Requirements of general application resulting from Commission Regulation (EU) 2016/1447 of 26 August 2016 establishing a network code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules (NC HVDC)

PSE S.A.

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Introduction

These requirements of general application resulting from Commission Regulation (EU) 2016/1447 of 26 August 2016 establishing a network code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules (hereinafter: Requirements) constitute a document containing substantive resolutions concerning the technical requirements resulting from NC HVDC[1] and subject to approval by the competent regulatory authority, which PSE S.A. has been obliged to prepare on the basis of NC HVDC and Article 9ga (1) of the Energy Law[2]. In line with NC HVDC, the requirements of general application are to be developed by the system operator within whose territory the connection location is situated, i.e. TSO or DSO, as well as the designated transmission system operator. The Republic of Poland has taken advantage of the possibility of transferring the obligation to establish the requirements of general application from relevant system operators to PSE S.A. as the transmission system operator, referred to in Article 5(9) of NC HVDC. The Requirements developed by PSE S.A. were subject to the process of consultations with DSOs and market participants.

Unless indicated otherwise, articles in this document refer to articles of NC HVDC.

The table below presents abbreviations used in this *Proposal* that have not been directly defined in NC HVDC.

The remaining abbreviations and terms used in the Proposal are consistent with the definitions laid down in NC HVDC.

NC RfG	Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators, OJ EU, 27.4.2016, L112/1.
Relevant system operator	the relevant system operator to whose network an HVDC system is connected
TSO	Transmission System Operator
SSTI	subsynchronous torsional interaction, also referred to as (torsional) subsynchronous hunting (oscillation) in the AC network, resulting in vibrations of mechanical systems of power generating modules connected to that network
PN-EN 50160	Polish version of the standard EN 50160 “Voltage characteristics of electricity supplied by public electricity networks”
PN-EN 60909	Polish version of the standard IEC 60909 “Short-circuit currents in three-phase a.c. systems”

[1] Commission Regulation (EU) 2016/1447 of 26 August 2016 establishing a network code on requirements for grid connection of high voltage direct current systems and direct current-connected power park modules (OJ EU, 8.9.2016, L241/1) (NC HVDC).

[2] Act of 10 April 1997 – Energy Law (Journal of Laws of 2018, item 755, as amended).

Requirements of general application

Article 11(3) – automatic disconnection in the event of frequency disturbances

Without prejudice to the provisions of paragraph 1, the HVDC system shall be capable of automatic disconnection at frequencies lower than 47.5 Hz and higher than 52.0 Hz.

Article 11(4) – admissible active power reduction in the event of frequency disturbances

A frequency drop below 49.0 Hz in the AC network into which an HVDC system feeds active power from another control area shall not be accompanied by a reduction of active power transmitted over the HVDC system in relation to the operation point. However, in the event of a frequency drop below 49.0 Hz in a network from which an HVDC system feeds active power into another control area, the maximum admissible reduction of active power transmitted over the HVDC system in relation to the operation point shall be specified by the relevant TSO individually for each HVDC system, in coordination with other TSOs within whose area the HVDC system is situated.

Article 13(1)(a)(iii) – the maximum time delay in the adjustment of transmitted active power level

An HVDC system shall be capable of adjusting the transmitted active power with a maximum delay of 10 ms upon receipt of request from the relevant TSO.

Article 13(1)(b) – capability to modify the transmitted active power infeed in consequence of disturbances in the AC network

An HVDC system shall be capable of modifying the transmitted active power infeed between the minimum and maximum transmission capacity with a settable gradient within the 1 ÷ 1000 MW/s range in the case of disturbances in one or more AC networks to which it is connected. The initial delay prior to the start of the change shall not be greater than 10 ms from receiving the triggering signal sent by the relevant TSO. The gradient value shall be specified by the relevant TSO individually for each HVDC system.

Article 13(3) – automatic remedial actions of control functions

The control functions of an HVDC system shall be capable of taking automatic remedial actions. The function types, the triggering and blocking functions, shall be specified by the relevant TSO individually for each HVDC system.

Article 14(1) – capability to provide synthetic inertia

An HVDC system shall be capable of providing synthetic inertia in response to frequency changes. The TSO shall have the right to require an HVDC system owner to ensure that the HVDC system has such capability if needed to preserve or restore the operational security of an AC network. If having such capability is possible in economic and technical terms, the HVDC system owner shall not unreasonably withhold consent.

Article 18(1) – reference voltage

Reference 1 pu voltage is established at the following level:

a) 110 kV for the 110 kV network;

b) 220 kV for the 220 kV network;

c) 400 kV for the 400kV network.

Article 18(3) – automatic disconnection in the event of voltage disturbances

An HVDC system shall be capable of automatic disconnection in the even a voltage occurs exceeding the ranges resulting from paragraphs 1 and 2 of NC HVDC. The terms and settings for automatic disconnection shall be agreed between the relevant system operator and the HVDC system owner, in coordination with the relevant TSO, individually for each HVDC system.

Article 19(1) – fast fault current (symmetrical faults)

An HVDC system shall have the capability to provide fast fault current at a connection point in case of symmetrical 3-phase faults in an AC network.

Article 19(3) – fast fault current (asymmetrical faults)

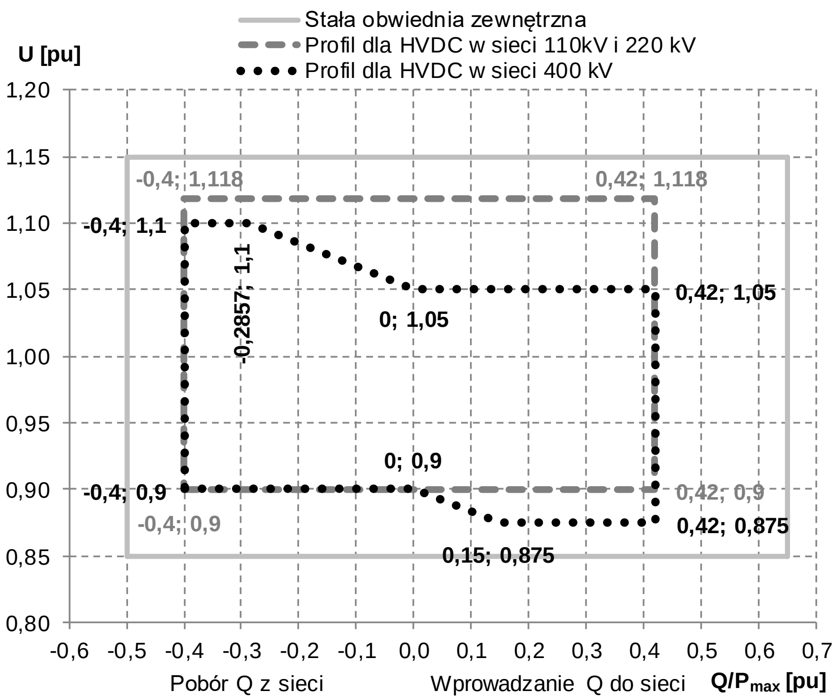
An HVDC system shall have the capability to provide asymmetrical fast fault current injection at a connection point in the case of asymmetrical (1-phase or 2-phase) faults in an AC network. The requirements concerning the method and conditions for determining the beginning and end of voltage deviation at the connection point of an HVDC system shall be specified individually for each HVDC system pursuant to Article 19(2)(a) of NC HVDC, with voltage control to be provided separately for each phase. The requirements concerning the characteristics, timing and accuracy of the fast fault current shall be specified individually for each HVDC system pursuant to Article 19(2)(b) and (c) of NC HVDC, with the injection of fast fault current to be limited only to the fault-affected phase(s).

Article 20(1) – capability of reactive power exchange with the AC network

An HVDC converter station shall have the capability to ensure reactive power exchange with the AC network with the maximum active power transmission capacity of the HVDC system within the boundary of the U-Q/Pmax-profile shown in the figure below. It should be possible to control reactive power autonomously and in coordination with AC network voltage and master reactive power control systems.

The relevant system operator shall have the right to modify the presented range of the U-Q/Pmax-profile (within the limits of the maximum values and fixed outer envelope provided for in NC HVDC), should such need be demonstrated by an expert opinion concerning the impact of a connected HVDC system on the power system.

U-Q/P_{max} profiles referred to in Article 20.



Stała obwiednia zewnętrzna	Fixed outer envelope
Profil dla HVDC w sieci 110 kV i 220 kV	Profile for HVDC in 110 kV and 220 kV network
Profil dla HVDC w sieci 400 kV	Profile for HVDC in 400 kV network
Pobór Q z sieci	Q consumption from network
Wprowadzanie Q do sieci	Q injection into network

Figure: U-Q/P_{max} profiles for HVDC systems, by voltage level at the connection point, where: U – voltage at connection point, Q/P_{max} – ratio of reactive power provided by the system for the AC network to its maximum active power transmission capacity.

Maximum range of Q/P_{max}	Maximum range of steady-state voltage values (pu)
0.82	0.225

Table: Inner envelope parameters in the above figure.

Article 22(1) – reactive power control modes

An HVDC converter station shall be capable of operating in the following control modes:

a) voltage control mode;

b) reactive power control mode;

c) power factor control mode.

Article 22(3)(a) – set voltage for the voltage control mode

It shall be possible to set a setpoint voltage at the connection point for the voltage control mode at an HVDC converter station in a continuous manner within the ranges specified in Article 18(1) or Article 18(2) of NC HVDC, taking into account rated voltage of the AC network at the connection point. Settings shall be specified by the relevant system operator, in coordination with the relevant TSO, individually for each HVDC converter station.

Article 22(3)(b) – voltage control deadband

In the voltage control mode, an HVDC converter station shall be capable of voltage control at a connection point with or without a deadband around the setpoint specified pursuant to Article 22(3)(a) of NC HVDC, selectable in a range from 0 to ±5% of reference voltage specified pursuant to Article 18(1) of NC HVDC, adjustable in 0.1% steps. The settable deadband value shall be specified by the relevant system operator individually for each HVDC system.

Article 22(3)(c)(i) – voltage control dynamics (time t_1)

In the voltage control mode, an HVDC converter station shall be capable of achieving 90% of the change in reactive power exchange with an AC network, and consequently a step change in voltage at a connection point as quickly as technically possible, provided that the time should not exceed t1 = 5s.

Article 22(3)(c)(ii) – voltage control accuracy and dynamics (time t_1)

In the voltage control mode, an HVDC converter station shall be capable of achieving a reactive power exchange with an AC network settled at the value specified by the operating slope in consequence of a step change in voltage at a connection point, as quickly as technically possible, provided that the time should not exceed t_2 = 6 s, with a steady-state tolerance not greater than 5% of the maximum reactive power or 5 Mvar (whichever value is lower).

Article 22(3)(d) – range and step of voltage control

In the voltage control mode, an HVDC converter station shall be capable of voltage control at a connection point in accordance with a control characteristic whose slope is specified by an adjustable range between 2 and 7% and an adjustable step not exceeding 0.5%.

Article 22(6) – remote reactive power control

An HVDC system shall be capable of providing the capability of remote selection of reactive power control modes and relevant settings. As part of the capability to operate in coordination with a master voltage and reactive power control system of the AC network, it is necessary to provide:

a) the capability of the voltage and reactive power control system of an HVDC system to receive for execution information on a change of the reactive power control mode and a change of the active control mode settings;

b) the change of the reactive power control mode and change of the active control mode settings by the HVDC in real time (on-line);

c) an appropriate communication channel dedicated to a voltage and reactive power master control system.

Devices ensuring remote coordination with a voltage and reactive power master control system shall meet the requirements for communication standards, protocols and data transmission adopted by the relevant system operator.

Article 24 – the maximum admissible level of voltage distortion or fluctuation at a connection point

The HVDC system owner shall ensure that the connection of its system to the AC network does not result in a level of voltage distortion or fluctuation in the network (calculated at the connection point):

1. the HVDC system shall not cause any abrupt voltage changes or surges at the connection point exceeding 3%. Where such distortions are of a repetitive nature, the admissible levels and frequencies of abrupt voltage changes and steps triggered by the operation of the HVDC system shall be specified by the relevant system operator individually for each HVDC system;
2. the share of an HVDC system connected to a meshed network in total voltage fluctuations, measured by the increase in the value of short-term (Pst) and long-term (Plt) flicker severity factor above the background value should not exceed:
    a. Pst < 0.35 for 110 kV networks and Pst < 0.30 for 220 kV and 400 kV networks;
    b. Plt < 0.25 for 110 kV networks and Plt < 0.20 for 220 kV and 400 kV networks;
3. an HVDC system shall not cause the presence of voltage harmonics with values exceeding the limits referred to in PN-EN 50160 ”Voltage characteristics of electricity supplied by public electricity networks”;

The values of power quality ratios stated above shall be met for a weekly period with a probability of 99%.

The HVDC system shall be equipped with a power quality measurement and recording system (measurement of RMS voltage and current levels, voltage fluctuation, and voltage and current harmonics in measurement class A) and a system for data transmission to the relevant system operator.

It the event the HVDC system fails to meet the above power quality standards, it may be shut down on instruction from the relevant system operator until the irregularities are eliminated.

Article 25(1) – voltage profile of the required HVDC system operation area during a symmetrical fault in the AC network

An HVDC converter station shall be capable of staying connected to the AC network during a symmetrical fault within the network and continuing stable operation after the network has recovered following fault clearance.

The capability concerns faults for which phase-to-phase voltages at a connection point are not lower than the voltage-against-time profile specified below:

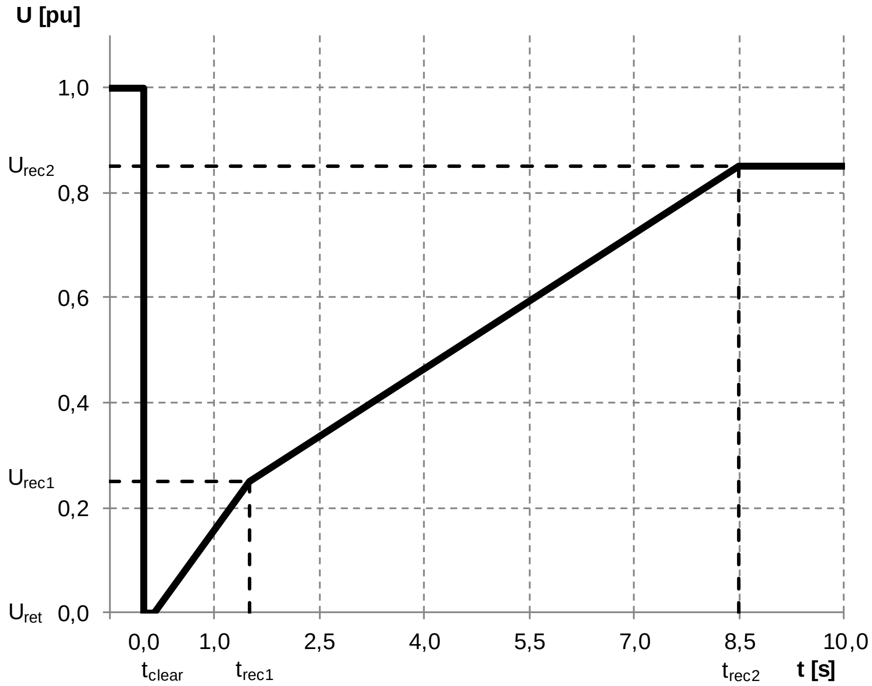


Figure: Fault-ride-through profile of an HVDC converter station. Uret – voltage at connection point during a fault; tclear – time of fault clearance in the AC network; Urec1 and trec1 – points of lower limits of voltage recovery following fault clearance; Urec1 and trec2 – points of upper limits of voltage recovery following fault clearance;

Voltage parameters [pu]		Time parameters [s]	
Uret	0.00	tclear	0.15
Urec1	0.25	trec1	1.5
Urec2	0.85	trec2	8.5

Table: Parameters referring to HVDC converter station fault ride through capability in an AC network.

Article 25(6) – capability to ride through an asymmetrical fault in an AC network

An HVDC converter station shall be capable of staying connected to the AC network during an asymmetrical (1- or 2-phase) fault within the network and continuing stable operation after the network has recovered following fault clearance. The capability concerns faults for which phase-to-phase voltages at a connection point are not lower than the voltage-against-time profile determined pursuant to Article 25(1) of NC HVDC, but the HVDC may disconnect from the network during a fault if at least one of the phase-to-phase voltages drops below that profile.

Article 26 – post-fault recovery of transmitted active power

The HVDC system shall be capable of providing the recovery, after fault clearance in an AC network, of active power transmission at the level of at least 90% of the pre-fault value with a gradient defined pursuant to Article 13(1)(b) of NC HVDC (provided that the HVDC system stays connected to the AC network and no switching problems occur at the converter stations of the HVDC system). Post-fault active power recovery should start immediately when voltage at the connection point returns to 90% of the pre-fault value.

Article 28 – energisation and synchronisation of HVDC converter stations

An HVDC converter station shall have the capability to limit any voltage changes during its energisation or synchronisation to the AC network or during the connection of an energised HVDC converter station to an HVDC system, to a level resulting from the voltage control deadband defined pursuant to Article 22(3)(b) of NC HVDC, within a time period not longer than that resulting from the voltage control dynamics specified pursuant to Article 22(3)(c)(ii) of NC HVDC, with a measurement window not shorter than the time t2 specified pursuant to Article 22(3)(c)(ii) of NC HVDC.

Article 30 – power oscillation damping capability

The HVDC system shall be capable of contributing to the damping of power oscillations in connected AC networks, with frequencies up to 5 Hz through management of the level of power transmitted by the system.

Article 31(2) – subsynchronous torsional interaction studies

The HVDC system owner shall carry out SSTI studies in the AC network to which the HVDC system is to be connected, identifying:

a. the AC equipment necessary to perform the study;

b. SSTI occurrence conditions;

c. SSTI sources (in particular the share of the HVDC in SSTI);

d. SSTI extent.

Specific conditions for the study shall be specified by the HVDC system owner and agreed with the TSO.

The scope of the study shall include the identification and assessment of threats to equipment connected to the network and the proposal and performance assessment of remedial measures.

Article 32(1) – method for the calculation of the minimum and maximum short circuit power at a connection point

Short-circuit calculations shall be made taking into account the provisions of the standard PN-EN 60909 “Short-circuit currents in three-phase a.c. systems”. For the purposes of calculation of the maximum short circuit power at connection points of the HVDC system, the AC network configuration should be assumed with all generating plants (or at least all conventional generating plants connected to the meshed network) active and divisions/bus bar couplers closed at network nodes (or at least in the immediate vicinity of the planned connection point of the HVDC system), while observing secure operational conditions of the network. For the purposes of calculation of the minimum short circuit power at connection points of the HVDC system, the AC network configuration should be assumed with the smallest possible number of active generating plants and divisions/bus bar couplers open at network nodes, while preserving the integrity of the network and satisfying consumers’ power demand.

Article 32(2) – AC network characteristics

HVDC systems connected to an AC network shall be capable of operating:

a) within the frequency ranges and in periods specified pursuant to Article 11(1) or (2) of NC HVDC;

b) at a voltage at the connection point within the range specified pursuant to Article 18(1) or (2) of NC HVDC;

c) within the short circuit power range at their connection point specified pursuant to Article 32(1) of NC HVDC, taking into account the required short-circuit withstand at 3-phase and 1-phase faults and the admissible earth fault coefficient (defined as the ratio of the maximum value of phase voltage during a phase-to-earth fault to the rated value of phase voltage at a given network point) equal 1.3 (for 220 kV and 400 kV networks) and 1.4 (for 110 kV networks).

Additional requirements defining the operational capability of HVDC systems, characteristic of their connection points to the AC network, shall be specified by the relevant system operator individually for each HVDC system.

Article 33(2) – voltage changes in the AC network during connection or disconnection

The admissible limit of voltage transients at the connection point, triggered by tripping or disconnection of an HVDC converter station, as part of any multi-terminal or embedded HVDC system, shall be specified by the relevant TSO individually for each HVDC system, the value of which shall not exceed 3% of the voltage existing before tripping or disconnection of the HVDC converter station, taking into account the requirements specified pursuant to Article 24 and Article 28.

Article 35(2) – prioritisation of protection and control

The HVDC system owner shall organise the functionality and settings of its protection and control systems in compliance with the following priority ranking, listed in decreasing order of importance:

a) AC network and HVDC system protection;

b) active power control for emergency assistance;

c) synthetic inertia, if applicable;

d) automatic remedial actions as specified in Article 13(3);

e) LFSM;

f) FSM and frequency control;

g) power gradient constraint.

Article 36(1) – changes to protection and control modes and settings

The HVDC system shall be capable of changing the settings of control modes and protection settings in the HVDC converter station.

Article 36(3) – remote changes to control modes and settings

The HVDC system shall provide the capability of changing of control modes and settings remotely from the load dispatch centres of the relevant system operator or the relevant TSO.

Article 39(1)(b) – coordinated frequency control

If the TSO decides, pursuant to the provisions of Article 16(1), to equip the HVDC system with an independent control mode to modulate the active power output of the HVDC converter station depending on frequencies, DC-connected power park modules connected via HVDC systems which connect with more than one control area shall be capable of delivering coordinated frequency control.

Article 40(1)(c) – automatic disconnection in the event of voltage disturbances

A DC-connected power park module which has an HVDC interface point to a remote-end HVDC converter station network, shall be capable of automatic disconnection if a voltage occurs in the HVDC interface which exceeds the ranges resulting from points (a) and (b). The terms and settings for automatic disconnection shall be agreed between the relevant system operator and the HVDC system owner, the relevant TSO and the DC-connected power park module owner individually for each DC-connected power park module.

Article 40(2)(b)(i) – reactive power capability

DC-connected power park modules shall have the reactive power capability, in the context of varying voltage at the connection point, with the U-Q/Pmax-profile shape determined in accordance with Article 21(3)(b)(i) of NC RfG. Modifications of the U-Q/Pmax-profile, with ranges in accordance with Table 11, Annex VII of NC HVDC, shall be specified individually for each plant between the relevant TSO, the relevant system operator and the DC-connected power park module owner, if necessary to preserve or restore operational security of the AC network.

If modification of the U-Q/Pmax-profile is possible in economic and technical terms, the DC-connected power park module owner shall not unreasonably withhold consent.

Article 40(2)(b)(ii) – supplementary reactive power

Supplementary reactive power shall be provided for DC-connected power park modules the connection point of which is neither located at the high-voltage terminals of the step-up transformer to the voltage level of the connection point nor at the alternator terminals, if no step-up transformer exists.

The power value shall be specified by the relevant system operator individually for each DC-connected power park module.

Article 41(1) – synchronisation to the AC network

A DC-connected power park module shall have the capability to limit any voltage changes during its synchronisation to the AC network to a level not exceeding 5% of the pre-synchronisation voltage, within a time period not longer than that resulting from the voltage control dynamics specified pursuant to Article 21(3)(d)(iv) of NC RfG, with a measurement window not shorter than the time t2 specified pursuant to Article 21(3)(d)(iv) of NC RfG.

Article 41(2) – output signals

The DC-connected power park module owner shall provide output signals in accordance with those specified pursuant to Article 14(5)(d)(ii) of NC RfG.

Article 42(a) – method for the calculation of the minimum and maximum short circuit power at a connection point

Short-circuit calculations shall be made taking into account the standard PN-EN 60909 "Short-circuit currents in three-phase a.c. systems". For the purposes of calculation of the maximum short circuit power at the HVDC interface point, the AC network configuration should be assumed with all generating plants (or at least all conventional generating plants connected to the meshed network) active and divisions/bus barcouplers closed at network nodes (or at least in the immediate vicinity of the planned HVDC interface point), while observing secure operational conditions of the network.

For the purposes of calculation of the minimum short circuit power at the HVDC interface point, the AC network configuration should be assumed with the smallest possible number of active generating plants and divisions/bus bar couplers open at network nodes, while preserving the integrity of the network and satisfying consumers' power demand.

Article 42(b) – AC network characteristics

DC-connected power park modules shall be capable of stable operation:

a) within the frequency ranges in the AC network and within the periods specified pursuant to Article 39(2)(a) or (b) of NC HVDC;

b) at the HVDC interface point voltage within the range specified pursuant to Article 40(1)(a) or (b) of NC HVDC;

c) within the short circuit power range at their connection point specified pursuant to Article 42(a) of NC HVDC, taking into account the required short-circuit withstand capability at 3-phase and 1-phase faults and the admissible earth fault coefficient (defined as the ratio of the maximum value of phase voltage during a phase-to-earth fault to the rated value of phase voltage at a given network point) equal 1.3 (for 220 kV and 400 kV networks) and 1.4 (for 110 kV networks).

Additional requirements defining the capability of DC-connected power park modules to operate, characteristic of the location of their HVDC interface point, shall be specified by the relevant system operator individually for each DC-connected power park module.

Article 44 – voltage changes in the AC network during connection

The DC-connected power park module owner shall ensure that connection of its module to the AC network does not result in voltage distortion or fluctuation in the network (as calculated at the connection point):

1. the DC-connected power park module shall not cause abrupt voltage changes or spikes at the connection point exceeding 3%.

   Where such distortions are of a repetitive nature, the admissible levels and frequencies of abrupt voltage changes and steps triggered by the operation of the DC-connected power park module shall be specified by the relevant system operator individually for each module;

2. the share of the DC-connected power park module connected to a meshed network in total voltage fluctuations, measured by the increase in the value of short-term (Pst) and long-term (Plt) flicker severity factor above the background value should not exceed:
   a. Pst < 0.35 for 110 kV networks and Pst < 0.30 for 220 kV and 400 kV networks;
   b. Plt < 0.25 for 110 kV networks and Plt < 0.20 for 220 kV and 400 kV networks;
3. the DC-connected power park module shall not cause the presence of voltage harmonics with values exceeding the limits referred to in the standard PN-EN 50160 ”Voltage characteristics of electricity supplied by public electricity networks”;

The values of power quality ratios stated above shall be met for a weekly period with a probability of 99%.

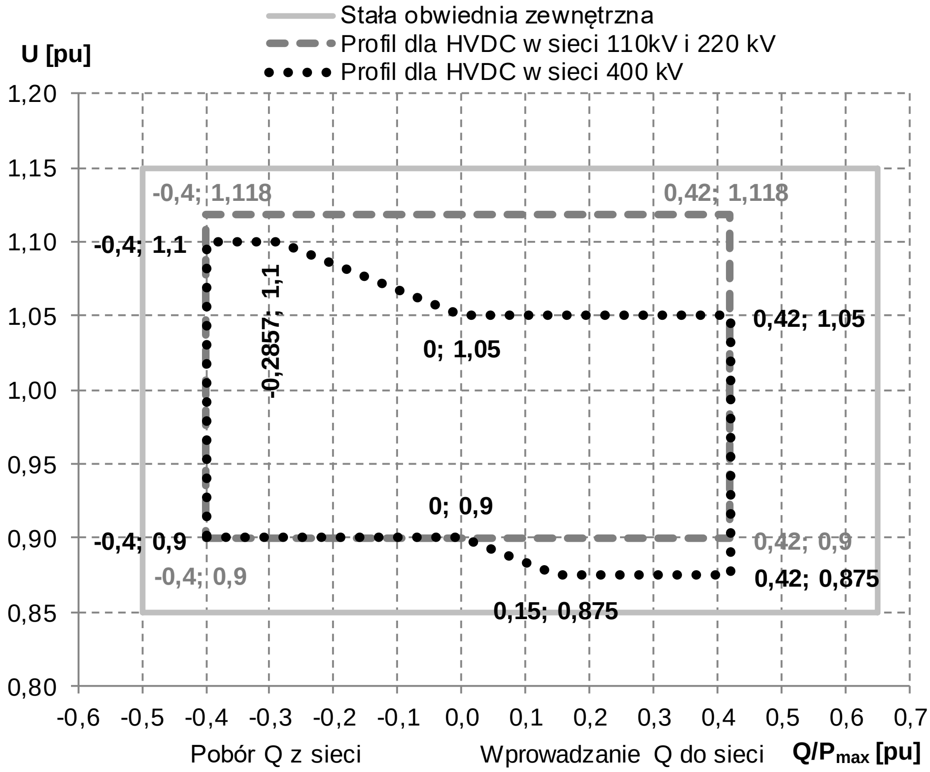
DC-connected power park modules shall be equipped with a power quality measurement and recording system (measurement of RMS voltage and current levels, voltage fluctuation, and voltage and current harmonics in measurement class A) and a system for data transmission to the relevant system operator.

In the event the DC-connected power park module fails to meet the above power quality standards, it may be shut down on instruction from the relevant system operator until the irregularities are eliminated.

Article 48(2)(a) and (b) – capability to ensure reactive power exchange with the AC network

A remote-end HVDC converter station shall have the capability to ensure reactive power exchange with the AC network with the maximum HVDC active power transmission capacity within the boundary of the U-Q/Pmax-profile shown in the chart below. It should be possible to control reactive power autonomously and in coordination with AC network voltage and reactive power master control systems. The relevant system operator reserves the right to modify the presented range of the U-Q/Pmax-profile (within the limits of the maximum values and fixed outer envelope provided for in Table 14 of Annex VIII to NC HVDC), should such need be demonstrated by an expert opinion concerning the impact of a connected remote-end HVDC converter station on the power system.

U-Q/Pmax-profiles referred to in Article 48.



Stała obwiednia zewnętrzna	Fixed outer envelope
Profil dla HVDC w sieci 110 kV i 220 kV	Profile for HVDC in 110 kV and 220 kV network
Profil dla HVDC w sieci 400 kV	Profile for HVDC in 400 kV network
Pobór Q z sieci	Q consumption from network
Wprowadzanie Q do sieci	Q injection into network

Figure: U-Q/Pmax-profile at remote-end HVDC converter station. U – voltage at connection point, Q/Pmax – ratio of reactive power provided by the system for the AC network to its maximum active power transmission capacity.

Maximum range of Q/Pmax	Maximum range of steady-state voltage values (pu)
0.82	0.225

Table: Maximum range of both Q/Pmax and steady-state voltage for a remote-end HVDC converter station.

Article 50 – voltage changes in the AC network during connection

The remote-end HVDC converter station owner shall ensure that connection of its station to the AC network does not result in voltage distortion or fluctuation in the network (as calculated at the connection point):

1. the remote-end HVDC converter station shall not cause any abrupt voltage changes or surges at the connection point exceeding 3%. Where such distortions are of a repetitive nature, the admissible levels and frequencies of abrupt voltage changes and surges triggered by the operation of the remote-end HVDC converter station shall be specified by the relevant system operator individually for each remote-end HVDC converter station, individually for each remote-end HVDC converter station;
2. the share of the remote-end HVDC converter station connected to a meshed network in total voltage fluctuations, measured by the increase in the value of short-term (Pst) and long-term (Plt) flicker severity factor above the background value should not exceed:
    a. Pst < 0.35 for 110 kV networks and Pst < 0.30 for 220 kV and 400 kV networks;
    b. Plt < 0.25 for 110 kV networks and Plt < 0.20 for 220 kV and 400 kV networks;
3. the remote-end HVDC converter station shall not cause the presence of voltage harmonics with values exceeding the limits referred to in PN-EN 50160 ”Voltage characteristics of electricity supplied by public distribution systems”;

The values of power quality ratios stated above shall be met for a weekly period with a probability of 99%.

Remote-end HVDC converter stations shall be equipped with a system for the measurement and recording of power quality parameters (measurement of RMS voltage and current levels, voltage fluctuation, and voltage and current harmonics in measurement class A) and a system for data transmission to the relevant system operator;

It the event the remote-end HVDC converter station fails to meet the above power quality standards, it may be shut down on instruction from the relevant system operator until the irregularities are eliminated.

Article 51(1) – prioritisation of protection and control of an HVDC converter unit

The HVDC system owner shall organise the functionality and settings of its protection and control system ensuring the following priority ranking, listed in decreasing order of importance:

a) actions to ensure that the HVDC system rides through faults in the AC network, including fast fault current;

b) actions to preserve or restore operational security of the AC network, including active power control for emergency assistance (e.g., synthetic inertia, power output oscillation damping, subsynchronous torsional interaction damping), frequency support (FSM, LFSM-O, LFSM-U);

c) voltage and reactive power control in coordination with AC network voltage and reactive power master control systems, including remote change of control modes and parameters;

d) reactive power control in coordination with AC network voltage master control systems, including remote change of control modes;

e) local voltage and reactive power control and active power control;

f) post-failure actions to restore the AC network, including black start.

Article 53(4) – oscillation detection trigger

HVDC system recording and dynamic behaviour monitoring equipment shall include an oscillation trigger for the detection of poorly damped active power oscillations at frequencies within a range specified pursuant to Article 30 of NC HVDC. The trigger shall be activated upon exceeding a preset admissible threshold of active power transmitted by the HVDC system, with a simultaneous control of the oscillation damping factor. The settings of alarm activation criteria shall be specified by the relevant system operator in coordination with the relevant TSO, individually for each HVDC system.

Article 54(1) – delivery of simulation models

The HVDC system owner shall deliver to the relevant system operator simulation models that properly reflect the behaviour of the HVDC system in symmetrical and asymmetrical states in both steady-state simulations and dynamic simulations (for 50 Hz frequency) and in electromagnetic transient simulations.

In the case of change of the HVDC system parameters, the system owner shall deliver to the relevant system operator updated simulation models. Unless the TSO or the relevant system operator decides otherwise, the format of delivery of the models and related documentation shall be in compliance with CGMES 2.4.15 or newer standard.

The documentation shall fully specify the structure and functionality of model components, while respecting the provisions of paragraph 2.

Article 54(5) – equivalent model of the control system for identified control interactions

The HVDC system owner shall deliver a control system model when adverse control interactions may result with HVDC converter stations and other connections in close electrical proximity. The model shall contain all necessary data for the realistic simulation of the adverse control interactions, taking into account the requirements arising from Article 29(1) and Article 54(1) of NC HVDC.

Annex I Table 1 – frequency ranges

Frequency ranges referred to in Article 11.

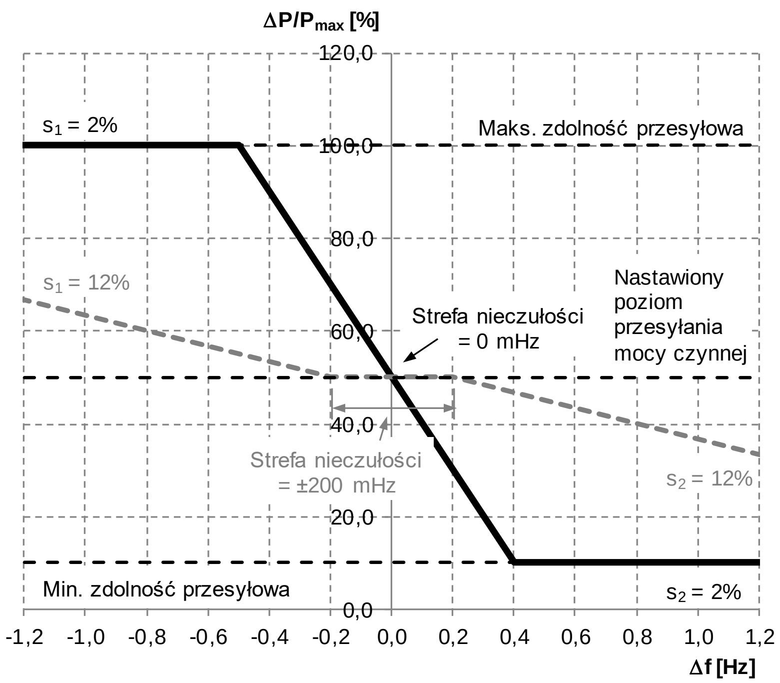
Frequency range	Time period for operation
47.0 Hz - 47.5 Hz	60 s
47.5 Hz - 52.0 Hz	Unlimited

Table: Minimum time periods an HVDC system shall be able to operate for different frequencies deviating from a nominal value without disconnecting from the network.

Annex II (A)(1)(a) – FSM control parameters

The HVDC system shall be capable of responding to frequency deviations in each connected AC network by adjusting the active power transmission as indicated in the figure below and in accordance with the parameters specified in the table below.

Within the ranges stated, the ability to select and set the frequency response deadband and the droops s1 and s2 shall be ensured.



Maks. zdolność przesyłowa	Max transmission capacity
Strefa nieczułości	Deadband
Nastawiony poziom przesyłania mocy czynnej	Preset active power transmission level

Figure: Active power frequency response capability of HVDC systems in FSM illustrating the cases of zero deadband and droops s1 and s2 (for illustration purposes, the minimum active power transmission capacity of the system has been assumed equal to 10% and the set level of active power transmission by the system equal to 50%; the illustration concerns the active power frequency response capability of HVDC systems in FSM for insensitivity with a positive active power setpoint – import mode).

Parameters	Ranges
Frequency response deadband	0 ÷ ±200 mHz
Droop s1 (upward regulation)	2 ÷ 12%
Droop s2 (downward regulation)	2 ÷ 12%
Frequency response insensitivity	±10 mHz

Table: Parameters for active power frequency response in FSM.

Annex II (A)(1)(d)(ii) – FSM control parameters

Control time ranges referred to in area A(1)(d)(ii).

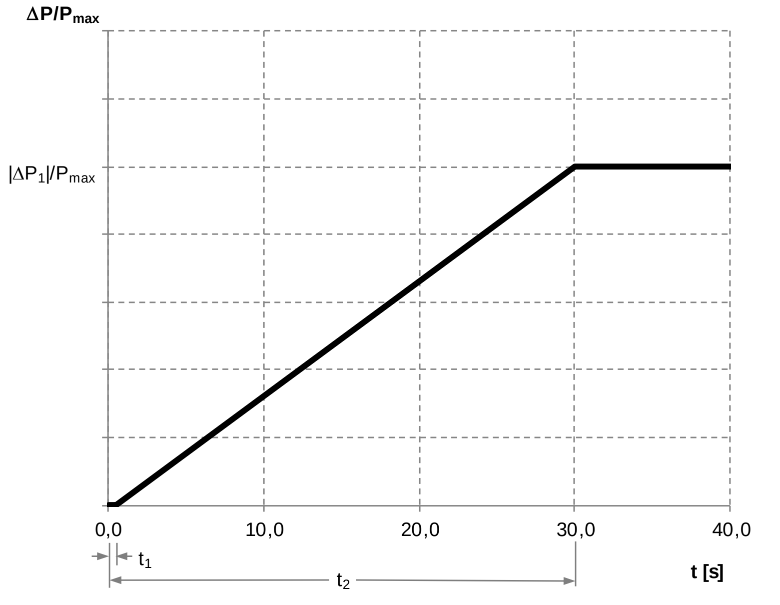


Figure: Active power frequency response capability of HVDC systems in FSM.

Parameters	Time
Maximum admissible initial delay t1	0.5 s

Maximum admissible time for full activation t2	30 s

Table: Parameters for full activation of active power frequency response resulting from frequency step change.

Annex II (B)(1)(c) – control parameters in LFSM-O

When operating in limited frequency sensitivity mode - over frequency, the HVDC system shall be capable of adjusting active power frequency response as quickly as technically possible, with the maximum admissible initial delay of 0.5 s and the maximum admissible time for full activation of 30 s.

Annex II (B)(2) – control parameters in LFSM-O

When operating in limited frequency sensitivity mode – overfrequency, the HVDC system shall be capable of adjusting active power frequency response to the AC network or networks, during both import and export, according to the figure below, at a frequency threshold f1 in the 50.2 ÷ 50.5 Hz range, with a droop S3 in the 2 ÷ 12% range. Within the ranges stated, the ability to select and set the frequency response threshold f1 and droop s3 shall be ensured.

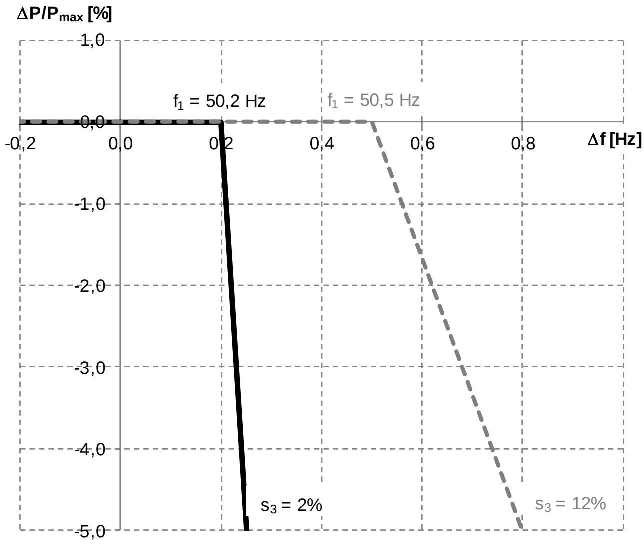


Figure: Active power frequency response capability of HVDC systems in LFSM-O illustrating the cases of extreme values of frequency f1 and droop s3.

Annex II (C)(1)(c) – control parameters in LFSM-U

When operating in limited frequency sensitivity mode - underfrequency, the HVDC system shall be capable of adjusting active power frequency response as quickly as technically possible, with the maximum admissible initial delay of 0.5 s and the maximum admissible time for full activation of 30 s.

Annex II (C)(2) – control parameters in LFSM-U

When operating in limited frequency sensitivity mode - underfrequency, the HVDC system shall be capable of adjusting active power frequency response to the AC network or networks, during both import and export, according to the figure below, at a frequency threshold f2 in the 49.8 ÷ 49.5 Hz range, with a droop s4 in the 2 ÷ 12% range. Within the ranges stated, the ability to select and set the frequency response threshold f2 and droop s3 shall be ensured.

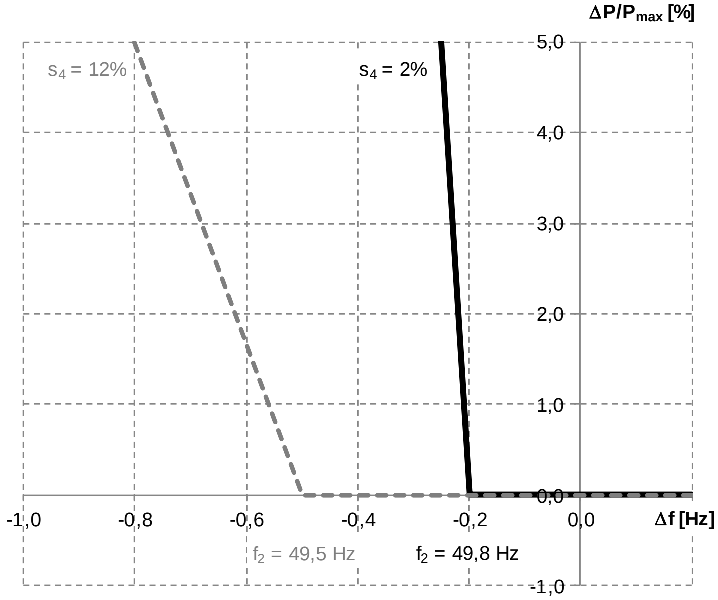


Figure: Active power frequency response capability of HVDC systems in LFSM-U illustrating the cases of extreme values of frequency f2 and droop s4.

Annex III Table 4 – voltage ranges for HVDC system connected to 110 kV and 200 kV networks

Voltage ranges referred to in Article 18.

Voltage range	Time period for operation
1.118 ÷ 1.15 pu	60 minutes

Table: Minimum time periods an HVDC system shall be capable of operating for voltages deviating from the reference 1 pu value at the connection points without disconnecting from the AC network, limited to HVDC systems connected to 110 kV and 220 KV networks.

Annex III Table 5 – voltage ranges for HVDC system connected to 400 kV networks

Voltage ranges referred to in Article 18.

Voltage range	Time period for operation
1.05 pu ÷ 1.0875 pu	60 minutes

Table: Minimum time periods an HVDC system shall be capable of operating for voltages deviating from the reference 1 pu value at the connection points without disconnecting from the AC network, limited to HVDC systems connected to 400 kV networks.

Annex VII Table 9 – voltage ranges for DC-connected power park modules connected to 110 kV and 200 kV networks

Voltage ranges referred to in Article 40.

Voltage range	Time period for operation
1.118 pu ÷ 1.15 pu	60 minutes

Table: Minimum time periods for which a DC-connected power park module shall be capable of operating for different voltages deviating from a reference 1 pu value without disconnecting from the AC network, limited to DC-connected power park modules connected to 110 kV and 220 kV networks.

Annex VII Table 10 – voltage ranges for DC-connected power park modules connected to 400 kV

Voltage ranges referred to in Article 40.

Voltage range	Time period for operation
1.05 pu ÷ 1.10 pu	60 minutes
1.10 pu ÷ 1.15 pu	No minimum time period for operation is defined

Table: Minimum time periods for which a DC-connected power park module shall be capable of operating for different voltages deviating from a reference 1 pu value without disconnecting from the AC network, limited to DC-connected power park modules connected to 400 kV networks.

Annex VIII Table 12 – voltage ranges for remote-end HVDC converter stations connected to 110 kV and 200 kV networks

Voltage ranges referred to in Article 40.

Voltage range	Time period for operation
1.10 pu ÷ 1.12 pu	Unlimited
1.12 pu ÷ 1.15 pu	60 minutes

Table: Minimum time periods for which a remote-end HVDC converter station shall be capable of operating for different voltages deviating from a reference 1 pu value without disconnecting from the AC network, limited to remote-end HVDC converter stations connected to 110 kV and 220 kV networks.

Annex VIII Table 13 – voltage ranges for remote-end HVDC converter stations connected to 400 kV networks

Voltage ranges referred to in Article 40.

Voltage range	Time period for operation
1.05 pu ÷ 1.10 pu	60 minutes
1.10 pu ÷ 1.15 pu	No minimum time period for operation is defined

Table: Minimum time periods for which a remote-end HVDC converter station shall be capable of operating for different voltages deviating from a reference 1 pu value without disconnecting from the AC network, limited to remote-end HVDC converter stations connected to 400 kV networks.