European Network of
Transmission System Operators
for Electricity

NETWORK CODE FOR REQUIREMENTS FOR GRID CONNECTION APPLICABLE TO ALL GENERATORS

JUSTIFICATION OUTLINES

26 JUNE 2012

Disclaimer: This document is not legally binding. It only aims at clarifying the content of the network code for requirements for grid connection applicable to all generators. This document is not supplementing the final network code nor can be used as a substitute to it.

Requirement:	Frequency Ranges				
Reference to NC RfG:	Article 8(1) (a)				
Cross-border impact:	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 Power Generating Modules immediately in a common way regardless of their size and voltage level of connection.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
Justification:	• Due to their immediate cross-border impact, frequency requirements need to be harmonised as much as possible at least on the level of a synchronous area. In particular, the range for unlimited operation needs to be identical to share the burdens of deviations equally. • The ranges and time periods where time-limited operation of Power Generating Modules is requested however may vary and shall take into account regional characteristics and the network operators' operational requirements, because these ranges are primarily needed for management of system disturbances and restoration. • Inherent inertia of the electricity supply system will decrease due to less synchronous generators connected in future, consequently larger sudden frequency deviations occur in case of load imbalances.				
Principle/Methodology only:			**(Ranges of) values/parameters given:**	X	
Justification:	• Frequency is the same across a synchronous area and across all voltage levels. • Deviations of frequency from its nominal occur everywhere at the same time and affect all Power Generating Modules immediately in a common way regardless of their size and voltage level of connection.				
Alternative solutions:	• Limitations on penetration of (RES) generation without inherent inertia, however this will jeopardize achieving EU energy policy targets.				
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; …"* • paragraph 2.1.3: *"… the detail of possible deviations of significant parameters (e.g. voltage, frequency) that generation units must withstand …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Rate of Change of Frequency Withstand Capability				
Reference to NC RfG:	Article 8(1) (b)				
Cross-border impact:	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 Power Generating Modules immediately in a common way regardless of their size and voltage level of connection. The rate of change of frequency depends on the inherent inertia of the electricity supply system which decreases due to less synchronous generators connected in future; consequently larger sudden frequency deviations occur in case of load imbalances.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	• Due to their immediate cross-border impact, frequency requirements need to be harmonised as much as possible at least on the level of a synchronous area. However, currently the rate of change of frequency in case of a major disturbance can be hardly assessed and depends on the system inertia. Hence it is reasonable to define this parameter on a national level to be able to take into consideration the consequences of system splits and the expected behaviour in case of national islanding and system restoration. • Inherent inertia of the electricity supply system decreases due to less synchronous generators connected in future; consequently larger sudden frequency deviations occur in case of load imbalances.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	• Low experience so far on rate of change of frequency in case of major disturbances of the system. • Rate of change of frequency depends on the inherent system inertia. • Assuming national islanding and system restoration is the critical case, a definition of the rate of change of frequency parameters on national level is appropriate.				
Alternative solutions:	Limitations on penetration of (RES) generation without inherent inertia, however this will jeopardize achieving EU energy policy targets.				
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; …"* • paragraph 2.1.3: *"… the detail of possible deviations of significant parameters (e.g. voltage, frequency) that generation units must withstand …"*				

Requirement:	Limited Frequency Sensitive Mode - Overfrequency				
Reference to NC RfG:	Article 8(1) (c)				
Cross-border impact:	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 Power Generating Modules 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 Power Generating Modules 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 can be overcome by a smooth reduction of active power output of Power Generating Modules at high frequencies, avoiding its tripping.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
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 generation 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 larger sudden frequency deviations occur in case of load imbalances. • Smooth reduction of active power output of Power Generating Modules is needed at high frequencies to maintain system stability.				
Principle/Methodology only:			**(Ranges of) values/parameters given:**	X	
Justification:	• Frequency is the same across a synchronous area and across all voltage levels. • Deviations of frequency from its nominal occur everywhere at the same time and affect all Power Generating Modules immediately in a common way regardless of their size and voltage level of connection. • As far as technically feasible, a common behaviour of all Power Generating Modules shall be endeavoured to achieve a smooth reduction of active power output of Power Generating Modules at high frequencies beyond full activation of contracted active power frequency response reserves.				
Alternative solutions:	• Excessive active power frequency response reserves to be contracted, which has adverse impact on cost-effectiveness. • Limitations on penetration of (RES) generation without inherent inertia, however this will jeopardize achieving EU energy policy targets.				
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 …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Constant Output at Target Active Power				
Reference to NC RfG:	Article 8(1) (d)				
Cross-border impact:	Changes in active power output, other than scheduled or which are technically inevitable, result in load imbalances in the system, which shall be avoided in order to maintain system stability and security by minimizing deviations of frequency from its nominal value.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
Justification:	• The principle of maintaining active power output at its target value already describes this requirement exhaustively. • All Power Generating Modules shall follow this principle in order to maintain system stability and security by minimizing deviations of frequency from its nominal value.				
Principle/Methodology only:		X	**(Ranges of) values/parameters given:**		
Justification:	The principle of maintaining active power output at its target value already describes this requirement exhaustively. There are no parameters to be specified.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
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. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Maximum Active Power Reduction at Low Frequencies
Reference to NC RfG:	Article 8(1) (e)
Cross-border impact:	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 Power Generating Modules immediately. Active power reduction at low frequencies aggravates a situation where already a lack of generation persists and shall be limited as much as possible.

Exhaustive requirement:		**Non-exhaustive requirement:**	X	
Justification:	• The frequency-sensitivity of synchronous areas is different according to their system characteristics and generation portfolio. Whereas larger systems with more inherent inertia are less sensitive, the opposite applies to smaller system with less inherent inertia. The admissible active power reduction also needs to be weighed against the risk of instability and loss of a Power Generating Module by each TSO in its responsibility area. • Active power reduction at low frequencies aggravates a situation where already a lack of generation persists and shall be limited as much as possible.			

Principle/Methodology only:		**(Ranges of) values/parameters given:**	X	
Justification:	• Frequency-sensitivity is different for synchronous areas. • Limitations on maximum active power out at low frequencies depend on generation technologies and ambient conditions. • Admissible active power reduction also needs to be weighed against the risk of instability and loss of a Power Generating Module.			

Alternative solutions:	• Excessive active power frequency response reserves to be contracted, which has adverse impact on cost-effectiveness. • All Power Generating Modules, who shall deliver active power frequency response cannot run at their maximum power output, resulting in less efficiency and - in case of RES - potentials of carbon-free generation are not used. This may jeopardize achieving EU energy policy targets.
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; …"* • paragraph 2.1.3: *"… the detail of possible deviations of significant parameters (e.g. voltage, frequency) that generation units must withstand …"*

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Remote Switch On/Off				
Reference to NC RfG:	Article 8(1) (f)				
Cross-border impact:	In particular in emergency situations which may endanger system stability and security, network operators need to have the possibility to instruct the output of Power Generating Modules to be able to meet their responsibilities for system security.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
Justification:	The mere capability to receive an instruction to cease active power output is requested.				
Principle/Methodology only:		X	**(Ranges of) values/parameters given:**		
Justification:	• The smallest types of Power Generating Modules are not controllable in their active power output, therefore the minimum feature to control their output is an option to selectively switch them on/off remotely. • Further specifications beside the general principle/methodology depend on the specific system characteristics and communication infrastructure in the responsibility area of each network operator and can be specified at that level only.				
Alternative solutions:	Limitations on penetration of dispersed (RES) generation, however this will jeopardize achieving EU energy policy targets.				
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. …"* • paragraph 3.2: *"… The network code(s) shall set the requirement for every significant grid user to be able to receive and to execute the instructions sent by the TSO and/or DSO, …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Automatic Connection				
Reference to NC RfG:	Article 8(1) (g)				
Cross-border impact:	Connection of Power Generating Modules triggers dynamic processes, because it changes the system state. In particular in disturbed situations automatic connections, which are out of any control by the network operator, need to be restricted in order to maintain or restore system security and to avoid an aggravation of disturbances. Hence, the conditions for automatic connections need to be specified.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	Conditions for automatic connection depend on system characteristics in the responsibility area of each TSO and therefore shall be specified at that level.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	• In particular smaller Power Generating Modules are connected without prior explicit authorization by the network operator, therefore conditions for automatic connection need to be specified. • Further specifications beside the general principle/methodology depend on the specific system characteristics in the responsibility area of each TSO and can be specified at that level only.				
Alternative solutions:	Limitations on penetration of (RES) generation without inherent inertia, however this will jeopardize achieving EU energy policy targets.				
Link to FWGL:	• paragraph 2.1.3: *"… The network code(s) shall define minimum conditions for (re)connection to the grid in disturbed/critical operating state. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Active Power Reduction				
Reference to NC RfG:	Article 9(2) (a)				
Cross-border impact:	In particular in emergency situations which may endanger system stability and security, network operator need to have the possibility to instruct the output of Power Generating Modules to be able to meet their responsibilities for system security.				
Exhaustive requirement:	X	**Non-exhaustive requirement:**			
Justification:	The mere capability to receive an instruction to reduce active power output is requested.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	• Smaller types of Power Generating Modules have no operational staff on site. The necessary feature, in particular in emergency situations which may endanger system stability and security, is an option to control their output remotely. • Further specifications beside the general principle/methodology depend on the specific system characteristics and communication infrastructure in the responsibility area of each network operator and can be specified at that level only.				
Alternative solutions:	Limitations on penetration of dispersed (RES) generation, however this will jeopardize achieving EU energy policy targets.				
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. …"* • paragraph 3.2: *"… The network code(s) shall set the requirement for every significant grid user to be able to receive and to execute the instructions sent by the TSO and/or DSO, …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Fault-ride-through Capability of Power Generating Modules connected below 110 kV				
Reference to NC RfG:	Article 9(3) (a)				
Cross-border impact:	Riding through faults is important in terms of system frequency and voltage stability, which in turn are fundamental requirements for cross-border trading. The fault ride through requirement for Types B and C (unlike for Type D) are not extended down to zero retained voltage at the point of connection, reflecting that the main concern is a simultaneous loss of generation of multiple units connected below 110 kV, associated with a fault at the highest voltage levels (110kV and above). This reduces the needed severity of the requirement. Failure to deliver robustness against a simultaneous loss of generation of multiple units is clearly a major system security issue with cross-border issues.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	The parameters for the voltage against time profile are left for the TSO to determine at a national level while respecting the provisions of Article 4(3). This allows for a combination of taking into account existing requirements and local needs which vary.				
Principle/Methodology only:			**(Ranges of) values/parameters given:**	X	
Justification:	Ranges of parameters for national choices are provided which maintain a proportionate approach reflecting varying system needs (e.g. level of RES) and existing network protection schemes (both transmission and distribution).				
Alternative solutions:	Leave the capability for market to deliver. However, this would not deliver the required certainty for planning and operation of the power system and would therefore lead to major restrictions in the development of RES in order to maintain system security.				
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 …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Reconnection after an incidental Disconnection due to a Network Disturbance
Reference to NC RfG:	Article 9(4) (a)
Cross-border impact:	Reconnection after an incidental disconnection due to a network disturbance must fit the circumstances. The absence of this capability was demonstrated as a cross border issue in Continental Europe during the major 3 way system split on 4 November 2006. Following the system split uncontrolled reconnections caused the restoration of the system to be prolonged as the TSOs were hindered in resynchronising the islands. As a consequence mass consumer disconnections prolonged in many countries.

Exhaustive requirement:		**Non-exhaustive requirement:**	x	
Justification:	• Article 8 (4) a) refers to a TSO decision pursuant to Article 4(3) defining specific conditions for reconnection and also define that automatic reconnection shall be subject to prior authorisation by the Relevant Network Operator. • The above limitation in the requirement is necessary in order to be proportionate and fit for local circumstances.			

Principle/Methodology only:	X	**(Ranges of) values/parameters given:**		
Justification:	It is important that the local conditions are taken into account when considering the best approach for the required coordination between TSOs, DSOs and Power Generating Module Owners.			

Alternative solutions:	Rely on markets to behave as required when needed. However, the Continental Europe system split in 4 November 2006 demonstrated that this can lead to substantial delays in restoration following loss of demand and creates further risks during major disturbances.
Link to FWGL:	• 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. …"*

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Control Schemes and Settings				
Reference to NC RfG:	Article 9(5) (a)				
Cross-border impact:	Dynamic behaviour of Power Generating Modules, in particular in disturbed system operating conditions is crucial for system stability as a whole. This dynamic behaviour is largely determined by the unit's control schemes and settings.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• Maintaining transmission system stability is a responsibility of the Relevant TSO. • Control schemes and settings of Power Generating Modules are designed individually; therefore they cannot be described exhaustively on a European level with their impact on transmission system stability. This impact needs to be evaluated taking into account regional system characteristics and shall be agreed with the Relevant Network Operator and the Relevant TSO.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	• Control schemes and settings of Power Generating Modules are designed individually- • Only the principle/methodology can be described in the network code, the detailed values and parameters, which need the network operator's consent, depend on the individual scheme.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
Link to FWGL:	• 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. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Protection Schemes and Settings				
Reference to NC RfG:	Article 9(5) (b)				
Cross-border impact:	Proper network protection is essential for maintaining system stability and security, in particular in case of disturbances to the system. Protection schemes shall prevent from aggravation of disturbances and limit their consequences (e. g. selective short-circuit fault clearance).				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	• Maintaining system stability and security is a responsibility of the Relevant Network Operator. • Protection schemes and settings of the network and of Power Generating Modules need to be well coordinated in order to fulfil its purpose of maintaining system stability and security. The schemes and settings depend on both the Power Generating Module's and the network's protection strategies, as well as regional system characteristics and thus have to be further specified at the level of the Relevant Network Operator.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	• Protection schemes and settings of the network and of Power Generating Modules depend on both the Power Generating Module's and the network's protection strategies, as well as regional system characteristics. • Only the principle/methodology can be described in the network code, the detailed values and parameters, which need to be coordinated and agreed depend on the individual scheme and system characteristics.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
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 … Requirements for protection devices and settings; …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Priority Ranking of Protection and Control				
Reference to NC RfG:	Article 9(5) (c)				
Cross-border impact:	Protection of the network and the Power Generating Module need to have highest priority in order to maintain system stability and security, as well as health and safety of staff and the public.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
Justification:	• A ranking needs to be given in order to specify which capabilities shall take precedence when designing the protection and control schemes, if conflicting otherwise. • A harmonised ranking shall apply to achieve a common basis for operational strategies for secure system operation.				
Principle/Methodology only:		X	**(Ranges of) values/parameters given:**		
Justification:	A ranking specifies the priority of certain types of requirements. No values/parameters are given by such a priority list.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
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 … Requirements for protection devices and settings; …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Information Exchange				
Reference to NC RfG:	Article 9(5) (d)				
Cross-border impact:	Adequate information exchange between network operators and Power Generating Module operators 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 as well as the possibility to communicate with them in order to direct operational instructions.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	The mere capability to exchange information is required. Details on the information to be exchanged (communication infrastructure, protocols) depend on the operational strategies of the Relevant Network Operator and the Relevant TSO.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	Further specifications beside the general principle/methodology depend on operational strategy and communication infrastructure in the responsibility area of each network operator and TSO and can be specified at that level only.				
Alternative solutions:	Have no requirement and leave capability to the market. However, it is unlikely, based on extensive experience, that the required minimum capability will be made available without detailing what is required.				
Link to FWGL:	• paragraph 3.1: *"… The network code(s) shall set out the procedures and requirements to coordinate and ensure information sharing between … System operator and significant grid user …"* • paragraph 3.2: *"… The network code(s) shall set the requirement for every significant grid user to be able and obliged to provide the necessary real-time operational information to the DSO and TSO that their connection has significant impact upon. The network code(s) shall set the requirement for every significant grid user to be able to receive and to execute the instructions sent by the TSO and/or DSO, on a contractual basis or in critical operating state."*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Active Power Controllability				
Reference to NC RfG:	Article 10(2) (a)				
Cross-border impact:	In particular in emergency situations which may endanger system stability and security, network operators need to have the possibility to instruct the output of Power Generating Modules to be able to meet their responsibilities for system security.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	The capability to adjust an active power setpoint is requested. Details of such adjustments, like time periods and accuracy, depend on the network operator's operation philosophy and on technical capabilities of the Power Generating Module.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	• Larger types of Power Generating Modules have more complex control structures which allow for more flexible control of output following network operator instructions. • Further specifications besides the general principle/methodology depend on the specific system characteristics and communication infrastructure in the responsibility area of each network operator and can be specified at that level only.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
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. …"* • paragraph 3.2: *"… The network code(s) shall set the requirement for every significant grid user to be able to receive and to execute the instructions sent by the TSO and/or DSO, …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Limited Frequency Sensitive Mode - Underfrequency
Reference to NC RfG:	Article 10(2) (b)
Cross-border impact:	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 Power Generating Modules 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 Power Generating Modules 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 can be overcome by a smooth increase of active power output of Power Generating Modules at low frequencies, and which aims at preventing from load shedding.

Exhaustive requirement:	X	**Non-exhaustive requirement:**		
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 generation technologies some flexibility is needed 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 larger sudden frequency deviations occur in case of load imbalances. • Smooth increase of active power output of Power Generating Modules can be used at low frequencies to maintain system stability from those Power Generating Modules which have headroom available because of operation at partial load.			

Principle/Methodology only:		**(Ranges of) values/parameters given:**	X	
Justification:	• Frequency is the same across a synchronous area and across all voltage levels. • Deviations of frequency from its nominal occur everywhere at the same time and affect all Power Generating Modules immediately in a common way regardless of their size and voltage level of connection. • As far as technically feasible, a common behaviour of all Power Generating Modules shall be endeavoured to achieve a smooth increase of active power output of Power Generating Modules at low frequencies beyond full activation of contracted active power frequency response reserves.			

Alternative solutions:	Excessive active power frequency response reserves to be contracted with adverse impact on cost-effectiveness. All Power Generating Modules, which shall deliver active power frequency response on a contractual basis cannot run at their maximum power output, resulting in less efficiency and - in case of RES - potentials of carbon-free generation are not used.
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 …"*

Requirement:	Frequency Sensitive Mode
Reference to NC RfG:	Article 10(2) (c)
Cross-border impact:	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 Power Generating Modules 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 Power Generating Modules 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 can be overcome by a reduction/increase of active power output of Power Generating Modules at high/low frequencies.

Exhaustive requirement:	X	**Non-exhaustive requirement:**		
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 generation technologies some flexibility still has to remain for setting the frequency threshold of activation, deadband, droop, initial delay and maximum time of activation. • Inherent inertia of the electricity supply system decreases due to less synchronous generators connected in future; consequently larger sudden frequency deviations occur in case of load imbalances. • Removal of load imbalances by active power frequency response reserves is needed to maintain system stability.			

Principle/Methodology only:		**(Ranges of) values/parameters given:**	X	
Justification:	• Frequency is the same across a synchronous area and across all voltage levels. • Deviations of frequency from its nominal occur everywhere at the same time and affect all Power Generating Modules immediately in a common way regardless of their size and voltage level of connection. • As far as technically feasible, a common behaviour of all Power Generating Modules shall be endeavoured to achieve a removal of load imbalances by active power frequency response reserves.			

Alternative solutions:	• Excessive active power frequency response reserves to be contracted, which has adverse impact on cost-effectiveness. • Limitations on penetration of (RES) generation without inherent inertia, however this will jeopardize achieving EU energy policy targets.
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 …"*

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Frequency Restoration Control				
Reference to NC RfG:	Article 10(2) (d)				
Cross-border impact:	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 therefore occur everywhere at the same time and affect all Power Generating Modules immediately in a common way immediately regardless of their size and voltage level of connection. Any frequency deviation shall be mitigated by restoring frequency at its nominal value.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• Frequency restoration to its nominal value is essential in order to release active power frequency response reserves previously activated due to frequency deviations in order to be able to use them again in case of new deviations. • Frequency restoration control is performed in a different way in the synchronous areas depending on their historical development and their system characteristics and operational strategies. The detailed capabilities have to consider this and need to be further specified accordingly.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	• Further parameters can only be specified on national level taking into consideration the system characteristics and operational strategies for frequency restoration control.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
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 …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Low Frequency Load Disconnection				
Reference to NC RfG:	Article 10(2) (e)				
Cross-border impact:	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 Power Generating Modules 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 Power Generating Modules will disconnect due to frequency, which is out of the range of their design for operation. This will result in an endangerment of system stability and security, which can be overcome by load disconnections at low frequencies.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
Justification:	The mere capability to disconnect load other than auxiliary supply is requested.				
Principle/Methodology only:		X	**(Ranges of) values/parameters given:**		
Justification:	• Load disconnection at low frequencies is a common practise emergency feature to restore a balance in load and generation. • Further specifications beside the general principle/methodology are not needed.				
Alternative solutions:	• Excessive active power frequency response reserves to be contracted, which has adverse impact on cost-effectiveness. • All Power Generating Modules, who shall deliver active power frequency response cannot run at their maximum power output, resulting in less efficiency and - in case of RES - potentials of carbon-free generation are not used. This may jeopardize achieving EU energy policy targets.				
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 …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Monitoring of FSM				
Reference to NC RfG:	Article 10(2) (f)				
Cross-border impact:	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 Power Generating Modules 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 Power Generating Modules 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 can be overcome by a reduction/increase of active power output of Power Generating Modules at high/low frequencies.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	• The mere capability to monitor active power frequency response and the corresponding minimum parameters are requested. • Active power frequency response is a feature with high impact on system stability and security, because it aims at maintaining the generation – load equilibrium. Hence the TSO shall be in a position to monitor whether this service is appropriately provided as contractually agreed and remunerated.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	Further specifications beside the general principle/methodology depend on operational strategy and communication infrastructure in the responsibility area of each TSO and can be specified at that level only.				
Alternative solutions:	Have no requirement and leave capability to the market. However, it is unlikely, based on extensive experience, that the required minimum capability will be made available without detailing what is required.				
Link to FWGL:	• paragraph 3.1: *"… The network code(s) shall set out the procedures and requirements to coordinate and ensure information sharing between … System operator and significant grid user …"* • paragraph 3.2: *"… The network code(s) shall set the requirement for every significant grid user to be able and obliged to provide the necessary real-time operational information to the DSO and TSO that their connection has significant impact upon. The network code(s) shall set the requirement for every significant grid user to be able to receive and to execute the instructions sent by the TSO and/or DSO, on a contractual basis or in critical operating state."*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	High/low Voltage Disconnection				
Reference to NC RfG:	Article 10(3) (a)				
Cross-border impact:	Disconnection of Power Generating Modules beyond operating ranges can be critical in context of prompt restoration of service and is a cross-border issue in terms of coordination of restoration.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	The requirement makes two references to further details / decisions from the Relevant Network Operator pursuant to Article 4 (3). Delegating details to national / local level is appropriate to ensure good coordination of restoration plans.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	Details including values to be added at national / local level to ensure essential local coordination.				
Alternative solutions:	Have no requirement at all at European level, but rely upon individual operational decisions by Power Generating Module Owners. This could lead to slow restoration after a major disturbance and absence of equitable burden sharing.				
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; …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Steady-state Stability				
Reference to NC RfG:	Article 10(4) (a)				
Cross-border impact:	Stable operation is the foundation for cross-border trading. Generators are required to be robust and deliver steady state stability over the full operating range.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
Justification:	Stable operation is a fundamental basis for system operation and cross-border trading. No specific parameters are prescribed in NC RfG, nor are such parameters expected at a national level.				
Principle/Methodology only:		X	**(Ranges of) values/parameters given:**		
Justification:	No specific parameters are prescribed in NC RfG, nor required to define the required capability.				
Alternative solutions:	Rely on markets to encourage generators to deliver stable operation. This is not acceptable as it could result in large scale system wide disturbances including cross border power oscillations and would not facilitate clear assumptions in system design and operation.				
Link to FWGL:	• 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. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Auto Reclosures				
Reference to NC RfG:	Article 10(4) (b)				
Cross-border impact:	Power Generating Modules need to have the capability to withstand auto-reclosures without tripping in order to avoid widespread consequential system impact while the system is weak after a fault. Possible impact includes cross-border loss of supply. Auto-reclosure is a key TSO measure to quickly restore circuits in the network immediately after a fault. This prepares the system for a further fault, which is particularly important for avoiding consumer disconnections under adverse conditions (e.g. bad weather), when multiple faults may occur in a short period.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	Details of the capability are subject to coordination and agreement according to Article 9(6) (a).				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	The requirement is given in principle only, with details subject to coordination and agreement on protection schemes and settings.				
Alternative solutions:	• Have no requirement on Power Generating Modules, hoping that the Power Generating Modules will have adequate operational / market incentive to be robust and stay connected during automatic system restoration switching following faults. • Such incentives do not exist and therefore could result in risk of substantial loss of generation at the time the system is already disturbed. Also, it would not allow the TSOs to plan the system design and operation with any certainty. This is not acceptable from a point of view of system security and therefore from the point of view of providing a stable platform for cross-border trading.				
Link to FWGL:	• paragraph 2.1.3: *"… The network code(s) shall define situations in general (e.g. which kinds of network faults, which electrical distance) … that generation units must withstand, while remaining connected to the grid. ...."*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Black Start Capability				
Reference to NC RfG:	Article 10(5) (a)				
Cross-border impact:	Black start capability is critical to restoration of a power system to a stable condition in which cross border trading can be resumed after a major disturbance.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• Article 10 (5) a) contains reference to Article 4 (3) for the Relevant Network Operator to define the timeframe for restoration and the Relevant Network Operator defines the voltage limits. • This achieves an appropriate level of subsidiarity, while ensuring the wider interest.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	• The requirement is given only in broad principle. Details are defined locally by the Relevant Network Operator. • Leaving details to local level is appropriate to achieve the optimal arrangement and ensuring that the relevant parties are well co-ordinated at a local level.				
Alternative solutions:	• Black start could be entirely left to market. However, this would not achieve an adequate level of certainty to deliver efficient planning between adjacent TSOs and may therefore result in less efficient system restorations, with longer losses of supply. • An optimal level of reliance on market (in procurement) is ensured by leaving the requirements at a principle level and ensure that the services can be delivered when required, without unnecessary investments for the Power Generating Module Owners.				
Link to FWGL:	• 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:* • *House load operation including the minimum duration of house load operation;* • *Black start; and* • *Island operation."*				

Requirement:	Capability to take part in Island Operation				
Reference to NC RfG:	Article 10(5) (b)				
Cross-border impact:	Island operation occurs seldom. The consequences of islanding are significantly reduced if all plants remain in operation. The absence of this quality played a significant part in turning a severe disturbance into a total blackout for the Italian island in September 2003. Consequences can be widespread as during the Continental Europe islanding on 4 November 2006.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	• The requirement refers to decision of the Relevant Network Operator pursuant of Article 4 (3) for Types C & D. • This provides an appropriate level of subsidiarity while protecting the wider system needs.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	• Predominantly, the requirement focuses on principles, although part 2) describes a minimum power reduction capability (to 55%). • This compromise ensures that proven experience is shared and delivers an adequate minimum performance, with equitable sharing between users of system resilience.				
Alternative solutions:	• Have no requirement and leave capability to the market. However, it is unlikely, based on extensive experience, that the required minimum capability will be made available without detailing what is required. • This would also be undesirable both for network operators (capture best practice experience) and for cost-effective European manufacturing.				
Link to FWGL:	• 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:* ○ *House load operation including the minimum duration of house load operation;* ○ *Black start; and* ○ *Island operation."*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Quick Re-synchronization Capability				
Reference to NC RfG:	Article 10(5) (c)				
Cross-border impact:	Quick re-synchronisation is important in terms of restoring the power system after a major disturbance. This may have cross-border consequences in large disturbances.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• Reference is made in Article 10 (5) c) 3) to Article 4 (3) for selecting the duration of continued operation. • This provides an appropriate level of subsidiarity while protecting the wider system needs.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	• The requirement is kept as a principle rather than specifically calling for house load operation, in order to maximise the freedom for designers. By specifying in general terms rather than calling for trip to house-load for all Power Generating Modules, it avoids unnecessary investments, e.g. for hydro stations.				
Alternative solutions:	• Require house load operation. The requirement is kept more general than suggested by the FWGL in order to make it more proportionate and hence to allow cost savings for some technologies. • Having no requirement at all, could lead to an inadequate capability for fast restoration (with unequal burden sharing) and or less competitive European manufacturing (absence of a clear specification).				
Link to FWGL:	• 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:* ○ *House load operation including the minimum duration of house load operation;* ○ *Black start; and* ○ *Island operation."*				

Requirement:	Loss of Stability				
Reference to NC RfG:	Article 10(6) (a)				
Cross-border impact:	Loss of stability or loss of control of a Power Generating Module is a threat to stability and security of other Power Generating Modules and to the system as a whole. It may occur, inter alia, as a consequence of a short-circuit in the network, if this fault is not cleared sufficiently fast. Other phenomena, like power oscillations in the transmission system may put a risk to stability of Power Generating Modules as well.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• Loss of stability or controllability of a Power Generating Module is a situation the network needs to be protected against in order to avoid adverse impacts on system stability and security as a whole. • In order to protect the Power Generating Module against damage and the system against further disturbances and instability, a module which has lost stability or controllability shall be disconnected from the network. The criteria for detection of loss of stability or loss of control may depend on regional system characteristics and need to be agreed with the relevant network operator.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	• The generality of disconnection in case of loss of stability or control is required by the network code. • Criteria for detection of loss of stability or loss of control may depend on regional system characteristics and need to be agreed with the relevant network operator.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
Link to FWGL:	• 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. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Instrumentation for Fault and Dynamic Behaviour Recording				
Reference to NC RfG:	Article 10(6) (b)				
Cross-border impact:	Adequate dynamic behaviour of Power Generating Modules, in particular during and after disturbances to the system, is a prerequisite for network operators to maintain system stability and security. Recordings of such behaviour enable the network operators to analyse the system behaviour in critical states, e.g. for risk assessments, and to draw conclusions for possible improvements, if applicable.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	Network operators need to have access to data which characterise the dynamic behaviour of Power Generating Modules, in particular during and after disturbances to the system in order to have the possibility to further investigate such behaviour and its consequences to system stability and security.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	The requirement specifies data provision by Power Generating Modules. Details on such provision need to be defined and agreed between the relevant network operator and the Power Generating Module.				
Alternative solutions:	Have no requirement and leave capability to the market. However, it is unlikely, based on extensive experience, that the required minimum capability will be made available without detailing what is required.				
Link to FWGL:	• paragraph 3.1: *"… The network code(s) shall set out the procedures and requirements to coordinate and ensure information sharing between … System operator and significant grid user …"* • paragraph 3.2: *"… The network code(s) shall set the requirement for every significant grid user to be able and obliged to provide the necessary real-time operational information to the DSO and TSO that their connection has significant impact upon. The network code(s) shall set the requirement for every significant grid user to be able to receive and to execute the instructions sent by the TSO and/or DSO, on a contractual basis or in critical operating state."*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Simulation Models				
Reference to NC RfG:	Article 10(6) (c)				
Cross-border impact:	Network operators need to simulate the system behaviour with regard to system stability and security in order to detect early possible weaknesses or threats. For such simulations models of all components of the system need to be mathematically modelled. In addition network operators need to simulate the compliance of Power Generating Modules with the provisions of this network code, if compliance tests are not possible or not sufficient.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• The steady-state and dynamic behaviour of Power Generating Modules has a significant impact on system stability and security. Hence, they need to be adequately modelled for the corresponding simulations, which are performed regularly by the network operators. The requirements for such models depend on the scope of simulations to be performed. • Depending on the scope of simulations to be performed by the network operator, simple standard models or more sophisticated models are needed. If more comprehensive and detailed models are needed in particular for dynamic studies, these need to be explicitly required from the Power Generating Module Owner.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	The details of the simulation models depend on the scope of the simulations and can only be specified in this context.				
Alternative solutions:	Have no requirement and leave capability to the market. However, it is unlikely, based on extensive experience, that the required minimum capability will be made available without detailing what is required.				
Link to FWGL:	• paragraph 3.1: *"… The network code(s) shall set out the procedures and requirements to coordinate and ensure information sharing between … System operator and significant grid user …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Installation of Devices for System Operation and/or Security				
Reference to NC RfG:	Article 10(6) (d)				
Cross-border impact:	This requirement contributes to system security, as it allows for installation of devices, which support this purpose.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	• The mere option to agree on such devices, which are not covered by this network code otherwise, is introduced by this requirement. • This requirement is a precautionary option for unpredictable issues with impact on system security.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	Further specifications can only be made, if an issue is identified, which shall be covered by this requirement.				
Alternative solutions:	Have no requirement and leave capability to the market. However, it is unlikely, based on extensive experience, that the required minimum capability will be made available without detailing what is required.				
Link to FWGL:	paragraph 3.1: *"… The network code(s) shall set out the procedures and requirements to coordinate and ensure information sharing between … System operator and significant grid user …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Rate of Change of Active Power
Reference to NC RfG:	Article 10(6) (e)
Cross-border impact:	Fast changes of active power output may lead to load imbalances and consequently to deviations of frequency from its nominal value. 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 Power Generating Modules immediately in a common way regardless of their size and voltage level of connection.

Exhaustive requirement:		**Non-exhaustive requirement:**	X	
Justification:	• In particular RES Power Generating Modules may be subject to sudden changes in active power output due to their prime mover dependency (e. g. wind fronts). This may result in significant load imbalances, if large RES power parks are affected simultaneously. In order to mitigate such rapid changes, the rate of change of active power needs to be limited. Further details need to be specified taking into consideration system and operational characteristics. • Rapid changes of active power output by RES Power Generating Modules in particular, have to be compensated by other modules providing active power frequency response in order to balance load and generation. As active power frequency response reserves cannot be activated indefinitely fast, the rate of change of active power needs to be limited.			

Principle/Methodology only:	X	**(Ranges of) values/parameters given:**		
Justification:	• The detailed parameters of limiting rate of change of active power output depend on a number of system and operational characteristics. • System inertia has impact on the magnitude of frequency deviations in case of load imbalances and thus indirectly influences the admissible rate of change of active power output. • Activation time of active power frequency response determines how fast load imbalances can be mitigated.			

Alternative solutions:	• Excessive active power frequency response reserves to be contracted, which has adverse impact on cost-effectiveness. • Limitations on penetration of (RES) generation without inherent inertia, however this will jeopardize achieving EU energy policy targets.
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; …"* • paragraph 2.1.3: *"… the detail of possible deviations of significant parameters (e.g. voltage, frequency) that generation units must withstand …"*

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Transformer Neutral-Point Treatment				
Reference to NC RfG:	Article 10(6) (f)				
Cross-border impact:	Proper earthing arrangements of the neutral-point at the network side of step-up transformers are crucial for reliable detection of faults by network protection to ensure system stability and security.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	• Neutral-point treatment of transformers is essential for the functioning of protection schemes and settings. • The neutral-point treatment needs to be specified further by the Relevant Network Operator due to its earthing arrangements and regional earthing conditions of the network.				
Principle/Methodology only:		X	**(Ranges of) values/parameters given:**		
Justification:	Further specifications on the neutral-point treatment can only be made by the Relevant Network Operator taking into consideration earthing arrangements and conditions.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
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, …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Modernisation or Replacement of Equipment
Reference to NC RfG:	Article 10(6) (g)
Cross-border impact:	The requirements of this network code are needed in order to maintain system stability and security, which is the overall objective of this network code. To achieve this purpose as many Power Generating Modules as reasonably possible shall meet these requirements.

Exhaustive requirement:		**Non-exhaustive requirement:**	X	
Justification:	• The Relevant Network Operator and/or the Relevant TSO need to be aware of such changes to Power Generating Modules due to modernisation/replacements as far as they relate to requirements of this network code, because of the impact on system stability and security. If reasonably possible, compliance with the relevant requirements of this network code shall be achieved in such a case. • Further specifications on compliance of modernised existing Power Generating Modules with the requirements of this network code need an investigation of the individual case, which shall be initiated by this requirement. • This strikes a balance between the code's focus on new units and the treatment of existing installations.			

Principle/Methodology only:	X	**(Ranges of) values/parameters given:**		
Justification:	The requirement itself describes a principle/methodology. No values/parameters are to be given. The investigation of the individual case will reveal, whether values/parameters for this specific case are needed.			

Alternative solutions:	Do nothing. However it is rather common practise of Power Generating Facility Owners to modernise/reinforce their installations and this often includes an increase of the installed generation capacity (e. g. Repowering of RES generation units). While is it acceptable, that existing generators shall not be enforced to meet the requirements of this network code (except for an application for retroactive application is made) for their remaining lifetime, it is on the other hand appropriate to require compliance in cases of modernisation/reinforcement, because such investments target, amongst others, at extending the lifetime rendering such units a sustainable part of the future generation portfolio, for which this set of requirements is needed.
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, …"*

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Voltage Ranges				
Reference to NC RfG:	Article 11(2) (a)				
Cross-border impact:	Voltage ranges are critical to secure planning and operation of a power system within a synchronous area. These needs to be coordinated between adjacent interconnected networks. This can often be a cross border issue.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
Justification:	This requirement is given exhaustively in tables 6.1 and 6.2. There is an exception for one voltage range in Continental Europe. Because of the size of this system, there is room for limited variation, while retaining wider coordination.				
Principle/Methodology only:			**(Ranges of) values/parameters given:**	X	
Justification:	• Details are given for in tables 6.1 and 6.2. • There is a clear need to coordinated between adjacent interconnected networks and therefore operating ranges need to be specified.				
Alternative solutions:	Have no defined voltage ranges. However, this would lead to widespread uncertainty in planning and operation of the system with respect to operation beyond normal operating conditions.				
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; …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Voltage Control System (simple)				
Reference to NC RfG:	Article 11(2) (b)				
Cross-border impact:	Voltage control for Types B and C Synchronous Power Generating Modules can be a cross border issue. The absence of such a facility can lead to voltage instability which can spread to neighbouring systems. The absence of a voltage control system, if applied to many Power Generating Modules may remove the fundamental requirement for cross-border trading, namely system stability.				
Exhaustive requirement:		X	**Non-exhaustive requirement:**		
Justification:	A simple high level principle requirement is provided for the voltage control system. This is exhaustive.				
Principle/Methodology only:		X	**(Ranges of) values/parameters given:**		
Justification:	• Only a high level principle is defined for the voltage control: "without instability over the entire operating range". • In context of size of units and their potential impact this is considered proportionate and appropriate in context of cross-border aspects.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system. A voltage control system is required to ensure voltage stability.				
Link to FWGL:	• 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. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Fault-ride-through Capability of Power Generating Modules connected at 110 kV or above
Reference to NC RfG:	Article 11(3) (a)
Cross-border impact:	Failure to ride through faults for synchronous generators can create major system instability with cross-border implications. This condition has been experienced in the Nordic Area, where failure of large generators to ride through a fault in Sweden caused a total system black-out for an extended period, including a black-out of Copenhagen in Denmark. The ability to ride through faults on the ≥ 110kV system even for 0 V retained voltage is central to system security. It has to be implemented in all systems. Example: Weaker FRT capability and robustness of large synchronous generators during a major system disturbance (the Italian islanded system in Sept 2003) are thought to have contributed to the total collapse (frequency instability). This resulted from 15 large generators failing to ride through faults during the system split.

Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• In order to reflect geographical differences (between synchronous areas and TSOs) key parameters are left to be defined at a national level, see Table 7.1. • These differences also reflect more severe fault duration FRT requirements in some countries (Nordic synchronous area) where total system shut down has been experienced. This experience has lead subsequently due to political decisions to raising the degree of FRT cover to a further level, securing the system integrity for double contingencies. • At a European level it is at the same time undesirable to waste these investments (by not allowing the tougher requirements (250ms) to be retained) and also undesirable to force all others to make the further investments needed to achieve this higher level of security.				

Principle/Methodology only:		**(Ranges of) values/parameters given:**	X		
Justification:	• Ranges of values are given to allow appropriate national choices, e.g. as discussed above. At a national level it is important that there is good coordination between choice of parameters and choice of initial pre-fault system conditions which the FRT capability has to be demonstrated against. • Stakeholders have correctly pointed out that the worst combination possible of long durations and most severe pre fault conditions are not achievable. There is no intention to have such combinations. This aspect has to be taken proper care of at the national level, within the national processes (Article 4(3)).				

Alternative solutions:	Have no requirement relying on market incentives. However, there are no appropriate market incentives for this basic capability. Absence of this requirement would result in an unacceptable lower level of system security and lead to major restrictions in development of RES in.
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 …"*

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Synchronization				
Reference to NC RfG:	Article 11(4) (a)				
Cross-border impact:	Larger Power Generating Modules shall be connected only after authorisation by the relevant network operator. Otherwise, if connection conditions are not fulfilled, a risk of instability of the unit or the security of the system may result. Furthermore it has to be possible to connect a Power Generating Module, even if system parameter like frequency or voltage deviate from their nominal values, in particular, if these units are needed in disturbed operating situations in order to restore normal conditions.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	To manage system stability and security the relevant network operator shall specify conditions for connection of Power Generating Modules. Both connection authorization and values/ranges of system parameters need to be covered by such conditions.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	Detailed parameters for connection conditions depend on regional system characteristics, which have impact on stable connection and subsequent operation of a Power Generating Module.				
Alternative solutions:	Leave this requirement to market incentives to deliver the necessary stability. However, there would be no certain basis upon which to plan and operate the system.				
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. …"* • paragraph 3.2: *"… The network code(s) shall set the requirement for every significant grid user to be able to receive and to execute the instructions sent by the TSO and/or DSO, …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Reactive Power Capability for type B Synchronous Power Generating Modules				
Reference to NC RfG:	Article 12(2) (a)				
Cross-border impact:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. For Type B Synchronous Power Generating Modules the influence on overall system voltage stability will vary with location. Therefore the requirement for Type B Synchronous Power Generating Modules reflects this.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• The Relevant Network Operator shall have the right to adopt a decision pursuant to Article 4(3) determining the capability of a Power Generating Module to provide Reactive Power. • For Type B this is a proportional and appropriate approach to allow the local needs to influence the requirements.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	The principle of the requirement stated only in order to optimise local freedom and to keep the requirement proportional in different local circumstances.				
Alternative solutions:	No requirement leaving market incentives to deliver adequate capacity. However, market incentives are usually absent at connection points for Type B Synchronous Power Generating Modules. Therefore the approach adopted is a proportionate and appropriate approach to allow the local needs to influence the requirements.				
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:* ○ *Requirements for reactive power; …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Post-fault Active Power Recovery				
Reference to NC RfG:	Article 12(3) (a)				
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.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	• This requirement is only specified as the Relevant TSO shall adopt a decision pursuant to Article 4 (3) specifying magnitude and time for Active Power Recovery. • This level of delegation to national level is appropriate to adequately reflect the different needs of the different sizes of synchronous areas.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	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.				
Alternative solutions:	Have no requirement. However, this could result in significantly increased danger of demand disconnection and unequal treatment of Synchronous Power Generating Modules.				
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 …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Reactive Power Capability at Maximum Active Power				
Reference to NC RfG:	Article 13(2) (b)				
Cross-border impact:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. For Type C and D Synchronous Power Generating Modules the influence on overall system voltage stability will vary with location. Therefore the requirement for Type C and D Synchronous Power Generating Modules reflects this.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	The power system need for Reactive Power is influenced by local conditions. Therefore the requirements are not specified in an exhaustive manner in order to be proportional to local needs.				
Principle/Methodology only:			**(Ranges of) values/parameters given:**	X	
Justification:	Ranges of reactive power allow national / local choices to be made, ensuring requirements are appropriate to local conditions and ensuring proportionality.				
Alternative solutions:	• Rely upon markets to deliver adequate reactive capability. However, experience has shown that markets are better suited to optimise the use of reactive power than ensure adequate capability and therefore liquidity in the market. • The requirement is proportionate in order in order to secure Reactive Capability to ensure system stability for the full range of operating conditions.				
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:* ○ *Requirements for reactive power; …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Reactive Power Capability below Maximum Active Power				
Reference to NC RfG:	Article 13 (2) (c)				
Cross-border impact:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. For Type C and D Synchronous Power Generating Modules he influence on overall system voltage stability will vary with location. Therefore the requirement for Type C and D Synchronous Power Generating Modules reflects this.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	The capacity is only defined in outline. The requirement states that whatever the capacity is, the capability shall be to be able to operate at every possible operating point. This is proportionate and it allows local needs to be considered.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	This is a principle requirement. There is no range involved in this part.				
Alternative solutions:	• Have no requirement for this capability, rely entirely on market signals. However, this would not be appropriate and proportionate for this size of plant in context of required flexibility required for stable operation of the system. • Experience has shown that markets are better suited to utilise capability than to secure the capability and hence ensuring a liquid market in operation.				
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:* ○ *Requirements for reactive power; …"*				

Requirement:	Voltage Control System				
Reference to NC RfG:	Article 14(2) (a)				
Cross-border impact:	Voltage control for Types D Synchronous Power Generating Modules can be a cross border issue. The presence of an effective voltage control for Type D Synchronous Power Generating Modules is essential for voltage stability. The absence of a voltage control system may lead to voltage instability which can spread to neighbouring systems, removing the fundamental requirement for cross-border trading, namely system stability.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	The requirement carries reference to Article 4 (3) introducing national / local contributions to complete the requirement. This is a proportional measure, allowing consideration of local conditions. It also allows for agreement with the Power Generating Facility Owner.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	• The requirement sets out the principle requirements without specifying any associated ranges. This is appropriate and proportional to define the main system concerns without limiting design freedom in how to deliver this. • The voltage control system requirement is included in order to ensure system stability.				
Alternative solutions:	Have no requirement, but rely instead upon market encouragement. However, this is a topic unlikely to be suitable for market to deliver the certainty required for system planning and operation.				
Link to FWGL:	• 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. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Reactive Power Capability for type B Power Park Modules				
Reference to NC RfG:	Article 15(2) (a)				
Cross-border impact:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. For Type B Power Park Modules the influence on overall system voltage stability will vary with location. Therefore the requirement for Type B Power Park Modules reflects this.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	• The Relevant Network Operator shall have the right to adopt a decision pursuant to Article 4(3) determining the capability of a Synchronous Power Generating Module to provide Reactive Power. • For Type B Power Park Modules this is a proportional and appropriate approach to allow the local needs to influence the requirements.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	The principle of the requirement stated only in order to optimise local freedom and to keep the requirement proportional in different local circumstances.				
Alternative solutions:	• No requirement could be implemented, hoping that the market would encourage such capability. • In addition to the weakness of markets to deliver capacity to ensure liquid markets, there are unlikely to be any markets at all for these services at the typical connection points of Type B Power Park Modules. • This alternative approach would not be proportional to the system needs in context of the rapidly expanding volume of embedded generation.				
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:* ○ *Requirements for reactive power; …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Reactive Current Injection				
Reference to NC RfG:	Article 15(2) (b) and (c)				
Cross-border impact:	Reactive 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.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	The requirement refers to Article 4 (3) in respect 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.				
Principle/Methodology only:	X	**(Ranges of) values/parameters given:**			
Justification:	• Provide in the main principles, although it contains also one range (not less than 10ms) as a national choice. • The requirement is a good balance between a clear statement of the common developing system need (driven by increases in RES penetration increases) and opportunities to build on national existing arrangements, particularly for the less severe asymmetrical faults (which have less widespread impact), without prescribing detailed technical specifications or implementations.				
Alternative solutions:	Rely on markets to deliver the required current injection capability. However, this is a detailed technical area which markets are not well equipped to deliver solutions for which can be relied upon in planning and operation of the power systems.				
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 …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Post-fault Active Power Recovery				
Reference to NC RfG:	Article 15(3) (a)				
Cross-border impact:	Post fault power recovery is important in terms of system frequency stability, which in turn is a fundamental requirement for cross-border trading.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	The urgency of post fault recovery varies between systems depending upon the overall system inertia, which in turn depends upon the synchronous area system size and the types of generation. A high proportion of RES (wind and PV) tend to lower the system inertia. Because of these variations, the detailing of the requirement is left to national level in accordance with Article 4 (3).				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	No specific ranges are specified. It is up to the national level to determine magnitude and time for Active Power recovery. This is proportionate to reflect the large variations in need between synchronous areas.				
Alternative solutions:	Leave this issue to the market to deliver. However, the consequent uncertainty would not facilitate effective system design, planning and operation.				
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 …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Synthetic Inertia Capability
Reference to NC RfG:	Article 16(2) (a)
Cross-border impact:	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 Power Generating Modules 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 many RES 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. It is therefore paramount in allowing further expansion of RES which does not naturally contribute to inertia, to provide a synthetic component to make its contribution.

Exhaustive requirement:		**Non-exhaustive requirement:**	X	
Justification:	This is an area which is still under development. It is therefore appropriate to allow developing experience to be introduced at a national level.			

Principle/Methodology only:	X	**(Ranges of) values/parameters given:**		
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.			

Alternative solutions:	Leave topic out and allow market to deliver solutions when mature. However, due to the critical nature of this topic in context of allowing RES integration to progress, it is important to provide a firm signal about the system need at this stage.
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; …"* • paragraph 2.1.3: *"… the detail of possible deviations of significant parameters (e.g. voltage, frequency) that generation units must withstand …"*

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Reactive Power Capability at Maximum Active Power				
Reference to NC RfG:	Article 16(3) (b)				
Cross-border impact:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. For Type C and D Power Park Modules the influence on overall system voltage stability will vary with location.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	The power system need for Reactive Power is influenced by local conditions. Therefore the requirements are not specified in an exhaustive manner in order to be proportionate to local needs.				
Principle/Methodology only:		**(Ranges of) values/parameters given:**	X		
Justification:	Ranges of reactive power are provided to allow national / local choices of requirements appropriate to local conditions, ensure proportionality and appropriateness.				
Alternative solutions:	• Rely upon markets to deliver adequate reactive capability. However, experience has shown that markets are better suited to optimise the use of reactive power than ensure adequate capability and therefore liquidity in the market. • Inadequate reactive capability would be a consequence (under high RES production) of this alternative with associated additional system security risks. Limitations in RES developments could therefore be a result of this alternative.				
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:* ○ *Requirements for reactive power; …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Reactive Power Capability below Maximum Active Power				
Reference to NC RfG:	Article 16(3) (c)				
Cross-border impact:	Reactive power is a key component in terms of voltage stability, which in turn is the foundation for cross-border trading. For Type C and D Power Park Modules the influence on overall system voltage stability will vary with location.				
Exhaustive requirement:		**Non-exhaustive requirement:**	X		
Justification:	The power system need for Reactive Power is influenced by local conditions. Therefore the requirements are not specified in an exhaustive manner in order to be proportionate to local needs.				
Principle/Methodology only:		**(Ranges of) values/parameters given:**	X		
Justification:	The requirement is specified with ranges to allow for national / local choices associated with local conditions of voltage stability, with the aim to achieve certainty voltage stability across the full operating range.				
Alternative solutions:	• Rely upon markets to deliver adequate reactive capability. However, experience has shown that markets are better suited to optimise the use of reactive power than ensure adequate capability and therefore liquidity in the market. • Inadequate reactive capability would be a consequence (under high RES production) of this alternative with associated additional system security risks. Limitations in RES developments could therefore be a result of this alternative.				
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:* ○ *Requirements for reactive power; …"*				

Requirement:	Reactive Power Control Modes				
Reference to NC RfG:	Article 16(3) (d)				
Cross-border impact:	Voltage control for Types C and D Power Park Modules can be a cross border issue. The absence of such a facility can lead to voltage instability which can spread 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.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	This requirement allows 3 in principle different control modes. This allows the selection to reflect the national / local needs.				
Principle/Methodology only:			**(Ranges of) values/parameters given:**	X	
Justification:	A choice of control mode as well as parameter choices allowed the requirement to reflect varied national / local needs.				
Alternative solutions:	Have no requirement. However, this alternative has the risk of the appropriate control mode not being available across the manufacturing range and also lacks clarity for the European RES manufacturing industry.				
Link to FWGL:	• 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. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Priority to Active or Reactive Power Contribution				
Reference to NC RfG:	Article 16(3) (e)				
Cross-border impact:	This is a part of the Fault Ride Through family of requirements. Failure to ride through faults (which risks simultaneous loss of large volumes of generation) at a time when the system is already disturbed carries a significant risk of loss of stability, the condition which is a pre-requisite for cross-border trading. Priority for power contribution is a cross-border issue as the wrong choice may lead to avoidable frequency or voltage instability.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	The TSO shall decide pursuant to Article 4 (3). This requirement is non-exhaustive in order to reflect the different priorities between on the one hand small synchronous areas (urgency of real power recovery for frequency stability) and on the other large synchronous areas (with less urgency on real power and more focus on voltage restoration).				
Principle/Methodology only:			**(Ranges of) values/parameters given:**	X	
Justification:	A choice is involved, although it is only between two options. This is needed to reflect system-specific conditions.				
Alternative solutions:	Have no requirement . However, this could result in sub-optimal choices which could lead to system instability. The uncertainty would also create unnecessary difficulties in system planning and operation.				
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 …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu

Requirement:	Power Oscillations Damping Control				
Reference to NC RfG:	Article 16(3) (f)				
Cross-border impact:	Power system oscillations can spread across borders and if inadequate measures are taken, it can result in angular (dynamic) instability. Therefore the means to prevent such instability must be considered a cross-border issue.				
Exhaustive requirement:			**Non-exhaustive requirement:**	X	
Justification:	This is a non-exhaustive requirement because many technologies already inherently provide such a capability and for others the need for special measures is under development.				
Principle/Methodology only:	X		**(Ranges of) values/parameters given:**		
Justification:	• Only the high level principle is specified. • It is intended to be applied only where needed combined with a selection of versions of Power Park Modules for which the need for special measured is justified.				
Alternative solutions:	Have no requirement. However, considering the importance of damping power system oscillations to the stability of the European power system, it is important that a clear message is provided to manufacturers. Where there is no need for special measures these will be avoided.				
Link to FWGL:	• 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. …"*				

ENTSO-E AISBL • Avenue Cortenbergh 100 • 1000 Brussels • Belgium • Tel +32 2 741 09 50 • Fax +32 2 741 09 51 • info@entsoe.eu • www.entsoe.eu