control function is to control active power at grid frequencies between f_1 and f_2.

1.1.27 Generator convention

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

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

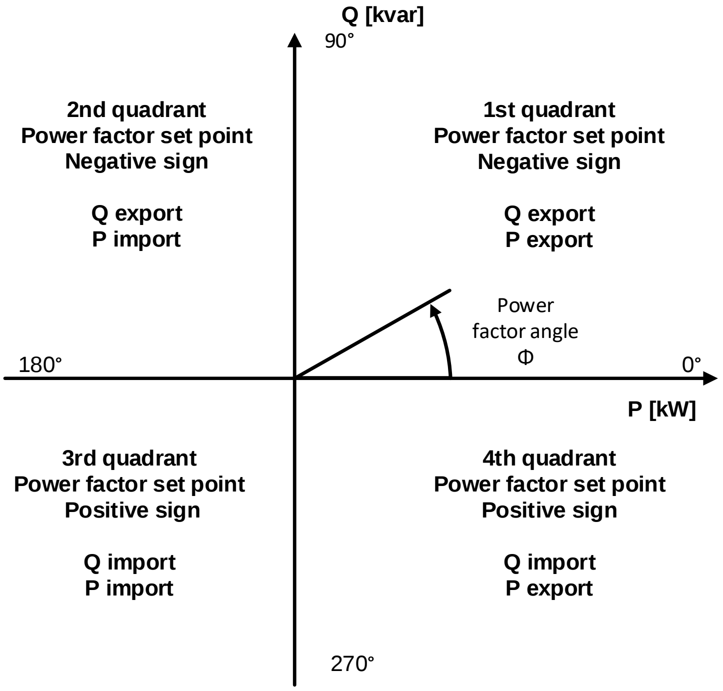


Figure 1 Definition of signs for active and reactive power and power factor set points, cf. the IEC 61850 series [3] and IEEE 1459 [4].

1.1.28 G_{lt}

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

1.1.29 Ramp rate constraint

A ramp rate constraint controls the interval of active power with a set point-defined maximum increase/reduction (ramp rate) of active power. See section 6.2.4.2 for a more detailed description.

1.1.30 Harmonic distortions

Harmonic distortions are defined as electrical disturbances caused by overharmonic currents and voltages. Harmonic distortions are also referred to as overtones, overharmonic tones, overharmonic distortion or simply harmonics. See section 5.1 for a more detailed description.

1.1.31 Rapid voltage changes

Rapid voltage changes are defined as brief, isolated voltage changes (RMS values). Rapid voltage changes are expressed as percentages of the normal operating voltage.

1.1.32 Point of connection in Installation (PCI)

The point of connection in installation (PCI) is the point in the installation where the installation's energy storage facility is connected or can be connected and where consumption is connected. See Figure 3 for a typical location.

1.1.33 Internal power infrastructure

The electrical infrastructure which connects one or more units to the POC.

1.1.34 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.

1.1.35 Point of communication (PCOM)

The point of communication (PCOM) is the point in an energy storage facility where the data communication properties specified in section 8 must be made available and verified.

1.1.36 Short-circuit power, S_k

Short-circuit power (S_k) is the amount of power [VA] that the public electricity supply grid can deliver in the point of connection in the event of a short-circuit of the energy storage facility's terminals.

1.1.37 Short-circuit power electricity quality, $Sk_{\text{electricity quality}}$

The level of three-phase short-circuit power in the point of connection which is used to calculate power quality for distribution-connected facilities.

1.1.38 Short-circuit ratio, SCR

The short-circuit ratio (SCR) is the ratio between short-circuit power in the point of connection (S_k) and the energy storage facility's rated apparent power S_n.

1.1.39 Short-circuit current, I_k

Short circuit current (I_k) is the amount of current [kA] that the energy storage facility can deliver in the point of connection in the event of a short circuit at the energy storage facility's terminals.

1.1.40 Point of common coupling, PCC

The point of common coupling (PCC) is the point in the public electricity supply grid where consumers are or can be connected.

Electrically, the point of common coupling and the point of connection may coincide. The point of common coupling (PCC) is always placed closest to the public electricity supply grid, see Figure 3 and Figure 4.

The electricity supply undertaking defines the point of common coupling.

1.1.41 LFSM-O

LFSM-O, limited frequency sensitive mode – overfrequency, is the operational frequency response to occurrences of overfrequency as well as a defined frequency range in which an energy storage facility reduces active power if the system frequency crosses a specific threshold.

1.1.42 LFSM-U

LFSM-U, limited frequency sensitive mode – underfrequency, is the operational frequency response to occurrences of underfrequency as well as a defined frequency range in which an energy storage facility increases active power if the system frequency crosses a specific threshold.

1.1.43 Rated power – normalised conditions, P/P_n

P/P_n is the normalised ratio for rated power. P_n may be either P_{no} or P_{nl}.

1.1.44 Rated reactive power delivery, Q_{nl}

Q_{nl} denotes the rated reactive power delivered of an energy storage facility which the energy storage facility is designed to deliver continuously and which appears from the type approval.

1.1.45 Rated voltage, U_n

Rated voltage (U_n) is the voltage level at the POC for which a grid is defined and to which operational characteristics refer. Voltage is measured phase to phase.

1.1.46 Rated current, I_n

Rated current (I_n) is defined as the maximum continuous current that an energy storage facility is designed to deliver or consume under normal operating conditions.

1.1.47 Rated reactive power absorbed, Q_{no}

Q_{no} denotes the rated reactive power absorbed of an energy storage facility which the energy storage facility is approved to continuously absorb in the point of common coupling under normal operating conditions.

1.1.48 Rated value for apparent power, S_n

The rated value for apparent power (S_n) is the highest level of power, consisting of both the active and reactive component, which the energy storage facility is designed to continuously deliver.

1.1.49 Normal operating voltage, U_c

Normal operating voltage indicates the voltage range within which an energy storage facility must be able to continuously deliver the specified rated power, see sections 4.2 and 4.3. Normal operating voltage is determined by the electricity supply undertaking. Voltage is measured phase to phase.

1.1.50 Normal operating range

Normal operating range indicates the voltage/frequency range within which an energy storage facility must be able to continuously maintain operation in relation to the specified rated power, see sections 4.2 and 4.3.

1.1.51 $P_{current}$

$P_{current}$ denotes the current level of active power. The term is used in connection with the illustration of any power level in any operating point.

1.1.52 Partial Weighted Harmonic Distortion, PWHD

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

$$PWHD = \sqrt{\sum_{h=14}^{h=40} h * \left(\frac{X_h}{X_1}\right)^2}$$

See IEC 61000-3-12 [5], for more detail

where:

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

1.1.53 $P_{deliver}$

$P_{deliver}$ indicates the direction of active power which is delivered by an energy storage facility at a given time. The term is used in connection with the illustration of any power level in a random operating point as well as the energy storage facility's actual operation.

1.1.54 P_{min}

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

1.1.55 P_{nl}

P_{nl} is the designation for rated power supplied by an energy storage facility. This is the highest level of active power that the facility is designed to provide continuously and which appears from the type approval.

1.1.56 P_{no}

P_{no} denotes the nominal power absorbed by an energy storage facility. This is the highest level of active power that the facility is designed to absorb continuously and which appears from the type approval.

1.1.57 P_{absorb}

P_{absorb} indicates the direction of active power, which is absorbed by an energy storage facility at a given time. The term is used in connection with the illustration of any power level in a random operating point as well as the energy storage facility's actual operation.

1.1.58 Positive list

With a view to streamlining the approval process for grid connection of category A energy storage facilities, a so-called positive list has been created for energy storage facilities where energy storage facilities with nominal power up to 50 kW can be entered.

1.1.59 Q control

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

1.1.60 Reactive current, I_q

I_q denotes the reactive current delivered or absorbed by the energy storage facility.

1.1.61 ROCOF

ROCOF, rate of change of frequency, (DF/DT) is the designation for frequency change as a function of time.

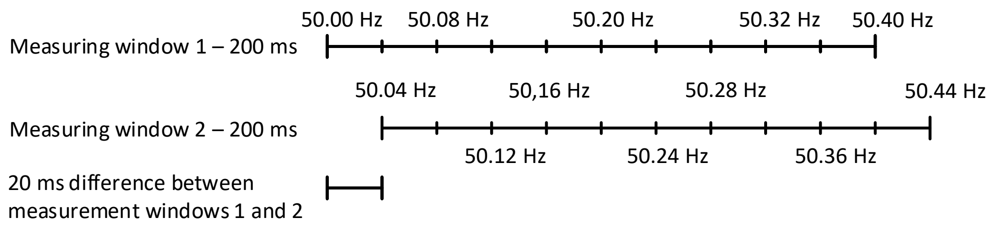
Note 4: The frequency change, ROCOF, is calculated according to the principle below or an equivalent principle. The frequency measurement used to calculate the frequency change is based on a 200 millisecond measuring period for which the mean value is calculated.

Frequency measurements must be made continuously, so that a new value is calculated every 20th millisecond.

ROCOF [Hz/s] must be calculated as the difference between the mean value frequency calculation just done and the mean value frequency calculation done 20 milliseconds ago.

(df/dt = (mean value 2 – mean value 1)/0,020 [Hz/s]

Example:



ROCOF calculation:

Average value 1: 50.20 Hz   Average value 2: 50.24 Hz

df/dt = (average value 2 – average value 1)/dt = (50.24 – 50.20)/0.020 = 0.040/0.020 = 2 Hz/s

Figure 2 Example of ROCOF calculation (df/dt).

1.1.62 Interconnected electricity supply system

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

1.1.63 Voltage fluctuation

Voltage fluctuation is a series of rapid voltage changes or a periodic variation of the voltage RMS value.

1.1.64 Voltage reference point

Measuring point used for voltage control. The voltage reference point is either in the point of connection, the point of common coupling or a specified point in between. The voltage reference point is defined by the electricity supply undertaking.

1.1.65 Voltage control

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

1.1.66 Droop

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

1.1.67 Sum of harmonic voltages

U_h denotes the sum of harmonic voltages.

1.1.68 Sum of individual harmonic currents, I_h

I_h denotes the sum of individual harmonic currents.

1.1.69 Point of connection, POC

The point of connection (POC) is the point in the public electricity supply grid, where the energy storage facility is or can be connected. See Figure 3 and Figure 4 for typical locations.

All requirements in this regulation apply to the point of connection.

Following agreement with the electricity supply undertaking, reactive compensation at no load can be placed somewhere else in the public electricity supply grid. The electricity supply undertaking determines the point of connection.

Figure 3 shows a typical installation connection of one or more energy storage facilities, indicating the typical location of the energy storage facility's connection terminals (PEC), point of connection (POC), point of connection in installation (PCI) and point of common coupling (PCC). In the example shown, the point of common coupling (PCC) and the point of connection (POC) coincide.

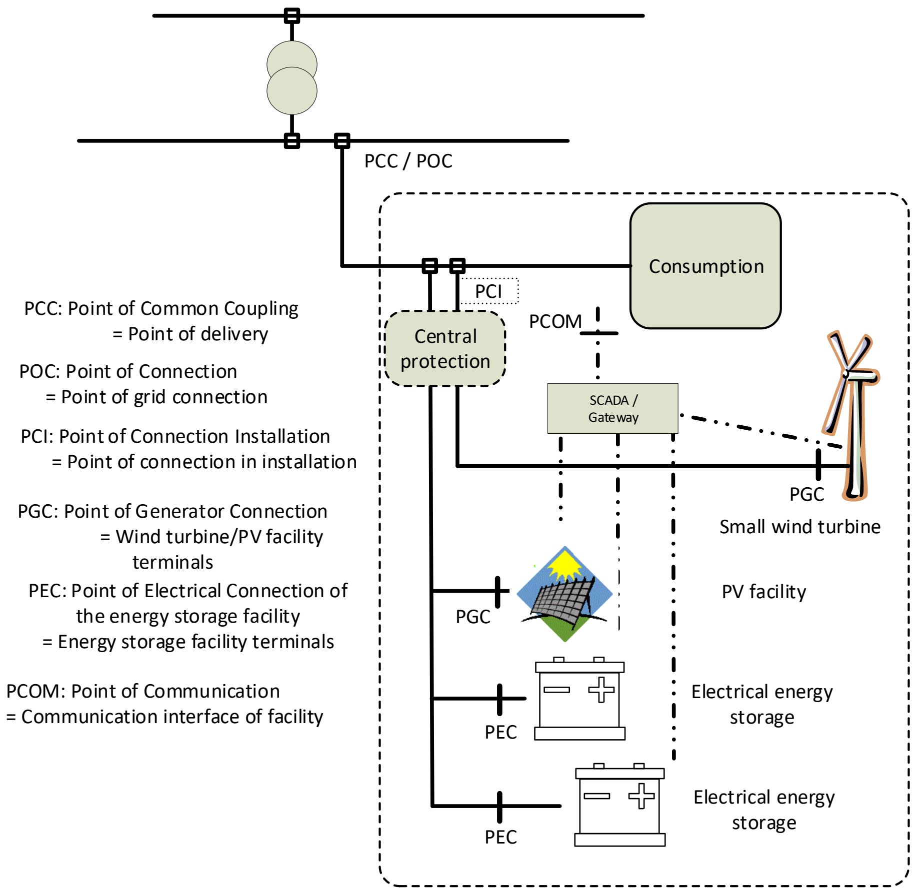


Figure 3 Example of installation connection of a facility.

Figure 4 shows a typical grid connection of several facilities, indicating where the point of generator connection (PGC), the energy storage facility's terminals (PEC), the point of connection (POC), the point of common coupling (PCC) and the voltage reference point may be located. The voltage reference point is either the point of connection (POC), the point of common coupling (PCC) or a point in between.

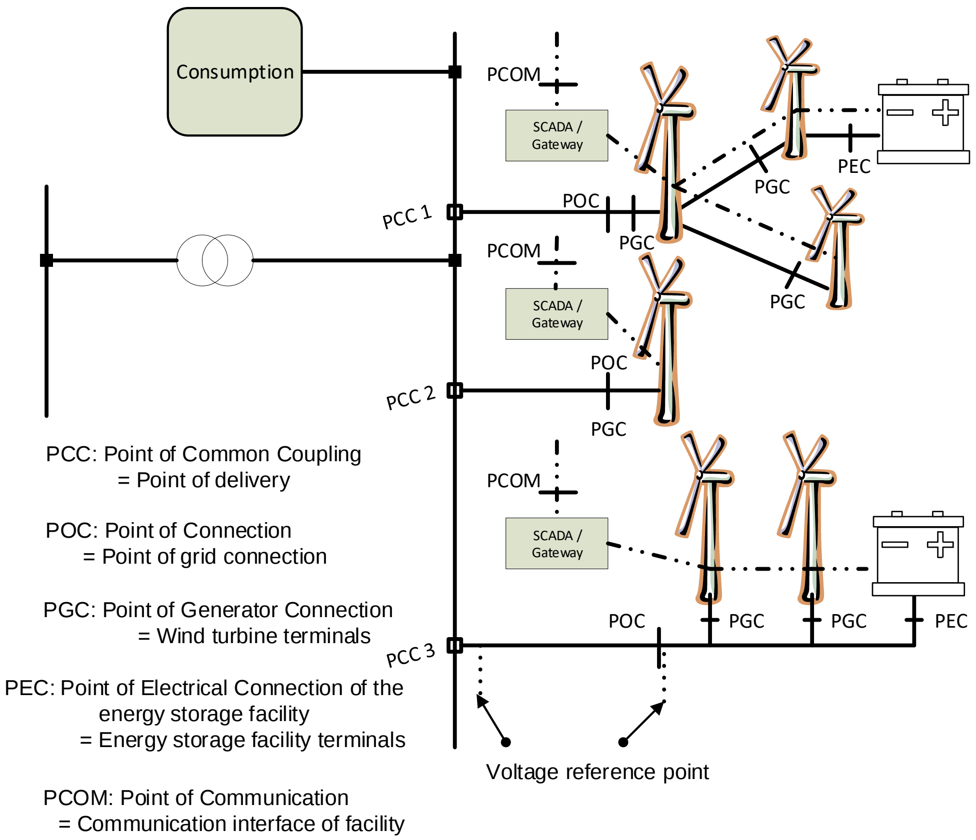


Figure 4 Example of grid connection of a facility.

1.1.70 Connection terminals, PEC

The connection terminals, point of connection (PEC), of the energy storage facility or unit are what the facility or unit's manufacturer defines as connection terminals and where the electrical connection to the public electricity system is established. U_{PEC} denotes voltage measured in the energy storage facility's terminals.

1.1.71 Rated apparent power, S

Rated apparent power (S) (apparent power) is defined as volt × ampere and is normally expressed as VA or volt ampere.
Apparent power consists of both the active and the reactive component.

$$S = \sqrt{P^2 + Q^2} = \sqrt{(UIcos\varphi)^2 + (UIsin\varphi)^2} = UI$$

S is also stated as a complex size defined as S = UI *
Where U is the voltage vector and I* is the current vector's conjugated value. Apparent power thus becomes a complex size S = P + jQ with the real part P referred to as active power, and the imaginary part Q referred to as reactive power.

1.1.72 Total Harmonic Distortion, THD

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

$$THD_I = \sqrt{\sum_{h=2}^{h=H}\left(\frac{X_h}{X_1}\right)^2}$$

See IEC 61000-3-6 [6] for more detail,

where:

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

1.1.73 Two-way charger

Charger which, when connected to the public electricity system, allows electrical energy to be delivered to and supplied from the public electricity system.

1.1.74 U_{max}

U_{Max} denotes the maximum RMS value of rated voltage U_n.

1.1.75 U_{min}

U_{min} denotes the minimum RMS value of rated voltage U_n.

1.1.76 Coordinated universal time, UTC

UTC is the abbreviation for Coordinated Universal Time (Universal Time, Coordinated). In Danish, the terms 'universal time' or 'world time' are also used.

1.1.77 Ψ_k

Ψ_k is used as an abbreviation for the short-circuit angle in the point of connection. Flicker values are calculated using the ψ_k parameter.

2. Objective, scope of application and regulatory provisions

2.1 Objective

Under the authority of section 7 (1), no. 1, 3 and 4 of executive order no. 1402 dated 13 December 2019 on transmission system operation and use of the electricity transmission system etc. (hereinafter referred to as executive order on transmission system operation), Energinet has prepared this regulation to define the technical and functional minimum requirements which an energy storage facility must comply with in the point of connection when said energy storage facility is connected to the public electricity supply grid.

An energy storage facility must be registered with master data to ensure that data and experience concerning the impact on the public electricity supply grid can be collected and used for development of the energy storage facility and the public electricity supply grid. For energy storage facilities that incorporate RE generation, master data for the respective RE generation facilities must also be submitted.

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

2.2 Scope of application

This regulation applies to energy storage facilities connected to the public electricity supply grid. An energy storage facility must comply with the provisions of the regulation throughout the service life of said energy storage facility.

The technical requirements specified in the regulation are divided into the following categories based on the total rated power in the point of connection:

- A. Energy storage facilities up to 125 kW
- B. Energy storage facilities from and including 125 kW up to 3 MW
- C. Energy storage facilities from and including 3 MW up to 25 MW
- D. Energy storage facilities from and including 25 MW or connected at voltages above 100 kV
- SX. Category A or B energy storage facilities
- T. Temporarily connected energy storage facilities.

2.2.1 New energy storage facilities

This regulation applies to all energy storage facilities connected to the public electricity supply grid and commissioned as of the effective date of this regulation.

2.2.2 Existing energy storage facilities

Facilities connected to the public electricity supply grid before the effective date of this regulation must comply with the regulation in force at the time of its commissioning.

2.2.3 Modifications to existing energy storage facilities

Existing energy storage facilities to which substantial functional modifications are made must comply with the provisions of this regulation relating to such modifications.

A substantial modification is one that changes one or more vital facility components that may alter the properties of the energy storage facility.

In case of doubt, Energinet Elsystemansvar A/S decides whether a specific modification is substantial.

The documentation described in section 9 must be updated and submitted in a version indicating any modifications made using Appendix 1.

2.3 Delimitation

This technical regulation is part of the complete set of technical regulations issued by Energinet.

This technical regulation does not define requirements for energy storage facilities which use synchronous or asynchronous generators in their connection to the public electricity system. Energy storage facilities that use water as energy storage are also not covered by this technical regulation.

The technical regulations contain the technical minimum requirements that apply to facility owners, facility operators and electricity supply undertakings in regard to the connection of facilities to the public electricity supply grid.

In combination with market regulations, the technical regulations, including system operation regulations, constitute the set of rules which facility owners, facility operators and electricity supply undertakings must comply with when operating facilities:

- National implementing measure, information exchange: Requirement document no. 1 - generation and demand (awaiting approval by the Danish Utility Regulator) [7]
- National implementing measure, information exchange: Requirement document no. 3 - standards, protocols etc. (awaiting approval by the Danish Utility Regulator) [8]
- Technical regulation TR 5.9.1 'Systemtjenester' (Ancillary services) [9]
- Regulation D1 "Settlement metering" [10]
- Regulation D2 'Technical requirements for electricity metering' [11]
- Technical regulation TR 3.3.1 'Technical regulation for grid connection of battery plants above 11 kW'. [12]

In case of discrepancies between the requirements of the individual regulations, Energinet Elsystemansvar A/S determines which requirements should apply.

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

Operational issues must be agreed between the facility owner and the electricity supply undertaking.

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

This regulation does not deal with the financial aspects of using control capabilities or settlement metering, nor with technical settlement metering requirements.

The facility owner must safeguard the energy storage facility against possible damaging impacts due to a lack of electricity supply from the public electricity supply grid for short or long periods of time.

2.3.1 Exceptions from minimum requirements

The following functionalities are excepted from the minimum requirements:
The system protection requirement has not been included as a minimum requirement to be fulfilled in order to be granted grid connection. See section 6.4 for more detail.

2.4 Effective date

This regulation takes effect from 18 December 2019 concurrently with the notification hereof to the Danish Utility Regulator.

Please direct requests for additional information and questions on this technical regulation to Energinet Elsystemansvar A/S. Contact information is available at
https://energinet.dk/El/Nettilslutning-og-drift/Regler-for-nye-anlaeg#Nyebatterianlaeg

The regulation was registered with the Danish Utility Regulator pursuant to the provisions of section 26 of the Danish Electricity Supply Act and section 7 of the Danish executive order on transmission system operation and the use of the electricity transmission grid, etc.

As regards energy storage facilities, the construction of which was finally ordered in a binding written order before this regulation was registered with the Danish Energy Regulatory Authority, but which are scheduled to be commissioned after this regulation comes into force, an exemption can be applied for in accordance with section 2.8; any relevant documentation should be enclosed.

2.5 Complaints

Complaints about this regulation can be filed with the Danish Utility Regulator, www. forsyningstilsynet.dk, cf. section 7(3) executive order on transmission system operation and the use of the electricity transmission grid, etc.

Complaints about decisions made by Energinet in pursuance of this regulation cannot be appealed to another administrative authority. Decisions can only be appealed to the courts.

2.6 Breaches

The facility owner shall ensure that the provisions of this regulation are complied with throughout the energy storage facility's service life.

The energy storage facility must be regularly maintained to ensure that the provisions of this regulation are complied with.

Expenses incurred in complying with the provisions of this regulation must be paid by the facility owner.

2.7 Penalties

If an energy storage facility does not comply with the provisions of section 3 and onwards of this regulation, the electricity supply undertaking is entitled to cut off the grid connection to the energy storage facility as a last resort until the provisions are complied with.

2.8 Exemptions and unforeseen events

The transmission system operator may grant exemptions from specific requirements in the regulation.

An exemption can only be granted if:

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

or

- the energy storage facility was ordered before this regulation was registered with the Danish Utility Regulator, cf. section 2.4.

In order to obtain exemption, a written application must be submitted to the electricity supply undertaking, indicating which provisions the exemption concerns and the reason for the exemption.

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

If events not foreseen in this regulation occur, the transmission system operator must decide what to do in consultation with the parties involved.

If an agreement cannot be reached, the transmission system operator must decide on a course of action.

The decision must be based on what is reasonable, taking the views of the parties involved into consideration where possible.

3. The energy storage facility's storage medium, categories A-D, SX and T

3.1 Connection of a new energy storage facility

As part of the grid connection process, an energy storage facility must provide information about the storage medium of the energy storage facility.

3.1.1 Information about storage medium, categories A, B, C, D

Category A, B, C or D energy storage facilities must supply facility information about the storage medium used:

- Storage medium – manufacture
- Storage medium – model no.
- Storage medium – usable energy storage capacity [kWh]

3.2 Connection of storage medium to an existing generation facility, category SX

If a storage medium (energy storage or other type of storage unit) is connected to an existing category A or B generation facility, the storage medium must comply with the requirements in this technical regulation, while the existing generation facility must continue to comply with the requirements in force when said production facility was originally connected.

The facility owner must provide facility information about the storage medium used as described below.

3.2.1 Information about storage medium, category SX

Category SX energy storage facilities must supply facility information about the storage medium used:

- Storage medium – manufacture
- Storage medium – model no.
- Storage medium – usable energy storage capacity [kWh]
- Inverter – rated power [kW]

3.3 Modifications to an energy storage facility, category SX

If facility properties change for an existing category SX facility, i.e. characteristics used in the evaluation of the facility's grid connection to the public electricity system, the entire energy storage facility must comply with the requirements in this technical regulation.

3.4 Connection of energy storage facilities, category T

As part of the grid connection process, an energy storage facility must provide information about the properties of the two-way charger.

3.4.1 Information about two-way chargers

As part of the grid connection process, a two-way charger, a temporarily connected energy storage facility, must provide information about the charger:

- Charger – manufacture
- Charger – model no.
- Charger rated active power, P_{nl} and P_{no} [kW]

4. Voltage and frequency

4.1 Tolerance of frequency and voltage deviations (general information)

An energy storage facility must be able to withstand frequency and voltage deviations in the point of connection under normal and abnormal operating conditions while reducing active power as little as possible.

The energy storage facility may have a one-phase connection when neither P_{no} nor P_{nl} exceed 3.68 kW ≈ to a phase current of 16 A.

If the phase current of the energy storage facility exceeds 16 A, an equal distribution of total power on two or three phases is required.

4.2 Determination of voltage level

The following requirements apply to energy storage facilities in categories A, B, C and D as well as T.

The electricity supply undertaking determines the voltage level for the energy storage facility's point of connection within the voltage thresholds stated in Table 3, Table 4 or Table 5.

Normal operating voltage may differ from location to location, and the electricity supply undertaking must therefore state the normal operating voltage U_c for the point of connection. For rated voltages up to 1 kV, $U_c = U_n$.

The electricity supply undertaking must ensure that the maximum voltage stated in Table 3 is never exceeded.

If the normal voltage range, U_c±10%, is lower than the minimum voltage stated in Table 3, the output requirements in the event of frequency and voltage variations must be adjusted to avoid overload of the energy storage facility.

Voltage level descriptions	Rated system voltage U_n [kV]	Minimum voltage U_{min} [kV]	Maximum voltage U_{max} [kV]
High voltage (HV)	60	54.0	72.5
	50	45.0	60.0
Medium voltage (MV)	33	30.0	36.0
	30	27.0	36.0
	20	18.0	24.0
	15	13.5	17.5
	10	9.00	12.0
Low voltage (LV)	0.69	0.62	0.76
	0.40	0.36	0.44

Table 3 Voltage levels used in the distribution system in DK1 and DK2, respectively.

Maximum (U_{max}) and minimum (U_{min}) voltage thresholds are determined using the standards DS/EN 50160 (10-minute mean values) [13] and DS/EN 60038 [14].

DK1	p.u.	150 kV	220 kV	400 kV
60 min. operation	1.118 – 1.15	174.8	253	-
Maximum voltage at continuous operation	1.118	170	246	-
60 min. operation	1.05 – 1.1	-	-	440
Maximum voltage at continuous operation	1.05	-	-	420
	1	152	220	400
Minimum voltage at continuous operation	0.9	137	198	360
60 min. operation	0.9 – 0.85	129.2	187	340

Table 4 Transmission system voltages with operational tolerances in DK1.

DK2	p.u.	132 kV	220 kV	400 kV
60 min. operation	1.05 – 1.1	151.8	253	440
Maximum voltage at continuous operation	1.05	145	246	420
	1	138	234	400
Minimum voltage at continuous operation	0.9	137	198	360

Table 5 Transmission system voltages with operational tolerances in DK2.

Voltage threshold and operating hours in Table 4 and Table 5 are determined on the basis of EU regulation 2016/631 [15].

The energy storage facility must be able to briefly withstand voltages exceeding the maximum voltages within the required protective functions as specified in section 7.

4.3 Normal operating conditions

Within the normal operating range, an energy storage facility must be able to start and operate continuously within the design specifications, restricted only by the settings of the protective functions as described in section 7 and/or other functions impacting the energy storage facility's operation.

4.3.1 Automatic connection and gradient for active power

The following requirements apply to energy storage facilities in categories A, B, C and D as well as T.

Automatic connection of an energy storage facility may at the earliest take place three minutes after the voltage has come within the tolerance range of the normal operating voltage, and the grid frequency is within the range indicated by f_1 and f_2.

FSM band	DK1		DK2	
	f_1	f_2	f_1	f_2
Hz	49.80	50.20	49.90	50.10

Table 6 FSM band for automatic connection.

Frequency limit settings are determined by Energinet Elsystemansvar A/S.

In case of automatic connection or reconnection, it must be possible to set the active power gradient to an integer value between minimum and maximum, both inclusive expressed as a percentage of rated output.

Facility category	A	B	C	D
Minimum [%]		1	1	1
Maximum [%]	20	20	20	20
Maximum [MW/min]		60	60	60

Table 7 Gradient for automatic connection.

4.3.2 Normal operating range, distribution system connection, category A

The following requirements apply to category A energy storage facilities.

The overall requirements for the normal operating range of active power in the event of frequency and voltage deviations for an energy storage facility in the point of connection are shown in Figure 5.

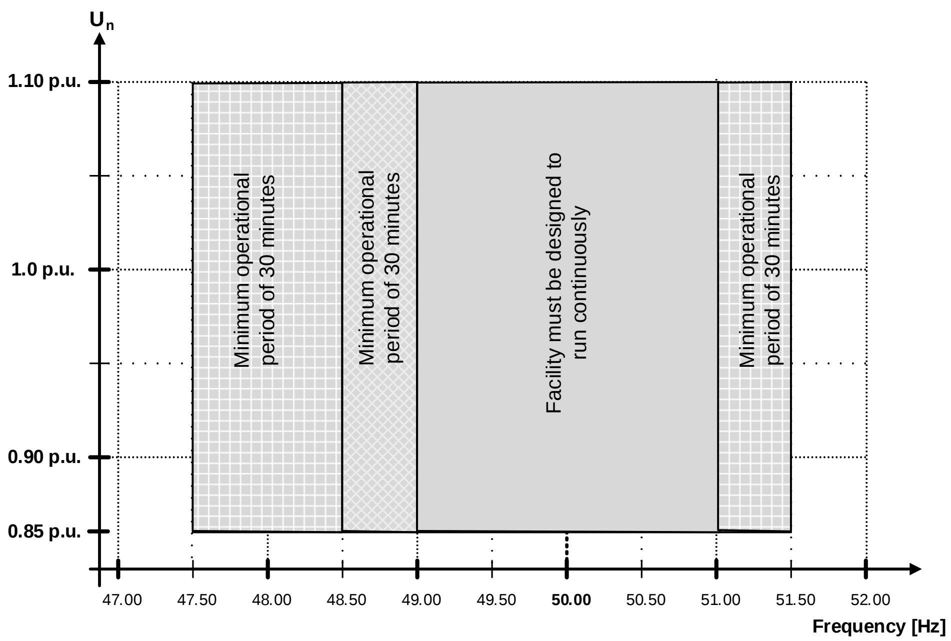


Figure 5 Requirements for rated power and rated current in the event of frequency and voltage variations.

4.3.3 Normal operating range, distribution system connection, categories B, C and D

The following requirements apply to category B, C and D energy storage facilities.

The overall requirements for the normal operating range of active power in the event of frequency and voltage deviations for an energy storage facility in the point of connection are shown in Figure 6.

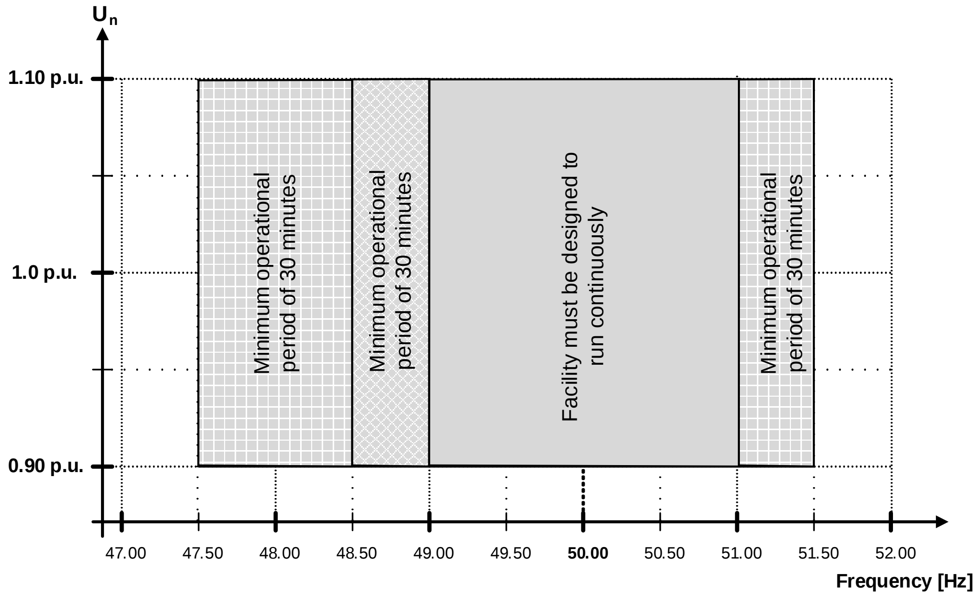


Figure 6 Requirements for rated power and rated current in the event of frequency and voltage variations.

4.3.4 Normal operating range, transmission system connection

The overall requirements for the normal operating range of active power in the event of frequency and voltage deviations for an energy storage facility in the point of connection are shown in Figure 7 and Figure 8 for DK1 and in Figure 9 and Figure 10 for DK2.

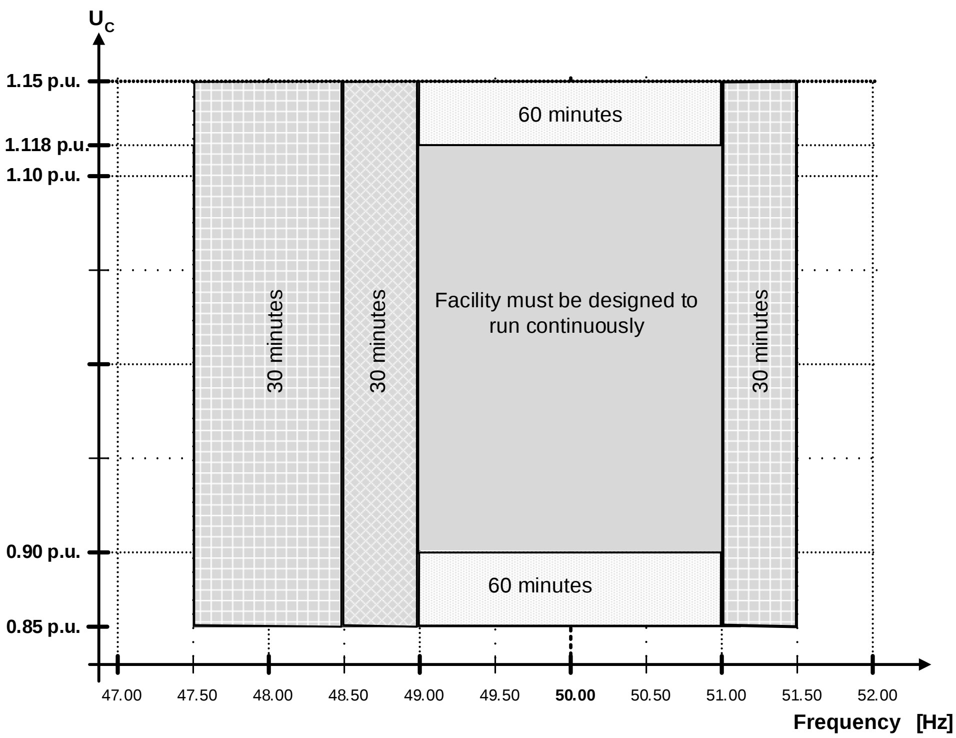


Figure 7 Normal operating range: transmission-connected facilities in DK1, 110-130 kV.

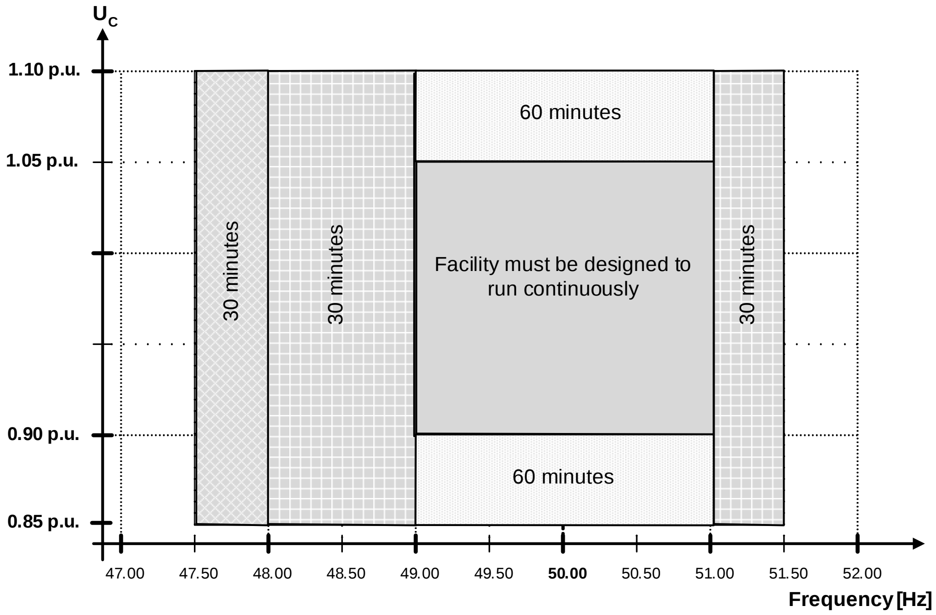


Figure 8 Normal operating range: transmission-connected facilities in DK1, 300-400 kV.

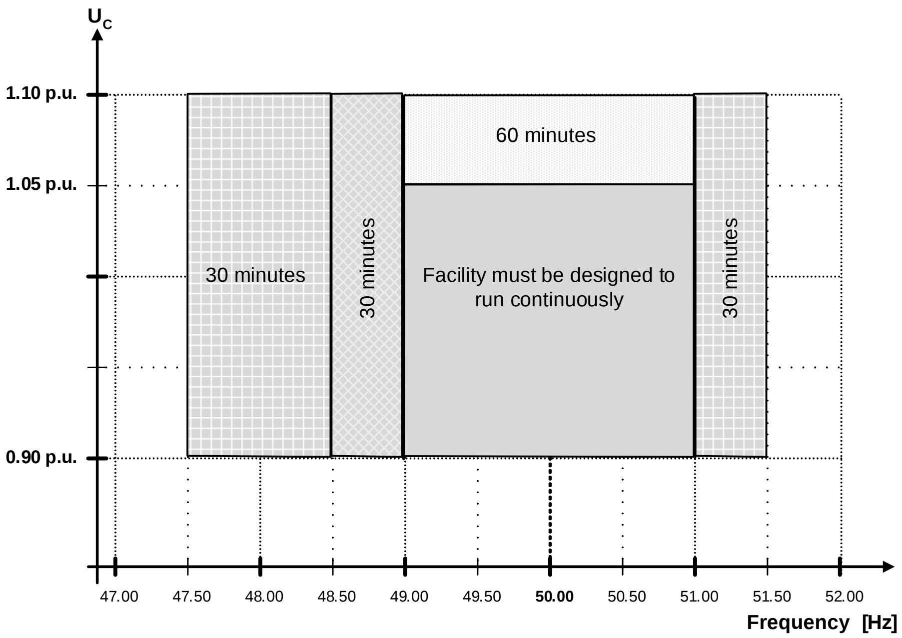


Figure 9 Normal operating range: transmission-connected facilities in DK2, 100-300 kV.

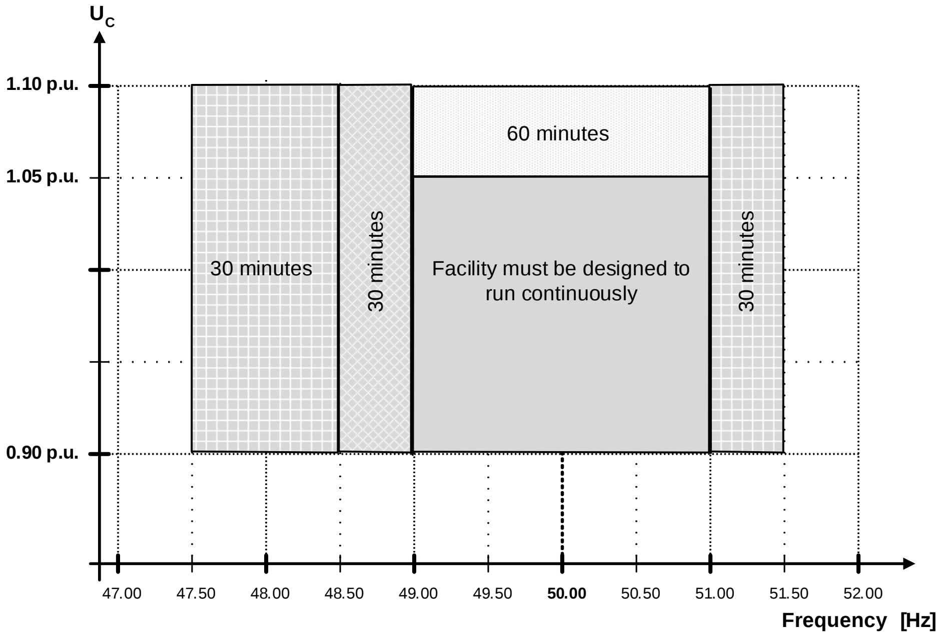


Figure 10 Normal operating range: transmission-connected facilities in DK2, 300-400 kV.

4.4 Abnormal operating conditions

The following requirements apply to category A, B, C and D energy storage facilities.

4.4.1 Phase jumps

The energy storage facility must be designed to withstand transitory phase jumps of up to 20° in the point of connection (POC) without disconnecting from the POC and shutting down.

4.4.2 ROCOF

The energy storage facility must be able to withstand transient frequency gradients, ROCOF, of up to ±2 Hz/s in the point of connection without disconnecting from the POC and shutting down.

4.4.3 Normal operation after voltage dips

The following requirements apply to category B, C and D energy storage facilities.
After a voltage dip, the energy storage facility must be able to return to normal operation no later than 5 seconds after the operating conditions in the point of connection have returned to the normal operating range.

4.4.4 Tolerance of voltage dips, distribution system

The following requirements apply to category B, C and D energy storage facilities connected in the distribution system.

In the point of connection, an energy storage facility must be designed to withstand voltage dips down to 15% of the voltage in the point of connection over a period of minimum 250 milliseconds without disconnecting, as shown in Figure 11, and must be able to deliver additional reactive current during the fault sequence, as shown in Figure 12.

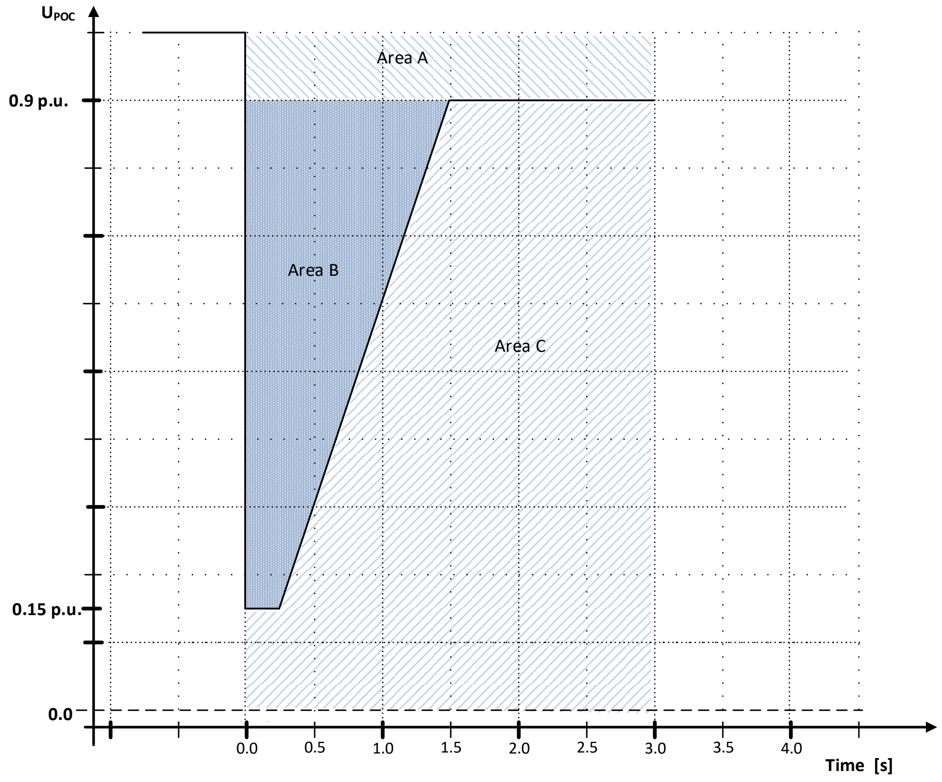


Figure 11 Tolerance requirements for voltage dips for category B, C and D energy storage facilities.

The following requirements must be complied with in the event of symmetrical and asymmetrical faults. This means that the requirements apply in the event of faults in three, two or a single phase:

- Area A: The energy storage facility must maintain normal operation without disconnecting from the POC and shutting down.

- Area B: Without disconnecting from the POC and shutting down, the energy storage facility must provide maximum voltage support by delivering a controlled amount of additional reactive current to ensure that the energy storage facility contributes to voltage stabilisation within the design framework offered by current energy storage facility technology, see Figure 11.

- Area C: Energy storage facility disconnection is permitted.

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

If several successive fault sequences occur within area B, causing a move into area C time-wise, disconnecting is allowed.

In connection with fault sequences in area B, the energy storage facility must have a control function capable of controlling the positive sequence of the reactive current as specified in Figure 12.

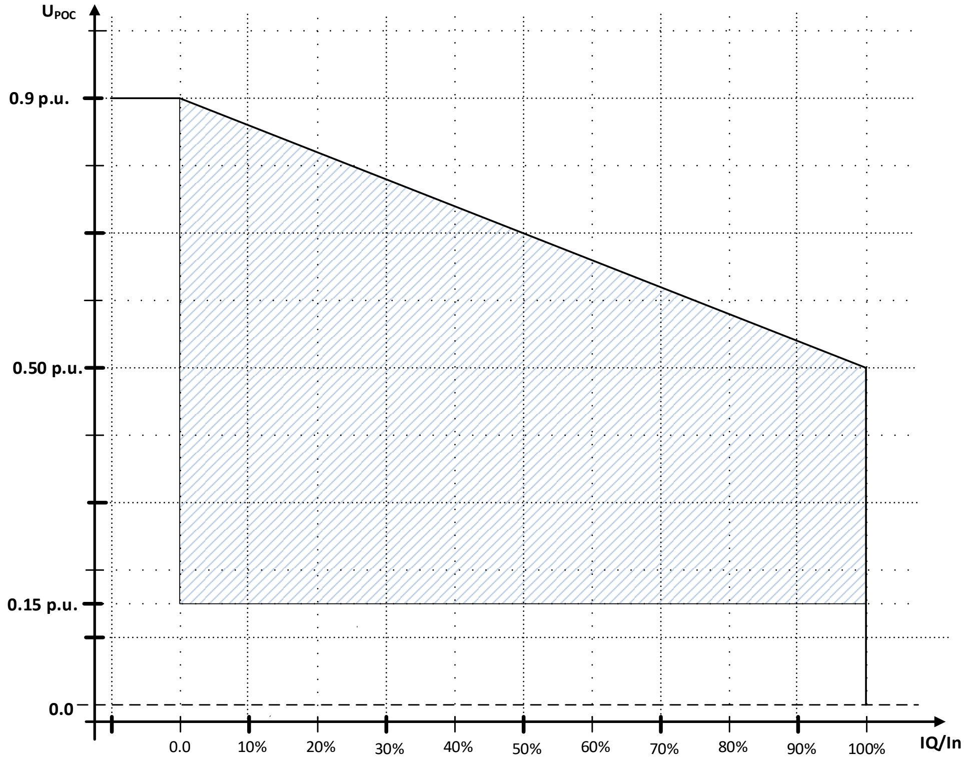


Figure 12 Requirements for the delivery of additional reactive current IQ during voltage dips for category B, C and D energy storage facilities.

Control must follow Figure 12 so that the additional reactive current (positive sequence) follows the characteristic with a tolerance of ±20% after maximum 100 milliseconds after the voltage dip.

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

4.4.5 Tolerance of voltage dips, transmission system

The following requirements apply to energy storage facilities connected to the transmission system.

In the point of connection, an energy storage facility must be designed to withstand voltage dips down to 0% of the voltage in the point of connection over a period of minimum 150 milliseconds without disconnecting.

In the point of connection, an energy storage facility must be designed to withstand voltage dips down to 0% of the voltage in the point of connection over a period of minimum 150 milliseconds without disconnecting, as shown in Figure 13 for DK1 and Figure 15 for DK2, and must be able to deliver additional reactive current during the fault sequence, as shown in Figure 14 for DK1 and Figure 16 for DK2.

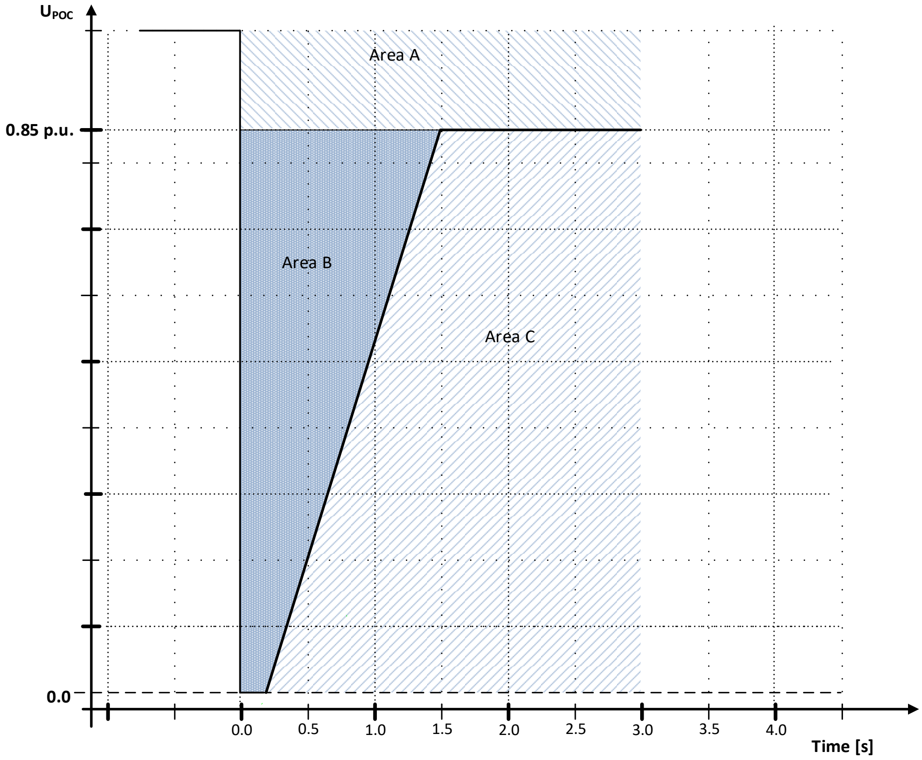


Figure 13 Tolerance requirements for voltage dips for energy storage facilities connected in the DK1 transmission system.

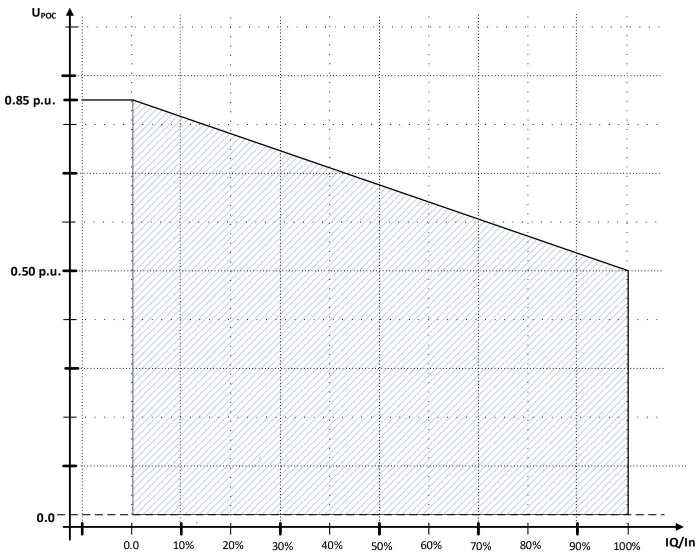


Figure 14 Requirements for the delivery of additional reactive current IQ during voltage dips for energy storage facilities connected to the transmission system in DK1.

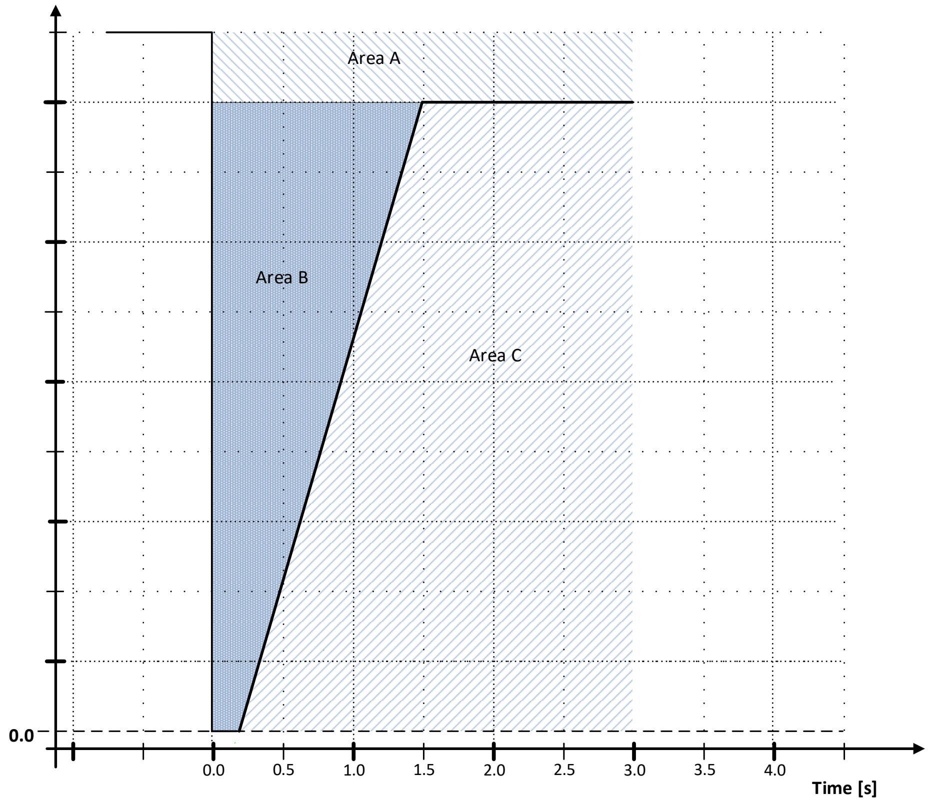


Figure 15 Tolerance requirements for voltage dips for energy storage facilities connected in the DK2 transmission system.

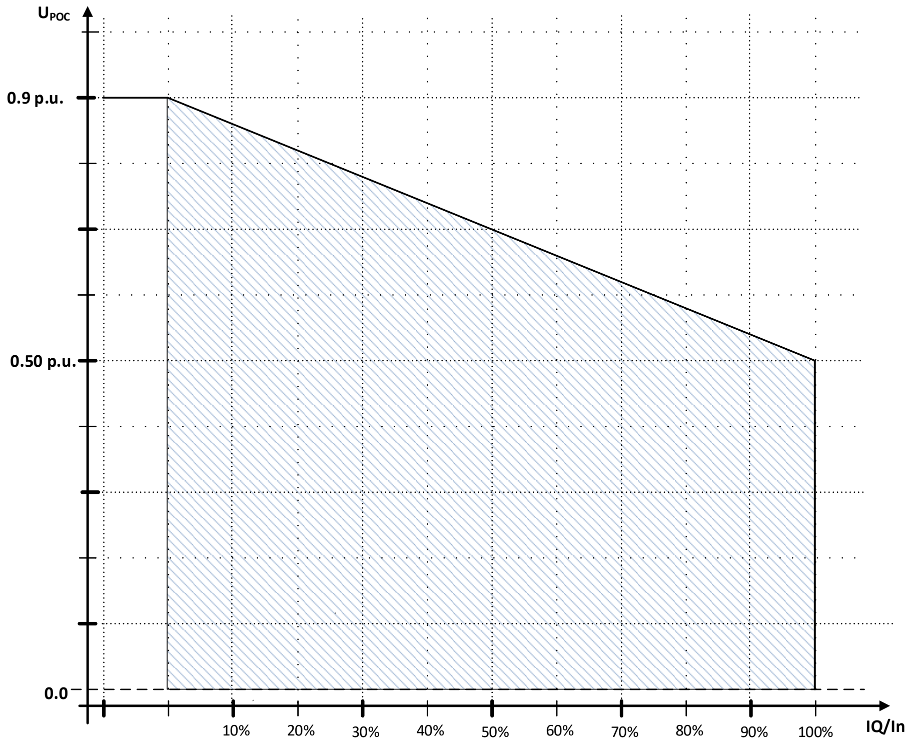


Figure 16 Requirements for the delivery of additional reactive current IQ during voltage dips for energy storage facilities connected to the transmission system in DK2.

The following requirements must be complied with in the event of symmetrical and asymmetrical faults. This means that the requirements apply in the event of faults in three, two or a single phase:

- Area A: The energy storage facility must maintain normal operation without disconnecting from the POC and shutting down.

- Area B: Without disconnecting from the POC and shutting down, the energy storage facility must provide maximum voltage support by delivering a controlled amount of additional reactive current to ensure that the energy storage facility contributes to voltage stabilisation within the design framework offered by current energy storage facility technology, see Figure 13.

- Area C: Energy storage facility disconnection is permitted.

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

If several successive fault sequences occur within area B, causing a move into area C time-wise, disconnecting is allowed.

In connection with fault sequences in area B, the energy storage facility must have a control function capable of controlling the positive sequence of the reactive current as specified in Figure 14 for DK1 and Figure 16 for DK2, respectively.

5. Power quality

5.1 Power quality, energy storage facilities categories A, B and T, connected to the distribution system

An energy storage facility must comply with the power quality requirements set out in European standards and the requirements in this section. Different standards apply, depending on the capacity of the energy storage facility.

An energy storage facility must comply with the requirements in this section in both generation and consumption mode.

5.1.1 Threshold values

All energy storage facilities must comply with the requirements described in sections 5.1.1.1 and 5.1.1.2. In addition, the specific requirements below apply, depending on the capacity of the energy storage facility.

- If each energy storage unit in an energy storage facility of up to and including 50 kW complies with relevant product standards or the DS/EN 61000-3 series, requirements for rapid voltage changes, flicker and harmonics are considered to be complied with.
- Energy storage facilities above 50 kW must also comply with the requirements and threshold values set out in sections 5.1.1.3 to 5.1.1.7. These sections concern, among other things, flicker, rapid voltage changes and harmonics.

5.1.1.1 DC content

An energy storage facility's injection of DC currents in the electricity grid must be limited to a value below 0.5% of the energy storage facility's rated current.

If the facility is connected through a facility transformer, the requirement is considered to be complied with.

5.1.1.2 Current imbalance

An energy storage facility’s current imbalance must not exceed 16 A between the three phases.

Energy storage facilities above 11 kW must be balanced three-phase, which means that they must be designed to deliver the same current on all three phases at the same time.

5.1.1.3 Rapid voltage changes

An energy storage facility cannot cause rapid voltage changes greater than the threshold value stated in Table 8.

	Threshold value
U ≤ 33 kV	d (%) = 4 %
U > 33 kV	d (%) = 3 %

Table 8 Threshold value for rapid voltage changes as a percentage of U_n.

5.1.1.4 Flicker

An energy storage facility cannot cause flicker contribution higher than the threshold values for short-term and long-term flicker specified in Table 9.

	Short-term flicker (P)	Long-term flicker (P_{lt})
U ≤ 1 kV	0.35/0.45/0.55*	0.25/0.30/0.40*
U > 1 kV	0.3	0.2
* Threshold values apply if 4+/2/1 energy storage facilities, respectively, are already connected in the same substation.		

Table 9 Threshold value for short-term and long-term flicker.

5.1.1.5 Harmonics

An energy storage facility cannot emit harmonic currents higher than the threshold values in Table 10 for the individual harmonics, which are stated as percentages of the facility's rated current, (I_h/I_n (%)). Threshold values depend on the ratio of SCR between an energy storage facility’s rated apparent power and the short-circuit power in the energy storage facility's point of connection.

	SCR	Odd harmonic order h							Even harmonic order h						
		3	5	7	9	11	13	15	2	4	6	8	10	12
U ≤ 1 kV	<33	3.4	3.8	2.5	0.5	1.2	0.7	0.35	0.5	0.5	1.0	0.8	0.6	0.5
	≥33	3.5	4.1	2.7	0.5	1.3	0.7	0.37	0.5	0.5	1.0	0.8	0.6	0.5
	≥66	3.9	5.2	3.4	0.6	1.8	1.0	0.43	0.5	0.5	1.0	0.8	0.6	0.5
	≥120	4.6	7.1	4.6	0.8	2.5	1.5	0.5	0.5	0.5	1.0	0.8	0.6	0.5
	≥250	6.3	11.6	7.3	1.3	4.4	2.7	0.8	0.5	0.5	1.0	0.8	0.6	0.5
	≥350	7.5	15.0	9.5	1.6	5.7	3.7	1.0	0.5	0.5	1.0	0.8	0.6	0.5
U > 1 kV	-	3.4	3.8	2.5	0.5	1.2	0.7	0.35	0.5	0.5	1.0	0.8	0.6	0.5

Table 10 Threshold values for harmonic currents I_h/I_n (% of I_n).

In addition to the threshold values for the individual harmonics, there are also thresholds for all harmonics overall. Threshold values for THD_I and $PWHD_I$ are stated in Table 11.

	SCR	THD_I	$PWHD_I$
U ≤ 1 kV	<33	4.4	4.4
	≥33	4.7	4.7
	≥66	6.1	6.1
	≥120	8.4	8.4
	≥250	13.8	13.8
	≥350	18.0	18.0
U > 1 kV	-	4.4	4.4

Table 11 Threshold values for THD_I and $PWHD_I$ in current (% of I_n).

5.1.1.6 Interharmonics

An energy storage facility must observe the threshold values stated in currents for all inter-harmonics, as specified in Table 12.

If harmonics have been measured with grouping activated (see measuring method), there are no separate requirements for interharmonics, as these are then included in the harmonics.

	SCR	Frequency (Hz)		
		75 Hz	125 Hz	> 175 Hz
U ≤ 1 kV	<33	0.4	0.6	$\frac{75}{f}$*
	≥33	0.5	0.7	$\frac{83}{f}$*
	≥66	0.6	0.8	$\frac{104}{f}$*
	≥120	0.7	1.1	$\frac{139}{f}$*
	≥250	1.2	1.8	$\frac{224}{f}$*
	≥350	1.5	2.3	$\frac{289}{f}$*
U > 1 kV	-	0.44	0.66	$\frac{83}{f}$ *
	* However, no less than measuring uncertainty.			

Table 12 Threshold values for interharmonics in current (% of In).

5.1.1.7 Disturbances in the 2-9 kHz interval

An energy storage facility must comply with the threshold value stated in current in Table 13 for all 200 Hz frequency groups between 2 kHz and 9 kHz.

Threshold value
0.2%

Table 13 Threshold value in current stated as a percentage of I_n for all frequencies in the 2-9 kHz range.

5.1.2 Division of responsibilities

5.1.2.1 Facility owner's obligations

Generally, the facility owner must ensure that the energy storage facility is designed, constructed and configured in compliance with all specified threshold values.

The facility owner must verify compliance with the emission thresholds in the point of connection.

The facility owner must use the typical three-phase short-circuit power to calculate power quality, $S_{k,\text{ power quality}}$ in the point of connection.

5.1.2.2 The electricity supply undertaking's obligations

The electricity supply undertaking is responsible for setting emission thresholds in the point of connection.

The electricity supply undertaking must state the short-circuit level $S_{k,\text{ power quality}}$ and related impedance angle ψ_k in the point of connection.

5.1.3 Measuring method

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

Measurements 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 precisions specified for class I.

Measurements of interharmonic distortion up to 2 kHz must be carried out as defined in IEC 61000-4-7 Annex A and must be measured as interharmonic groups (interharmonic subgroup).

Alternatively, it is permitted to measure harmonic distortion up to 2 kHz with grouping activated (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 activated, measuring interharmonic distortion up to 2 kHz separately is not required.

Measurements of disturbances in the 2-9 kHz range must be carried out in accordance with IEC 61000-4-7 annexe B and must be measured in 200 Hz windows with centre frequencies from 2100 Hz to 8900 Hz.

5.2 Power quality, energy storage facilities categories C, D and T, connected to the distribution system

An energy storage facility cannot cause unacceptable power quality in the electricity grid. To avoid this, the energy storage facility must comply with the requirements specified in the following sections.

There may be additional requirements for an energy storage facility in special cases where an energy storage facility may have a significant impact on the public electricity supply grid (the distribution grid and/or the transmission grid), see section 5.2.2.1.

5.2.1 Threshold values

An energy storage facility must comply with the requirements described in the following sections.

5.2.1.1 DC content

An energy storage facility cannot inject DC currents into the electricity grid. This requirement is met if the DC content of the current that the energy storage facility injects into the grid is less than 0.5% of the rated current of the energy storage facility.

If the facility is connected through a facility transformer, the requirement is expected to be complied with.

5.2.1.2 Voltage unbalance

An energy storage facility must be balanced three-phase so that the facility does not cause voltage unbalances.

5.2.1.3 Rapid voltage changes

An energy storage facility cannot cause rapid voltage changes greater than the threshold value stated in Table 14.

	Threshold value
U > 33 kV	d (%) = 3 %

Table 14 Threshold value for rapid voltage changes as a percentage of Un.

5.2.1.4 Flicker

The energy storage facility must comply with the flicker threshold values defined by the electricity supply undertaking.

5.2.1.5 Harmonics

The energy storage facility must comply with the voltage thresholds for emission of harmonics defined by the electricity supply undertaking.

5.2.1.6 Interharmonics

The energy storage facility must comply with the voltage thresholds for interharmonics defined by the electricity supply undertaking.

5.2.1.7 Disturbances in the 2-9 kHz interval

The energy storage facility must comply with the voltage thresholds for distortions in the 2-9 kHz frequency range defined by the electricity supply undertaking.

5.2.2 Division of responsibilities

5.2.2.1 Facility owner's obligations

The facility owner must ensure that the energy storage facility is designed, constructed and configured in compliance with all specified thresholds.

The facility owner must verify compliance with the emission thresholds in the point of connection. The facility owner must use the typical three-phase short-circuit power to calculate power quality, $S_{k,\text{ power quality}}$ in the point of connection.

The grid enterprise and transmission company jointly make an assessment of whether an energy storage facility has a significant impact on the public electricity supply grid. If an energy storage facility has a significant impact on the public electricity supply grid, the facility owner must also:

- use frequency-dependent impedance polygons for the calculation of power quality
- verify that emission thresholds have also been met in the connection point with the transmission grid, and
- be able to provide an impedance model for the energy storage facility, cf. section 9 on documentation.

5.2.2.2 The electricity supply undertaking's obligations

The electricity supply undertaking is responsible for setting emission thresholds in the point of connection.

The electricity supply undertaking must state the short-circuit level $S_{k,\ power\ quality}$ and related impedance angle ψ_k in the point of connection.

5.2.3 Measuring method

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

Measurements 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 precisions specified for class I.

Measurements of interharmonic distortion up to 2 kHz must be carried out as defined in IEC 61000-4-7 Annex A and must be measured as interharmonic groups (interharmonic subgroup).

Alternatively, it is permitted to measure harmonic distortion up to 2 kHz with grouping activated (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 activated, measuring interharmonic distortion up to 2 kHz separately is not required.

Measurements of disturbances in the 2-9 kHz range must be carried out in accordance with IEC 61000-4-7 annexe B and must be measured in 200 Hz windows with centre frequencies from 2100 Hz to 8900 Hz.

5.3 Power quality, energy storage facilities connected to the transmission system

When connecting an energy storage facility to the transmission system, voltage quality aspects must be treated similarly to a transmission connection of a Power Park module, cf. Technical regulation 3.2.7 Requirements for voltage quality for generation facility connections to the transmission grid, which is available on Energinet's website www.energinet.dk.

6. Control

6.1 General requirements

The following requirements apply to category A, B, C and D energy storage facilities.

All control functions mentioned in the following chapters refer to the point of connection.

Currently activated functions and parameter settings are determined by the electricity supply undertaking within the framework laid down by Energinet Elsystemansvar A/S in this technical regulation.

In order to ensure security of supply, Energinet Elsystemansvar A/S must be able to activate or deactivate specified control functions by agreement with the facility owner.

The signs used in all figures below comply with the generator convention.

The table below specifies the minimum control functionality requirements for energy storage facilities in facility categories A, B, C and D.

Category / Control function	A	B	C	D
Frequency response, LFSM-O (6.2.2.1)	X	X	X	X
Frequency response, LFSM-U (Category C and D facilities6.2.2.3)	-	-	X	X
Frequency control (6.2.3) **	-	-	X	X
Absolute power constraint (6.2.4.1)	X	X	X	X
Ramp rate limit (6.2.4.2)	X	X	X	X
Q control (6.3.1)*	X	X	X	X
Power factor control (6.3.2)*	X	X	X	X
Automatic power factor control (6.3.2) *	X	X	-	-
Voltage control (6.3.3) **	-	-	X	X
System protection (6.4)***	-	-	(X)	(X)

Bracketed numbers indicate the sections that describe the respective functions.
*) A facility must not perform Q control, power factor control or automatic power factor control except by prior agreement with the electricity supply undertaking.
**) A facility must not perform frequency control or voltage control without prior specific agreement with the electricity supply undertaking and Energinet Elsystemansvar A/S.
***) System protection is not a minimum requirement for grid connection to the public electricity supply grid, but a requirement which can be imposed on the energy storage facility.

Table 15 Control functions for energy storage facilities.

The purpose of the various control functions is to ensure overall control and monitoring of the energy storage facility's operation.

The various control functions may be implemented in the individual unit, be combined in a single energy storage facility controller or a combination thereof, provided there is only one communication interface as shown in Figure 17.

This means that if any number of energy storage units are connected to the same POC, so that the rated power in the POC is the sum of the connected energy storage units, the connected units must thus function as one energy storage facility.

The sum of the rated power in the POC determines the facility category and thus the requirements for connection.

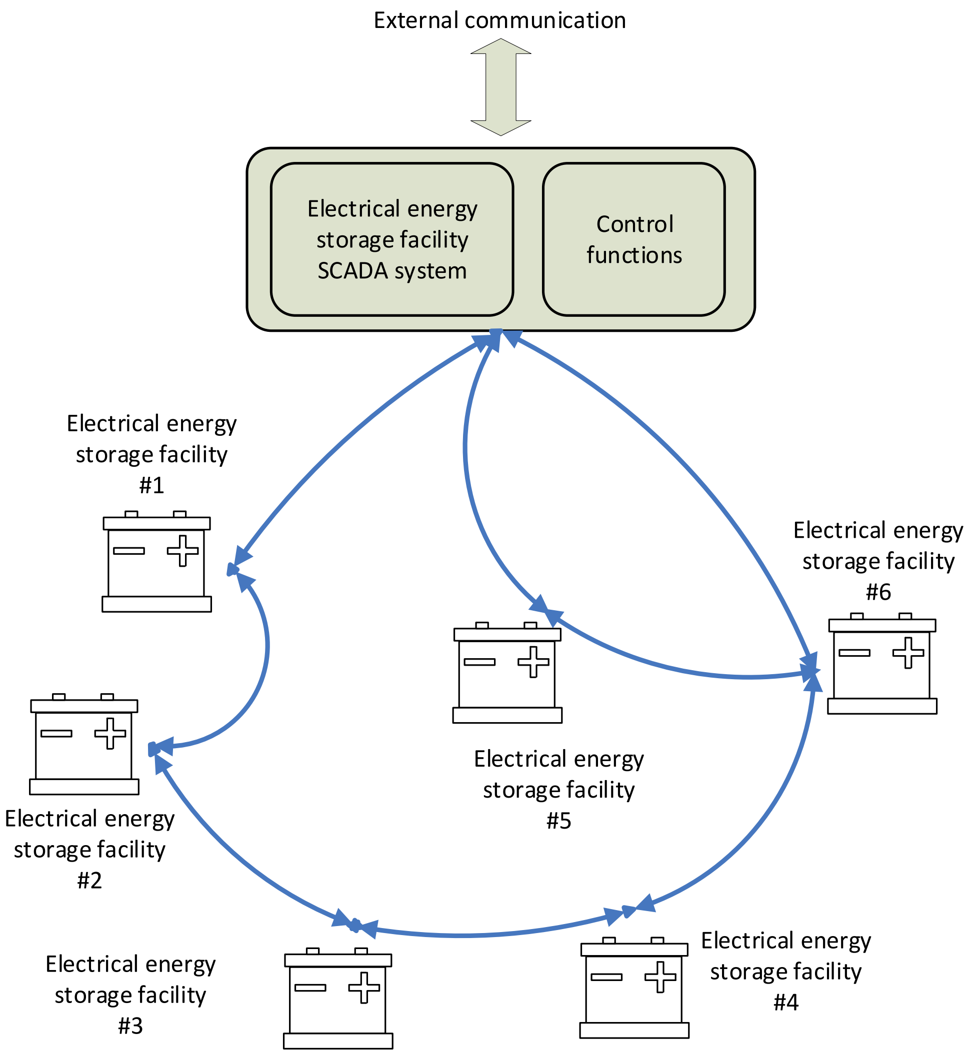


Figure 17 Drawing of a facility controller.

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

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

6.2 Active power and frequency control functions

The following requirements apply to category A, B, C and D energy storage facilities.

An energy storage facility must be equipped with control functions capable of controlling the active power delivered or absorbed in the point of connection.

It must be possible to specify set points for active power with a resolution of 1% of P_{no} or P_{nl} or higher.

Current parameter settings for activated active power control functions are determined by the electricity supply undertaking in collaboration with Energinet Elsystemansvar A/S before commissioning.

In addition to the general requirements in section 6.1, active power control functions must comply with the requirements outlined in the following sections.

6.2.1 Frequency response, LFSM-U and LFSM-O

In the event of frequency deviations in the public electricity supply grid, the energy storage facility must contribute to ensuring frequency stability by automatically increasing or reducing active power at grid frequencies below or above the reference frequencies f_1 and f_2. This is referred to as frequency response and is an autonomous function.

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

To facilitate detection of island operation in the distribution system, facilities connected in the distribution system cannot commence downward regulation of active power until 500 milliseconds have elapsed.

Frequency measurements must be carried out with 10 mHz accuracy or higher. Control function sensitivity must be 10 mHz or less (frequency response insensitivity). The setting for the frequency response function's corner frequencies and droop is determined by Energinet Elsystemansvar A/S.

6.2.1.1 LFSM-U and LFSM-O

It must be possible to set the frequency response function's frequency points (corner frequencies), indicated in Table 16 for DK1 and Table 17 for DK2, respectively, to any value in the 47.50-51.50 Hz range with a resolution of maximum 10 mHz.

It must be possible to set the droop for both downward and upward regulation to any value in the 2% to 12% of P_n range and to effect this with an inaccuracy of maximum ±10 % of P_n.

In this context, droop is the change in active power as a function of the grid frequency. Droop is stated as a percentage of P_{no} and P_{nl}, respectively, for the energy storage facility.

Droop for control between the various frequency points is shown in Figure 18 and Figure 19 for energy storage facilities which can only absorb power from the grid and energy storage facilities which can absorb power from and deliver power to the grid, respectively.

6.2.1.2 Power flow to energy storage facilities

$P_{current}$ is a fictitious point illustrating a set point between P_{nl} and P_{no}.

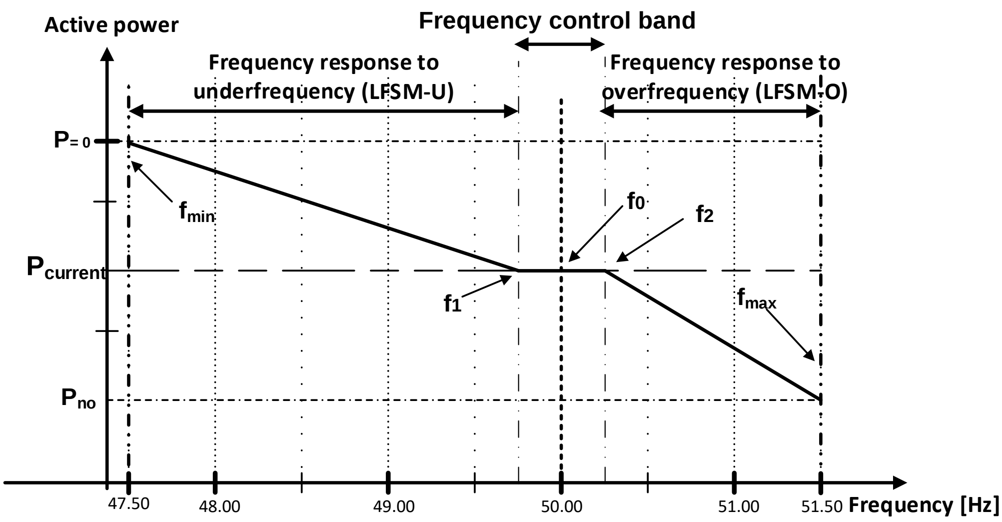


Figure 18 Frequency response for an energy storage facility which can only absorb power from the public electricity supply grid. The figure illustrates functions and responses, but values other than frequency-related values are fictitious.

If frequency increases to above f_2 (LFSM-O), the droop must be followed, i.e. power flow from the grid increases as frequency increases. If frequency is subsequently stabilised and decreases, the droop must still be followed until system frequency is once again below frequency f_2.

If frequency decreases to below f_1 (LFSM-U), the droop must be followed, i.e. power flow from the grid is reduced as frequency decreases. If frequency is subsequently stabilised and increases, the droop must still be followed until system frequency is once again above frequency f1.

6.2.1.3 Power flow to and from energy storage facilities

$P_{current}$ is a fictitious point illustrating a set point between P_{nl} and P_{no}.
P_{no} is the energy storage facility's rated power absorbed from the grid.
P_{nl} is the energy storage facility's rated power delivered to the grid.

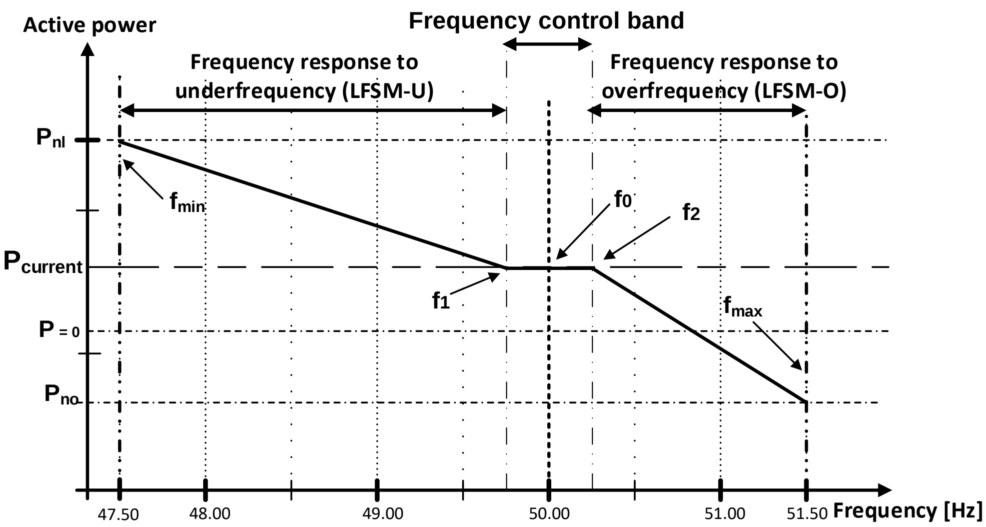


Figure 19 Frequency response from an energy storage facility which can deliver to and absorb power from the public electricity supply grid. The figure illustrates functions and responses, but values other than frequency-related values are fictitious.

If frequency increases to above f_2 (LFSM-O), the droop must be followed, i.e. absorption of active power increases as frequency increases. If frequency is subsequently stabilised and decreases, the droop must still be followed until system frequency is once again below frequency f_2.

If frequency decreases to below f_1 (LFSM-U), the droop must be followed, i.e. delivery of active power increases as frequency decreases. If frequency is subsequently stabilised and increases, the droop must still be followed until system frequency is once again above frequency f1.

6.2.2 Frequency settings and frequency response

Requirements for standard frequency settings are shown below in Table 16 and Table 17.

	f_{min}	f_{max}	f_0	f_1	f_2
Hz	47.50	51.50	50.00	49.80	50.20

Table 16 Standard frequency response settings for DK1.

	f_{min}	f_{max}	f_0	f_1	f_2
Hz	47.50	51.50	50.00	49.50	50.50

Table 17 Standard frequency response settings for DK2.

Requirements for droop settings (% of P_n) in DK1 and DK2, respectively, are specified in Table 18.

Synchronous area	Droop [%]
DK1	5
DK2	4

Table 18 Droop settings in DK1 and DK2, respectively.

6.2.2.1 LFSM-O, categories A, B, C and D

For category A, B, C and D energy storage facilities, an overfrequency frequency response is required, cf. Figure 18 or Figure 19 and with the frequency settings shown in Table 16 or Table 17 as well as Table 18.

6.2.2.2 LFSM-U, categories A and B

For categories A and B energy storage facilities, there are no requirements for underfrequency frequency response, LFSM-U.

6.2.2.3 Category C and D facilities

For category C and D energy storage facilities, the underfrequency frequency response functionality is required, LFSM-U, cf. Figure 18 or Figure 19 and with the frequency settings shown in Table 16 or Table 17 as well as Table 18.

6.2.3 Frequency control (FSM)

In case of frequency deviations in the public electricity supply grid, the energy storage facility must have control functions that can provide frequency control to stabilise grid frequency (50.00 Hz).

The purpose of the frequency control function is to control active power at grid frequencies between f_1 and f_2 as shown in Figure 20.

Frequency measurement must be carried out with a ± 10 mHz accuracy or higher, measured/calculated over 1 second.

The accuracy of a completed frequency control regulation, including set point accuracy, may not deviate by more than ±5% of the set point value or ±0.5% of rated power, depending which of these yields the most stringent tolerances. Regulation must be done without delay and take no more than one second.

It must be possible to set the frequency control function so that it is possible to set any frequency point in Figure 20 between the frequencies f_{min} and f_{max} (47.50-51.50 Hz range) with a maximum 10 mHz resolution.

Regulation droop for DK1 is shown in Figure 20.

In this context, droop is the change in active power as a function of the grid frequency. Droop is stated as a percentage of the energy storage facility's rated power.

Figure 20 illustrates the location of the various parameters and thresholds for the frequency control function in DK1.

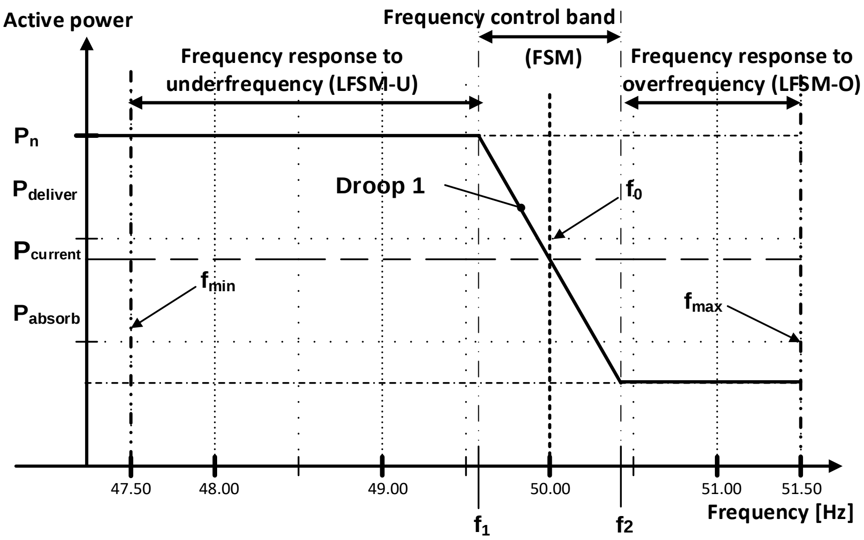


Figure 20 FSM band and frequency response for DK1. The figure illustrates functions and responses, but values other than frequency-related values are fictitious.

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

Standard frequency control settings – DK1 (FCR)					
	f_{min}	f_{max}	f_0	f_1	f_2
Hz	47.50	51.50	50.00	49.80	50.20

Table 19 Standard frequency control settings – DK1

Figure 21 illustrates the location of FCR-N regulation and thresholds for the frequency control function for DK2.

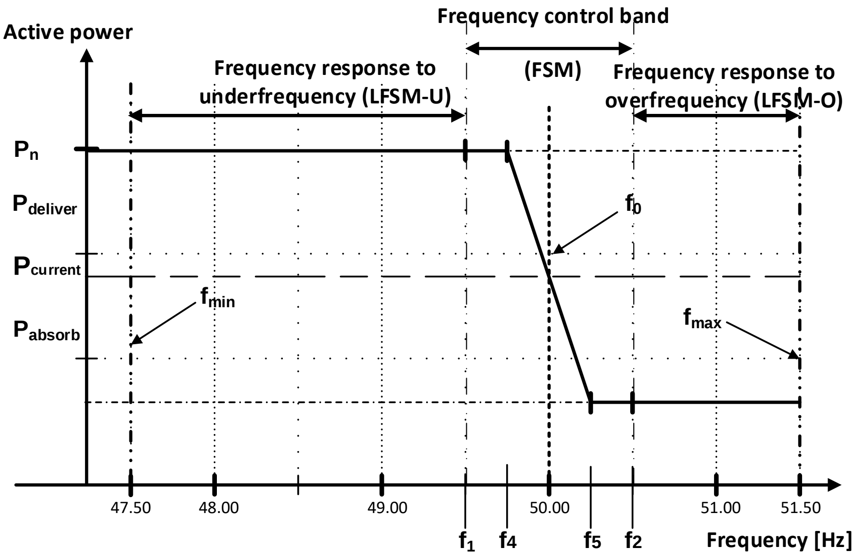


Figure 21 FSM band, FCR-N and frequency response for DK2. The figure illustrates functions and responses, but values other than frequency-related values are fictitious.

Standard frequency control settings – DK2 (FCR-N)					
	f_{min}	f_{max}	f_0	f_4	f_5
Hz	47.50	51.50	50.00	49.90	50.10

Table 20 Standard FCR-N frequency control settings for DK2

Figure 22 illustrates the location of FCR-D regulation and thresholds for the frequency control function for DK2.

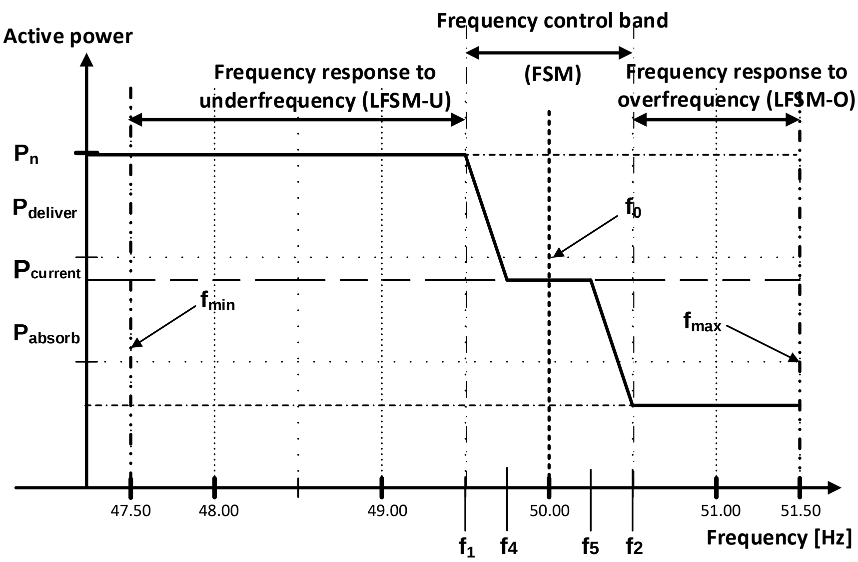


Figure 22 FSM band, FCR-D and frequency response for DK2. The figure illustrates functions and responses, but values other than frequency-related values are fictitious.

Standard frequency control settings – DK2 (FCR-D)							
	f_{min}	f_{max}	f_0	f_1	f_2	f_4	f_5
Hz	47.50	51.50	50.00	49.50	50.50	49.90	50.10

Table 21 Standard frequency control settings for DK2

6.2.3.1 FSM, categories A and B

There are no requirements for frequency control function for categories A and B energy storage facilities.

6.2.3.2 FSM, categories C and D

For category C and D energy storage facilities, frequency control function with functionality is required.

Activation of the functionality is not required to obtain grid connection.

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

6.2.4 Limiter functions – active power control

An energy storage facility must be equipped with control functions (limiter functions) to control active power to ensure stable operation based on a selected operating point.

Examples of the use of these control functions include load control based on a power schedule and secondary control based on centrally commanded control (FRR-a, FRR-m).

Control using a new parameter for the limiter functions must be commenced within 2 seconds and completed no later than 10 seconds after receipt of an order to change the parameter.

It must be possible to specify set points for active power with a resolution of minimum 1% of P_{nl} and P_{no} or higher.

Accuracy of the control performed and of the set point must not deviate by more than ±5% of the set point value or ±0.5% of rated power, depending which yields the highest tolerance.

Required limiter functions are specified in the following sections.

6.2.4.1 Absolute power constraint (part load)

An absolute power constraint is used to limit active power absorbed by or delivered to an energy storage facility to a set point-defined maximum power limit in the point of connection.

An absolute power constraint is typically used to protect the public electricity supply grid against overload in critical situations, or to restrict the maximum active power absorbed or delivered by the energy storage facility as a result of legislation.

6.2.4.1.1 Absolute power constraint, categories A, B, C and D

For category A1, A2, B, C and D energy storage facilities, the absolute power constraint limiter function is required.

The limiter function must, as a minimum, be set to ensure that the facility never exceeds its rated power.

6.2.4.2 Ramp rate constraint (load ramp rate – ramp function)

Ramp rate constraint is used to limit the maximum speed by which active power can be changed in the event of changes in power or in the set points of an energy storage facility.

6.2.4.2.1 Ramp rate constraint, categories A, B, C and D

For category A, B, C and D energy storage facilities, the ramp rate gradient limiter function is required.

The limiter function must be usable for both upward and downward regulation of active power and possible to set to any value within the following parameters.

Upward regulation: Min. 1% Pn/min.
Upward regulation: Max. 20% of Pn, however, not exceeding 60 MW/min.
Downward regulation: Min. 1% Pn/min.
Downward regulation: Max. 20% of Pn, however, not exceeding 60 MW/min.

Requirements for minimum and maximum gradients for active power changes apply, if other stipulations do not provide relevant gradients, including ancillary services, energy markets, etc.

6.3 Reactive power and voltage control functions

An energy storage facility must be equipped with reactive power and voltage control functions capable of controlling reactive power in the point of connection and controlling voltage in the voltage reference point, respectively, via activation orders containing set points for the specified parameters.

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

Before commissioning, relevant control functions and settings for these must be determined by the electricity supply undertaking.

In addition to fulfilling the general requirements stated in section 6.1, reactive power and voltage control functions must comply with the requirements outlined in the following sections.

The table below shows the minimum functionality requirements for reactive power control in the various facility categories.

Category / Control function	A	B	C	D
Q control (6.3.1)*	X	X	X	X
Power factor control (6.3.2)*	X	X	X	X
Voltage control (6.3.3) **	-	-	X	X
Automatic power factor control (6.3.4)	X	X	-	-

Bracketed numbers indicate the sections that describe the respective functions.
*) By default, a facility must be configured with Q control and a set point of 0 VAr. Any other methods of reactive power control must be agreed with the electricity supply undertaking.
* *) A facility is not allowed to carry out voltage control without a special agreement with the electricity supply undertaking and Energinet Elsystemansvar A/S.

Table 22 Reactive power control functions.

6.3.1 Q control

The Q control function controls reactive power independently of grid voltage and active power in the point of connection. This control function is shown as a horizontal line in Figure 23.

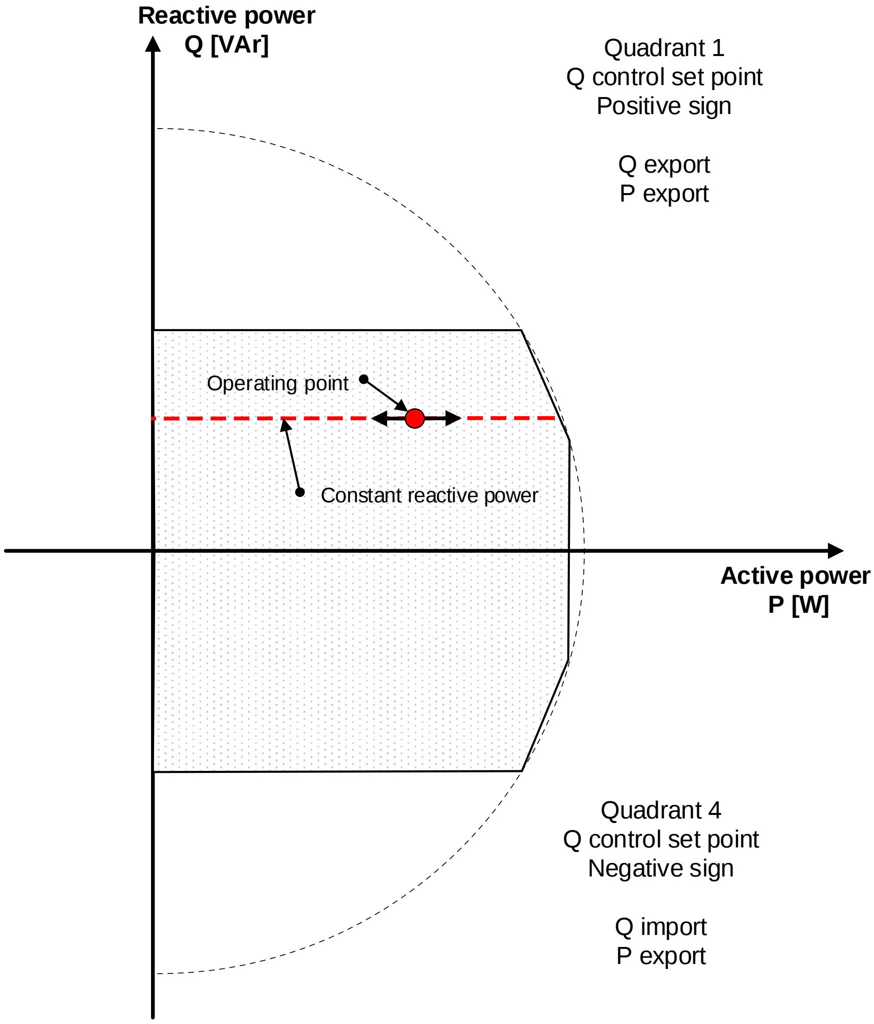


Figure 23 Reactive power control functions for an energy storage facility.

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

For the control function, the accuracy of a completed or continuous control operation, including the accuracy at the set point, must not deviate by more than 1% of Q_n over a period of 1 minute.

It must be possible to specify set points for reactive power with a resolution of minimum 1% of Q_{nl} and Q_{no} or higher.

6.3.1.1 Q control, categories A, B, C and D

Energy storage facilities in categories A, B, C and D must have the Q-control function.

6.3.2 Power factor control

The power factor control function controls reactive power proportionately (determined by the droop) to active power in the point of connection, which is illustrated by a line with a constant gradient in Figure 24.

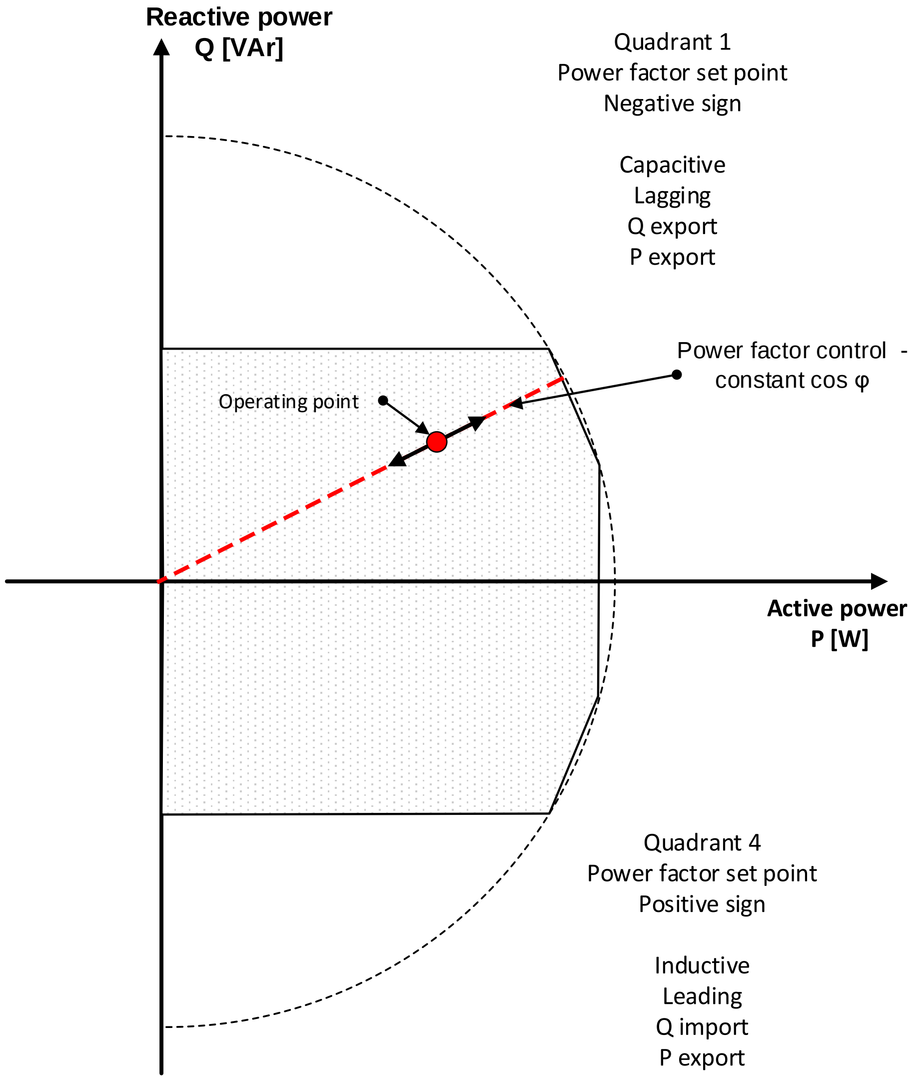


Figure 24 Power factor control (PF) for an energy storage facility.

The energy storage facility must be able to receive a power factor set point with a resolution of maximum 0.01.

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

For the control function, the accuracy of a completed or continuous control operation, including accuracy at the set point, must not deviate by more than 1% of the power factor set point over a period of 0.01 minute. The energy storage facility must be able to set a power factor set point with a resolution of 0.01.

6.3.2.1 Power factor control, categories A, B, C and D

Category A, B, C and D energy storage facilities must have the power factor control function.

6.3.3 Voltage control

A facility is not allowed to carry out voltage control without specific agreement with the electricity supply undertaking and Energinet Elsystemansvar A/S.

Automatic voltage control (AVR) is a control function that automatically controls voltage in the voltage reference point. The voltage control setting range must lie within the minimum to maximum voltage range stated in Table 3, with an accuracy of maximum 0.5% or higher of rated voltage.

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

For the control function, the accuracy of a completed control operation, including the accuracy at the set point, must not deviate by more than 0.5% of U_C over a period of 1 minute.

It must be possible to set the droop for voltage control to a value in the 2-12% range. The specific droop setting must be agreed between the facility owner and the electricity supply undertaking.

The standard setting value is 4%.

An illustration of the voltage control concept is shown in Figure 25.

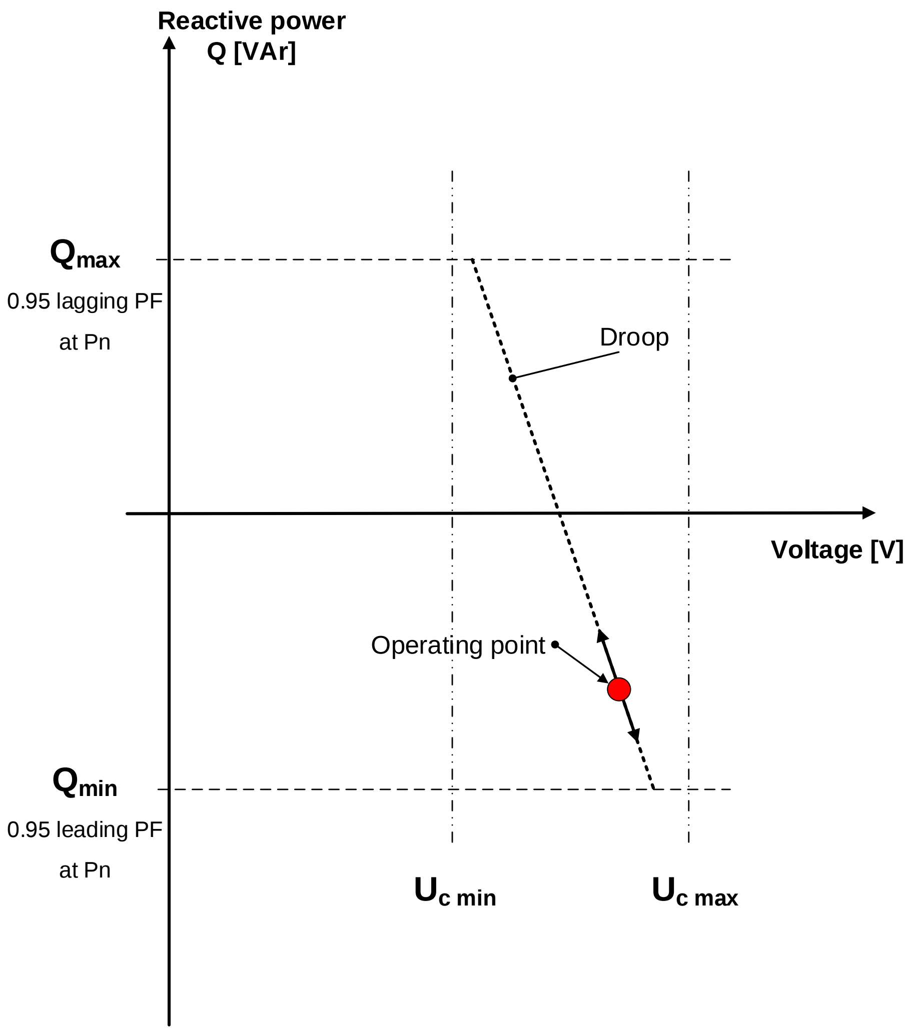


Figure 25 Voltage control for an energy storage facility.

6.3.3.1 Voltage control, categories A and B

For category A and B energy storage facilities, the voltage control function is not required.

6.3.3.2 Voltage control, categories C and D

Category C and D energy storage facilities must have the voltage control function.

6.3.4 Automatic power factor control

The automatic power factor control function automatically activates/deactivates power factor control at defined voltage levels in the voltage reference point. The principle of automatic power factor control is illustrated in Figure 26.

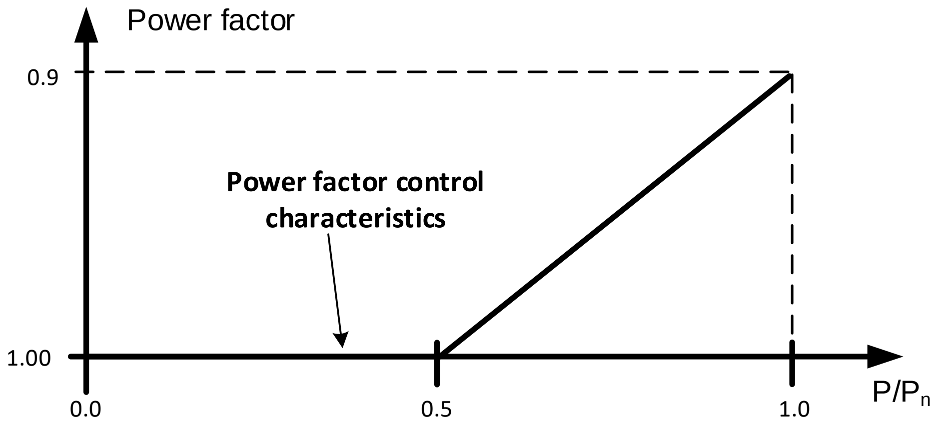


Figure 26 Automatic power factor control for an energy storage facility.

The default setting for automatic power factor control (PF) is given by the following three support points with linear interpolation between them:

1: P/P_n = 0.0, PF = 1.00
2: P/P_n = 0.5, PF = 1.00
3: P/P_n = 1.0, PF = 0.90

The activation level for the function is normally 105% of rated voltage, and the deactivation level is normally 100% of rated voltage. The activation/deactivation level must be adjustable via set points.

As a starting point, the function must be deactivated and must be activated only by agreement with the electricity supply undertaking.

6.3.4.1 Automatic power factor control, categories A and B

Category A and B energy storage facilities must have the automatic power factor control function.

6.3.4.2 Automatic power factor control, categories C and D

For category C and D energy storage facilities, the automatic power factor control function is not required.

6.3.5 Requirements for reactive power properties of the facility in relation to P_n

In addition to complying with the general requirements in section 6.1 and the requirements for normal operating conditions in section 4.4, an energy storage facility must, as a minimum, be equipped with the control functions specified in Table 22.

The energy storage facility must be designed so that the operating point can always be ordered to lie within the hatched functional area in the relevant figures for the different facility categories.

In addition to complying with the general requirements in section 6.1 and the requirements for normal operating conditions in section 4.3, an energy storage facility must, by default, follow a power factor of 1.00, unless otherwise agreed with the electricity supply undertaking.

6.3.5.1 Reactive power, categories A and B connected at low voltages

The energy storage facility must be designed so that its operating point can be ordered to lie within the defined functional area shown in Figure 27 at any time for facilities connected at low voltages. There are no precision and accuracy requirements when apparent power is less than 10% of rated power.

When the energy storage facility is disconnected or not delivering or absorbing active power, no compensation is required for reactive power from the facility infrastructure.

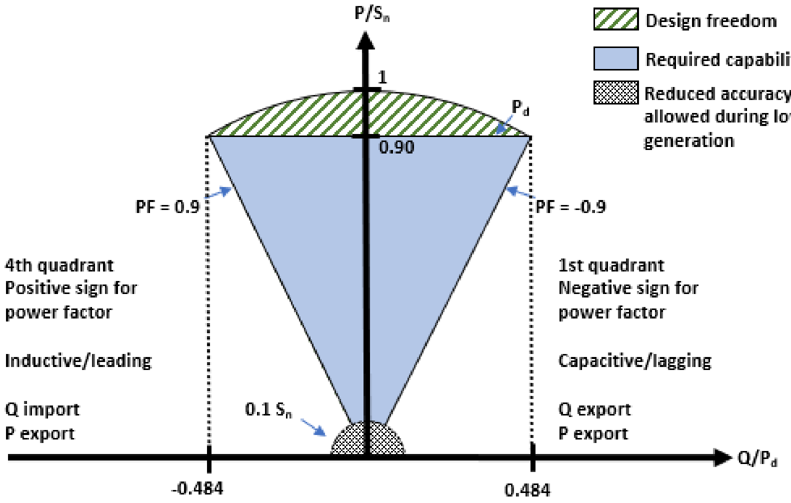


Figure 27 Requirements for delivery of reactive power at work points below P_{nl} for category A and B energy storage facilities connected at low voltages.

Reactive power must be deliverable in the voltage range shown in the below Figure 28 at rated active power (P_{nl}) for low-voltage connected category A and B energy storage facilities.

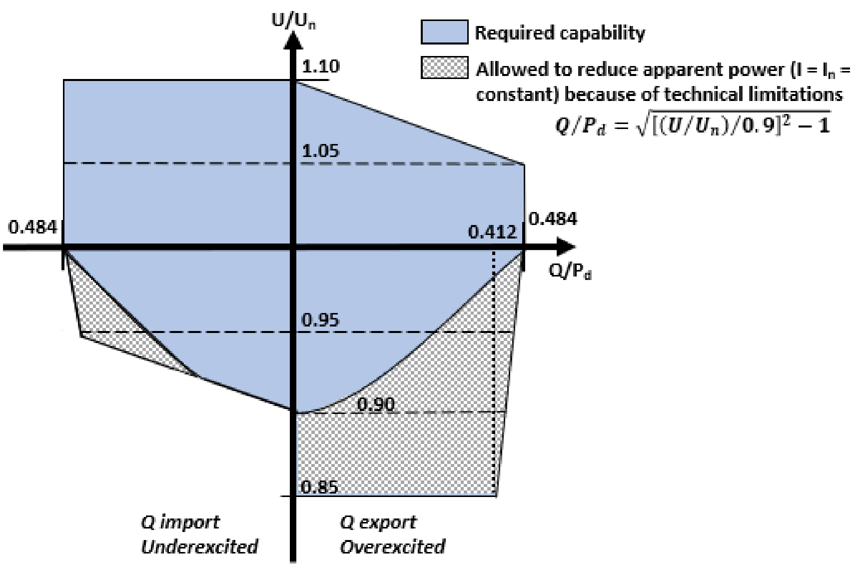


Figure 28 Requirements for delivery of reactive power at P_{nl} as a function of voltage in the POC for category A and B energy storage facilities connected at low voltages.

6.3.5.2 Reactive power, category B

The energy storage facility must be designed so that its operating point can be ordered to lie within the defined functional area shown in Figure 29 at any time. There are no precision and accuracy requirements when apparent power is less than 10% of rated power.

When the energy storage facility is disconnected or not delivering or absorbing active power, no compensation is required for reactive power from the facility infrastructure.

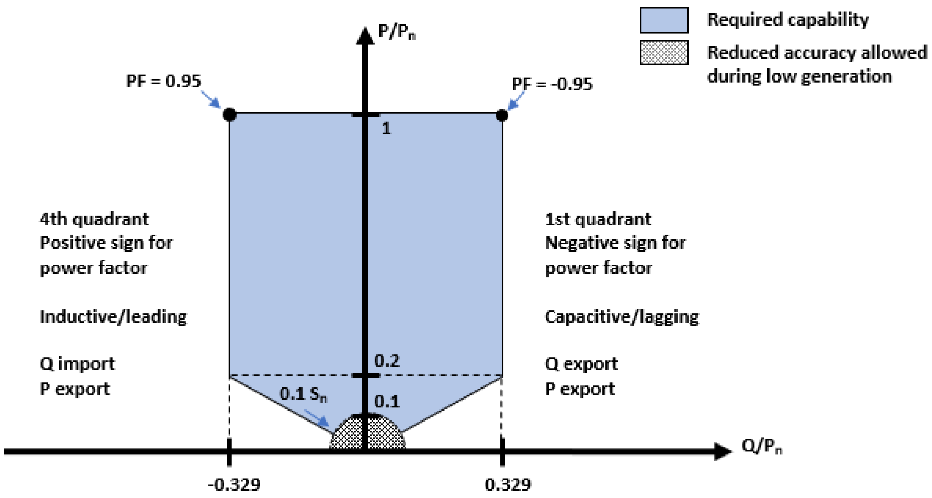


Figure 29 Requirements for delivery of reactive power at work points below P_{nl} for category B energy storage facilities connected at medium voltages.

Reactive power must be deliverable in the voltage range shown in Figure 30 at rated active power (P_{nl}) for category B energy storage facilities .

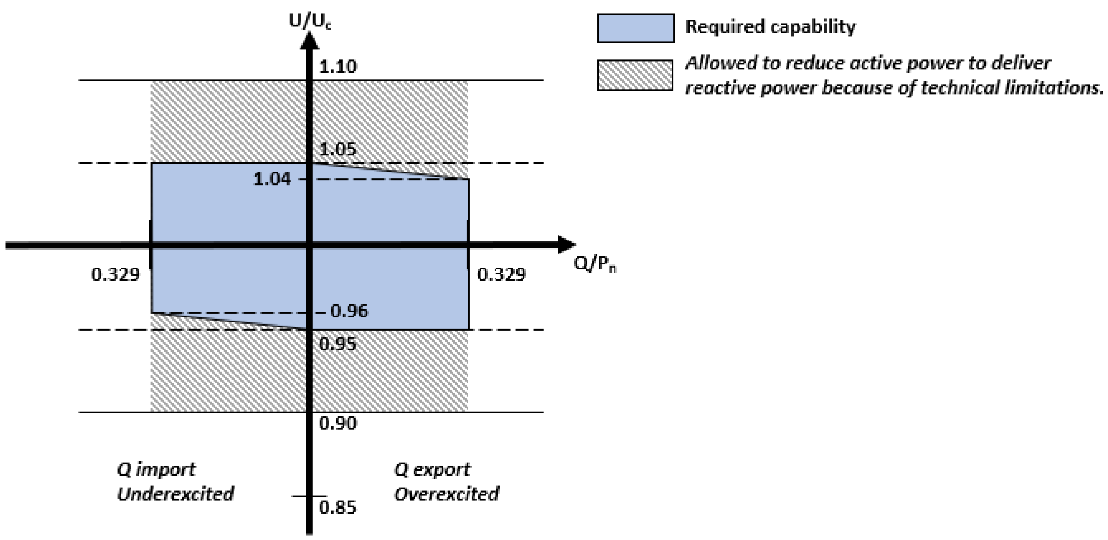


Figure 30 Requirements for delivery of reactive power at P_{nl} as a function of voltage in the POC for category B energy storage facilities.

6.3.5.3 Reactive power, category C

The energy storage facility must be designed so that its operating point can be ordered to lie within the defined functional area shown in Figure 31 at any time. There are no precision and accuracy requirements when apparent power is less than 10% of rated power.

Control form and settings must be agreed with the electricity supply undertaking.

The facility owner must compensate for the reactive power of the internal grid infrastructure in situations where the energy storage facility is disconnected or is not absorbing or delivering active power. Compensation may take place in the electricity system by agreement with the electricity supply undertaking.

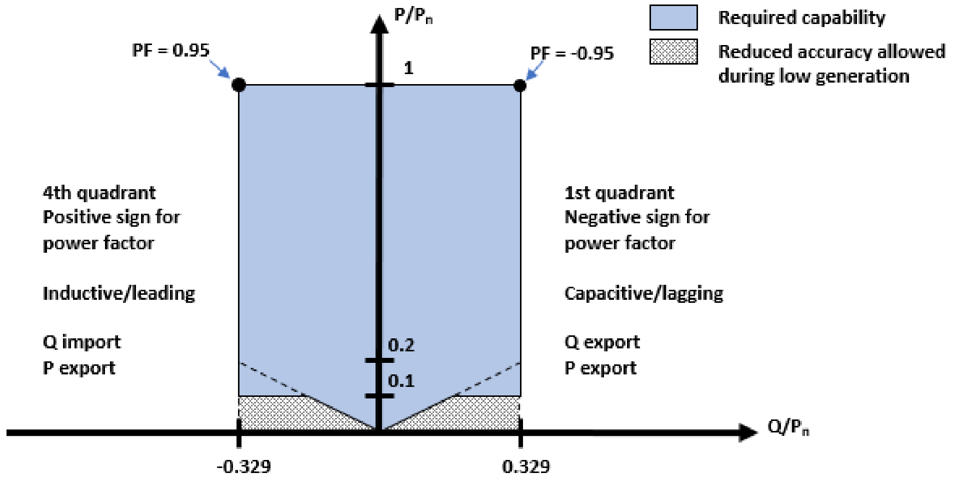


Figure 31 Requirements for delivery of reactive power at operating points below P_{nl} for category C energy storage facilities.

When the energy storage facility absorbs active power from the public electricity supply grid, the energy storage facility must follow a power factor of 1. At rated active power (P_{nl}), reactive power must be deliverable in the voltage range indicated in Figure 32.

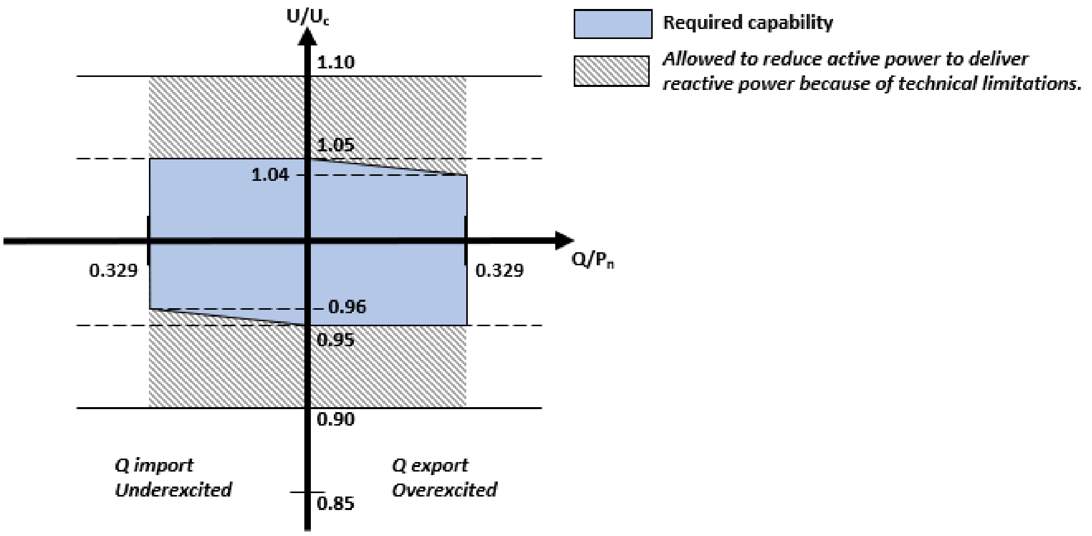


Figure 32 Requirements for delivery of reactive power at P_{nl} as a function of voltage in the POC for category C energy storage facilities.

6.3.5.4 Reactive power, category D

The energy storage facility must be designed so that its operating point can be ordered to lie within the defined functional area shown in Figure 33 at any time. There are no precision and accuracy requirements when apparent power is less than 10% of rated power.
Control form and settings must be agreed with the electricity supply undertaking.

The facility owner must compensate for the reactive power of the internal grid infrastructure in situations where the energy storage facility is disconnected or is not absorbing or delivering active power. Compensation may take place in the electricity system by agreement with the electricity supply undertaking.

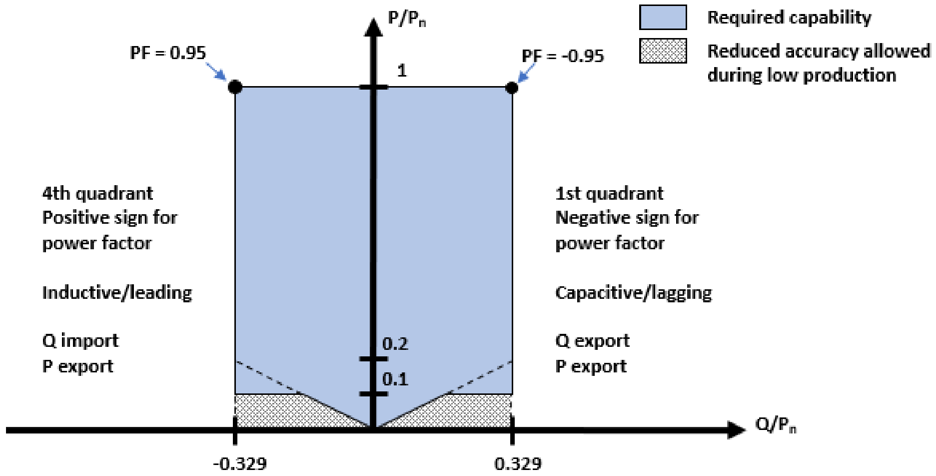


Figure 33 Requirements for delivery of reactive power at operating points below P_{nl} for category D energy storage facilities .

When the energy storage facility absorbs active power from the public electricity supply grid, the energy storage facility must follow a power factor of 1. At rated active power (P_{nl}), reactive power must be deliverable in the voltage range indicated in Figure 34.

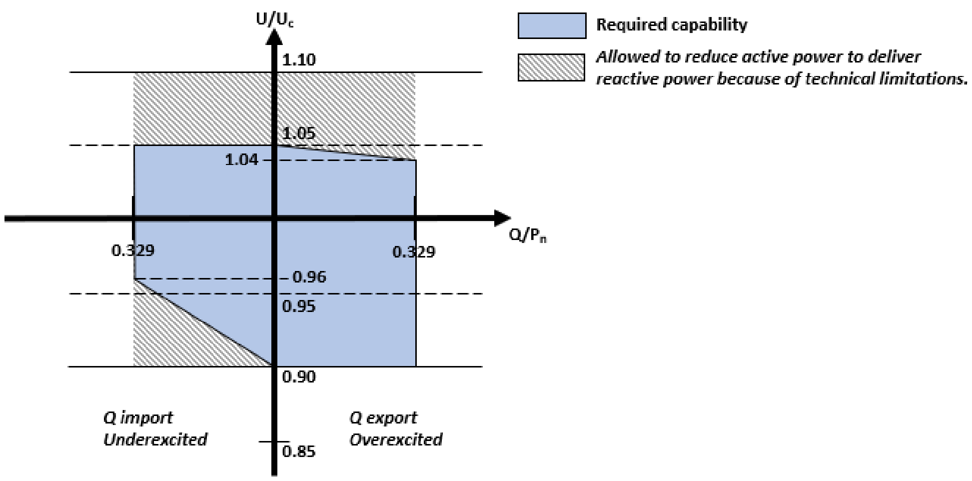


Figure 34 Requirements for delivery of reactive power at P_{nl} as a function of voltage in the POC for category C energy storage facilities.

6.3.5.5 Reactive power, category D*

The energy storage facility must be designed so that its operating point can be ordered to lie within the hatched area shown in Figure 35 at any time.

Control form and settings must be agreed with the electricity supply undertaking.

The facility owner must compensate for the reactive power of the internal grid infrastructure in situations where the energy storage facility is disconnected or is not absorbing or delivering active power. Compensation may take place in the electricity system by agreement with the electricity supply undertaking.

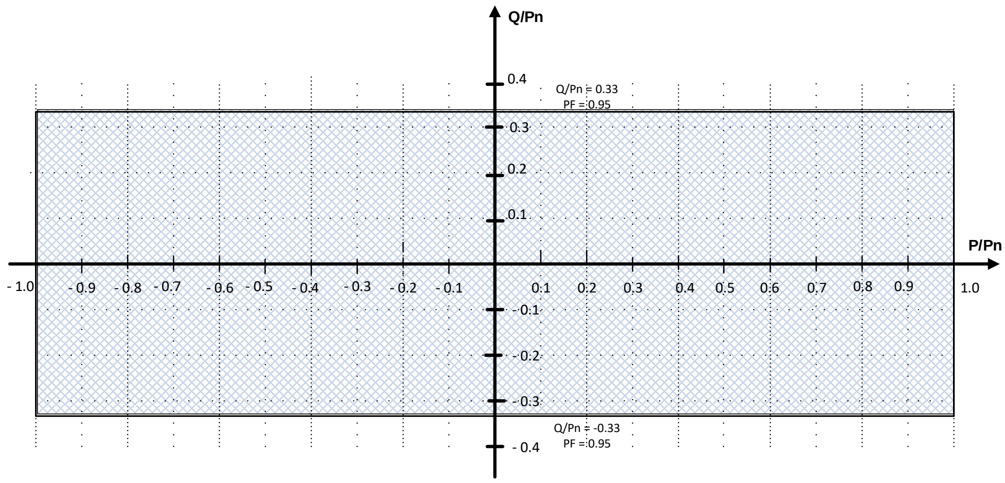


Figure 35 Requirements for delivery of reactive power at operating points below P_{nl} and P_{no} for category D energy storage facilities connected in the transmission system.

At rated active power, reactive power must be deliverable in the voltage range indicated in Figure 36.

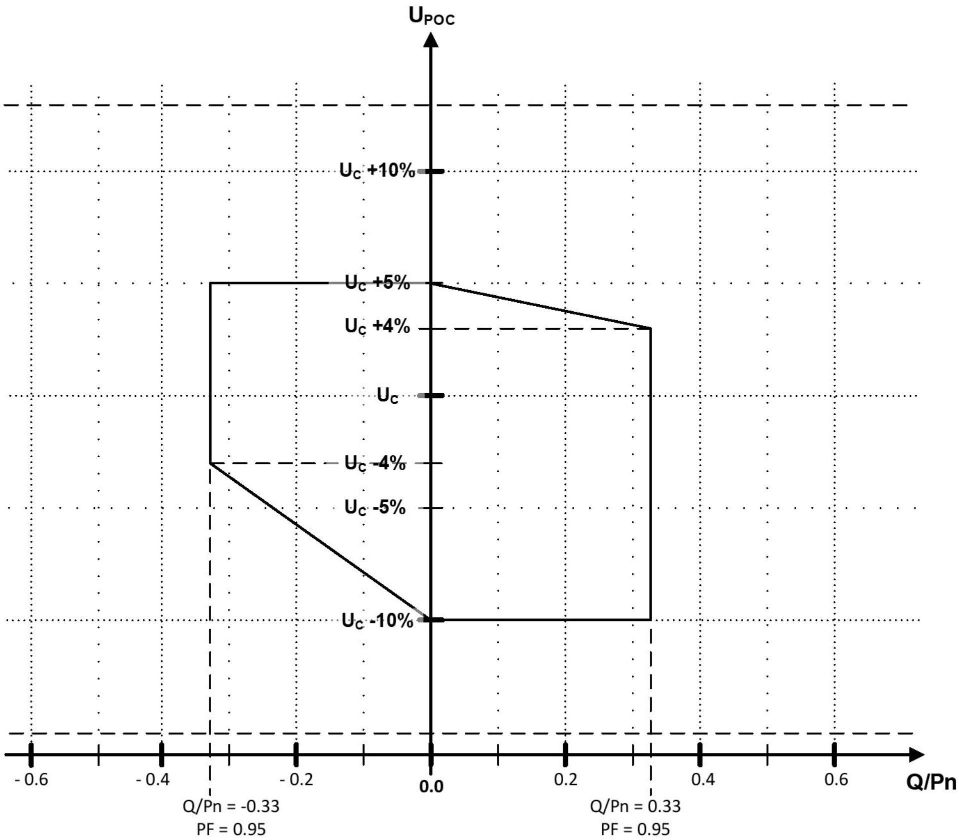


Figure 36 Requirements for delivery of reactive power at P_{nl} and P_{no} as a function of voltage in the POC for category D energy storage facilities connected in the transmission system.

6.4 System protection

System protection is not a minimum requirement for grid connection to the public electricity supply grid, but a requirement that may be imposed on a facility by Energinet Elsystemansvar A/S, depending on the location of the point of connection in the public electricity supply grid and/or the size of an energy storage facility.

System protection is an auxiliary function for maintaining system security and security of supply and is therefore not a normal operation control function.

System protection is a facility functionality, which, based on an order received from Energinet Elsystemansvar A/S or an autonomous signal from one or more relays installed in the public electricity supply grid, must be able to very quickly adjust an energy storage facility's active power to one or more predefined set points. Active power is both $P_{deliver}$ and P_{absorb}.

6.4.1 System protection, categories A and B

There are no system protection requirements for category A and B energy storage facilities.

6.4.2 System protection, categories C and D

Category C and D energy storage facilities must be equipped with system protection which can adjust active power delivered from the energy storage facility to one or more predefined set points. These set points are determined by the electricity supply undertaking upon commissioning.

The energy storage facility must have minimum five different configurable control range options. The following control ranges are recommended as default values:

1. Up to 70% of rated power
2. Up to 50% of rated power
3. Up to 40% of rated power
4. Up to 10% of rated power
5. Up to 0% of rated power, which means that the energy storage facility has been stopped, but not disconnected from the grid.

For this control function, the accuracy of a completed or continuous control operation, including the accuracy at the set point, must not deviate by more than 1% of the power factor set point over a period of 1 minute.

6.5 Order of priority for control functions and protection

The following requirements apply to energy storage facilities in categories A, B, C and D as well as T.

The individual control and protective functions for an energy storage facility must be ranked in order of priority. Section 6.5 does not specify requirements relating to the function or protection, but only to the mutual prioritisation.

All functions are not necessarily represented in all facility categories. The priority 1 function takes precedence over priority 2, etc.

The order of priority is as follows:

1. Protective functions, see section 7
2. Frequency response, see section 6.2.1
3. Frequency control, see section 6.2.3
4. Limiter functions, see section 6.2.4.

7. Protection

7.1 Introduction

The purpose of an energy storage facility's protective functions is to protect the energy storage facility and to ensure a stable public electricity supply grid.

The facility owner is responsible for ensuring that the energy storage facility is dimensioned and equipped with the necessary protective functions so that the energy storage facility:

- is protected against damage due to faults and incidents in the public electricity supply grid
- is protected against disconnections in non-critical situations for the energy storage facility
- protects the public electricity supply grid to the widest possible extent against unwanted impacts from the energy storage facility.

The electricity supply undertaking or Energinet Elsystemansvar A/S may demand that the settings for protective functions be changed following commissioning if this is found to be of importance to the operation of the public electricity supply grid.

However, such change must not result in the energy storage facility being exposed to impacts from the public electricity supply grid outside of the design requirements specified in section 3.

After an energy storage facility has been disconnected due to a fault in the public electricity supply grid, the energy storage facility must be automatically reconnected no earlier than three minutes after voltage and frequency are once again within the normal operating ranges stated in section 4.3.

An energy storage facility which has been disconnected by an external signal prior to a fault occurring in the public electricity supply grid must not be reconnected until the external signal is no longer active, and voltage and frequency are once again within the normal operating ranges stated in section 4.3.

At the facility owner's request, the electricity supply undertaking must state the highest and lowest short-circuit currents that can be expected in the point of connection as well as any other information about the public electricity supply grid necessary to set the energy storage facility's protective functions.

In addition to relay protection, protection must be established specifically aimed at internal faults in the energy storage facility or installation, including short-circuits, etc. Such protection must not trip the energy storage facility in case of short-circuits or grid rerouting.

In case of internal faults in the energy storage facility, protection must be selective with the grid protection, meaning that, for example, short circuits in the energy storage facility must be cut out within 100 milliseconds.

7.2 Protective setting requirements

The energy storage facility's protective functions and associated settings must match the requirements specified in the following subsections. Settings deviating from the required settings in the event of, for example, problems with local overvoltage may only be used with the electricity supply undertaking's permission.

All settings are stated as root-mean-square (RMS) values. The energy storage facility must be disconnected if a measuring signal deviates more from its nominal value than the setting.

The trip time stated is the measuring period during which the trip condition must constantly be met before the protective function can release a trip signal.

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

It is assumed that the rated voltage of the energy storage facility is determined on the low-voltage side of the facility transformer. For three-winding transformers, this is the rated voltage of the low-voltage winding to which the energy storage facility is connected.

If voltage is measured on the high-voltage side, the setting value must be determined by converting rated voltage on the low-voltage side to the high-voltage side of the facility transformer.

Voltage and frequency must be measured for all three phases as line-to-line voltage in multi-phase facilities. Alternatively, if the measuring point is located on the low-voltage side of the facility transformer, voltage can be measured between the three phases and ground. Frequency must be measured simultaneously on all three phases.

For single-phase connections, voltage is measured between phase and zero. Frequency is measured on the phase used.

7.2.1 Protective functions, category A

Protective functions with associated operating settings and trip time must match the values in the table below.

Protective function	Symbol	Setting		Trip time		Recom-mended value
Overvoltage (step 2)	$U_{>>}$	$1.15 \cdot U_n$	V	200	ms	200 ms
Overvoltage (step 1)	$U_{>}$	$1.10 \cdot U_n$	V	60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.85 \cdot U_n$	V	10 - 60	s	50 s
Undervoltage (step 2) *	$U_{<<}$	$0.80 \cdot U_n$	V	50 - 1500	ms	200 ms
Overfrequency	$f_{>}$	51.5	Hz	200	ms	200 ms
Underfrequency	$f_{<}$	47.5	Hz	200	ms	200 ms
Frequency change*	df/dt	±2.5	Hz/s	80	ms	80 ms

*) One of the specified functions must be implemented.

Table 23 Requirements for category A energy storage facilities.

7.2.2 Protective functions, category B

Protective functions with associated operating settings and trip time must match the values in the table below.

Protective function	Symbol	Setting		Trip time		Recom-mended value
Overvoltage (step 2)	$U_{>>}$	$1.15 \cdot U_n$	V	200	ms	200 ms
Overvoltage (step 1)	$U_{>}$	$1.10 \cdot U_n$	V	60	s	60 s
Undervoltage (step 1) *)	$U_{<}$	$0.90 \cdot U_n$	V	10 - 60	s	60 s
Overfrequency	$f_{>}$	51.5	Hz	200	ms	200 ms
Underfrequency	$f_{<}$	47.5	Hz	200	ms	200 ms
Frequency change	df/dt	±2.5	Hz/s	80	ms	80 ms

*) The value is 0.85 for low-voltage connections

Table 24 Requirements for category B energy storage facilities.

7.2.3 Protective functions, category C and D

Protective functions with associated operating settings and trip time must match the values in the table below.

Protective function	Symbol	Setting		Trip time		Recom-mended value
Overvoltage (step 3)	$U_{>>>}$	$1.20 \cdot U_n$	V	100	ms	100 ms
Overvoltage (step 2)	$U_{>>}$	$1.15 \cdot U_n$	V	100...200	ms	200 ms
Overvoltage (step 1)	$U_{>}$	$1.10 \cdot U_n$	V	60	s	60 s
Undervoltage (step 1)	$U_{<}$	$0.90 \cdot U_n$	V	10 - 60	s	60 s
Overfrequency	$f_{>}$	51.5	Hz	200	ms	200 ms
Underfrequency	$f_{<}$	47.5	Hz	200	ms	200 ms
Frequency change	df/dt	±2.5	Hz/s	200	ms	80 ms

Table 25 Requirements for category C and D energy storage facilities.

It must be ensured that the energy storage facility fulfils the requirements specified in section 7, and that protection does not prevent the energy storage facility from complying with the additional requirements in this regulation.

The set relay settings that are important to the operation of the public electricity supply grid must be approved by Energinet Elsystemansvar A/S and the electricity supply undertaking in whose grid the energy storage facility is connected.

7.2.4 Protective functions, transmission system connections

For category D energy storage facilities connected to the transmission system, the facility owner is responsible for ensuring that stability and selectivity studies are carried out with the aim of determining the facility unit's protective functions.

The purpose of these studies is to ensure that the energy storage facility fulfils the requirements specified in section 7, and that protection does not prevent the energy storage facility from complying with the additional requirements of this regulation.

The set relay settings that are important to the operation of the public electricity supply grid must be approved by Energinet Elsystemansvar A/S and the electricity supply undertaking in whose grid the energy storage facility is connected.

8. Exchange of signals and data communication

In the interests of operation of the public electricity supply grid, the energy storage facility's communication interface must be prepared for signal exchanges between the facility operator and the electricity supply undertaking in line with this regulation.

In connection with the harmonisation of facility categories A-D, category B has been divided into B1 and B2, respectively. This division of category B only applies to setting the extent of the exchange of signals and data communication.

8.1 Measurement requirements

Specific requirements for installed measuring equipment and measuring accuracy that must be in place for an energy storage facility to be connected to the public electricity supply grid are specified in the following regulations:

1. Regulation D1 'Settlement metering' [10]
2. Regulation D2 'Technical requirements for electricity metering' [11]
3. National implementing measure, information exchange: Requirement document no. 1 - generation and demand (awaiting approval by the Danish Utility Regulator) [7].

Compliance with the above regulations must be verified by the meter operator as part of the checks and tests that form the basis for a final approval of the grid connection.

The latest version of the applicable regulations can be found on Energinet's website, www.energinet.dk.

8.2 Data communication

For an energy storage facility, information exchange must, as a minimum, be implemented using a protocol stack as specified in the IEC 61850 series [3]. The protocol stack must be configured so that the energy storage facility, as a minimum, can communicate with two master units (masters) in a master/slave configuration.

Data communication with the energy storage facility must be available to the electricity supply undertaking in the energy storage facility's communication interface referred to as PCOM, as illustrated in Figure 3 or Figure 4.

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

Activation of individual functions in energy storage facilities and configuration of the specific parameters must comply with the requirements stated in the National implementing measure, information exchange: Requirement document no. 1 - generation and demand (awaiting approval by the Danish Utility Regulator) [7].

Specific requirements for the extent of information and signals are stated in Table 26 for each energy storage facility category.

A	B1	B2	C	D	Generic signal designation
x	x	x			Stop signal
x	x	x			Hold signal
		x	x	x	Grid connection switch / switch gear status in the facility's point of connection
		(x)	x	x	Energy storage circuit breaker/switch gear status in the energy storage facility's point of connection (The electricity supply undertaking decides whether they want this signal for B2 facilities)
		x	x	x	Active power kW – measured in the point of connection
			x	x	Scheduled active power (shows current set point)
				x	Possible active power control properties
				x	Possible reactive power control properties
		x	x	x	Active power control - absolute constraint
		x	x	x	Active power control – requisite maximum active power
		x	x	x	Active power control - current measured in point of connection
		x	x	x	Reactive power control - MVAr measured in point of connection
		x	x	x	Reactive power control – activated/deactivated
		x	x	x	Reactive power control - requisite MVAr in point of connection
		x	x	x	Power factor control - cos (phi) measured in point of connection
		x	x	x	Power factor control - activated/deactivated
		x	x	x	Power factor control - requisite cos (phi) in point of connection
			x	x	Voltage measured in point of connection
			x	x	Voltage control – activated/deactivated
			x	x	Droop for voltage control
			x	x	Requisite voltage in voltage reference point
			x	x	System protection
			x	x	System protection

Table 26 Requirements for information exchange with an energy storage facility.

8.2.1 Information exchange, category A and B1

Online communication is not required for category A and B1 energy storage facilities.

Category A and B1 energy storage facilities must have the capability to receive external signals for 'Stop' of generation and 'Released for start'.

The energy storage facility may restart generation when stipulations for normal operating conditions specified in section 4.3 have been met, and the 'Released for start' signal has been received.

Signal exchange must be accessible via a terminal strip or in the PCOM-interface and must, as a minimum, include signals for categories A and B1, see Table 26.

8.2.2 Information exchange, categories B2, C and D

Online communication is required for category B2, C and D energy storage facilities.

It must be possible to obtain correct measurements and maintain data communication in all situations, including when the facility is shut down and the grid is dead. Local back-up supply must as a minimum ensure logging of relevant measurements and data and ensure controlled shutdown of the facility's control and monitoring system. Logging in connection with a shutdown must be performed per minute.

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

Signal exchange must be accessible in the PCOM interface and must, as a minimum, include signals for categories C and D, see Table 26.

8.3 Fault incident recording

Requirements for recording fault incidents in the public electricity supply grid are specified below.

Recording must be performed using electronic equipment that can be configured, as a minimum, to log relevant incidents for the signals below in the point of connection in case of faults in the public electricity supply grid.

In the point of connection, the facility owner must install logging equipment capable of recording at least:

- Voltage for each phase of the energy storage facility
- Current for each phase of the energy storage facility
- Active power of the energy storage facility (can be computed values)
- Reactive power of the energy storage facility (can be computed values)
- Frequency of the energy storage facility (can be computed values).

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

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

The specific settings for incident-based logging must be agreed with Energinet Elsystemansvar A/S upon commissioning of the energy storage facility.

All measurements and data (metered data) to be collected in accordance with National implementing measure, information exchange: Requirement document no. 1 - generation and demand (awaiting approval of the Danish Utility Regulator) must be logged with time stamps and an accuracy that ensures that that these can be correlated with each other and with similar recordings in the public electricity supply grid. Time stamping of incidents and data must refer to UTC with a 10 millisecond accuracy or higher.

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

Upon request, the electricity supply undertaking must be granted access to logged and relevant recorded information in COMTRADE format.

8.3.1 Fault incident recording, categories A, B and C

There are no requirements for recording fault incidents in the public electricity supply grid for category A, B and C energy storage facilities.

8.3.2 Fault incident recording, category D

Requirements for recording fault incidents in the public electricity supply grid apply to category D energy storage facilities.

8.4 Requesting metered data and documentation

Requirements apply to category D energy storage facilities.

The electricity supply undertaking and Energinet Elsystemansvar A/S must be able to request relevant information about an energy storage facility at any time.

Energinet Elsystemansvar A/S can request metered data and fault recorder data collected for the energy storage facility for a period of up to three months back in time.

Such requests must be based on metered data and/or calculations specified by the electricity supply undertaking or Energinet Elsystemansvar A/S.

9. Verification and documentation

The facility owner is responsible for ensuring that the energy storage facility complies with this technical regulation and that it can be documented that requirements are complied with.

The electricity supply undertaking and Energinet Elsystemansvar A/S are entitled to request, at any time, verification and documentation that an energy storage facility complies with the provisions of this regulation.

The energy storage facility documentation to be provided is specified in the following sections, stated per facility category based on total rated power in the point of connection.

Product certificates issued by an approved certification body may be used. The electricity supply undertaking assesses and approves the applicability of individual certificates.

A documentation package must be submitted to the electricity supply undertaking.

9.1 Standard procedure

The standard procedure regarding grid connection, approval and issue of a final operating permit for an energy storage facility is described below:

9.1.1 Procedure, categories A, B and T

1. The electricity supply undertaking assigns the facility owner a POC.
2. Documentation is submitted electronically to the electricity supply undertaking.
3. The electricity supply undertaking reviews the submitted documentation, determines whether any facility functionality or documentation is missing and approves the documentation.
4. When the documentation as well as connection and facility have been approved, the final operating permit can be issued.

9.1.2 Procedure, categories C and D

1. The electricity supply undertaking assigns the facility owner a POC. The electricity supply undertaking informs the transmission system operator about the expected grid connection when it assigns the POC.
2. Documentation is submitted electronically to the electricity supply undertaking.
3. The electricity supply undertaking reviews the documentation and determines whether any facility functionality or documentation is missing.
4. Establishment and tests now follow these steps:
    a. Energisation operational notification
    b. Interim operational notification
    c. Final operational notification
5. When the documentation as well as connection and facility have been approved, the final operating permit can be issued.

9.1.3 Simulation model, category C

The documentation form is filled in with preliminary data for the energy storage facility and sent to the electricity supply undertaking no later than:

- three months before the time of the energisation operational notification at rated output ≥ 10 MW.

As regards submission of the simulation model:

- facilities with rated power < 10 MW are exempted.

From the design phase to the verification phase, the facility owner must inform the electricity supply undertaking if preliminary facility data is no longer representative of the final commissioned energy storage facility.

No later than three months after issue of the final operational notification, documentation must be filled in, stating specific data for the entire energy storage facility, and sent to the electricity supply undertaking.

9.1.4 Procedure, category D

The documentation form is filled in with preliminary data for the energy storage facility and sent to the electricity supply undertaking no later than six months before issue of the energisation operational notification.

From the design phase to the verification phase, the facility owner must regularly inform the electricity supply undertaking if preliminary facility data is no longer representative of the final commissioned energy storage facility.

No later than three months after issue of the final operational notification, documentation must be filled in, stating specific data for the entire energy storage facility, and sent to the electricity supply undertaking.

9.1.5 Procedure, category D *, connected to the transmission system

The documentation form is filled in with preliminary data for the energy storage facility and sent to Energinet Elsystemansvar A/S no later than six months before issue of the energisation operational notification.

From the design phase to the verification phase, the facility owner must regularly inform Energinet Elsystemansvar A/S if preliminary facility data is no longer representative of the final commissioned energy storage facility.

No later than three months after issue of the final operational notification, documentation must be filled in, stating specific data for the entire energy storage facility, and sent to Energinet Elsystemansvar A/S.

9.2 Documentation requirements

Required documentation to be submitted for the different facility categories is stated in Table 27.

Category / Documentation	A	A*	B	C	D	SX	T
Supplier statement	X		X	X	X		
Protective functions	X	X	X	X	X		
Single-line representation	X	X	X	X	X		
Power quality	X		X	X	X		X
Voltage dip tolerance			X	X	X		
PQ diagram				X	X		
Signal list				X	X		
Dynamic simulation model				X	X		
Verification report				X	X		
Storage medium of the energy storage facility	X	X	X	X	X	X	
CE declaration of conformity	X		X	X	X	X	X
Relevant part of appendix 1	X	X	X	X	X	X	X

X: Documentation must be provided as described in this section.
*: Category A facilities included on the positive list.

Table 27 Documentation requirements for facility categories.

9.2.1 Supplier statement

By signing a supplier statement, the supplier guarantees that the specific facility complies with all requirements specified in Technical regulation 3.3.1.

9.2.2 Protective functions

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

9.2.3 Single-line representation

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

9.2.4 Power quality

Power quality is a collection of parameters that characterise the quality of power delivered. The verification report must document how requirements in section 5 have been met.

9.2.5 Voltage dip tolerance

Voltage dip is the energy storage facility's ability to stay connected to the electricity system during a voltage dip. The energy storage facility's ability to stay connected to the electricity grid must be documented in the electrical simulation model submitted. Alternatively, data from type tests is supplied, demonstrating that requirements have been met. Model simulations must show that requirements in section 4.4.4 have been met.

9.2.6 PQ diagram

A PQ diagram is a figure illustrating the energy storage facility's properties and ability to deliver reactive power as a function of the energy storage facility's ability to deliver active power.

Measurements must show that requirements in section 6.3 have been met. Alternatively, data from type tests is supplied, demonstrating that requirements have been met.

9.2.7 Signal list

The signal list is a list of the signals/information that must be exchanged between the parties that control and monitor a facility. Documentation proving that signals specified in section 8.2 are present in the PCOM interface must form part of the verification report.

9.2.8 Dynamic simulation model

A dynamic simulation model is a model of an energy storage facility's electrical properties and limitations. The electrical simulation model must comply with requirements specified in section 0.

9.2.9 Verification report

A verification report is a report on completed tests, demonstrating that the required functions have been implemented and work as intended with the configured parameters.

9.2.10 Storage medium of the energy storage facility

The energy storage facility's storage medium refers to information about the manufacturer of the storage medium and selected electrical properties.

9.2.11 CE declaration of conformity

A declaration of conformity is the manufacturer's or importer's statement that a product can be legally marketed in Europe. The statement of conformity includes, among other things:

- Manufacturer's name and address
- Unique reference to product
- Specification of the directive the declaration relates to
- Date and signature

9.2.12 Category A energy storage facility

The energy storage facility may be included on the positive list. Rated power of the facility must not exceed 50 kW.

Documentation requirements for category A energy storage facilities are divided into the following subsections.

9.2.12.1 Procedure for inclusion of facilities and facility components on the positive list

To request that an energy storage facility with rated power of maximum 50 kW be included on the positive list, documentation required under section 9.2 must be submitted to positivlister@danskenergi.dk.

Product certificates issued by an approved certification body may be used. Product certificates may cover some documentation requirements. The process for inclusion on the positive list is explained on Danish Energy's website: www.danskenergi.dk/positivlister.

10. Simulation model requirements

Due to the ongoing transition of the electricity system, with conventional generation facilities gradually being phased out and replaced by more complex facilities, including energy storage facilities, the transmission system operator requires greater insight into these new facilities' structural designs and their systemic impact on the public electricity supply grid.

For analytical purposes related to planning and operation of the public electricity supply grid, the transmission system operator must be able to carry out grid and system analyses, e.g. when connecting new energy storage facilities to the grid. This requires up-to-date and accurate simulation models of grid-connected energy storage facilities.

Simulation models are used to analyse the transmission and distribution grids' static and dynamic states, including voltage, frequency and rotor angle stability, short-circuit ratios, transient phenomena and harmonic states.

The facility owner must submit the simulation models specified below to Energinet Elsystemansvar A/S In pursuance of Section 84a of the Danish Electricity Supply Act. The transmission system operator is bound by a duty of confidentiality where commercially sensitive information is concerned.

Simulation models may be sent directly from the manufacturer of the energy storage facility to Energinet Elsystemansvar A/S. The facility owner is responsible for ensuring that such data is forwarded at the correct time and to the correct extent.

From the design phase to the verification phase, the facility owner must regularly inform Energinet Elsystemansvar A/S if preliminary facility data are no longer representative of the final commissioned energy storage facility.

If significant modifications are made to the properties of an existing energy storage facility, the facility owner must submit an updated [1] and documented simulation model of the modified energy storage facility.

No later than three months after the date of commissioning, the documentation must be filled in with specific data for the entire energy storage facility and sent to the electricity supply undertaking and for transmission-connected facilities to Energinet Elsystemansvar A/S.

Model delivery is deemed complete only when the transmission system operator has approved the simulation models and required documentation submitted by the facility owner.

10.1 General simulation model requirements

The facility owner must submit simulation models to the transmission system operator, and these simulation models must properly reflect the energy storage facility's static and quasi-static state properties. The facility owner must also submit a dynamic simulation model (RMS model) and a transient simulation model (EMT model) to the transmission system operator for time domain analyses. The facility owner must also submit a harmonic simulation model for

[1] The necessary model update is only required to comprise replaced facility components or control, regulation or facility protection systems, as it is assumed that the transmission system operator is already in possession of a valid simulation model for the relevant electrical energy storage facility. If the transmission system operator has not received such a model, a significant modification to an energy storage facility requires the submission of a complete and fully documented simulation model in compliance with section 0.

analysis of the harmonic state of the public electricity supply grid, including the energy storage facility's contribution to harmonic emissions in the point of connection.

Please see Table 28 for information on requirements for simulation models and delivery scope for the respective types of energy storage facilities. The facility owner must ensure that models are forwarded on time under current procedures for grid connection of energy storage facilities and other provisions in this regulation.

Energy storage facility type	Requirements for simulation model
A	No requirement
B	No requirement
C [Pn ≥ 10MW]	• Static • Dynamic (RMS) • Harmonic
D	• Static • Dynamic (RMS) • Transient (EMT) • Harmonic

Table 28 Simulation model requirements for individual energy storage facility types.

Depending on the model type, the simulation model for the entire energy storage facility must describe the static and dynamic electrical properties of the energy storage facility in the point of connection.

If the generation facility incorporates external components, for example to comply with grid connection requirements or for the supply of commercial ancillary services, the simulation model must include the necessary representation of these components applicable for all required model types.

The content and level of detail of the simulation model for the energy storage facility controller as well as for the individual energy storage facility must be such that both model types can easily be integrated into a comprehensive grid model of the public electricity supply grid so that this appears as a complete, fully functional simulation model.

The simulation model must be verified as specified in section 10.4.

10.2 General documentation requirements

In order to ensure correct model use, the required simulation models must be documented in the form of user instructions. These must include descriptions of the models' structural composition as well as descriptions of the parameterisation and valid boundary conditions of the simulation models in the form of operating points.

Any restrictions in relation to grid conditions (short-circuit conditions and R/X conditions) in the point of connection as well as in connection with the simulation of external incidents in the public electricity supply grid must also be included. User instructions must also contain information about special model-technical conditions, e.g. the maximum applicable step size for the equation solver used in connection with the implementation of dynamic and transient simulations, etc.

User instructions must also include descriptions of the control, protective and regulation functions implemented in the simulation model to be used when evaluating the energy storage facility's characteristics in the point of connection, with special emphasis on the following conditions:

- Single-line representation of the simulation model's electrical main components up to the point of connection.
- Descriptions of the simulation model's electrical input and output signals (electrical terminals), including relevant issues in relation to applied measuring points, their measuring units and applied base values for these.
- A comprehensive parameter list, where all parameter values must be stated in the enclosed data sheets for main components, block diagrams and transfer functions, etc.
- Description of structure and activation thresholds of protective functions used.
- Descriptions of set-up and initialisation of the simulation model as well as any limitations to the application hereof.
- Description of how the simulation model can be integrated into a comprehensive grid and system model as used by the transmission system operator.
- Unique version control of simulation model and related documentation.

Model-specific documentation requirements are described in the following sections.

10.3 Model-technical requirements

10.3.1 Requirements for static simulation model (static conditions and short-circuit ratio)

The following requirements, see Table 28, apply to type C and D energy storage facilities.

The simulation model of the entire energy storage facility must represent this facility's static and quasi-static properties in the point of connection, applicable to the defined normal operating range, see section 4.3, and in all relevant static grid conditions under which the energy storage facility must be operational.

In this context, quasi-static properties include the characteristics of the energy storage facility in connection with a short circuit in the point of connection or anywhere in the public electricity supply grid. A short circuit may here take the form of:

- A phase-to-earth short circuit with any impedance in the fault point.
- A phase-to-phase-to-earth or phase-to-phase short circuit with any impedance in the fault point.
- A three-phase short circuit with any impedance in the fault point.

The static simulation model must:

- Be underpinned by model descriptions that, as a minimum, comprise function descriptions of the main model modules.
- Include descriptions of the individual model components and related parameters.
- Include descriptions of the set-up of the simulation model as well as any limitations to the application hereof.
- Include characteristics of the energy storage facility's static operating ranges for active and reactive power, so that the simulation model is not erroneously operated in an invalid operating point.
- Allow for the use of all required reactive power control functions:
    - Power factor control (cos ϕ control) with indication of set point.
    - Q control (MVAr control) with indication of set point.
    - Voltage control, including parameters for applied droop/compounding with indication of set point.
- Allow simulation of root-mean-square values in the individual phases during symmetrical incidents and faults in the public electricity supply grid.
- Allow simulation of root-mean-square values in the individual phases during asymmetrical incidents and faults in the public electricity supply grid.
- As a minimum, cover the 47.5-51.5 Hz frequency range and 0.0-1.4 p.u. voltage range.

If the energy storage facility comprises several parallel installations, the simulation model must be representative of the properties of the entire or aggregated energy storage facility in the point of connection, see above. Simulation model parameter settings must contain complete data sets for each individual installation.

The simulation model must be submitted implemented in the most recent version of the simulation tool DIgSILENT PowerFactory, using the built-in grid component models and standard programming features, which must be reflected in the applied model structure, etc. The model implementation used must not require the use of special settings of or deviations from the standard settings for the simulation tool's numerical equation solver or otherwise prevent integration between the simulation model submitted by the facility owner and the more extensive grid and system model used by the transmission system operator.

The scope and level of detail of data for grid components and other equipment that form part of the facility infrastructure must enable the construction of a complete and fully operational simulation model.

If the static simulation model is identical to the dynamic simulation model described in section 10.3.2, the requirement for a separate static simulation model no longer applies.

The simulation model must be verified as specified in section 10.4.

10.3.1.1 Accuracy requirements

In general, the simulation model must show no properties that cannot be proven for the actual energy storage facility.

10.3.2 Requirements for dynamic simulation model (RMS model)

The following requirements, see Table 28, apply to type C and D energy storage facilities.

The dynamic simulation model of the energy storage facility must represent the facility's static and dynamic properties in the point of connection, applicable to the defined normal operation range, see section 4.3, and in all relevant grid conditions under which the energy storage facility must be operational. The dynamic simulation model must be able to represent the static and dynamic properties of the energy storage facility in connection with set point changes for the facility's delivery and absorption of active and reactive power, including change of control mode for this, as well as the following external incidents, or combinations of these external incidents in the public electricity supply grid:

- External faults in the public electricity supply grid within the required FRT characteristics as measured in the point of connection, where a short circuit here can take the form of:
  - A phase-to-earth short circuit with any impedance in the fault point.
  - A phase-to-phase-to-earth or phase-to-phase short circuit with any impedance in the fault point.
  - A three-phase short circuit with any impedance in the fault point.
- Disconnection, and possible subsequent automatic reconnection, of any faulty grid component in the public electricity supply grid, cf. the above fault sequence, and the resulting vector jump in the point of connection.
- Manual connection or disconnection (without prior fault) of any grid component in the public electricity supply grid and the resulting vector jump in the point of connection.
- Voltage disturbances and near-miss voltage collapses of a duration within the required minimum simulation period, cf. details below, and as a minimum within the transient start-up period for the energy storage facility's transition to a new static state.
- Frequency disturbances of a duration within the required minimum simulation period, cf. details below, and as a minimum within the transient start-up period for the energy storage facility's transition to a new static state.
- Activation of imposed system protection (via an external signal) for fast regulation of the energy storage facility's active power generation in reference to a predefined final value and gradient. Requirements are applicable if system protection is imposed.

The dynamic simulation model must:

- Be underpinned by model descriptions that, as a minimum, include Laplace domain transfer functions, sequence diagrams for applied state machines and function descriptions of the arithmetical, logical and sequence-controlled modules used in the simulation model.
- Include descriptions of and related parameter values for the individual model components, including saturation, non-linearity, dead band, time delays and constraint functions (non-wind-up/anti wind-up etc.) as well as look-up table data and principles applied to interpolation, etc.
- Include descriptions and clear indications of the simulation model's input and output signals, which, as a minimum, must include the following:
  - Active power.

  - Reactive power
  - Set points for:
    - Active power control.
    - Power factor control (cos ϕ control).
    - Q control (MVAr control).
    - Voltage control including parameters for droop/compounding used.
    - Frequency control (droop and deadband).
    - System protection measures (final value and gradient for active power control).
  - Signal for activation of system protection.
- Include descriptions of set-up and initialisation of the simulation model as well as any limitations to the application hereof.
- Include all required control functions, see section 6.
- Include relevant protective functions that can be activated by external incidents and faults in the public electricity supply grid, implemented in the form of block diagrams with indication of transfer functions and sequence diagrams for the individual elements.
- Include all control functions[2] that can be activated during all relevant incidents and faults in the public electricity supply grid.
- Allow simulation of root-mean-square (RMS) values in the individual phases during symmetrical incidents and faults in the public electricity supply grid.
- Allow simulation of root-mean-square (RMS) values in the individual phases during asymmetrical incidents and faults in the public electricity supply grid.
- As a minimum, cover the 47.5-51.5 Hz frequency range and 0.0-1.4 p.u. voltage range.
- Allow initialisation in a stable operating point on the basis of a single load flow simulation without subsequent iterations. Show a derived value (dx/dt) on initialisation for any of the simulation model state variables below 0.0001.
- Allow description of the energy storage facility's dynamic properties for at least 60 seconds after any of the above set point changes and external incidents in the public electricity supply grid.
- Be numerically stable through a simulation of minimum 60 seconds without application of a sequence of events or changes to boundary conditions with simulated values for active power, reactive power, voltage and frequency remaining constant throughout the simulation.
- Be capable of utilising numerical equation solvers with variable time steps in the 1-10 millisecond range.
- Be numerically stable through an instantaneous vector jump of up to 20 degrees in the point of connection.
- Not contain encrypted or compiled parts (unacceptable), as the transmission system operator must be able to quality assure the results of the simulation model and maintain this without the restrictions of software updates, etc.

The fact that the simulation model may return a number of non-convergence error messages relating to applied external incidents in the public electricity supply grid when running a simulation sequence is accepted. This will, however, generally be perceived as imperfections related to model implementation, and cause and mitigation proposals must appear from the relevant model documentation. If it can be documented that the simulation model's non-

[2] Control functions in relation to the required electrical energy storage facility fault-ride-through properties, including dynamic voltage support in connection with a voltage dip.

convergence will adversely impact the application of the transmission system operator's comprehensive grid and system model, the simulation model in question will be rejected.

If a simulation model is used to aggregate individual facilities for a common representation of these energy storage facilities in the point of connection, the model must be able to represent the characteristics of the energy storage facility in the point of connection, cf. above. The accompanying documentation must include descriptions of the principles used for aggregation and any limitations on the use of this. Simulation model parameter settings must include complete data sets for the individual energy storage facilities as well as the aggregated energy storage facility.

The content and level of detail of the simulation model for the energy storage facility controller as well as for the individual energy storage facility must be such that they can easily be integrated into a comprehensive grid and system model as used by the transmission system operator and subsequently appear as complete, fully functional simulation models.

If the energy storage facility incorporates external components, for example to comply with grid connection requirements or for the delivery of commercial ancillary services, the simulation model must include the necessary representation of these components as required in section 10.1.

The simulation model must be submitted implemented in the most recent version of the simulation tool DIgSILENT PowerFactory, using the built-in grid component models and standard programming features, which must be reflected in the applied model structure, etc. The model implementation used must not require the use of special settings of or deviations from the standard settings for the simulation tool’s numerical equation solver or otherwise prevent integration between the simulation model submitted by the facility owner and the more extensive grid and system model used by the transmission system operator.

The scope and level of detail of data for grid components and other equipment that form part of the facility infrastructure must enable the construction of a complete and fully operational simulation model as required in section 10.1

The simulation model must be verified as specified in section 10.4.

10.3.2.1 Accuracy requirements

The simulation model must represent the static and dynamic properties of the energy storage facility in the point of connection. The simulation model must thus respond sufficiently accurately in reflection of the physical facility’s static response for an actual static operating point and similarly for the dynamic response in connection with a set point change or an external incident in the public electricity supply grid.

The facility owner must ensure that simulation models are verified with the results of the compliance tests required as a result of requirements in sections 4, 6 and 7, and submit the required documentation hereof.

Since model verification includes the energy storage facility’s static and dynamic properties in connection with external incidents in the public electricity supply grid and, correspondingly, in connection with set point changes for the energy storage facility’s absorption and delivery of active and reactive power, it is advisable to define accuracy requirements and handle the verification procedure for these issues separately, as described in the following sections.

10.3.2.1.1 Accuracy requirements in connection with external incidents in the public electricity supply grid

In this context, external incidents comprise momentary voltage changes measured in the energy storage facility's point of connection, e.g. in connection with the short circuit of a grid component or manual switching with a grid component in the public electricity supply grid.

Test and verification of an energy storage facility's static and dynamic properties in connection with such external incidents is typically only done in connection with certification and type approval of the relevant energy storage facility.

The primary purpose of these standard tests is verification and certification of the energy storage facility's compliance with the required FRT properties, including requirements for delivery of dynamic voltage support (added reactive current I_Q) during the fault sequence in accordance with the defined FRT characteristics. The results of these standard tests are used for the subsequent verification of the functional requirements defined for and the accuracy of the required simulation model.

Model simulations must show that requirements in section 4.4 have been met.

The standard tests used for model verification must be performed and documented in accordance with definitions and descriptions as a result of requirements in sections 4, 6 and 7.

Model verification is based on an evaluation of the statistical accuracy of the simulation model, where accuracy is determined based on a calculation of the deviation between the model's simulated response and the corresponding measured value, defining the deviation as:
$X_E(n) = X_{sim}(n) – X_{measured}(n)$.

- MXE - Maximum deviation (maximum error).
- ME - Average deviation (mean error).
- MAE - Average (absolute) deviation (mean absolute error).

Appendix 1 lists the generation facility electrical signals that are covered by the above accuracy requirements.

In order to ensure an objective assessment of the simulation model accuracy, the following quantitative requirements must be met for each of the standard tests performed as the deviations calculated for the model must be less than or equal to the permissible deviations specified in Table 29 for each of the defined time periods (pre-fault, fault and post-fault).

The permissible deviations stated in Table 29 for the specified electrical signals are relative to the energy storage facility's base values of rated active power (for the evaluation of active power and reactive power values) as well as rated current (for the evaluation of active and reactive current component values).

		Synchronous and negative-sequence components											
		Active power			Reactive power			Power (active component)			Power (reactive component)		
		MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE
Permissible deviation	Pre-fault	0.150	±0.100	0.120	0.150	±0.100	0.120	0.150	±0.100	0.120	0.150	±0.100	0.120
	Fault	0.170	±0.150	0.170	0.170	±0.150	0.170	0.500	±0.300	0.400	0.170	±0.150	0.170
	Post-fault	0.170	±0.150	0.170	0.170	±0.150	0.170	0.170	±0.150	0.170	0.170	±0.150	0.170

Table 29 Accuracy requirements - permissible deviation.

Accuracy requirements for the required simulation model are seen as complied with if all of the defined tolerances of permissible deviations have been met.

In general, the simulation model must show no properties that cannot be proven for the actual energy storage facility.

10.3.2.1.2 Accuracy requirements in connection with changes to the generation facility's operating point

In this context, the phrase *changes to the energy storage facility's operating point* comprises manual changes to energy storage facility's static operating point, for example in connection with a set point change to the facility's delivery or absorption of active power or corresponding changes to set points for other required control functions.

The primary purpose of these tests is verification of the energy storage facility's compliance with required static and dynamic properties in the point of connection, including compliance with the requirements defined in relation to, for example, response time and control gradients, activation levels for control and constraint functions as well as verification of the energy storage facility's operating range, etc.

Test results are used for the subsequent verification of the functional requirements defined for and the accuracy of the simulation model.

The standard tests used for model verification must be performed and documented in accordance with definitions and descriptions as a result of requirements in sections 4, 6 and 7.

Model simulations must show that requirements in section 4.4 have been met. At a minimum, the following simulation model control functions must be included in model verification:

- Active power control.
- Reactive power control:
  - Power factor control (cos ϕ control).
  - Q control (MVAr control).
- Voltage control (voltage reference point in the point of connection).
- Frequency control (required control functions).
- System protection measures (final value and gradient for downward regulation of active power) if required.

The accuracy of the simulation model with respect to the required control functions must be verified using a calculation of the deviation of the model's simulated responses in relation to the corresponding measured value.

Appendix 1 lists the generation facility electrical signals that are covered by the above accuracy requirements.

In order to ensure an objective assessment of the simulation model accuracy, the following quantitative requirements, applicable to the energy storage facility's step response, must be met for each of the standard tests performed as the deviations calculated for the model must be less than or equal to the permissible deviations specified in Table 30.

	Rise time	Reaction time	Settling time	Overshoot	Steady state
	$X_E = X_{sim} - X_{measured}$	$X_E = X_{sim} - X_{measured}$	$X_E = X_{sim} - X_{measured}$	$X_E = X_{sim} - X_{measured}$	$X_E = X_{sim} - X_{measured}$
Permissible deviation	< 50 ms	< 50 ms	< 100 ms	< 15%	< 2% < 2% of P_{rated}

Table 30 Accuracy requirements - permissible deviations.

Accuracy requirements for the required simulation model are seen as complied with if all of the defined tolerances of permissible deviations have been met.

In general, the simulation model must show no properties that cannot be proven for the actual energy storage facility.

10.3.3 Requirements for transient simulation model (EMT model)

The following requirements, see Table 28, apply to type D energy storage facilities.

The facility owner must submit a transient simulation model of the energy storage facility to the transmission system operator, complying with the following specifications:

- The EMT model must be built and implemented to PSCAD/EMTDC in the software version specified by the transmission system operator.
- If the energy storage facility is made up of several identical energy storage installations, the EMT model must be representative of the individual energy storage installation as well as an optional number of installations for model aggregation.
- The EMT model may comprise precompiled and encrypted parts. The EMT model must be DLL-based and usable with Intel Fortran from version 12 up to and including the latest release on the date of the signing of the contract between the facility owner and the energy storage facility manufacturer. Dependence on PSCAD versioning updates is accepted, subject to the EMT model using standard components available to the user.
- It must be possible for the user to set the simulation time for the start of the EMT model's absorption and delivery of active and reactive power.
- It must be possible for the user to set the simulation time for activation of the energy storage facility's protection systems in the EMT model.
- The EMT model must be validated for simulations at different simulation time steps. The model must present approximately the same results at transient simulations at any time step in the valid range. The highest possible time step must be stated in the user instructions.
- The EMT model must be able to be implemented functionally several times in the same PSCAD simulation file without requiring significant changes to be made. Therefore, it must be possible to use the EMT model as several "definitions" or "instances".

If the model contains an alternative to the use of several "definitions" or "instances", this must be described in the user instructions.

- The EMT model must support the use of PSCAD/EMTDC's "snapshot" function. It is mandatory for the model to give the same response with and without the use of the snapshot function.
- It must be possible to initialise the model in maximum 3 seconds of simulation time.
- The EMT model must represent all components, control systems and protection systems relevant for EMT analyses.
- All relevant function settings in the energy storage facility's control system that are relevant for EMT analyses and that can be changed either locally or remotely must appear as available parameters in the simulation model. The scope of the delivery must be approved by the transmission system operator.
- All electrical, control and protection signals relevant to EMT analyses of the public electricity supply grid must be available in the EMT model. The scope of the delivery must be approved by the transmission system operator.
- Grid components and other equipment that form part of the facility infrastructure must be implemented in the EMT model to an extent and at a level of detail valid for EMT studies. This includes collection cables, transformers, filters, etc. The scope of the delivery must be approved by the transmission system operator.
- For energy storage facilities with a grid-connected converter, this must be modelled at transistor level for a proper representation in transient studies.
- The EMT model must represent the FRT properties of the energy storage facility, cf. section 4.4.
- If the energy storage facility has special functions, for example a control regime for a particularly weak grid, these functions must be included in the EMT model. A relevant model-technical description of the special functions and their restrictions must be included in the EMT model's user instructions.
- The model must be valid for static operating conditions.
- The EMT model must be usable for EMT simulations of balanced and unbalanced faults and interruptions of the energy storage facility's connection to the public electricity supply grid.

10.3.3.1 Model submission

On submission, the EMT model must include the following:

- PSCAD/EMTDC simulation model - version according to agreement with the transmission system operator.
- User instructions with descriptions of model limitations.
- Verification report for the EMT model.
- A functional PSCAD simulation model must be supplied for the energy storage facility connected to a simple model representation of the public electricity supply grid, for example a Thévenin-equivalent model.
- User instructions must describe the EMT model assumptions and application.
- A detailed description of model limitations must be submitted, with a description of all energy storage facility functions that are not included in the EMT model, but which could be assumed to be of significance to the electromagnetic transient properties and performance of the energy storage facility.
- The EMT model verification report must include a comparison of the PSCAD/EMTDC model's static and dynamic responses with measurements made on the physical energy storage facility.

- There are no requirements as to the validity of the EMT model for static harmonic conditions. Reference is made to section 10.3.4.

10.3.3.2 Accuracy requirements

The accuracy of the required transient simulation model is determined in the same way as for the dynamic simulation model (RMS model), see section 10.3.2. Thus, accuracy requirements and applied evaluation method are identical to those for the required dynamic simulation model.

Suitable filtering is used for the calculation of the fundamental component of measured and simulated values. The method used for filtering is agreed between the facility owner and the transmission system operator.

10.3.4 Requirements for harmonic simulation model

The following requirements, see Table 28, apply to type C and D energy storage facilities.

The simulation model of the energy storage facility must represent the facility's emission of harmonics and passive harmonic response (harmonic impedance) in the point of connection, applicable to the defined normal operation range and in all relevant static grid conditions under which the energy storage facility must be operational.

The single-unit model provided must be a Thévenin equivalent, representative of the energy storage facility's emission of integer harmonics, indicated as RMS-voltages as well as the facility's passive responses in the 50-2500 Hz frequency range. The model must include all relevant positive, negative sequence and zero-sequence impedance within the specified frequency range at a frequency resolution of 1 Hz.

If the facility consists of several energy storage installations, an aggregated simulation model representative of total emissions and total passive harmonic responses in the point of connection must be submitted in addition to the single-unit model. Requirements for frequency range and resolution are identical to those for the single-unit model.

If the energy storage facility's emission or harmonic impedance are dependent on the facility's operating point, the model must be submitted for three power ranges at rated voltage and zero reactive power: P = 0.0 p.u., P = 0.5 p.u. and P = 1.0 p.u. In addition, a description of reactive power's impact on harmonic emission and impedance must be included. In addition, the facility owner must submit a model based on the highest emissions per harmonic. This applies to both the aggregated and single-unit models. The facility owner must document any dependencies on the operating point and ensure correct implementation in the models.

The facility owner must specify a method for summation of emissions from several energy storage facilities. This can be done either by specifying requirement for setting the angle of the Thévenin voltage for each harmonic frequency specifically for each energy storage unit, or by using a summation law such as the one specified in IEC TR 61000-3-6:2008 [6]. If a summation law is applied, α coefficients must be specified by the facility owner. Explanations must be given for the selected α coefficient values for all harmonics. In both cases, the facility owner shall substantiate that the method applied results in a correct representation of the energy storage facility's total emissions.

The scope and level of detail of data about grid components and other components of the facility infrastructure must enable the creation of a complete frequency-dependent simulation model in the 50 Hz-2500 Hz frequency range. This includes collection cables, transformers, filters etc. The scope of the delivery must be approved by the transmission system operator.

10.3.4.1 Accuracy requirements

The method used for the creation of a model for the individual energy storage facility must be specified and approved by the transmission system operator. If model parameters are set based on measurements, a measurement report must be enclosed as documentation. In addition, an account must be given of how model parameters are set using the results in the measurement report. If model parameters are set based on calculations or simulations, the method used must be specified and examples of result processing for the deduction of model parameters given.

10.4 Verification of simulation model

The simulation model for the entire facility, including all control methods, must be verified by the facility owner, as a result of requirements in sections 4, 6 and 7.

The facility owner must handle all aspects of verification tests, including providing necessary measuring equipment, data loggers and personnel. The facility owner must also ensure completion and documentation of the required model verification, including documentation of compliance with defined accuracy requirements for simulation models.

No later than three months before the final commissioning of the facility, the practical performance of verification tests must be determined on the basis of the facility owner's proposal and in collaboration with Energinet Elsystemansvar A/S.

The facility owner must document the measurements used for verification of the simulation model for the energy storage facility in a report containing descriptions of each data set, including measuring equipment used and subsequent data processing, as well as boundary conditions for completed compliance tests and cause(s) of any deviations as regards specified boundary conditions.

Measured results are compared with the corresponding simulated results and the accuracy of the simulation model is documented in a verification report. The model verification procedure is deemed complete only when the transmission system operator has approved the model verification report submitted by the facility owner.

Time-series measurements used for verification of the simulation model must be attached to the verification report in CSV format (comma-separated values).

10.4.1 Signals included in the model verification requirement

Signals included in the model verification requirement:

- Active power – measured in the point of connection (or on the primary side of the generator transformer for type tests).
- Reactive power – measured in the point of connection (or on the primary side of the generator transformer for type tests).
- Phase currents (active component) – measured in the point of connection (or on the primary side of the generator transformer for type tests).
- Phase currents (reactive component) – measured in the point of connection (or on the primary side of the generator transformer for type tests).

11. References

[1] IEC 60050-415:1999 International Electrotechnical Vocabulary - Part 415: Wind turbine generator systems, International Electrotechnical Commission, 1999.

[2] DS/EN 61000-4-15:2011 Electromagnetic compatibility (EMC) - Part 4-15: Testing and measurement techniques - Flickermeter - Functional and design specifications, Danish Standards, 2011.

[3] DS/EN 61850-8-1:2011 Communication networks and systems for power utility automation - Part 8-1: Specific communication service mapping (SCSM) - Mappings to MMS (ISO 9506-1 and ISO 9506-2) and to ISO/IEC 8802-3, International Electrotechnical Commission, 2011.

[4] IEEE 1459:2010 Standard Definitions for the Measurement of Electric Power Quantities Under Sinusoidal, Nonsinusoidal, Balanced, or Unbalanced Conditions, Institute of Electrical and Electronics Engineers, 2010.

[5] DS/EN 61000-3-12:2012 Electromagnetic compatibility (EMC) - Part 3-12: Limits - Limits for harmonic currents produced by equipment connected to public low-voltage systems with input current > 16 A and ≤ 75 A per phase, Danish Standards, 2012.

[6] 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.

[7] Energinet, National implementing measure, information exchange: Requirement document no. 1 - generation and demand (awaiting approval by the Danish Utility Regulator), Energinet (www.energinet.dk), Erritsø, 2019.

[8] Energinet, National implementing measure, information exchange: Requirement document no. 3 - standards, protocols etc. (awaiting approval by the Danish Utility Regulator), Energinet (www.energinet.dk), Erritsø, 2019.

[9] Technical regulation 5.9.1 Systemtjenester (ancillary services), rev. 1.1, Energinet, 06.07.2012 (Danish only). [Online]. Available: https://energinet.dk/El/Nettilslutning-og-drift/Regler-for-systemdrift#tekniskeforskrifter.

[10] Regulation D1: Settlement metering (afregningsmåling), v. 4.12, Energinet, 06.07.2018 (Danish only). [Online]. Available: https://energinet.dk/El/Elmarkedet/Regler-for-elmarkedet/Markedsforskrifter.

[11] Regulation D2 Technical requirements for electricity metering, rev. 1, Energinet, 05.2007. [Online]. Available: https://en.energinet.dk/Electricity/Rules-and-Regulations/Market-Regulations.

[12] Technical regulation 3.3.1 for battery plants, revision 1, Energinet 23.06.2017. [Online]. Available: https://en.energinet.dk/Electricity/Rules-and-Regulations/Regulations-for-grid-connection.

[13] DS/EN 50160:2010 Voltage characteristics of electricity supplied by public electricity networks; Corr. 2010:2011; A1:2015, Danish Standards, 2010.

[14] DS/EN 60038:2011 IEC/ CENELEC standard voltages, Danish Standards, 2011.

[15] Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators, EU Commission, 14 April 2016. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32016R0631.

Appendix 1 Documentation

Appendix 1 specifies the documentation requirements for the five facility categories, see section 1.1.4:

- A. Energy storage facilities up to 125 kW
- B. Energy storage facilities from and including 125 kW up to 3 MW
- C. Energy storage facilities from and including 3 MW up to 25 MW
- D. Energy storage facilities from and including 25 MW or connected at voltages above 100 kV
- SX. Category A or B energy storage facilities
- T. Temporarily connected energy storage facilities

Documentation, see specifications in section 9, must be sent electronically to the electricity supply undertaking.

The technical documentation must include configuration parameters and configuration data applicable to the energy storage facility at the time of commissioning.

All appendix subsections must be filled in for the facility in question.

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

Templates for Appendix 1 for the various facility categories are available on Energinet's website www.energinet.dk.

Contents Appendix 1

Documentation – category A

B1.1. Documentation for category A energy storage facilities

Documentation must be filled in with data for the energy storage facility and sent to the electricity supply undertaking.

B1.1.1. Identification

Facility	Description of the facility
GSRN no.	
Facility owner name and address	
Facility owner telephone no.	
Facility owner e-mail	
Inverter – manufacture	
Inverter – model	
Inverter – rated power	
Storage medium – manufacture	
Storage medium – model no.	
Storage medium – usable energy storage capacity [kWh]	

B1.1.2. Positive list

Only applies to facilities up to 50 kW.

Is the energy storage facility on the positive list? If No, B1.2. must also be filled in.	Yes ☐ No ☐

B1.1.3. Active power control

Is the frequency response function for overfrequency activated?	Yes ☐ No ☐
If Yes, with which settings? Frequency threshold (f_{RO}): Droop: Time for island operation detection (minimum response time):	 _________ Hz _________ % _________ ms

B1.1.4. Reactive power control

B1.1.4.1. Power factor control

Is the power factor control function activated?	Yes ☐ No ☐
If Yes, with which set point? (Value differing from cosϕ 1.0 must be agreed with the electricity supply undertaking.)	_________ cosϕ Inductive ☐ Capacitive ☐

B1.1.4.2. Automatic power factor control

Is the automatic power factor control function activated? (Not to be activated without agreement with the electricity supply undertaking.)	Yes ☐ No ☐
If Yes, with which set points? Point 1 – P/Pn Point 1 – Power factor (inductive) Point 2 – P/Pn Point 2 – Power factor (inductive) Point 3 – P/Pn Point 3 – Power factor (inductive)	_________ % _______ cosϕ _________ % _______ cosϕ _________ % _______ cosϕ

B1.1.4.3. Q control

Is the Q control function activated?	Yes ☐ No ☐
If Yes, with which set point? (Value differing from 0 kVAr must be agreed with the electricity supply undertaking.)	_________ kVAr

B1.1.5. Protection

B1.1.5.1. Relay settings

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

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

* At least one of the functions must be activated.

B1.1.6. Signature

Date of commissioning	
Installation contractor	
Person responsible for commissioning	
Signature (person responsible for commissioning)	
Facility owner	
Signature (facility owner)	

B1.2. Documentation for category A energy storage facilities

Documentation must be filled in with data for the energy storage facility to be included on the positive list, or if the facility is not on the positive list.

B1.2.1. Identification

Facility	Description of the facility
Facility owner name and address	
Facility owner telephone no.	
Facility owner e-mail	
Inverter – manufacture	
Inverter – model	
Inverter – rated power	
Storage medium – manufacture	
Storage medium – model no.	
Storage medium – usable energy storage capacity [kWh]	

B1.2.2. Normal operation

Can the facility be started and operate continuously within the normal operation range, restricted only by protective settings, c.f. requirements in section 7? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.3. Tolerance of frequency deviations

Will the energy storage facility remain connected to the public electricity supply grid during frequency deviations as specified in section 4? Where to find documentation that this requirement has been met?	Yes ☐ No ☐
Will the facility remain connected in the event of frequency changes of 2.0 Hz/s in the POC? If Yes, reference to documentation:	Yes ☐ No ☐

B1.2.4. Start-up and automatic reclosing of an energy storage facility

Does start-up and automatic reclosing occur after three minutes following voltage and frequency coming within the areas specified in section 4.3.1? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.5. Power quality

Please state how each power quality parameter result was achieved.

B1.2.5.1. Rapid voltage changes

Does the energy storage facility comply with the rapid voltage changes threshold specified in section 5.1.1.3? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.5.2. DC content

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

B1.2.5.3. Current imbalance

Does the current imbalance at normal operation exceed 16 A? Where to find documentation that this requirement has been met?	Yes ☐ No ☐
If the facility is made up of single-phase energy storage units, have measures been taken to ensure that the above threshold is not exceeded? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.5.4. Flicker

Is the flicker contribution for the entire facility below the threshold specified in section 5.1.1.4? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.5.5. Harmonics

Are all harmonics for the entire facility below the thresholds specified in section 5.1.1.5? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.5.6. Interharmonics

This part must only be filled in for energy storage facilities larger than 50 kW.

Are all interharmonics for the entire energy storage facility below the thresholds specified in section 5.1.1.6? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.5.7. Disturbances in the 2-9 kHz range

This part must only be filled in for energy storage facilities larger than 50 kW.

Is the emission of disturbances with frequencies in the 2-9 kHz range lower than 0.2% of rated current I_n as required in section 5.1.1.7? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.6. Control functions

B1.2.6.1. Active power control

B1.2.6.1.1. Frequency response at overfrequency

Is the energy storage facility equipped with a frequency response function in case of overfrequency?	Yes ☐ No ☐

B1.2.6.1.2. Absolute power constraint

Is the energy storage facility equipped with an absolute power constraint function?	Yes ☐ No ☐

B1.2.6.1.3. Ramp rate constraint function

Is the energy storage facility equipped with a ramp rate constraint function?	Yes ☐ No ☐

B1.2.6.2. Reactive power control

B1.2.6.2.1. Work area

Can the energy storage facility supply reactive power at P_n and varying operating voltages, as specified in section 6.3? Where to find documentation that this requirement has been met?	Yes ☐ No ☐
Can the energy storage facility supply reactive power at varying active power as specified in section 6.3? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.2.6.2.2. Power factor control

Is the energy storage facility equipped with a power factor control function as specified in sections 6.3.2 and 6.3.2.1?	Yes ☐ No ☐

B1.2.6.2.3. Automatic power factor control

Is the energy storage facility equipped with automatic power factor control as specified in sections 6.3.4 and 6.3.4.1?	Yes ☐ No ☐

B1.2.6.2.4. Q control

Is the energy storage facility equipped with a Q control function as specified in sections 6.3.1 and 6.3.1.1?	Yes ☐ No ☐

B1.2.7. Protection against electricity system faults

B1.2.7.1. Relay settings

The table below lists default values for relay settings. If default values deviate from the values specified in section 7.2.1, documentation must be provided to ensure that relay settings can be set to the correct values upon commissioning.

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

B1.2.8. Signature

Date	
Company	
Person responsible for commissioning	
Signature (person responsible for commissioning)	
Facility owner	
Signature (facility owner)	

Documentation – category B

B1.3. Documentation for category B energy storage facilities (Part 1)

Please fill in the documentation form with data for the facility, valid before commissioning, and submit it to the electricity supply undertaking.

B1.3.1. Identification

Facility	Description of the facility
Facility owner name and address	
Facility owner telephone no.	
Facility owner e-mail	
Inverter – manufacture	
Inverter – model	
Inverter – rated power	
Storage medium – manufacture	
Storage medium – model no.	
Storage medium – usable energy storage capacity [kWh]	

B1.3.2. Normal operation

Can the energy storage facility be started and operate continuously within the normal operation range, restricted only by grid protection settings, c.f. requirements in section Figure 6? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.3. Tolerance of frequency deviations

Will the energy storage facility remain connected to the public electricity supply grid during frequency deviations as specified in section 4? If Yes, reference to documentation:	Yes ☐ No ☐
Will the facility remain connected in the event of frequency changes of 2.0 Hz/s in the POC? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.4. Tolerance of voltage deviations (FRT)

Will the energy storage facility remain connected to the public electricity supply grid during voltage dips as specified in section 4.4? If Yes, reference to documentation:	Yes ☐ No ☐
Will the energy storage facility remain connected to the public electricity supply grid during voltage increases as specified in section 4.4? If Yes, reference to documentation:	Yes ☐ No ☐
After a voltage dip, the energy storage facility is able to return to normal operation no later than 5 s after operating conditions have returned to the normal operating range.	Yes ☐ No ☐

B1.3.5. Additional reactive current

Does the energy storage facility deliver additional reactive current as specified in section 4.4.4? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.6. Start-up and automatic reclosing of an energy storage facility

Do connection and synchronisation occur as specified in section 4.3.1? If Yes, reference to documentation:	Yes ☐ No ☐
Is it possible to circumvent automatic synchronisation? If No, reference to documentation:	Yes ☐ No ☐

B1.3.7. Active power control

B1.3.7.1. Frequency Response – Overfrequency

Is the energy storage facility equipped with a frequency response function for overfrequency as specified in section 6.2.2.1? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.7.2. Absolute power constraint function

Is the energy storage facility equipped with an absolute power constraint function as specified in section 6.2.4.1.1? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.7.3. Ramp rate limit

Is the energy storage facility equipped with a ramp rate constraint as specified in section 6.2.4.2.1? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.8. Reactive power control

B1.3.8.1. Work area

Can the energy storage facility supply reactive power at P_n and varying operating voltages, as specified in section 6.3? Where to find documentation that this requirement has been met?	Yes ☐ No ☐
Can the energy storage facility supply reactive power at varying active power as specified in section 6.3.5.2? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.3.8.2. Power factor control

Is the energy storage facility equipped with a power factor control function as specified in section? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.8.3. Q control

Is the energy storage facility equipped with a Q control function as specified in section? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.8.4. Automatic power factor control

Is the automatic power factor control function activated? (Not to be activated without agreement with the electricity supply undertaking.) If Yes, with which set points? Point 1 – P/Pn Point 1 – Power factor (inductive) Point 2 – P/Pn Point 2 – Power factor (inductive) Point 3 – P/Pn Point 3 – Power factor (inductive)	Yes ☐ No ☐ _________ % _______ cosϕ _________ % _______ cosϕ _________ % _______ cosϕ

B1.3.9. Power quality

Are stated emission values calculated values?	Yes ☐ No ☐
Are stated emission values measured values?	Yes ☐ No ☐
Is a report enclosed, documenting that calculations or measurements comply with emission requirements? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.9.1. Rapid voltage changes

Does the energy storage facility comply with the threshold for rapid voltage changes specified in section 5.1.1.3? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.9.2. DC content

Does DC content at normal operation exceed 0.5% of rated current? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.9.3. Voltage unbalance

Is the facility three-phase balanced? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.9.4. Flicker

Is the flicker contribution for the entire energy storage facility below the threshold specified in section 5.1.1.4? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.9.5. Harmonics

Are all harmonics for the entire energy storage facility below the thresholds specified in section 5.1.1.5? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.9.6. Interharmonics

Are all interharmonics for the entire energy storage facility below the thresholds specified in section 5.1.1.6? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.9.7. Disturbances in the 2-9 kHz range

Is the emission of disturbances with frequencies in the 2-9 kHz range lower than 0.2% of I_n as required in section 5.1.1.7? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.10. Protection

Is the facility protected with the functions required in section 7.2.2? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.10.1. Island operation detection

Is the facility protected with the functions required in section 7.2.2? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.11. Information exchange requirements

Can the facility exchange information as required in section 8.2? If Yes, reference to documentation:	Yes ☐ No ☐

B1.3.12. Signature

Date	
Installation contractor	
Person responsible for commissioning	
Signature (person responsible for commissioning)	
Facility owner	
Signature (facility owner)	

B1.4. Documentation for category B energy storage facilities (part 2)

Please fill in the documentation form with data for the energy storage facility, valid after commissioning, and submit it to the electricity supply undertaking.

B1.4.1. Identification

Facility	Description of the facility
Facility owner name and address	
Facility owner telephone no.	
Facility owner e-mail	
Inverter – manufacture	
Inverter – model	
Inverter – rated power	
Storage medium – manufacture	
Storage medium – model no.	
Storage medium – usable energy storage capacity [kWh]	

B1.4.2. Active power control

B1.4.2.1. Active power control at overfrequency

Is the frequency response function for overfrequency activated?	Yes ☐ No ☐
If Yes, with which settings? Frequency threshold (f_2): Droop: Time for island operation detection (minimum response time):	 _________ Hz _________ % _________ ms

B1.4.2.2. Absolute power constraint function

Is the absolute power constraint function activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which value?	_________ kW

B1.4.2.3. Ramp rate limit

Is the energy storage facility's ramp rate constraint activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which value?	______% P_n/min

B1.4.3. Reactive power control

B1.4.3.1. Q control

Is the Q control function activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which set point? (Value differing from 0 kVAr must be agreed with the electricity supply undertaking.)	_________ kVAr

B1.4.3.2. Power factor control

Is the power factor control function activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which set point? (Value differing from cosϕ 1.0 must be agreed with the electricity supply undertaking.)	_________ cosϕ Inductive ☐ Capacitive ☐

B1.4.4. Protection

B1.4.4.1. Relay settings

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

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

* Used for island operational detection in the distribution grid

B1.4.5. Signature

Date	
Installation contractor	
Person responsible for commissioning	
Signature (person responsible for commissioning)	
Facility owner	
Signature (facility owner)	

Documentation – categories C and D

B1.5. Documentation for category C and D energy storage facilities (part 1)

Please fill in the documentation form with data for the facility, valid before commissioning, and submit it to the electricity supply undertaking.

B1.5.1. Identification

Facility	Description of the facility
Facility owner name and address	
Facility owner telephone no.	
Facility owner e-mail	
Inverter – manufacture	
Inverter – model	
Inverter – rated power	
Storage medium – manufacture	
Storage medium – model no.	
Storage medium – usable energy storage capacity [kWh]	

B1.5.2. Normal operating conditions

Can the energy storage facility be started and operate continuously within the normal operation range, restricted only by grid protection settings, c.f. requirements in Figure 6-Figure 10?	Yes ☐ No ☐

B1.5.3. Tolerance of frequency deviations

Will the energy storage facility remain connected to the public electricity supply grid during frequency deviations as specified in section 4 for categories C and D?	Yes ☐ No ☐
Will the facility remain connected in the event of frequency changes of 2.0 Hz/s in the POC?	Yes ☐ No ☐

B1.5.4. Tolerance of voltage deviations (FRT)

Will the energy storage facility remain connected to the public electricity supply grid at the voltage dips, as specified in 4.4.4 and 4.4.5 for categories C and D, respectively?	Yes ☐ No ☐
After a voltage dip, the energy storage facility is able to return to normal operation no later than 5 s after operating conditions have returned to the normal operating range.	Yes ☐ No ☐

B1.5.4.1. Additional reactive current

Does the energy storage facility deliver additional reactive current as specified in sections 4.4.4 or 4.4.5 for categories C and D, respectively?	Yes ☐ No ☐

B1.5.5. Connection and synchronisation

Do connection and synchronisation occur as specified in section 4.3.1 for categories C and D?	Yes ☐ No ☐

B1.5.6. Active power control

B1.5.6.1. Active power control at overfrequency

Is the energy storage facility equipped with a frequency response function for overfrequency as specified in section 6.2.2.1 for categories C and D?	Yes ☐ No ☐

B1.5.6.2. Active power control at underfrequency

Is the energy storage facility equipped with a frequency response function for underfrequency as specified in section **Fejl! Henvisningskilde ikke fundet.**6.2.2.3 for categories C and D? If Yes, reference to documentation:	Yes ☐ No ☐

B1.5.6.3. Frequency control

Is the energy storage facility equipped with a frequency control function as specified in section 6.2.3.2 for categories C and D? If Yes, reference to documentation:	Yes ☐ No ☐

B1.5.6.4. System protection

Is the energy storage facility equipped with a system protection function as specified in section 6.4.2? If Yes, reference to documentation:	Yes ☐ No ☐

B1.5.6.5. Absolute power constraint function

Is the energy storage facility equipped with an absolute power constraint function as specified in section 6.2.4.1.1 for categories C and D? If Yes, reference to documentation:	Yes ☐ No ☐

B1.5.6.6. Ramp rate constraint function

Is the energy storage facility equipped with a ramp power constraint function as specified in section 6.2.4.2.1 for categories C and D? If Yes, reference to documentation:	Yes ☐ No ☐

B1.5.7. Reactive power control functions

B1.5.7.1. Requirements for reactive power control area

Can the facility supply reactive power at P_n and varying operating voltages, as specified in sections 6.3.5.3, 0 and 6.3.5.5 for categories C, D and D*, respectively?	Yes ☐ No ☐
Can the energy storage facility supply reactive power at varying active power as specified in sections 6.3.5.3, 0 and 6.3.5.5 for categories C, D and D, respectively?	Yes ☐ No ☐

B1.5.7.2. Q control

Is the energy storage facility equipped with a Q control function as specified in section 6.3.1.1 for categories C and D?	Yes ☐ No ☐

B1.5.7.3. Power factor control

Is the energy storage facility equipped with a power factor control function as specified in section 6.3.2.1 for categories C and D?	Yes ☐ No ☐

B1.5.7.4. Voltage control

Is the energy storage facility equipped with a voltage control function as specified in section 6.3.3.2 for categories C and D?	Yes ☐ No ☐
Where is the voltage reference point located?	

B1.5.8. Power quality

Are stated emission values calculated values?	Yes ☐ No ☐
Are stated emission values measured values?	Yes ☐ No ☐
Is a report enclosed, documenting that calculations or measurements comply with emission requirements?	Yes ☐ No ☐

B1.5.8.1. Rapid voltage changes

Does the energy storage facility comply with the rapid voltage changes thresholds specified in sections 5.2.1.3 and 5.3 for categories C and D distribution connections and category D* transmission connections, respectively?	Yes ☐ No ☐

B1.5.8.2. DC content

Does DC content at normal operation exceed the thresholds set out in sections 5.2.1.1 and 5.3 for categories C and D distribution connections and category D* transmission connections, respectively?	Yes ☐ No ☐

B1.5.8.3. Voltage unbalance

Is the facility three-phase balanced?	Yes ☐ No ☐

B1.5.8.4. Flicker

Is flicker contribution for the energy storage facility below the thresholds set out in sections 5.2.1.4 and 5.3 for categories C and D distribution connections and category D* transmission connections, respectively?	Yes ☐ No ☐

B1.5.8.5. Harmonics

Are all harmonic distortions for the energy storage facility below the thresholds set out in sections 5.2.1.5 and 5.3 for categories C and D distribution connections and category D* transmission connections, respectively?	Yes ☐ No ☐

B1.5.8.6. Interharmonics

Are all interharmonics for the energy storage facility below the thresholds set out in sections 5.2.1.6 and 5.3 for categories C and D distribution connections and category D* transmission connections, respectively?	Yes ☐ No ☐

B1.5.8.7. Disturbances in the 2-9 kHz range

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

B1.5.9. Protection

Is the facility protected with the functions required in sections 7.2.3 and 7.2.4 for categories C and D, respectively?	Yes ☐ No ☐

B1.5.9.1. Island operation detection

Is the facility protected with the functions required in section 6.2.3.2 for categories C and D?	Yes ☐ No ☐

B1.5.10. Information exchange

B1.5.10.1. Data communication

Have data communication protocols and data security factors been implemented as specified in section 8.2?	Yes ☐ No ☐
Are signals as specified in section 8.2 available in the PCOM interface?	Yes ☐ No ☐

B1.5.10.2. Fault incident recording

Only for category D facilities

Have logging equipment been installed in the POC as specified in section 8.3 for category D?	Yes ☐ No ☐
Has it been agreed with the transmission system operator which incidents should be logged? If 'Yes', which?	Yes ☐ No ☐

B1.5.11. Simulation model requirements

Only for facilities with power output above 10 MW

Has a simulation model been prepared as specified in section 10.1 for categories C and D? If Yes, reference to documentation and model:	Yes ☐ No ☐

B1.5.12. Conformity testing

Has a conformity testing plan been prepared as specified in section 9.2.11 for categories C and D? If Yes, reference to documentation:	Yes ☐ No ☐

B1.5.13. Signature

Date	
Installation contractor	
Person responsible for commissioning	
Signature (person responsible for commissioning)	
Facility owner	
Signature (facility owner)	

B1.6. Documentation for category C and D energy storage facilities (part 2)

Please fill in the documentation form with data for the facility, valid before final commissioning, and submit it to the electricity supply undertaking.

B1.6.1. Identification

Facility	Description of the facility
GSRN no.	
Facility owner name and address	
Facility owner telephone no.	
Facility owner e-mail	
Inverter – manufacture	
Inverter – model	
Inverter – rated power	
Storage medium – manufacture	
Storage medium – model no.	
Storage medium – usable energy storage capacity [kWh]	

B1.6.2. Active power control

B1.6.2.1. Active power control at overfrequency

Is the frequency response function for overfrequency as specified in section 6.2.2.1 for categories C and D activated?	Yes ☐ No ☐
If Yes, with which settings? Frequency threshold: Droop: Time for island operation detection (minimum response time):	 ________ Hz ________ % ________ ms

B1.6.2.2. Active power control at underfrequency

Is the frequency response function for underfrequency as specified in section 6.2.2.3 for categories C and D activated?	Yes ☐ No ☐
If Yes, with which settings? Frequency threshold: Droop: Time for island operation detection (minimum response time):	 _________ Hz _________ % _________ ms

B1.6.2.3. Frequency control

Is the frequency control function specified in section 6.2.3.2 for categories C and D activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which settings? Frequency threshold - Low (f_{RU}): Frequency threshold - High (f_{RO}): Droop: Desired frequency: ΔP:	 _________ Hz _________ Hz _________ % _________ Hz ________ kW

B1.6.2.4. Absolute power constraint function

Is the absolute power constraint function as specified in section 6.2.4.1.1 for categories C and D activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which value?	_________ kW

B1.6.2.5. Ramp rate constraint function

Is the energy storage facility's ramp rate constraint function as specified in section 6.2.4.2.1 for categories C and D activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which value?	________%P_n/min

B1.6.3. Reactive power control

B1.6.3.1. Q control

Is the Q control function as specified in section 6.3.1.1 for categories C and D activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which set point? (Value differing from 0 kVAr must be agreed with the electricity supply undertaking.)	_________ kVAr

B1.6.3.2. Power factor control

Is the power factor control function as specified in section 6.3.2.1 for categories C and D activated?	Yes ☐ No ☐ Online control ☐
If Yes, with which set point? (Value differing from cosϕ 1.0 must be agreed with the electricity supply undertaking.)	_________ cosϕ Inductive ☐ Capacitive ☐

B1.6.3.3. Voltage control

Is the voltage control function as specified in section 6.3.3.2 for categories C and D activated? (Not to be activated without agreement with the electricity supply undertaking.)	Yes ☐ No ☐ Online control ☐
If Yes, with which set point?	_________ kV

B1.6.4. Protection

Has a list of protective functions and settings at the time of commissioning been enclosed?	Yes ☐ No ☐
If Yes, reference to documentation:	

B1.6.5. Conformity testing

Is documentation of compliance testing enclosed?	Yes ☐ No ☐

B1.6.6. Verification of simulation model

Only for facilities with power output above 10 MW

Is the verification report for the simulation model enclosed?	Yes ☐ No ☐

B1.6.7. Signature

Date	
Installation contractor:	
Person responsible for commissioning	
Signature (person responsible for commissioning)	
Facility owner	
Signature (facility owner)	

Documentation – category SX

B1.7. Documentation for category SX energy storage facilities

Documentation must be filled in with data for the energy storage facility and sent to the electricity supply undertaking.

B1.7.1. Identification

Facility	Description of the facility
GSRN no.	
Facility owner name and address	
Facility owner telephone no.	
Facility owner e-mail	
Inverter – manufacture	
Inverter – model	
Inverter – rated power	
Storage medium – manufacture	
Storage medium – model no.	
Storage medium – usable energy storage capacity [kWh]	

B1.7.2. Signature

Date of commissioning	
Installation contractor	
Person responsible for commissioning	
Signature (person responsible for commissioning)	
Facility owner	
Signature (facility owner)	

Documentation – category T

B1.8. Documentation for category T energy storage facilities

Documentation must be filled in with data for the energy storage facility and sent to the electricity supply undertaking.

B1.8.1. Identification

Facility	Description of the facility
GSRN no.	
Facility owner name and address	
Facility owner telephone no.	
Facility owner e-mail	
Inverter – manufacture	
Inverter – model	
Inverter – rated power	
Storage medium – manufacture	
Storage medium – model no.	
Charger's rated active power, Pnl og Pno [kW]	

B1.8.2. Normal operation

Can the energy storage facility be started and operated continuously within the normal operation range, restricted only by grid protection settings, c.f. requirements in sections Figure 5 or Figure 6? If Yes, reference to documentation:	Yes ☐ No ☐

B1.8.3. Tolerance of frequency deviations

Will the energy storage facility remain connected to the public electricity supply grid during frequency deviations as specified in section 4.1? If Yes, reference to documentation:	Yes ☐ No ☐
Will the facility remain connected in the event of frequency changes of 2.0 Hz/s in the POC? If Yes, reference to documentation:	Yes ☐ No ☐

B1.8.4. Power quality

Please state how each power quality parameter result was achieved.

B1.8.4.1. Rapid voltage changes

Does the energy storage facility comply with the rapid voltage changes threshold specified in section 5.1.1.3? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.8.4.2. DC content

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

B1.8.4.3. Current imbalance

Does the current imbalance at normal operation exceed 16 A? Where to find documentation that this requirement has been met?	Yes ☐ No ☐
If the facility is made up of single-phase energy storage units, have measures been taken to ensure that the above threshold is not exceeded? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.8.4.4. Flicker

Is the flicker contribution for the entire facility below the threshold specified in section 5.1.1.4? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.8.4.5. Harmonics

Are all harmonics for the entire facility below the thresholds specified in section 5.1.1.5? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.8.4.6. Interharmonics

This part must only be filled in for energy storage facilities larger than 50 kW.

Are all interharmonics for the entire energy storage facility below the thresholds specified in section 5.1.1.6? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.8.4.7. Disturbances in the 2-9 kHz range

This part must only be filled in for energy storage facilities larger than 50 kW.

Is the emission of disturbances with frequencies in the 2-9 kHz range lower than 0.2% of rated current I_n as required in section 5.1.1.7? Where to find documentation that this requirement has been met?	Yes ☐ No ☐

B1.8.5. Signature

Date of commissioning	
Installation contractor	
Person responsible for commissioning	
Signature (person responsible for commissioning)	
Facility owner	
Signature (facility owner)	