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)

April 2025

Disclaimer for the English translation of *Wymogi ogólnego stosowania wynikające z rozporządzenia Komisji (UE) 2016/1447 z dnia 26 sierpnia 2016 r. ustanawiającego kodeks sieci określający wymogi dotyczące przyłączenia do sieci systemów wysokiego napięcia prądu stałego oraz modułów parku energii z podłączeniem prądu stałego (NC HVDC)*

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Introduction and scope of application

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. Pursuant to Article 5(9) of NC HVDC, the Republic of Poland has transferred the obligation to establish the requirements of general application from the relevant system operators to PSE S.A. as the transmission system operator. The Requirements developed by PSE S.A. were subject to the process of consultations with DSOs and market participants.

The President of the Energy Regulatory Authority (Urząd Regulacji Energetyki - URE), by decision of 20 March 2019, ref. DRE.WOSE.7128.384.4.2018.2019.ZJ, approved the document "Requirements for 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)", hereinafter "**Requirements 2019**".

At the request of the TSO, after working out the changes and consulting them with market participants, including the DSOs, the President of URE approved the updated requirements of general application presented in this document titled: "Requirements of general application arising 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) – April 2025" hereinafter "**Requirements 2025**".

The date of entry into force of **Requirements 2025** has been set for 6 months after the publication in the Public Information Bulletin of the Energy Regulatory Office of the decision of the President of URE to amend the decision of 20 March 2019, ref. DRE.WOSE.7128.384.4.2018.2019.ZJ.

Requirements 2025 shall apply to HVDC systems and DC-connected power generation modules:

a) for which connection conditions will be issued after the entry into force of **Requirements 2025**; or

b) in the event of notification to the relevant system operator of modernisation or replacement affecting changes to the existing technical parameters of an HVDC system or DC-connected power park module, necessitating a significant amendment to the connection agreement in accordance with Article 4(1)(a) of NC HVDC, after the date of entry into force of **Requirements 2025**, as appropriate to the extent of the modernisation or overhaul.

Requirements 2019 shall apply to other HVDC systems and DC connected power generating modules subject to NC HVDC requirements, to which **Requirements 2025** do not apply.

For cases not listed above, the scope of application of the NC HVDC requirements of general application shall be specified in the connection agreement.

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

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[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 2024, item 266, as amended).

The table below presents abbreviations used in these Requirements that are not directly defined in NC HVDC. The abbreviations and terms used in the Requirements 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
IEC 60909	Polish version of the standard IEC 60909 “Short-circuit currents in three-phase a.c. systems”

Requirements of general application

Article 3(2) – scope of application of requirements for a DC-connected power park with a single connection point to a transmission network or distribution network which is not part of a synchronous area

The provisions of NC HVDC together with documents developed pursuant to NC HVDC shall apply to DC-connected power park modules with a single connection point to a transmission network or distribution network which is not part of a synchronous area, referred to in Article 3(2) of NC HVDC.

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 unless the relevant TSO and HVDC system owner have agreed on wider frequency ranges in accordance with Article 11(2) of NC HVDC. Then the frequencies at which the HVDC system must have automatic disconnection capability shall be determined by the TSO on a case-by-case basis.

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)(i) – power step size for adjusting the transmitted active power

The HVDC system shall be capable of modifying the set transmitted active power in the range from minimum to maximum active power transmission capacity in 0.1 MW steps with an adjustable gradient in the range of 1 ÷ 1000 MW/min in 0.1 MW/min steps in both directions.

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

An HVDC system shall be capable of starting a change in the transmitted active power with a maximum delay of 100 ms upon receipt of an instruction from the relevant TSO.

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

The HVDC system shall be capable of modifying the set transmitted active power infeed in the range from minimum to maximum active power transmission capacity with an adjustable gradient in the range of 1 ÷ 1000 MW/s in 1 MW/s steps in both directions in case of disturbances in one or more AC networks to which it is connected.

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 criteria shall be specified by the relevant TSO individually for each HVDC system.

Article 14(1) – capability to provide synthetic inertia

The HVDC shall be capable of providing synthetic inertia by rapidly adjusting the active power injected to or withdrawn from the AC network in order to limit the rate of change of frequency.

Article 16 (1) – frequency control capability

The HVDC system shall be equipped with an independent control mode to modulate the active power output of the HVDC converter station.

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 400 kV network.

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

An HVDC system shall be capable of automatic disconnection in the event 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)

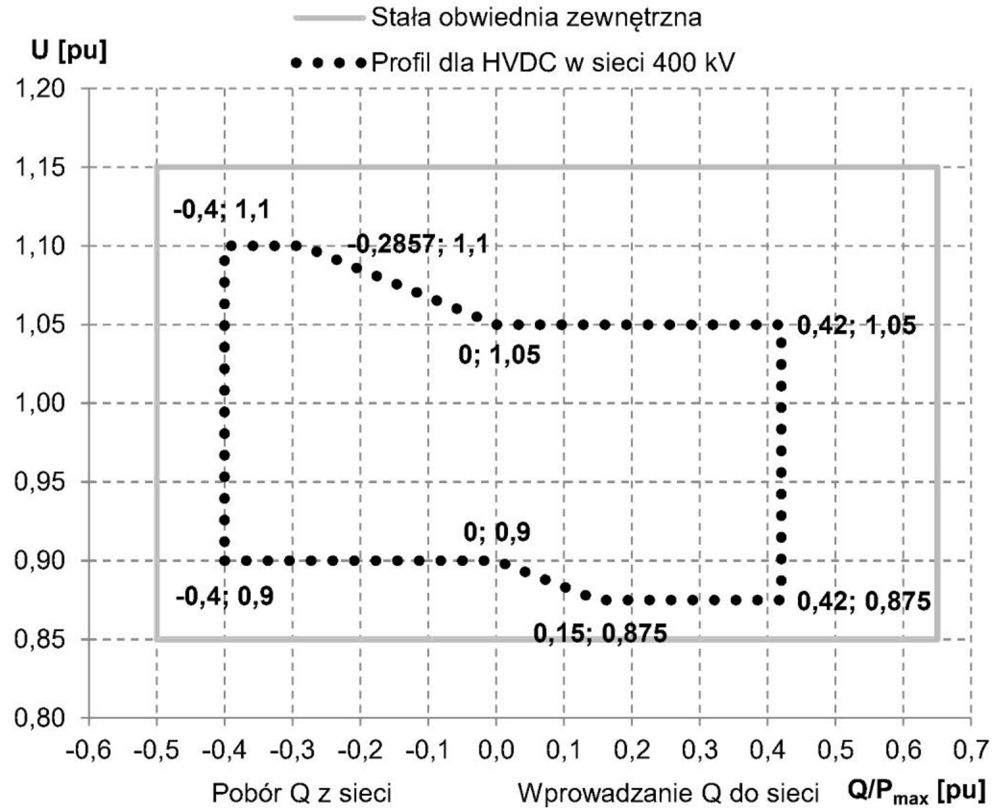
An HVDC system shall have the capability to provide asymmetrical fast fault current injection at a connection point in the case of asymmetrical (1-phase or 2-phase) faults in an AC network. The requirements concerning the method and conditions for determining the beginning and end of voltage deviation 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. 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 be capable of providing 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 figures 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 shall have the right, in determining the connection conditions, 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.

a)



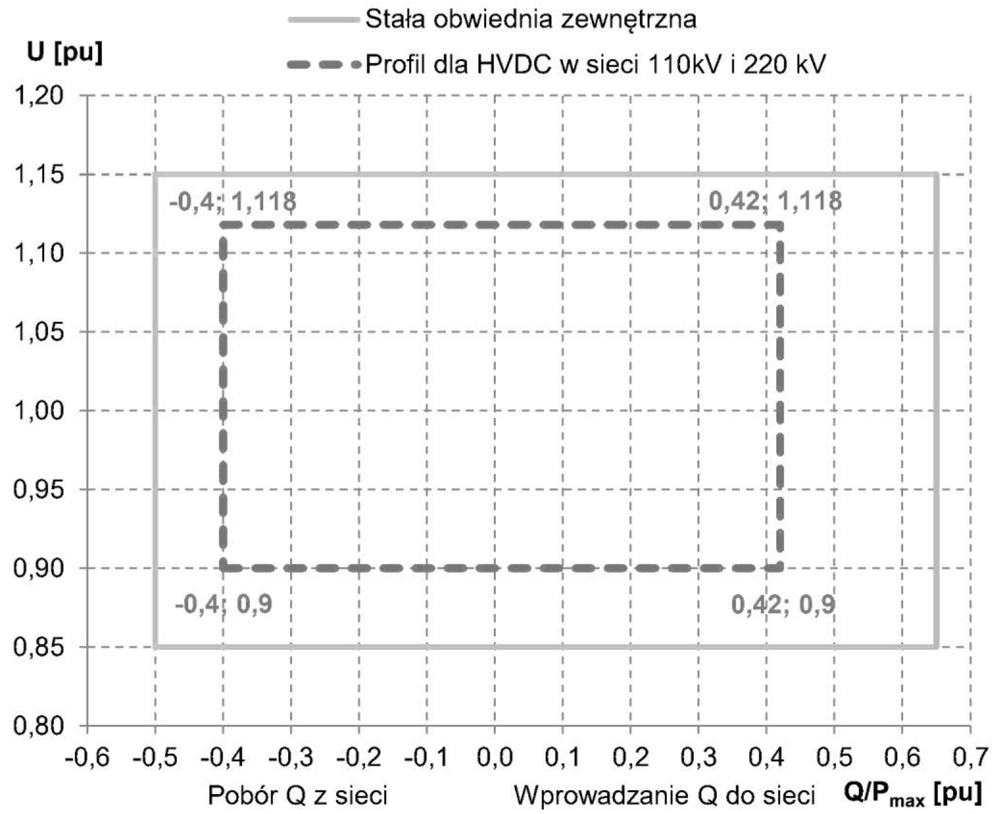
Stała obwiednia zewnętrzna	Fixed outer envelope
Profil dla HVDC w sieci 400 kV	Profile for HVDC in the 400 kV network
Pobór Q z sieci	Q Consumption from the network
Wprowadzanie Q do sieci	Q Production into the network

Figure a: U-Q/P_{max} profile for HVDC systems connected at 400 kV, where: U – voltage at the connection point, expressed as the ratio of its actual value to the reference 1 pu value, Q/P_{max} — the ratio of the reactive power provided by this system for the AC network to its maximum active power transmission capacity.

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

Table a: Inner envelope parameters in the above figure.

b)



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

Figure b: U-Q/P_{max} profile for HVDC systems connected at 220 kV and 110 kV, where: U – voltage at the connection point, expressed as the ratio of its actual value to the reference 1 pu value, Q/P_{max} – the ratio of the reactive power provided by this system for the AC network to its maximum active power transmission capacity.

Maximum Q/P_{max} range	Maximum range of steady-state voltage values (pu)
0.82	0.218

Table b: 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;

Reactive power control should be possible in coordination with network voltage and reactive master power control systems of the relevant system operator in the AC network in accordance with the relevant TSO's requirements.

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

Voltage setpoint setting continuously at the connection point for the voltage control mode at an HVDC converter station shall be possible 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. Voltage setpoints 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 deadband setpoint 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 = 10 s.

Article 22(3)(c)(ii) – voltage control accuracy and dynamics (time t_2)

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 = 12 s, with a steady-state tolerance not greater than 5% of the maximum reactive power or 5 Mvar (whichever 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 setpoints from the relevant system operator’s power dispatch centres. 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 active control mode settings;

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

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

Devices ensuring remote coordination with a master voltage and reactive power 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

Unless the relevant system operator has specified otherwise, 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):

(a) An HVDC system should not cause rapid voltage changes (RVC) according to the values specified in the table below:

No.	**Range of RVC values**	**Maximum admissible number and frequency of occurrence of RVC events**
1	0.5% ≤ RVC < 1.5%	100 per hour
2	1.5% ≤ RVC < 3.0%	10 per hour
3	3.0% ≤ RVC	0

The above requirements shall also apply to start-up and shutdown operations;

b) The share of the HVDC system in total voltage fluctuations at the connection point, measured by the increase in the value of Percentile Short Term (Pst) and Percentile Long Term (Plt) flicker severity factor above the background value should not exceed the values specified in the table below:

No.	**Rated network voltage (U_n)**	P_{st}	P_{lt}
1	$U_n \geq 220$ kV	0.30	0.20
2	110 kV $\leq U_n <$ 220 kV	0.35	0.25

c) The HVDC system should not cause, at the network connection point with a rated voltage equal to 110 kV or higher, the presence of voltage harmonics (of orders between 2 and 50) with values greater than the limits specified in the table below:

harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (U_h)	harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (U_h)	harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (U_h)
5	1%	3	1%	2	0.75%
7	1%	9	0.5%	4	0.5%
11	0.75%	15	0.25%	>4	0.25%
13	0.75%	>15	0.25%		
17	0.5%				
19	0.5%				
23	0.35%				
25	0.35%				
>25	$0.1 + 0.25 \cdot \frac{25}{h}\%$				

d) The flicker severity factors (voltage fluctuation) and voltage harmonic coefficients given above should be met during 99% of the time each week.

e) The value of the total harmonic distortion (THD) coefficient, taking into account higher harmonics up to the order of 50, at the HVDC system connection point to a network with a rated voltage equal to 110 kV or higher, shall be ≤ 1.5% for 100% of the time each week.

The HVDC system shall have 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, if the relevant system operator so requires, the HVDC system shall have a system for data transmission to the system operator.

In 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:

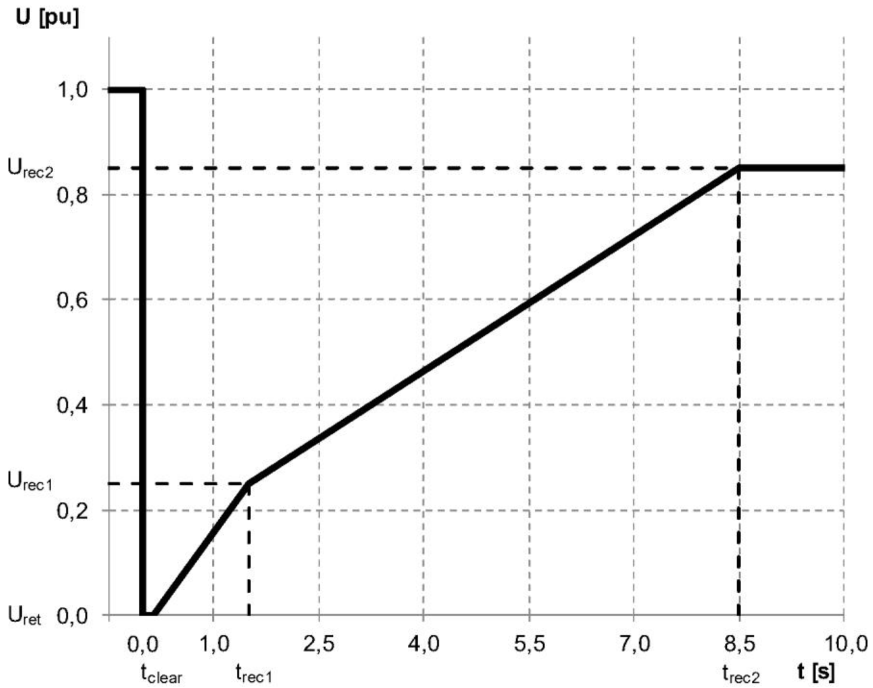


Figure: Fault-ride-through profile of an HVDC converter station. Uret – voltage at connection point during a fault; Tclear – time of fault clearance in the AC network; Urec1 and trec1 – points of lower limits of voltage recovery following fault clearance; Urec2 and trec2 – points of upper limits of voltage 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 fault (one or two-phase) 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 during and after the fault are not lower than the voltage-against-time profile specified 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 should have the capability to:

(i) commencement of post-fault restoration of active power from the moment voltage is restored to a value of not less than 0.9 pu of the rated network voltage at the connection point;

(ii) restoration of active power to at least 90% of pre-fault value of transmitted power within a period of not more than 500 ms, provided that the voltage at the connection point does not exceed 1.05 pu of the rated network voltage at the connection point.

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 of voltage 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 active power oscillations with frequencies up to 5 Hz in connected AC networks.

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) AC equipment necessary to perform the study;

b) SSTI occurrence conditions;

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

d) SSTI extent.

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

The following shall be calculated at the connection point:

(i) minimum short circuit power taking into account the provisions of IEC 60909,

(ii) maximum short circuit power taking into account the modified provisions of IEC 60909 to represent power park modules and HVDC converter stations in the form of uncontrollable voltage sources and fixed-value impedance,

while ensuring the integrity of the National Power System's network with a voltage rating of 110 kV (inclusive) and higher and covering the power demand of consumers. When calculating the maximum short circuit power, the share of all existing power generation modules and those planned to be connected shall be taken into account, and the system configuration that leads to the maximum short circuit current shall be assumed. This assumes, among other things, operation without network splits of networks with a voltage rating of 220 kV (inclusive) and higher, as well as substations with a voltage rating of 110 kV (inclusive) up to 220 kV in the immediate vicinity of the connection point.

In terms of the minimum short-circuit power, the pre-fault and post-fault minimum short-circuit power at the connection point shall be calculated:

The pre-fault minimum short-circuit power shall be calculated taking into account, among other things:

a) the structure of the network with a voltage rating of 110 kV (inclusive) and higher of the National Power System as planned at the date of commencement of use of a HVDC system, without taking into account planned network elements for which the TSO has identified a high risk of non-commissioning by the date of commencement of use of the HVDC system,

b) the operation condition of the National Power System corresponding to the minimum share of synchronous power-generating modules and power park modules ensuring similarity of behaviour to synchronous power-generating modules during faults, including, but not limited to, the absence of the share of such modules connected to the substation where the HVDC system connection point is located,

c) the states of switching devices in substations (network splits) corresponding to the accepted state of normal operation of the National Power System,

d) potential repair states in the network: an outage of system component (e.g. a single-circuit line with a voltage rating of 220 kV (inclusive) or higher, a double-circuit line with a voltage rating of 220 kV (inclusive) or higher, or a transformer taking out power from the HVDC system connection substation or the network area under consideration injecting the largest share of short circuit power at the connection point.

In calculating the minimum post-fault short circuit power, the emergency disconnection of the next network element with a voltage rating of 110 kV (inclusive) and higher of the National Power System with the largest share of short circuit power at the HVDC system connection point shall be additionally taken into account, including shutdowns related to the disturbance in the substation busbar area.

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 determined pursuant to Article 32(1) of NC HVDC, taking into account symmetrical and asymmetrical disturbances, as well as an admissible earth fault factor (defined as the ratio of the maximum phase voltage during an earth fault to the rated phase voltage at a given point of the network) equal to 1.3 (for networks with a rated voltage of 220 kV (inclusive) or higher) and 1.4 (for networks with a rated voltage of 110 kV (inclusive) up to 220 kV).

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 shall be specified, triggered by tripping or disconnection of an HVDC converter station, as part of any multi-terminal or embedded HVDC system, which 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 of NC HVDC.

Article 35(2) – prioritisation of protection and control

The HVDC system owner shall organise its protection devices and control devices of the system 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 specified in Article 13(3) of NC HVDC;

e) LFSM;

f) FSM and frequency control;

g) power gradient constraint.

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

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

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

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

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

If the relevant TSO decides, pursuant to the provisions of Article 16(1) of NC HVDC, 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 Article 40(1)(a) and (b) of NC HVDC. The terms and settings for automatic disconnection shall be agreed between the relevant system operator, 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 value of the power 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 of voltage 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

The following shall be calculated at the connection point:

(i) minimum short circuit power taking into account the provisions of IEC 60909,

(ii) maximum short circuit power taking into account the modified provisions of IEC 60909 to represent power park modules and HVDC converter stations in the form of uncontrollable voltage sources and fixed-value impedance,

while ensuring the integrity of the National Power System's network with a voltage rating of 110 kV (inclusive) and higher and covering the power demand of consumers. When calculating the maximum short circuit power, the share of all existing power generation modules and those planned to be connected shall be taken into account, and the system configuration that leads to the maximum short circuit current shall be assumed. This assumes, among other things, operation without network splits of networks with a voltage rating of 220 kV (inclusive) and higher, as well as substations with a voltage rating of 110 kV (inclusive) up to 220 kV in the immediate vicinity of the connection point.

In terms of minimum short-circuit power, the pre-fault and post-fault minimum short-circuit power at the connection point shall be determined:

a) the structure of the network with a voltage rating of 110 kV (inclusive) and higher of the National Power System as planned at the date of commencement of use of a DC-connected power park module, without taking into account planned network elements for which the TSO has identified a high risk of non-commissioning by the date of commencement of use of DC-connected power park module,

b) the operation condition of the National Power System corresponding to the minimum share of synchronous power-generating modules and power park modules ensuring similarity of behaviour to synchronous power-generating modules during faults, including, but not limited to, the absence of the share of such modules connected to the substation where the DC-connected power park module connection point is located,

c) the states of switching devices in substations (network splits) corresponding to the accepted state of normal operation of the National Power System,

d) potential repair states in the network: an outage system component (e.g. a single-circuit line with a voltage rating of 220 kV (inclusive) or higher, a double-circuit line with a voltage rating of 220 kV (inclusive) or higher, or a transformer taking out power from the DC-connected power park module connection substation or the network area under consideration injecting the largest share of short circuit power at the connection point.

In calculating the minimum post-fault short circuit power, the emergency disconnection of the next network element with a voltage rating of 110 kV (inclusive) and higher of the National Power System with the largest share of short circuit power at the DC-connected power park module connection point shall be additionally taken into account.

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 during the periods established under Article 39(2)(a) or (b) of NC HVDC;

b) at the HVDC connection 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 determined pursuant to Article 42(a) of NC HVDC, taking into account symmetrical and asymmetrical disturbances, as well as an admissible earth fault coefficient (defined as the ratio of the maximum phase voltage during an earth fault to the rated phase voltage at a given point of the network) equal to 1.3 (for networks with a rated voltage of 220 kV (inclusive) or higher) and 1.4 (for networks with a rated voltage of 110 kV (inclusive) up to 220 kV).

Additional requirements determining the capability of DC-connected energy park modules to operate, specific to the location of their HVDC connection, shall be determined by the relevant system operator individually for each DC-connected energy park module.

Article 44 – the maximum admissible level of voltage distortion or fluctuation at a connection point

Unless the relevant system operator has specified otherwise, 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):

a) A DC-connected power park module should not cause rapid voltage changes (RVC) according to the values specified in the table below:

No.	Range of RVC values	Maximum admissible number and frequency of occurrence of RVC events
1	0.5% ≤ RVC < 1.5%	100 per hour
2	1.5% ≤ RVC < 3.0%	10 per hour
3	3.0% ≤ RVC	0

The above requirements shall also apply to start-up and shutdown operations;

b) The share of the DC-connected power park module in total voltage fluctuations at the connection point, measured by the increase in the value of Percentile Short Term (Pst) and Percentile Long Term (Plt) flicker severity factor above the background value should not exceed the values specified in the table below:

No.	Rated network voltage (Un)	Pst	Plt
1	Un ≥ 220 kV	0.30	0.20
2	110 kV ≤ U_n < 220 kV	0.35	0.25

The DC-connected power park module should not cause, at the network connection point with a rated voltage equal to 110 kV or higher, the presence of voltage harmonics (of orders between 2 and 50) with values greater than the limits specified in the table below:

harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (uh)	harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (uh)	harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (uh)
5	1%	3	1%	2	0.75%
7	1%	9	0.5%	4	0.5%
11	0.75%	15	0.25%	>4	0.25%
13	0.75%	>15	0.25%		
17	0.5%				
19	0.5%				

23	0.35%				
25	0.35%				
>25	$0.1 + 0.25 \cdot \frac{25}{h}\%$				

c) The flicker (voltage fluctuation) and voltage harmonic coefficients given above should be met during 99% of the time each week.

d) The value of the total harmonic distortion (THD) coefficient, taking into account higher harmonics up to the order of 50, at the DC-connected power park module connection point to a network with a rated voltage equal to 110 kV or higher, shall be ≤ 1.5% for 100% of the time each week.

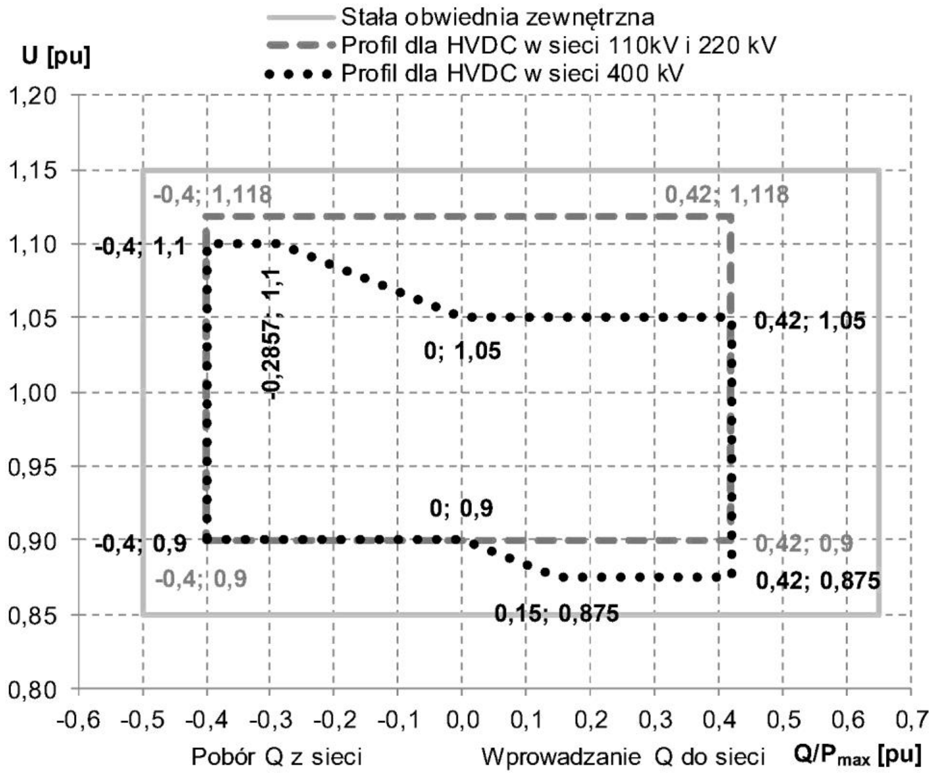
e) The DC-connected power park module shall have a power quality measurement and recording system (measurement of RMS voltage and current levels, voltage fluctuation, and voltage and current harmonics in measurement class A) and, if the relevant system operator so requires, the DC-connected power park module shall have 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 be capable of ensuring 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. A remote-end island system owner, in coordination with a remote end HVDC system owner, shall have the right to modify the presented 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.

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



Stała obwiednia zewnętrzna	Fixed outer envelope
Profil dla HVDC w sieci 110kV i 220 kV	Profile for HVDC in the 110 kV and 220 kV network
Profil dla HVDC w sieci 400 kV	Profile for HVDC in the 400 kV network
Pobór Q z sieci	Withdrawal of Q from the network
Wprowadzanie Q do sieci	Injection of Q to the 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 station 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 – the maximum admissible level of voltage distortion or fluctuation at a connection point

Unless the relevant system operator specifies otherwise, 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):

(a) A remote-end HVDC converter station should not cause rapid voltage changes (RVC) according to the values specified in the table below:

No.	Range of RVC values	Maximum admissible number and frequency of occurrence of RVC events
1	0.5% ≤ RVC < 1.5%	100 per hour

2	1.5% ≤ RVC < 3.0%	10 per hour
3	3.0% ≤ RVC	0

The above requirements shall also apply to start-up and shutdown operations;

b) The share of a remote-end HVDC converter station in total voltage fluctuations at the connection point, measured by the increase in the value of Percentile Short Term (Pst) and Percentile Long Term (Plt) flicker severity factor above the background value should not exceed the values specified in the table below:

No.	Rated network voltage (Un)	Pst	Plt
1	Un ≥ 220 kV	0.30	0.20
2	110 kV ≤ U_n < 220 kV	0.35	0.25

c) A remote-end HVDC converter station should not cause, at the network connection point with a rated voltage equal to 110 kV or higher, the presence of voltage harmonics (of orders between 2 and 50) with values greater than the limits specified in the table below:

harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (uh)	harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (uh)	harmonic order (h)	the relative value of the voltage as a percentage of the fundamental component (uh)
5	1%	3	1%	2	0.75%
7	1%	9	0.5%	4	0.5%
11	0.75%	15	0.25%	>4	0.25%
13	0.75%	>15	0.25%		
17	0.5%				
19	0.5%				
23	0.35%				
25	0.35%				
>25	$0.1 + 0.25 \cdot \frac{25}{h}\%$				

d) The flicker (voltage fluctuation) and voltage harmonic coefficients given above should be met during 99% of the time each week.

e) The value of the total harmonic distortion (THD) coefficient, taking into account higher harmonics up to the order of 50, at the remote-end HVDC converter station connection point to a network with a rated voltage equal to 110 kV or higher, shall be ≤ 1.5% for 100% of the time each week.

The remote-end HVDC converter station shall have 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, if the relevant system operator so requires, the remote-end HVDC converter station shall have a system for data transmission to the relevant system operator.

In 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 or HVDC converter unit owner shall organise its protection equipment and control equipment of the system 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 specified in Article 13(3) of NC HVDC;

e) power gradient constraint;

f) voltage / reactive power control.

Article 53(4) – oscillation trigger

HVDC system dynamic-state operation recording and monitoring equipment shall have 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 oscillation trigger shall be activated upon exceeding a set admissible threshold of active power transmitted by the HVDC system, with a simultaneous control of the oscillation damping factor. The setpoints of activation criteria for the oscillation trigger 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 and dynamic-state 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 updated simulation models to the relevant system operator. 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.

Annex I Table 1 – frequency ranges

Frequency ranges referred to in Article 11.

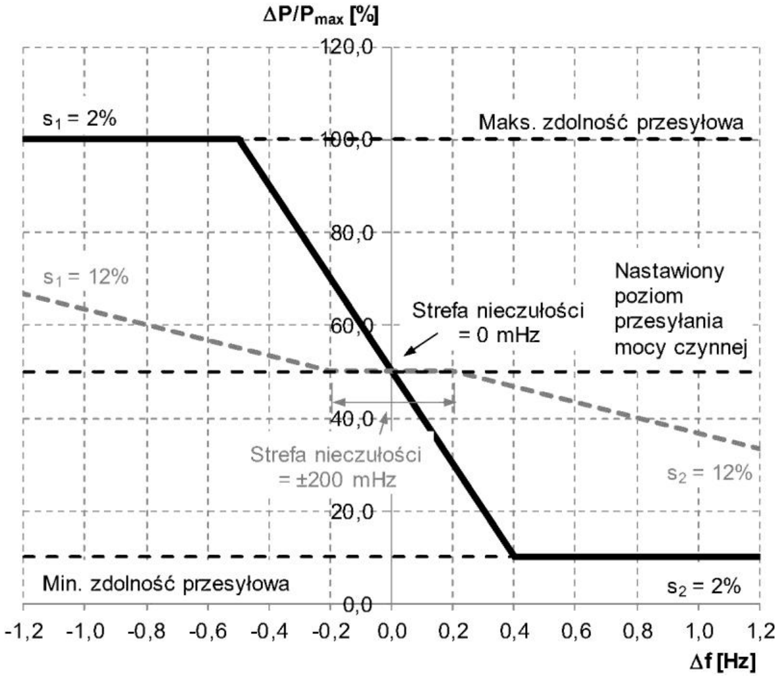
Frequency range	Operating time
47.0 Hz - 47.5 Hz	60s
47.5 Hz - 52.0 Hz	Unlimited

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	Maximum transmission capacity
Strefa nieczułości= 0 mHz	Deadband = 0 mHz
Nastawiony poziom przesyłania mocy czynnej	Set active power transmission level
Strefa nieczułości= 200 mHz	Deadband = 200 mHz
Min. zdolność przesyłowa	Minimum transmission capacity

Figure: Active power frequency response capability of HVDC systems in FSM illustrating the extreme cases specified in the Table below, values of 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	Value 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 Area (A)(1)(d)(ii) – FSM control parameters

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

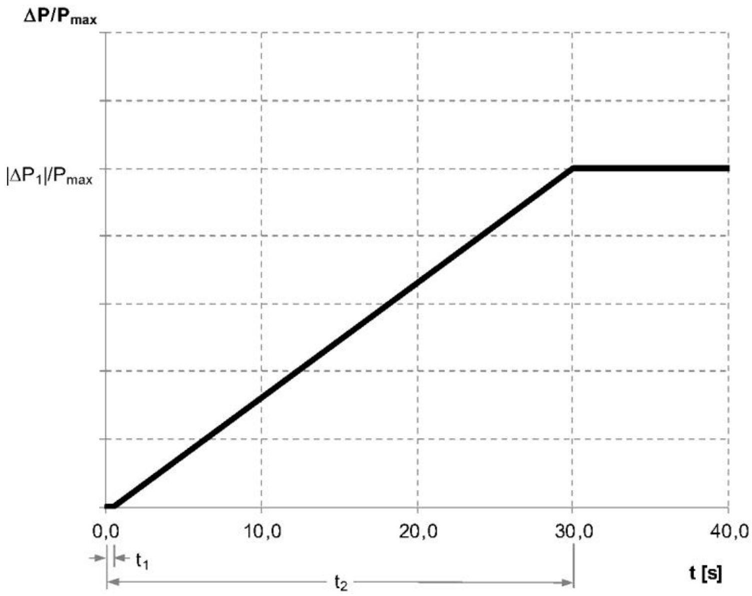


Figure: Active power frequency response capability of HVDC systems in FSM.

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

When operating in LFSM-O, 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 Area B (2) – control parameters in LFSM-O

When operating in LFSM-O, 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.

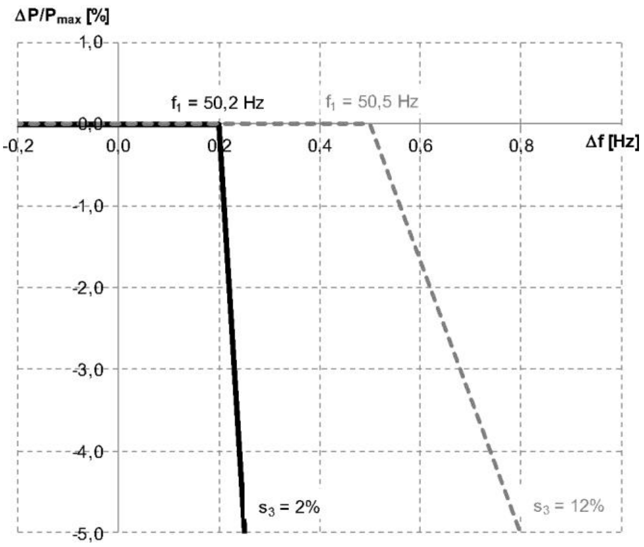


Figure: Active power frequency response capability of HVDC systems in LFSM-O illustrating the cases of extreme values of frequency f1 and droop s3.

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

When operating in LFSM-U, 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 Area C (2) – control parameters in LFSM-U

When operating in LFSM-U, 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 s4 shall be ensured.

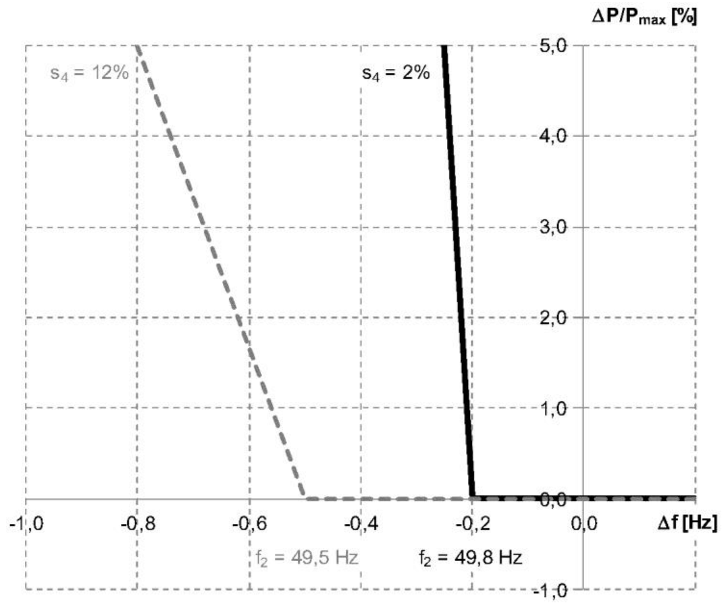


Figure: Active power frequency response capability of HVDC systems in LFSM-U illustrating the cases of extreme values of frequency f2 and droop s4.

Annex III Table 4 – voltage ranges for HVDC systems connected to 110 kV and 220 kV networks

Voltage ranges referred to in Article 18 of NC HVDC.

Voltage range	Operating time
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 systems connected to 400 kV networks

Voltage ranges referred to in Article 18 of NC HVDC.

Voltage range	Operating time
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 220 kV networks

Voltage ranges referred to in Article 40 of NC HVDC.

Voltage range	Operating time
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 of NC HVDC.

Voltage range	Operating time
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 220 kV networks

Voltage ranges referred to in Article 40 of NC HVDC.

Voltage range	Operating time
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 of NC HVDC.

Voltage range	Operating time
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.