ENTSO-E Draft Network Code on High Voltage Direct Current Connections and DC-connected Power Park Modules

2 September 2013

Notice
This document reflects the status of the work of Transmission System Operator experts as of 2 September 2013 in line with the ACER Framework Guidelines on Electricity Grid Connections published on 21 July 2011 after the EC mandate letter was received by ENTSO-E on 29 April 2013. **The document does not in any case represent a firm, binding or definitive ENTSO-E position on the content, the structure or the prerogatives of the Network Code on High Voltage Direct Current Connections and DC-connected Power Park Modules.** **Such version of the draft Network Code will be released for public consultation in accordance with the provisions of the Article 10 of Regulation (EC) N°714/2009 in November 2013.**

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THE EUROPEAN COMMISSION,

Having regard to the Treaty on the Functioning of the European Union,

Having regard to Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC,

Having regard to Regulation (EC) No 713/2009 of the European Parliament and of the Council of 13 July 2009 establishing an Agency for the Cooperation of Energy Regulators (ACER),

Having regard to Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 on conditions for access to the network for cross-border exchanges in electricity and repealing Regulation (EC) No 1228/2003 and especially Article 6,

Having regard to the priority list issued by the European Commission on 19 July 2012,

Having regard to the Framework Guideline on Electricity Grid Connections issued by the Agency for the Coordination of Energy Regulators on 21 July 2011,

Whereas:

(1) Directive 2009/72/EC of the European Parliament and of the Council of 13 July 2009 concerning common rules for the internal market in electricity and repealing Directive 2003/54/EC and Regulation (EC) No 714/2009 of the European Parliament and of the Council of 13 July 2009 underline the need for an increased cooperation and coordination among transmission system operators within a European Network of Transmission System Operators for Electricity (ENTSO-E) to create Network Codes for providing and managing effective and transparent access to the transmission networks across borders, and to ensure coordinated and sufficiently forward-looking planning and sound technical evolution of the transmission system in the European Union, including the creation of interconnection capacities, with due regard to the environment.

(2) Transmission System Operators (TSO(s)) are according to Article 2 and 12 of Directive 2009/72/EC responsible for providing and operating high and extra-high Voltage networks for long-distance transmission of electricity as well as for supply of lower-level regional distribution systems and directly connected customers. Besides this transmission and supply task it is also the TSO(s)' responsibility to ensure the system security with a high level of reliability and quality.

(3) [Further elements on the background which lead to the elaboration of such Network Code, especially if linked to the energy policy objectives of the European Union, i.e. functioning and competitive energy market; security of supply, and sustainability.]

(4) ENTSO-E has drafted this Network Code on HVDC Connections and DC-connected Power Park Modules aiming at setting out clear and objective requirements for HVDC System Owners, Power Generating Facility Owners of DC-connected Power Park Modules, Transmission System Operators and National Regulatory Authorities in order to contribute to non-discrimination, effective competition and the efficient functioning of the internal electricity market and to ensure system security.

(5) This Network Code has been drafted in accordance with the Article 8(7) of Regulation (EC) N°714/2009 according to which the Network Codes shall be developed for cross-border issues and market integration issues and shall be without prejudice to the right of Member States to establish national network codes which do not affect cross-border trade.

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(6) [Further elements explaining the philosophy of the Network Code. What is the NC trying to achieve: e.g.: ensuring further liquidity on the electricity market by making more interconnection capacity available.]

(7) [Further elements explaining the main principles of the Network Code, in order of appearance. What are the main tools which are supporting the philosophy of the Network Code. E.g.: calculating the available capacity in an harmonised way; foreseeing the possibility to hedge the risks via long term transmission rights.]

(8) [Further elements explaining important deviations to the main principles of the Network Code. E.g.: specific way to calculate capacity for a specific timeframe.]

HAS ADOPTED THIS NETWORK CODE:

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CONTENTS

CHAPTER 1 GENERAL PROVISIONS 7
Article 1 Subject-matter and scope 7
Article 2 Definitions 9
Article 3 Regulatory aspects 10
Article 4 Recovery of costs 11
Article 5 Confidentiality obligations 11
CHAPTER 2 GENERAL REQUIREMENTS FOR HVDC CONNECTIONS 13
SECTION 1 REQUIREMENTS FOR ACTIVE POWER CONTROL AND FREQUENCY SUPPORT 13
Article 6 Frequency ranges 13
Article 7 Rate-of-change-of-Frequency withstand capability 13
Article 8 Active power controllability; control range and ramping rate 14
Article 9 Synthetic inertia 15
Article 10 Frequency Sensitive Mode (FSM) 15
Article 11 Limited Frequency Sensitive Mode Overfrequency (LFSM-O) 17
Article 12 Limited Frequency Sensitive Mode Underfrequency (LFSM-U) 18
Article 13 Frequency control 19
SECTION 2 REQUIREMENTS FOR REACTIVE POWER CONTROL AND VOLTAGE SUPPORT 20
Article 14 Voltage ranges 20
Article 15 Short circuit contribution during faults requirements 21
Article 16 Reactive power capability 22
Article 17 Reactive power exchanged with the Network 23
Article 18 Reactive power control mode 24
Article 19 Priority to active or reactive power contribution 25
Article 20 Power quality 25
SECTION 3 REQUIREMENTS FOR FAULT RIDE THROUGH 25
Article 21 Fault ride through capability 25
Article 22 Post fault active power recovery 27
Article 23 Autoreclosure 27
SECTION 4 REQUIREMENTS FOR CONTROL 27
Article 24 Converter energisation and synchronisation 27
Article 25 Interaction between HVDC System(s) and other Connections 28
Article 26 Power oscillation damping capability 28

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Article 27 Sub-synchronous torsional interaction damping capability 28
Article 28 Network characteristics 29
Article 29 HVDC System robustness 29
SECTION 5 REQUIREMENTS FOR PROTECTION DEVICES AND SETTINGS 29
Article 30 Reconnection 30
Article 31 Electrical protection schemes and settings 30
Article 32 Priority ranking of protection and control 30
Article 33 Changes to protection and control schemes and settings 31
SECTION 6 REQUIREMENTS FOR POWER SYSTEM RESTORATION 31
Article 34 Black start 31
Article 35 Isolated network operation 31
Article 36 Modernisation, development and replacement 32
CHAPTER 3 REQUIREMENTS FOR DC-CONNECTED POWER PARK MODULES AND HVDC SUBSTATIONS CONNECTING DC-CONNECTED POWER PARK MODULES 33
Article 37 Frequency stability requirements 33
Article 38 Reactive Power and Voltage requirements 34
Article 39 Control Requirements 35
Article 40 Network characteristics 36
Article 41 Protection requirements 37
Article 42 Power Quality 37
Article 43 General System Management Requirements applicable to DC connected PPMs 37
CHAPTER 4 INFORMATION EXCHANGE AND COORDINATION 38
SECTION 1 MONITORING 38
Article 44 Operation 38
Article 45 Parameter setting 39
Article 46 Fault recording and Monitoring 39
Article 47 Fault analysis and disturbances 40
Article 48 Simulation models 40
CHAPTER 5 OPERATIONAL NOTIFICATION PROCEDURE FOR CONNECTION 42
Article 49 General provisions 42
Article 50 Energisation Operational Notification (EON) for HVDC Systems 42
Article 51 Interim Operational Notification (ION) for HVDC Systems 42
Article 52 Final Operational Notification (FON) for HVDC Systems 42
Article 53 Limited Operational Notification (LON) for HVDC Systems 42

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Article 54 General provisions 42
Article 55 Energisation Operational Notification (EON) for DC-connected Power Park Modules 42
Article 56 Interim Operational Notification (ION) for DC-connected Power Park Modules 42
Article 57 Final Operational Notification (FON) for DC-connected Power Park Modules 42
Article 58 Limited Operational Notification (LON) for DC-connected Power Park Modules 42
Article 59 General provisions 43
Article 60 General provisions 43
CHAPTER 6 COMPLIANCE 44
CHAPTER 7 DEROGATIONS 45
Article 61 General Provisions 45
Article 62 Request for Derogation 45
Article 63 Decision on Derogation 45
Article 64 Compliance of Existing HVDC Systems and Existing DC-connected Power Park Modules 45
Article 65 Register of derogations to the Network Code 45
CHAPTER 8 FINAL PROVISIONS 46
Article 66 Amendment of contracts and general terms and conditions 46
Article 67 Entry into force 46

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CHAPTER 1
GENERAL PROVISIONS

Article 1
Subject-matter and scope

1. This Network Code establishes common rules for HVDC Systems and DC-connected Power Park Modules which are significant according to the provisions of this Network Code.

2. The Network Code sets up a common framework for Network Connection Agreements between Network Operators and HVDC System Owners, and between Network Operators and Power Generating Facility Owners of DC-connected Power Park Modules.

3. HVDC Systems which are considered to be Significant HVDC Systems within the scope of this Network Code are categorized as follows:

   (a) HVDC Systems connecting Synchronous Areas or Control Areas, including back to back schemes;
   (b) HVDC Systems connecting Power Park Modules to the Network;
   (c) HVDC Systems embedded within one Control Area and connected to the Transmission Network; and
   (d) HVDC Systems embedded within one Control Area and connected to the Distribution Network when a cross-border impact is demonstrated by the Relevant TSO and approved by the NRA.

4. DC-connected Power Park Modules which are AC collected that are DC connected to the main electricity system (which is operating at any AC transmission Voltage), are considered to be Significant Power Generating Modules and are within the scope of this Network Code.

5. The requirements set forth by this Network Code shall apply to New HVDC Systems and New DC-connected Power Park Modules in a Member State, which are significant according to the provisions of this Network Code unless otherwise provided in this Network Code.

6. [Particular approach for embedded HVDC systems within on Control Area, owned by the TSO]

7. The requirements of this Network Code shall apply to Existing HVDC Systems and Existing DC-connected Power Park Modules deemed significant regarding the provisions of this Network Code, according to the provisions of Article 36 where applicable or by a decision of the Relevant National Regulatory Authority according to the provisions of Article 59 and Article 60 where applicable.

8. With regard to HVDC Systems not yet connected to the Network:
   (a) Within a delay not exceeding thirty months as from the day of entry into force of this Network Code, the HVDC System Owner shall provide the Relevant TSO with a confirmation of final and binding contracts it has concluded for the construction, assembly or purchase of the main plant of a HVDC System with relevance to the provisions of this Network Code and which exists prior to the day, which is two years after the day of entry into force of this Network Code.

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(b) The confirmation shall at least indicate the contract title, its date of signature and of entry into force, and the specifications of the main plant to be constructed, assembled or purchased.

(c) The Relevant TSO may demand that the National Regulatory Authority confirms the existence, relevance and finality of such a contract, i.e. that its material terms can no longer be changed by one of the parties to the contract unilaterally and that no party to the contract has the right to terminate it at will. The HVDC System Owner shall supply the National Regulatory Authority with all documents the National Regulatory Authority requests in order to ascertain that a binding and final contract exists.

(d) The HVDC System shall be considered as an Existing HVDC System, provided that:

i. In accordance with Article 1(8) (a) and (b) above, the Relevant TSO is provided with sufficient evidence of the existence of binding and final contracts for the construction, assembly or purchase of the main plant of a HVDC System prior to the day, which is two years after the day of entry into force of this Network Code; or

ii. Following the verification performed by the National Regulatory Authority in accordance with Article 1(8) (c), it is ascertained that binding and final contracts for the construction, assembly or purchase of the main plant of a HVDC System exist prior to the day, which is two years after the day of entry into force of this Network Code.

(e) In case the HVDC System Owner does not provide the Relevant TSO with the confirmation within the delay set forth in Article 1(8) (a), the HVDC System shall be considered as a New HVDC System.

9. With regard to DC-connected Power Park Modules not yet connected to the Network:

(a) Within a delay not exceeding thirty months as from the day of entry into force of this Network Code, the DC-connected Power Park Module Owner shall provide the Relevant TSO with a confirmation of final and binding contracts it has concluded for the construction, assembly or purchase of the main plant of a the DC-connected Power Park Module and/or the HVDC System (when the HVDC System Owner is the same as the DC-connected Power Park Module Owner and is built as part of the development of the DC-connected Power Park Module) with relevance to the provisions of this Network Code and which exists prior to the day, which is two years after the day of entry into force of this Network Code.

(b) The confirmation shall at least indicate the contract title, its date of signature and of entry into force, and the specifications of the main plant to be constructed, assembled or purchased.

(c) The Relevant TSO may demand that the National Regulatory Authority confirms the existence, relevance and finality of such a contract, i.e. that its material terms can no longer be changed by one of the parties to the contract unilaterally and that no party to the contract has the right to terminate it at will. The DC-connected Power Park Module Owner shall supply the National Regulatory Authority with all documents the National Regulatory Authority requests in order to ascertain that a binding and final contract exists.

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(d) The DC-connected Power Park Module shall be considered as an Existing DC-connected Power Park Module, provided that:

i. In accordance with Article 1(9) (a) and (b) above, the Relevant TSO is provided with sufficient evidence of the existence of binding and final contracts for the construction, assembly or purchase of the main plant of a DC-connected Power Park Module and/or where applicable the HVDC System prior to the day, which is two years after the day of entry into force of this Network Code; or

ii. Following the verification performed by the National Regulatory Authority in accordance with Article 1(9) (c), it is ascertained that binding and final contracts for the construction, assembly or purchase of the main plant of a DC-connected Power Park Module and where applicable the HVDC System exist prior to the day, which is two years after the day of entry into force of this Network Code.

(e) In case the DC-connected Power Park Module Owner does not provide the Relevant TSO with the confirmation within the delay set forth in Article 1(9) (a), the DC-connected Power Park Module and as applicable HVDC System shall be considered as a New DC-connected Power Park Module and/or HVDC System.

10. In Member States where more than one transmission system operator exists, this Regulation shall apply to all transmission system operators within that Member State. Where a transmission system operator does not have a function relevant to one or some obligations under this Network Code, Member States may under the national regulatory regime provide that the responsibility to comply with one or some obligations under this Network Code is assigned to one or more different transmission system operators. In case of such assignment, the Network Code shall apply accordingly to the transmission system operator(s) to which responsibilities have been assigned.

Article 2

Definitions

1. For the purpose of this Network Code, the definitions contained in Article 2 of Directive 2009/72/EC and in Article 2 of Regulation (EC) N°714/2009 apply. The definitions contained in the Article 2 of the [NC RfG], [NC CACM], [NC DCC], [NC OS], [NC OPS], [NC LFC&R], [NC FWD] and [NC BAL] shall also apply, with the exception of the following terms, for which the definition given in this paragraph shall apply :

...

2. The following definitions shall apply:

DC-connected Power Park Module is a Power Park Module which is part of a new synchronous AC network which is only connected to an existing synchronous AC via conversion to DC and back to AC.

DC-connected Power Park Module System Owner means a natural or legal entity owning a HVDC System.

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HVDC Converter Unit means an operative unit comprising of one or more converter bridges, together with one or more converter transformers, reactors, converter unit control equipment, essential protective and switching devices and auxiliaries, if any, used for the conversion;

HVDC Converter Units Owner means a natural or legal entity owning a HVDC Substation.

HVDC Substation means part of an HVDC System which consists of one or more Converter Units installed in a single location together with buildings, reactors, filters, reactive power devices, control, monitoring, protective, measuring and auxiliary equipment;

HVDC Substation Owner means a natural or legal entity owning a HVDC Substation.

HVDC System means an electrical power system which transfers energy in the form of high-voltage direct current between two or more AC buses. A HVDC System comprises of at least two HVDC Substations with DC transmission lines or direct DC circuit connections between the pair of HVDC Substations.

HVDC System Owner means a natural or legal entity owning a HVDC System.

New HVDC System...

New DC-connected Power Park Module...

Reactive Short Circuit Current.....

Relevant National Regulatory Authority ....

ΔUmax…

…

Article 3
Regulatory aspects

1. The requirements established in this Network Code and their applications are based on the principle of non-discrimination and transparency as well as the principle of optimisation between the highest overall efficiency and lowest total cost for all involved parties.

2. Notwithstanding the above, the application of non-discrimination principle and the principle of optimization between the highest overall efficiency and lowest total costs for all involved parties shall be balanced with the aim of achieving the maximum transparency in issues of interest for the market and the assignment to the real originator of the costs.

3. Where reference is made to this paragraph, the terms and conditions for connection and access to networks or their methodologies shall be established by the National Regulatory Authorities, or by the Member States in accordance with the rules of national law

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implementing Directive 2009/72/EC, and with the principles of transparency, proportionality and non-discrimination.

4. Any decision by a Network Operator other than the Relevant TSO and any agreement between a Network Operator other than the Relevant TSO and either Power Generating Facility Owner of a DC-connected Power Park Module or a HVDC System Owner shall be exercised in compliance with and respecting the Relevant TSO's responsibility to ensure system security according to national legislation. Further details to ensure this principle may be specified either by national legislation, or by agreements between the Relevant TSO and the Network Operators in its Control Area, as the case may be.

5. The allocation of tasks between the Relevant Network Operators, as well as the legal framework under which they determine the grid connections requirements under this Network Code, are established pursuant to this Network Code. TSO(s) granted public authority or competence according to national law can adopt decisions when defining requirements under this Network Code while respecting Directive 2009/72/EC.

6. Any decision or agreement adopted pursuant to paragraphs 3 through 5 of this Article and affecting more than one Member State shall be coordinated among the concerned TSOs and NRAs.

Article 4
Recovery of costs

1. The costs related to the obligations referred to in this Network Code which have to be borne by regulated Network Operators shall be assessed by National Regulatory Authorities.

2. Costs assessed as efficient, reasonable and proportionate shall be recovered as determined by National Regulatory Authorities.

3. If requested to do so by National Regulatory Authorities, regulated Network Operators shall, within three months of such a request, use best endeavours to provide such additional information as reasonably requested by National Regulatory Authorities to facilitate the assessment of the costs incurred.

Article 5
Confidentiality obligations

1. Each Relevant TSO, DSO, HVDC System Owner or Power Generating Facility Owner shall preserve the confidentiality of the information and data submitted to them in connection with this Network Code and shall use them exclusively for the purpose they have been submitted in compliance with the Network Code.

2. Without prejudice to the obligation to preserve the confidentiality of commercially sensitive information obtained in the course of carrying out its activities, each TSO shall provide to the operator of any other transmission system with which its system is interconnected, sufficient information to ensure the secure and efficient operation, coordinated development and interoperability of the interconnected system.

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3. In case of disclosure for other purposes than those described in Article 5(1) and/or (2), a Relevant TSO shall seek the consent of the owner of such information and data. This consent cannot be unreasonably withheld.

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CHAPTER 2
GENERAL REQUIREMENTS FOR HVDC CONNECTIONS

SECTION 1
REQUIREMENTS FOR ACTIVE POWER CONTROL AND FREQUENCY SUPPORT

Article 6 Frequency ranges

1. An HVDC System shall fulfil the following requirements referring to Frequency stability:

   (a) An HVDC System shall be capable of staying connected to the Network and remain operable within the Frequency ranges and time periods specified by Table 1.

   (b) While respecting the provisions of Article 3(3), wider Frequency ranges or longer minimum times for operation can be agreed between the Relevant TSO and the HVDC System Owner to ensure the best use of the technical capabilities of a HVDC System 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 consent of the HVDC Connection Owner shall not be unreasonably withheld.

   (c) While respecting the provisions of Article 6(1)a) a HVDC System shall be capable of automatic disconnection at specified frequencies, if required by the Relevant TSO. While respecting the provisions of Article 3(3), terms and settings for automatic disconnection shall be agreed between the Relevant TSO and the HVDC System Owner.

Synchronous Area	Frequency Range	Time period for operation
All	47.0 Hz – 47.5 Hz	30 minutes
	47.5 Hz – 51.5 Hz	Unlimited
	51.5 Hz – 52.0 Hz	30 minutes

Table 1: This table shows the minimum time periods an HVDC System has to be able to operate for different frequencies deviating from a nominal value without disconnecting from the network.

Article 7 Rate-of-change-of-Frequency withstand capability

With regard to the rate of change of Frequency withstand capability, an HVDC System shall be capable of staying connected to the Network and operable at rates of change of Frequency up to a 2.5 Hz/s based on a rolling measurement of Frequency at the Connection Point over a 500 ms window value.

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Article 8 **Active power controllability; control range and ramping rate**

1. With regard to the capability of controlling the transmitted active power:

   (a) The HVDC System shall be capable of adjusting the transmitted active power in both directions within the HVDC System Maximum Capacity following an Instruction from the Relevant TSO(s).

      i. The Relevant TSO(s) shall have the right to specify, while respecting the provisions of Article 3(3), a minimum power resolution for adjusting the transmitted active power.

      ii. The Relevant TSO(s) have the right, while respecting the provisions of Article 3(3) to define a minimum active power transmission capability for both directions, below which active power transmission capability is not requested.

      iii. A procedure for adjusting the transmitted active power shall be defined by the Relevant TSO(s) and HVDC System Owner, defining in particular the maximal delay within which the HVDC System is capable of adjusting the transmitted active power upon receipt of request from the Relevant TSO(s).

   (b) In case of Disturbance in one of the connecting AC Networks, the HVDC System shall be capable of modifying the transmitted active power in accordance with pre-defined regulation sequences as fast as technically feasible with an initial delay as short as possible, and reasonably justified by the HVDC System Owner to the Relevant TSO(s) if greater than 10 milliseconds after receiving the triggering signal.

   (c) The Relevant TSO(s) have the right, while respecting the provisions of Article 3(3) to require the HVDC System to be capable of fast active power reversal. The power reversal shall be possible from the Maximum Capacity in one direction to the Maximum Capacity in the other direction as fast as technically feasible with and reasonably justified by the HVDC System Owner to the Relevant TSOs if greater than 2 seconds.

   (d) For HVDC Systems linking various Control Areas or Synchronous Areas, the HVDC System shall be capable of providing FCR and FRR by static and/or dynamic means. They shall also be capable of allowing Imbalance Netting Power Interchange between the Relevant TSO(s).

2. With regard to the capability of controlling ramping rate, the HVDC System shall be capable of adjusting the ramping rate of active power variations in accordance with instructions sent by the relevant TSO(s).

3. The Relevant TSO shall have the right to require, while respecting the provisions of Article 3(3), in co-operation with other involved TSO(s), that the control functions of a HVDC System shall be capable of taking automatic remedial actions such as, but not limited to, stopping the ramping, blocking FSM, LFSM-O, LFSM-U or Frequency control when its available reserve capacity is exhausted or reduced under a critical level. The triggering and blocking criteria shall be defined by the relevant TSO(s).

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Article 9 **Synthetic inertia**

1. With regard to the capability of providing Synthetic Inertia to a Frequency change:

   (a) The Relevant TSO shall have the right to require, while respecting the provisions of Article 3(3), in co-operation with other TSO(s) in the relevant Synchronous Area, that a HVDC System shall be capable of providing synthetic inertia as a quantified 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.

   (b) The operating principle of this control system and the associated performance parameters shall be defined by the Relevant TSO while respecting the provisions of Article 3(3).

Article 10 **Frequency Sensitive Mode (FSM)**

1. In addition to Article 6(1)c, the following shall apply accumulatively when the HVDC System is operating in Frequency Sensitive Mode (FSM):

   (a) The HVDC System shall be capable of responding to Frequency deviations in each connected AC network by adjusting the active power transmission as indicated in Figure 1 and in accordance with the parameters specified by each TSO within the ranges shown in Table 2. The specification will be notified to the Relevant National Regulatory Authority as applicable by the national regulatory framework.

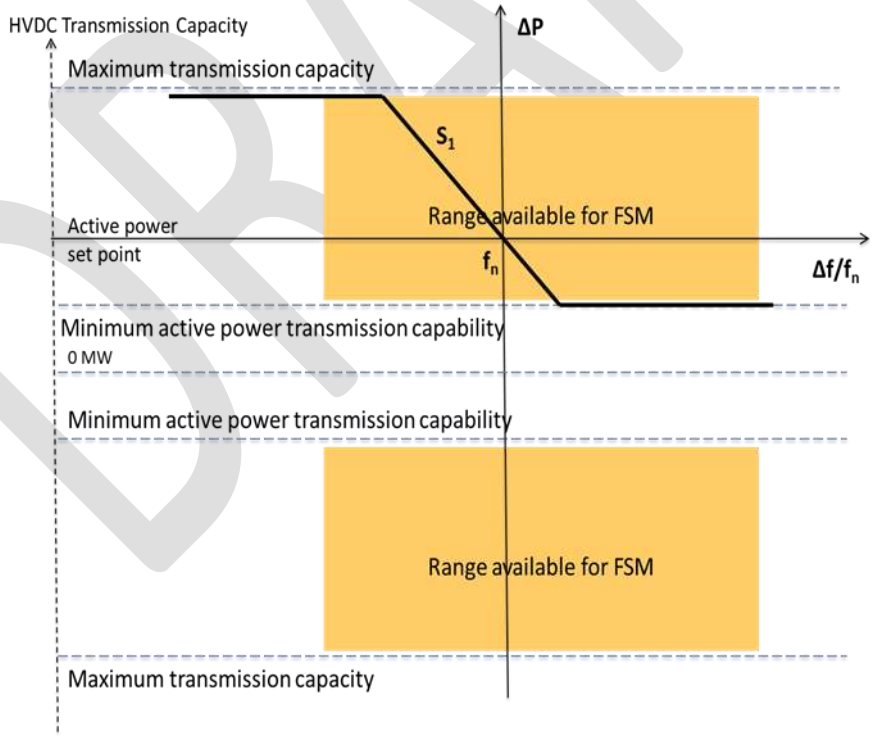

Figure 1: Active Power Frequency Response capability of a HVDC Connection Scheme in FSM illustrating the case of zero deadband and insensitivity. ΔP is the change in Active Power output from the HVDC System. f_n is the target Frequency in the AC Network where the FSM service is provided and Δf is the Frequency deviation in the AC Network where the FSM service is provided.

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Parameters	Ranges
Frequency Response Deadband	0 – 500 mHz
Droop s_1	minimum 0.1%

Table 2: Parameters for Active Power Frequency Response in FSM

(b) The Frequency Response Deadband of Frequency deviation and Droop are selected by the by the Relevant TSO and must be able to be reselected subsequently within the given frames in Table 2. The selection will be notified to the relevant National Regulatory Authority as applicable by the national regulatory framework.

(c) The HVDC System shall be capable of adjusting the Active Power range available for FSM within the limits set by Article 10 (1) (b) and (c) following an instruction of the relevant TSO.

(d) As a result of a Frequency step change, the HVDC system shall be capable of adjusting full Active Power Frequency Response, at or above the solid line according to Figure 2 in accordance with the parameters specified by each TSO within the ranges according to Table 3. The specification will be notified to the Relevant National Regulatory Authority as applicable by the national regulatory framework. The initial delay of activation shall be as short as possible and reasonably justified by the HVDC System Owner to the Relevant TSO, by providing technical evidence for why a longer time is needed, if greater than 0,5 second, while respecting the provisions of Article 3(3).

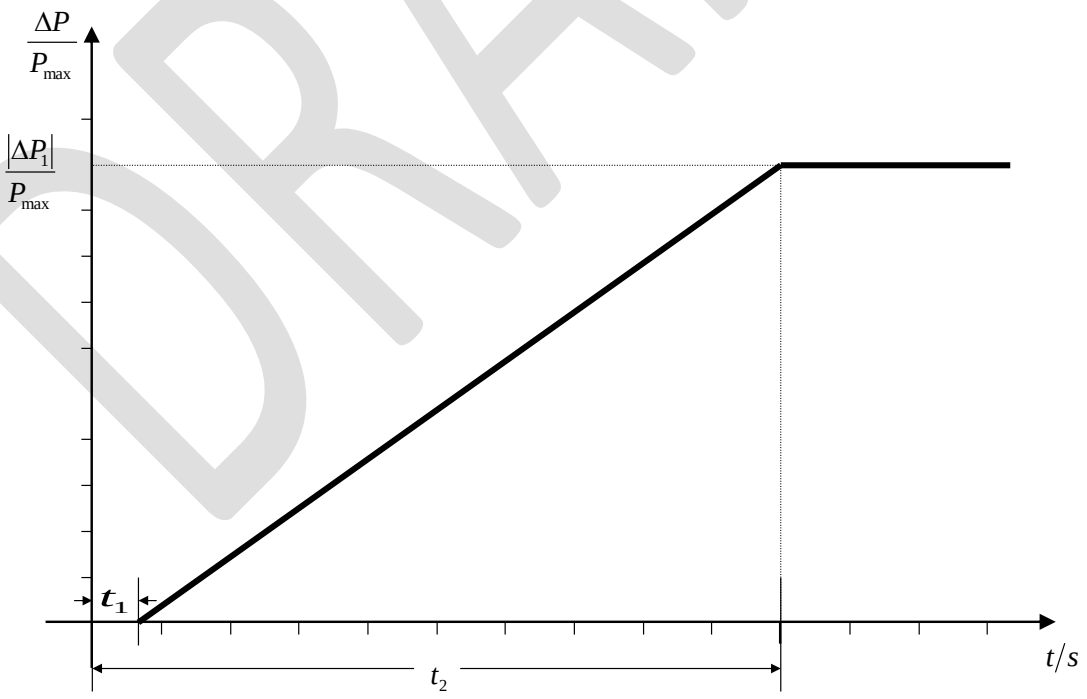

Figure 2: Active Power Frequency Response capability of HVDC System. ΔP is the change in Active Power triggered by the step change in Frequency. The HVDC System has to adjust Active Power Output ΔP up to the limit of the Active Power range requested by the Relevant TSO in accordance with the times t_1 and t_2 with the values of $t_1$and t_2 being specified by the Relevant TSO according to Table 3. t_1 is the initial delay. t_2 is the time for full activation.

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Parameters	Time
Maximum admissible initial delay t_1	0.5 seconds
Maximum admissible choice of full activation time t_2 , unless longer activation times are admitted by the Relevant TSO due to system stability reasons	30 seconds

Table 3: Parameters for full activation of Active Power Frequency Response resulted from Frequency step change

(e) For HVDC Systems in Frequency Sensitive Mode operation mode linking various Control Areas or Synchronous Areas, the HVDC System shall be capable of adjusting full Active Power Frequency Response at any time and for a continuous time period

(f) As long as a Frequency deviation continues Active Power control shall not have any adverse impact on the Frequency response within the time limits of the Active Power range requested by the TSO.

Article 11 **Limited Frequency Sensitive Mode Overfrequency (LFSM-O)**

1 In addition to Article 12 the following shall apply cumulatively with regard to Limited Frequency Sensitive Mode – Overfrequency (LFSM-O):

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(a) With regard to the Limited Frequency Sensitive Mode - Overfrequency (LFSM-O) the following shall apply: The HVDC system shall be capable of adjusting Active Power transmission to the AC Network(s) according to Figure 3 at a Frequency threshold between and including 50.2 Hz and 50.5 Hz with a Droop S_2 of at least 0.1 %. The actual Frequency threshold and Droop settings shall be determined by the Relevant TSO and will be notified to the Relevant National Regulatory Authority as applicable by the national regulatory framework. The HVDC system shall be capable of adjusting Active Power Frequency Response as fast as technically feasible with an initial delay that shall be as short as possible. If greater than 0.5 seconds, the delay must be reasonably justified by the HVDC System Owner to the Relevant TSO.

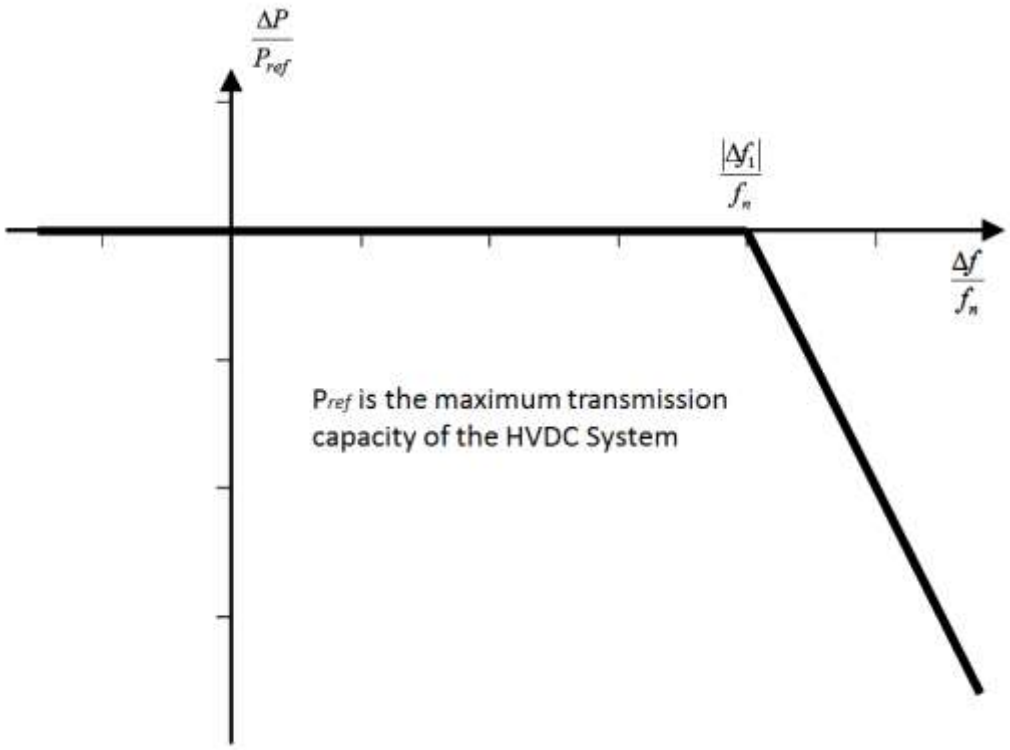

Figure 3: Active Power Frequency Response of HVDC Systems in LFSM-O. ΔP is the change in Active Power output from the HVDC system. f_n is the nominal Frequency of the AC Network(s) the HVDC System is connected to and Δf is the Frequency change in the AC Network(s) the HVDC is connected. At over frequencies where Δf is above Δf_1 the HVDC system has to reduce Active Power according to the Droop setting.

(b) The HVDC system shall be capable of stable operation during LFSM-O operation. When LFSM-O is active, the LFSM-O Setpoint will prevail over any other Active Power Setpoints, including FSM setpoints

Article 12 **Limited Frequency Sensitive Mode Underfrequency (LFSM-U)**

1. With regard to Limited Frequency Sensitive Mode – Underfrequency (LFSM-U):

(a) The HVDC system shall be capable of adjusting the Active Power Frequency Response to the AC Network(s) according to Figure 4 at a Frequency threshold between and including 49.8 Hz and 49.5 Hz with a Droop of at least -0.1 %. In the LFSM-U mode the HVDC system shall be capable of adjusting a power increase up to its Maximum Transmission

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Capacity.. The actual Frequency threshold and Droop settings shall be determined by the Relevant TSO and will be notified to the Relevant National Regulatory Authority as applicable by the national regulatory framework. The Active Power Frequency Response shall be activated as fast as technically feasible with an initial delay that shall be as short as possible and reasonably justified by the HVDC System Owner to the Relevant TSO if greater than 0.5 second.

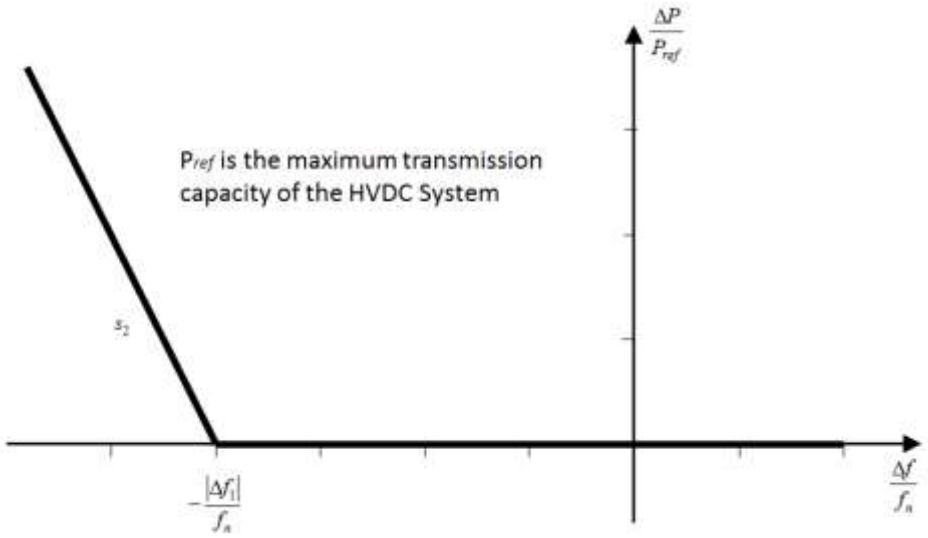

Figure 4: Active Power Frequency Response capability of HVDC Systems in LFSM-U. ΔP is the change in Active Power output from the HVDCsystem. f_n is the nominal Frequency in the AC Network(s) the HVDC System is connected and Δf is the Frequency change in the AC Network(s) the HVDC is connected. At under frequencies where Δf is below Δf_1 the HVDC system has to increase Active Power output according to the Droop S_2.

(b) Stable operation of the HVDC System during LFSM-U operation shall be ensured. The LFSM-U reference Active Power shall be the Active Power output at the moment of activation of LFSM-U and shall not be changed unless triggered by Frequency restoration action.

Article 13 **Frequency control**

1. With regard to the capability of providing additional Frequency control above those defined in Articles 10, 11 and 12:

(a) The relevant TSO shall have the right to require, while respecting the provisions of Article 3(3), in co-operation with other TSO(s) in the relevant synchronous area, that a HVDC System shall be provided with an independent control mode to modulate the power output of the HVDC Converter Unit depending on the frequencies at all Connection Points of the HVDC System in order to maintain stable system frequencies.

(b) The operating principle of this control system, the associated performance parameters and the activation criteria shall be defined by the relevant TSO(s) while respecting the provisions of Article 3(3).

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SECTION 2
REQUIREMENTS FOR REACTIVE POWER CONTROL AND VOLTAGE SUPPORT

Article 14 Voltage ranges

1. HVDC System shall fulfill the following requirements with regard to steady state Voltage ranges*:*

   (a) While still respecting the provisions of Article 21, a HVDC System shall be capable of staying connected to the Network and operating (without changing the active power output unless it's converter rating is infringed or it is responding to frequency changes) within the ranges of the Network Voltage at the Connection Point, expressed by the Voltage at the Connection Point related to nominal Voltage (per unit), and the time periods specified by Table 4 or Table 5. The establishment of the reference nominal Voltage shall be subject to coordination between the adjacent TSO(s).

Synchronous Area	***Voltage Range***	***Time period for operation***
Continental Europe	0.85 pu – 1.118 pu	Unlimited
	1.118 pu – 1.15 pu	To be decided by each TSO while respecting the provisions of Article 3(3), but not less than 20 minutes
Nordic	0.90 pu – 1.05 pu	Unlimited
	1.05 pu – 1.10 pu	60 minutes
Great Britain	0.90 pu – 1.10 pu	Unlimited
Ireland	0.90 pu – 1.118 pu	Unlimited
Baltic	0.85 pu – 1.12 pu	Unlimited
	1.12 pu – 1.15 pu	20 minutes

Table 4: This table shows the minimum time periods a HVDC System shall be capable of operating for Voltages deviating from the nominal value at the Connection Point(s) without disconnecting from the Network. The Voltage base for pu values below 300 kV.

Synchronous Area	Voltage Range	Time period for operation
Continental Europe	0.85 pu – 1.05 pu	Unlimited
	1.05 pu – 1.0875 pu	To be decided by each TSO while respecting the provisions of Article 3(3), but not less than 60 minutes
	1.0875 pu – 1.10 pu	60 minutes
Nordic	0.90 pu – 1.05 pu	Unlimited
	1.05 pu – 1.10 pu	60 minutes
Great Britain	0.90 pu – 1.05 pu	Unlimited
	1.05 pu – 1.10 pu	15 minutes
Ireland	0.90 pu – 1.05 pu	Unlimited

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Baltic	0.88 pu – 1.10 pu	Unlimited
	1.10 pu – 1.15 pu	20 minutes

Table 5: This table shows the minimum time periods a HVDC System shall be capable of operating for Voltages deviating from the nominal value at the Connection Point(s) without disconnecting from the Network. The Voltage base for pu values from 300 kV to 400 kV (included).

(b) While respecting the provisions of Article 3(3), wider Voltage ranges or longer minimum times for operation can be agreed between the Relevant TSO and the HVDC System Owner to ensure the best use of the technical capabilities of a 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 consent of the HVDC System Owner shall not be unreasonably withheld.

(c) While still respecting the provisions of Article 3(3), the Relevant TSO shall have the right to specify Voltages at the Connection Point at which a HVDC Substation shall be capable of automatic disconnection. The terms and settings for automatic disconnection shall be agreed between the Relevant TSO and the HVDC Owner, while respecting the provisions of Article 3(3).

(d) For Connection Point(s) at AC voltages that are not included in the scope of Table 5 and Table 6, the Relevant TSO(s) shall define applicable requirements at the Connection Point(s).

Article 15 **Short circuit contribution during faults requirements**

1. While respecting the provisions of Article 3(3), all HVDC Substations shall fulfill the following requirements referring to short-circuit current:

The Relevant TSO shall have the right to require Reactive Short Circuit Current contribution at the Connection Point of each of the HVDC Converter Units of the HVDC System in the case of symmetrical (3-phase) faults.

(a) The HVDC System shall be capable of activating this Reactive Short Circuit Current contribution during the period of faults. The HVDC System shall be capable of ensuring the supply of the Reactive Short Circuit Current contribution at the Connection Point of each HVDC Converter Unit of the HVDC System according to further specifications by the Relevant TSO of the magnitude of this Current, depending on the deviation of the Voltage at the Connection point from its nominal value.

(b) Each HVDC System shall be capable of providing with each of its HVDC Converter Units connected to the AC system at least 2/3 of the nominal reactive short circuit current within a time period specified by the Relevant TSO(s) while respecting the provisions of Article 3(3). The target value of this reactive short circuit current contribution shall be reached within a time period and with an accuracy specified by the relevant TSO(s) while respecting the provisions of Article 3(3).

(c) With regard to fast acting additional reactive Current injection in the case of asymmetrical (1-phase or 2-phase) faults, the Relevant TSO(s) shall have the right to introduce a requirement for asymmetrical Current injection, while respecting the provisions of Article 3(3).

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Article 16 **Reactive power capability**

1. HVDC Substation shall fulfil the following requirements referring to Voltage stability, at the Connection Point(s):

(a) With regard to Reactive Power capability at Maximum Capacity:

i. The Relevant TSO(s) shall define while respecting the provisions of Article 3(3) the Reactive Power capability requirements in the context of varying Voltage. For doing so, it shall define a U-Q/Pmax-profile that shall take any shape within the boundaries of which the HVDC Converter Unit or HVDC Substation shall be capable of providing Reactive Power at its Maximum Capacity.

ii. The U-Q/Pmax-profile shall be defined by the Relevant TSO(s) while respecting the provisions of Article 3(3) in conformity with the following principles:

- the U-Q/Pmax-profile shall not exceed the Q/Pmax-profile envelope represented by the inner envelope in Figure 5, and does not need to be rectangular.
- the dimensions of the U-Q/Pmax-profile envelope (Q/Pmax range and Voltage range) are defined for each Synchronous Area in Table 6; and
- the position of the U-Q/Pmax-profile envelope lies within the limits of the fixed outer envelope in Figure 5.

iii. For profile shapes other than rectangular, the Voltage range represents the highest and lowest voltage points. Such a profile would not give rise to the full Reactive Power range being available across the range of steady-state Voltages; at minimum or maximum voltage point the reactive range is zero.

iv. The HVDC System shall be capable of moving to any operating point within its U-Q/Pmax profile in appropriate timescales to target values requested by the Relevant TSO.

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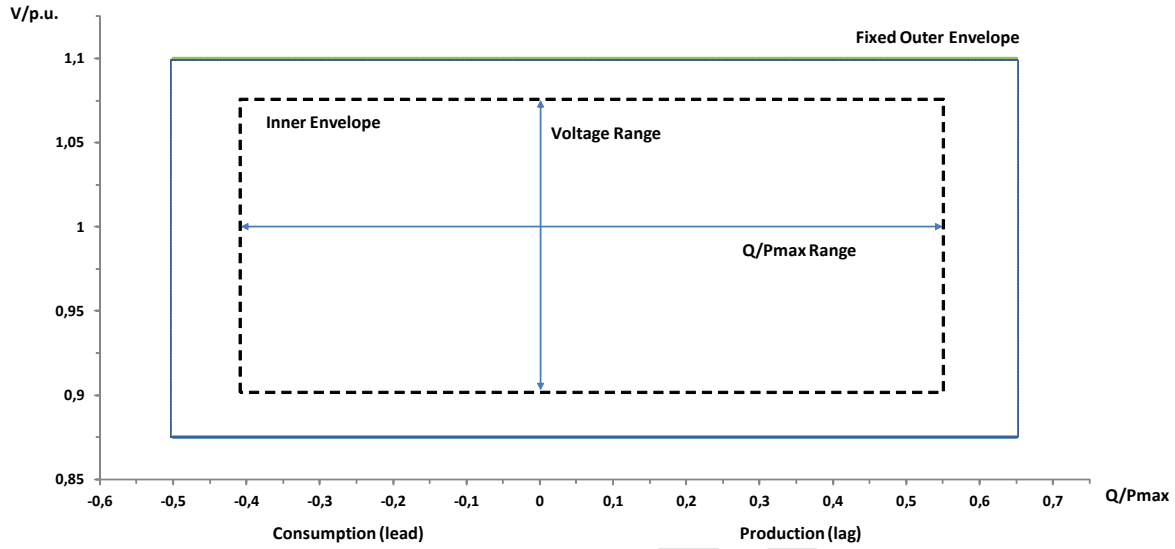

Figure 5: U-Q/Pmax-profile of a HVDC System at the Connection Point. The diagram represents boundaries of a U-Q/Pmax-profile of the Voltage at the Connection Point[s], expressed by the ratio of its actual value to its nominal value in per unit, against the ratio of the Reactive Power (Q) to the Maximum Capacity (Pmax).

Synchronous Area	Maximum range of Q/Pmax	Maximum range of steady-state Voltage level in PU
Continental Europe	0.95	0.225
Nordic	0.95	0.150
Great Britain	0.95	0.100
Ireland	1.08	0.218
Baltic States	1.0	0.220

Table 6: Parameters for the Fixed Inner Envelope in Figure 5

(b) With regard to Reactive Power capability below Maximum Capacity, when operating at an Active Power output below the Maximum Capacity (P<Pmax), the HVDC System shall be capable of operating in every possible operating point in the P-Q /Pmax Capability Diagram defined by the Relevant TSO(s) for various per unit voltages at the connection point(s) within the inner envelope voltage range defined in Table 6, and within the fixed outer envelope in Figure 5.

Article 17 **Reactive power exchanged with the Network**

1. The HVDC System shall ensure the reactive power exchanged with the Network at the Connection Point is regulated according to values defined by the Relevant TSO(s) within the operational active power ranges. The TSO shall have the right to subsequently revise these ranges, provided it is within the capability of the HVDC system, to meet changed operational or network conditions.

2. The Reactive Power variation ΔQ caused by the control mode operation of the HVDC Substation shall not exceed the range given by the Relevant TSO. The ΔQ is calculated so as not to exceed the allowed range of Voltage steps at the Connection Point ΔUmax, due to switching of filters and capacitor banks of the HVDC Substation;

Article 18 **Reactive power control mode**

1. Each HVDC Substation shall as a minimum be able to operate in either of the following three reactive-power-control modes:

   (a) Voltage Control mode;

   (b) Reactive-Power Control mode;

   (c) Power-Factor Control mode.

2. The desired Control mode shall result in an operating point that fulfils the active-power-against-reactive-power (PQ-) characteristics of the HVDC System. The relevant TSO shall have the right to require other reactive power control mode capabilities, while respecting the provision of Article 3(3).

3. The control modes of an HVDC Substation shall not be in conflict with each other.

4. For the purposes of Voltage Control mode, each HVDC Substation shall be capable of contributing to Voltage control at the Connection Point utilising its capabilities, while respecting the provisions of Articles 16 and 17, in accordance with the following control characteristics:

   (a) Set-point Voltage which is specified to cover a specific operation range, either continuously or in steps with a maximum allowed step, as defined by the Relevant TSO(s);

   (b) A Slope which is specified with a range and step defined by the Relevant TSO(s);

   (c) The Set-point Voltage may be operated with or without a dead band selectable in a range from zero to +/-5 % of nominal Network Voltage. The dead band shall be adjustable in steps with a maximum allowed step in % of nominal Network Voltage, specified by the Relevant TSO.

   (d) Following a step change in Voltage, the Converter Station shall be capable of achieving 90 % of the change in Reactive Power output within a time t1 to be specified by the Relevant TSO(s), while respecting the provisions of Article 3(3) in the range of 0.1 - 5 seconds and settle at the value defined by the operating Slope within a time t2 to be specified by the Relevant TSO in the range of 5 - 60 seconds, with a specified steady-state reactive tolerance in % of the maximum Reactive Power.

5. For the purposes of Reactive Power Control mode, the HVDC Substation shall be capable of providing the Reactive Power at the Connection Point(s) utilising its capabilities, while respecting the provisions of Articles 16 and 17.In addition, the Relevant TSO(s) and the HVDC System Owner shall agree on a Reactive Power range within a certain accuracy in Mvar or in % of full Reactive Power, of the control of the Reactive Power at the Connection Point(s).

6. For the purposes of Power Factor Control mode, the HVDC Substations shall be is capable of controlling the Power Factor at the Connection Point utilising its capabilities, while respecting the provisions of Articles 16 and 17, with a target Power Factor in steps no greater than a maximum allowed step, specified by the Relevant TSO. The maximum allowed step shall result in acceptable network Voltage steps.

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7. The Relevant TSO(s) shall define, while respecting the provisions of Article 3(3), any equipment needed to enable the remote selection of relevant Set-point(s) and control modes.

Article 19 **Priority to active or reactive power contribution**

With regard to priority to Active or Reactive Power contribution, the Relevant TSO shall define while respecting the provisions of Article 3(3), whether Active Power contribution or Reactive Power contribution has priority during normal operation, during low or high Voltage operation and during faults for which fault-ride-through capability is required.

Article 20 **Power quality**

All HVDC Systems 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(s), exceeding the level allocated to them by the Relevant TSO, while respecting the provisions of Article 3(3).

SECTION 3
REQUIREMENTS FOR FAULT RIDE THROUGH

Article 21 **Fault ride through capability**

1. With regard to fault-ride-through capability of HVDC System:

   (a) The Relevant TSO(s) shall define, while respecting the provisions of Article 3(3), a Voltage-against-time-profile according to Figure 6 at the Connection Point(s) for fault conditions under which the HVDC Substation shall stay connected to the Network and continue stable operation after the power system has recovered following fault clearance.

   (b) This Voltage-against-time-profile shall be expressed by a lower limit of the course of the phase-to-phase Voltages on the Network Voltage level at the Connection Point(s) during a symmetrical fault, as a function of time before, during and after the fault. This lower limit is defined by the TSO using parameters in Figure 6 according to Table 7.

   (c) The Relevant TSO(s) shall define and make publicly available, while respecting the provisions of Article 3(3), the pre-fault and post-fault conditions for the fault-ride-through capability according to Article 28.

   (d) The Relevant TSO(s) shall provide on request by the HVDC System Owner the pre-fault and post-fault conditions to be considered for fault-ride-through capability as an outcome of the calculations at the Connection Point(s) as defined in Article 28 regarding:
      i. pre-fault minimum short circuit capacity at the Connection Point(s) expressed in MVA;
      ii. pre-fault operating point of the HVDC Substation expressed in Active Power output and Reactive Power output, and the operating voltage at the Connection Point[s];
      iii. post-fault minimum short circuit capacity at the Connection Point[s] expressed in MVA.

   Alternatively, generic values for the above conditions derived from typical cases may be provided by the Relevant TSO(s).

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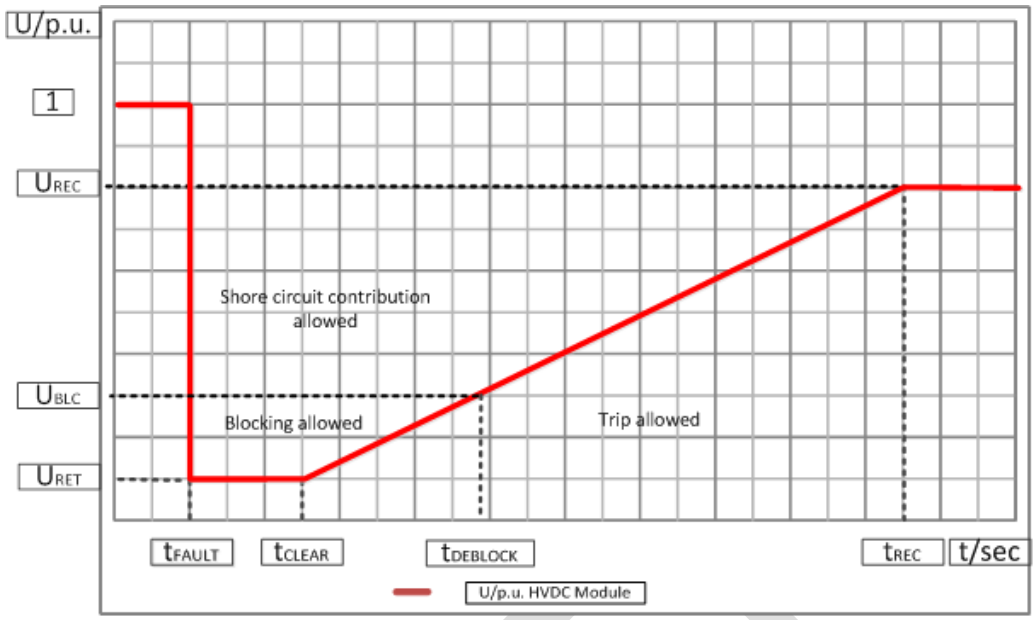

Figure 6: Fault-ride-through profile of a HVDC Substation. The diagram represents the lower limit of a Voltage-against-time profile at the Connection Point(s), expressed by the ratio of its actual value and its nominal value in per unit before, during and after a fault. Uret is the retained Voltage at the Connection Point(s) during a fault, tclear is the duration of the fault, , Urec, and trec specify a point of lower limits of Voltage recovery following fault clearance. Ublc is the blocking Voltage at the connection point at time Tblc. Blocking of the HVDC system is allowed within the boundary defined by the red solid line, Tclear and Tblc. Tblc is the instant when the HVDC system is deblocking . The HVDC system is allowed to trip within the boundary defined by the red solid line, Tblc and Trec.

Voltage parameters [pu]		**Time parameters [seconds]**	
Uret:	0.00 – 0.30	Tclear	0.14-0.25
Urec:	0.85	Trec	1.5 - 10.0
Ublc:	0.0 – 0.75	Tblc:	0.1 – 0.5

Table 7: Parameters for Figure 6 for fault-ride-through capability of HVDC Substation.

(e) The HVDC Substation 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(s) during a symmetrical fault, given the pre-fault and post-fault conditions according to Article 28, remain above the lower limit defined in Figure 6, unless the protection scheme for internal electrical faults requires the disconnection of the HVDC Substation from the Network. The protection schemes and settings for internal electrical faults shall be designed not to jeopardize fault-ride-through performance.

(f) In order to fulfil fault ride through requirements, under network conditions defined in Table 8, the HVDC system is allowed to block, that is to remain connected to the network although cancelling active and reactive power contribution for a time frame that shall be

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as short as technically feasible that shall be agreed between the Relevant TSO(s) and the HVDC system owner.

(g) While still respecting the provisions of Article 3(3), the Relevant TSO(s) shall have the right to specify Voltages at the Connection Point(s) under specific network conditions whereby the HVDC system is allowed to block..

(h) While still respecting the provisions of Article 32, undervoltage protection (either fault-ride-through capability or minimum Voltage defined at the connection point Voltage) shall be set by the HVDC System Owner to the widest possible technical capability of the HVDC Substation. The Relevant TSO may require less wide settings according to Article 33. The agreed settings shall be justified by the HVDC System.

(i) Fault-ride-through capabilities in case of asymmetrical faults shall be defined by each TSO while respecting the provisions of Article 3(3). The response of the HVDC Substation to asymmetrical faults shall be to contribute to the re-establishment of the phase-voltages in the fault-affected phases and avoid excitation of Voltages above an acceptable Voltage range in the healthy phases.

Article 22 **Post fault active power recovery**

1. With regard to post fault Active Power recovery after AC network fault at or remote from the Connection Point(s), while respecting the provisions of Article 21, and Article 3(3), the Relevant TSO shall specify the magnitude and time capability of active power recovery required from the HVDC System.

2. With regard to faults within the HVDC System, the Relevant TSO shall specify while respecting the provisions of Article 3(3), the magnitude and time capability of Active Power recovery required from the HVDC System.

Article 23 **Autoreclosure**

1. Transient faults on HVAC lines adjacent or close to HVDC Systems shall not cause any of the equipment in the HVDC System to disconnect from the Network. HVDC Systems with overhead lines shall, if applicable, be capable of auto reclosing for transient faults. Details of this capability shall be subject to coordination and agreements on protection schemes and settings according to Article 31.

SECTION 4
REQUIREMENTS FOR CONTROL

Article 24 **Converter energisation and synchronisation**

1. Unless following an instruction by the relevant TSO, the following shall apply:

(a) During the energisation or synchronisation of an HVDC Converter Unit to the AC network at the Connection Point(s), the HVDC converter unit or HVDC Substation shall smooth any Voltage transients to a level not exceeding 3 per cent of the pre-synchronisation AC Voltage.

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(b) During the synchronisation of an energised HVDC Substation to an HVDC System, the HVDC converter unit or HVDC Substation shall smooth any Voltage transients, at any Connection Point of the HVDC System, to a level not exceeding 3 per cent of the pre-synchronisation AC Voltage.

Article 25 **Interaction between HVDC System(s) and other Connections**

1. Any of the Relevant TSO(s) shall have the right to require and to define the scope and extent of studies, if several HVDC Substations or HVDC Substations and other Connections are within close electrical proximity, in order to demonstrate that no adverse interaction (such as, but not limited to interference with or jeopardisation of the operation of other HVDC Systems, Power Generation Modules or any protection devices in the adjacent AC grid) may occur. If adverse interaction is identified, the study shall identify possible mitigating actions necessary to ensure compliance with the requirements of this Network Code, to be implemented..

2. The studies shall be carried out by the owner of the connecting HVDC Substation, with the participation of all other parties as identified by the TSO(s) relevant to each new Connection Point. The necessary contribution of the owners of existing HVDC Systems to such studies shall not be unreasonably withheld.

3. Any necessary mitigating actions identified by the studies and reviewed by the relevant TSO(s) shall be undertaken as part of the connection of the new HVDC Converter Unit or HVDC Substation, while respecting the provisions of Article 3(3).

4. In addition, in respect of the transient performance of the link for example for switching, load rejection and energisation the Relevant TSO shall have the right to specify levels of performance upon the individual HVDC system or collectively across HVDC systems commonly impacted to both protect the integrity of TSO equipment and that of connected users to its system in a manner consistent with its own national code requirements

Article 26 **Power oscillation damping capability**

1. With regard to power oscillations damping control, the HVDC System shall be capable of contributing to the damping of power oscillations. The control characteristics of the HVDC System shall not adversely affect the damping of power oscillations. The relevant TSO(s) shall specify the network conditions, and a modal range of oscillations which the control scheme shall positively damp; the control parameter settings shall be agreed between the Relevant TSO(s) and the HVDC system owner.

Article 27 **Sub-synchronous torsional interaction damping capability**

1. With regard to sub-synchronous torsional interaction (SSTI) damping control, the HVDC System shall be capable of contributing to damping torsional mode frequencies.

2. The TSO shall define the necessary extent of SSTI studies and provide input parameters related to the equipment and relevant system conditions in his network. The SSTI studies shall be provided by the HVDC Substation Owner; it should identify the conditions, if any, where SSTI exists and

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propose any necessary mitigation procedure The necessary contribution of the owners of existing Connections to such studies shall not be unreasonably withheld.

3. In case harmful SSTI are present, the relevant TSO shall have the right to require activation of the SSTI damping control and to specify its performance and parameters based on the SSTI-studies, with the involvement of the HVDC Substation owner.

Article 28 **Network characteristics**

1. With regard to the Network characteristics, the following shall apply for the HVDC Systems during normal and disturbed conditions:

   (a) Each TSO shall define and make publicly available, while respecting the provisions of Article 3(3), the method and the pre-fault and post-fault conditions for the calculation of minimum and maximum Short Circuit Power at the Connection Point(s).

   (b) The HVDC System shall be capable of operating within the range of short circuit power and network characteristics defined by the relevant TSO.

   (c) Each Relevant TSO, DC-connected Power Park Module System Owner, and HVDC System Owner shall exchange equivalents to represent the system enabling the owners to design the system with regard to harmonics.

Article 29 **HVDC System robustness**

1. The HVDC Substations within the HVDC System shall be capable of finding stable operation points with a minimum change in power flow and Voltage level, during and after any expected or unexpected change in the HVDC System or AC network to which it is connected. Changes in the system include, but are not limited to:

   (a) loss of communication
   (b) reconfiguring the HVDC or AC system
   (c) changes in load flow
   (d) changes in DC Voltage
   (e) change of control mode
   (f) control system failure
   (g) trip of one pole or converter
   (h) depletion of fault levels
   (i) failure of HVDC system elements

SECTION 5
REQUIREMENTS FOR PROTECTION DEVICES AND SETTINGS

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Article 30 **Reconnection**

1. With regard to capability of reconnection after an incidental disconnection due to a Network disturbance, the Relevant TSO shall define the conditions under which an HVDC System shall be capable of reconnecting to the Network, while respecting the provisions of Article 3(3).

2. Fast reconnection capability is required in case of disconnection of the HVDC System from the Network in line with the protection strategy agreed between the Relevant TSO and the HVDC System Owner. The Relevant TSO shall have the right to specify, while respecting the provisions of Article 3(3), a maximum time after which the HVDC system shall be ready to reconnect.

Article 31 **Electrical protection schemes and settings**

1. The Relevant TSO shall define the schemes and settings necessary to protect the Network taking into account the characteristics of the HVDC System and HVDC systems or generation in close proximity, defined by the Relevant TSO. While respecting the provisions of Article 3(3), 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 TSO and the HVDC System Owner(s). The protection schemes and settings for internal electrical faults shall be designed so as not to jeopardize the performance of the HVDC System in accordance with this Network Code.

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.

3. While respecting the provisions of Article 3(3), any changes to the protection schemes relevant for the HVDC System and the Network and to the setting relevant for the HVDC System shall be agreed between the Relevant TSO and the HVDC System Owner and be concluded prior to the introduction of changes.

Article 32 **Priority ranking of protection and control**

1. While respecting the provisions of Article 3(3), a control scheme, defined by the Owner of an HVDC System and usually consisting of different control modes, including the settings of the specific parameters shall be coordinated and agreed between the relevant TSO and the HVDC System Owner.

2. With regard to priority ranking of protection and control, the HVDC System Owner shall organize its protections and control devices in compliance with the following priority ranking, organized in decreasing order of importance, unless otherwise specified by the relevant TSO(s):

    (a) Network system and HVDC System protection;
    (b) Active power control for emergency assistance
    (c) Synthetic Inertia, if applicable;
    (d) Ramp blocking;
    (e) LFSM;
    (f) FSM and Frequency control ;
    (g) Power gradient constraint;
    (h) Power quality supression.

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Article 33 Changes to protection and control schemes and settings

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 Substation, if required by the Relevant TSO(s) in line with Article 33(3).

2. While respecting the provisions of Article 3(3), 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 TSO(s) and the HVDC System Owner.

3. The control modes and associated setpoints of the HVDC System shall be capable of being changed remotely, as defined by the relevant TSO(s), while respecting the provisions of Article 3(3).

SECTION 6
REQUIREMENTS FOR POWER SYSTEM RESTORATION

Article 34 Black start

1. If the relevant TSO(s) deem(s) system security to be at risk due to a lack of Black Start Capability in a Control Area, the relevant TSO shall have the right to obtain a quote from the HVDC System owner, while respecting the possibilities of the design of the HVDC System.

2. An HVDC System with Black Start Capability shall be able to energize the remote dead AC-substation to which it is connected from shut down within a timeframe decided by the relevant TSO(s) while respecting the provisions of Article 3(3), without any external energy supply. The HVDC System shall be able to synchronise within the Frequency limits defined in Article 6 and Voltage limits defined by the Relevant TSO or defined by Article 14 where applicable.

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.

Article 35 Isolated network operation

1. The capability to take part in Isolated Network Operation, if required by the Relevant TSO while respecting the provisions of Article 3(3), shall be possible within the Frequency limits defined in Article 6, Voltage Limits according to Article 14 and the Network Characteristics according to Article 28.

2. If required, the HVDC System shall be capable of finding a new stable operating point within the P-Q-Capability Diagram, as much as inherently technically feasible, when either the HVDC system becomes isolated to house load operation only or when in case of an emergency situation the short circuit level of the interconnected AC-system is lower than agreed for normal operation

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Article 36 **Modernisation, development and replacement**

1. All Existing HVDC Systems, HVDC Substations, HVDC Converter Units and DC-Connected Power Park Modules, deemed significant pursuant to the provisions of this Network Code, shall fulfil the following requirements related to equipment development, modernisation and replacement:

   a) An HVDC System Owner, HVDC Substation Owner, HVDC Converter Station Owner or DC-connected Power Park Module System Owner intending to develop, modernise or replace a part or equipment of the Existing HVDC System, Existing HVDC Substation, Existing HVDC Converter Unit or Existing DC-Connected Power Park Module in a way that may have an impact on its performance and ability to meet the requirements of this Network Code shall notify the Relevant Network Operator directly or indirectly. The notification shall take place in advance to the national timescales defined, while respecting the provisions of Article 3(3). This equipment development, modernisation or replacement may include high-voltage equipment, power electronic system, protection and control systems (including hardware and software) and auxiliary equipment.

   b) The developed, modernised or replaced equipment shall comply with the respective Network Code requirements which are relevant to the planned work.

   c) While respecting the provisions of Article 3(3), the use of existing spare components that do not comply with the requirements has to be agreed with the Relevant Network Operator in coordination with the Relevant TSO in each case.

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CHAPTER 3
REQUIREMENTS FOR DC-CONNECTED POWER PARK MODULES AND HVDC SUBSTATIONS CONNECTING DC-CONNECTED POWER PARK MODULES

Article 37 **Frequency stability requirements**

1. In addition to fulfilling the requirements listed in Articles 6 to 36 unless referred to otherwise in this Article, HVDC Substations which are AC Connected to DC-connected Power Park Modules, shall fulfill the requirements in this Article.

2. With regards to frequency response:

   (a) A fast signal from AC Network to the DC-connected Power Park Module of less than 1 second from sending to activation of response is required from the AC Network which the DC-connected Power Park Module is providing frequency response to. Frequency deviation is measured at the connection point of AC Network.

   (b) Control coordination between DC-Connected Power Park Modules and HVDC Substations would be required to deliver optimal response.

3. With regard to Frequency ranges:

   (a) A DC-Connected Power Park Module shall be capable of staying connected to the Network and operating within the Frequency ranges and time periods specified by table 8.

Synchronous Area	Frequency Range	Time period for operation
All ENTSO-E	47.0 Hz – 47.5 Hz	15 minutes
	47.5 Hz – 49.0 Hz	90 minutes
	49.0 Hz – 51.0 Hz	Unlimited
	51.0 Hz – 51.5 Hz	90 minutes
	51.5 Hz – 52.0 Hz	15 minutes

Table 8: Minimum time periods for which a PPM shall be capable of operating for different frequencies deviating from a nominal value without disconnecting from the Network.

   (b) While respecting the provisions of Article 3(3), wider Frequency ranges or longer minimum times for operation can be agreed between the Relevant TSO and the PPM 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 consent of the DC-Connected Power Park Module Owner shall not be unreasonably withheld.

   (c) While respecting the provisions of Article 37(1)(a), a DC-Connected Power Park Module shall be capable of automatic disconnection at specified frequencies, if required by the Relevant TSO. While respecting the provisions of Article 3(3), Terms and settings for automatic disconnection shall be agreed between the Relevant TSO and the DC-Connected Power Park Module Owner.

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4. With regard to the Rate of Change of Frequency withstand capability, a DC-connected Power Park Module shall be capable of staying connected to the network and operating at rates of change of frequency up to 2 Hz/s based on a rolling measurement of frequency over a 500 ms window value at the point of connection of the DC-Connected Power Park Module at the remote end of the HVDC Substation.

5. Capability for Limited Frequency Sensitive Mode - Over Frequency shall be determined in accordance with Article 8(1)(c) of the NC RfG, subject to a fast signal response as specified in Article 37 (1) of this Network Code.

6. Capability of maintaining constant power shall be determined in accordance with Article 8(1)(d) of the NC RfG.

7. Active Power controllability shall be determined in accordance with Article 10(2)(a) of the NC RfG.

8. Capability for Limited Frequency Sensitive Mode - Under Frequency shall be determined in accordance with Article 10(2)(b) of the NC RfG, subject to a fast signal response as specified in Article 37 (1) of this Network Code.

9. Capability for Frequency Sensitive Mode shall be determined in accordance with Article 10(2)(c) of the NC RfG, subject to a fast signal response as specified in Article 37 (1) of this Network Code.

10. Capability for Frequency Restoration shall be determined in accordance with Article 10(2)(d) of the NC RfG.

11. Monitoring of FSM shall be determined in accordance with Article 10(2)(f) of the NC RfG.

12. The rights to Synthetic Inertia shall be determined in accordance with Article 9.

Article 38 **Reactive Power and Voltage** requirements

1. In addition to fulfilling the requirements listed in Articles 6 to 36 unless referred to otherwise in this Article, HVDC Substations which are AC Connected to DC-connected Power Park Modules, shall fulfill the requirements in this Article.

2. With respect to Voltage ranges for DC-Connected Power Park Modules these shall be determined in accordance with Article 20.1. of the NC RfG.

3. With respect to Reactive Power Capability for DC-Connected Power Park Modules:

   (a) For DC-Connected Power Park Modules, where the DC-Connected Power Park Module Owner is also the owner of all HVDC Systems connecting the DC-Connected Power Park Module to a single point on a AC Network then the DC-Connected Power Park Module must:

      i. Be capable of being able to meet the Reactive Power capabilities in 16.3.a) in NC RfG.
      ii. Be either:

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- Installed with these capabilities at time of initial connection and commissioning as part of connection of the DC-Connected Power Park Module to the AC Network (during the ION stage in CHAPTER 5).
- Demonstrate and agree with the Relevant TSO how the Reactive Power capability will be provide at a time when the DC-Connected Power Park Module is connected to more than the single point in the AC Network, or has another DC-Connected Power Park Module with a different owner. This agreement will include a contract by the DC-Connected Power Park Module Owner (of any subsequent Owner), that it will finance and install Reactive Power capabilities required by this Article at a point in time defined by the Relevant TSO.

iii. The Relevant TSO must perform a CBA based on information supplied by DC-Connected Power Park Module Owner to ensure that the Reactive Power capability required under this Article is not required for the Network at the time of its connection to the AC Network or within the time period that would be required to install this capability in the future before it may agree to a DC-Connected Power Park Module being initially installed without the Reactive Power capability. This CBA must also consider developments from the HVDC Substation to which the DC-Connected Power Park Module will be connected to other TSOs.

iv. The Relevant TSO must account for the development time of retrofitting the Reactive Power capability to the DC-Connected Power Park Module in specifying the point in time that this Reactive Power capability retrofitting is to take place. The development time will be provided by the DC-Connected Power Park Module Owner at the time connection to the AC Network.

(b) All other DC-Connected Power Park Modules shall be determined in accordance with Article 16.3.a), b) and c) of the NC RfG.

4. With respect to Voltage stability for DC-Connected Power Park Modules these shall be determined in accordance with Article 15.2. of the NC RfG.

5. With respect to Reactive Power control modes for DC-Connected Power Park Modules these shall be determined in accordance with Article 16.3.d) of the NC RfG.

6. With respect to priority of Active Power or Reactive Power contribution for DC-Connected Power Park Modules these shall be determined in accordance with Article 16.3.e) of the NC RfG.

7. With respect to Fault Ride Through for DC-Connected Power Park Modules these shall be determined in accordance with Article 11.3. of the NC RfG.

Article 39 **Control Requirements**

1. In addition to fulfilling the requirements listed in Articles 6 to 36 unless referred to otherwise in this Article, HVDC Substations which are AC Connected to DC-connected Power Park Modules, shall fulfil the requirements in this Article.

2. During the energisation or synchronisation of an HVDC Substation or a Power Park Module to the AC collection network at the Connection Point(s), the HVDC converter unit or HVDC Substation or Power Park Module shall smooth any Voltage transients to a level not exceeding 2 per cent of the pre-synchronisation AC Voltage.

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3. During the synchronisation of an energised HVDC Substation to an HVDC System, the HVDC converter unit or HVDC Substation shall smooth any Voltage transients, at any Connection Point of the HVDC System, to a level not exceeding 2 per cent of the pre-synchronisation AC Voltage

4. With regard to Active Power controllability and control range, the PPM control system shall be capable of adjusting an Active Power Setpoint as instructed by the Relevant TSO within a period specified and within a defined tolerance (subject to the availability of the prime mover resource), subject to notification to the National Regulatory Authority. The modalities of that notification shall be determined in accordance with the applicable national regulatory framework. automatic remote control equipment shall be duplicated to permit continued automatic remote control when any of the devices is out of service

5. An output signal shall be required from the PPM and control coordination with the HVDC system and DC-connected Power Park Module[s] is required to deliver an optimum response.

6. Power oscillation damping capability of Power Park Modules shall be determined in accordance with Article 16.3.(f) of the NC RfG

7. Sub-synchronous torsional interaction damping capability of Power Park Modules ...

8. A DC-connected Power Park Module shall be capable of staying connected to the Network and operating without power reduction, as long as Voltage and Frequency remain within the admissible limits pursuant to this Network Code.

9. Reconnection capability of Power Park Modules shall be determined in accordance with Article 9.4 of the NC RfG.

Article 40 **Network characteristics**

1. In addition to fulfilling the requirements listed in Articles 6 to 36 unless referred to otherwise in this Article, HVDC Substations which are AC Connected to DC-connected Power Park Modules, shall fulfil the requirements in this Article.

2. With regard to the Network characteristics, the following shall apply for the DC-connected Power Park Modules during normal and disturbed conditions:

   (a) Each TSO shall define and make publicly available, while respecting the provisions of Article 3(3), the method and the pre-fault and post-fault conditions for the calculation of minimum and maximum Short Circuit Power at the Connection Point.

   (b) The DC-connected Power Park Module shall be capable of operating within the range of short circuit power and network characteristics defined by the relevant TSO.

   (c) Each TSO, owner of PPMs and HVDC shall exchange equivalent model information to represent the system enabling the DC-Connected Power Park Module Owners and as applicable the HVDC Substation Owners to design the system with regard to harmonics.

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Article 41 **Protection requirements**

1. In addition to fulfilling the requirements listed in Articles 6 to 36 unless referred to otherwise in this Article, HVDC Substations which are AC Connected to DC-connected Power Park Modules, shall fulfil the requirements in this Article.

2. Electrical protection schemes and settings of Power Park Modules shall be determined in accordance with Article 8.5.b) of the NC RfG. 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.

3. Priority ranking of protection and control of Power Park Modules shall be determined in accordance with Article 8.5.c) of the NC RfG.

Article 42 **Power Quality**

1. In addition to fulfilling the requirements listed in Articles 6 to 36 unless referred to otherwise in this Article, HVDC Substations which are AC Connected to DC-connected Power Park Modules, shall fulfil the requirements in this Article.

2. DC-Connected Power Park Modules Owners and AC connected HVDC Substations to 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 allocated to them by the Relevant TSO, while respecting the provisions of Article 3(3).

Article 43 **General System Management Requirements applicable to DC connected PPMs**

1. In addition to fulfilling the requirements listed in Articles 6 to 36 unless referred to otherwise in this Article, HVDC Substations which are AC Connected to DC-connected Power Park Modules, shall fulfill the requirements in this Article.

2. With regard to general system management requirements, Articles 9(5), 10(6) and 11(4) of the NC RfG shall apply to any DC-connected Power Park Module.

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CHAPTER 4
INFORMATION EXCHANGE AND COORDINATION

SECTION 1
MONITORING

Article 44 **Operation**

1. With regard to instrumentations for the operation, the HVDC system shall be equipped of an automatic controller operated by the relevant TSOs. The automatic controller, per each convert units of the whole HVDC system, shall be capable of operating the HVDC system in coordinated way among converter units which are part of the HVDC system. The relevant TSOs define the automatic controller hierarchy per each HVDC convert units.

2. The signal types exchanged from the HVDC system and the automatic controller are: operational signals, urgent alarm signals and severe alarm signals.

   (a) With regard to operational signals, those are classified, but not limited to, by the following per each converter units, if applicable:
   - AC and DC Voltage;
   - AC and DC Current;
   - Active and Reactive AC power;
   - Active DC power;
   - Multi pole operational type at converter units level with regard to HVDC system;
   - FSM, LFSM-O and LFSM-U active power range;

   (b) With regard to urgent alarm signals, those are classified, but not limited to, by the following per each converter units, if applicable:
   - Startup;
   - Emergency blocking;
   - Ramp blocking;
   - Active power reversal;

   (c) With regard to severe alarm signals, those are classified, but not limited to, by the following per each converter units, if applicable:
   - Active power fast reversal;
   - HVDC system auxiliary service;

3. The signal types exchanged from the Relevant TSOs to the automatic controller are: operational signals, urgent alarm signals and severe alarm signals:

   (a) With regard to operational signals, those are classified, but not limited to, by the following per each converter units, if applicable:
   - Active Power Set-points;
   - Frequency Sensitive modes;
   - Reactive Power, Voltage or similar set-poits;

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- Reactive power control modes;
- Power oscillation damping;
- Synthetic inertia;

(b) With regard to urgent alarm signals, those are classified, but not limited to, by the following per each converter units, if applicable:
- Startup command;
- Emergency blocking command;
- Ramp blocking command;
- Active power flow direction;

(c) With regard to severe alarm signals, those are classified, but not limited to, by the following per each converter units, if applicable:
- Active power fast reversal command;

4. With regards to each category of signal, the relevant TSOs shall have the right to define, while respecting the provisions of Article 3(3), the quality of the supplied signal.

Article 45
Parameter setting

While respecting the provisions of Article 4(3), the parameters and settings of the main control functions of the HVDC system shall be agreed between the HVDC System Owner and the Relevant TSO(s). The parameters and settings shall be implemented within such a control hierarchy that makes their modification possible if necessary. These main control functions are at least:

- Synthetic inertia, if applicable, defined within Article 9 and 37.

- Frequency Sensitive Modes (FSM, LFSM-O, LFSM-U) defined in Articles 10, 11 12, and 37

- Frequency Control, if applicable, defined within Article 13

- Reactive power control mode, if applicable, defined in Article 18

- Power oscillation damping capability, as defined in Article 26 and 39

- Sub-synchronous torsional interaction damping capability, defined in Article 27 and 39

Article 46
Fault recording and Monitoring

1. With regard to instrumentation:

a) A HVDC system shall be equipped with a facility to provide fault recording and dynamic system behaviour monitoring of the following parameters for each converter station within a HVDC system:
- AC and DC Voltage;
- AC and DC Current;
- Active Power;
- Reactive Power; and

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- Frequency.

The Relevant TSO shall have the right to define while respecting the provisions of Article 3(3) quality of supply parameters to be complied with provided a reasonable prior notice is given.

b) While respecting the provisions of Article 3 (3), the particulars of the fault recording equipment, including analogue and digital channels, the settings, including triggering criteria and the sampling rates shall be agreed between the HVDC system Owner and the Relevant TSO.

c) All dynamic system behaviour monitoring shall include an oscillation trigger, specified by the Relevant TSO, for detecting poorly damped power oscillations.

d) The facilities for quality of supply and dynamic system behaviour monitoring shall include arrangements for the HVDC system Owner and/or the Relevant TSO to access the information electronically. While respecting the provisions of Article 3(3) the communications protocols for recorded data shall be agreed between the HVDC system Owner and the Relevant TSO.

Article 47
Fault analysis and disturbances

[tbc]

Article 48
Simulation models

1. While respecting the provisions of Article 3(3), the HVDC System Owner shall deliver simulation models to the relevant TSO which properly reflect the behaviour of the HVDC System in both steady-state, dynamic simulations (50 Hz component) and in electromagnetic transient simulations.
The format in which models shall be provided and the provision of documentation of models structure and block diagrams shall be defined by the Relevant TSO.

2. For the purpose of dynamic simulations, the models provided shall contain the following sub-models, depending on the existence of the mentioned components:

   - Converter models;
   - DC System as physical representation;
   - Voltage and power control;
   - Special control features if applicable e.g. Power System Stabilizer (PSS) function, SSTR control;
   - Multi terminal control, if applicable; and
   - HVDC System protection models as agreed between the Relevant TSO and the Power Generating Facility Owner, while respecting the provisions of Article 3(3).

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3. The models shall be verified against the results of compliance tests carried out according to CHAPTER 6. They shall then be used for the purpose of verifying the requirements of this Network Code including but not limited to Compliance Simulations as of Section 8, and for use in studies for continuous evaluation in system planning and operation.

4. The Relevant TSO shall have the right to require, while respecting the provisions of Article 3(3), HVDC System recordings in order to compare the response of the models with these recordings.

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CHAPTER 5
OPERATIONAL NOTIFICATION PROCEDURE FOR CONNECTION

SECTION 1 OPERATIONAL NOTIFICATION PROCEDURE FOR CONNECTION OF NEW HVDC SYSTEMS

Article 49
General provisions

Article 50 **Energisation Operational Notification (EON) for HVDC Systems**

Article 51 **Interim Operational Notification (ION) for HVDC Systems**

Article 52 **Final Operational Notification (FON) for HVDC Systems**

Article 53 **Limited Operational Notification (LON) for HVDC Systems**

SECTION 2 OPERATIONAL NOTIFICATION PROCEDURE FOR CONNECTION OF NEW DC-CONNECTED POWER PARK MODULES

Article 54 **General provisions**

Article 55 **Energisation Operational Notification (EON) for DC-connected Power Park Modules**

Article 56 **Interim Operational Notification (ION) for DC-connected Power Park Modules**

Article 57
Final Operational Notification (FON) for DC-connected Power Park Modules

Article 58 **Limited Operational Notification (LON) for DC-connected Power Park Modules**

SECTION 3 OPERATIONAL NOTIFICATION PROCEDURE FOR EXISTING HVDC SYSTEMS

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Article 59
General provisions

SECTION 4 OPERATIONAL NOTIFICATION PROCEDURE FOR EXISTING DC-CONNECTED POWER PARK MODULES

Article 60
General provisions

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CHAPTER 6
COMPLIANCE

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CHAPTER 7
DEROGATIONS

Article 61
General Provisions

Article 62
Request for Derogation

Article 63
Decision on Derogation

Article 64
Compliance of Existing HVDC Systems and Existing DC-connected Power Park Modules

Article 65
Register of derogations to the Network Code

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CHAPTER 8
FINAL PROVISIONS

Article 66
Amendment of contracts and general terms and conditions

All relevant clauses in contracts and/or relevant clauses in general terms and conditions relating to the Network connection of New HVDC Systems, New HVDC Substations, New HVDC Converter Units or New DC-connected Power Park Module Systems shall be amended to achieve compliance with the requirements of this Network Code.

The relevant clauses shall be amended within three years after the entry into force of this Network Code.

This requirement for amendment shall apply regardless of whether the relevant contracts or general terms and conditions provide for such an amendment.

Article 67
Entry into force

This Network Code shall enter into force on the twentieth day following that of its publication in the Official Journal of the European Union.

With the exception of Article 1(8)-(9), which shall apply thirty months after the entry into force, all provisions of this Network Code shall apply as from the day of expiration of a three year period following its publication.

This Network Code shall be binding in its entirety and directly applicable in all Member States.

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