Requirements laid down under EU regulation 2016/631 – Requirements for grid connection of Generators (RfG)

TEXT	VERSION	DATE
Requirements approved by the Danish Utility Regulator in connection with the implementation of EU regulation 2016/631 including changes made as a result of the Danish Utility Regulator's public consultation	1	19.11.2018
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Normative requirements - no changes made	
Requirements set	

Art. no.	Sub. art. no.	Art. para.	Art. point	Article subject			Rev.
General requirements for type A power-generating modules							
13	1			Type A power generating modules shall fulfil the following requirements relating to frequency stability:	-		
13	1	a		With regard to frequency ranges:	-		
13	1	a	i	a power generating module shall be capable of remaining connected to the network and operate within the frequency ranges and time periods specified in Table 2;	Table 2 CE: 47.5 – 48.5 Hz: 30 min. 48.5 – 49.0 Hz: 30 min. N: 48.5 – 49.0 Hz: 30 min. Technical specification text: This means minimum 30 minutes in the 48.5 Hz to 49 Hz frequency range and 30 minutes in the 47.5 Hz to 48.5 Hz frequency range. However, total operation time below 49 Hz may not exceed 60 minutes.		

13	1	a	ii	the relevant system operator, in coordination with the relevant TSO, and the power generating facility owner may agree on wider frequency ranges, longer minimum times for operation or specific requirements for combined frequency and voltage deviations to ensure the best use of the technical capabilities of a power generating module, if it is required to preserve or to restore system security;	Transmission system: not relevant Distribution system: not relevant		
13	1	a	iii	the power generating facility owner shall not unreasonably withhold consent to apply wider frequency ranges or longer minimum times for operation, taking account of their economic and technical feasibility.	-		
13	1	b		With regard to the rate of change of frequency withstand capability, a power-generating module shall be capable of staying connected to the network and operate at rates of change of frequency up to a value specified by the relevant TSO, unless disconnection was triggered by rate-of-change-of-frequency-type loss of mains protection. The relevant system operator, in coordination with the relevant TSO, shall specify this rate-of-change-of-frequency-type loss of mains protection. Table 2 Minimum time periods for which a power-generating module has to be capable of operating on different frequencies, deviating from a nominal value, without disconnecting from the network.	ROCOF: 2.0 Hz/s *ROCOF* denotes frequency change as a function of time. The frequency change, ROCOF, is calculated according to the principle below or an equivalent principle. The frequency measurement used to calculate the frequency change is based on a 200 ms measuring period for which the mean value is calculated. Frequency measurements must be made continuously, so that a new value is calculated every 20 ms. *ROCOF [Hz/s]* must be calculated as the difference between the mean value frequency calculation just done and the mean value frequency calculation done 20 ms ago. (df/dt = (mean value 2 – mean value 1) [Hz/s]) LOM detection: SPGM/PPM/Types A, B, C and D ROCOF is used in the distribution grid, mean value/measurement is calculated as described in connection with ROCOF robustness. ROCOF – Tripping overfrequency: if calculated ROCOF value is > + 2.5 Hz/s for more than 80 ms. ROCOF – Tripping underfrequency: if calculated ROCOF value is > -2.5 Hz/s for more than 80 ms.		R1

					Undervoltage step 2 may be used for type A facilities as an alternative to ROCOF. Undervoltage (step 2): Uc < 0.8 pu for 200 ms.		
13	2			With regard to the limited frequency sensitive mode — overfrequency (LFSM-O), the following shall apply, as determined by the relevant TSO for its control area in coordination with the TSOs of the same synchronous area to ensure minimal impacts on neighbouring areas:	-		
13	2	a		the power generating module shall be capable of activating the provision of active power frequency response according to figure 1 at a frequency threshold and droop settings specified by the relevant TSO;	a) is specified Pn is used as Pref for PPM. It must be possible to set the frequency parameters in the active power control functions to a resolution of 10 mHz or higher. - It must be possible to set the control droops to a resolution of 1% or higher. - The accuracy of a completed or continuous regulation relating to the frequency response control function for overfrequency must not deviate by an average fault scale < 5% of *Pn* measured over a period of 1 minute. - Frequency measurements must be carried out with a ± 10 mHz accuracy or higher. Technical specification text: In LFSM-O mode, the facility's active power must follow the required droop when the grid frequency exceeds the specified threshold value, corner frequency, for LFSM-O, regardless of whether grid frequency is increasing or decreasing.		
13	2	b		instead of the capability referred to in paragraph (a), the relevant TSO may choose to allow within its control area automatic disconnection and reconnection of power generating modules of Type A at randomised frequencies, ideally uniformly distributed, above a frequency threshold, as determined by the relevant TSO where it is able to demonstrate to the relevant regulatory authority, and with the cooperation of power generating modulefacility owners, that this has a limited cross-border impact and maintains the same level of operational security in all system states;	b) is not specified.		
13	2	c		the frequency threshold shall be between 50.2 Hz and 50.5 Hz inclusive;	CE: 50.2 Hz N: 50.5 Hz		
13	2	d		the droop settings shall be between 2% and 12%;	CE:		

					SPG: 5% PPM: 5% N: SPG: 4% PPM: 4%		
13	2	e		the power generating module shall be capable of activating a power frequency response with an initial delay that is as short as possible. If that delay is greater than two seconds, the power generating facility owner shall justify the delay, providing technical evidence to the relevant TSO;			
13	2	f		the relevant TSO may require that upon reaching minimum regulating level, the power generating module be capable of either:	-		
13	2	f	i	continuing operation at this level; or	i) is selected.		
13	2	f	ii	further decreasing active power output;	ii) is not selected.		
13	2	g		the power generating module shall be capable of operating stably during LFSM-O operation. When LFSM-O is active, the LFSM-O setpoint will prevail over any other active power setpoints.			
13	3			The power generating module shall be capable of maintaining constant output at its target active power value regardless of changes in frequency, except where output follows the changes specified in the context of paragraphs 2 and 4 of this Article or points (c) and (d) of Article 15(2) as applicable.			
13	4			The relevant TSO shall specify admissible active power reduction from maximum output with falling frequency in its control area as a rate of reduction falling within the boundaries, illustrated by the full lines in Figure 2:	6% of Pn per Hz, start at 49.0 Hz.		
13	4	a		below 49 Hz falling by a reduction rate of 2% of the maximum capacity at 50 Hz per 1 Hz frequency drop;			
13	4	b		below 49.5 Hz falling by a reduction rate of 10% of the maximum capacity at 50 Hz per 1 Hz frequency drop.			
13	5			The admissible active power reduction from maximum output shall:			
13	5	a		clearly specify the ambient conditions applicable;	Under normal operating conditions and as well as possible in relation to the current set point as well as at ambient conditions that, cf. the facility manufacturer's clear facility specifications, the facility owner has been informed of and that have been validated in the form of a relevant generation facility performance test.		R1
13	5	b		take account of the technical capabilities of power generating modules.			

13	6			The power generating module shall be equipped with a logic interface (input port) in order to cease active power output within five seconds following an instruction being received at the input port. The relevant system operator shall have the right to specify requirements for equipment to make this facility operable remotely.	Dx requirement. Not relevant for Tx.		
13	7			The relevant TSO shall specify the conditions under which a power generating module is capable of connecting automatically to the network. Those conditions shall include:			
13	7	a		frequency ranges within which an automatic connection is admissible, and a corresponding delay time; and	DK1: 47.5 - 50.2 Hz DK2: 47.5 - 50.5 Hz Automatic connection of a facility may be done at the earliest three minutes after voltage has reached the normal operating voltage range and frequency has reached the specified range. Synchronisation between a facility and the public electricity supply grid must be automatic.		
13	7	b		(b) maximum admissible gradient of increase in active power output. Automatic connection is allowed unless specified otherwise by the relevant system operator in coordination with the relevant TSO.	RSO requirements: 20% Pn/min.		
General requirements for type B power-generating modules							
14	1			Type B power generating modules shall fulfil the requirements set out in Article 13, except for Article 13(2)(b).	-		
14	2			Type B power generating modules shall fulfil the following requirements in relation to frequency stability:	-		
14	2	a		to control active power output, the power generating module shall be equipped with an interface (input port) in order to be able to reduce active power output following an instruction at the input port; and	-		
14	2	b		the relevant system operator shall have the right to specify the requirements for further equipment to allow active power output to be remotely operated.	A and B facilities		
14	3			Type B power generating modules shall fulfil the following requirements in relation to robustness:	-		
14	3	a		with regard to fault-ride-through capability of power generating modules:	-		
14	3	a	i	each TSO shall specify a voltage-against-time-profile in line with Figure 3 at the connection point for fault conditions, which describes the conditions in which the power generating module is capable of staying connected to the network and continuing to operate stably after the power system has been disturbed by secured faults on the transmission system;	Requirements, cf. Appendix 1.C		

CE/N – PPM - #1 - A14(3)(a)			
Voltage (pu)		Time [seconds]	
U_{ret}:	0.15	t_{clear}:	0.25
U_{clear}:	0.15	t_{rec1}:	0.25
U_{rec1}:	0.15	t_{rec2}:	0.25
U_{rec2}:	0.9	t_{rec3}:	1.5

CE/N – SPGM - #2 - A14(3)(a)			
Voltage (pu)		Time [seconds]	
U_{ret}:	0.3	t_{clear}:	0.25
U_{clear}:	0.7	t_{rec1}:	0.25
U_{rec1}:	0.7	t_{rec2}:	0.70
U_{rec2}:	0.9	t_{rec3}:	1.5

14	3	a	ii	the voltage-against-time-profile shall express a lower limit of the actual course of the phase-to-phase voltages on the network voltage level at the connection point during a symmetrical fault, as a function of time before, during and after the fault;	Cf. A14(3)(a)(i)
14	3	a	iii	the lower limit referred to in point (ii) shall be specified by the relevant TSO using the parameters set out in Figure 3, and within the ranges set out in Tables 3.1 and 3.2;	Cf. A14(3)(a)(i)
14	3	a	iv	each TSO shall specify and make publicly available the pre-fault and post-fault conditions for the fault-ride-through capability in terms of: – the calculation of the pre-fault minimum short circuit capacity at the connection point; – pre-fault active and reactive power operating point of the power generating module at the connection point and voltage at the connection point; and – calculation of the post-fault minimum short circuit capacity at the connection point.	A short-circuit catalogue specifies the method for calculating short-circuit power and calculates conditions in known connection points. Facility properties: Facility properties are specified by Pn and PF = 1
14	3	a	v	at the request of a power generating facility owner, the relevant system operator shall provide the pre-fault and post-fault conditions to be considered for fault-ride-through capability as an outcome of the calculations at the connection point as specified in point (iv) regarding: – pre-fault minimum short circuit capacity at each connection point expressed in MVA; – pre-fault operating point of the power generating module expressed in active power output and reactive power output at the connection point and voltage at the connection point; and – post-fault minimum short circuit capacity at each connection point expressed in MVA. Alternatively, the relevant system operator may provide generic values derived from typical cases;	Established calculation method is used.
14	3	a	vi	the power generating module shall be capable of remaining connected to the network and continuing to operate stably when the actual course of the phase-to-phase voltages on the network voltage level at the connection point during a symmetrical fault, given the pre-fault and post-fault conditions in points (iv) and (v) of paragraph (3)(a), remain above the lower	

				limit specified in point (ii) of paragraph (3)(a), unless the protection scheme for internal electrical faults requires the disconnection of the power generating module from the network. The protection schemes and settings for internal electrical faults must not jeopardise fault-ride-through performance;			
14	3	a	vii	without prejudice to point (vi) of paragraph (3)(a), undervoltage protection (either fault-ride-through capability or minimum voltage specified at the connection point voltage) shall be set by the power generating facility owner according to the widest possible technical capability of the power generating module, unless the relevant system operator requires narrower settings in accordance with point (b) of paragraph (5). The settings shall be justified by the power generating facility owner in accordance with this principle;	-		
14	3	b		Fault-ride-through capabilities in case of asymmetrical faults shall be specified by each TSO.	FRT requirements are applicable to both symmetrical and asymmetrical faults.		
14	4			Type B power generating modules shall fulfil the following requirements relating to system restoration:	-		
14	4	a		the relevant TSO shall specify the conditions under which a power generating module is capable of reconnecting to the network after an incidental disconnection caused by a network disturbance; and	DK1: 47.5 - 50.2 Hz DK2: 47.5 - 50.5 Hz In the voltage range for unlimited operating time. Reconnection after 3 min. Gradient 20% Pn/min. Switching with own equipment permitted as long as the grid is energised. Switching with alternative equipment is subject to agreement with the facility owner.		
14	4	b		installation of automatic reconnection systems shall be subject both to prior authorisation by the relevant system operator and to the reconnection conditions specified by the relevant TSO.	Dx: A14(4)(a) Tx: n/a		
14	5			Type B power generating modules shall fulfil the following general system management requirements:	-		
14	5	a		with regard to control schemes and settings:	-		
14	5	a	i	the schemes and settings of the different control devices of the power generating module that are necessary for transmission system stability and for taking emergency action shall be coordinated and agreed between the relevant TSO, the relevant system operator and the power generating facility owner;	System protection: The system operator – in cooperation with the transmission system operator – must state whether there is a requirement to establish system protection when deciding on the POC. Absolute power limit:		

					An absolute power constraint is used to protect the public electricity supply grid against overload in critical situations.	
14	5	a	ii	any changes to the schemes and settings, mentioned in point (i), of the different control devices of the power generating module shall be coordinated and agreed between the relevant TSO, the relevant system operator and the power generating facility owner, in particular if they apply in the circumstances referred to in point (i) of paragraph (5) (a);	-	
14	5	b		with regard to electrical protection schemes and settings:	-	
14	5	b	i	the relevant system operator shall specify the schemes and settings necessary to protect the network, taking into account the characteristics of the power generating module. The protection schemes needed for the power generating module and the network as well as the settings relevant to the power generating module shall be coordinated and agreed between the relevant system operator and the power generating facility owner. The protection schemes and settings for internal electrical faults must not jeopardise the performance of a power generating module, in line with the requirements set out in this Regulation;	RSO uses: Line protection Transformer protection Reactor protection Auxiliary power transformer protection Busbar protection Facility owner: The facility must be protected against damage resulting from faults and incidents in the grid. The facility must be protected against internal short circuits The facility must be protected against disconnection in non-critical situations. All applicable settings are specified based on the relevant grid and facility analyses. Settings are noted in the operating agreement. Wherever possible, the public electricity supply system must be protected against any unwanted impact from the facility. The facility must be able to handle the FRT requirements set, wherein Energinet ensures that faults, etc. are disconnected accordingly.	
14	5	b	ii	electrical protection of the power generating module shall take precedence over operational controls, taking into account the security of the system and the health and safety of staff and of the public, as well as mitigating any damage to the power generating module;	-	
14	5	b	iii	protection schemes may cover the following aspects: – external and internal short circuit; – asymmetric load (negative phase sequence); – stator and rotor overload; – over-/underexcitation; – over-/undervoltage at the connection point; – over-/undervoltage at the alternator terminals; – inter-area oscillations; – inrush current; – asynchronous operation (pole slip);	The facility owner must ensure that a protection coordination study is done. The facility owner must ensure that the facility is dimensioned and equipped with the necessary protective functions so that:	

				– protection against inadmissible shaft torsions (for example, subsynchronous resonance); – power generating module line protection; – unit transformer protection; – backup against protection and switchgear malfunction; – overfluxing (U/f); – inverse power; – rate of change of frequency; and – neutral voltage displacement.	- the facility is protected against damage due to faults and incidents in the public electricity supply grid - the facility is protected against disconnection in non-critical situations for the facility. Relay protection established to target faults in the facility, including short-circuits, overspeed, excitation monitoring, reverse power, etc. must not trip the unit in the event of short-circuits or grid rerouting. In case of facility short-circuiting, facility protection must last selective with grid protection. The use of vector jump relays as protection against island operation/loss of mains is not allowed. A positive-sequence undervoltage relay is only a requirement in cases where out-of-phase reclosing by means of automatic reclosing can occur. If a facility is isolated with part of the public electricity supply grid, the facility must not give rise to temporary overvoltages that may damage the facility or the public electricity supply grid.		
14	5	b	iv	changes to the protection schemes needed for the power generating module and the network and to the settings relevant to the power generating module shall be agreed between the system operator and the power generating facility owner, and agreement shall be reached before any changes are made;	-		
14	5	c		the power generating facility owner shall organise its protection and control devices in accordance with the following priority ranking (from highest to lowest):	-		
14	5	c	i	network and power generating module protection;	-		
14	5	c	ii	synthetic inertia, if applicable;	-		
14	5	c	iii	frequency control (active power adjustment);	-		
14	5	c	iv	power restriction; and	-		
14	5	c	v	power gradient constraint.	-		
14	5	d		with regard to information exchange:	-		
14	5	d	i	power generating facilities shall be capable of exchanging information with the relevant system operator or the relevant TSO in real time or periodically with time stamping, as specified by the relevant system operator or the relevant TSO;	Information exchange: real-time or periodically – with time stamp.		

					Maximum update time of functional status (activated/deactivated) is 10 ms. Maximum update time of parameter value is 1 second. Maximum update value of measurement values is 1 second. Other requirements are specified in A14(5)(d)(ii).		
14	5	d	ii	the relevant system operator, in coordination with the relevant TSO, shall specify the content of information exchanges including a precise list of data to be provided by the power generating facility.	Requirements, cf. Appendix 1.A		R1
General requirements for type C power-generating modules							
15	1			Type C power generating modules shall fulfil the requirements laid down in Articles 13 and 14, except for Article 13(2)(b) and(6) and Article14(2).	-		
15	2			Type C power generating modules shall fulfil the following requirements relating to frequency stability:	-		
15	2	a		with regard to active power controllability and control range, the power generating module control system shall be capable of adjusting an active power setpoint in line with instructions given to the power generating facility owner by the relevant system operator or the relevant TSO. The relevant system operator or the relevant TSO shall establish the period within which the adjusted active power setpoint must be reached. The relevant TSO shall specify a tolerance (subject to the availability of the prime mover resource) applying to the new setpoint and the time within which it must be reached;	SPM: minimum 1% of Pn/minute, also 10-minute response time for technology neutrality, if necessary. PPM: minimum 20% of Pn/minute. It must be possible to specify set points for active power with a resolution of 1% of Pn or higher. It must be possible to set the frequency parameters in the active power control functions with a resolution of 10 mHz or higher. It must be possible to set control droops with a resolution of 1% or higher of Pn. For all active power control functions, the accuracy of a completed or continuous regulation must not deviate by more than an average fault scale of 2% of Pn measured over a period of 1 minute (not applicable, however, to LFSM-O and LFSM-U). Frequency measurements must be carried out with a ± 10 mHz accuracy or higher.		
15	2	b		manual, local measures shall be allowed in cases where the automatic remote control devices are out of service. The relevant system operator or the relevant TSO shall notify the regulatory	Cf. A15(2)(a)		

				authority of the time required to reach the setpoint together with the tolerance for the active power;			
15	2	c		In addition to paragraph 2 of Article 13,(2), the following requirements shall apply to type C power generating modules with regard to limited frequency sensitive mode – underfrequency (LFSM-U):			
15	2	c	i	the power generating module shall be capable of activating the provision of active power frequency response at a frequency threshold and with a droop specified by the relevant TSO in coordination with the TSOs of the same synchronous area as follows: – the frequency threshold specified by the TSO shall be between 49.8 Hz and 49.5 Hz inclusive; – the droop settings specified by the TSO shall be in the range 2 – 12%. This is represented graphically in Figure 4;	CE: 49.8 Hz Droop range: 2-12% Droop: SPG/PPM = 5% N: 49.5 Hz Droop range: 2-12% Droop: SPG/PPM = 4% Frequency measurements must be carried out with a ± 10 mHz accuracy or higher. The control function's sensitivity must be ± 10 mHz or higher.		
15	2	c	ii	the actual delivery of active power frequency response in LFSM-U mode shall take into account: – ambient conditions when the response is to be triggered; – the operating conditions of the power generating module, in particular limitations on operation near maximum capacity at low frequencies and the respective impact of ambient conditions according to paragraphs 4 and 5 of Article 13; and – the availability of the primary energy sources.			
15	2	c	iii	the activation of active power frequency response by the power generating module shall not be unduly delayed. In the event of any delay greater than two seconds, the power generating facility owner shall justify it to the relevant TSO;	-		
15	2	c	iv	in LFSM-U mode the power generating module shall be capable of providing a power increase up to its maximum capacity;	-		
15	2	c	v	stable operation of the power generating module during LFSM-U operation shall be ensured; Figure 4: active power frequency response capability of power generating modules in LFSM-U. Pref is the reference active power to which DP is related and may be specified differently for synchronous power generating modules and power park modules. DP is the change in active power output from the power generating module. fn is the nominal frequency (50 Hz) in the network and Df is the frequency deviation in the network. At underfrequencies where Df is below Df1 the power generating module has to provide a positive active power output change according to the droop S2.	Pn is used as Pref for both SPG and PPM.		
15	2	d		in addition to point (c) of paragraph (2), the following shall apply cumulatively when frequency sensitive mode ('FSM') is operating:	-		

15	2	d	i	the power generating module shall be capable of providing active power frequency response in accordance with the parameters specified by each relevant TSO within the ranges shown in Table 4. In specifying those parameters, the relevant TSO shall take account of the following facts: – in case of overfrequency, the active power frequency response is limited by the minimum regulating level; – in case of underfrequency, the active power frequency response is limited by maximum capacity; – the actual delivery of active power frequency response depends on the operating and ambient conditions of the power generating module when this response is triggered, in particular limitations on operation near maximum capacity at low frequencies according to paragraphs 4 and 5 of Article 13 and available primary energy sources; Parameters Ranges Active power range related to maximum capacity 1.5 – 10% Frequency response insensitivity 10 – 30 mHz 0.02 – 0.06% Frequency response deadband 0 – 500 mHz Droop 2-12% Table 4: Parameters for active power frequency response in FSM (explanation for Figure 5) Figure 5: Active power frequency response capability of power generating modules in FSM illustrating the case of zero deadband and insensitivity. Pref is the reference active power to which DP is related. DP is the change in active power output from the power generating module. fn is the nominal frequency (50 Hz) in the network and Df is the frequency deviation in the network.	CE: Active power range: 1.5 – 10% (minimum requirements) FRI: 10 mHz FRD: 0 – 200 mHz Droop: 12 PN is used as Pref for both SPG and PPM. N: Active power range: 1.5 – 10% (minimum requirements) FRI: 10 mHz FRD: 0 – 500 mHz Droop: 12 PN is used as Pref for both SPG and PPM.		R1
15	2	d	ii	the frequency response deadband of frequency deviation and droop must be able to be reselected repeatedly;	-		
15	2	d	iii	in the event of a frequency step change, the power generating module shall be capable of activating full active power frequency response, at or above the full line shown in Figure 6 in accordance with the parameters specified by each TSO (which shall aim at avoiding active power oscillations for the power generating module) within the ranges given in Table 5. The combination of choice of the parameters specified by the TSO shall take possible technology-dependent limitations into account;	PGM: 30 seconds		
15	2	d	iv	The initial activation of active power frequency response required shall not be unduly delayed. If the delay in initial activation of active power frequency response is greater than two seconds, the power generating facility owner shall provide technical evidence demonstrating why a longer time is needed. For power generating modules without inertia, the relevant TSO may specify a shorter time than two seconds. If the power generating facility owner cannot meet this requirement they shall provide technical evidence demonstrating why a longer time is needed for the initial activation of active power frequency response; ~~Figure 6: Active power frequency response capability. Pmax is the maximum capacity to which DP relates. DP is the change in active power output from the power generating module. The power generating module has to provide active power output DP up to the point DP1 in accordance with the times t1 and t2 with the values of DP1, t1and t2 being specified by the relevant TSO according to Table 5. t1 is the initial delay. t2 is the time for full activation.~~	As short as possible, must be justified if time > 2 seconds.		

15	2	d	v	the power generating module shall be capable of providing full active power frequency response for a period of between 15 and 30 minutes as specified by the relevant TSO. In specifying the period, the TSO shall have regard to active power headroom and primary energy source of the power generating module;	15 minutes.
15	2	d	vi	within the time limits laid down in point (v) of paragraph (2) (d), active power control must not have any adverse impact on the active power frequency response of power generating modules;	-
15	2	d	vii	the parameters specified by the relevant TSO in accordance with paragraphs 1, 2, 3points (i), (ii), (iii) and (v)5 shall be notified to the relevant regulatory authority. The modalities of that notification shall be specified in accordance with the applicable national regulatory framework; Parameters ranges or values Active power range related to maximum capacity (frequency response range) 1.5 – 10 % For power generating modules with inertia, the maximum admissible initial delay unless justified otherwise in line with Article 15 (2) (d) (iv) 2 seconds For power generating modules without inertia, the maximum admissible initial delay unless justified otherwise in line with Article 15 (2) (d) (iv) as specified by the relevant TSO. Maximum admissible choice of full activation time, unless longer activation times are allowed by the relevant TSO for reasons of system stability 30 seconds Table 5: Parameters for full activation of active power frequency response resulting from frequency step change (explanation for Figure 6).	
15	2	e		with regard to frequency restoration control, the power generating module shall provide functionalities complying with specifications specified by the relevant TSO, aiming at restoring frequency to its nominal value or maintaining power exchange flows between control areas at their scheduled values;	
15	2	f		with regard to disconnection due to underfrequency, power generating facilities capable of acting as a load, including hydro pump-storage power generating facilities, shall be capable of disconnecting their load in case of underfrequency. The requirement referred to in this point does not extend to auxiliary supply;	CE/DK1: 49.0 Hz N/DK2: 48.5 Hz
15	2	g		with regard to real-time monitoring of FSM:	-
15	2	g	i	to monitor the operation of active power frequency response, the communication interface shall be equipped to transfer in real time and in a secured manner from the power generating facility to the network control centre of the relevant system operator or the relevant TSO, at the request of the relevant system operator or the relevant TSO, at least the following signals: – status signal of FSM (on/off); – scheduled active power output; – actual value of the active power output; – actual parameter settings for active power frequency response; – droop and deadband;	Requirements and list specified, cf. A14(5)(d)(1) + (ii).
15	2	g	ii	the relevant system operator and the relevant TSO shall specify additional signals to be provided by the power generating facility by monitoring and recording devices in order to	Requirements and list specified, cf. A14(5)(d)(1) + (ii).

				verify the performance of the active power frequency response provision of participating power generating modules.		
15	3			With regard to voltage stability, type C power generating modules shall be capable of automatic disconnection when voltage at the connection point reaches levels specified by the relevant system operator in coordination with the relevant TSO. The terms and settings for actual automatic disconnection of power generating modules shall be specified by the relevant system operator in coordination with the relevant TSO.	Dx requirements. Overvoltage (step 3) = 1.2 pu for 100 ms Overvoltage (step 2) = 1.15 pu for 200 ms Overvoltage (step 1) = 1.1 pu for 60 seconds Undervoltage (step 1) = 0.9 pu for 60 seconds	
15	4			Type C power generating modules shall fulfil the following requirements relating to robustness:	-	
15	4	a		in the event of power oscillations, power generating modules shall retain steady-state stability when operating at any operating point of the P-Q-capability diagram;	-	
15	4	b		without prejudice to paragraph 4 and 5 of Article 13, power generating modules shall be capable of remaining connected to the network and operating without power reduction, as long as voltage and frequency remain within the specified limits pursuant to this Regulation;	-	
15	4	c		power generating modules shall be capable of remaining connected to the network during single-phase or three-phase auto-reclosures on meshed network lines, if applicable to the network to which they are connected. The details of that capability shall be subject to coordination and agreements on protection schemes and settings as referred to in point (b) of Article 14(5).	The facility must be designed to withstand transitory phase jumps of up to 20° in the point of connection without disconnecting.	
15	5			Type C power generating modules shall fulfil the following requirements relating to system restoration:	-	
15	5	a		with regard to black start capability:	-	
15	5	a	i	black start capability is not mandatory without prejudice to the Member State’s rights to introduce obligatory rules in order to ensure system security;	-	
15	5	a	ii	power generating facility owners shall, at the request of the relevant TSO, provide a quotation for providing black start capability. The relevant TSO may make such a request if it considers system security to be at risk due to a lack of black start capability in its control area;		
15	5	a	iii	a power generating module with black start capability shall be capable of starting from shutdown without any external electrical energy supply within a timeframe specified by the relevant system operator in coordination with the relevant TSO;	R-TSO prepares analysis of requirements, arranges for tenders and makes agreements with relevant market participants.	
15	5	a	iv	a power generating module with black start capability shall be able to synchronise within the frequency limits laid down in point (a) of Article 13(1) and, where applicable, voltage limits specified by the relevant system operator or in paragraph 2 of Article 16;(2);	-	

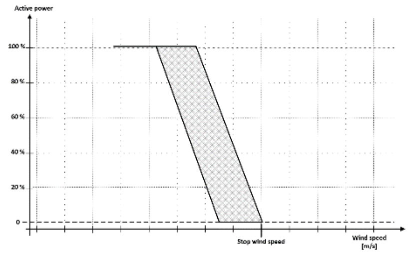
15	5	a	v	a power generating module with black start capability shall be capable of automatically regulating dips in voltage caused by connection of demand;	-		
15	5	a	vi	a power generating module with black start capability shall: – be capable of regulating load connections in block load; – be capable of operating in LFSM-O and LFSM-U, as specified in point (c) of paragraph 2 and Article 13(2); – control frequency in case of overfrequency and underfrequency within the whole active power output range between minimum regulating level and maximum capacity as well as at houseload level; – be capable of parallel operation of a few power generating modules within one island; and – control voltage automatically during the system restoration phase;	-		
15	5			with regard to the capability to take part in island operation:	-		
15	5	b	i	power generating modules shall be capable of taking part in island operation if required by the relevant system operator in coordination with the relevant TSO and: – the frequency limits for island operation shall be those established in accordance with point (a) of Article 13(1); – the voltage limits for island operation shall be those established in accordance with paragraph 3 of Article 15(3) or paragraph 2 of Article 13,(2), where applicable;	Type D facilities must be able to participate in area island operation.		
15	5	b	ii	power generating modules shall be able to operate in FSM during island operation, as specified in point (d) of paragraph 2. In the event of a power surplus, power generating modules shall be capable of reducing the active power output from a previous operating point to any new operating point within the P-Q-capability diagram. In that regard, the power generating module shall be capable of reducing active power output as much as inherently technically feasible, but to at least 55 % of its maximum capacity;	-		
15	5	b	iii	the method for detecting a change from interconnected system operation to island operation shall be agreed between the power generating facility owner and the relevant system operator in coordination with the relevant TSO. The agreed method of detection must not rely solely on the system operator's switchgear position signals;	ESKC changes operational status to "alert state". Detection PMU data with island operation detection module.		
15	5	b	iv	power generating modules shall be able to operate in LFSM-O and LFSM-U during island operation, as specified in point of paragraph 2 and Article 13(2).	-		
15	5	c		with regard to quick re-synchronisation capability:	-		
15	5	c	i	in case of disconnection of the power generating module from the network, the power generating module shall be capable of quick re-synchronisation in line with the protection strategy agreed between the relevant system operator in coordination with the relevant TSO and the power generating facility;	Quick re-synchronisation required for type D facilities.		
15	5	c	ii	a power generating module with a minimum re-synchronisation time greater than 15 minutes after its disconnection from any external power supply must be designed to trip to houseload from any operating point in its P-Q-capability diagram. In this case, the identification of houseload operation must not be based solely on the system operator's switchgear position signals;			

15	5	c	iii	power generating modules shall be capable of continuing operation following tripping to houseload, irrespective of any auxiliary connection to the external network. The minimum operation time shall be specified by the relevant system operator in coordination with the relevant TSO, taking into consideration the specific characteristics of prime mover technology.	SPGM: 0 min. PPM: 0 min. as re-synchronization time is < 15 minutes.		
15	6			Type C power generating modules shall fulfil the following general system management requirements:	-		
15	6	a		with regard to loss of angular stability or loss of control, a power generating module shall be capable of disconnecting automatically from the network in order to help preserve system security or to prevent damage to the power generating module . The power generating facility owner and the relevant system operator in coordination with the relevant TSO shall agree on the criteria for detecting loss of angular stability or loss of control;	The generation facility must be equipped with protection for detection of pole slip or loss of synchronism. If pole slip or loss of synchronism is detected, the generation facility must disconnect immediately to safeguard "system and facility safety". The protection functions used cannot affect the generation facility's "FRT properties" as the protective settings used are determined on the basis of simulations of relevant fault scenarios.		
15	6	b		with regard to instrumentation:	-		
15	6	b	i	Power generating facilities shall be equipped with a facility to provide fault recording and monitoring of dynamic system behaviour. This facility shall record the following parameters: – voltage; – active power; – reactive power; and – frequency. The relevant system operator shall have the right to specify quality of supply parameters to be complied with on condition that reasonable prior notice is given;	Facilities that provide ancillary services must be equipped with a PMU unit for verification of the specified service, including the generation facility's dynamic response.		
15	6	b	ii	the settings of the fault recording equipment, including triggering criteria and the sampling rates shall be agreed between the power generating facility owner and the relevant system operator in coordination with the relevant TSO;	Logging must be performed using electronic equipment that as a minimum can be configured to log relevant incidents for the signals below in the point of connection in case of faults in the public electricity supply grid. The facility owner must install logging equipment (fault recorder) in the point of connection which records, as a minimum: - Voltage of each phase of the facility - Current of each phase of the facility - Active power of the facility (can be computed values) - Reactive power of the facility (can be computed values) - Frequency of the facility		R1

					- Frequency deviations - Speed deviations (synchronous generator) - Activation of internal protective functions Specific measurement requirements are described in the grid connection agreement. Logging must be performed as correlated time series of measuring values from 10 seconds before an incident until 60 seconds after an incident. Minimum sample frequency of all fault logs must be 1 kHz. The specific settings for incident-based logging must be agreed with the transmission system operator upon commissioning of the facility. All measurements and data to be collected in accordance with TR 5.8.1 must be logged with a time stamp and an accuracy ensuring that such measurements and data can be correlated with each other and with similar recordings in the public electricity supply grid. Logs must be saved for at least three months from the time of the fault situation. However, the maximum number of incidents to be recorded is 100. Upon request, the electricity supply undertaking and the transmission system operator must be granted access to logged and relevant recorded information.		
15	6	b	iii	the dynamic system behaviour monitoring shall include an oscillation trigger specified by the relevant system operator in coordination with the relevant TSO, with the purpose of detecting poorly damped power oscillations;	Included in trigger signals from A15(6)(b)(ii)		
15	6	b	iv	the facilities for quality of supply and dynamic system behaviour monitoring shall include arrangements for the power generating facility owner, and the relevant system operator and the relevant TSO to access the information. The communications protocols for recorded data shall be agreed between the power generating facility owner, the relevant system operator and the relevant TSO;	File format: COMTRADE IEEE C37.111:1999, *IEEE Standard Common Format for Transient Data Exchange (COMTRADE) for Power Systems*		
15	6	c		with regard to the simulation models:	-		
15	6	c	i	at the request of the relevant system operator or the relevant TSO, the power generating facility owner shall provide simulation models which properly reflect the behaviour of the	Requirements, cf. Appendix 1.B.		R1

				power generating module in both steady-state and dynamic simulations (50 Hz component) or in electromagnetic transient simulations. The power generating facility owner shall ensure that the models provided have been verified against the results of compliance tests referred to in Chapters 2, 3 and 4 of Title IV, and shall notify the results of the verification to the relevant system operator or relevant TSO. Member States may require that such verification be carried out by an authorised certifier;			
15	6	c	ii	the models provided by the power generating facility owner shall contain the following sub-models, depending on the existence of the individual components: – alternator and prime mover; – speed and power control; – voltage control, including, if applicable, power system stabiliser ('PSS') function and excitation control system; – power generating module protection models, as agreed between the relevant system operator and the power generating facility owner; and – converter models for power park modules;	-		
15	6	c	iii	the request by the relevant system operator referred to in point (i) shall be coordinated with the relevant TSO. It shall include: – the format in which models are to be provided; – the provision of documentation on a model's structure and block diagrams; – an estimate of the minimum and maximum short circuit capacity at the connection point, expressed in MVA, as an equivalent of the network;	Requirements specified in A15(6)(c)(i).		
15	6	c	iv	the power generating facility owner shall provide recordings of the power generating module's performance to the relevant system operator or relevant TSO if requested. The relevant system operator or relevant TSO may make such a request, in order to compare the response of the models with those recordings;	-		
15	6	d		with regard to the installation of devices for system operation and devices for system security, if the relevant system operator or the relevant TSO considers that it is necessary to install additional devices in a power generating facility in order to preserve or restore system operation or security, the relevant system operator or relevant TSO and the power generating facility owner shall investigate that matter and agree on an appropriate solution;	System protection: SGM procedure: Requirements for synchronous generators' requirements for system protection are identified when POC has been assigned. PPM procedure: A facility must be equipped with system protection, i.e. an emergency control function which must be capable of very quickly regulating the active power supplied by a generation facility to one or more predefined set points based on a downward regulation order. The set points are determined by the electricity supply undertaking upon commissioning. The facility must have at least five different configurable control options. The following adjustment ranges are recommended as default values: 1. Up to 70% of rated power		

					2. Up to 50% of rated power 3. Up to 40% of rated power 4. Up to 25% of rated power 5. Up to 0% of rated power, i.e. the facility has shut down. Regulation must be commenced within 1 second and completed no later than 10 seconds after receiving a downward regulation order. If system protection comprises an order for an upward regulation, for example from step 4 (25%) to step 3 (40%), it is accepted that the design specifications for the facility's generators or other facility units may result in delayed completion of the order. Automatic downward regulation control function of active power at cut-out wind speed: A generation facility with wind as its primary energy form must be able to reduce active power generation if high wind speeds occur before the wind turbines' built-in protective functions are activated (cut-out wind speed). The generation facility must be capable of regulating active power to a random value in the interval from 100% to 10% of Pn. It must be possible to activate/deactivate the control function using orders. Downward regulation can be performed as continuous or discrete regulation. Discrete regulation must have a step size of maximum 25% of rated power within the hatched area shown in Figure x.		

					 The downward regulation headroom must be agreed with the electricity supply undertaking upon commissioning of the generation facility. The dimensions of the downward regulation headroom may depend on local wind conditions. The automatic downward control function is specified, at a minimum by: Wind speed - activation downward regulation [m/s], wind speed - 10% of Pn [m/s], wind speed - cutout [m/s]		
15	6	e		the relevant system operator shall specify, in coordination with the relevant TSO, minimum and maximum limits on rates of change of active power output (ramping limits) in both an up and down direction of change of active power output for a power generating module, taking into consideration the specific characteristics of prime mover technology;	Up: Min.: 1% Pn/min. Up: Max.: 20% of Pn, not, however, exceeding 60 MW/min. Down: Min.: 1% Pn/min. Down: Max.: 20% of Pn, not, however, exceeding 60 MW/min. Requirements for minimum and maximum gradients for active power changes apply, if other conditions/rules do not provide relevant gradients, including ancillary services, energy markets, etc.		
15	6	f		earthing arrangement of the neutral-point at the network side of step-up transformers shall comply with the specifications of the relevant system operator.	The star point must be insulated and installed so that it can be earthed directly or earthed through a reactance. Other requirements are defined in the grid dimensioning criteria for grids above 100 kV.		
General requirements for type D power-generating modules							
16	1			In addition to fulfilling the requirements listed in Article 13, except for Article 13(2)(b), (6) and (7), Article 14, except for Article 14(2), and Article 15, except for Article 15(3), type D power generating modules shall fulfil the requirements set out in this Article.	-		
16	2			Type D power generating modules shall fulfil the following requirements relating to voltage stability:	-		
16	2	a		with regard to voltage ranges:			

					-		
16	2	a	i	without prejudice to point (a) of Article 14(3) and point (a) of Article 13(3),paragraph 3 a power generating module shall be capable of staying connected to the network and operating within the ranges of the network voltage at the connection point, expressed by the voltage at the connection point related to the reference 1 pu voltage, and for the time periods specified in Tables 6.1 and 6.2;	**6.1: (110 – 300 kV)** **CE** 0.85 – 0.90 pu/ 60 min. 1.118 – 1.15 pu/ 60 min. **N** 1.05 – 1.1 pu/60 min. **6.2 (300 – 400 kV)** **CE** 0.85 – 0.90 pu/ 60 min. 1.05 – 1.1 pu/ 60 min. **N** 1.05 – 1.1 pu/ 60 min.		
16	2	a	ii	the relevant TSO may specify shorter periods of time during which power generating modules shall be capable of remaining connected to the network in the event of simultaneous overvoltage and underfrequency or simultaneous undervoltage and overfrequency;	n/a		
16	2	a	iii	notwithstanding the provisions of point (i), the relevant TSO in Spain may require power generating modules be capable of remaining connected to the network in the voltage range between 1.05 pu and 1.0875 pu for an unlimited period;	n/a		
16	2	a	iv	for the 400 kV grid voltage level (or alternatively commonly referred to as 380 kV level) the reference 1 pu value is 400 kV, for other grid voltage levels the reference 1 pu voltage may differ for each system operator in the same synchronous area;	-		
16	2	a	v	notwithstanding the provisions of point (i), the relevant TSOs in the Baltic synchronous area may require power generating modules to remain connected atto the 400kV network in the voltage range limits and for the time periods that apply in the Continental Europe synchronous area. --- Synchronous area Voltage range Time period for operation Continental Europe 0.85 pu – 0.90 pu 60 minutes 0.90 pu – 1.118 pu Unlimited 1.118 pu – 1.15 pu To be specified by each TSO, but not less than 20 minutes and not more than 60 minutes Nordic 0.90 pu – 1.05 pu Unlimited 1.05 pu – 1.10 pu 60 minutes Great Britain 0.90 pu–1.10 pu Unlimited Ireland and Northern Ireland 0.90 pu – 1.118 pu Unlimited Baltic 0.85 pu – 0.90 pu 30 minutes 0.90 pu – 1.118 pu Unlimited 1.118 pu – 1.15 pu 20 minutes ~~Table 6.1: The table shows the minimum time periods during which a power generating module must be capable of operating for voltages deviating from the reference 1 pu value at~~	n/a		

				~~the connection point without disconnecting from the network, where the voltage base for pu values is from 110 kV to 300 kV.~~ Synchronous area Voltage range Time period for operation Continental Europe 0.85 pu – 0.90 pu 60 minutes 0.90 pu – 1.05 pu Unlimited 1.05 pu – 1.10 pu To be specified by each TSO, but not less than 20 minutes and not more than 60 minutes Nordic 0.90 pu – 1.05 pu Unlimited 1.05 pu – 1.10 pu To be specified by each TSO, but not more than 60 minutes Great Britain 0.90 pu – 1.05 pu Unlimited 1.05 pu – 1.10 pu 15 minutes Ireland and Northern Ireland 0.90 pu – 1.05 pu Unlimited Baltic 0.88 pu – 0.90 pu 20 minutes 0.90 pu – 1.097 pu Unlimited 1.097 pu – 1.15 pu 20 minutes ~~Table 6.2: The table shows the minimum time periods during which a power generating module must be capable of operating for voltages deviating from the reference 1 pu value at the connection point without disconnecting from the network where the voltage base for pu values is from 300 kV to 400 kV.~~			
16	2	b		wider voltage ranges or longer minimum time periods for operation may be agreed between the relevant system operator and the power generating facility owner in coordination with the relevant TSO. If wider voltage ranges or longer minimum times for operation are economically and technically feasible, the power generating facility owner shall not unreasonably withhold an agreement;	Transmission system: currently not relevant		
16	2	c		Without prejudice to point (a), the relevant system operator in coordination with the relevant TSO shall have the right to specify voltages at the connection point at which a power generating module is capable of automatic disconnection. The terms and settings for automatic disconnection shall be agreed between the relevant system operator and the power generating facility owner.	Transmission system: currently not relevant Distribution system requirements. Overvoltage (step 3) = 1.2 pu for 100 ms Overvoltage (step 2) = 1.15 pu for 200 ms Overvoltage (step 1) = 1.1 pu for 60 seconds Undervoltage (step 1) = 0.9 pu for 60 seconds		
16	3			Type D power generating modules shall fulfil the following requirements in relation to robustness:			
16	3	a		with regard to fault-ride-through capability:			
16	3	a	i	power generating modules shall be capable of staying connected to the network and continuing to operate stably after the power system has been disturbed by secured faults.	Requirements, cf. Appendix 1.C		

<table>
<tr>
<td></td><td></td><td></td><td></td>
<td>That capability shall be in accordance with a voltage-against-time profile at the connection point for fault conditions specified by the relevant TSO.
The voltage-against-time-profile shall express a lower limit of the actual course of the phase-to-phase voltages on the network voltage level at the connection point during a symmetrical fault, as a function of time before, during and after the fault.
That lower limit shall be specified by the relevant TSO, using the parameters set out in Figure 3 and within the ranges set out in Tables 7.1 and 7.2 for type D power generating modules connected at or above the 110 kV level.
That lower limit shall also be specified by the relevant TSO, using parameters set out in Figure 3 and within the ranges set out in Tables 3.1 and 3.2 for type D power generating modules connected below the 110 kV level.;</td>
<td>
<table>
<tr><th colspan="4">CE – PPM - #3- A16(3)(a)</th></tr>
<tr><th colspan="2">Voltage (pu)</th><th colspan="2">Time [seconds]</th></tr>
<tr><td>U_{ret}:</td><td>0</td><td>t_{clear}:</td><td>0.15</td></tr>
<tr><td>U_{clear}:</td><td>0</td><td>t_{rec1}:</td><td>0.15</td></tr>
<tr><td>U_{rec1}:</td><td>0</td><td>t_{rec2}:</td><td>0.15</td></tr>
<tr><td>U_{rec2}:</td><td>0.85</td><td>t_{rec3}:</td><td>1.5</td></tr>
</table>
<table>
<tr><th colspan="4">CE – SPGM - #4- A16(3)(a)</th></tr>
<tr><th colspan="2">Voltage (pu)</th><th colspan="2">Time [seconds]</th></tr>
<tr><td>U_{ret}:</td><td>0</td><td>t_{clear}:</td><td>0.15</td></tr>
<tr><td>U_{clear}:</td><td>0.6</td><td>t_{rec1}:</td><td>0.15</td></tr>
<tr><td>U_{rec1}:</td><td>0.6</td><td>t_{rec2}:</td><td>0.75</td></tr>
<tr><td>U_{rec2}:</td><td>0.85</td><td>t_{rec3}:</td><td>1.5</td></tr>
</table>
<table>
<tr><th colspan="4">N – PPM - #5- A16(3)(a)</th></tr>
<tr><th colspan="2">Voltage (pu)</th><th colspan="2">Time [seconds]</th></tr>
<tr><td>U_{ret}:</td><td>0</td><td>t_{clear}:</td><td>0.15</td></tr>
<tr><td>U_{clear}:</td><td>0</td><td>t_{rec1}:</td><td>0.15</td></tr>
<tr><td>U_{rec1}:</td><td>0</td><td>t_{rec2}:</td><td>0.15</td></tr>
<tr><td>U_{rec2}:</td><td>0.9</td><td>t_{rec3}:</td><td>1.5</td></tr>
</table>
<table>
<tr><th colspan="4">N – SPGM - #6- A16(3)(a)</th></tr>
<tr><th colspan="2">Voltage (pu)</th><th colspan="2">Time [seconds]</th></tr>
<tr><td>U_{ret}:</td><td>0</td><td>t_{clear}:</td><td>0.15</td></tr>
<tr><td>U_{clear}:</td><td>0.6</td><td>t_{rec1}:</td><td>0.15</td></tr>
<tr><td>U_{rec1}:</td><td>0.6</td><td>t_{rec2}:</td><td>0.75</td></tr>
<tr><td>U_{rec2}:</td><td>0.9</td><td>t_{rec3}:</td><td>1.5</td></tr>
</table>
The voltage synchronous component must be considered in any voltage evaluation.
</td>
<td></td><td></td>
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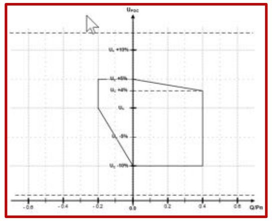
<tr>
<td>16</td><td>3</td><td>a</td><td>ii</td>
<td>each TSO shall specify the pre-fault and post-fault conditions for the fault-ride-through capability referred to in point (iv) of Article 14(3)(a). The specified pre-fault and post-fault conditions for the fault-ride-through capability shall be made publicly available;
Voltage parameters [pu] Time parameters [seconds]
Uret: 0 tclear: 0.14 – 0.15 (or 0.14 - 0.25 if system protection and secure operation so require)</td>
<td>A short-circuit catalogue specifies the method for calculating short-circuit power and calculates conditions in known connection points.</td>
<td></td><td></td>
</tr>
</table>

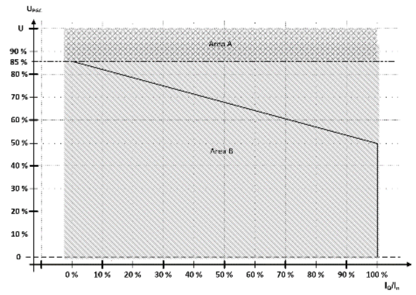
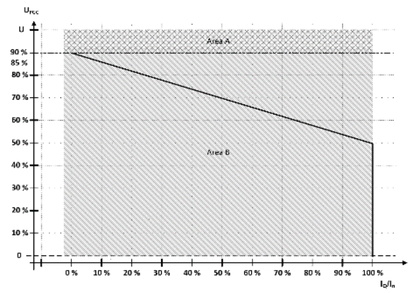
				Uclear: 0.25 trec1: tclear – 0.45 Urec1: 0.5 – 0.7 trec2: trec1 – 0.7 Urec2: 0.85 – 0.9 trec3: trec2 – 1.5 Table 7.1: Parameters for Figure 3 for fault-ride-through capability of synchronous power generating modules. Voltage parameters [pu] Time parameters [seconds] Uret: 0 tclear: 0.14 – 0.15 (or 0.14 - 0.25 if system protection and secure operation so require) Uclear: Uret trec1: tclear Urec1: Uclear trec2: trec1 Urec2: 0.85 trec3: 1.5 – 3.0 Table 7.2: Parameters for Figure 3 for fault-ride-through capability of power park modules.			
16	3	b		at the request of a power generating facility owner, the relevant system operator shall provide the pre-fault and post-fault conditions to be considered for fault-ride-through capability as an outcome of the calculations at the connection point as specified in point (iv) of Article 14(3)(a) regarding:	A14(3)(a)(iv)		
16	3	b	i	pre-fault minimum short circuit capacity at each connection point expressed in MVA;	A14(3)(a)(iv)		
16	3	b	ii	pre-fault operating point of the power generating module expressed as active power output and reactive power output at the connection point and voltage at the connection point; and	Facility properties: Facility tolerance is specified by Pn and Qmin.		
16	3	b	iii	post-fault minimum short circuit capacity at each connection point expressed in MVA;	A14(3)(a)(iv)		
16	3	c		fault-ride-through capabilities in case of asymmetrical faults shall be specified by each TSO.	The specified FRT requirements apply to symmetrical and asymmetrical faults, where the reference is the voltage synchronous component.		
				Additional requirements:	Robustness requirements for repeated faults: The facility owner shall ensure that the generation facility is protected against resulting mechanical and electrical effects from possible reconnection after symmetrical and asymmetrical faults in the transmission system. Measures taken in this connection must not compromise other properties specified for the generation facility.		
16	4			Type D power generating modules shall fulfil the following general system management requirements:	-		
16	4	a		with regard to synchronisation, when starting a power generating module, synchronisation shall be performed by the power generating facility owner only after authorisation by the relevant system operator;			
16	4	b		the power generating module shall be equipped with the necessary synchronisation facilities;	-		

16	4	c		synchronisation of power generating modules shall be possible at frequencies within the ranges set out in Table 2;	-		
16	4	d		the relevant system operator and the power generating facility owner shall agree on the settings of synchronisation devices to be concluded prior to operation of the power generating module. This agreement shall cover:	-		
16	4	d	i	voltage;	-		
16	4	d	ii	frequency;	-		
16	4	d	iii	phase angle range;	-		
16	4	d	iv	phase sequence;	-		
16	4	d	v	deviation of voltage and frequency.	-		
Requirements for type B synchronous power-generating modules							
17	1			Type B synchronous power generating modules shall fulfil the requirements listed in Articles 13, except for Article 13(2)(b), and 14.	-		
17	2			Type B synchronous power generating modules shall fulfil the following additional requirements relating to voltage stability:	-		
17	2	a		with regard to reactive power capability, the relevant system operator shall have the right to specify the capability of a synchronous power generating module to provide reactive power;	-		
17	2	b		with regard to the voltage control system, a synchronous power generating module shall be equipped with a permanent automatic excitation control system that can provide constant alternator terminal voltage at a selectable setpoint without instability over the entire operating range of the synchronous power generating module.	-		
17	3			With regard to robustness, type B synchronous power generating modules shall be capable of providing post-fault active power recovery. The relevant TSO shall specify the magnitude and time for active power recovery.	No further robustness response requirements are set than those specified in the other articles. Facility robustness properties must not be delayed or limited by a specific design based on this article.		
Requirements for type C synchronous power-generating modules							
18	1			Type C synchronous power generating modules shall fulfil the requirements laid down in Articles 13, 14, 15 and 17, except for Article 13 (2)(b) and 13(6), Article 14(2) and Article 17(2)(a).	-		
18	2			Type C synchronous power generating modules shall fulfil the following additional requirements in relation to voltage stability:	-		

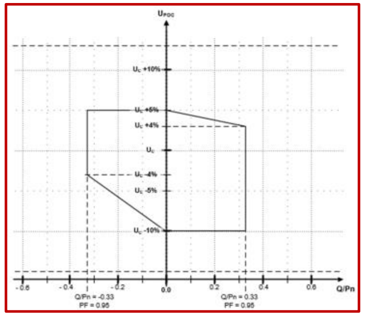
18	2	a		with regard to reactive power capability, the relevant system operator may specify supplementary reactive power to be provided if the connection point of a synchronous power generating module is neither located at the high-voltage terminals of the step-up transformer to the voltage level of the connection point nor at the alternator terminals, if no step-up transformer exists. This supplementary reactive power shall compensate the reactive power demand of the high-voltage line or cable between the high-voltage terminals of the step-up transformer of the synchronous power generating module or its alternator terminals, if no step-up transformer exists, and the connection point and shall be provided by the responsible owner of that line or cable.	The facility owner must compensate for the facility infrastructure's reactive power in situations where a facility is disconnected or is not generating active power.		
18	2	b		with regard to reactive power capability at maximum capacity:	-		
18	2	b	i	the relevant system operator in coordination with the relevant TSO shall specify the reactive power provision capability requirements in the context of varying voltage. For that purpose the relevant system operator shall specify a U-Q/Pmax-profile within the boundaries of which the synchronous power generating module shall be capable of providing reactive power at its maximum capacity. The specified U-Q/Pmax profile may take any shape, having regard to the potential costs of delivering the capability to provide reactive power production at high voltages and reactive power consumption at low voltages;	Requirements, cf. Appendix 1.D. 		
18	2	b	ii	the U-Q/Pmax-profile shall be specified by the relevant system operator in coordination with the relevant TSO, in conformity with the following principles: – the U-Q/Pmax-profile shall not exceed the U-Q/Pmax-profile envelope, represented by the inner envelope in Figure 7; – the dimensions of the U-Q/Pmax-profile envelope (Q/Pmax range and voltage range) shall be within the range specified for each synchronous area in Table 8; and – the position of the U-Q/Pmax-profile envelope shall be within the limits of the fixed outer envelope in Figure 7; Figure 7: U-Q/Pmax-profile of a synchronous power generating module. The diagram represents boundaries of a U-Q/Pmax-profile by the voltage at the connection point, expressed by the ratio of its actual value and its the reference 1 pu value, against the ratio of the reactive power (Q) and the maximum capacity (Pmax). The position, size and shape of the inner envelope are indicative. Synchronous area Maximum range of Q/Pmax Maximum range of steady-state voltage level in PU Continental Europe 0.95 0.225 Nordic 0.95 0.150 Great Britain 0.95 0.225 Ireland and Northern Ireland 1.08 0.218 Baltic 1.0 0.220 Table 8: Parameters for the inner envelope in Figure 7	-		
18	2	b	iii	the reactive power provision capability requirement applies at the connection point. For profile shapes other than rectangular, the voltage range represents the highest and lowest	-		

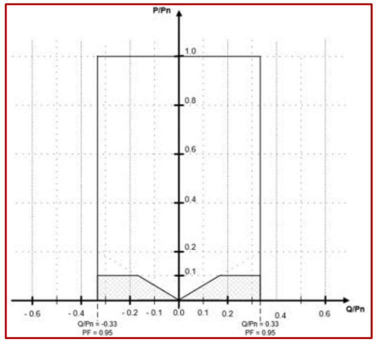
				values. The full reactive power range is therefore not expected to be available across the range of steady-state voltages;			
18	2	b	iv	the synchronous power generating module shall be capable of moving to any operating point within its U-Q/Pmax profile in appropriate timescales to target values requested by the relevant system operator;			R1
18	2	c		with regard to reactive power capability below maximum capacity, when operating at an active power output below the maximum capacity (P<Pmax), the synchronous power generating modules shall be capable of operating at every possible operating point in the P-Q-capability diagram of the alternator of that synchronous power generating module, at least down to minimum stable operating level. Even at reduced active power output, reactive power supply at the connection point shall correspond fully to the P-Q-capability diagram of the alternator of that synchronous power generating module, taking the auxiliary supply power and the active and reactive power losses of the step-up transformer, if applicable, into account.			
Requirements for type D synchronous power-generating modules							
19	1			Type D synchronous power generating modules shall fulfil the requirements laid down in Article 13, except for Article 13(2)(b), (6) and (~~6~~7), Article 14 except for Article 14(2), Article 15, except for Article 15(3), Article 16, Article 17, except for Article 17(2) and Article 18.	-		
19	2			Type D synchronous power generating modules shall fulfil the following additional requirements in relation to voltage stability:	-		
19	2	a		the parameters and settings of the components of the voltage control system shall be agreed between the power generating facility owner and the relevant system operator, in coordination with the relevant TSO;	See note at the end of this document.		
19	2	b		the agreement referred to in subparagraph (a) shall cover the specifications and performance of an automatic voltage regulator ('AVR') with regard to steady-state voltage and transient voltage control and the specifications and performance of the excitation control system. The latter shall include:	-		
19	2	b	i	bandwidth limitation of the output signal to ensure that the highest frequency of response cannot excite torsional oscillations on other power generating modules connected to the network;			
19	2	b	ii	an underexcitation limiter to prevent the AVR from reducing the alternator excitation to a level which would endanger synchronous stability;			
19	2	b	iii	an overexcitation limiter to ensure that the alternator excitation is not limited to less than the maximum value that can be achieved whilst ensuring that the synchronous power generating module is operating within its design limits;			
19	2	b	iv	a stator current limiter; and			
19	2	b	v	a PSS function to attenuate power oscillations, if the synchronous power generating module size is above a value of maximum capacity specified by the relevant TSO.	D facilities.		

19	3			The relevant TSO and the power generating facility owner shall enter into an agreement regarding technical capabilities of the power generating module to aid angular stability under fault conditions.	No further angle stability requirements are set than those specified in the other articles.		
Requirements for type B power park modules							
20	1			Type B power park modules shall fulfil the requirements laid down in Articles 13, except for Article 13(2)(b), and Article 14.	-		
20	2			Type B power park modules shall fulfil the following additional requirements in relation to voltage stability:	-		
20	2	a		with regard to reactive power capability, the relevant system operator shall have the right to specify the capability of a power park module to provide reactive power;			
20	2	b		the relevant system operator in coordination with the relevant TSO shall have the right to specify that a power park module be capable of providing fast fault current at the connection point in case of symmetrical (3-phase) faults, under the following conditions:	CE: IQ/In linear from 0% - 100 % at Upgc: 0.85 pu to 0.5 pu N: IQ/In linear from 0% - 100 % at Upgc: 0.9 pu to 0.5 pu Regulation must follow Figure X so that the additional reactive current (synchronous component) follows the characteristic with a tolerance of ±20% after 100 ms. In Figure X, the Y-axis indicates the applied control voltage for the 50 Hz component. With regard to the control concept for the delivery of added reactive current during a voltage dip, it is up to the PPM supplier to specify the control voltage used. This may be the minimum or maximum line-to-line voltage or phase voltage. Alternatively, the synchronous voltage component may be used as long as the characteristic shown in Figure X can be observed in the event of three-phase faults and after disconnection of all types of asymmetrical faults. In area B, the delivery of reactive current takes first priority, while the delivery of active power takes second priority. CE:		

					 N: 		
20	2	b	i	the power park module shall be capable of activating the supply of fast fault current either by: – ensuring the supply of the fast fault current at the connection point; or – measuring voltage deviations at the terminals of the individual units of the power park module and providing a fast fault current at the terminals of these units;	-		
20	2	b	ii	the relevant system operator in coordination with the relevant TSO shall specify: – how and when a voltage deviation is to be determined as well as the end of the voltage deviation; – the characteristics of the fast fault current, including the time domain for measuring the voltage deviation and fast fault current, for which current and voltage may be measured differently from the method specified in Article 2; – the timing and accuracy of the fast fault current, which may include several stages during a fault and after its clearance;	CE: Uc < 0.85 pu: start Uc > 0.85 pu: stop N: Uc < 0.9 pu: start Uc > 0.9 pu: stop Characteristics of fixed fault currents are specified in A20(2)(b).		
20	2	c		with regard to the supply of fast fault current in case of asymmetrical (1-phase or 2-phase) faults, the relevant system operator in coordination with the relevant TSO shall have the right to specify a requirement for asymmetrical current injection.	Currently no requirements for asymmetrical fault current injection.		
20	3			Type B power park modules shall fulfil the following additional requirements in relation to robustness:	-		

20	3	a		the relevant TSO shall specify the post-fault active power recovery that the power park module is capable of providing and shall specify:	After a transient start-up period, the facility must deliver normal production no later than five seconds after the operating conditions in the point of connection have reverted to the continuous operation range. Power control must be implemented with a gradient of at least 20% of the facility's nominal capacity.		
20	3	a	i	when the post-fault active power recovery begins, based on a voltage criterion;			
20	3	a	ii	a maximum allowed time for active power recovery; and			
20	3	a	iii	a magnitude and accuracy for active power recovery;			
20	3	b		the specifications shall be in accordance with the following principles:			
20	3	b	in	interdependency between fast fault current requirements according to points (b) and (c) of paragraph (2) and active power recovery;			
20	3	b	ii	dependence between active power recovery times and duration of voltage deviations;			
20	3	b	iii	a specified limit of the maximum allowed time for active power recovery;			
20	3	b	iv	adequacy between the level of voltage recovery and the minimum magnitude for active power recovery; and			
20	3	b	v	adequate damping of active power oscillations.			
Requirements for type C power park modules							
21	1			Type C power park modules shall fulfil the requirements listed in Articles 13, except for Article 13(2)(b) and (6), Article 14, except for Article 14(2), Article 15 and Article 20, except for Article 20(2)(a), unless referred to otherwise in point (v) of paragraph (3)(d).	-		
21	2			Type C power park modules shall fulfil the following additional requirements in relation to frequency stability:	-		
21	2	a		the relevant TSO shall have the right to specify that power park modules be capable of providing synthetic inertia during very fast frequency deviations;	No requirements are specified for synthetic inertia. Clarification of the demand for synthetic inertia will be initiated in the period 2018 – 2019.		
21	2	b		the operating principle of control systems installed to provide synthetic inertia and the associated performance parameters shall be specified by the relevant TSO.	n/a, cf. A21(2)(a).		
21	3			Type C power park modules shall fulfil the following additional requirements in relation to voltage stability:	-		
21	3	a		with regard to reactive power capability, the relevant system operator may specify supplementary reactive power to be provided if the connection point of a power park module is neither located at the high-voltage terminals of the step-up transformer to the voltage level of the connection point nor at the convertor terminals, if no step-up transformer exists. This supplementary reactive power shall compensate the reactive power demand of the high-voltage line or cable between the high-voltage terminals of the step-up transformer of the	The facility owner must compensate for the facility infrastructure's reactive power in situations where a facility is disconnected or is not generating active power.		

				power park module or its convertor terminals, if no step-up transformer exists, and the connection point and shall be provided by the responsible owner of that line or cable.			
21	3	b		with regard to reactive power capability at maximum capacity:			
21	3	b	i	the relevant system operator in coordination with the relevant TSO shall specify the reactive power provision capability requirements in the context of varying voltage. To that end, it shall specify a U-Q/Pmax-profile that may take any shape within the boundaries of which the power park module shall be capable of providing reactive power at its maximum capacity;	Requirements, cf. Appendix 1.D.  		
21	3	b	ii	the U-Q/Pmax-profile shall be specified by each relevant system operator in coordination with the relevant TSO in conformity with the following principles: – the U-Q/Pmax-profile shall not exceed the U-Q/Pmax-profile envelope, represented by the inner envelope in Figure 8; – the dimensions of the U-Q/Pmax-profile envelope (Q/Pmax range and voltage range) shall be within the values specified for each synchronous area in Table 9; – the position of the U-Q/Pmax-profile envelope shall be within the limits of the fixed outer envelope set out in Figure 8; and – the specified U-Q/Pmax profile may take any shape, having regard to the potential costs of delivering the capability to provide reactive power production at high voltages and reactive power consumption at low voltages; Figure 8: U-Q/Pmax-profile of a power park module. The diagram represents boundaries of a U-Q/Pmax-profile by the voltage at the connection point, expressed by the ratio of its actual value and its reference 1 pu value, against the ratio of the reactive power (Q) and the maximum capacity (Pmax). The position, size and shape of the inner envelope are indicative. Synchronous area Maximum range of Q/Pmax Maximum range of steady-state voltage level in PU Continental Europe 0.75 0.225 Nordic 0.95 0.150 Great Britain 0.66 0.225 Ireland and Northern Ireland 0.66 0.218 Baltic 0.80 0.220 Table 9: Parameters for the inner envelope in Figure 8			
21	3	b	iii	the reactive power provision capability requirement applies at the connection point. For profile shapes other than rectangular, the voltage range represents the highest and lowest values. The full reactive power range is therefore not expected to be available across the range of steady-state voltages;	-		

21	3	c		With regard to reactive power capability below maximum capacity:	-		
21	3	c	i	the relevant system operator in coordination with the relevant TSO shall specify the reactive power provision capability requirements and shall specify a P-Q/Pmax-profile that may take any shape within the boundaries of which the power park module shall be capable of providing reactive power below maximum capacity;	Requirements, cf. Appendix 1.D.  In this area, the reactive PPM properties may be limited if a reduced number of PPM units are in operation due to maintenance or faults. In this area, the reactive PPM properties may be limited if a reduced number of PPM units are in operation due to start-ups and shutdowns owing to primary energy, maintenance or faults.		
21	3	c	ii	the P-Q/Pmax-profile shall be specified by each relevant system operator in coordination with the relevant TSO, in conformity with the following principles: – the P-Q/Pmax-profile shall not exceed the P-Q/Pmax-profile envelope, represented by the inner envelope in Figure 9; – the Q/Pmax range of the P-Q/Pmax-profile envelope is specified for each synchronous area in Table 9; – the active power range of the P-Q/Pmax-profile envelope at zero reactive power shall be 1 pu; – the P-Q/Pmax-profile can be of any shape and shall include conditions for reactive power capability at zero active power; and – the position of the P-Q/Pmax-profile envelope shall be within the limits of the fixed outer envelope set out in Figure 9;			
21	3	c	iii	when operating at an active power output below maximum capacity (P<Pmax), the power park module shall be capable of providing reactive power at any operating point inside its P-Q/Pmax-profile, if all units of that power park module which generate power are technically available that is to say they are not out of service due to maintenance or failure, otherwise there may be less reactive power capability, taking into consideration the technical availabilities; ~~Figure 9: P-Q/Pmax-profile of a power park module. The diagram represents boundaries of a~~	-		

				~~P-Q/Pmax-profile at the connection point by the active power, expressed by the ratio of its actual value and the maximum capacity pu, against the ratio of the reactive power (Q) and the maximum capacity (Pmax). The position, size and shape of the inner envelope are indicative.~~			
21	3	c	iv	the power park module shall be capable of moving to any operating point within its P-Q/Pmax profile in appropriate timescales to target values requested by the relevant system operator;			
21	3	d		with regard to reactive power control modes:	-		
21	3	d	i	the power park module shall be capable of providing reactive power automatically by either voltage control mode, reactive power control mode or power factor control mode;	-		
21	3	d	ii	for the purposes of voltage control mode, the power park module shall be capable of contributing to voltage control at the connection point by provision of reactive power exchange with the network with a setpoint voltage covering 0.95 to 1.05 pu in steps no greater than 0.01 pu, with a slope having a range of at least 2 to 7 % in steps no greater than 0.5 %. The reactive power output shall be zero when the grid voltage value at the connection point equals the voltage setpoint;	-		
21	3	d	iii	the setpoint may be operated with or without a deadband selectable in a range from zero to +-5 % of reference 1 pu network voltage in steps no greater than 0.5 %;	-		
21	3	d	iv	following a step change in voltage, the power park module shall be capable of achieving 90 % of the change in reactive power output within a time t1 to be specified by the relevant system operator in the range of 1 to 5 seconds, and must settle at the value specified by the slope within a time t2 to be specified by the relevant system operator in the range of 5 to 60 seconds, with a steady-state reactive tolerance no greater than 5 % of the maximum reactive power. The relevant system operator shall specify the time specifications;	t1: 1-5 second(s): t1 = 1 second t2: 5-60 seconds: t2 = 5 seconds		
21	3	d	v	for the purpose of reactive power control mode, the power park module shall be capable of setting the reactive power setpoint anywhere in the reactive power range, specified by point (a) of Article 20(2) and by points (a) and (b) of Article 21(3), with setting steps no greater than 5 MVAr or 5 % (whichever is smaller) of full reactive power, controlling the reactive power at the connection point to an accuracy within plus or minus 5 MVAr or plus or minus 5 % (whichever is smaller) of the full reactive power;	-		
21	3	d	vi	for the purpose of power factor control mode, the power park module shall be capable of controlling the power factor at the connection point within the required reactive power range, specified by the relevant system operator according to point (a) of Article 20(2) or specified by points (a) and (b) of Article 1821(3), with a target power factor in steps no greater than 0.01. The relevant system operator shall specify the target power factor value, its tolerance and the period of time to achieve the target power factor following a sudden change of active power output. The tolerance of the target power factor shall be expressed through the tolerance of its corresponding reactive power. This reactive power tolerance shall be expressed by either an absolute value or by a percentage of the maximum reactive power of the power park module;	Target: Resolution of 0.01 Tolerance and time for new set point: For the control function, the accuracy of a completed control operation over a period of 1 minute may not deviate by more than 2% of Qn. If the power factor set point is to be changed, the change must be commenced within two seconds and completed not later than 30 seconds after receipt of an order to change the set point.		
21	3	d	vii	the relevant system operator, in coordination with the relevant TSO and with the power park module owner, shall specify which of the above three reactive power control mode options	Operational mode conditional on service delivery.		

				and associated setpoints is to apply, and what further equipment is needed to make the adjustment of the relevant setpoint operable remotely;	Production telegraph is used for operational and set point changes. For type D transmission-connected facilities, the maximum permissible value of the generator transformer/grid transformer's short-circuit reactance is set in cooperation with the transmission system operator, based on the facility owner's facility design studies and stability analyses. The permissible value must be stated in the grid connection agreement for the facility. Where tap changers are used on generator transformers/grid transformers, an agreement can be made with the transmission system operator that tap changers can be used to comply with requirements for reactive control capabilities. If such an agreement is made, this must be stated in the grid connection agreement for the facility. Where tap changers are used on generator transformers/grid transformers, the facility owner shall ensure proper coordination between the facility's reactive control functions and tap changer control.		
21	3	e		with regard to prioritising active or reactive power contribution, the relevant TSO shall specify whether active power contribution or reactive power contribution has priority during faults for which fault-ride-through capability is required. If priority is given to active power contribution, this provision has to be established no later than 150 ms from the fault inception;	Reactive power is prioritised.		
21	3	f		with regard to power oscillations damping control, if specified by the relevant TSO a power park module shall be capable of contributing to damping power oscillations. The voltage and reactive power control characteristics of power park modules must not adversely affect the damping of power oscillations.	PPM POD demands and performance to be clarified with stakeholder involvement in 2018/2019.		
Requirements for type D power park modules							
22				Type D power park modules shall fulfil the requirements listed in Articles 13, except for Article 13(2)(b), (6) and (~~6~~7), Article 14, except for Article 14(~~3~~2), Article 15, except for Article 15(3), Article 16, Article 20 except for Article 20(2)(a) and Article 21.	-		
General provisions							
23	1			The requirements set out in this Chapter apply to the connection to the network of AC-connected power park modules located offshore. An AC-connected power park module located offshore which does not have an offshore connection point shall be considered as an onshore power park module and thus shall comply with the requirements governing power park modules situated onshore.	-		
23	2			The offshore connection point of an AC-connected offshore power park module shall be specified by the relevant system operator.	-		

23	3			AC-connected offshore power park modules within the scope of this Regulation shall be categorised in accordance with the following offshore grid connection system configurations:	-		
23	3	a		configuration 1: AC connection to a single onshore grid interconnection point whereby one or more offshore power park modules that are interconnected offshore to form an offshore AC system are connected to the onshore system;	-		
23	3	b		configuration 2: Meshed AC connections whereby a number of offshore power park modules are interconnected offshore to form an offshore AC system and the offshore AC system is connected to the onshore system at two or more onshore grid interconnection points.	-		
Frequency stability requirements applicable to AC-connected offshore power park modules							
24				Frequency stability requirements applicable to AC-connected offshore power park modules The frequency stability requirements laid down respectively in Article 13(1) to (5), except for Article 13(2)(b), Article 15(2) and Article 21(2) shall apply to any AC-connected offshore power park module.	-		
Voltage stability requirements applicable to AC-connected offshore power park modules							
25	1			Without prejudice to point (a) of Article 14(3) and point (a) of Article 16(3), an AC-connected offshore power park module shall be capable of staying connected to the network and operating within the ranges of the network voltage at the connection point, expressed by the voltage at the connection point related to reference 1 pu voltage , and for the time periods specified in Table 10.	**CE** **(110 – 300 kV)** 1.118 – 1.15 pu/ 60 min. **(300 – 400 kV)** 1.05 – 1.1 pu/ 60 min. **N** **(300 – 400 kV)** 1.05 – 1.1 pu/60 min.		
25	2			Notwithstanding the provisions of paragraph 1, the relevant TSO in Spain may require AC-connected offshore power park modules to remain connected to the network in the voltage range between 1.05 pu and 1.0875 pu for an unlimited period.	n/a		
25	3			Notwithstanding the provisions of paragraph 1, the relevant TSOs in the Baltic synchronous area may require AC-connected offshore power park modules to remain connected atto the 400 kV network in the voltage range and for the time periods that apply to the Continental Europe synchronous area. -- Synchronous area Voltage range Time period for operation Continental Europe 0.85 pu – 0.90 pu 60 minutes 0.9 pu – 1.118 pu* Unlimited 1.118 pu – 1.15 pu* To be specified by each TSO, but not less than 20 minutes and not more than 60 minutes 0.90 pu – 1.05 pu** Unlimited 1.05 pu – 1.10 pu** To be specified by each TSO, but not less than 20 minutes and not more	n/a		

				than 60 minutes Nordic 0.90 pu – 1.05 pu Unlimited 1.05 pu – 1.10 pu* 60 minutes 1.05 pu – 1.10 pu** To be specified by each TSO, but not more than 60 minutes Great Britain 0.90 pu – 1.10 pu* Unlimited 0.90 pu – 1.05 pu** Unlimited 1.05 pu – 1.10 pu** 15 minutes Ireland and Northern Ireland 0.90 pu – 1.10 pu Unlimited Baltic 0.85 pu – 0.90 pu* 30 minutes 0.90 pu – 1.118 pu* Unlimited 1.118 pu – 1.15 pu* 20 minutes 0.88 pu – 0.90 pu** 20 minutes 0.90 pu – 1.097 pu** Unlimited 1.097 pu – 1.15 pu** 20 minutes * The voltage base for pu values is below 300 kV. ** The voltage base for pu values is from 300 kV to 400 kV. ~~Table 10: The table shows the minimum period during which an AC-connected offshore power park module must be capable of operating over different voltage ranges deviating from the reference 1 pu value without disconnecting.~~			
25	4			The voltage stability requirements specified respectively in points (b) and (c) of Article 20(2) as well as in Article 21(3) shall apply to any AC-connected offshore power park module.	-		
25	5			The reactive power capability at maximum capacity specified in point (b) of Article 21(3) shall apply to AC-connected offshore power park modules, except for Table 9. Instead, the requirements of Table 11 shall apply. Synchronous area Maximum range of Q/Pmax Maximum range of steady-state voltage level in PU Continental Europe 0.75 0.225 Nordic 0.95 0.150 Great Britain 0* 0.33** 0.225 Ireland and Northern Ireland 0.66 0.218 Baltic 0.8 0.22 *) at the offshore connection point for configuration 1 **) at the offshore connection point for configuration 2 Table 11: Parameters for Figure 8			
Robustness requirements applicable to AC-connected offshore power park modules							
26	1			The robustness requirements of power generating modules laid down in Article 15(4) and Article 20(3) shall apply to AC-connected offshore power park modules.	-		
26	2			The fault-ride-through capability requirements laid down in point (a) of Article 14(3) and point (a) of Article 16(3) shall apply to AC-connected offshore power park modules.	-		
System restoration requirements applicable to AC-connected offshore power park modules							

27				System restoration requirements applicable to AC-connected offshore power park modules The system restoration requirements laid down respectively in paragraph 4 of Article 14(4) and paragraph 5 of Article 15(5) shall apply to AC-connected offshore power park modules.	-		
General system management requirements applicable to AC-connected offshore power park modules							
28				General system management requirements applicable to AC-connected offshore power park modules The general system management requirements laid down in paragraph 5 of Article 14, paragraph 6 of(5), Article 15(6) and paragraph 4 of Article 16(4) shall apply to AC-connected offshore power park modules.	-		

Note to article 19(2)(a)

Article 19(2)(a)

Parameters and settings for voltage control components must be agreed and defined on the basis of specific analyses.

Facility components
This section specifies general stability requirements for generators and generator transformers in a facility (explanation).

Generator transformer/grid transformer
For type D facilities, the maximum permissible value for the generator transformer/grid transformer's short-circuit reactance is set in cooperation with the transmission system operator, based on the facility owner's facility design studies and stability analyses. The permissible value must be stated in the grid connection agreement for the facility.

Where tap changers are used on generator transformers/grid transformers, an agreement can be made with the transmission system operator that tap changers can be used to comply with requirements for reactive control capabilities. If such an agreement is made, this must be stated in the grid connection agreement for the facility.

Where tap changers are used on generator transformers/grid transformers, the facility owner shall ensure proper coordination between the facility's reactive control functions and tap changer control.

Generator
For type D facilities, short-circuit ratio and transient reactance requirements are set in cooperation with the transmission system operator, based on the facility owner's facility design studies and stability analyses. Permissible values must be stated in the grid connection agreement for the facility.

Excitation system

An SGM must be equipped with a continuously functioning automatic excitation system. The purpose is to ensure stable operation of the facility and allow it to contribute to regulating voltage and/or the reactive power balance in the public electricity supply grid.

The excitation system must be designed in conformity with European standard DS/EN 60034-16-1:2011 'Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Chapter 1: Definitions", [Ref. 21] and DS/CLC/TR 60034-16-3:2004 "Rotating electrical machines – Part 16: Excitation systems for synchronous machines – Section 3: Dynamic performance".

In the event of grid disturbances resulting in voltage reduction, it must be possible to overexcite the generator for at least 10 seconds to 1.6 times the excitation current and voltage at rated output and tgφ = 0.4 in the POC and rated operating voltage. If overexcitation properties depend on voltage in the POC, this property must be available at reduced grid voltages in the POC down to 0.6 pu.

The generator's overexcitation protection and other types of protection must be designed and set so that the generator's capacity for temporary overload can be utilised without overriding the generator's thermal limits.

The excitation system's limit functions must be selective with the facility's protective functions, thereby allowing for a brief utilisation of overload characteristics without the facility being disconnected.

The excitation system's time response (measured at the generator terminals) during idling (generator disconnected from the grid and operated at rated RPM) to a momentary 10% change to the reference voltage must be non-oscillatory and have a maximum rise time, as defined in DS/EN 60034-16-3, of 0.3 seconds for a static excitation system. For a rotating excitation system ('rotating exciter'), a time response of up to 0.5 seconds for a positive 10% change to the reference voltage is permitted, and correspondingly, up to 0.8 seconds for a negative 10% change to the reference voltage.

The excitation system's overshoot, measured at the generator terminals, as defined in DS/EN 60034-16-3, must not exceed 15% of the change during a momentary 10% change in the reference voltage.

Verification requirements excitation system
Verification of the above functional requirements for the excitation equipment must be attached as documentation. Simulations carried out, relevant measurements from the commissioning tests, function descriptions and 'as built' setting values must be enclosed with the full facility documentation.

Coordination between limit functions and protection functions must be documented in a P/Q graph of static and dynamic characteristics, containing trip times and activation levels.

Simulations, analyses and commissioning tests must be used to document that the excitation system has adequate dynamic characteristics.

Simulations done must include the following test scenarios:

1. RMS simulations of voltage dips in reference to the following function, where the machine's pre-fault set point is defined as UPOC = 1 pu, P = 1 pu, QPOC = 0.4 pu:
    a. Upoc(t) = $\begin{cases} 1\ pu\ where\ t < 0\ s \\ 0.6\ pu\ where\ t > 0\ s \end{cases}$
2. RMS simulation of step response test in the event of a momentary +/-10% change of the reference voltage, where the machine is operated at no load and at the rated RPM.

Completed commissioning must comprise the following tests:

1. Step response test in the event of a momentary +/-10% change of the reference voltage, where the machine is operated at no load and at the rated RPM.
2. Test of selectivity between underexcitation protection and underexcitation constraint. This is done by:
    a. Step response test, where it is attempted to force the machine to use an underexcitation set point outside the permissible underexcitation constraint range.
    b. Ramping-up of active power, from Pmin to Pn, where the machine, before the start of the test, is set to a fully underexcited set point.
3. Test of selectivity between overexcitation protection and overexcitation constraint. This is done by:
    a. Step response test, where it is attempted to force the machine to use an overexcitation set point outside the permissible overexcitation constraint range.
    b. Ramping-up of active power, from Pmin to Pn, where the machine, before the start of the test, is set to a fully overexcited set point.
4. Test of stator current constraint performance. This is done by:
    a. Step response test, where it is attempted to force the machine to use a set point outside the permissible current value for stator current constraint. The test is performed at reduced settings.

5. Test of the V/Hz constraint performance. This is done by:
    a. Step response test, where it is attempted to force the machine to use a set point outside the permissible ratio between voltage and frequency for the V/Hz constraint. The test is performed at reduced settings and with the machine operated at no load and at the rated RPM.
    b. Changing RPM, where it is attempted to force the machine to use a set point outside the permissible ratio between voltage and frequency for the V/Hz constraint. The test is performed at reduced settings and with the machine operated at no load and at the rated RPM before change to RPM.

PSS function

The PSS function must use input from rotor speed/grid frequency and active power (dual input) to derive the stability signal, where damping equipment of type IEEE PSS2B, see IEEE 421.5, is normative.

The PSS function must be adjusted to achieve a positive damping in the 0.2-0.7 Hz frequency range.

The phase of the supplied damping signal produced by the PSS function must be in phase with the change in speed for the generator rotor in the 0.2-0.7 Hz frequency range. Deviations of up to -30 degrees (under-compensated) are acceptable.

With the PSS function activated, damping of the facility’s power oscillations (exponentially declining function) must be faster than 1 second at all set points and for any distortion.

The facility’s natural damping of 'local mode' power oscillations must not be adversely affected by the PSS function.

The PSS function must be set so that changes to the facility's set point (active power) during normal operation, or in the event of a fault in, for example, a turbine regulator, boiler facility, feedwater facility or other auxiliary power facility must not cause the voltage on the high-voltage side of the generator transformer to change by more than 1%.

The PSS output signal must be limited so that activation of the PSS function does not lead to a change in generator voltage greater than +/- 5% of the generator's rated voltage. Limits may be automatically and dynamically reduced by the voltage regulator, for example when the excitation system's limit functions are activated.

The PSS function must be deactivated automatically when generated active power is less than 20% of rated output.
It must be possible to connect and disconnect the PSS function. When the PSS function is disconnected, an alarm must be set off.

Verification requirements PSS function

Compliance with the above functional requirements for the PSS function must be enclosed as documentation. Simulations carried out, relevant measurements from the commissioning tests, function descriptions and ‘as built’ setting values must be enclosed with the full facility documentation.

Simulations, analyses and commissioning tests must be used to document that the setting values used give the PSS function and the entire excitation system satisfactory dynamic characteristics.

The simulations performed must include the test scenarios below. With the exception of test 5, these must be simulated both with the PSS function activated and deactivated:

1. Verification of the frequency characteristic, including correct phase compensation for the entire excitation system, in the form of Bode plots for amplification and phase.
2. Step response to a momentary +/- 5% change to the reference voltage. Simulations must be performed for various set points, e.g. 25%, 50%, 75% and 100% of the facility's rated power.
3. Generator-near short circuit
4. Disconnection of a line with the change in the public electricity supply grid moving from the strongest to the weakest grid configuration (short-circuit power) Simulations must be performed for various set points, e.g. 25%, 50%, 75% and 100% of the facility's rated power.
5. A change to the generator's supplied mechanical power from the drive system in relation to the functions below (PSS device must be active):
    a. Sine function, p(t) = $A \cdot Sin(\omega \cdot t), A = 0.1\ pu, \omega = 2 \cdot \pi \cdot \frac{1}{60}\ rad$

b. Ramp function, $p(t) = \begin{cases} 0\ pu\ where\ t < 0\ s \\ 0.25 \cdot t\ pu\ where\ 0\ sec < t \leq 4\ s \\ 1\ pu\ where\ t > 4\ s \end{cases}$

c. Step function, $p(t) = \begin{cases} 1\ pu\ where\ t < 0\ s \\ 0.6\ pu\ where\ t > 0\ s \end{cases}$

Completed commissioning must comprise the following tests:

1. Measurements of phase and gain (bode plot) for the transfer function Vt(s)/Vref(s) with PSS function deactivated and SGM operated "off-grid", at rated RPM and terminal voltage.
2. Measurements of phase and gain (bode plot) for the transfer function Vt(s)/Vref(s) with PSS function deactivated and SGM operated "on-grid", using a set point as close to P = 0 and Q = 0 as possible.
3. Measurement of transfer function for the PSS function.
4. Step response test of a momentary +/- 5% change to the reference voltage. The test is done for different set points, e.g. 25%, 50%, 75% and 100% of the facility's rated power with the PSS function both activated and deactivated.
5. Increase of PSS gain by a factor 3 of the proposed value.

Reactive power control functions

The following requirements are set for reactive power and voltage control functions.

The control functions for Q control, power factor and voltage control are mutually exclusive, which means that only one of the three functions can be activated at a time.

Q control

The accuracy of a completed or continuous regulation relating to the Q control function must not deviate by an average fault scale < 3% of Qn measured over a period of 1 minute. The facility must be able to receive a set point with a minimum Q resolution of 100 kVAr.

Power factor control

The accuracy of a completed or continuous regulation relating to the power factor control function must not deviate by an average fault scale < 3% of Qn measured over a period of 1 minute.

The current Q value must be recalculated using the facility's current power factor set point.

The facility must be able to receive a set point with a minimum power factor accuracy of 0.01.

Automatic voltage control (AVR)

The accuracy of a completed change or continuous regulation, including set point accuracy, must not deviate by more than 0.5% of the voltage control set point.

The facility must be able to receive a voltage set point with a minimum resolution of 0.1 kV.

It must be possible to set the droop for automatic voltage control to a value in the range of 2-8% inclusive.