Krav fastsat i henhold til EU-forordning 2016/1447 – High Voltage Direct Current (HVDC)

Relevant forklaring:

Normativt krav - behandles ikke
Krav færdigbehandlet

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
TITLE II - GENERAL REQUIREMENTS FOR HVDC CONNECTIONS						
Requirements for active power control and frequency support						
Frequency ranges						
11	1			An HVDC system shall be capable of staying connected to the network and remaining operable within the frequency ranges and time periods specified in Table 1, Annex I for the short circuit power range as specified in Article 32(2).	CE/N: 100 – 300 kV/300 – 400 kV 47,5 – 48,5 Hz: 30 min (RfG) 48,5 – 49,0 Hz: 30 min (RfG) 51,0 – 51,5 Hz: 30 min (RfG) 51,5 – 52,0 Hz: 60 min	
11	2			The relevant TSO and HVDC system owner may agree on wider frequency ranges or longer minimum times for operation if needed to preserve or to restore system security. If wider frequency ranges or longer minimum times for operation are economically and technically feasible, the HVDC system owner shall not unreasonably withhold	HVDC system, POC and grid specific analysis. Part of connection agreement.	
11	3			Without prejudice to paragraph 1, an HVDC system shall be capable of automatic disconnection at frequencies specified by the relevant TSO.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
11	4			The relevant TSO may specify a maximum admissible active power output reduction from its operating point if the system frequency falls below 49 Hz.	No output power reduction specified.	
Rate-of-change-of-frequency withstand capability						
12				An HVDC system shall be capable of staying connected to the network and operable if the network frequency changes at a rate between – 2,5 and + 2,5 Hz/s (measured at any point in time as an average of the rate of change of frequency for the previous 1 s).	-	

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Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
Active power controllability, control range and ramping rate						
13	1			With regard to the capability of controlling the transmitted active power:	-	
13	1	a		an HVDC system shall be capable of adjusting the transmitted active power up to its maximum HVDC active power transmission capacity in each direction following an instruction from the relevant TSO. The relevant TSO:	-	
13	1	a	i	may specify a maximum and minimum power step size for adjusting the transmitted active power;	Minimum step 1 MW	
13	1	a	ii	may specify a minimum HVDC active power transmission capacity for each direction, below which active power transmission capability is not requested; and	No minimum lower limit. Power transmission requested at P > 0	
13	1	a	iii	shall specify the maximum delay within which the HVDC system shall be capable of adjusting the transmitted active power upon receipt of request from the relevant TSO.	Maximum processing time [s] Indication: 0.5 Command/set points: 0.25 Events exceeding data filter: 0.5 Cyclic measurement: 1 - 60	
13	1	b		the relevant TSO shall specify how an HVDC system shall be capable of modifying the transmitted active power infeed in case of disturbances into one or more of the AC networks to which it is connected. If the initial delay prior to the start of the change is greater than 10 milliseconds from receiving the triggering signal sent by the relevant TSO, it shall be reasonably justified by the HVDC system owner to the relevant TSO.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
13	1	c		the relevant TSO may specify that an HVDC system be capable of fast active power reversal. The power reversal shall be possible from the maximum active power transmission capacity in one direction to the maximum active power transmission capacity in the other direction as fast as technically feasible and reasonably justified by the HVDC system owner to the relevant TSOs if greater than 2 seconds.	Fast active power reversal required.	
13	1	d		for HVDC systems linking various control areas or synchronous areas, the HVDC system shall be equipped with control functions enabling the relevant TSOs to modify the transmitted active power for the purpose of cross-border balancing.	-	
13	2			An HVDC system shall be capable of adjusting the ramping rate of active power variations within its technical capabilities in accordance with instructions sent by relevant TSOs. In case of modification of active power according to points (b) and (c) of paragraph 1, there shall be no adjustment of ramping rate.	-	
13	3			If specified by a relevant TSO, in coordination with adjacent TSOs, the control functions of an HVDC system	HVDC system, POC and grid	

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				shall be capable of taking automatic remedial actions including, but not limited to, stopping the ramping and blocking FSM, LFSM-O, LFSM-U and frequency control. The triggering and blocking criteria shall be specified by relevant TSO and subject to notification to the regulatory authority. The modalities of that notification shall be determined in accordance with the applicable national regulatory framework.	specific analysis. Part of connection agreement.	
Synthetic inertia						
14	1			If specified by a relevant TSO, an HVDC system shall be capable of providing synthetic inertia in response to frequency changes, activated in low and/or high frequency regimes by rapidly adjusting the active power injected to or withdrawn from the AC network in order to limit the rate of change of frequency. The requirement shall at least take account of the results of the studies undertaken by TSOs to identify if there is a need to set out minimum inertia.	No requirement specified yet. The need for synthetic inertia will be started analyzed in 2018 – 2019.	
14	2			The principle of this control system and the associated performance parameters shall be agreed between the relevant TSO and the HVDC system owner.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Requirements relating to frequency sensitive mode, limited frequency sensitive mode overfrequency and limited frequency sensitive mode underfrequency						
15				Requirements applying to frequency sensitive mode, limited frequency sensitive mode overfrequency and limited frequency sensitive mode underfrequency shall be as set out in Annex II.	**FSM** **CE og N.** Se note 1: HVDC FSM **Table 3** Initial delay t1: 20 ms. Full activation t2: 100 ms. **LFSM-O** **CE:** Frequency threshold: 50.2 Hz Droope range: 1 – 12% Droop: 5% **N:** Frequency threshold: 50.5 Hz Droope range: 1 – 12% Droop: 4% **LFSM-U** **CE:** Frequency threshold: 48.8 Hz Droope range: 1 – 12% Droop: 5% **N:** Frequency threshold: 49.5 Hz Droope range: 1 – 12%	

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					Droop: 4%	
Frequency control						
16	1			If specified by the relevant TSO, an HVDC system shall be equipped with an independent control mode to modulate the active power output of the HVDC converter station depending on the frequencies at all connection points of the HVDC system in order to maintain stable system frequencies.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
16	2			The relevant TSO shall specify the operating principle, the associated performance parameters and the activation criteria of the frequency control referred to in paragraph 1.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Maximum loss of active power						
17	1			An HVDC system shall be configured in such a way that its loss of active power injection in a synchronous area shall be limited to a value specified by the relevant TSOs for their respective load frequency control area, based on the HVDC system's impact on the power system.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
17	2			Where an HVDC system connects two or more control areas, the relevant TSOs shall consult each other in order to set a coordinated value of the maximum loss of active power injection as referred to in paragraph 1, taking into account common mode failures.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Requirements for reactive power control and voltage support						
Voltage ranges						
18	1			Without prejudice to Article 25, an HVDC converter station shall be capable of staying connected to the network and capable of operating at HVDC system maximum current, within the ranges of the network voltage at the connection point, expressed by the voltage at the connection point related to reference 1 pu voltage, and the time periods specified in Tables 4 and 5, Annex III. The establishment of the reference 1 pu voltage shall be subject to coordination between the adjacent relevant system operators.	CE: 100 – 300 kV 1,118 – 1,15 pu: 60 min CE: 300 – 400 kV 1,05 – 1,0875 pu: 60 min N: 300 – 400 kV 1,05 – 1,1 pu: 60 min CE: System voltage 1pu @ 150kV: 152kV 1pu @ 220kV: 220 kV 1pu @ 400kV: 400 kV N: System voltage 1pu @ 132 kV: 138 kV 1pu @ 220 kV: 234 kV 1pu @ 400kV: 400 kV	

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18	2			The HVDC system owner and the relevant system operator, in coordination with the relevant TSO, may agree on wider voltage ranges or longer minimum times for operation than those specified in paragraph 1 in order to ensure the best use of the technical capabilities of an HVDC system if needed to preserve or to restore system security. If wider voltage ranges or longer minimum times for operation are economically and technically feasible, the HVDC system owner shall not unreasonably withhold consent.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
18	3			An HVDC converter station shall be capable of automatic disconnection at connection point voltages specified by the relevant system operator, in coordination with the relevant TSO. The terms and settings for automatic disconnection shall be agreed between the relevant system operator, in coordination with the relevant TSO, and the HVDC system owner.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
18	4			For connection points at reference 1 pu AC voltages not included in the scope set out in Annex III, the relevant system operator, in coordination with relevant TSOs, shall specify applicable requirements at the connection points.	-	
18	5			Notwithstanding the provisions of paragraph 1, the relevant TSOs in the Baltic synchronous area may, following consultation with relevant neighbouring TSOs, require HVDC converter stations to remain connected to the 400 kV network in the voltage ranges and for time periods that apply in the Continental Europe synchronous area.	N/A	
Short circuit contribution during faults						
19	1			If specified by the relevant system operator, in coordination with the relevant TSO, an HVDC system shall have the capability to provide fast fault current at a connection point in case of symmetrical (3-phase) faults.	Fast fault current required.	
19	2			Where an HVDC system is required to have the capability referred to in paragraph 1, the relevant system operator, in coordination with the relevant TSO, shall specify the following:	-	
19	2	a		how and when a voltage deviation is to be determined as well as the end of the voltage deviation;	CE: Uc < 0,85 pu: start Uc > 0,85 pu: stop N: Uc < 0,9 pu: start Uc > 0,9 pu: stop	
19	2	b		the characteristics of the fast fault current;	CE: IQ/In linear from 0% - 100 % at Upoc/pcc: 0,85 p.u to 0,5 p.u. N: IQ/In linear from 0% - 100 % at	

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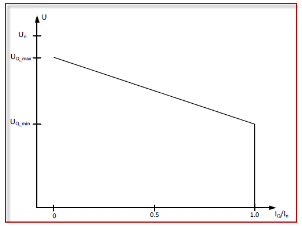
					Upoc/pcc: 0,9 p.u to 0,5 p.u. 	
19	2	c		the timing and accuracy of the fast fault current, which may include several stages.	The regulation must follow the characteristic of the fast fault current after 100 ms with a tolerance of ±20 %.	
19	3			The relevant system operator, in coordination the relevant TSO, may specify a requirement for asymmetrical current injection in the case of asymmetrical (1-phase or 2-phase) faults.	Requirement as article 19(1) Capability for asymmetrical fault current requested. Functionality enabled on the request of the TSO.	
Reactive power capability						
20	1			The relevant system operator, in coordination with the relevant TSO, shall specify the reactive power capability requirements at the connection points, in the context of varying voltage. The proposal for those requirements shall include a U-Q/P_{max}-profile, within the boundary of which the HVDC converter station shall be capable of providing reactive power at its maximum HVDC active power transmission capacity.	Jf. Annex D.	
20	2			The U-Q/P_{max}-profile referred to in paragraph 1 shall comply with the following principles: (a) the U-Q/P_{max}-profile shall not exceed the U-Q/P_{max}-profile envelope represented by the inner envelope in the figure set out in Annex IV, and does not need to be rectangular; (b) the dimensions of the U-Q/P_{max}-profile envelope shall respect the values established for each synchronous area in the table set out in Annex IV; and (c) the position of the U-Q/P_{max}-profile envelope shall lie within the limits of the fixed outer envelope in the figure set out in Annex IV.	-	
20	3			An HVDC system shall be capable of moving to any operating point within its U-Q/P_{max} profile in timescales specified by the relevant system operator in coordination with the relevant TSO.	Up to 999MW/min.	
20	4			When operating at an active power output below the maximum HVDC active power transmission capacity	-	

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				($P < P_{max}$), the HVDC converter station shall be capable of operating in every possible operating point, as specified by the relevant system operator in coordination with the relevant TSO and in accordance with the reactive power capability set out by the U-Q/P_{max} profile specified in paragraphs 1 to		
Reactive power exchanged with the network						
21	1			The HVDC system owner shall ensure that the reactive power of its HVDC converter station exchanged with the network at the connection point is limited to values specified by the relevant system operator in coordination with the relevant TSO.	-	
21	2			The reactive power variation caused by the reactive power control mode operation of the HVDC converter Station, referred to in Article 22(1), shall not result in a voltage step exceeding the allowed value at the connection point. The relevant system operator, in coordination with the relevant TSO, shall specify this maximum tolerable voltage step value.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Reactive power control mode						
22	1			An HVDC converter station shall be capable of operating in one or more of the three following control modes, as specified by the relevant system operator in coordination with the relevant TSO:	-	
22	1	a		voltage control mode;	Required	
22	1	b		reactive power control mode;	Required	
22	1	c		power factor control mode.	Required	
22	2			An HVDC converter station shall be capable of operating in additional control modes specified by the relevant system operator in coordination with the relevant TSO.	-	
22	3			For the purposes of voltage control mode, each HVDC converter station shall be capable of contributing to voltage control at the connection point utilising its capabilities, while respecting Articles 20 and 21, in accordance with the following control characteristics:	-	
22	3	a		a setpoint voltage at the connection point shall be specified to cover a specific operation range, either continuously or in steps, by the relevant system operator, in coordination with the relevant TSO;	HVDC system, POC and grid specific analysis. Part of connection agreement.	
22	3	b		the voltage control may be operated with or without a deadband around the setpoint selectable in a range from zero to +/– 5 % of reference 1 pu network voltage. The deadband shall be adjustable in steps as specified by the relevant system operator in coordination with the relevant TSO;	Range voltage control : CE: 100 – 300 kV: 0,85 – 1,15 pu 300 – 400 kV: 0,85 – 1,10 pu N: 0,9 – 1,05 pu Set point steps:	

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					Accuracy of 1 kV step	
22	3	c		following a step change in voltage, the HVDC converter station shall be capable of:	-	
22	3	c	i	achieving 90 % of the change in reactive power output within a time t1 specified by the relevant system operator in coordination with the relevant TSO. The time t1 shall be in the range of 0,1-10 seconds; and	Specific setting for t1 within mandatory range will be a part of the connection agreement	
22	3	c	ii	settling at the value specified by the operating slope within a time t2 specified by the relevant system operator in coordination with the relevant TSO. The time t2 shall be in the range of 1-60 seconds, with a specified steady- state tolerance given in % of the maximum reactive power.	Specific setting for t2 within mandatory range will be a part of the connection agreement	
22	3	d		voltage control mode shall include the capability to change reactive power output based on a combination of a modified setpoint voltage and an additional instructed reactive power component. The slope shall be specified by a range and step specified by the relevant system operator in coordination with the relevant TSO.	Voltage control mode Note 2: General requirement for the reactive power controller.	
22	4			With regard to reactive power control mode, the relevant system operator shall specify a reactive power range in MVAr or in % of maximum reactive power, as well as its associated accuracy at the connection point, using the capabilities of the HVDC system, while respecting Articles 20 and 21.	Reactive power control mode Note 2: General requirement for the reactive power controller.	
22	5			For the purposes of power factor control mode, the HVDC converter station shall be capable of controlling the power factor to a target at the connection point, while respecting Articles 20 and 21. The available setpoints shall be available in steps no greater than a maximum allowed step specified by the relevant system operator.	Power factor control mode Note 2: General requirement for the reactive power controller.	
22	6			The relevant system operator in coordination with the relevant TSO shall specify any equipment needed to enable the remote selection of control modes and relevant setpoints.	Equipment for remote control and relevant setpoints will be specified in the connection agreement.	
Priority to active or reactive power contribution						
23				Taking into account the capabilities of the HVDC system specified in accordance with this Regulation, the relevant TSO shall determine whether active power contribution or reactive power contribution shall have priority during low or high voltage operation and during faults for which fault-ride-through capability is required. If priority is given to active power contribution, its provision shall be established within a time from the fault inception as specified by relevant	Low/high Voltage: Autonomous reactive power regulation shall start at predefined low and high voltages. Faults/FRT: Reactive current must have higher priority than active power during voltage drop to maximize the reactive contribution.	

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Power quality						
24				An HVDC system owner shall ensure that its HVDC system connection to the network does not result in a level of distortion or fluctuation of the supply voltage on the network, at the connection point, exceeding the level specified by the relevant system operator in coordination with the relevant TSO. The process for necessary studies to be conducted and relevant data to be provided by all grid users involved, as well as mitigating actions identified and implemented, shall be in accordance with the process in Article 29.	Jf. Annex A	
Requirements for fault ride through capability						
Fault ride through capability						
25	1			The relevant TSO shall specify, while respecting Article 18, a voltage-against time profile as set out in Annex V and having regard to the voltage-against-time-profile specified for power park modules according to Regulation (EU) 2016/631. This profile shall apply at connection points for fault conditions, under which the HVDC converter station shall be capable of staying connected to the network and continuing stable operation after the power system has recovered following fault clearance. The voltage-against-time-profile shall express a lower limit of the actual course of the phase-to-phase voltages on the network voltage level at the connection point during a symmetrical fault, as a function of time before, during and after the fault. Any ride through period beyond t_{rec2} shall be specified by the relevant TSO consistent with Article 18.	Jf. Annex C. CE: U [pu] / t [s] U_{ret}: 0 / t_{clear}: 0,15 U_{clear}: 0 / t_{rec1}: 0,15 U_{rec1}: 0,8 / t_{rec2}: 2 U_{rec2}: 0,85 / t_{rec3}: 10 N: U [pu] / t [s] U_{ret}: 0 / t_{clear}: 0,15 U_{clear}: 0 / t_{rec1}: 0,15 U_{rec1}: 0,8 / t_{rec2}: 2 U_{rec2}: 0,9 / t_{rec3}: 10	
25	2			On request by the HVDC system owner, the relevant system operator shall provide the pre-fault and post-fault conditions as provided for in Article 32 regarding:	Kortslutningskatalog fastlægger metode for beregning af kortslutningseffekt samt beregner konditioner i kendte tilslutningspunkter.	
25	2	a		pre-fault minimum short circuit capacity at each connection point expressed in MVA;	-	
25	2	b		pre-fault operating point of the HVDC converter station expressed as active power output and reactive power output at the connection point and voltage at the connection point; and	-	
25	2	c		post-fault minimum short circuit capacity at each connection point expressed in MVA.	-	

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25	2			Alternatively, generic values for the above conditions derived from typical cases may be provided by the relevant system operator.	-	
25	3			The HVDC converter station shall be capable of staying connected to the network and continue stable operation when the actual course of the phase-to-phase voltages on the network voltage level at the connection point during a symmetrical fault, given the pre-fault and post-fault conditions provided for in Article 32, remain above the lower limit set out in the figure in Annex V, unless the protection scheme for internal faults requires the disconnection of the HVDC converter station from the network. The protection schemes and settings for internal faults shall be designed not to jeopardise fault-ride-through performance.	-	
25	4			The relevant TSO may specify voltages (U_{block}) at the connection points under specific network conditions whereby the HVDC system is allowed to block. Blocking means remaining connected to the network with no active and reactive power contribution for a time frame that shall be as short as technically feasible and which shall be agreed between the relevant TSOs and the HVDC system owner. In accordance Article 34, undervoltage protection shall be set by the HVDC system owner to the widest possible technical capability of the HVDC converter station. The relevant system operator, in coordination with the relevant TSO, may specify narrower settings pursuant to Article 34.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
25	5			In accordance Article 34, undervoltage protection shall be set by the HVDC system owner to the widest possible technical capability of the HVDC converter station. The relevant system operator, in coordination with the relevant TSO, may specify narrower settings pursuant to Article 34	HVDC system, POC and grid specific analysis. Part of connection agreement.	
25	6			The relevant TSO shall specify fault-ride-through capabilities in case of asymmetrical faults.	Requirement as article 25(1) Capability for asymmetrical fault current requested. Functionality enabled on the request of the TSO.	
Post fault active power recovery						
26				The relevant TSO shall specify the magnitude and time profile of active power recovery that the HVDC system shall be capable of providing, in accordance with Article 25.	Ved kortslutningsforhold > 3,5 Konverteren skal kunne levere 90 % af den aktive effekt fra før fejlen indenfor 200 ms (t_a) efter at spændingen i tilslutningspunktet er genopbygget til 90 % af niveauet før fejlen på ensretteren siden, og indenfor 300 ms (t_b) på inverter siden, uden vedvarende oscillation.	

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					Vedvarende oscillation defineres som maksimum 5 % oscillation af den faktiske effekt. Maksimum overshoot under genopbygningen af AC nettet efter fejl må ikke overstige 10 % af den ønskede effekt. Ved kortslutningsforhold < 3,5 skal anlægsproducenten oplyse t_a og t_b.	
Fast recovery from DC faults						
27				HVDC systems, including DC overhead lines, shall be capable of fast recovery from transient faults within the HVDC system. Details of this capability shall be subject to coordination and agreements on protection schemes and settings pursuant to Article 34.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Requirements for control						
Energisation and synchronisation of HVDC converter stations						
28				Unless otherwise instructed by the relevant system operator, during the energisation or synchronisation of an HVDC converter station to the AC network or during the connection of an energised HVDC converter station to an HVDC system, the HVDC converter station shall have the capability to limit any voltage changes to a steady-state level specified by the relevant system operator in coordination with the relevant TSO. The level specified shall not exceed 5 per cent of the pre-synchronisation voltage. The relevant system operator, in coordination with the relevant TSO, shall specify the maximum magnitude, duration and measurement window of the voltage transients.	Normal operation: +/- 3 % @Uc Special events : +/- 4 % @Uc Time/duration: HVDC system, POC and grid specific analysis. Part of connection agreement.	
Interaction between HVDC systems or other plants and equipment						
29	1			When several HVDC converter stations or other plants and equipment are within close electrical proximity, the relevant TSO <u>may specify</u> that a study is required, and the scope and extent of that study, to demonstrate that no adverse interaction will occur. If adverse interaction is identified, the studies shall identify possible mitigating actions to be implemented to ensure compliance with the requirements of this Regulation.	-	
29	2			The studies shall be carried out by the connecting HVDC system owner with the participation of all other parties identified by the TSOs as relevant to each connection point. Member States may provide that the responsibility for undertaking the studies in accordance with this Article lies with the TSO. All parties shall be informed of the results of the studies.	-	

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29	3			All parties identified by the relevant TSO as relevant to each connection point, including the relevant TSO, shall contribute to the studies and shall provide all relevant data and models as reasonably required to meet the purposes of the studies. The relevant TSO shall collect this input and, where applicable, pass it on to the party responsible for the studies in accordance with Article 10.	-	
29	4			The relevant TSO shall assess the result of the studies based on their scope and extent as specified in accordance with paragraph 1. If necessary for the assessment, the relevant TSO may request the HVDC system owner to perform further studies in line with the scope and extent specified in accordance with paragraph 1.	-	
29	5			The relevant TSO may review or replicate some or all of the studies. The HVDC system owner shall provide the relevant TSO all relevant data and models that allow such study to be performed.	-	
29	6			Any necessary mitigating actions identified by the studies carried out in accordance with paragraphs 2 to 5 and reviewed by the relevant TSO shall be undertaken by the HVDC system owner as part of the connection of the new HVDC converter station.	-	
29	7			The relevant TSO may specify transient levels of performance associated with events for the individual HVDC system or collectively across commonly impacted HVDC systems. This specification may be provided to protect the integrity of both TSO equipment and that of grid users in a manner consistent with its national code.	HVDC system, POC and grid specific analysis.	
Power oscillation damping capability						
30				The HVDC system shall be capable of contributing to the damping of power oscillations in connected AC networks. The control system of the HVDC system shall not reduce the damping of power oscillations. The relevant TSO shall specify a frequency range of oscillations that the control scheme shall positively damp and the network conditions when this occurs, at least accounting for any dynamic stability assessment studies undertaken by TSOs to identify the stability limits and potential stability problems in their transmission systems. The selection of the control parameter settings shall be agreed between the relevant TSO and the HVDC system owner.	Frequency range: 0.1 – 2 Hz. Network conditions: HVDC system, POC and grid specific analysis. Part of connection agreement.	
Subsynchronous torsional interaction damping capability						
31	1			With regard to subsynchronous torsional interaction (SSTI) damping control, the HVDC system shall be capable of contributing to electrical damping of torsional frequencies.	-	
31	2			The relevant TSO shall specify the necessary extent of SSTI studies and provide input parameters, to the extent available, related to the equipment and relevant system conditions in its network. The SSTI studies shall be provided by the HVDC system owner. The studies shall identify the conditions, if any, where SSTI exists and propose any necessary mitigation procedure. Member States may provide that the responsibility	HVDC system, POC and grid specific analysis. Part of connection agreement.	

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				for undertaking the studies in accordance with this Article lies with the TSO. All parties shall be informed of the results of the studies.		
31	3			All parties identified by the relevant TSO as relevant to each connection point, including the relevant TSO, shall contribute to the studies and shall provide all relevant data and models as reasonably required to meet the purposes of the studies. The relevant TSO shall collect this input and, where applicable, pass it on to the party responsible for the studies in accordance with Article 10.	-	
31	4			The relevant TSO shall assess the result of the SSTI studies. If necessary for the assessment, the relevant TSO may request that the HVDC system owner perform further SSTI studies in line with this same scope and extent.	-	
31	5			The relevant TSO may review or replicate the study. The HVDC system owner shall provide the relevant TSO all relevant data and models that allow such study to be performed.	-	
31	6			Any necessary mitigating actions identified by the studies carried out in accordance with paragraphs 2 or 4, and reviewed by the relevant TSOs, shall be undertaken by the HVDC system owner as part of the connection of the new HVDC converter station.	-	
Network characteristics						
32	1			The relevant system operator shall specify and make publicly available the method and the pre-fault and post-fault conditions for the calculation of at least the minimum and maximum short circuit power at the connection points.	Kortslutningskatalog fastlægger metode for beregning af kortslutningseffekt samt beregner konditioner i kendte tilslutningspunkter	
32	2			The HVDC system shall be capable of operating within the range of short circuit power and network characteristics specified by the relevant system operator.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
32	3			Each relevant system operator shall provide the HVDC system owner with network equivalents describing the behaviour of the network at the connection point, enabling the HVDC system owners to design their system with regard to at least, but not limited to, harmonics and dynamic stability over the lifetime of the HVDC system.	-	
HVDC system robustness						
33	1			The HVDC system shall be capable of finding stable operation points with a minimum change in active power flow and voltage level, during and after any planned or unplanned change in the HVDC system or AC network to which it is connected. The relevant TSO shall specify the changes in the system conditions for which the HVDC systems shall remain in stable operation.	**Voltage phase jump:** The system must be designed for uninterruptible operation, to tolerate one instantaneous voltage phase jump of up to 20 ° in the network connection point.	

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
33	2			The HVDC system owner shall ensure that the tripping or disconnection of an HVDC converter station, as part of any multi-terminal or embedded HVDC system, does not result in transients at the connection point beyond the limit specified by the relevant TSO.	Maximum 1.2 pu of Uc.	
33	3			The HVDC system shall withstand transient faults on HVAC lines in the network adjacent or close to the HVDC system, and shall not cause any of the equipment in the HVDC system to disconnect from the network due to auto- reclosure of lines in the network.	-	
33	4			The HVDC system owner shall provide information to the relevant system operator on the resilience of the HVDC system to AC system disturbances.	-	
Requirements for protection devices and settings						
Electrical protection schemes and settings						
34	1			The relevant system operator shall specify, in coordination with the relevant TSO, the schemes and settings necessary to protect the network taking into account the characteristics of the HVDC system. Protection schemes relevant for the HVDC system and the network, and settings relevant for the HVDC system, shall be coordinated and agreed between the relevant system operator, the relevant TSO and the HVDC system owner. The protection schemes and settings for internal electrical faults shall be designed so as not to jeopardise the performance of the HVDC system in accordance with this Regulation.	RSO anvender -linjebeskyttelse -transformerbeskyttelse -reaktorbeskyttelse -hjælpekrafttransformer-beskyttelse -samleskinnebeskyttelse Alle relevante indstillinger specificeres med udgangspunkt udgangspunkt I net- og anlægsanalyse Anlægsejer anvender som minimum: -anlægget sikres mod skader fra fejl og hændelser i nettet -anlægget sikres mod interne kortslutninger -anlægget sikres mod udkobling i ukritiske situationer -Det kollektive elforsyningsnet sikres i videst mulige omfang mod uønskede påvirkninger fra anlægget.	
34	2			Electrical protection of the HVDC system shall take precedence over operational controls taking into account system security, health and safety of staff and the public and mitigation of the damage to the HVDC system.	-	

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
34	3			Any change to the protection schemes or their settings relevant to the HVDC system and the network shall be agreed between the relevant system operator, the relevant TSO and the HVDC system owner before being implemented by the HVDC system owner.	-	
Priority ranking of protection and control						
35	1			A control scheme, specified by the HVDC system owner consisting of different control modes, including the settings of the specific parameters, shall be coordinated and agreed between the relevant TSO, the relevant system operator and the HVDC system owner.	-	
35	2			With regard to priority ranking of protection and control, the HVDC system owner shall organise its protections and control devices in compliance with the following priority ranking, listed in decreasing order of importance, unless otherwise specified by the relevant TSOs, in coordination with the relevant system operator:	HVDC system, POC and grid specific analysis. Part of connection agreement.	
35	2	a		network system and HVDC system protection;	-	
35	2	b		active power control for emergency assistance;	-	
35	2	c		synthetic inertia, if applicable;	-	
35	2	d		automatic remedial actions as specified in Article 13(3);	-	
35	2	e		LFSM;	-	
35	2	f		FSM and frequency control; and	-	
35	2	g		power gradient constraint.	-	
Changes to protection and control schemes and settings						
36	1			The parameters of the different control modes and the protection settings of the HVDC system shall be able to be changed in the HVDC converter station, if required by the relevant system operator or the relevant TSO, and in accordance with paragraph 3.	-	
36	2			Any change to the schemes or settings of parameters of the different control modes and protection of the HVDC system, including the procedure, shall be coordinated and agreed between the relevant system operator, the relevant TSO and the HVDC system owner.	-	
36	3			The control modes and associated set-points of the HVDC system shall be capable of being changed remotely, as specified by the relevant system operator, in coordination with the relevant TSO.	HVDC system, POC and grid specific analysis. Part of connection agreement.	

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
Requirements for power system restoration						
Black start						
37	1			The relevant TSO may obtain a quote for black start capability from an HVDC system owner.	Black start capability required.	
37	2			An HVDC system with black start capability shall be able, in case one converter station is energised, to energise the busbar of the AC-substation to which another converter station is connected, within a timeframe after shut down of the HVDC system determined by the relevant TSOs. The HVDC system shall be able to synchronise within the frequency limits set out in Article 11 and within the voltage limits specified by the relevant TSO or as provided for in Article 18, where applicable. Wider frequency and voltage ranges can be specified by the relevant TSO where needed in order to restore system security.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
37	3			The relevant TSO and the HVDC system owner shall agree on the capacity and availability of the black start capability and the operational procedure.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
TITLE III - REQUIREMENTS FOR DC-CONNECTED POWER PARK MODULES AND REMOTE-END HVDC CONVERTER STATIONS						
Requirements for DC-connected power park modules						
Scope						
38				The requirements applicable to offshore power park modules under Articles 13 to 22 of Regulation (EU) 2016/631 shall apply to DC-connected power park modules subject to specific requirements provided for in Articles 41 to 45 of this Regulation. These requirements shall apply at the HVDC interface points of the DC-connected power park module and the HVDC systems. The categorisation in Article 5 of Regulation (EU) 2016/631 shall apply to DC-connected power park modules.	-	
Frequency stability requirements						
39	1			With regards to frequency response:	-	
39	1	a		a DC-connected power park module shall be capable of receiving a fast signal from a connection point in the synchronous area to which frequency response is being provided, and be able to process this signal within 0,1 second from sending to completion of processing the signal for activation of the response. Frequency shall be measured at the connection point in the synchronous area to which frequency response is being provided;	-	
39	1	b		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 as specified by the relevant TSO.	HVDC system, POC and grid specific analysis. Part of connection agreement.	

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
39	2			With regard to frequency ranges and response:	-	
39	2	a		a DC-connected power park module shall be capable of staying connected to the remote-end HVDC converter station network and operating within the frequency ranges and time periods specified in Annex VI for the 50 Hz nominal system. Where a nominal frequency other than 50 Hz, or a frequency variable by design is used, subject to agreement with the relevant TSO, the applicable frequency ranges and time periods shall be specified by the relevant TSO taking into account specificities of the system and the requirements set out in Annex VI; 8.9.2016 L 241/20 Official Journal of the European Union EN	-	
39	2	b		wider frequency ranges or longer minimum times for operation can be agreed between the relevant TSO and the DC-connected power park module owner to ensure the best use of the technical capabilities of a DC-connected power park module if needed to preserve or to restore system security. If wider frequency ranges or longer minimum times for operation are economically and technically feasible, the DC-connected power park module owner shall not unreasonably withhold consent;	-	
39	2	c		while respecting the provisions of point (a) of paragraph 2, a DC-connected power park module shall be capable of automatic disconnection at specified frequencies, if specified by the relevant TSO. Terms and settings for automatic disconnection shall be agreed between the relevant TSO and the DC-connected power park module owner.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
39	3			With regards to rate-of-change-of-frequency withstand capability, a DC-connected power park module shall be capable of staying connected to the remote-end HVDC converter station network and operable if the system frequency changes at a rate up to +/– 2 Hz/s (measured at any point in time as an average of the rate of change of frequency for the previous 1 second) at the HVDC interface point of the DC-connected power park module at the remote end HVDC converter station for the 50 Hz nominal system.	-	
39	4			DC-connected power park modules shall have limited frequency sensitive mode — overfrequency (LFSM-O) capability in accordance with Article 13(2) of Regulation (EU) 2016/631, subject to fast signal response as specified in paragraph 1 for the 50 Hz nominal system.		
39	5			A capability for DC-connected power park modules to maintain constant power shall be determined in accordance with Article 13(3) of Regulation (EU) 2016/631 for the 50 Hz nominal system.		
39	6			A capability for active power controllability of DC-connected power park modules shall be determined in accordance with Article 15(2)(a) of Regulation (EU) 2016/631 for the 50 Hz nominal system. Manual control shall be possible in the case that remote automatic control devices are out of service.		
39	7			A capability for limited frequency sensitive mode — underfrequency (LFSM-U) for a DC-connected power park module shall be determined in accordance with Article 15(2)(c) of Regulation (EU) 2016/631, subject to fast signal response as specified in paragraph 1 for the 50 Hz nominal system.		

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
39	8			A capability for frequency sensitive mode for a DC-connected power park module shall be determined in accordance with Article 15(2)(d) of Regulation (EU) 2016/631, subject to a fast signal response as specified in paragraph 1 for the 50 Hz nominal system.		
39	9			A capability for frequency restoration for a DC-connected power park module shall be determined in accordance with Article 15(2)(e) of Regulation (EU) 2016/631 for the 50 Hz nominal system.		
39	10			Where a constant nominal frequency other than 50 Hz, a frequency variable by design or a DC system voltage is used, subject to the agreement of the relevant TSO, the capabilities listed in paragraphs 3 to 9 and the parameters associated with such capabilities shall be specified by the relevant TSO.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Reactive power and voltage requirements						
40	1			With respect to voltage ranges:		
40	1	a		a DC-connected power park module shall be capable of staying connected to the remote-end HVDC converter station network and operating within the voltage ranges (per unit), for the time periods specified in Tables 9 and 10, Annex VII. The applicable voltage range and time periods specified are selected based on the reference 1 pu voltage;	100 – 300 kV 1,12 – 1,15 pu : 30 min 300 – 400 kV 1,05 – 1,15: 60 min	
40	1	b		wider voltage ranges or longer minimum times for operation can be agreed between the relevant system operator, the relevant TSO and the DC-connected power park module owner to ensure the best use of the technical capabilities of a DC-connected power park module if needed to preserve or to restore system security. If wider voltage ranges or longer minimum times for operation are economically and technically feasible, the DC-connected power park module owner shall not unreasonably withhold consent;	HVDC system, POC and grid specific analysis. Part of connection agreement.	
40	1	c		for DC-connected power park modules which have an HVDC interface point to the remote-end HVDC converter station network, the relevant system operator, in coordination with the relevant TSO may specify voltages at the HVDC interface point at which a DC-connected power park module shall be capable of automatic disconnection. The terms and settings for automatic disconnection shall be agreed between the relevant system operator, the relevant TSO and the DC-connected power park module owner;	HVDC system, POC and grid specific analysis. Part of connection agreement.	
40	1	d		for HVDC interface points at AC voltages that are not included in the scope of Annex VII, the relevant system operator, in coordination with the relevant TSO shall specify applicable requirements at the connection point;	-	
40	1	e		where frequencies other than nominal 50 Hz are used, subject to relevant TSO agreement, the voltage ranges and time periods specified by the relevant system operator, in coordination with the relevant TSO, shall be proportional to those in Tables 9 and 10, Annex VII.	-	
40	2			With respect to reactive power capability for DC-connected power park modules:	-	

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
40	2	a		if the DC-connected power park module owner can obtain a bilateral agreement with the owners of the HVDC systems connecting the DC-connected power park module to a single connection point on a AC network, it shall fulfill all of the following requirements:	-	
40	2	a	i	it shall have the ability with additional plant or equipment and/or software, to meet the reactive power capabilities prescribed by the relevant system operator, in coordination with the relevant TSO, according to point (b), and it shall either: - have the reactive power capabilities for some or all of its equipment in accordance with point (b) already installed as part of the connection of the DC-connected power park module to the AC network at the time of initial connection and commissioning; or - demonstrate to, and then reach agreement with, the relevant system operator and the relevant TSO on how the reactive power capability will be provided when the DC-connected power park module is connected to more than a single connection point in the AC network, or the AC network at the remote-end HVDC converter station network has either another DC-connected power park module or HVDC system with a different owner connected to it. This agreement shall include a contract by the DC-connected power park module owner (or any subsequent owner), that it will finance and install reactive power capabilities required by this Article for its power park modules at a point in time specified by the relevant system operator, in coordination with the relevant TSO. The relevant system operator, in coordination with the relevant TSO shall inform the DC-connected power park module owner of the proposed completion date of any committed development which will require the DC-connected power park module owner to install the full reactive power capability.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
40	2	a	ii	the relevant system operator, in coordination with the relevant TSO shall account for the development time schedule of retrofitting the reactive power capability to the DC-connected power park module in specifying the point in time by which this reactive power capability retrofitting is to take place. The development time schedule shall be provided by the DC-connected power park module owner at the time of connection to the AC network.	-	
40	2	b		DC-connected power park modules shall fulfil the following requirements relating to voltage stability either at the time of connection or subsequently, according to the agreement as referred to in point (a):	-	
40	2	b	i	with regard to reactive power capability at maximum HVDC active power transmission capacity, DC-connected power park modules shall meet the reactive power provision capability requirements specified by the relevant system operator, in coordination with the relevant TSO, in the context of varying voltage. The relevant system operator shall specify a U-Q/P_{max}-profile that may take any shape with ranges in accordance with Table 11, Annex VII, within which the DC-connected power park module shall be capable of providing reactive power at its maximum HVDC active power transmission capacity. The relevant system operator, in coordination with the relevant TSO, shall consider the long term development of the network when determining these ranges, as well as the potential costs for power park modules of delivering the	Jf. EU Forordning 2016/631 artikel 21 stk. (3) litra (b)(1) samt litra (c)(1)	

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
				capability of providing reactive power production at high voltages and reactive power consumption at low voltages. If the Ten-Year Network Development Plan developed in accordance with Article 8 of Regulation (EC) No 714/2009 or a national plan developed and approved in accordance with Article 22 of Directive 2009/72/EC specifies that a DC-connected power park module will become AC-connected to the synchronous area, the relevant TSO may specify that either: - the DC-connected power park module shall have the capabilities prescribed in Article 25(4) of Regulation (EU) 2016/631 for that synchronous area installed at the time of initial connection and commissioning of the DC-connected power park module to the AC-network; or - the DC-connected power park module owner shall demonstrate to, and then reach agreement with, the relevant system operator and the relevant TSO on how the reactive power capability prescribed in Article 25(4) of Regulation (EU) 2016/631 for that synchronous area will be provided in the event that the DC-connected power park module becomes AC-connected to the synchronous area.		
40	2	b	ii	With regard to reactive power capability, the relevant system operator may specify supplementary reactive power to be provided if the connection point of a DC-connected power park module 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. This supplementary reactive power shall compensate the reactive power exchange of the high-voltage line or cable between the high-voltage terminals of the step-up transformer of the DC-connected power park module or its alternator terminals, if no step-up transformer exists, and the connection point and shall be provided by the responsible owner of that line or cable.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
40	3			With regard to priority to active or reactive power contribution for DC-connected power park modules, the relevant system operator, in coordination with the relevant TSO shall specify whether active power contribution or reactive power contribution has priority during faults for which fault-ride-through capability is required. If priority is given to active power contribution, its provision shall be established within a time from the fault inception as specified by the relevant system operator, in coordination with the relevant TSO.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Control requirements						
41	1			During the synchronisation of a DC-connected power park module to the AC collection network, the DC-connected power park module shall have the capability to limit any voltage changes to a steady-state level specified by the relevant system operator, in coordination with the relevant TSO. The level specified shall not exceed 5 per cent of the pre-synchronisation voltage. The relevant system operator, in coordination with the relevant TSO, shall specify the maximum magnitude, duration and measurement window of the voltage transients.	HVDC system, POC and grid specific analysis. Part of connection agreement.	

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
41	2			The DC-connected power park module owner shall provide output signals as specified by the relevant system operator, in coordination with the relevant TSO.	-	
Network characteristics						
42				With regard to the network characteristics, the following shall apply for the DC-connected power park modules:	-	
42	a			each relevant system operator shall specify and make publicly available the method and the pre-fault and post-fault conditions for the calculation of minimum and maximum short circuit power at the HVDC interface point;	HVDC system, POC and grid specific analysis. Part of connection agreement.	
42	b			the DC-connected power park module shall be capable of stable operation within the minimum to maximum range of short circuit power and network characteristics of the HVDC interface point specified by the relevant system operator, in coordination with the relevant TSO;	-	
42	c			each relevant system operator and HVDC system owner shall provide the DC-connected power park module owner with network equivalents representing the system, enabling the DC-connected power park module owners to design their system with regard to harmonics;	-	
Protection requirements						
43	1			Electrical protection schemes and settings of DC-connected power park modules shall be determined in accordance with Article 14(5)(b) of Regulation (EU) 2016/631, where the network refers to the synchronous area network. The protection schemes have to be designed taking into account the system performance, grid specificities as well as technical specificities of the power park module technology and agreed with the relevant system operator, in coordination with the relevant TSO.		
43	2			Priority ranking of protection and control of DC-connected power park modules shall be determined in accordance with Article 14(5)(c) of Regulation (EU) 2016/631, where the network refers to the synchronous area network, and agreed with the relevant system operator, in coordination with the relevant TSO.		
Power quality						
44				DC-connected power park modules owners shall ensure that their connection to the network does not result in a level of distortion or fluctuation of the supply voltage on the network, at the connection point, exceeding the level specified by the relevant system operator, in coordination with the relevant TSO. The necessary contribution from grid users to associated studies, including, but not limited to, existing DC-connected power park modules and existing HVDC systems, shall not be unreasonably withheld. The process for necessary studies to be conducted and relevant data to be provided by all grid users involved, as well as mitigating actions identified and implemented, shall be in accordance with the process in Article	Jf. Annex A	

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
				29.		
General system management requirements applicable to DC-connected power park modules						
45				With regard to general system management requirements, Articles 14(5), 15(6) and 16(4) of Regulation (EU) 2016/631 shall apply to any DC-connected power park module.	Jf. EU Forordning 2016/631	
Requirements for remote-end HVDC converter stations						
Scope						
46				The requirements of Articles 11 to 39 apply to remote-end HVDC converter stations, subject to specific requirements provided for in Articles 47 to 50.	-	
Frequency stability requirements						
47	1			Where a nominal frequency other than 50 Hz, or a frequency variable by design is used in the network connecting the DC-connected power park modules, subject to relevant TSO agreement, Article 11 shall apply to the remote-end HVDC converter station with the applicable frequency ranges and time periods specified by the relevant TSO, taking into account specificities of the system and the requirements laid down in Annex I.		
47	2			With regards to frequency response, the remote-end HVDC converter station owner and the DC-connected power park module owner shall agree on the technical modalities of the fast signal communication in accordance with Article 39(1). Where the relevant TSO requires, the HVDC system shall be capable of providing the network frequency at the connection point as a signal. For an HVDC system connecting a power park module the adjustment of active power frequency response shall be limited by the capability of the DC-connected power park modules.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Reactive power and voltage requirements						
48	1			With respect to voltage ranges:	-	
48	1	a		remote-end HVDC converter station shall be capable of staying connected to the remote-end HVDC converter station network and operating within the voltage ranges (per unit) and time periods specified in Tables 12 and 13, Annex VIII. The applicable voltage range and time periods specified are selected based on the reference 1 pu voltage;	110 – 300 kV. 1.12 – 1.15 pu: 30 min. 300 – 400 kV. 1.05 – 1.15 pu: 60 min. 1pu @ 150kV: 152kV 1pu @ 220kV: 220 kV 1pu @ 400kV: 400 kV	

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
48	1	b		wider voltage ranges or longer minimum times for operation may be agreed between the relevant system operator, in coordination with the relevant TSO, and the DC-connected power park module owner in accordance with Article 40;	HVDC system, POC and grid specific analysis. Part of connection agreement.	
48	1	c		for HVDC interface points at AC voltages that are not included in the scope of Table 12 and Table 13, Annex VIII, the relevant system operator, in coordination with the relevant TSO shall specify applicable requirements at the connection points;	-	
48	1	d		where frequencies other than nominal 50 Hz are used, subject to agreement by the relevant TSO, the voltage ranges and time periods specified by the relevant system operator, in coordination with the relevant TSO, shall be proportional to those in Annex VIII.	-	
48	2			A remote-end HVDC converter station shall fulfil the following requirements referring to voltage stability, at the connection points with regard to reactive power capability:	-	
48	2	a		the relevant system operator, in coordination with the relevant TSO shall specify the reactive power provision capability requirements for various voltage levels. In doing so, the relevant system operator, in coordination with the relevant TSO shall specify a U-Q/P_{max}-profile of any shape and within the boundaries of which the remote-end HVDC converter station shall be capable of providing reactive power at its maximum HVDC active power transmission capacity;	Jf. Annex D.	
48	2	b		the U-Q/P_{max}-profile shall be specified by each relevant system operator, in coordination with the relevant TSO. The U-Q/P_{max}-profile shall be within the range of Q/P_{max} and steady-state voltage specified in Table 14, Annex VIII, and the position of the U-Q/P_{max}-profile envelope shall lie within the limits of the fixed outer envelope specified in Annex IV. The relevant system operator, in coordination with the relevant TSO, shall consider the long term development of the network when determining these ranges.	Jf. Annex D.	
Network characteristics						
49				With regard to the network characteristics, the remote-end HVDC converter station owner shall provide relevant data to any DC-connected power park module owner in accordance with Article 42.	-	
Power quality						
50				Remote-end HVDC converter station owners shall ensure that their connection to the network does not result in a level of distortion or fluctuation of the supply voltage on the network, at the connection point, exceeding the level allocated to them by the relevant system operator, in coordination with the relevant TSO. The necessary contribution from grid users to the associated studies shall not be unreasonably withheld, including from, but not limited to, existing DC- connected power park modules and existing HVDC systems. The process for necessary studies to be conducted and relevant data to be provided by all grid users involved, as well as mitigating actions identified and implemented shall be in accordance with the	Jf. Annex A	

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
				process provided for in Article 29.		
TITLE IV - INFORMATION EXCHANGE AND COORDINATION						
Operation of HVDC systems						
51	1			With regard to instrumentation for the operation, each HVDC converter unit of an HVDC system shall be equipped with an automatic controller capable of receiving instructions from the relevant system operator and from the relevant TSO. This automatic controller shall be capable of operating the HVDC converter units of the HVDC system in a coordinated way. The relevant system operator shall specify the automatic controller hierarchy per HVDC converter unit.	HVDC system, POC and grid specific analysis.	
51	2			The automatic controller of the HVDC system referred to in paragraph 1 shall be capable of sending the following signal types to the relevant system operator:	-	
51	2	a		operational signals, providing at least the following:	-	
51	2	a	i	start-up signals;	-	
51	2	a	ii	AC and DC voltage measurements;	-	
51	2	a	iii	AC and DC current measurements;	-	
51	2	a	iv	active and reactive power measurements on the AC side;	-	
51	2	a	v	DC power measurements;	-	
51	2	a	vi	HVDC converter unit level operation in a multi-pole type HVDC converter;	-	
51	2	a	vii	elements and topology status; and	-	
51	2	a	viii	FSM, LFSM-O and LFSM-U active power ranges.	-	
51	2	b		) alarm signals, providing at least the following:	-	
51	2	b	i	emergency blocking;	-	
51	2	b	ii	ramp blocking;	-	
51	2	b	iii	fast active power reversal.	-	
51	3			The automatic controller referred to in paragraph 1 shall be capable of receiving the following signal types from the relevant system operator:	-	

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
51	3	a		operational signals, receiving at least the following:	-	
51	3	a	i	start-up command;	-	
51	3	a	ii	active power setpoints;	-	
51	3	a	iii	frequency sensitive mode settings;	-	
51	3	a	iv	reactive power, voltage or similar setpoints;	-	
51	3	a	v	reactive power control modes;	-	
51	3	a	vi	power oscillation damping control; and	-	
51	3	a	vii	synthetic inertia.	-	
51	3	b		alarm signals, receiving at least the following:	-	
51	3	b	i	emergency blocking command;	-	
51	3	b	ii	ramp blocking command;	-	
51	3	b	iii	active power flow direction; and	-	
51	3	b	iv	fast active power reversal command.	-	
51	4			With regards to each signal, the relevant system operator may specify the quality of the supplied signal.	HVDC system, POC and grid specific analysis.	
Parameters and settings						
52				The parameters and settings of the main control functions of an HVDC system shall be agreed between the HVDC system owner and the relevant system operator, in coordination with the relevant TSO. The parameters and settings shall be implemented within such a control hierarchy that makes their modification possible if necessary. Those main control functions are at least:	HVDC system, POC and grid specific analysis. Part of connection agreement.	
52		a		synthetic inertia, if applicable as referred to in Articles 14 and 41;	-	
52		b		frequency sensitive modes (FSM, LFSM-O, LFSM-U) referred to in Articles 15, 16 and 17;	-	
52		c		frequency control, if applicable, referred to in Article 16;	-	
52		d		reactive power control mode, if applicable as referred to in Article 22;	-	

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
52		e		power oscillation damping capability, referred to Article 30;	-	
52		f		subsynchronous torsional interaction damping capability, referred to Article 31.	-	
Fault recording and monitoring						
53	1			An HVDC system shall be equipped with a facility to provide fault recording and dynamic system behaviour monitoring of the following parameters for each of its HVDC converter stations:	-	
53	1	a		AC and DC voltage;	-	
53	1	b		AC and DC current;	-	
53	1	c		active power;	-	
53	1	d		reactive power; and	-	
53	1	e		frequency.	-	
53	2			The relevant system operator may specify quality of supply parameters to be complied with by the HVDC system, provided a reasonable prior notice is given.	HVDC system, POC and grid specific analysis.	
53	3			The particulars of the fault recording equipment referred to in paragraph 1, including analogue and digital channels, the settings, including triggering criteria and the sampling rates, shall be agreed between the HVDC system owner, the relevant system operator and the relevant TSO.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
53	4			All dynamic system behaviour monitoring equipment shall include an oscillation trigger, specified by the relevant system operator, in coordination with the relevant TSO, with the purpose of detecting poorly damped power oscillations.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
53	5			The facilities for quality of supply and dynamic system behaviour monitoring shall include arrangements for the HVDC system owner and the relevant system operator to access the information electronically. The communications protocols for recorded data shall be agreed between the HVDC system owner, the relevant system operator and the relevant TSO.	HVDC system, POC and grid specific analysis. Part of connection agreement.	
Simulation models						
54	1			The relevant system operator in coordination with the relevant TSO may specify that an HVDC system owner deliver simulation models which properly reflect the behaviour of the HVDC system in both steady-state, dynamic simulations (fundamental frequency component) and in electromagnetic transient simulations.	Jf. Annex B	

HVDC (high voltage direct current), articles 11- 54 (titles II, III og IV)

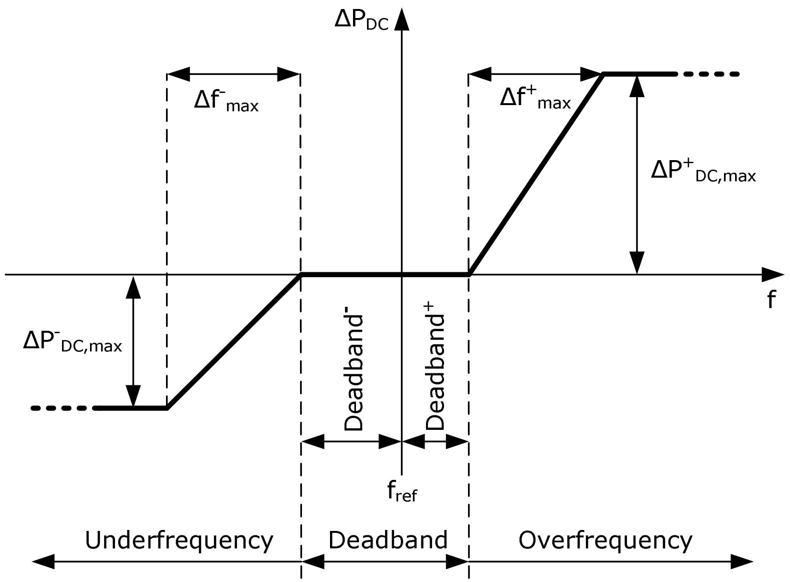
Art. nr.	Art. stk.	Art. afsn.	Art. enh.	Artikelemne	Krav	Vejledning
				The format in which models shall be provided and the provision of documentation of models structure and block diagrams shall be specified by the relevant system operator in coordination with the relevant TSO.		
54	2			For the purpose of dynamic simulations, the models provided shall contain at least, but not limited to the following sub-models, depending on the existence of the mentioned components:	-	
54	2	a		HVDC converter unit models;	-	
54	2	b		AC component models;	-	
54	2	c		DC grid models;	-	
54	2	d		Voltage and power controller;	-	
54	2	e		Special control features if applicable e.g. power oscillation damping (POD) function, subsynchronous torsional interaction (SSTI) control;	-	
54	2	f		Multi terminal control, if applicable;	-	
54	2	g		HVDC system protection models as agreed between the relevant TSO and the HVDC system owner.	-	
54	3			The HVDC system owner shall verify the models against the results of compliance tests carried out according to Title VI and a report of this verification shall be submitted to the relevant TSO. The models shall then be used for the purpose of verifying compliance with the requirements of this Regulation including, but not limited to, compliance simulations as provided for in Title VI and used in studies for continuous evaluation in system planning and operation.	-	
54	4			An HVDC system owner shall submit HVDC system recordings to the relevant system operator or relevant TSO if requested in order to compare the response of the models with these recordings.	-	
54	5			An HVDC system owner shall deliver an equivalent model of the control system when adverse control interactions may result with HVDC converter stations and other connections in close electrical proximity if requested by the relevant system operator or relevant TSO. The equivalent model shall contain all necessary data for the realistic simulation of the adverse control interactions.	-	

Noter:

Note 1: HVDC FSM

The active power frequency response shall be activated as fast as inherently technically feasible with an initial delay that shall be as short as possible.

Setting	Interval	Resolution
Reference frequency, f_{ref}	47 – 52 Hz	10 mHz
Reference frequency tomorrow	47 – 52 Hz	10 mHz
Dead band -	0-999 mHz	10 mHz
Dead band +	0-999 mHz	10 mHz
Regulating frequency band, Δf-	0-999 mHz	10 mHz
Regulating frequency band, Δf+	0-999 mHz	10 mHz
Maximum power change $\Delta P^{-}_{DC,max}$ (with respect to the maximum power rating of the converter)	0-max MW	1 MW
Maximum power change $\Delta P^{+}_{DC,max}$ (with respect to the maximum power rating of the converter)	0-max MW	1 MW
Maximum ramp rate $(dP/dt)_{max}$	0-200 MW/sec	1 MW/sec



Frequency control is automatically disabled during EPC-P and automatically enabled after EPC-P no longer persists.

If the frequency control mode is activated and frequency deviation leaves a certain deadband, which is definable separately for both sides of the Converter the additional frequency control mode power order ΔP_{DC} shall be linear dependent on the frequency deviation using a proportional control factor k_1 and k_2 for each side of the converter.

- All the settings shall be changeable both locally and remotely.
- It shall be possible manually to enable/disable if frequency regulation may block/de-block the pole.
- The frequency deviation Δf shall be measured locally with an accuracy of ± 2 mHz.
- There shall be an individual set of settings for each side of the Converter.
- All settings except "reference frequency tomorrow" shall only be changeable when the frequency control function is disabled.
- The settings "reference frequency tomorrow" shall be changeable when the frequency control is enabled.
- At midnight the value of "reference frequency" must be automatically updated with the value of "reference frequency tomorrow"
- The frequency control function shall send an indication each time the function is activated and redefines the converter reference power $P_{DC,ref}$ and a continuously updated value with the amount of regulated power ΔP_{DC}.

Note 2: General requirement for the reactive power controller (RPC).

General requirement for the reactive power controller (RPC).

In the complete active power operating range of the converters, the inherent reactive power capability must be possible to be continuously controlled.

- active power shall have higher priority than reactive power in normal operation i.e. voltage and frequency are within the unlimited or time limited operation ranged

The reactive power must be controllable when.

- no active power is transferred on the link irrespective if no active power is transferred due to zero demand
- at cable outage or
- remote end station outage

The reactive power control commands must be possible to execute independently in any of the converter stations. From local (OWS) and remote it must be possible to select.

- Voltage Control mode (Q= (V-Vref)*a)
- Reactive Power Control mode (Q = Q_ref)
- Power Factor Control mode (cos φ = const.)

General performance requirements.

- It must be possible to set parameters of the automatic control loops
- Transfer between the different control modes must be possible without any jumps of the converter stations active or reactive power
- No limitations in how often a new set point can be changed
- When the RPC is switched between the three reactive power operation modes in any order the valid reference value shall automatically be set equal to the actual measured voltage to avoid filter switching caused by the change of control mode
- Bump-less transition between the three control modes must always be ensured.

Local/remote control of RPC.

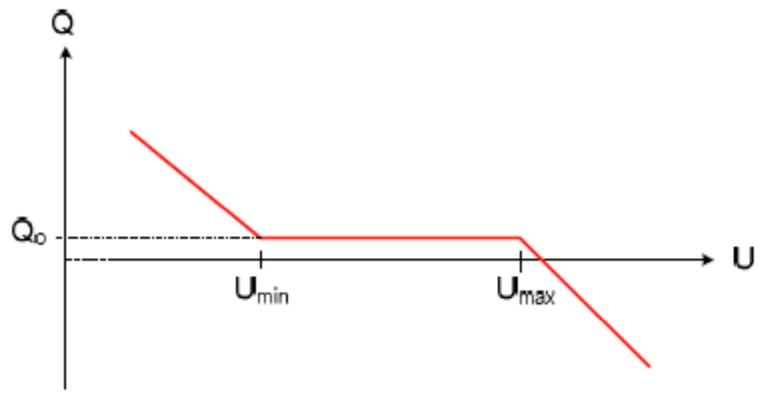
- it must be possible to select local control from OWS
- local/remote control of the RPC is independent of the local/remote modes for the Converter
- Both from OWS and from remote it must be possible to select all modes and to set all parameters for the RPC

Reactive Power Control

The Reactive Power control mode must keep a fixed reactive power exchange Q_o with the grid unless the voltage at the POC/voltage reference point is outside the selected U_{min},U_{max} for Q_o upon which the RPC must support the voltage with a droop control to restore the voltage, when the voltage is restored within U_{min},U_{max}, the RPC will "automatically' return to Q_o.

The Reactive Power control mode must

- Keep a fixed reactive power exchange Q_o with the grid within a specified Umin and Umax.
- If the voltage at the POC/voltage reference point is outside the specified U_{min},U_{max} for Q_o the RPC must support the voltage with a droop control to restore the voltage
- When the voltage is restored i.e. within U_{min},U_{max}, the RPC will "automatically' return to operate with a fixed reactive power exchange Q_o
- Change from the currently active set-point to a new target set-point must be done with the defined ramp $Q_{ramp\ speed}$.



Normal control characteristic for reactive power control mode

Voltage set-points must have a setting range within minimum to maximum voltage, i.e. in the voltage range for unlimited operation and the voltage range for time limited operation with an accuracy of 1 kV.

CE: 110 kV up to 300 kV Umin = between 0.85 – 1.0 pu	CE: 300 kV up to 400 (and including) Umin = between 0.85 – 1.0 pu

Umax = between 1.0 – 1.15 pu	Umax = between 1.0 – 1.10 pu
N: 110 kV up to 300 kV Umin = between 0.9 – 1.0 pu Umax = between 1.0 – 1.1 pu	CE: 300 kV up to 400 (and including) Umin = between 0.9 – 1.0 pu Umax = between 1.0 – 1.10 pu

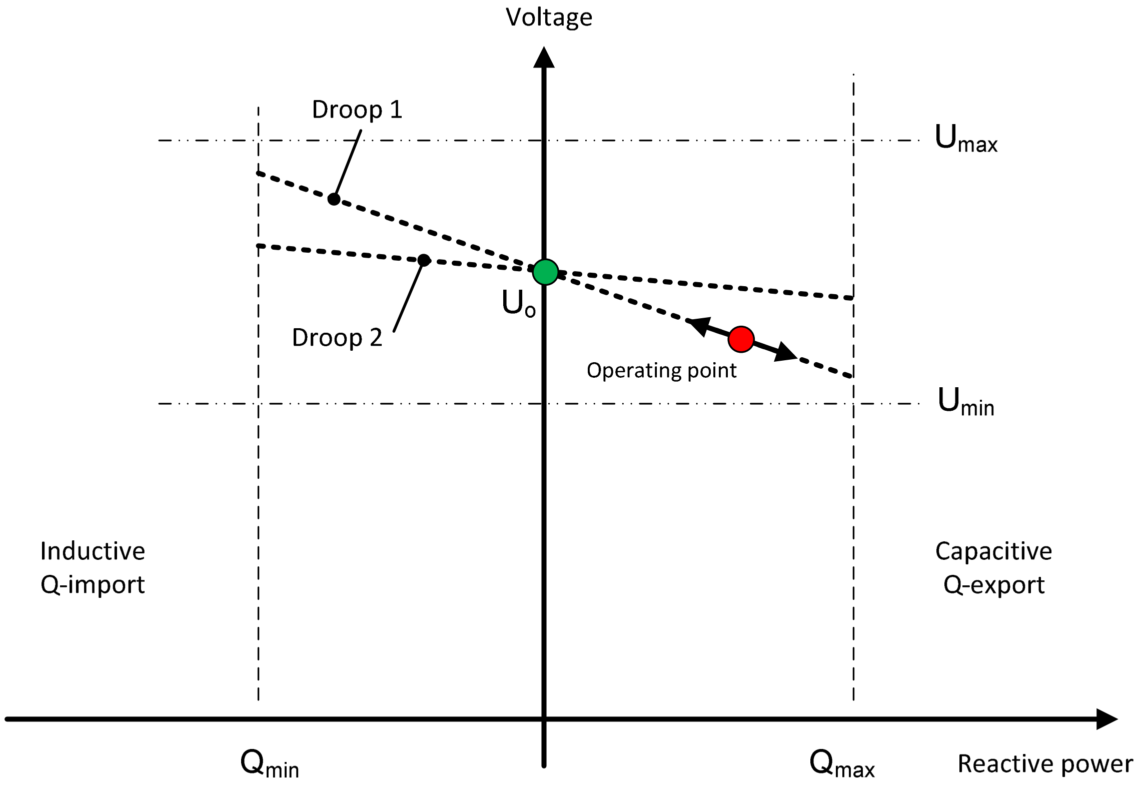
The set-points for the station must be adjustable between:

- Qo = between 0 and +/- the maximum converter reactive power rating
- $Q_{ramp\ speed}$ = between 1-30 Mvar/min (speed of set point reference change)
- Droop = between 1-10%, different values must be selectable for voltages below U_{min} and above U_{max}

Voltage Control

Voltage Control Mode must:

- be possible to select Voltage Control as the default control mode that is automatically activated in case of an outage of the DC cable or the other Converter Station.
- If the voltage set point is to be changed, such change must be commenced immediately after receipt of an order to change the set point.
- The HVDC station must be able to perform the control within its dynamic range and voltage limit with the *droop* configured. In this context, *droop* is the voltage change (p.u.) caused by a change in reactive power (p.u.).



Voltage control mode characteristic

Voltage control mode operation requirement

Voltage control mode must have a setting range within minimum to maximum voltage, i.e. in the voltage range for unlimited operation and the voltage range for time limited operation with an accuracy of 1 kV.

CE: 110 kV up to 300 kV Umin = between 0.85 – 1.0 pu Umax = between 1.0 – 1.15 pu	CE: 300 kV up to 400 (and including) Umin = between 0.85 – 1.0 pu Umax = between 1.0 – 1.10 pu
N: 110 kV up to 300 kV Umin = between 0.9 – 1.0 pu Umax = between 1.0 – 1.1 pu	CE: 300 kV up to 400 (and including) Umin = between 0.9 – 1.0 pu Umax = between 1.0 – 1.10 pu

U_0 = range within minimum to maximum voltage, as shown I below table, with an accuracy of 1 kV.

Qmin = Between 0 and - the maximum converter reactive power rating

Qmax = Between 0 and + the maximum converter reactive power rating

Droop = between 1-10%, different values must be selectable for voltages below Q_{min} and above Q_{max}

- All set points must be adjustable from local and remote.

Power Factor control mode

- Power Factor control mode can be enabled and disabled from operator level (OWS) independently at each station
- the actual measured active power is used as input of the Power Factor Controller
- The operator can input a desired power factor target value in the range between minimum and maximum PF value
- Besides the absolute value for the Power Factor, the inductive or capacitive characteristic is to be selected by operator.
- power factor target ramping speed must also be possible.
- At any time during the ramp the operator can initiate "ramp stop" to stop the power factor ramp and hold at the actual power factor target level.
- Initiating "ramp release" resumes the already defined ramp with the same destination, if no interim changes were made to the settings.
- The power factor order ramping process is stopped as soon as the desired power factor target order finally reached the new power factor target set-point.
- The power order calculation of the power factor controller is permanent, i.e. even when the controller is DISABLED, it calculates a potential order, but it is not contributed. In case of Enabling of the power factor controller the calculated order is immediately used for reactive power control. But for bumpless transition the actual calculated order is also added to the Q-controller with opposite sign.

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