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GENERAL REQUIREMENTS FOR HVDC CONNECTIONS

Aspect	Non-Exhaustive Requirement	Non-Mandatory Requirement	Article	Definition	Comment	DE	
	NA		5.4	RSO/TSO	Proposal of requirements of general applications	Proposal	Status (0 - no consideration; 1 - TSO internal consideration; 2 - preliminary shred with stakeholders; 3 - selected for approval; 4 - approved/binding)
FREQUENCY RELATED PARAMETERS	FREQUENCY RANGES		11.1	TSO	Time period for operation in the frequency ranges (According to Table 1, Annex I) 47.0 Hz - 47.5 Hz 47.5 Hz - 48.5 Hz 48.5 Hz - 49.0 Hz 49.0 Hz - 51.0 Hz 51.0 Hz - 51.5 Hz 51.5 Hz - 52.0 Hz	as per NC HVDC	2 - preliminary shared with stakeholders
			11.3	TSO	Automatic disconnection at specifed frequencies	as per NC HVDC	2 - preliminary shared with stakeholders
		x	11.4	TSO	Maximum admissible active power output reduction from its operating point if the system frequency falls below 49 Hz.	not implemented	0 - no consideration
	RATE-OF-CHANGE-OF-FREQUENCY WITHSTAND CAPABILITY		12	HVDC	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).	as per NC HVDC	2 - preliminary shared with stakeholders
	ACTIVE POWER CONTROLLABILITY, CONTROL RANGE AND RAMPING RATE		13.1.a	TSO	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. Maximum active power capacity, step size, minimum active power capacity, and delay before adjustment of the transmitted power	as per NC HVDC, max initial delay 100 ms	2 - preliminary shared with stakeholders
			13.1.b	TSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
		x	13.1.c	TSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
			13.1.d	TSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
			13.2	TSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
			13.3	TSO	Trigger and blocking criteria for automatic responses	as per NC HVDC	2 - preliminary shared with stakeholders
	SYNTHETIC INERTIA	X	14.1	TSO	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	as per NC HVDC with the following modification: control system and power exchange paramters are subject to agreement between TSO and owner	3 - selected for approval
	FREQUENCY SENSITIVE MODE		15	TSO	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.	as per NC HVDC, parameters harmoninized with VDE-AR-N 4130	3 - selected for approval

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VOLTAGE RELATED PARAMETERS	VOLTAGE RANGE		18.1	TSO, adjacent RSOs	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.	as per NC HVDC	3 - selected for approval
			18.4	RSO/RTSO's	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.	as per NC HVDC	3 - selected for approval
			18.5	RTSO's	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.	not implemented (not relevant)	0 - no consideration
	SHORT CIRCUIT CONTRIBUTION DURING FAULTS		19.1	RSO, RTSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
			19.2	RSO, RTSO	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: (a) how and when a voltage deviation is to be determined as well as the end of the voltage deviation; (b) the characteristics of the fast fault current; (c) the timing and accuracy of the fast fault current, which may include several stages.	as per NC HVDC	2 - preliminary shared with stakeholders
			19.3	RSO, RTSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
	REACTIVE POWER CAPABILITY		20.1	RSO, RTSO	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/Pmax-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.	as per NC HVDC	2 - preliminary shared with stakeholders
			20.3		An HVDC system shall be capable of moving to any operating point within its U-Q/Pmax profile in timescales specified by the relevant system operator in coordination with the relevant TSO.	as per NC HVDC	2 - preliminary shared with stakeholders
			20.4		When operating at an active power output below the maximum HVDC active power transmission capacity (P < Pmax), 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/Pmax profile specified in paragraphs 1 to 3.	as per NC HVDC	2 - preliminary shared with stakeholders
	REACTIVE POWER EXCHANGED WITH THE NETWORK		21.1	RSO,RTSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
			21.2	RSO,RTSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
	REACTIVE POWER CONTROL MODE		22.1			as per NC HVDC	2 - preliminary shared with
			22.2			not implemented. Reference to article	0 - no consideration
			22.3			as per NC HVDC. t1 = 1 -20 s; t2 = 5 -	2 - preliminary shared with stakeholders
			22.4			as per NC HVDC	2 - preliminary shared with
			22.5			as per NC HVDC	2 - preliminary shared with stakeholders
			22.6			as per NC HVDC	2 - preliminary shared with stakeholders
	POWER QUALITY		24	RSO,RTSO	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.	as per NC HVDC	3 - selected for approval
'''			25.1			as per NC HVDC	3 - selected for approval

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REQUIREMENTS FOR FAULT RIDE THROUGH CAPABILIGY	FAULT RIDE THROUGH CAPABILITY		25.2			not implemented.	0 - no consideration
			25.3			as per NC HVDC	3 - selected for approval
			25.4			as per NC HVDC	3 - selected for approval
			25.5			not implemented.	0 - no consideration
			25.6			only two phase faults are considered.	2 - preliminary shared with stakeholders
	POST FAULT ACTIVE POWER RECOVERY		26	RTSO	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.	as per NC HVDC	2 - preliminary shared with stakeholders
	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.	as per NC HVDC	2 - preliminary shared with stakeholders
REQUIREMENTS FOR CONTROL	ENERGISATION AND SYNCHRONISATION OF HVDC CONVERTER STATIONS		28	RSO, RTSO	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.	as per NC HVDC with the following modification: steady-state voltage changes limited to 2% of rated voltage under undisturbed conditions. Transient RMS voltage changes limited to 10% rated voltage reaching the steady-state values after 3s	2 - preliminary shared with stakeholders
	POWER OSCILLATION DAMPING CAPABILITY		30	RTSO, HVDC SO	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.	as per NC HVDC: frequency range of oscillations defined to 0.1 - 2.0 Hz Modification: manual (de-)activation has to be possible; control parameter settings have to be defined between TSO and owner	2 - preliminary shared with stakeholders

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REQUIREMENTS FOR DC-CONNECTED POWER PARK MODULES

Aspect	Non-Exhaustive Requirement	Non-Mandatory Requirement	Article	Definition	Comment	DE	
	NA		5.4	RSO/TSO	Proposal of requirements of general applications	Proposal	Status
FREQUENCY STABILITY REQUIREMENTS	FREQUENCY RESPONSE		39.1.a	RSO,RTSO	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;	as per NC HVDC	2 - preliminary shared with stakeholders
	FREQUENCY RANGES AND RESPONSE		39.2.a	RTSO	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;	as per NC HVDC	2 - preliminary shared with stakeholders
	RATE-OF-CHANGE-OF-FREQUENCY		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.	as per NC HVDC	2 - preliminary shared with stakeholders
	LFSM		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.	as per NC HVDC, parameters harmonized with VDE-AR-N 4130	2 - preliminary shared with stakeholders
			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.	as per NC HVDC	2 - preliminary shared with stakeholders
			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.	as per NC HVDC	2 - preliminary shared with stakeholders
			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.	as per NC HVDC, parameters harmonized with VDE-AR-N 4130	2 - preliminary shared with stakeholders
			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.	as per NC HVDC, parameters harmonized with VDE-AR-N 4130	2 - preliminary shared with stakeholders
			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.	as per NC HVDC	2 - preliminary shared with stakeholders
			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.	as per NC HVDC	2 - preliminary shared with stakeholders
PARAMETERS	VOLTAGE RANGE		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;		
			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;		

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VOLTAGE RELATED			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.		
	REACTIVE POWER CAPABILITY						
OTHER ASPECTS	**CONTROL REQUIREMENTS**		41.1				
			41.2				
	NETWORK CHARACTERISTIC		42				
	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 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.		

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