Network Code for HVDC Connections and DC-connected Power Park Modules

Requirement Outlines

30 April 2014

Requirement:	Frequency Ranges, Rate-of-change-of-Frequency Withstand Capability
Article:	7, 8
Cross-border impact and objective:	Frequency without any doubt is the parameter of an interconnected electricity system, which has the largest cross border impact. Frequency is the same across a synchronous area and across all voltage levels. Deviations of frequency from its nominal value due to generation/load imbalances therefore occur everywhere at the same time and affect all units connected immediately in a common way regardless of their size and voltage level of connection. The rate of change of Frequency therefore has cross border impact when HVDC systems and DC connected Power Park Modules cannot withstand and disconnect. For the avoidance of doubt, frequency withstand capabilities are not an indication of normal system operation in future, but address extreme system events (e.g. during system restoration).
Implementation:	The requirement is exhaustively defined with no further specifications to be given at national or project level.
Justification	The withstand capabilities ensure that network assets remain in operation during severe system events, especially under those conditions which generation (NC RfG, Art 8) and demand (DCC, Art 13) have to withstand as well. A differentiation per synchronous area was relevant in NC RfG, based on present best practices as well as to optimally balance rotating machine impact and system frequency sensitivity. This is not considered relevant for power electronics interfaced HVDC equipment, or for connections to offshore wind farms. No major cost implications as a result of these increased ranges have been identified (See feedback from manufacturer survey in the NC HVDC FAQs). For rate-of-change-of-frequency, the requirement sets out frequency measurement accuracy at a European level which ensures the correct level of accuracy for all the synchronous systems within Europe.
Link to other NCs:	• NC RfG and DCC: The ranges cover those for generation and demand. • NC OS: The ranges for unlimited time cover the Normal State • NC LFC&R: A clear distinction is made between connection withstand capabilities (NC RfG, DCC, NC HVDC) which cope with system events, and system frequency quality targets under normal operation (NC LFC&R)
Link to framework guidelines:	• paragraph 2.1: *"… Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …"* • Paragraph 2.1.3: "...The network code(s) shall define: • - situations in general (e.g. which kinds of network faults, which electrical distance) And - the detail of possible deviations of significant parameters (e.g. voltage, frequency) that … must withstand, while remaining connected to the grid.

Requirement:	Active power controllability; control range and ramping rate
Article:	9
Cross-border impact and objective:	This capability of modifying the transmitted active power according to instructions sent manually or automatically by the TSO(s) enables the HVDC connections between control areas or synchronous areas to support the development of cross-border exchange of reserve and control energy (transmission of balancing energy resulting from the activation of cross-border reserves (frequency containment, frequency restoration and replacement reserves). This capability also enable to exchange control energy resulting from imbalance netting processes between several synchronous or control areas. Quick modification of active power transmission in case of disturbance in the network (for example aiming at mitigating overloads in the network) is an additional “defence line” in network operation enabling TSO to allocate more capacities for commercial cross-border exchanges. Such measures have a cross-border impact not only for HVDC system linking various control areas or synchronous areas but also for embedded HVDC systems when emergency changes in transmitted power enable to change the power flows in cross-border lines. Ramp rates shall be controllable by the TSOs in order to mitigate power imbalances between control areas and frequency deviations between synchronous zones. The capability of stopping the ramping in case of exhaustion of reserves in one of the synchronous or control areas also contributes to operate cross-border exchanges in a secure way.
Implementation:	Two requirements are not mandatory : fast active power reversal because some HVDC technologies (LCC) do not enable such a capability and a mandatory requirement would not be technology neutral ; capability to inhibit some control modes because system need are variable depending on the location of the HVDC system. All the other requirements are mandatory. All the requirements are non-exhaustive. Various parameters, triggering criteria and procedures need to be defined by the relevant TSO(s)
Link to other NCs:	• NC OS: HVDC systems can help to recover stable operation after a disturbance • NC LFC&R: implementation of function enabling cross-border exchange of FCR and FRR and allowing imbalance netting power interchange between the relevant TSOs
Link to framework guidelines:	• paragraph 2.1: “*… Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters con-tributing to secure system operation, including … Frequency and voltage parame-ters; … and Provision of ancillary services …*” • …

Requirement:	Synthetic Inertia Capability
Article:	10
Cross-border impact and objective:	Frequency is the parameter of an interconnected electricity transmission and distribution system which has the largest cross-border impact. The frequency is the same across a synchronous area and across all voltage levels. Deviations of frequency from its nominal value due to load imbalances therefore occur everywhere at the same time and affect all Grid Users immediately in a common way regardless of their size and voltage level of connection. Synchronous Generators have an inherent capability to resist / slow down frequency changes which converter based technologies do not have. This will result in larger rate of change of frequency during high RES production, at least unless counter measures are taken e.g. by converter based technologies. It is therefore paramount in allowing further expansion of RES which does not naturally contribute to inertia, to provide a synthetic component by converter based technology to make its contribution to overall system inertia. For the smallest synchronous areas (GB and Ireland) total system inertia is already a problem requiring system operator action and modeling out to 2030 has demonstrated a dramatic further reduction, particularly under low demand combined with high RES production. The modeling also shows a problem with inadequate synchronizing torque. Therefore enabling future use of synthetic inertia from converters in a controlled manner (giving the inertia the additional quality of synchronizing torque) can contribute solutions. The requirement also enables this.
Implementation:	This is an area which is still under development. It is therefore appropriate to allow developing experience to be introduced at a national level. The trigger for action can be the inertia studies as prescribed in NC OS
Justification	From the combination of circumstances of a topic which is under rapid development (not mature) and varying needs between synchronous areas, this requirement is stated only as a high level principle and non-mandatory. This also allows alternative methods such as fast acting frequency response to be considered, if adequate for the expected system conditions.
Link to other NCs:	• NC RfG and DCC: This non-mandatory requirement is also covered for generation (Synthetic Inertia) and demand (Very Fast Active Power Control). • NC OS and NC LFC&R define the TSO responsibility to manage the total system inertia.
Link to framework guidelines:	• paragraph 2.1: *"… Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …"* • Paragraph 2.1.3: "...The network code(s) shall define: • - situations in general (e.g. which kinds of network faults, which electrical distance) And - the detail of possible deviations of significant parameters (e.g. voltage, frequency) that … must withstand, while remaining connected to the grid.

Requirement:	Frequency Sensitive Modes and Frequency Control
Article:	11, 14
Cross-border impact and objective:	Frequency is the parameter of an interconnected electricity transmission and distribution system which has the largest cross-border impact. The frequency is the same across a synchronous area and across all voltage levels. Deviations of frequency from its nominal value due to load imbalances therefore occur everywhere at the same time and affect all Grid Users immediately in a common way regardless of their size and voltage level of connection. The requirement prescribes various capabilities for autonomous and remote-controlled actions to alter Active Power flows to control Frequency at all Connection Points.
Implementation:	The NC HVDC sets a frame for various capabilities in this class (non-exhaustive requirement).
Justification	**1.1 System needs in normal operation** **HVDC system embedded within one synchronous area** As a starting point, an HVDC system is expected to be as flexible as an AC line regarding network topology changes which can be requested by TSO(s). To that end, an HVDC system shall have the capability to feed a passive electric island (radial connection). This kind of topology is currently used in operation to reduce short-circuit power on AC system or to control flows in the AC system. In order to do so, the HVDC system shall be capable of controlling the frequency at the end of the HVDC system where the passive electric island is connected by adjusting the active power output in order to maintain stable system frequency inside the island (synthetic frequency). This could be done by FSM (mandatory mode) using a droop close to zero or by an ad-hoc frequency control mode (non-mandatory mode; the TSO can require it according to article 14 on Frequency Control). **HVDC system connecting several synchronous areas** The HVDC connections between control areas or synchronous areas shall support the development of cross-border exchange of reserve and control energy. The HVDC system shall be capable of providing Frequency Containment Reserve at each end of the system. In order to do so, FSM shall be available at each HVDC Converter Station. **HVDC system connecting remote PPM** The HVDC system shall be capable of maintaining stable system frequency at the remote end (synthetic frequency). This could be done by FSM (mandatory mode) using a droop close to zero or by an ad-hoc frequency control mode according to article 13. The HVDC system shall allow PPM to participate in frequency control in the main AC system (on-shore). If the HVDC system provides synthetic frequency at the remote end (PPM AC collecting network), no additional control mode is needed. FSM could be a possible solution to enable the whole system (PPM + HVDC system) to participate in frequency control in the main land synchronous area. **1.2 System needs in emergency operation** **HVDC system embedded within one synchronous area** The HVDC system shall be capable of participating in frequency control for an islanded area resulting from a network split. FSM can be used to support the generation units remaining connected to the island. **HVDC system connecting several synchronous areas and HVDC system connecting**

	remote PPM For HVDC system capable of black-start, they shall be capable of maintaining stable system frequency in a passive electric island (synthetic frequency) in order to enable step by step network restoration after a black-out. This could be done by FSM (mandatory mode) using a droop close to zero or by an ad-hoc frequency control mode according to article 14.
Link to other NCs:	• NC RfG: related capabilities with consistent range – inherent capabilities of HVDC technology is made optimal use of • NC LFC&R: enables present LFC&R products to be delivered/exchanged.
Link to framework guidelines:	• paragraph 2.1: *"… Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …"*

Requirement:	Limited Frequency Sensitive Mode Overfrequency (LFSM-O), and Limited Frequency Sensitive Mode Underfrequency (LFSM-U)
Article:	12, 13
Cross-border impact and objective:	Frequency without any doubt is the parameter of an interconnected electricity transmission and distribution system, which has the largest cross-border impact. Frequency is the same across a synchronous area and across all voltage levels. Deviations of frequency from its nominal value due to load imbalances therefore occur everywhere at the same time and affect all Grid users immediately in a common way regardless of their size and voltage level of connection. If load imbalances are not removed and frequency deviations increase, masses of Grid Users will disconnect due to frequency, which is out of the range of their design for operation. This will result in a deterioration of system stability and security, which HVDC systems can contribute to overcome by a smooth reduction or increase of active power output of HVDC systems at respectively high or low frequencies (in particular meaningful in case of HVDC system connects different synchronous areas or in case of a system split).
Implementation:	The requirement is exhaustively defined with no further specifications to be given at national or project level.
Justification	• Due to their immediate cross-border impact, frequency requirements need to be harmonised as much as possible. In order to consider appropriately the capabilities of HVDC technologies some flexibility still has to remain for setting the frequency threshold of activation, the droop and the initial delay of activation. • Inherent inertia of the electricity supply system decreases due to less synchronous generators connected in future; consequently frequency sensitivity increases and larger sudden frequency deviations occur in case of generation/load imbalance. • In case that a HVDC system connects different synchronous areas (or in case of a system split) a smooth reduction or increase of active power output at the HVDC connection point with respectively over- or underfrequency is needed to maintain system stability.
Link to other NCs:	• NC RfG: The ranges cover those for generation. • NC LFC&R: A clear distinction is made between connection withstand capabilities (NC RfG, DCC, NC HVDC) which cope with system events, and system frequency quality targets under normal operation (NC LFC&R)
Link to framework guidelines:	• paragraph 2.1: “... *Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …”* • Paragraph 2.1.3: “...The network code(s) shall define: • - situations in general (e.g. which kinds of network faults, which electrical distance) And - the detail of possible deviations of significant parameters (e.g. voltage, frequency) that … must withstand, while remaining connected to the grid.

Requirement:	Maximum Loss of Active Power
Article:	15
Cross-border impact and objective:	The sudden loss of a large amount of active power injected into, or delivered out of a Synchronous Area can result in large generation/load imbalances which need to be covered by operational reserves. In order to maintain a reasonable size of reserves, preserve a proportional treatment of all users and ensure adequate frequency management, specific consideration may need to be given to the configuration of an HVDC System.
Implementation:	The Relevant TSO at each Connection Point has an obligation to set a reference for maximum Active Power loss for a given LFC Block.
Justification	HVDC technology allows for links with a capacity of several GWs. The sudden loss of such link could have a severe impact on frequency stability within a Synchronous Area. The intention of the requirement is not to constrain the total transmission capability of an HVDC System project, rather to ensure that a transient or permanent fault within the system does not result in a trip of the entire HVDC System resulting in a loss of active power infeed above a set reference. Such a limit is necessary to ensure that the reserves described in operational codes, and thus the associated socio-economic costs can be kept at a reasonable level while maintaining security of operation and without limiting the actual capacity of new HVDC projects.
Link to other NCs:	• NC LFC&R: The implemented requirement relates to the sizing of operational reserves as prescribed in NC LFC&R • NC RfG and DCC: In theory a similar requirement could be requested from generation and demand, but was deemed not relevant or appropriate given the commonly smaller active power rating compared to what is feasible in an HVDC configuration.
Link to framework guidelines:	• paragraph 2.1: *"… Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …"* • Paragraph 2.1.3: "...The network code(s) shall define: • - situations in general (e.g. which kinds of network faults, which electrical distance) and - the detail of possible deviations of significant parameters (e.g. voltage, frequency) that … must withstand, while remaining connected to the grid.

Requirement:	Voltage Ranges
Article:	16
Cross-border impact and objective:	Voltage ranges are critical to secure planning and operation of a power system within a synchronous area. This needs to be coordinated between adjacent interconnected networks. This can often be a cross border issue.
Implementation:	The requirement is mandatory and exhaustively defined in the code.
Justification	This requirement is given exhaustively in tables 5 and 6. There is an exception for one voltage range in Continental Europe in each table. Because of the size of this system, there is a need for limited variation, while retaining wider coordination. Voltage ranges for HVDC connections have slight wider times to withstand than NC RfG or NC DCC as in case of network disturbance HVDC connections, as part of the transmission system, shall withstand more than generation and demand. This is needed to maintain coordination among generators, demand and HVDC systems and avoid subsequent inopportune tripping.
Link to other NCs:	• NC RfG / DCC: NC HVDC ensures the HVDC assets are the last to disconnect in case of system events.
Link to FWGL:	• paragraph 2.1*: "… The network code(s) shall define the physical connection point between the significant grid user's equipment and the network to which they apply. Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* ○ *Frequency and voltage parameters; …"*

Requirement:	Short circuit contribution during faults requirements
Article:	17
Cross-border impact and objective:	Current injection is critical to both recovering the voltage during faults and to injecting enough current quickly enough for system protections to function reliably. Both of these aspects which are part of the fault-ride-through family of requirements are essential to system stability which in turn is the foundation for cross-border trading.
Implementation:	To be further specified at national level. The NC indicates the basic principles of having Fast Fault Current with specifications set for subsequent stages.
Justification:	Although the direct effect is quite local, this is a cross border issue as an abnormal system protection performance may cause overall effects and it has to be agreed by the Relevant TSO(s). The requirement refers to Article 4(3) in respect to national / TSO choices of parameters for the current injection. This freedom allows national choices to reflect developing local needs and to take account of existing requirements. Furthermore, the freedom of choice of parameters allows this requirement to be technology neutral.
Link to other NCs:	• NC RfG: consistent requirement for PPMs to ensure both a fast and slow component is delivered.
Link to FWGL:	• paragraph 2.1: *"… The network code(s) shall define the physical connection point between the significant grid user's equipment and the network to which they apply. Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* ○ *Fault-ride-through capability …"*

Requirement:	Reactive Power Capability
Article:	18
Cross-border impact and objective:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. For HVDC system the influence on overall system voltage stability will vary with location and electrical characteristics on the connection points. Therefore the requirement for HVDC system reflects this. Reactive power provisions at the connection point ensure for the transmission system to operate with adequate margin of reliability aiming to preserve the system against the risk of voltage collapse, voltage instability and inappropriate service quality.
Implementation:	The NC offers a frame within which national or project specific capabilities can be set, driven by local system conditions and technology characteristics.
Justification:	The Relevant TSO(s) shall define while respecting the provisions of Article 4(3) the Reactive Power Capability requirements at Maximum HVDC Active Power Transmission Capacity in the context of varying Voltage which shall be provided by the HVDC substation. The Relevant TSO(s) shall define while respecting the provisions of Article 4(3) the Reactive Power Capability requirements below the Maximum HVDC Active Power Transmission Capacity while respecting the technical limitations identified by the U-Q/Pmax-profile. The frame of the code offers a proportional and appropriate approach to allow the local needs to influence the requirements. The basic principles of the requirement still leave room to choose for either LCC or VSC technology.
Link to other NCs:	• NC RfG: consistent envelopes • NC OS: prescriptions on reactive power management
Link to FWGL:	• paragraph 2.1: *"... The network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* ○ *Requirement for Reactive Power;..."*

Requirement:	Reactive power exchanged with the Network
Article:	19
Cross-border impact and objective:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. For HVDC system the influence on overall system voltage stability will vary with location and electrical characteristics on the connection points. Therefore the requirement for HVDC system reflects this. Reactive power provisions at the connection point ensure for the transmission system to operate with adequate margin of reliability aiming to preserve the system against the risk of voltage collapse, voltage instability and inappropriate service quality.
Implementation:	Further details on maximum exchange or resulting voltage steps are to be specified by the Relevant TSO.
Justification:	The HVDC System shall ensure that 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. Not having this requirement could result in significantly increased danger of voltage instability situations and/or operation conditions where the sudden voltage change cannot be controlled.
Link to other NCs:	• NC DCC: similar requirement on capability to restrict maximum reactive power exchange. • NC OS: prescriptions on reactive power management
Link to FWGL:	• paragraph 2.1: "… *The network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* o *Requirement for Reactive Power;…"*

Requirement:	Reactive power control mode
Article:	20
Cross-border impact and objective:	Insufficient reactive power in AC transmission system at normal operation or contingencies may lead to low voltage or voltage instability and eventually voltage collapse with cross-border impact. The objective is to utilise the inherent capability of HVDC systems to provider reactive power control.
Implementation:	Three reactive power control modes are required with further details to be specified by the Relevant TSO.
Justification	A choice of control modes and the possibility to specify specific reactive control function allowed the requirement to reflect particular national and local needs. Only principal control characteristic is given, but ranges are given regarding response time of reactive power output following a step change in system Voltage. The response time range is wider than the defined in NC RfG taking into account the higher flexibility of the HVDC systems: response time may be shorter than RfG depending on the needs, as there is not a technical limitation; and it also may be longer than RfG if a slow voltage control is required (for instance in case of interaction with other controllers managing reactive power implemented in the HVDC System).
Link to other NCs:	NC RfG: consistent requirement with due consideration for inherent HVDC technology characteristics.
Link to FWGL:	Paragraph 2.1: "The network code(s) shall set out how the TSO defines the technical requirements related to frequency and active power control and to voltage and reactive power management. …"

Requirement:	Priority to active or reactive power contribution
Article	21
Cross-border impact:	Power recovery after a fault is important in order to restore the pre-fault operation after fault clearance. The relative priority of restoring the reactive power and voltage versus restoring real power and frequency depends upon the system size, predominantly of the synchronous area. For smaller synchronous areas (with less system inertia than larger areas) the real power restoration is particular time critical, in order to avoid reaching a system frequency following a large sudden power imbalance which results in demand disconnection.
Implementation:	The level of delegation to national level is appropriate to adequately reflect the different needs of the different sizes of synchronous areas. Ranges are not provided. This is left open to deal nationally with the combination of issues of the nature of the network as well as changes over time of the expected level of system inertia.
Justification:	Inappropriate priority settings could result in frequency and/or voltage stability.
Link to other NCs	• NC RfG: consistent requirement.
Link to FWGL:	• paragraph 2.1: *"… The network code(s) shall define the physical connection point between the significant grid user's equipment and the network to which they apply. Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* o *Fault-ride-through capability …"*

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Requirement:	Power quality
Article:	22
Cross-border impact and objective:	Power and Voltage Quality is determined by the level of distortion measured at the connection point due to both HVDC system and all connections in a synchronous system area. The scale of this distortion is an aggregated effect of all connections, and simultaneously the aggregated distortion levels inversely impacts on all connected parties.
Implementation:	This requirement is to be further specified by the Relevant TSO based on local system conditions. Requirements may need to be altered to provide efficient and effective management of power and voltage quality for the HVDC system or to meet the acceptable distortion levels for those with an existing connection. The requirement for power and voltage quality is impacted by the scale of a synchronous network, the effective system strength of the network, its topography and component parts.
Justification	Power and voltage quality distortion levels needs to applied accounting for varying network factors to ensure the aggregated impact across the synchronous system is acceptable both in terms of individual contribution to and the aggregated impact of these distortions.
Link to other NCs:	• DCC: consistent requirement
Link to FWGL:	• paragraph 2.1: *"… The network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* ○ *Frequency and voltage requirements;…"*

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Requirement:	Fault ride through capability
Article:	23
Cross-border impact and objective:	In order to maintain system integrity and avoiding cross border impact it is important that HVDC systems and HVDC connected PPMs remain connected to the network when system voltages are low during and after recovery from temporary fault in the AC transmission system.
Implementation:	The NC gives a clear frame within which to specify a voltage-against-time profile, provide appropriate post and pre-fault conditions, and to exchange relevant information to ensure relevant compliance checks (physical testing or appropriate simulations). Range of settings specifying the FRT-curve will allow adaption to be made with the purpose to cover local or national conditions and ensuring proportionality and coordination with fault ride through capability with other generation. In a situation with high penetration of asynchronous generators (or induction motors), the voltage recovery after a short circuit fault may be significantly delayed. This is caused by the reactive power drawn by these machines until the normal speed (slip) is regained. This process may take 10 seconds or longer in severe cases. Under these conditions an extended recovery time (Trec2) of 10s is essential.
Justification:	Avoid sudden large generation/load imbalance after a secured fault, which would result in frequency disturbances.
Link to other NCs:	NC RfG: consistent framework of which parameters need to be specified – with due consideration for inherent HVDC technology characteristics.
Link to FWGL:	• paragraph 2.1: "… *The network code(s) shall define the physical connection point between the significant grid users equipment and the network to which they apply. Furthermore, the network code(s) shall define the equipment on significant grid users in relation to the relevant system parameter contributing to secure system operation, including:* 　o *Fault-ride-through capability;"*

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Requirement:	Post fault Active Power recovery
Article:	24
Cross-border impact and objective:	Power recovery after an AC fault at or remote from the connection point is important in order to restore the pre-fault operation after fault clearance. For smaller synchronous areas (with less system inertia than larger areas) the real power restoration is particular time critical, in order to avoid reaching a system frequency following a large sudden power imbalance which can result in over frequency in an exporting area and under frequency in an importing area. This can precipitate wide spread frequency instability. HVDC with the capability for active power recovery can thus help to secure the system. This capability has to be coordinated with the operational and market requirements imposed on HVDC. Active power recovery can also help restore voltage stability which can also have a beneficial impact on transient rotor angle stability. This is critical in supporting the frequency and/or voltage of the grid after disturbance coming from a voltage or frequency dip. Ramp rate after disturbance (rise time and settling time) is vital to maintain system frequency stability and therefore system security. Conventional generating units respond to a fall or rise in frequency by increasing/decreasing their power output, which occurs over a 5 to 30 second interval after a contingency.
Implementation:	The requirement is non-exhaustively defined as the speed of recovery is dependent on local network conditions, including fault levels; thus further specifications are to be given at national or project level.
Link to other NCs:	• NC RfG: consistent requirement for type B-D Power Generating Modules.
Link to framework guidelines:	• paragraph 2.1: "... *Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Fault Ride Through capability …"*

Requirement:	Fast recovery of DC faults
Article:	25
Cross-border impact and objective:	Proper network protection is essential for maintaining system stability and security, in particular in cases of disturbances to the system. Protection schemes shall prevent aggravation of disturbances and limit their consequences. Protection schemes and settings must protect properly the electrical and electronic devices but also be discriminatory so that the equipment can fulfil performance requirements under defined system conditions. It is a cross border issue as abnormal conditions in the network may spread along synchronous areas Autoreclose capability for transient faults on HVDC system, where applicable, would enable fast restoration of the integrity of the network and reduce risk of system instability across borders. This requirement complements Article 23 “Fault Ride Through Capability” and together with Article 24 “Post fault active power recovery” will contribute to securing power system stability.
Implementation:	The requirement is non-exhaustive as it needs coordination with protection schemes and settings at project level.
Link to other NCs:	• not applicable to generation or demand
Link to framework guidelines:	• paragraph 2.1: “… *Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Fault Ride Through capability …”*

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Requirement:	Converter energisation and synchronisation
Article:	26
Cross-border impact and objective:	This article intends to mitigate large voltage changes on the AC system when energising or synchronising an HVDC system with the adjacent grid. Furthermore the occurrence of voltage transients (magnitude, duration) shall be limited to a level specified by the Relevant Network Operator. Large voltage changes and transients in an AC network have a negative influence on the performance of the network. It may lead to increased aging of equipment due to electrical stresses and/or thermal effects due to additional losses, unwanted operation of protection devices or transient voltage instability.
Implementation:	The mandatory requirement defines a maximum level of allowable Voltage change. The requirements with respect to the voltage transients shall be given at national or project level.
Link to other NCs:	• NC RfG: Requirements regarding the smooth synchronisation of Power Generating Modules to the grid • NC DCC: Requirements for synchronization settings for demand
Link to framework guidelines:	• Paragraph 2.1: "… *Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …*"

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Requirement:	Interaction between HVDC System(s) and/or other plant(s) and equipment
Article:	27
Cross-border impact and objective:	The presence of other links in close proximity and the different constituent of PPM's and HVDC links could lead to adverse interaction between converter controls during transient or steady state conditions. The intention of this requirement is to satisfy that undesirable interaction of HVDC control system with offshore wind farm control or between nearby HVDC controls is avoided by proper and robust control design and control coordination. Control Instability can limit transfer capability of interconnection and compromise the overall system security. Therefore the means of preventing such instability must be considered a cross-border issue.
Implementation:	The requirement is mandatory, but non-exhaustive. The exact scope and extent of the studies are specified at national or project level.
Link to other NCs:	• No explicit related requirement in NC RfG, DCC. Existing grid users are explicitly referred to in this code to provide relevant input to reasonable extent.
Link to framework guidelines:	• Paragraph 2.1: *"… Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Requirements for protection devices and settings; …"* • Paragraph 2.1.3: *"The network code(s) shall set out how generation units must be able to execute their control activities in normal and in alert (disturbed) operating states. Specific parameters for operation outside these operating states will be agreed bilaterally between generation units and system operators."*

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Requirement:	Power oscillation damping capability
Article:	28
Cross-border impact and objective:	Power oscillations may occur in an AC network, which causes system instability. HVDC could enhance power system oscillation damping and thus contribute to the overall system stability. The method of damping could be by active and/or reactive power modulating of the HVDC link, or by active power modulation of the offshore PPMs, or a combination of both. Network instability can limit transfer capability of interconnection and compromise the overall system security. Therefore the means of preventing such instability must be considered a cross-border issue.
Implementation:	The implementation of POD capability is mandatory. The activation and the control parameter settings of the POD capability shall be defined at national level.
Link to other NCs:	• NC RfG: Requirements with respect to Power System Stabilizer. • NC DCC: Requirements with respect to Demand Side Response Active Power Control • NC LFC&R: LFC&R covers nominal frequency range. The POD-capability covers low frequency oscillations, which contributes to the quality. • NC OS: Article 15 Dynamic Stability Management
Link to framework guidelines:	• Paragraph 2.1: *"…The network code(s) shall set out how the TSO defines the technical requirements related to…..active power control…"* • Paragraph 2.1.3: *"The network code(s) shall set out how generation units must be able to execute their control activities in normal and in alert (disturbed) operating states. Specific parameters for operation outside these operating states will be agreed bilaterally between generation units and system operators."*

Requirement:	Sub-synchronous torsional interaction damping capability
Article:	29
Cross-border impact and objective:	Sub-synchronous torsional interaction (SSTI) oscillations can arise in a power system due to interaction between various components in the system. These sub-synchronous torsional oscillations can result in damage on the shaft of connected turbines. Introduction of a new HVDC system can affect the present level of these torsional oscillations. By a properly adjusted SSTI controller in the HVDC system the HVDC system can efficiently contribute to the damping of harmful sub-synchronous oscillations and therefore contribute to a robust behaviour of the synchronous power system. Results of SSTI studies performed by the HVDC system owner shall reveal the need of activation of the SSTI controller and its specific parameter settings. HVDC converter stations without adequate SSTI control may endanger synchronous generators and therefore the entire system. A negative impact on one of the connected synchronous system will also have a cross border impact.
Implementation:	The implementation of SSTI controller is mandatory. Specific parameter settings are to be defined by SSTI studies performed by the HVDC System Owner.
Link to other NCs:	• no direct equivalent in NC RfG / DCC
Link to framework guidelines:	• Paragraph 2.1: *"…the network code(s) shall define the requirements…including …requirements for protection devices and settings"*

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Requirement:	Network characteristics
Article:	30
Cross-border impact and objective:	A proper design of a HVDC system will ensure stable operation during normal and disturbed conditions. To achieve this, in-depth studies of system performance for various network conditions are required. An insufficient security of operation of HVDC system(s) during different conditions in the connecting network(s) will have a cross border impact. This article sets the requirement of operability of the system for the, by TSO defined, relevant network conditions.
Implementation:	The requirement is mandatory but non-exhaustively defined. Figures and configuration in network characteristics are to be defined at project level.
Link to other NCs:	• NC RfG and DCC: Related requirements on short circuit levels • NC OS: Requirement in line with NC OS Article 11 and 21.
Link to framework guidelines:	• Paragraph 2.1: *"…Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation..."*

Requirement:	HVDC System robustness
Article:	31
Cross-border impact and objective:	A non-robust design of HVDC System(s) will result in a cross border impact due to high risk of instability caused by changes in power flow and transients in voltage/frequency when system conditions change, planned or unplanned.
Implementation:	The requirement is mandatory but non-exhaustive. Details regarding the verification of the resilience of the HVDC System shall be discussed at project level.
Link to other NCs:	No explicit requirement in RfG/DCC, but indirectly covered in various requirements.
Link to framework guidelines:	• paragraph 2.1: "*… Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation…*"

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Requirement:	Electrical protection schemes and settings
Article:	32
Cross-border impact and objective:	Proper network protection is essential for maintaining system stability and security, in particular in cases of disturbances to the system. Protection schemes shall prevent aggravation of disturbances and limit their consequences. Protection schemes and settings must protect properly the electrical and electronic devices but also be discriminatory so that the equipment can fulfil performance requirements under defined system conditions. It is a cross border issue as abnormal conditions in the network may spread along synchronous areas on the AC side and fault clearance in the DC side is not a current capability as evidenced by the state of the art in DC circuit breakers. The intention of this requirement is to ensure that the HVDC links are designed in a way that the protection devices are discriminative and stable so as to minimise malfunction operations.
Implementation:	The requirement is mandatory but non-exhaustive. The exact scope and extent of the schemes and settings are specified at national or project level, focused on coordination and agreements.
Link to other NCs:	• NC RfG: Article 9(5)(b) • DCC: Article 17
Link to framework guidelines:	• paragraph 2.1: *"… Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* ○ *…* ○ *Requirements for protection devices and settings;* ○ *…"*

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Requirement:	Priority ranking of protection and control
Article:	33
Cross-border impact and objective:	This requirement is necessary because different control modes might interfere with each other and could lead to different control targets if not ranked. Hence, a clear list, what control modes are active and dominating together with the values is essential. It is a cross border issue as unexpected operation of control and protection of the HVDC System may cause an abnormal condition in the network which could spread along synchronous areas in the AC side.
Implementation:	Control schemes to be further coordinated/agreed. An explicit priority ranking list is given in the NC HVDC, which could be specified further or amended at national level.
Link to other NCs:	• NC RfG: Article 9.(5).(c) • DCC: Article 17(3)
Link to framework guidelines:	• paragraph 2.1: *"… Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* ○ ○ *Requirements for protection devices and settings;* ○ …"

Requirement:	Changes to protection and control schemes and settings
Article:	34
Cross-border impact and objective:	The Relevant TSO(s) shall maintain system stability en security, which is a cross border related task. When changes in the AC or DC system takes place, it might be necessary to adjust settings of protection and control schemes. Therefore adequate coordination of system changes, requiring adjustment of protection and control devices, is a prerequisite for network operators to maintain system stability and security. Network operators continuously need to have an overview over the state of the system, which includes information on the operating conditions of Power Generating Modules, demand and HVDC links.
Implementation:	The requirement is mandatory but non-exhaustive.
Link to other NCs:	• NC RfG: Article 9(5).(b)(4) • DCC: Article 17
Link to framework guidelines:	• paragraph 2.1: *"… Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including:* ○ ○ *Requirements for protection devices and settings;* ○ *…"*

Requirement:	Black start
Article:	35
Cross-border impact and objective:	Black start capability is critical to restore a power system to a stable condition in which normal system operation and cross border trading can be resumed after a black-out.
Implementation:	The requirement is non-mandatory and non-exhaustive. Implementation is technology dependent. The TSO shall have the right to obtain a quote.
Link to other NCs:	• NC RfG: Article 10(5).(a)
Link to framework guidelines:	• paragraph 2.1.3: *"… The network code(s) shall define minimum conditions for (re)connection to the grid in disturbed/critical operating state. The network code(s) shall set out how generation units must be able to execute their control activities in normal and in alert (disturbed) operating states. Specific parameters for operation outside these operating states will be agreed bilaterally between generation units and system operators. Coordination requirements and procedures for reconnection after tripping shall be defined transparently in the network code(s) for the different parties involved. The network code(s) shall elaborate their different roles and responsibilities. In particular for the following services the network code(s) shall set out the minimum requirements for those generators providing them on a contractually-agreed basis:* ○ *…;* ○ *Black start ;…"*

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Requirement:	Frequency Ranges, Rate-of-change-of-Frequency Withstand Capability
Article:	37, 45
Cross-border impact and objective:	Frequency without any doubt is the parameter of an interconnected electricity system, which has the largest cross border impact. Frequency is the same across a DC connected AC collection grid. The rate of change of Frequency therefore has cross border impact when HVDC systems and DC connected Power Park Modules cannot withstand frequency deviations and disconnect with a resulting infeed loss in the Synchronous Area.
Implementation:	The requirements are exhaustively defined with no further specifications to be given at national or project level.
Justification	The withstand capabilities ensure that network assets remain in operation during severe system events, especially under those conditions which generation (NC RfG, Art 8) and demand (DCC, Art 13) have to withstand as well. For DC connected PPMs and remote end HVDC converters it is decisive to have at least the same withstand capability as other grid users provide. Therefor frequency ranges and withstand capability are considered comparable to those in the different synchronous areas. A differentiation per synchronous area was relevant in NC RfG, based on present best practices as well as to optimally balance rotating machine impact and system frequency sensitivity. This is not considered relevant for power electronics interfaced HVDC equipment, or for connections to offshore wind farms. No major cost implications as a result of these increased ranges have been reported. Due to their immediate cross-border impact, frequency requirements need to be harmonised as much as possible. For DC connected PPMs and remote end HVDC converters, the range for unlimited operation needs to be at least the same than in the smallest synchronous area. Furthermore a change in frequency in such DC connected islands shall not lead to large outages of generated power. Therefore adequate frequency ranges and rate of change of frequency parameters are essential. Inherent inertia of the electricity supply system is not available in such DC connected AC collection systems, consequently larger sudden frequency deviations occur in case of load imbalances.
Link to other NCs:	• NC HVDC: the ranges cover HVDC converters connected to the main system • NC RfG and DCC: The ranges cover those for generation and demand. • NC OS: The ranges cover the Normal State • NC LFC&R: A clear distinction is made between connection withstand capabilities (NC RfG, DCC, NC HVDC) which cope with system events, and system frequency quality targets under normal operation (NC LFC&R)
Link to framework guidelines:	• paragraph 2.1: *"... Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …"* • Paragraph 2.1.3: *"...The network code(s) shall define:* - *situations in general (e.g. which kinds of network faults, which electrical distance) And* - *the detail of possible deviations of significant parameters (e.g. voltage, frequency) that … must withstand, while remaining connected to the grid…"*

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Requirement:	Voltage Range Requirements
Article:	38, 46
Cross-border impact and objective:	Voltage ranges are critical to secure planning and operation of a power system within a synchronous area. These need to be coordinated between adjacent interconnected networks. Purely DC connected AC collector networks are in their own right synchronous and require a voltage range. The loss of a synchronous network given their typical size and configuration is likely to create a voltage or frequency cross border impact in the Synchronous Area as a consequence.
Implementation:	The voltage requirement is exhaustively defined with no further specifications to be given at national or project level.
Justification	The voltage requirements given in the NC RfG set the capabilities of generators, which may be initially AC connected but ultimately DC connected or vice versa. There is considerable evidence in offshore grid and network studies that AC and DC integrated networks over time are likely to occur (e.g. NSCOGI) and therefore ensure a consistent minimum voltage range for either an initially connected AC or DC-connected PPMs. Inadequate voltage range will often be a cross border issue, DC links are by their very nature often large capacity and are primed for development of further generation or for interconnection between networks. Therefore AC collector networks off DC links are likely to either directly influence a cross border power flow as a interconnector, or given their size likely to create a cross border impact upon their loss (for networks connected at or above 110 kV). The requirement sets out voltage ranges for DC Connected PPMs at a European level which ensures the correct range for the synchronous systems within Europe and provides cost effective development of a minimum range of devices suitable across Europe.
Link to other NCs:	• NC RfG and DCC: The voltage ranges cover those for generation and demand. • NC OS: The voltage ranges cover the Normal State
Link to framework guidelines:	• Paragraph 2.1*: "… The network code(s) shall define the physical connection point between the significant grid user's equipment and the network to which they apply. Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing secure system operation, including:* o *Frequency and voltage parameters;…"*

Requirement:	Reactive Power Requirements for DC connected PPMs
Article:	38
Cross-border impact and objective:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. Purely DC connected AC collector networks are in their own right synchronous and require reactive power range. The loss of a synchronous network given their typical size and configuration is likely to create a voltage or frequency cross border impact as a consequence. Also requirements must ensure the plant and equipment provides the necessary capabilities over their asset life and given the ongoing development of the network DC connected PPMs may become AC connected and would then influence other 'cross border' synchronous networks directly and should be compatible for this change.
Implementation:	The Reactive Power requirement is non-exhaustively defined with further specification as to the range and applicability to be given at national or project level. This also covers the option of optimizing DC link and PPM design, or placing the delivery of reactive power capability in the appropriate long term network development perspective.
Justification	The reactive power requirements in the NC RfG set the capabilities of generators, which may be initially AC connected but ultimately DC connected or vice versa. There is considerable evidence in offshore grid and network studies that AC and DC integrated networks over time are likely to occur and therefore a consistent minimum reactive power range that is consistently applied for an AC or DC connected PPM as an AC connection has a high probability of becoming DC or vice versa. Reactive power provision whether for an AC collector network when purely DC connected or in future as part of a wider AC network following AC subsequent connection should be provided in a cost beneficial way. For an individual DC connected PPM then reactive power provision needs only to match reactive power provision from most effective methods. However given the risk of additional PPMs connecting to the AC collector network or future network development, the PPPM must be able to provide reactive power consistent with the NC RfG requirements. Where multiple PPM owners exist in the same DC connected AC collector network then the reactive power provision should be provided by all to share the reactive power provision costs in a non-discriminatory manner. The size of AC collector networks and AC connections to synchronous systems will vary both in size and topography in the immediate and future years. Therefore flexibility is needed to account for configuration variations and a reactive power range is the most appropriate way of ensuring cost effective and technically acceptable requirements are imposed.

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	Inadequate reactive power range will often become a cross border issue, DC links are by their very nature often large capacity and are primed for development of further generation or for interconnection between networks. Therefore reactive power provision for voltage stability in AC collector networks with DC links are likely to either directly influence a cross border power flow as an interconnector, or given their size are likely to create a cross border impact upon their loss. The requirement sets out reactive power capability ranges for DC Connected PPMs at a European level which ensures the correct range for the synchronous systems within Europe and provides cost effective development of a minimum range of devices suitable across Europe.
Link to other NCs:	• NC RfG and DCC: The reactive power ranges cover those for generation and demand. • NC OS: The reactive power ranges in Article 10 • NC OPS: The reactive power ancillary services in Article 51
Link to framework guidelines:	• Paragraph 2.1*: "… The network code(s) shall define the physical connection point between the significant grid user's equipment and the network to which they apply. Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing secure system operation, including:* ○ *Requirements for reactive power; …"*

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Requirement:	Reactive Power Requirements for DC Connected HVDC Convertors
Article:	46
Cross-border impact and objective:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. Purely DC connected AC collector networks are in their own right synchronous and require reactive power range. The loss of a synchronous network given their typical size and configuration is likely to create a voltage or frequency cross border impact as a consequence. Also requirements must ensure the plant and equipment provides the necessary capabilities over their asset life and given the ongoing development of the network DC connected HVDC Convertors may become AC connected and would then influence other 'cross border' synchronous networks directly and should be compatible for this change.
Implementation:	The Reactive Power requirement is non-exhaustively defined with further specification as to the range and applicability to be given at national or project level. This also covers the option of optimizing DC link and PPM design, or placing the delivery of reactive power capability in the appropriate long term network development perspective.
Justification	The reactive power requirements in the AC connected HVDC in Article 16 set the capabilities required for operation in the synchronous areas. There is considerable evidence in offshore grid and network studies that AC and DC integrated networks will develop over time and therefore a HVDC convertor should be capable of the reactive power range in Article 16 whether it is an initially connected AC or DC. This reactive range however does not need to be installed immediately but rather the capability should be ensured as it arises. Reactive power provision whether for an AC collector network when purely DC connected or in future as part of a wider AC network following AC subsequent connection should be provided in a cost beneficial way. The size of AC collector networks and AC connections to synchronous systems will vary both in size and topography in the immediate and future years. Therefore flexibility is needed to account for configuration variations and a reactive power range is the most appropriate way of ensuring cost effective and technically acceptable requirements are imposed. Inadequate reactive power range will often become a cross border issue, DC links are by their very nature often large capacity and are primed for development of further generation or for interconnection between networks. Therefore reactive power provision for voltage stability in a AC collector networks with DC links are likely to either directly influence a cross border power flow as a interconnector, or given their size likely to create a cross border impact upon their loss. The requirement sets out reactive ranges for DC Connected PPMs at a European level which ensures the correct range for the synchronous systems within Europe and

	provides cost effective development of a minimum range of devices suitable across Europe.
Link to other NCs:	• NC RfG and DCC: The reactive power ranges cover those for generation and demand. • NC OS: The reactive power ranges in Article 10 • NC OPS: The reactive power ancillary services in Article 51
Link to framework guidelines:	• Paragraph 2.1*: "… The network code(s) shall define the physical connection point between the significant grid user's equipment and the network to which they apply. Furthermore, the network code(s) shall define the requirements on significant grid users in relation to the relevant system parameters contributing secure system operation, including:* o *Requirements for reactive power; …"*

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Requirement:	Voltage Stability capability and Reactive Power Control Modes
Article:	38
Cross-border impact and objective:	Voltage control for DC Connected Power Park Modules can be a cross border issue. The absence of such a facility can lead to voltage instability which can cause failure of the DC connected PPMs and given the relative size of typical DC links create a voltage of frequency change to neighbouring systems. The absence of a voltage control system, if applied to many Power Park Modules may remove the fundamental requirement for cross-border trading, namely system stability, notably in DC connected PPMs which are part of an interconnector.
Implementation:	A choice of control mode as well as parameter choices allowed needs to reflect varied national / local system condition. Aside from the choices of three modes, the Reactive Power control mode technical capability is exhaustively defined.
Justification	This requirement allows three control modes. This allows the selection to reflect the national / local needs.
Link to other NCs:	• NC RfG and DCC: The reactive power control modes cover those for generation and are consistent with these reactive power control modes. • NC OS: The reactive power ranges in Article 10 • NC OPS: The reactive power ancillary services in Article 51
Link to framework guidelines:	• Paragraph 2.1*: "… The network code(s) shall set out how the TSO defines the technical requirements related to … and to voltage and reactive power management. …"*

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Requirement:	Control Requirements
Article	39
Cross-border impact:	Control requirements are critical in the delivery of the basic functionalities of the PPM and HVDC System in timely response to disturbances on the network. Failure to deliver could result in frequency, voltage and stability phenomena that would transcend border(s) causing widespread impact, even resulting in blackouts.
Implementation:	To be further specified at national level
Justification:	• The control functions required from DC connected PPMs, for example Active Power control, Power oscillation damping, capability for power restoration, are non-exhaustive as their specifications are dependent upon local network conditions, and thus have to be left to the Relevant TSO to specify. If these functions are not available, it would not be possible to operate the network in a secure, economic and reliable manner. These requirements are similar or same as those required from PPMs which are AC connected, i.e. as in NC RfG. The additional functionalities required from DC connected PPMs stem from having HVDC converter which isolate the PPM from the AC onshore network. • A limit on steady state voltage deviation from converter or PPM energisation or synchronisation is specified to keep disturbances to other Users to a minimum, and be mindful of the operating range of the network voltage. This requirement is exhaustive. • As the PPM and the HVDC converter do provide similar controls of, for example, reactive power, coordination is needed between these two control systems such that reactive power or voltage control is optimised. An output signal from the PPM is thus required.
Link to other NCs:	• NC RfG: consistent requirements
Link to FWGL:	• paragraph 2.1: *"… Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; … Load-Frequency control related issues …"* • paragraph 2.1.3: *"… the detail of possible deviations of significant parameters (e.g. voltage, frequency) that generation units must withstand …"*

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Requirement:	Network Characteristics
Article:	40, 47
Cross-border impact and objective:	Proper designed equipment is a precondition to ensure the conformity of the installed devices with the requirements and ensures that it remain in operation during severe system events, especially under those conditions which generation (NC RfG, Art 8) and demand (DCC, Art 13) have to withstand as well. This requires certain design studies to be performed. The publication of the method and the pre-fault and post-fault conditions for the calculation of minimum and maximum Short Circuit Power at the Connection Point ensure that projects can design there equipment according to the network characteristics.
Implementation:	The requirement is non-exhaustively defined. Each TSO has to define the necessary framework at national or project level.
Justification	The requirement defines a minim set of information needed by the user when designing the equipment thus ensuring the proper future operation.
Link to other NCs:	• NC RfG and DCC: Similar clauses, e.g. on min/max short circuit power levels, are given for generation and demand.
Link to framework guidelines:	• paragraph 2.1: "… *Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …"* • Paragraph 2.1.3: *"...The network code(s) shall define: * - *situations in general (e.g. which kinds of network faults, which electrical distance) And* - *the detail of possible deviations of significant parameters (e.g. voltage, frequency) that … must withstand, while remaining connected to the grid.*

Requirement:	Protection Requirements
Article:	41
Cross-border impact and objective:	Electrical protection, its settings and priority ranking do not ensure the investment only but are the effective means in order to limit the faults effect. It is therefore indispensable to detect faults fast and with a required selectivity when aiming to limit the effects to a small area. The protection schemes ensure that the overall network remain in operation during severe system events.
Implementation:	The requirement is non-exhaustively defined. The TSO has to define the specifics bearing in mind the network specifics and the equipment's performance
Justification	The requirement sets out the need to co-ordinate the protection schemes, the priority ranking and parameters in order to ensure the overall selectivity of fault detection and clearing.
Link to other NCs:	• NC RfG: Article 8.5.b) an c). • DCC: Article 17
Link to framework guidelines:	• paragraph 2.1: "… *Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …"* -

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Requirement:	Power Quality
Article:	42, 48
Cross-border impact and objective:	Harmonic distortion or voltage fluctuations exceeding certain limits do stress the equipment and may lead to sudden loss of equipment and generation. Therefore the overall level of acceptable voltage distortion in the system has to be defined in order to design the equipment to operate under these requirements. Further, the max. distortion a DC-Connected Power Park Modules is allowed to contribute to the overall level has to be defined to reach the aim of limited level of harmonic distortion and to enable the proper design of the equipment.
Implementation:	The requirement is non-exhaustively defined. At national or project level the TSO has to define the detailed specifications.
Justification	The requirement sets out harmonic distortion levels to keep when contributing to the distortion resp. to be able to withstand when connecting to the system.
Link to other NCs:	• DCC: Article 25
Link to framework guidelines:	• paragraph 2.1: "... *Furthermore, the network code(s)shall define the requirements on significant grid users in relation to the relevant system parameters contributing to secure system operation, including … Frequency and voltage parameters; …*" -

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Requirement:	General System Management
Article:	43
Cross-border impact and objective:	System management is an indispensable precondition for secure and reliable operation of the electricity system. It ensures stability and adequate measures in the case of the loss of stability or faults as well as the adequate exchange of information.
Implementation:	The requirement is non-exhaustively defined. Further specifications have to be given at national or project level.
Justification	The requirement sets out system management needs enabling the TSO to plan and operate the system.
Link to other NCs:	• NC RfG: Articles 9(5), 10(6) and 11(4).
Link to framework guidelines:	• Paragraph 2.1.3: *"...The network code(s) shall define:* - *situations in general (e.g. which kinds of network faults, which electrical distance) And* - *the detail of possible deviations of significant parameters (e.g. voltage, frequency) that … must withstand, while remaining connected to the grid.*

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