Disclaimer for the English translation of Odobritev Predloga neizčrpnih zahtev iz Uredbe Komisije (EU) 2016/631

This document is an English translation of Odobritev Predloga neizčrpnih zahtev iz Uredbe Komisije (EU) 2016/631, Agencija za energijo Republike Slovenije, 19.11.2018 ("Approval of the proposals for the non-exhaustive requirements of Commission Regulation 2016/631" by Slovene Energy Agency).

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Annex 1: FREQUENCY STABILITY

Article 13(1)(a)(i): Operating frequency ranges of the power-generating module

General requirements regarding operating frequency ranges of the power-generating module and the time period for operation:

Frequency range	Time period for operation
47.5 Hz-48.5 Hz	at least 30 minutes
48.5 Hz-49.0 Hz	at least 30 minutes
49.0 Hz-51.0 Hz	unlimited
51.0 Hz-51.5 Hz	30 minutes

Article 13(1)(b): Rate of change of frequency (RoCoF)

1. The power-generating module (PGM) shall stay connected to the network and operate stably at the rate of change of frequency (RoCoF) up to the value of at least ±2 Hz/s with a 500 ms window based on the moving average with the accuracy of the RoCoF measurement of at least ±10 mHz/s.
   Type C and type D power-generating modules which take part in the power system restoration scheme/plan (bottom-up approach or in island operation or during the transition into island operation), or which are connected to the part of the network which is exposed to higher risks/probability of transitioning into island operation, are required to have the capability of staying connected to the network and operating at a rate of change of frequency up to the value of at least ±5 Hz/s.

2. The rate-of-change-of-frequency-type loss of mains protection is not foreseen. If the power-generating module owner wishes to implement the said protection, the latter shall be set at the rate of change of frequency (RoCoF) of minimum ±5 Hz/s with a 500 ms moving average window.

Article 13(2)(a): Limited frequency sensitive mode – overfrequency (LFSM-O)

The following requirements apply to power-generating modules, Figure 1:

1. The frequency threshold for the limited frequency sensitive mode – overfrequency (LFSM-O) shall be set as follows: $f_1 = 50.2$ Hz or at overfrequency $\Delta f_1 = +\ 200$ mHz.
2. The droop settings for the limited frequency sensitive mode – overfrequency (LFSM-O) shall be set as follows: $s_2 = 5\%$ and shall be adjustable within the range of 2% and 12%.
3. The frequency response initial delay must be as short as possible, as soon as technically feasible (without any intentional delay).
4. The frequency measurement accuracy shall be at least ±50 mHz with a 100 ms moving average window.

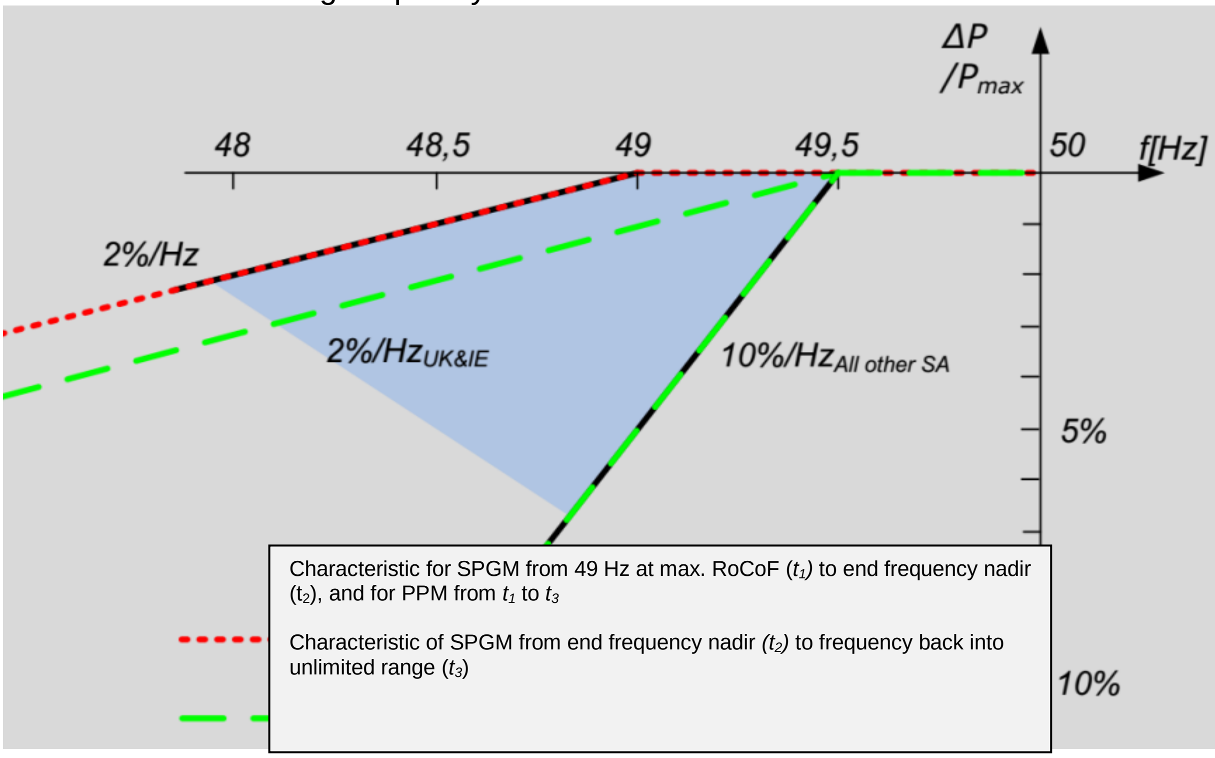
Once the LFSM-O threshold is reached the following shall apply to power park modules: $P_{ref} = P_{max}$ (the reference active power equals the maximum capacity of power park module), Figure 1.

Article 13(4)(a)(b), 13(5)(a)(b): The admissible active power reduction from maximum output with falling frequency and the applicable ambient conditions

The following shall apply to power-generating modules:

1. The maximum admissible active power reduction from maximum output (maximum capacity - P_{max}) with falling frequency as shown in Figure 2.

Figure 2: The maximum admissible active power reduction from maximum output with falling frequency.



Taking into account the power system needs and technological limitations, two profiles are specified, each of them separately covering:
a) a transient state of the power-generating module (time period between t_1 and t_2) and
b) a steady state (time period between t_2 and t_3).
If there are no technical limitations for maintaining the active power with falling frequency, the active power reduction is not permitted.
Table 1 covers the requirement in transient state during which it is required that the power-generating module (with falling frequency) does not exceed the reduction rate of 2% of the maximum active power per Hz (2% P_{max}/Hz), for at least 30 seconds, which enables the activation of other frequency regulating systems. In the steady state (30 seconds after the occurrence of the incident), the power-generating module may, if necessary, apply the maximum active power reduction, not exceeding the reduction rate of 10% of the maximum active power per Hz (10% P_{max}/Hz).

Table 1: The maximum admissible active power reduction from maximum active power output with falling frequency for the power-generating module (PGM): synchronous power-generating module (SPGM) and power park module (PPM).

	Parameters	**SPGM**	**PPM**
Transient state	frequency threshold	49 Hz	49 Hz
	slope	≤ 2% P_{max}/Hz	≤ 2% P_{max}/Hz
	t_1	≤ 2 s	≤ 2 s
	t_2	30 s	30 s
Steady state	frequency threshold	49.5 Hz	49 Hz
	slope	≤ 10% P_{max}/Hz	≤ 2% P_{max}/Hz
	t_3	30 min	30 min

2. Taking into account the technical capability of power-generating modules (standard ambient conditions) the applicable ambient conditions are specified at:
   a. a temperature of: 25° C
   b. an altitude: between 0 m and 600 m
   c. humidity levels: between 15 and 20 g H_2O/kg

   The power-generating module is required to provide the expected characteristics at the following set of temperatures [-10°C, 0°C, 15°C, 25°C, 30°C, 40°C]. This does not mean that the aforementioned requirement (the maximum admissible active power reduction from maximum output with falling frequency) has to be met for the whole set of temperatures. However, this information is important for a transmission system operator to be able to size reserves (frequency containment reserves, frequency restoration reserves and replacement reserves) as well as the underfrequency load shedding scheme and eventually minimum power system inertia. Furthermore, the provision of this information will support the verification of compliance of the power-generating module with the defined requirement.

Article 13(6): Requirements for equipment to make the facility operable remotely (cessation of active power output within five seconds following an instruction being received at the input port)

The type of equipment to make the facility operable remotely shall be determined in *The operational notification procedure for connection.*

Article 13(7): Conditions under which the power-generating module shall be able to connect automatically to the network

Technical conditions of type A and type B power-generating module under which it shall be able to connect automatically to the network:

1. Voltage range at the network connection point: 0.9 p.u. $\leq U \leq$ 1.1 p.u., and shall be adjustable within the range of 0.85 p.u. $\leq U \leq$ 1.1 p.u.
2. Frequency range: 49.9 Hz $\leq f \leq$ 50.1 Hz, and shall be adjustable within the range of 47.5 Hz $\leq f \leq$ 51.0 Hz.
3. The command at the logic interface (input port) of the power-generating module in order to cease active power output is not active.
4. Observation time (time within which all the above conditions have to be met without interruptions): $T_{observation}$ = 60 s, and shall be adjustable within the range of 0 s and 300 s.
5. Maximum admissible gradient of increase in active power output: $\Delta P_{Ramp\text{-}up\ limit} \leq 20\ \%\ P_{max}$/min and shall be adjustable within the range of up to $\Delta P_{Ramp\text{-}up\ limit} \leq 20\ \%\ P_{max}$/min.

An automatic connection to the network for type C power-generating modules is prohibited unless specified otherwise by the relevant system operator in coordination with the relevant transmission system operator. An automatic connection to the network depends on the individual authorisation determined in network connection agreements.

Article 14(2)(b): Requirements for equipment to make active power output operable remotely (the control with the aim to reduce the active power output following an instruction being received at the input port)

The type of additional equipment to make the active power output operable remotely shall be determined in *The operational notification procedure for connection.*

Article 15(2)(a)(b):
(a) Active power setpoint controllability and control range
(b) Manual local measures for cases where the automatic remote control devices are out of service

Active power setpoint controllability and control range

With regard to active power controllability and the control range, the power-generating module control system shall be capable of:

1. adjusting the active power output of the power-generating module (at the connection point of the PGM to the network) to a newly set value (the active power output setpoint of the PGM) within the time period:
    a. less than 15 minutes **when increasing** the SPGM active power. For SPGM the following dP/dt shall apply:
        i. HPP: dP/dt ≥ 40% P_{max}/min
        ii. OCGT: dP/dt ≥ 10 - 20% P_{max}/min
        iii. other SPGMs: dP/dt ≥ 5% P_{max}/min
    b. less than 1 minute **when increasing** the PPM active power. For PPM the following shall apply: dP/dt ≥ 200% P_{max}/min.
2. reaching the new setpoint subject to the availability of the prime mover resource for the power-generating module, referring to the new setpoint within the tolerance range of: ±1.5% P_{max}

P… active power output of the power-generating module at the connection point to the network.

The required dP/dt values shall be lower if the require by transmission system operator.

Manual local measures for cases where the automatic remote control devices are out of service

Type C PGM
In cases where the remote automatic devices are out of service:

1. The required tolerance to reach the active power setpoint shall be ≤ 10% P_{max}.
2. The time required to reach the active power setpoint shall be ≤ 6 hours.

Type D PGM
In cases where the remote automatic devices are out of service:

1. The required tolerance to reach the active power setpoint shall be ≤ 5% P_{max}.
2. The time required to reach the active power setpoint shall be ≤ 60 min.

Article 15(2)(c)(i): Limited frequency sensitive mode – underfrequency (LFSM- U)

The following requirements apply to type C and type D power-generating modules, Figure 4:

1. The frequency threshold for the limited frequency sensitive mode – underfrequency (LFSM-U) shall be set as follows: f_1= 49.8 Hz or at overfrequency Δf1 = - 200 mHz.
2. The droop settings for the limited frequency sensitive mode – underfrequency (LFSM-U) shall be as follows: s_2 = 5% and shall be adjustable within the range of 2% and 12%. The droop settings shall enable different settings for LFSM-U and LFSM-O mode.
3. The frequency response initial delay must be as short as possible, as soon as technically feasible (without an intentional delay).
4. The frequency measurement accuracy shall be at least ± 50 mHz with a 100 ms moving average window.

Once the LFSM-U threshold is reached the following shall apply to power park modules: $P_{ref} = P_{max}$ (the reference active power equals the maximum capacity of power park module), Figure 4.

Article 15(2)(d)(i)(iii)(iv)(v): Frequency sensitive mode (FSM)

15(2)(d)(i)
Parameters for the active power frequency response in the frequency sensitive mode (explanation for Figure 5):

Parameters		Ranges and values
Active power ranges related to maximum capacity $\frac{\lvert\Delta P_1\rvert}{P_{max}}$		Requirement as to the parameter $\frac{\lvert\Delta P_1\rvert}{P_{max}}$ setting: a) in the event of failure of FCR market the following shall apply for all type C and type D PGMs: 10% $P_{max} \geq \frac{\lvert\Delta P_1\rvert}{P_{max}} \geq$ 2% P_{max} or as agreed with the transmission system operator, b) in the event of operation of FCR market the type C and type D PGM shall have the $\frac{\lvert\Delta P_1\rvert}{P_{max}}$ in the range between 1.5% P_{max} and 10% P_{max}.
Frequency response insensitivity	$\lvert\Delta f_i\rvert$	10 mHz
	$\frac{\lvert\Delta f_i\rvert}{f_n}$	0.02%
Frequency response deadband		0 mHz and shall be adjustable between 0 and 500 mHz (the total sum of frequency response insensitivity, potential delay and frequency response deadband is limited to ≤ 10 mHz). The transition between FSM and LFSM shall be without delay and frequency response deadband ranges.
Droop s_1		Adjustable between 2 – 12 % to ensure the full activation of $\frac{\lvert\Delta P_1\rvert}{P_{max}}$ at a frequency of 200 mHz.

The following shall apply for PPMs: $P_{ref} = P_{max}$ (the reference active power equals the maximum capacity of power park module), Figure 5.

15(2)(d)(iii)(iv)
The characteristic of the full active power activation timing as a response to the frequency step change, Figure 6, shall be defined as follows:

- t_1: max. 2 seconds for PGM with inherent inertia and max. 500 milliseconds for PGM without inherent inertia;
- t_2: max. 30 seconds (15 seconds at a 50% of the fully/completely activated active power).

The power-generating module shall be able to provide the full active power as a response to the frequency change for at least 15 minutes.
The frequency measurement accuracy shall be at least ±10 mHz with a 100–200 ms moving average window.

15(2)(d)(v)
The power-generating module shall be capable of to providing full active power frequency response for a period of at least 15 minutes. In specifying the period, the TSO shall have regard to active power headroom and primary energy source of the power-generating module.

Article 15(2)(e): Frequency restoration control

The power-generating module shall provide frequency control restoration functionalities complying with specifications of the relevant TSO, aiming at restoring frequency to its nominal value and maintaining power exchange flows between control areas at their scheduled value. To this aim the power-generating module shall provide adequate communication interfaces and equipment enabling the implementation of this service. In the framework of *The operational notification procedure for connection* the relevant system operator shall, in coordination with the transmission system operator, specify the required scope of control as well as the required response characteristics to be complied with by the power-generating module. The TSO's requirements are further specified in the document which sets out the conditions and requirements for the power system balancing service providers.

Annex 2: VOLTAGE STABILITY

Article 15(3): Ability of automatic disconnection when the voltage at the connection point reaches specified values

Type C power-generating module shall be disconnected automatically from the network when the following voltage values at the PGM's connection point are exceeded:

Parameter	Maximum allowed time of operation (s)	Settings
Overvoltage protection (level 2)	0.2	U_n + 15%
Overvoltage protection (level 1)	2.0	U_n + 11%
Undervoltage protection (level 1)	2.0	U_n – 15%
Undervoltage protection (level 2)	0.2	U_n – 30%

The maximum allowed time of operation is the total operation time of the protection and protection switch (the circuit breaker).

Article 16(2)(a)(i): Voltage ranges

Type D power-generating modules connected to voltages between 110 kV and 300 kV in the voltage range between 1.118 p.u. and 1.15 p.u. shall have the capacity to operate in this voltage range for at least 60 minutes.
Type D power-generating modules connected to voltages between 300 kV and 400 kV in the voltage range between 1.05 p.u. and 1.1 p.u. shall have the capacity to operate in this voltage range for at least 60 minutes.

Article 16(2)(a)(ii): Operation voltage ranges in the event of overvoltage and underfrequency or undervoltage and overfrequency

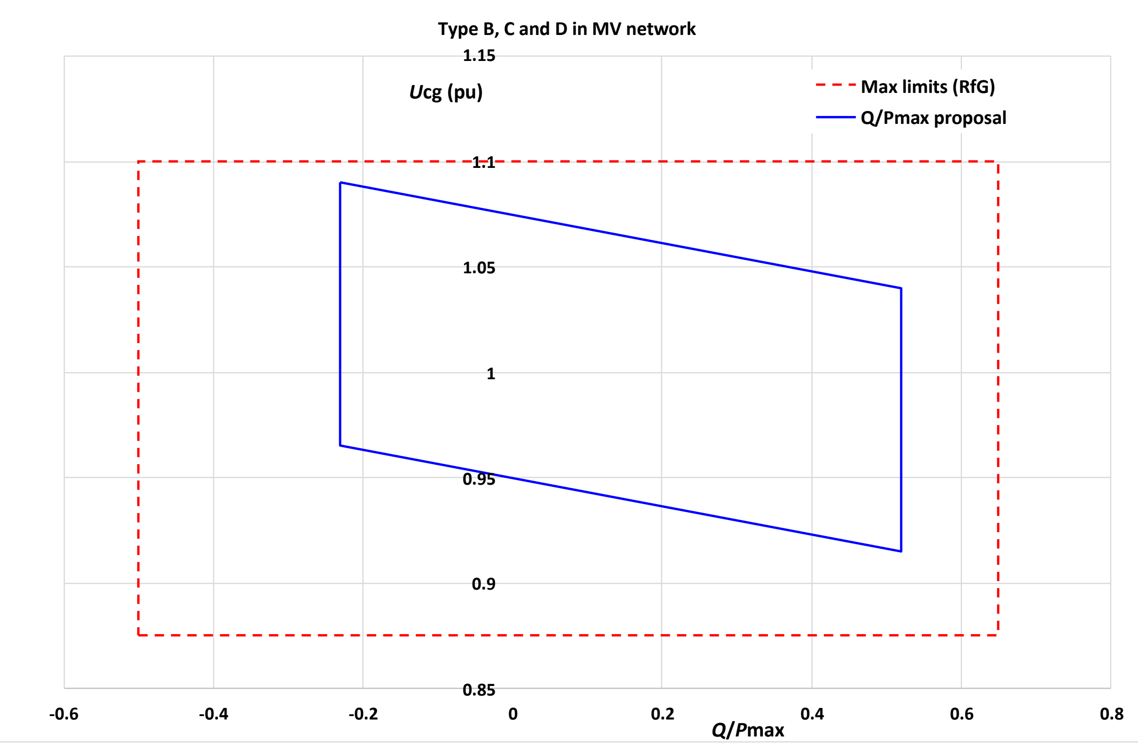
Protection setting:

$$\frac{U}{f} \leq 120\ \% \frac{U_n}{f_n}$$

Time delay setting of protection operation (time during which the value has to be exceeded without interruptions): t = 5 s.

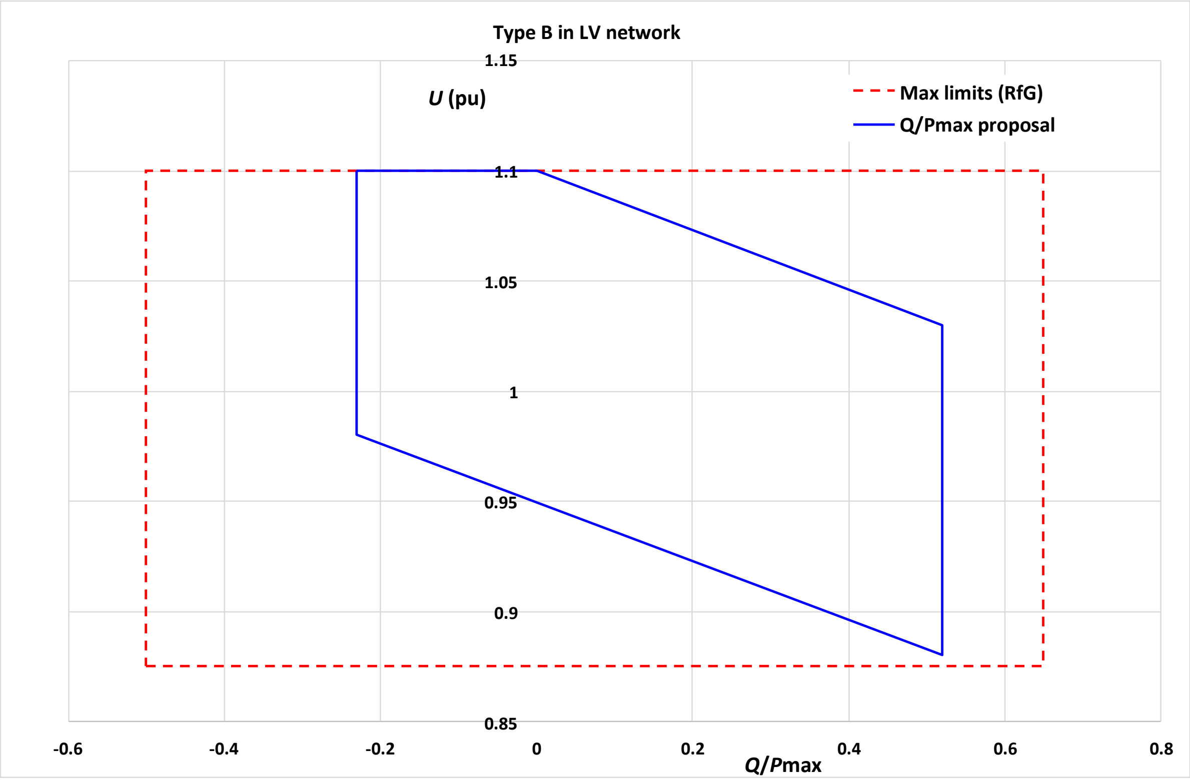
Article 17(2)(a); 20(2)(a): Capability of power-generating module to provide reactive power (U-Q/P_{max} profile)

Reactive power capability characteristic for all **type B PGMs (SPGM and PPM)** connected to the MV level:



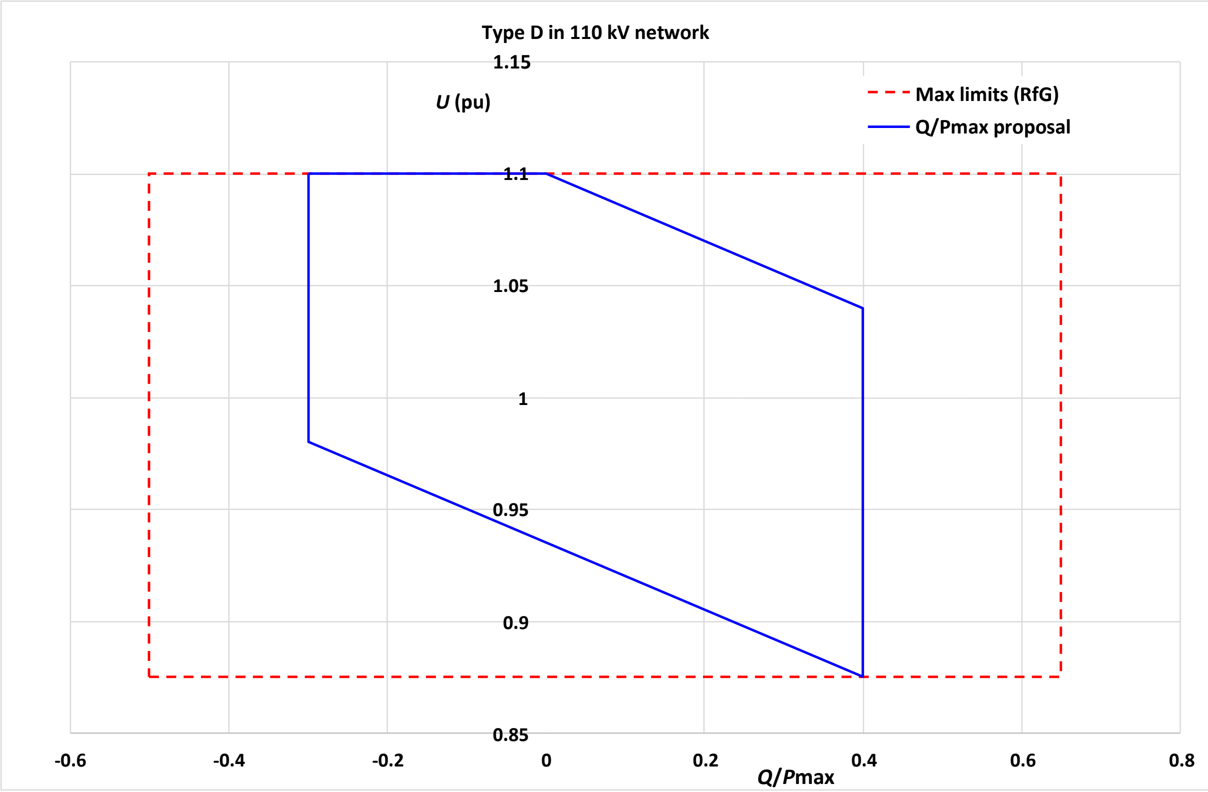
U_{cg} is the agreed voltage specified by the relevant network system operator.

Reactive power capability characteristic for all **type B PGMs (SPGM and PPM)** connected to the LV level:

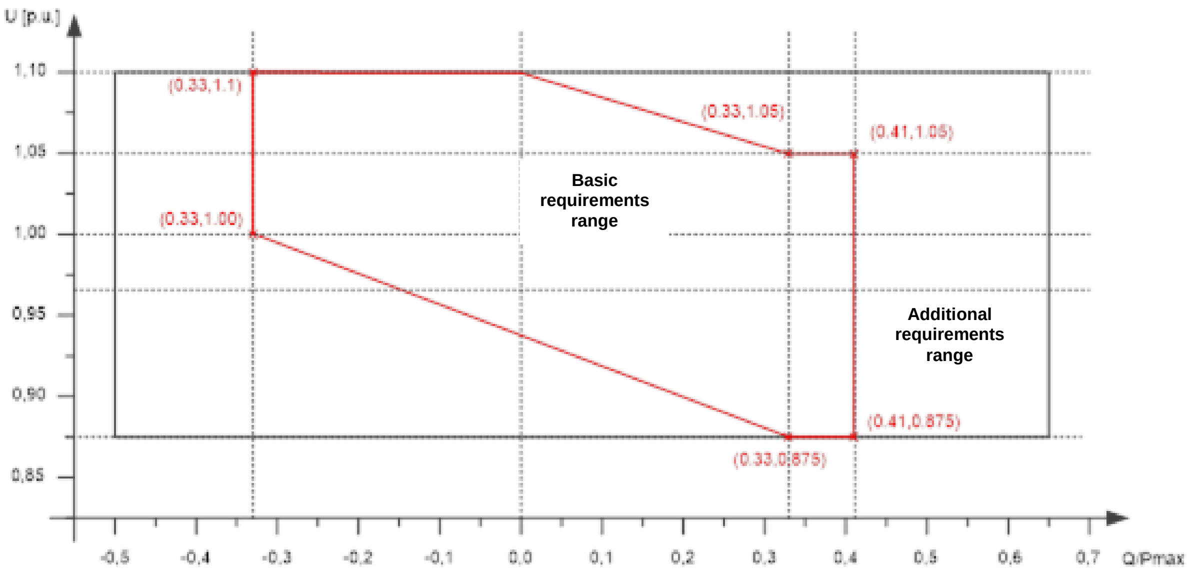


Article 18(2)(b)(i)(ii): Capability of synchronous power-generating module to provide reactive power at maximum active power (U-Q/P_{max} profile)

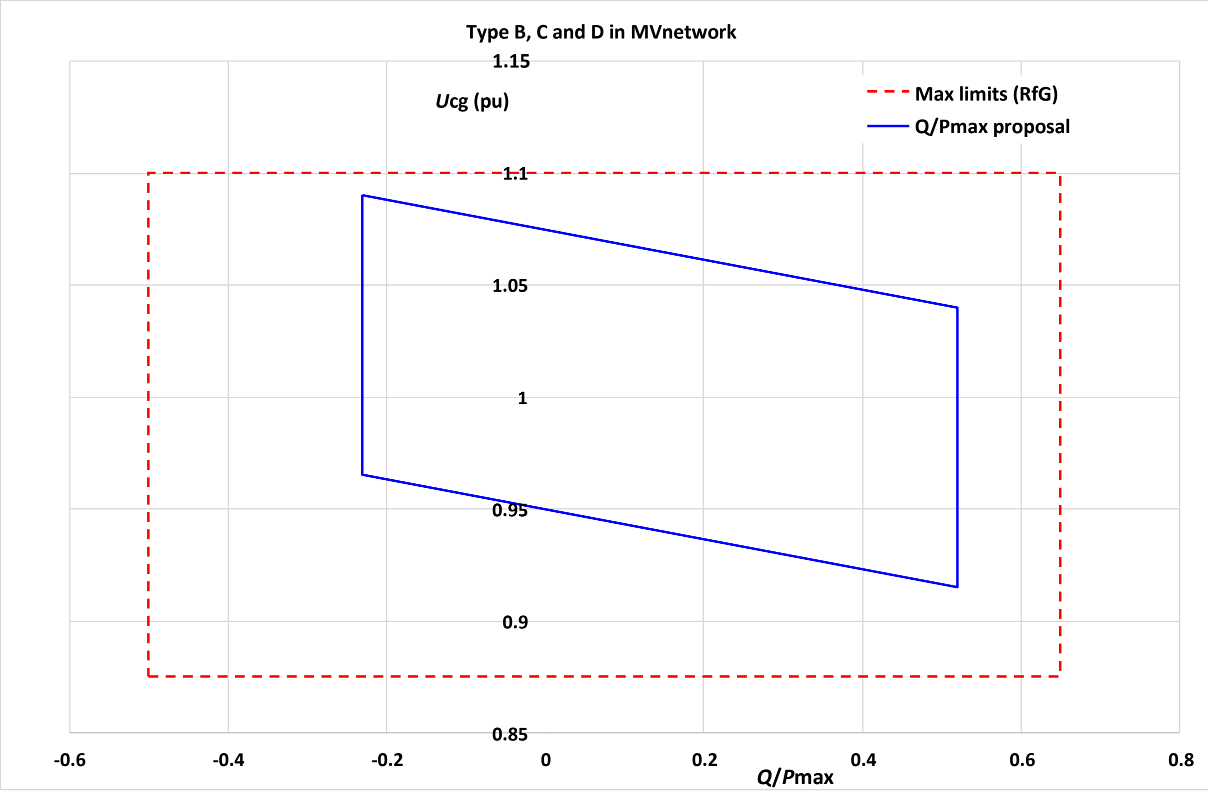
Reactive power capability characteristic (U-Q/P_{max} profile) of type D synchronous power-generating modules connected to a voltage level of 110 kV:



Reactive power capability characteristic (U-Q/P_{max} profile) of type D synchronous power-generating modules connected to a voltage level above 110 kV:



Reactive power capability characteristic (U-Q/P_{max} profile) of type C and type D synchronous power-generating modules (SPGMs) connected to a MV level:



Article 18(2)(b)(iv): Capability of the synchronous power-generating module to move to any operating point within its U-Q/P_{max} profile

110 kV level

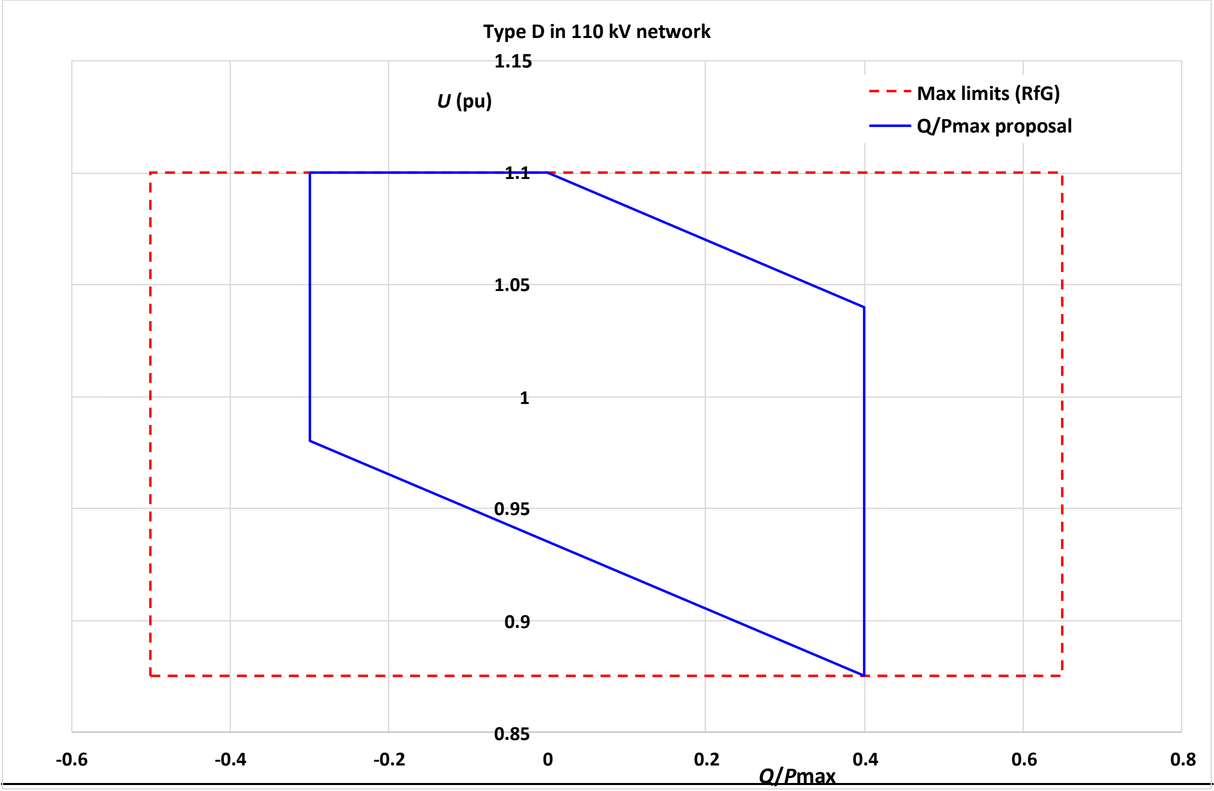
The synchronous power-generating module shall be able to move to any operating point within its U-Q/P_{max} profile as a result of the change in the voltage reference value (U_{ref}) no later than in 1 minute, if the request is made by switching the regulating transformer step, or in 3 seconds, if the request is made by changing the excitation current of the synchronous power-generating module.

MV level

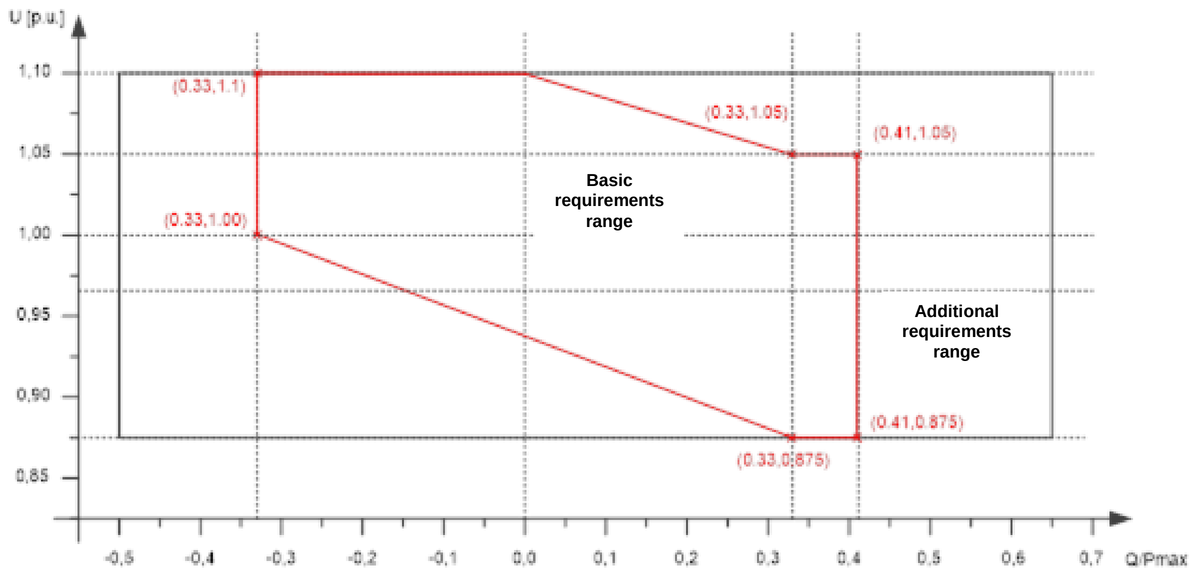
The synchronous power-generating module shall be able to move to any operating point within its U-Q/P_{max} profile as a result of the change in the voltage reference value (U_{ref}), namely no later than in 1 minute.
The synchronous power-generating module shall respond to sudden network voltage changes by way of automatic control no later than within 5 seconds.

Article 21(3)(b)(i)(ii): Capability of power park module to provide reactive power at maximum active power (U-Q/Pmax profile)

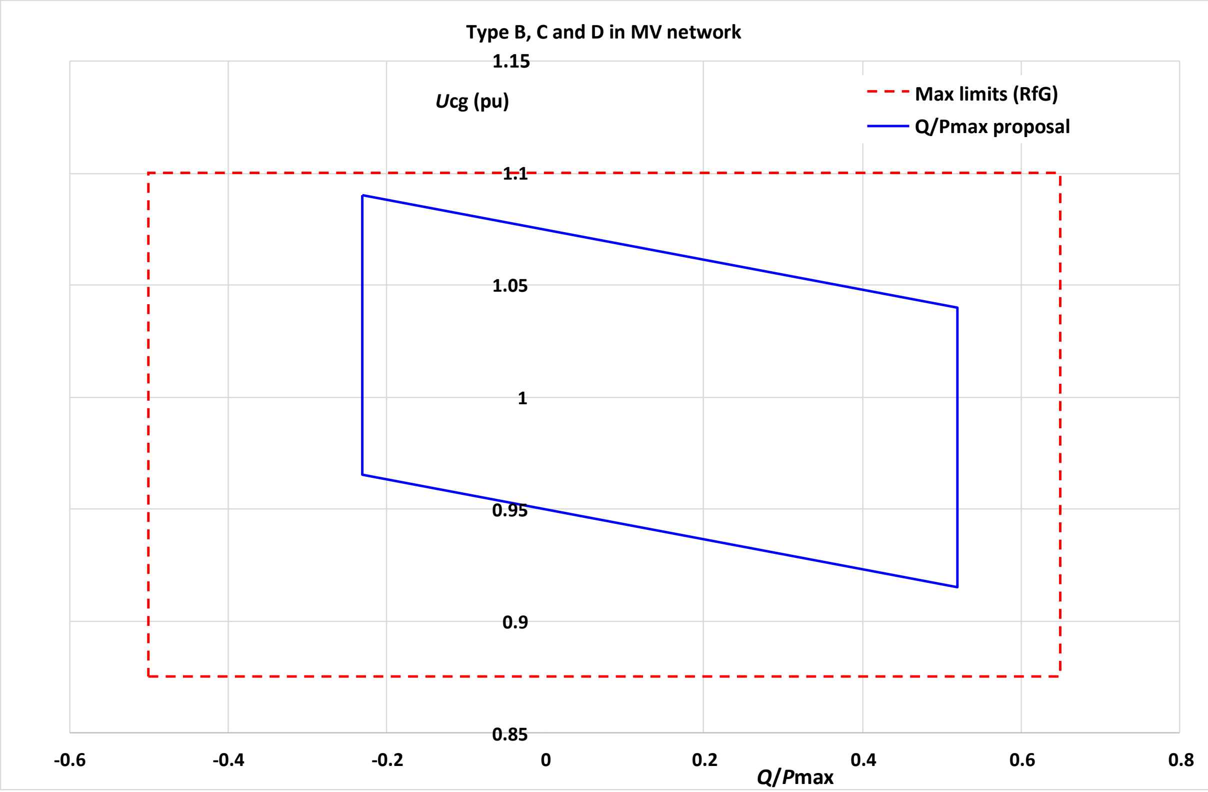
Reactive power capability characteristic (U-Q/P_{max} profile) of type D PPMs connected to a voltage level of 110 kV:



Reactive power capability characteristic (U-Q/P_{max} profile) of type D PPMs connected to a voltage level above 110 kV:

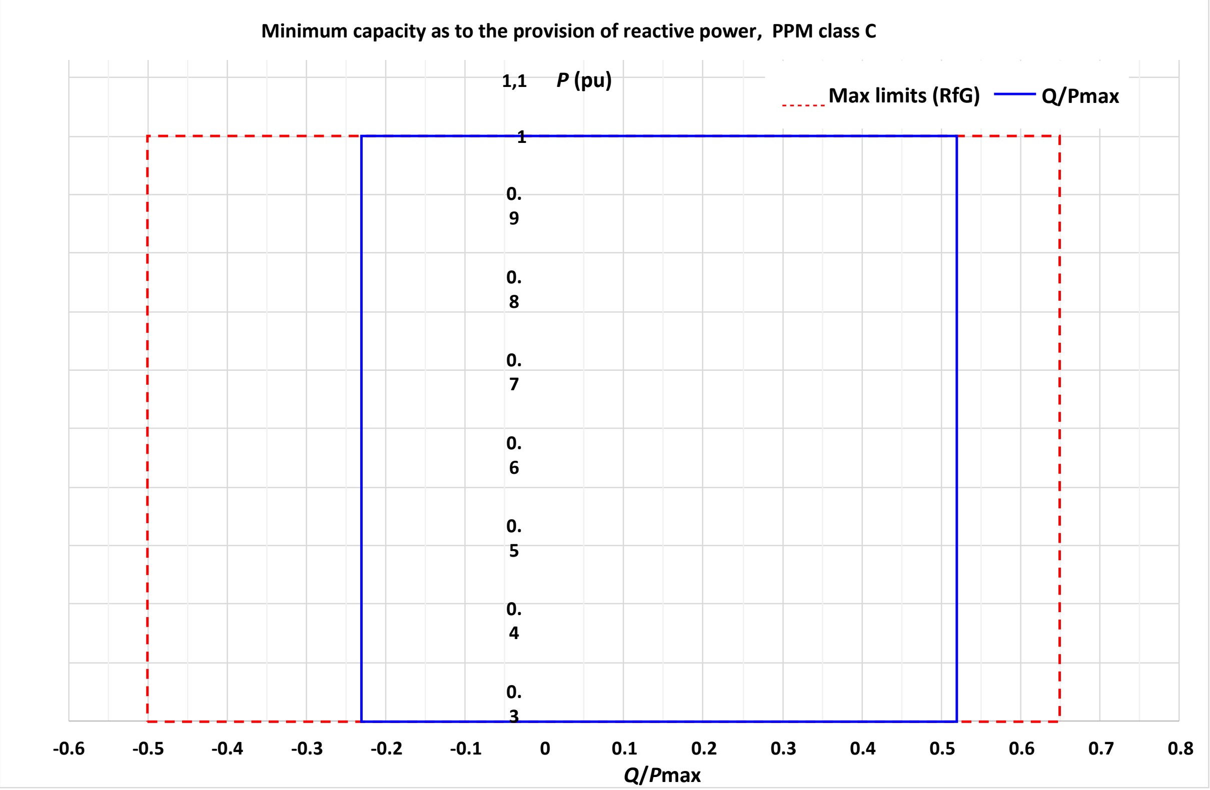


Reactive power capability characteristic (U-Q/P_{max} profile) of type C and type D PPMs connected to a MV level:



Article 21(3)(c)(i)(ii): Capability of power park module to provide reactive power below its maximum active power (U-Q/P_{max} profile)

The PPM shall be capable of providing reactive power for the entire active power operating range at least within the U-Q/P_{max} profile envelope within the following boundaries: Q/P_{max} = [-0.23 to +0.52] where negative values shall mean the PPM underexcited operation (reactive power consumption - the so called leading regime) and positive values shall mean the PPM overexcited operation (reactive power production - the so called lagging regime).



Article 21(3)(c)(iv): Capability of the power park module to move to any operating point within its U-Q/P_{max} profile

In the event of a sudden change of the network voltage, the power park module shall be capable of moving to the point of the reactive power output final response ($Q_{final\ response}$) within its P-Q/P_{max} profile, within the following time frames:

- up to the value between 90 % and 130 % of the $Q_{final\ response}$ within 5 seconds,
- up to the value between 98 % and 102 % of the $Q_{final\ response}$ within 15 second.

Article 19(2)(b)(v): Parameters and settings of voltage control system components

Each synchronous power-generating module with a power input exceeding 10 MW must be equipped with a power system stabiliser (PSS).

Article 20(2)(b)(ii): Capability of the power park module to provide fast fault current at the connection point in the event of symmetrical (3-phase) faults
Article 20(2)(c): Capability to provide fast fault current at the connection point in the event of asymmetrical (1- or 2-phase) faults

1. The right to specify the capability of providing fast fault current

The power park module shall contribute to the retention of the network short-term voltage stability with additional short-term fault current i.e. by providing fast fault current when overvoltage/undervoltage is detected.
The power park module shall be capable of activating the supply of fast fault current in the event of symmetrical (3-phase) faults and asymmetrical (1- and 2-phase) faults, and with the activation point, all in accordance with Article 20(2)(b)(i) of Commission Regulation (EU) 2006/631 as specified by the relevant system operator in *The operational notification procedure for connection*. Unless the relevant system operator specifies otherwise, cases when the power park module is electrically remote from the network connection point, which makes the voltage support inefficient, require the voltage dips to be measured at the network connection point, and the voltage support to be provided depending on the value measured.
For a reliable detection of asymmetrical faults the power park module unit shall, in the event of a fault, contribute with a positive, negative and zero sequence current.
The required fast fault current characteristic settings depend on the network short circuit capacity at the connection point and the the power system needs for the short-term voltage stability, and may be changed during the power park module lifetime according to the state of the network development. The required fast fault current characteristic settings shall be specified in *The operational notification procedure for connection*and shall be adjustable within the specified ranges due to the needs of the power system for the voltage stability, but no earlier than every 5 years.

2. Fast fault current activation and the fast fault current characteristics (properties)

2.1 Identifying voltage deviations and the end of voltage deviations

The power park module activates the fast fault current by injecting or absorbing additional reactive current (ΔI_q) according to the pre-fault condition, when at least one of the following conditions is met:

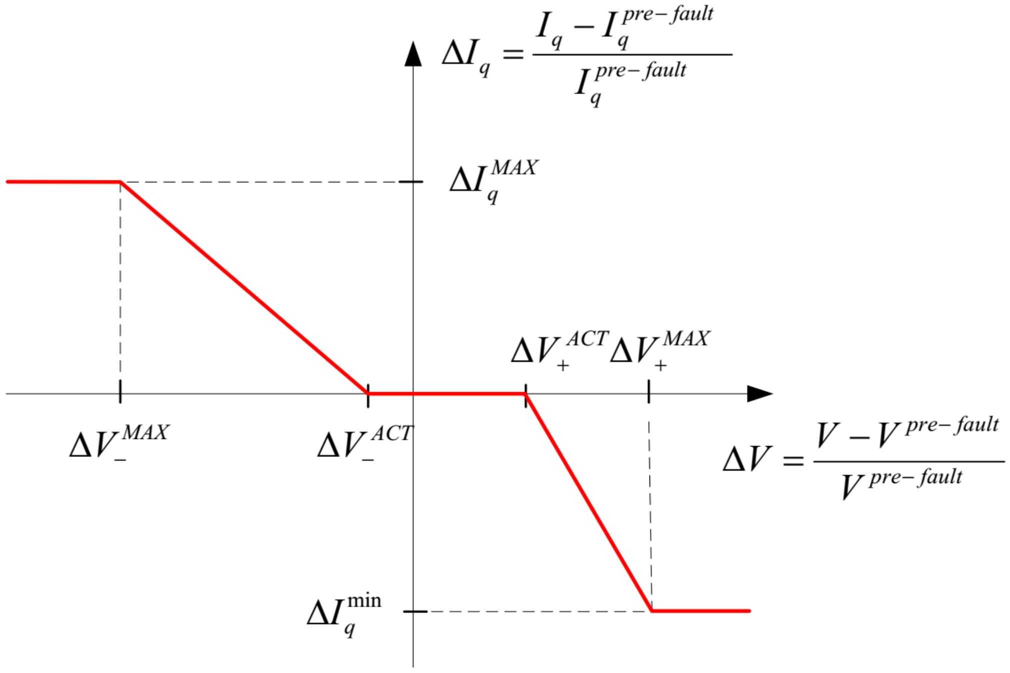
1. One or more phase voltages are outside the steady voltage range or
2. One or more phase-to-phase voltages are outside the steady voltage range.

Static voltage range is specified as the power park module voltage range.

When overvoltage/undervoltage is detected, the power park module shall provide the fast fault current (reactive current) with minimum delay when the voltage deviation (ΔU) is outside the steady voltage range or when the relative voltage deviation (ΔV) given the pre-fault condition is within the following range Figure FFC (1):

- between + ΔV^{ACT} and + ΔV^{MAX} or
- between -ΔV^{ACT} and -ΔV^{MAX}.

Figure FFC(1): Fast fault current characteristic: relative contribution of the reactive current depending on the relative voltage change according to the pre-fault condition. Left: undervoltage range, PPM overexcitation. Right: overvoltage range, PPM underexcitation. Deadband is set at the following value: between - ΔV^{ACT} and + ΔV^{ACT}.



Relative voltage change according to the pre-fault condition: $\Delta V = \frac{V - V^{pre-fault}}{V^{pre-fault}}$.
Fast fault current characteristic, Figure FFC(2), may also be specified as a relative ratio i.e. as a change in voltage according to the nominal voltage: $\frac{\Delta U}{U_N}$.
Nominal voltage (U_N) of the power park module connected to the MV network may be changed with an agreed voltage (U_{cg}) specified by the relevant system operator. $\frac{\Delta U}{U_{cg}}$.
Change of voltage: $\Delta U = U - U_o$.

The deadband shall be set as follows:

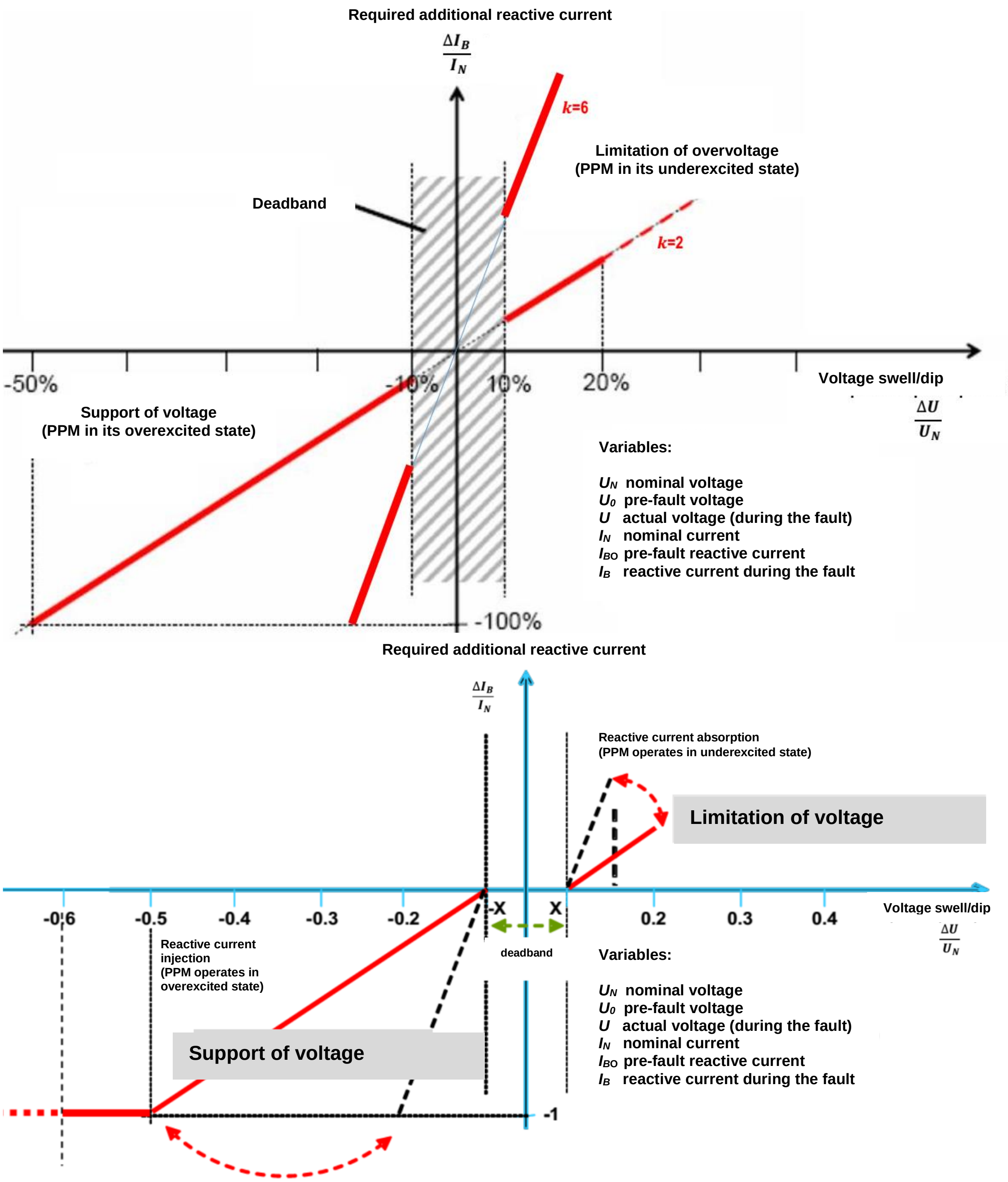
- for the undervoltage boundary within the range of: from 80% U_c to 100% U_c,
- for the overvoltage boundary within the range of: from 100% U_c to 120% U_c.

U_c…declared voltage is the voltage agreed by and between the relevant system operator and consumer.

The operating voltage steady range is, unless the relevant system operator defines otherwise, a default deadband setting. Within the deadband magnitude, the additional reactive current is neither required nor prohibited if no disturbances are caused by such additional reactive current. Within the deadband range, the power park module operates in the normal voltage control mode.

Figure FFC(2): Fast fault current characteristic: relative contribution of the reactive current (according to the pre-fault condition) depending on the relative voltage change (according to the nominal voltage). Left: undervoltage range, PPM overexcitation. Right: overvoltage range, PPM underexcitation. The deadband range is set to the value:

a) between 0.9 p.u. and 1.1 p.u. (see example above);
b) between -X and +X (see example hereunder).



The following applies to the PPM:

a) for the duration of the fault it shall provide maximum reactive current according to the specified characteristic;
b) it shall not exceed the maximum transient value of the apparent current;
c) the fast fault current provided shall be smaller or equal to the 0.8-times of the short circuit protection setting at the PPM connection point, if so required by the relevant system operator.

Relative change of the fast fault current (ΔI_q), Figure FFC(1):
$\Delta I_q = \frac{I_q - I_q^{pre-fault}}{I_q^{pre-fault}}$ shall be within the range from ΔI_q^{min} to ΔI_q^{max}.

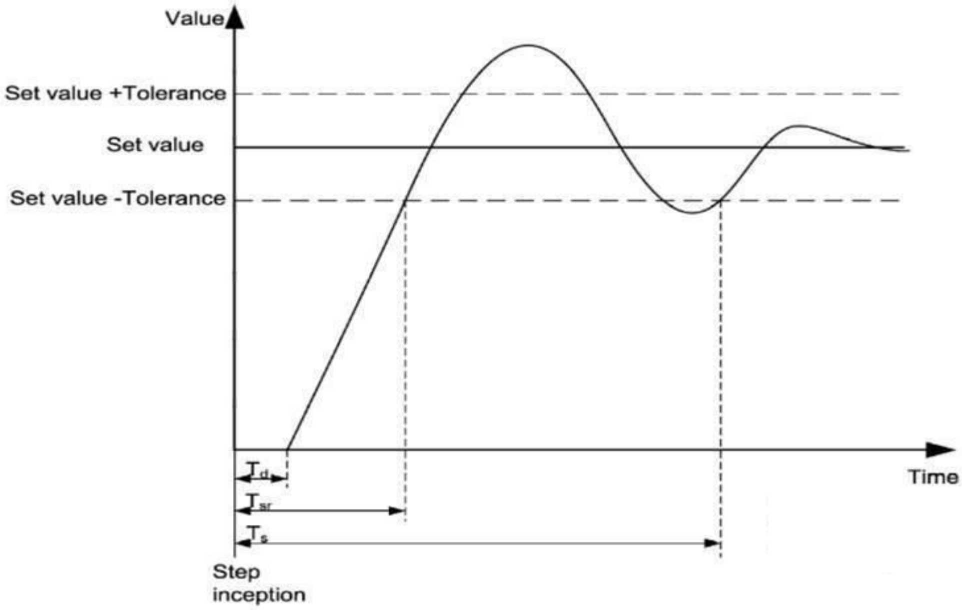
Change of the fast fault current, Figure FFC(2): $\Delta I_B = I_B - I_{B0}$.
The relative change of the fast fault current may also be specified according to the nominal current, Figure FFC(2): $\frac{\Delta I_B}{I_N}$.

Reactive current droop (gradient k): $k = \frac{\Delta I_B}{I_N} \Big/ \frac{\Delta U}{U_N} \geq 2$.

2.2 Fast fault current time characteristic

The fast fault current time characteristic is shown in Figure FFC(3):

Figure FFC(3): Fast fault current timing in the event of a fault.



Step response time (rise time T_{sr}) shall not exceed 30 ms.
Settling time (T_s) shall not exceed 60 ms.
Step response time and settling time during the fault and when the fault is cleared shall apply to both the positive and the negative sequence.
Unless the relevant system operator determines otherwise, the voltage control shall respond within 20 ms after the fault detection by providing the reactive current, which corresponds to at least 2% of the nominal current for each percent of the voltage dip. If necessary, the reactive power with at least 100% nominal current shall be provided.

Unless the relevant system operator determines otherwise, the functionality of fast fault current provision shall remain active at least during the times as specified below:

a) type D PPM connected to HV (level 1): 1 second,
b) type B PPM connected to LV or MV, type C PPM connected to MV, type D PPM connected to MV, type D PPM connected to HV (level 2): 2.5 seconds.

Unless the relevant system operator determines otherwise in *The operational notification procedure for connection*, once the time (of level 1 and level 2) expires, the fast fault current magnitude shall be reduced to the value as specified hereunder:

a) type B PPM connected to LV or MV, type C PPM connected to MV, type D PPM connected to MV (level 2 after the time of 2.5 s has expired): $I_q \geq \frac{1{,}077 \cdot P_{max}}{\sqrt{3} U_N}$
b) type D PPM connected to HV:
Level 1 (after the time of 1 s has expired): $I_q \geq \frac{1.077 \cdot P_{max}}{\sqrt{3} U_N}$,
Level 2 (after the time of 2.5 s has expired): $I_q \geq \frac{0.4 \cdot P_{max}}{\sqrt{3} U_N}$.

2.3 Fast fault current characteristic in the event of symmetrical and asymmetrical faults

The requirement regarding the fast fault current applies to the voltage deviation in both positive voltage sequence components and negative voltage sequence components of basic voltage (50 Hz). Voltage deviations in positive voltage sequence components result in the change of the additional reactive current in the positive sequence, while the voltage deviations in negative voltage sequence components result in the change of the additional reactive current in the negative sequence.

Additional reactive current in the positive sequence (ΔI_{q1}) shall be set according to gradient k_1:

$\Delta I_{q1} = k_1 \, \Delta U_1$
$\Delta U_1 = (U_1 - U_{1\_1min}) / U_c$

U_1… actual voltage of the positive sequence;
U_{1_1min}… 1 min average of the pre-fault positive sequence voltage;
Gradient k_1 shall be adjustable in range between 2 and 6 in steps not smaller than 0.5.

Additional reactive current in the negative sequence (ΔI_{q2}) shall be set according to gradient k_2:

$\Delta I_{q2} = k_2 \, \Delta U_2$
$\Delta U_2 = (U_2 - U_{2\_1min}) / U_c$

U_2… actual voltage of the negative sequence;
U_{2_2min}… 1 min average of the pre-fault negative sequence voltage;
Gradient k_2 shall be adjustable in range between 2 and 6 in steps not smaller than 0.5.

Changes in the negative sequence voltage near zero require the reactive current response only if the deadband can be set near zero, and if the negative sequence voltage is high enough to enable a reliable detection of the phase angle.

3. Fast fault current deactivation

The criterion for the fast fault current deactivation is the return of the phase or phase-to-phase voltage into the steady voltage range (within the deadband) and the continuation of the support for another 500 ms in accordance with the prescribed characteristic. The transient balancing process following the voltage return within the deadband shall be completed within 300 ms.

4. Settings of parameters which may be defined by the relevant system operator

In the framework of the *The operational notification procedure for connection* the relevant system operator may define the following parameters:

- Fast fault current activation point;

- Deadband setting;
- Reactive current droop: gradient k_1 and k_2;
- Type of fast fault current characteristic: $(\frac{V - V^{pre-fault}}{V^{pre-fault}})$ or $(\frac{\Delta U}{U_n})$ or $(\frac{\Delta U}{U_{cg}})$,
- Functionality of fast fault current provision depending on time.

Article 21(3)(d)(iv): Reactive power control mechanisms

In the event of the frequency step change the power park module shall be capable of reaching:

- a 90% change of reactive power at the output port ($Q_{final\ response}$) within 5 seconds;
- the stationary point of the output reactive power final response ($Q_{final\ response}$) within the settling time of 15 seconds.

Article 21(3)(e): Priority contribution to the active power or reactive power production during faults that require fault-ride-through capability

With regard to the contribution to active power or reactive power production during faults that require fault-ride-through capability, the power park modules shall have the priority of reactive power production.

Article 21(3)(f): Capability of power oscillations damping

The power park module shall be capable of contributing to active power oscillations damping.

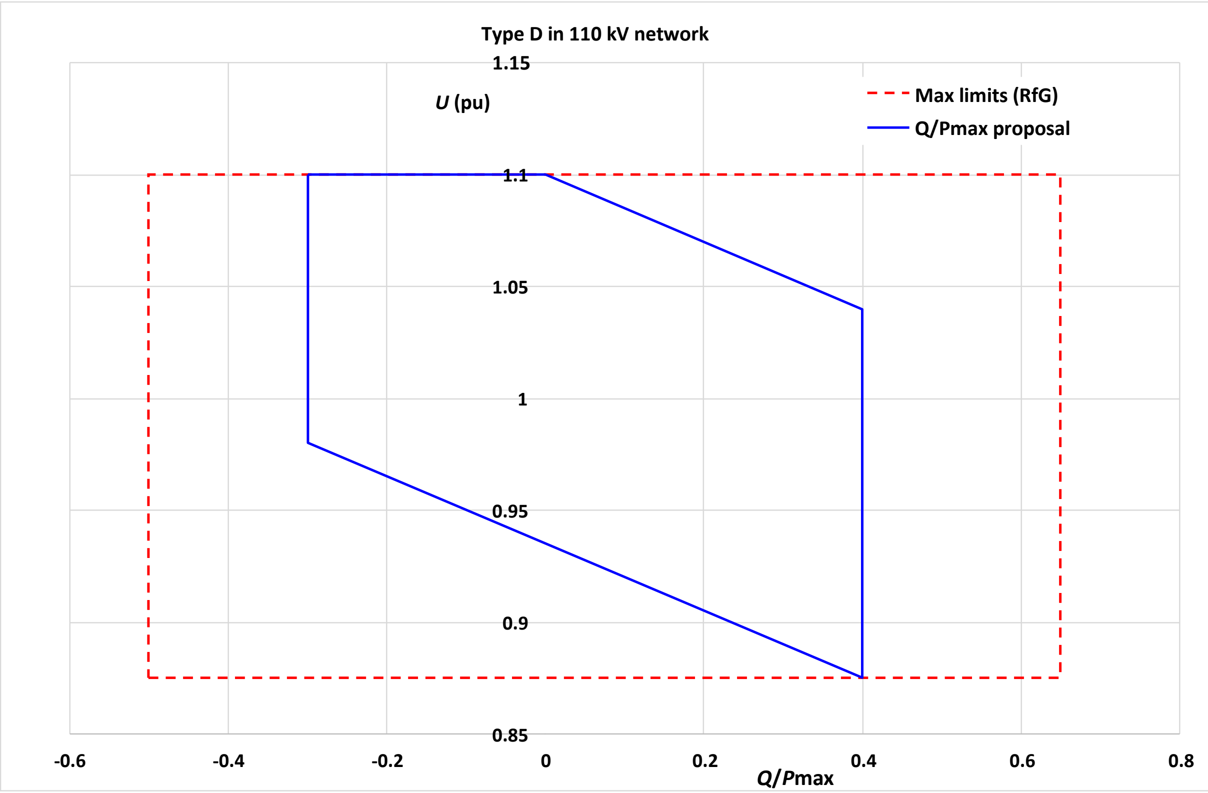
Article 25(1): Voltage ranges for AC-connected offshore power park modules

Voltage range	Time period for operation
0.85–0.90 pu	60 minutes
0.90-1.118 pu (*)	unlimited
1.118–1.15 pu (*)	60 minutes
0.90–1.05 pu (**)	unlimited
1.05-1.10 pu (**)	60 minutes

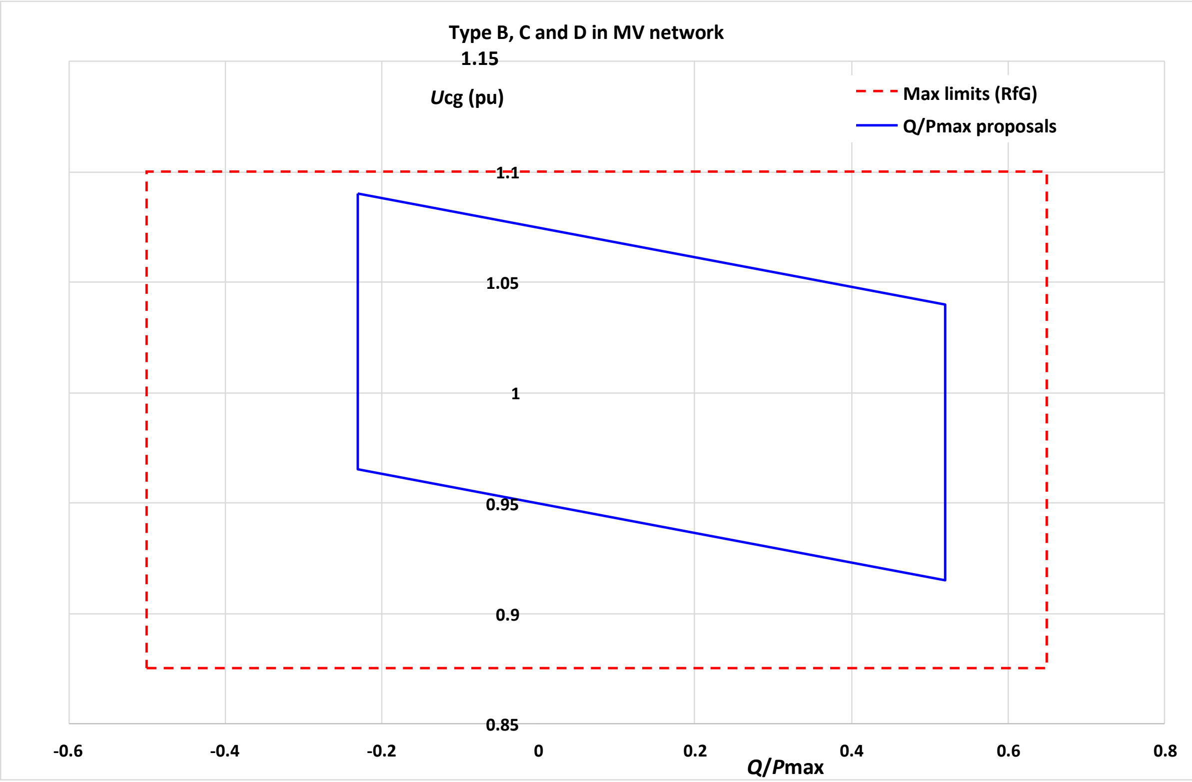
(*) Reference value for pu values is below 300 kV.
(*) Reference value for pu values is between 300 and 400 kV.

Article 25(5): Reactive power capability at maximum capacity for AC-connected offshore power park modules

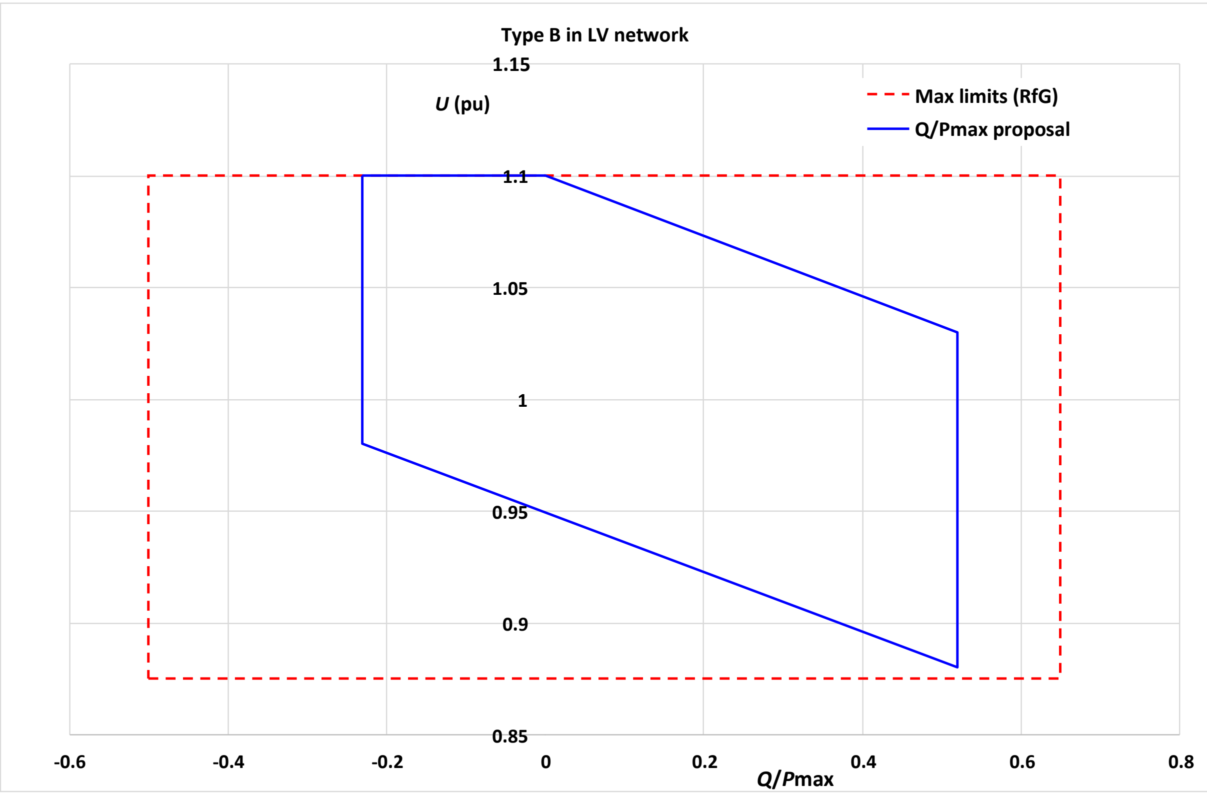
Reactive power capability (U-Q/P_{max} profile) at maximum capacity for type D offshore power park modules connected to AC system of 110 kV or above:



Reactive power capability (U-Q/P_{max} profile) at maximum capacity for type B, C and D offshore power park modules connected to AC system of MV:



Reactive power capability (U-Q/P_{max} profile) at maximum capacity for type B offshore power park modules connected to AC system of LV:



Annex 3: Angular stability

Article 14(3)(a)(i)(iii): The power-generating module's capability to ride through faults (the PGM's fault-ride-through profile - voltage-against-time FRT profile)

Voltage-against-time FRT profile for type B SPGM and its associated parameters for symmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear}= 0.70 pu t_{rec1} = 0.150 sec
U_{rec1}= 0.70 pu t_{rec2} = 0.700 sec
U_{rec2}= 0.85 pu t_{rec3} = 1.500 sec

Voltage-against-time FRT profile for type B PPM and its associated parameters for symmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear}= 0.05 pu t_{rec1} = 0.150 sec
U_{rec1}= 0.05 pu t_{rec2} = 0.150 sec
U_{rec2}= 0.85 pu t_{rec3} = 2.500 sec

According to Article 15 (1) Article 14 (3)(a)(i)(iii) shall apply

Voltage-against-time FRT profile for type C SPGM and its associated parameters for symmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.70 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.70 pu t_{rec2} = 0.700 sec
U_{rec2} = 0.85 pu t_{rec3} = 1.500 sec

Voltage-against-time FRT profile for type C PPM and its associated parameters for symmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.05 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.05 pu t_{rec2} = 0.150 sec
U_{rec2} = 0.85 pu t_{rec3} = 2.500 sec

Article 14(3)(a)(iv): Pre-fault and post-fault conditions for the fault-ride-through capability:

- **Type B SPGM;**
- **Type B PPM.**

Type C PGM: Article 15 (1) refers to Article 14(3)(a)(iv)

With the aim to verify whether the PGM complies with the fault-ride-through capability requirement:

- the type of simulated fault shall be selected (usually a 3-phase short circuit);
- the location of the simulated fault shall be selected (electrically as close to the PGMS' connection point as possible);
- it shall be checked which of the conditions in the network most influence the critical clearing time (CCT), and the most critical network operation scenario prior to the fault has to be selected accordingly:
    - whether this is the state with the lowest voltages in the system (usually a state during the day which, on the other hand, may have higher short circuit capacity due to higher number of SPGMs in operation),
    - whether this is the state with the lowest short circuit capacity at the PGM's connection point (usually a state during the night with a low number of generators in the network which, on the other hand, has higher voltages due to being load-free);
- it shall be determined whether the situation at the connection point corresponds to the conditions below/above the saturation knee-point of the impact of short circuit power on the CCT. Accordingly, a decision has to be made whether simultaneously while clearing the fault, the change of topology shall also be simulated by disconnecting the network elements (lines, transformers);
- before the fault, the PGM's operation point shall be set to the highest active power production level and to the corresponding underexcitation limit.

Article 14(3)(b): Fault-ride-through capabilities in the event of asymmetrical faults (voltage-against-time FRT profile)

Voltage-against-time FRT profile for type B SPGM and its associated parameters for asymmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.70 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.70 pu t_{rec2} = 0.700 sec
U_{rec2} = 0.85 pu t_{rec3} = 1.500 sec

Voltage-against-time FRT profile for type B PPM and its associated parameters for asymmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.05 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.05 pu t_{rec2} = 0.150 sec
U_{rec2} = 0.85 pu t_{rec3} = 2.500 sec

According to Article 15 (1) Article 14 (3)(b) shall apply

Voltage-against-time FRT profile for type C SPGM and its associated parameters for asymmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.70 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.70 pu t_{rec2} = 0.700 sec
U_{rec2} = 0.85 pu t_{rec3} = 1.500 sec

Voltage-against-time FRT profile for type C PPM and its associated parameters for asymmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.05 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.05 pu t_{rec2} = 0.150 sec
U_{rec2} = 0.85 pu t_{rec3} = 2.500 sec

Article 16(3)(a)(i): The PGM's capability to ride through faults due to symmetrical fault in the network (voltage-against-time FRT profile)

Voltage-against-time FRT profile for type D SPGM (the voltage at the connection point < 110 kV) and its associated parameters for symmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.70 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.70 pu t_{rec2} = 0.700 sec
U_{rec2} = 0.85 pu t_{rec3} = 1.500 sec

Voltage-against-time FRT profile for type D PPM (the voltage at the connection point < 110 kV) and its associated parameters for symmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.05 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.05 pu t_{rec2} = 0.150 sec
U_{rec2} = 0.85 pu t_{rec3} = 2.500 sec

Voltage-against-time FRT profile for type D SPGM (the voltage at the connection point ≥ 110 kV) and its associated parameters for symmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.00 pu t_{clear} = 0.150 sec
U_{clear} = 0.25 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.50 pu t_{rec2} = 0.600 sec
U_{rec2} = 0.85 pu t_{rec3} = 1.500 sec

Voltage-against-time FRT profile for type D PPM (the voltage at the connection point ≥ 110 kV) and its associated parameters for symmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.00 pu t_{clear} = 0.150 sec
U_{clear} = 0.00 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.00 pu t_{rec2} = 0.150 sec
U_{rec2} = 0.85 pu t_{rec3} = 3.000 sec

Article 16(3)(a)(ii): Pre-fault and post-fault conditions for the fault-ride-through capability:

- **Type D SPGM:**
  a) **Voltage at the connection point < 110 kV or**
  b) **Voltage at the connection point ≥ 110 kV,**

- **Type D PPM:**
  a) **Voltage at the connection point < 110 kV or**
  b) **Voltage at the connection point ≥ 110 kV.**

With the aim to verify whether the PGM complies with the fault-ride-through capability requirement:

- the type of simulated fault shall be selected (usually a 3-phase short circuit);
- the location of the simulated fault shall be selected (electrically as close to the PGMS' connection point as possible);
- it shall be checked, which of the conditions in the network most influence the critical clearing time (CCT), and the most critical network operation scenario prior to the fault shall be selected accordingly:
  - whether this is the state with the lowest voltages in the system (usually a state during the day which on the other hand may have higher short circuit capacity due to higher number of SPGMs in operation);
  - whether this is the state with the lowest short circuit capacity at the PGM's connection point (usually a state during the night with a low number of generators in the network which, on the other hand, has higher voltages due to being load-free);
- it shall be determined whether the situation at the connection point corresponds to the conditions below/above the saturation knee-point of the impact of short circuit power on the CCT. Accordingly, a decision has to be made whether simultaneously, while clearing the fault, the change of topology shall also be simulated by disconnecting the network elements (lines, transformers);
- before the fault, the PGM's operation point shall be set to the highest active power production level and to the corresponding underexcitation limit.

Article 16(3)(c): Fault-ride-through capabilities in the event of asymmetrical faults (voltage-against-time FRT profile)

Voltage-against-time FRT profile for type D SPGM (the voltage at the connection point < 110 kV) and its associated parameters for asymmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.70 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.70 pu t_{rec2} = 0.700 sec
U_{rec2} = 0.85 pu t_{rec3} = 1.500 sec

Voltage-against-time FRT profile for type D PPM (the voltage at the connection point < 110 kV) and its associated parameters for asymmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.05 pu t_{clear} = 0.150 sec
U_{clear} = 0.05 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.05 pu t_{rec2} = 0.150 sec
U_{rec2} = 0.85 pu t_{rec3} = 2.500 sec

Voltage-against-time FRT profile for type D SPGM (the voltage at the connection point ≥ 110 kV) and its associated parameters for asymmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.00 pu t_{clear} = 0.150 sec
U_{clear} = 0.25 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.50 pu t_{rec2} = 0.600 sec
U_{rec2} = 0.85 pu t_{rec3} = 1.500 sec

Voltage-against-time FRT profile for type D PPM (the voltage at the connection point ≥ 110 kV) and its associated parameters for asymmetrical faults

The parameters of the voltage-against-time FRT profile are as follows:

U_{ret} = 0.00 pu t_{clear} = 0.150 sec
U_{clear} = 0.00 pu t_{rec1} = 0.150 sec
U_{rec1} = 0.00 pu t_{rec2} = 0.150 sec
U_{rec2} = 0.85 pu t_{rec3} = 3.000 sec

Article 17(3), type B SPGM: Capability of type B synchronous power-generating modules to provide post-fault active power recovery
Type C SPGM – reference from Article 18(1),
Type D SPGM – reference from Article 19(1).

Synchronous power-generating modules shall be capable of providing post-fault active power recovery at at the same reference active power of the speed governor as the pre-fault one. During the fault, when voltage drops below 0.5 pu, the reference active power shall not be increased.

Article 20(3)(a)(i)(ii)(iii), PPM, type B: Capability of power park module to provide post-fault active power recovery
Type C PPM – reference from Article 21(1),
Type D PPM – reference from Article 22.

Article 20(3)(a)(i)
The post-fault active power recovery starts immediately after the voltage reach 85% of the nominal voltage.

Article 20(3)(a)(ii),
The power park module (PPM) shall be capable of providing post-fault active power recovery with a rate of active power increase of at least 20 % P_{max}/s. The current active power may be reduced proportionaly to the ratio between voltage dip and the PPM's nominal voltage, when network voltage is reduced.

Article 20 (3) (a) (iii)
The active power recovery shall be provided in the full range of the pre-fault active power.
The current active power may be reduced proportionaly to the ratio between voltage dip and the PPM's nominal voltage, when network voltage is reduced.

The accuracy of the active power recovery shall be +/-5% of the pre-fault active power.

Annex 4: System restoration

Article 14(4)(a)(b): Conditions under which the PGM is capable of reconnecting to the network after an incidental (unintentional) disconnection caused by a network disturbance and installation of automatic reconnection system

After an unintentional disconnection due to network disturbance, type B power-generating module shall be able to re-connect to the network under the following conditions:

1. Voltage range at the network connection point: 0.9 p.u. ≤ U ≤ 1.1 p.u., and shall be adjustable within the range of 0.85 p.u. ≤ U ≤ 1.1 p.u.
2. Frequency range: 49.9 Hz ≤ f ≤ 50.1 Hz, and shall be adjustable within the range of 47.5 Hz ≤ f ≤ 51.0 Hz.
3. The command at the logic interface (input port) of the power-generating module in order to cease active power output is not active.
4. Observation time (time within which all the above conditions have to be met without interruptions): $T_{observation}$ = 60 s, and shall be adjustable within the range of 0 s and 300 s.
5. Maximum admissible gradient of increase in active power output: $\Delta P_{Ramp\text{-}up\ limit} \leq 10\ \%\ P_{max}$/min and shall be adjustable within the range of up to $\Delta P_{Ramp\text{-}up\ limit} \leq 20\ \%\ P_{max}$/min..

An automatic re-connection to the network for type C power-generating modules, after an unintentional disconnection caused by a network disturbance, is prohibited unless specified otherwise by the relevant system operator in coordination with the relevant transmission system operator. An automatic connection to the network depends on the individual authorisation determined in network connection agreements.

Automatic reconnected to the network of type D PGM is prohibited.

Article 15(5)(a)(iii): Black start capability

A power-generating module with black start capability which is capable of starting from shutdown without any external electrical energy supply, must start the power-generating module as soon as possible and no later than within 45 minutes after the instruction is issued by the relevant system operator.

Article 15(5)(c)(iii): Quick re-synchronisation capability

Power-generating modules type C and type D shall be capable of continuing operation following tripping to houseload for at least 3 hours, if they are not capable of starting from shutdown without any external electrical energy supply (black start capability) within a time frame less than 15 minutes.

Annex 5: General management requirements

Article 14(5)(b)(i): Protection schemes and settings necessary to protect the network at the PGM's connection point to the network

Voltage-frequency protection settings for the disconnection point of type B PGM connected to a MV or LV network

Parameter	Maximum allowed time of operation (s)	Settings
Overvoltage protection (level 2)	0.2	U_n + 15%
Overvoltage protection (level 1)	2.0	U_n + 11%
Undervoltage protection (level 1)	2.0	U_n – 15%
Undervoltage protection (level 2)	0.2	U_n – 30%
Overfrequency [a]	0.2	52 Hz
Underfrequency [a]	0.2	47 Hz
Network outage[b]	0.5	5 Hz/s

a The underfrequency protection shall be capable of operating at least within the range determined by the voltage protection maximum operation settings.

b The network outage protection (e.g. camber angle jumps, df/dt, network impedance changes) is not necessary. If the PGM owner wishes to set it anyway it shall be set to the specified value.

Voltage-frequency protection settings for the disconnection point of type C and D PGM connected to a MV network

In the event of the communication interruption between the PGM and STO command centre or between the PGM and the relevant network operator command centre, type C and D PGM connected to the MV network shall immediately adopt the protection scheme prescribed for type B PGM!

Parameter	Maximum allowed time of operation (s)	Settings
Overvoltage protection (level 2)	0.2	U_n + 15%
Overvoltage protection (level 1)	2.0	U_n + 11%
Undervoltage protection (level 1)	2.0	U_n – 15%
Undervoltage protection (level 2)	0.2	U_n – 30%
Overfrequency (level 2) [a]	0.2	60 Hz

Overfrequency (level 1) [a]	5 – 60 [b]	55 Hz
Underfrequency (level 1) [a]	5 – 60 [b]	45 Hz
Underfrequency (level 2) [a]	0.2	40 Hz
Network outage [c]	0.5	5 Hz/s

The settings apply if a fast communication between the relevant distribution system operator and the power-generating module IS ESTABLISHED AND OPERATIVE.

a The frequency protection shall be capable of operating at least within the range determined by the voltage protection maximum operation settings.

b The setting depends on the PGM’s frequency stabilisation time at its load shedding from 100 % active power and is determined by means of measurements at the PGM.

c The network outage protection (e.g. camber angle jumps, df/dt, network impedance changes) is not necessary. If the PGM owner wishes to set it anyway it shall be set to the specified value.

Article 14(5)(d)(i)(ii): Exchange of information

Article 14(5)(d)(i)

The power-generating module (PGM) must provide the exchange of real-time operational data to the control centres of the relevant system operator (distribution system operator (DSO), closed distribution system operator (CDSO) and transmission system operator (TSO); refreshing rate shall be at least every 2 seconds for type C and type D PGMs or at least every minute for type B PGMs.

Type B and C power-generating modules exchanges data with DSOs and CDSOs, and type D PGMs directly with TSOs. DSO and CDSO transmit summarized data for PGMs as per individual location to TSO through existing communications.

Article 14(5)(d)(ii)

Operational data:

- position of switching devices and transformer tap positions at the HV and MV level (depending on the type of PGM),
- Measurements of:
  - active and reactive power;
  - phase current and voltage;
  - frequency (only for type D power-generating module).

Article 15(6)(b)(iii): Measuring equipment/systems

15(6)(b)(iii)
The frequency range between 0.1 Hz and 3 Hz forms the basis for the agreement on the settings of the device monitoring the power system dynamic behaviour (active power oscillations). As regards type D PGMs, the installation of a dedicated phasor measurement device, which shall be integrated into the WAMPAC system of the relevant system operator, forms the basis for the agreement.

Article 15(6)(e): Minimum and maximum limits on rates of change of active power output (ramping limits) in both directions, up and down, taking into consideration the specific characteristics of prime mover technology

Minimum and maximum limits on rates of change of active power output (minimum and maximum ramping limits) in both directions, up and down, taking into consideration the specific characteristics of prime mover technology, are determined by the relevant system operator in coordination with the relevant TSO in *The operational notification procedure for connection* on a case-by-case basis, and shall be included in the network connection agreement.

Article 15(6)(f): Earthing arrangement of the neutral-point at the network side of step-up transformers

The relevant system operator determines the earthing arrangement of the neutral-point at the network side of step-up transformers in *The operational notification procedure for connection,* in line with the concept of network neutral point earthing of the relevant system operator and the current valid analysis of earth fault current conditions in the power system.