Requirements of general application resulting from Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators (NC RfG)

PSE S.A.

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Introduction

These requirements of general application resulting from Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators (hereinafter referred to as the: Requirements) constitute a document containing substantive resolutions concerning the technical requirements resulting from NC RfG [1] and subject to approval by the competent regulatory authority, to the preparation of which PSE S.A. has been obliged on the basis of NC RfG and Article 9(1) of the Energy Law[2]. In line with NC RfG, general use requirements are to be drawn up by a system operator competent with the connection location, i.e. TSO or DSO, as well as a selected transmission system operator. The Republic of Poland has used a possibility of transferring the obligation to establish the general use requirements from relevant system operators to PSE S.A. as the transmission system operator, as referred to in Article 7(9) of NC RfG. The Requirements drawn up by PSE S.A. were subject to the process of consultations held with DSO and market participants.

The document has been divided in accordance with the classification included in NC RfG and refers to, successively, PGM type A, B, C and D, in line with the classification carried out by TSO on the basis of Article 5 (3) of NC RfG.

In accordance with Article 14(1), Article 15(1) and Article 16(1) of NC RfG, modules of the higher type must also meet, in principle, the requirements for lower types (A<B<C<D).

If not indicated otherwise, articles invoked in this document refer to articles of NC RfG.

The table below presents abbreviations used in these Requirements that have not been directly defined in NC RfG. The remaining scope of abbreviations and terms used in the Requirements is in line with the definitions laid down in NC RfG.

FRT	Fault Ride Through
PPS	Polish Power System
PGM	Power Generating Module
PPM	Power Park Module
HO	Houseload Operation

[1] Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators OJ EU of 27 April 2016, L112/1 (NC RfG).

[2] Act of 10 April 1997 – Energy Law (Journal of Laws of 2018, item 755, as amended)

Requirements of general application Article 13(1)(a)(i) - frequency parameters

Minimum operating time period of the power generating module at frequencies deviating from the nominal value:

Frequency range	Operating time
47.5 Hz-48.5 Hz	30 minutes
48.5 Hz-49.0 Hz	30 minutes

Article 13(1)(b) - rate of change of frequency

Required PGM capability of remaining connected to the network and operate at the rate of change of frequency up to:

$$\left|\frac{df_{max}}{dt}\right| = 2.0 \left|\frac{Hz}{s}\right|$$

where this value would be measured as an average value within a shiftable measurement window with a length of 500 ms.

The requirement $\left|\frac{df_{max}}{dt}\right| = 2.0 \left|\frac{Hz}{s}\right|$ constitutes a minimum requirement. If the applied technology allows connection to the network and operation at a higher rate of change of frequency, limiting the operation of the PGM to the value defined above is not allowed, unless it results from the arranged rate-of-change-of-frequency-type loss of mains protection.

Article 13(2)(a) - static parameters of the LFSM-O mode

- Capability of setting the frequency threshold of the LFSM-O in the range: 50.2 Hz-50.5 Hz, default value 50.2 Hz.
- Capability of droop settings of the LFSM-O in the range: 2-12%, default value 5%.
- As regards Power Park Modules, the P_{ref} value means maximum active power.

A possibility of selecting, upon TSO order, the setting of the frequency threshold for activating the LFSM-O and droop settings in the required range must be ensured.

Regardless of the prevalence of setpoint of power for the LFSM-O, the possibility of blocking the LFSM-O mode and the capability of executing intervention operation with set values indicated by the relevant SO must be ensured.

Article 13(2)(b) - disconnection of PGM type A instead of the LFSM-O

It is not allowed to disconnect PGM type A instead of providing capabilities for the LFSM-O.

The above mentioned decision does not exclude adapting PGM type A to the LFSM-O through gradually disconnection of particular units generating electricity within PGM, in particular PPM.

Article 13(2)(f) - minimum regulating level of the LFSM-O

It is required that following the reaching the minimum regulating level in the LFSM-O, the power generation module is capable of stable operation at this level. Operation below the minimum regulating level is not required, unless such a requirement has been individually determined as part of adapting PGM to island operation.

Reduction of active power of PPM resulting from operation in the LFSM-O is executed from the active power output in the moment of reaching the activation threshold of the LFSM-O to the power value resulting from the static characteristics of the LFSM-O, provided that the power of the primary source of energy has not been decreased below the level that allows reaching the required level of operation.

Article 13(4) - admissible active power reduction

Admissible active power reduction compared to the maximum generated power (defined at the frequency of 50 Hz), amounts to the following at dropping frequency:

a. for synchronous power-generating modules, excluding synchronous power-generating units referred to in (b): 10% of maximum power per 1 Hz, at a frequency drop below 49 Hz (Fig. a);

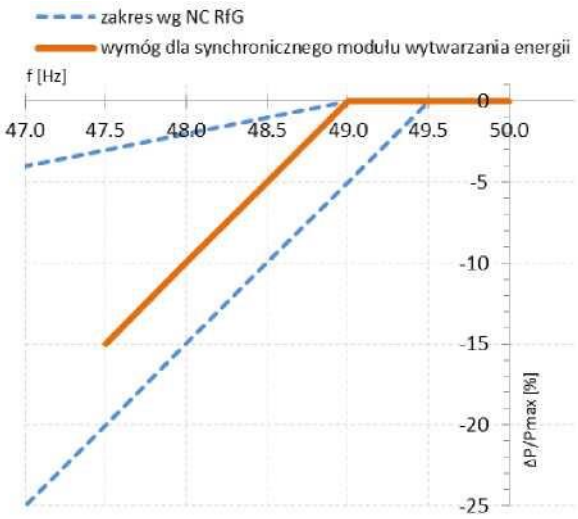
b. for synchronous power-generating modules such as gas unit or combined cycle gas and steam unit: 4% of maximum power per 1 Hz, at a frequency drop below 49.5 Hz (Fig. b);

c. for power park modules: 2% of maximum power per 1 Hz, at a frequency drop below 49 Hz (Fig. c);

If a given PGM can operate at a lower power reduction rate, it should ensure such operation (concerns PPM in particular).

Fig. Maximum power reduction at a frequency drop.

a)



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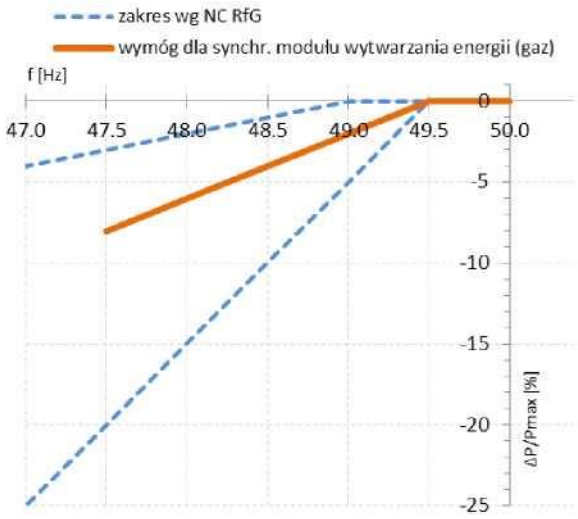
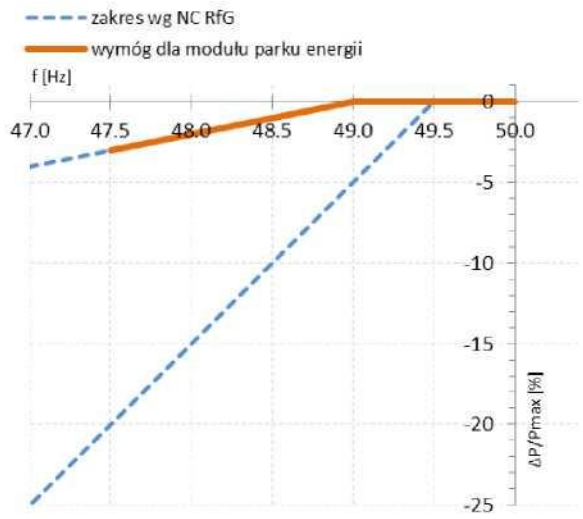


zakres v/g NC RfG	frame requirements according to NC RfG
wymóg dla synchronicznego modułu wytwarzania energii	requirement for synchronous power-generating module
wymóg dla synchr. modułu wytwarzania energii (gaz)	requirement for synchronous power-generating module (gas)

c)



zakres v/g NC RfG	frame requirements according to NC RfG
wymóg dla moduły parku energii	requirement for power park module

In accordance with Article 13(5), the requirement of admissible active power reduction is determined for nominal ambient conditions, which include in particular the following parameters:

- pressure,
- temperature,
- relative humidity.

If the ambient conditions have a considerable impact on the maximum power capability, the owner of the power-generating facility shall deliver relevant characteristics that identify these restrictions to the relevant SO.

Article 13(6) - remote control of PGM

It is required that PGM is adapted to remote control of the facility by a relevant SO, in terms of the cease of active power output. Telecommunication standards shall be determined by a relevant SO.

Article 13(7) - automatic connection to the network

Conditions for the automatic connection of PGM to the network (must be met cumulatively):

- power frequency in the network shall be in the range between 49.00 Hz and 50.05 Hz, and
- time delay (understood as time between the moment in which frequency value returns to the range defined above and the moment of connecting the power-generating module to the network) - at least 60 sec., and
- Maximum admissible gradient of increase in active power output amounts to 10% of the maximum power per minute.

Article 14(2)(b) - remote control of PGM type B

It is required that PGM has the capability of remote control of the facility by a relevant SO, in terms of

active power reduction at an order of relevant SO. The reduction requirement remains active also where the primary source of energy is insufficient to achieve the set limit value.

In order to allow remote operation of generated active power by means of additional devices, telecommunication standards determined and published by a relevant SO must be met.

Article 14(3)(a)(i) - FRT for symmetrical faults

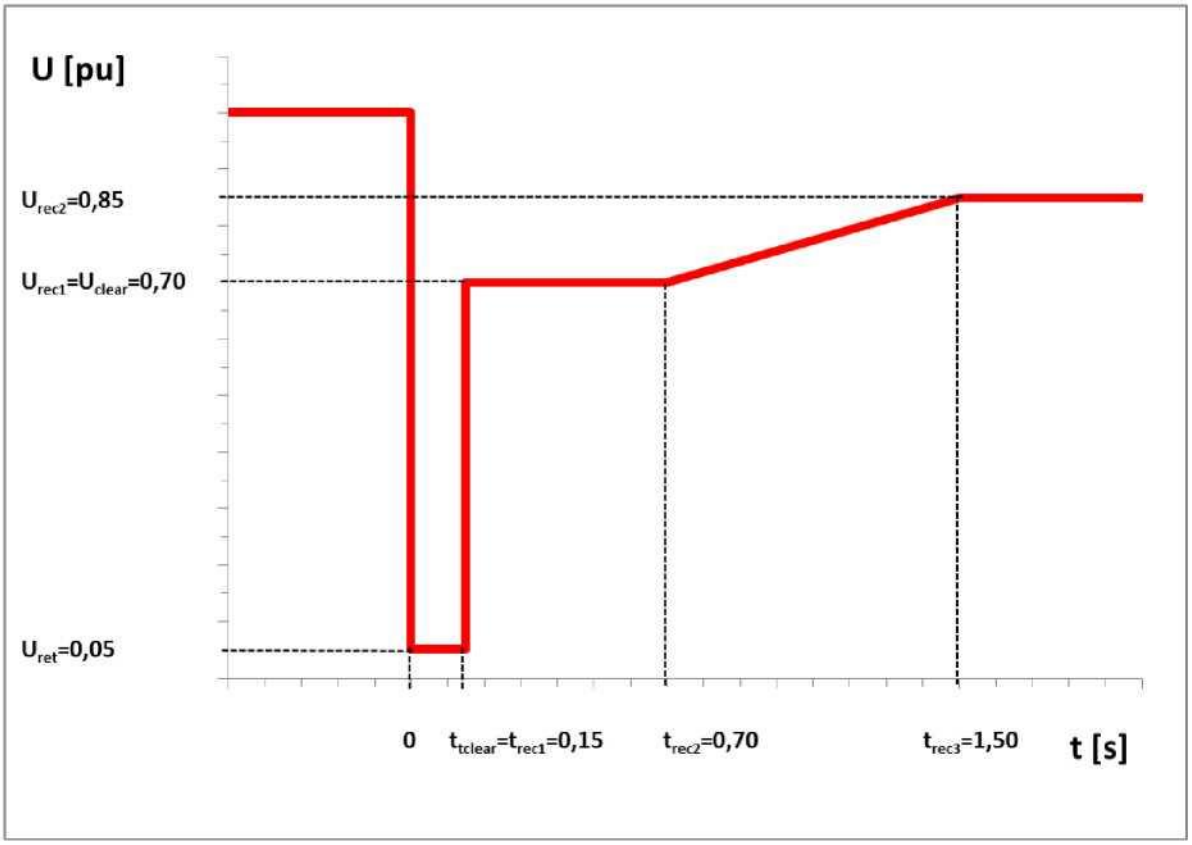
PGM may disconnect from the network, if phase-to-phase voltage at the connection point falls below the required profile of the fault ride through and voltages at the connection point exceed the admissible value laid down in relevant legal regulations directly before the fault.

- **Synchronous power-generating modules** must meet the requirements concerning the capability of fault ride through that are described in the table below and in the figure below.

Parameters referring to the capability of synchronous power-generating modules of fault ride through:

Voltage parameters [pu]		Time parameters [s]	
Uret:	0.05	tclear:	0.15
Uclear:	0.70	trec1:	0.15
Urec1:	0.70	trec2:	0.70
Urec2:	0.85	trec3:	1.50

Required fault ride through profile for synchronous power-generating module:



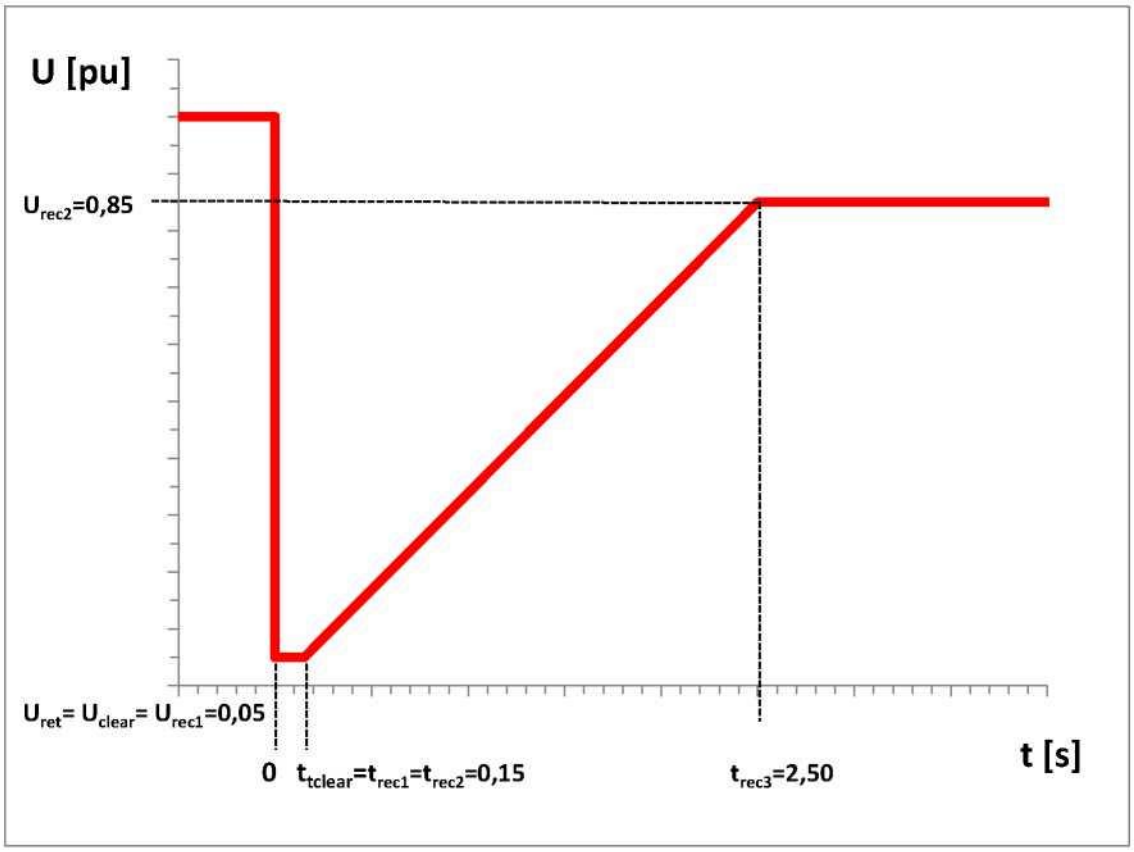
- **Power park modules** must meet the requirements concerning the capability of fault ride through

that are described in the table below and in the figure below:

Parameters referring to the capability of power park modules of fault ride through:

Voltage	parameters [pu]	Time parameters [s]	
Uret:	0.05	tclear:	0.15
Uclear:	0.05	trecl:	0.15
Urecl:	0.05	trec2:	0.15
Urec2:	0.85	trec3:	2.50

Required fault ride through profile for the power park module:



Article 14(3)(b) - FRT for non-symmetrical faults

The required PGM capabilities of fault ride through in the case of non-symmetrical faults concern the phase-to-phase voltage with the lowest amplitude.

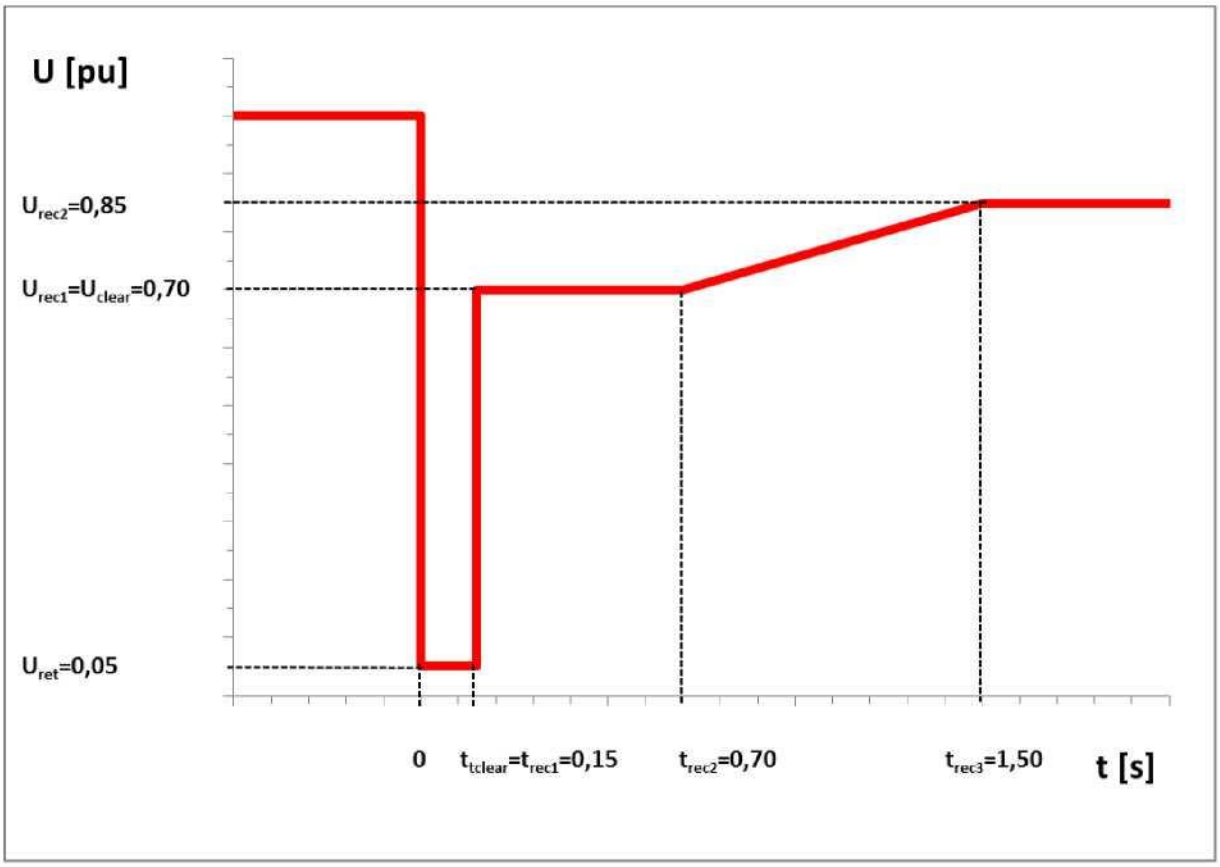
PGM may disconnect from the network during the non-symmetrical fault, if at least one phase-to-phase voltage at the connection point falls below the required profile of the fault ride through and voltages at the connection point exceed the admissible value laid down in relevant legal regulations directly before the fault.

- **Synchronous power-generating modules** must meet the requirements concerning the capability of fault ride through that are described in the table below and in the figure below.

Parameters referring to the capability of synchronous power-generating modules of fault ride through:

Voltage parameters [pu]		Time parameters [s]	
Uret:	0.05	tclear:	0.15
Uclear:	0.70	trecl:	0.15
Urec1:	0.70	trec2:	0.70
Urec2:	0.85	trec3:	1.50

Required fault ride through profile for synchronous power-generating module.

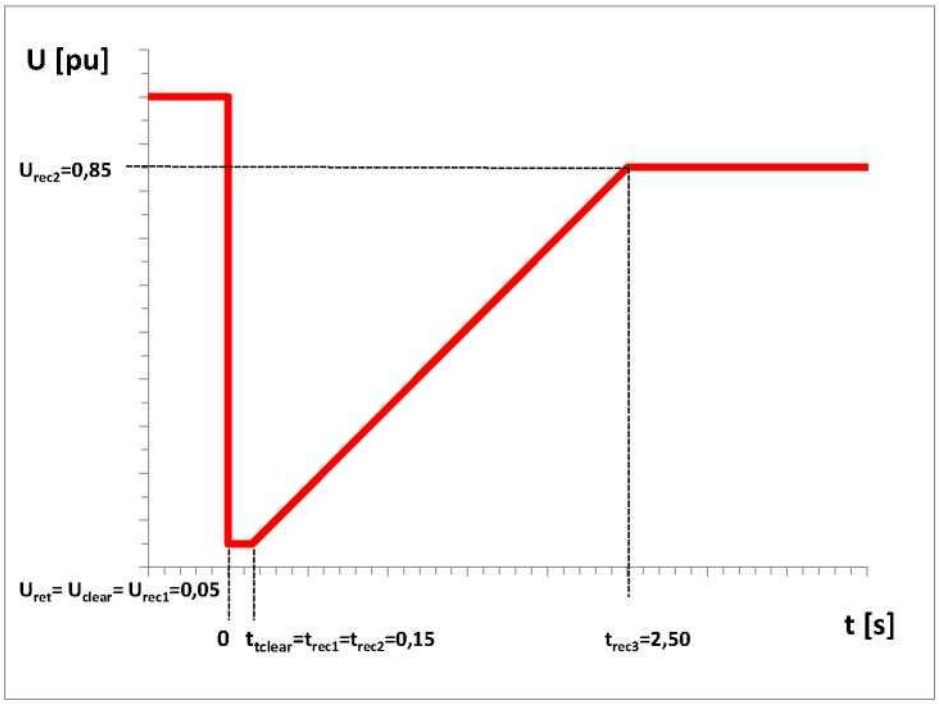


- **Power park modules** must meet the requirements concerning the capability of fault ride through that are described in the table below and in the figure below:

Parameters referring to the capability of power park modules of fault ride through:

Voltage	parameters [pu]	Time parameters [s]	
Uret:	0.05	tclear:	0.15
Uclear:	0.05	trec1:	0.15
Urec1:	0.05	trec2:	0.15
Urec2:	0.85	trec3:	2.50

Required fault ride through profile for the power park module.



Article 14(4)(a) - reconnection of PGM to the network

Conditions for the reconnection of PGM to the network after its accidental disconnection caused by network disturbance (must be met cumulatively):

- power frequency in the network shall be in the range between 49.00 Hz and 50.05 Hz, and
- voltage at the connection point falls into the range of admissive voltages laid down in relevant legal regulations, and
- time delay (understood as time between the moment in which the value of the abovementioned parameters returns to the range defined above and the moment of connecting the power-generating module to the network) - at least 60 sec.

If PGM was disconnected from the network as a result of opening the circuit breaker in the power output line, reconnection for PGM type C and D may take place exclusively upon consent or order of a relevant SO. It is allowed to use delay time by a relevant SO in order to block the automatic reconnection, depending on the location of the power station and configuration of the network to which the power-generating module is connected.

Article 14(5)(d)(i) - data exchange

It is required that power-generating modules safeguard the capability of the power-generating facility to exchange information in real time:

- type B with a relevant SO
- type C and D with a relevant SO and TSO.

Article 14(5)(d)(ii) - real time data exchange

For entities connected to the DSO network the scope of real time data should cover at least:

- position of main circuit switch at the connection point; and
- active and reactive power flows, current and voltage at the connection point

A relevant SO, in agreement with TSO, has the right to require a broader scope of exchanged information in real time that is necessary for planning and conducting the system operation.

For entities connected to the TSO network the scope of real time data should cover at least:

- position of main circuit switch at the connection point or another point of interaction agreed with TSO;
- active and reactive power flows, current and voltage at the connection point or another point of interaction agreed with TSO;
- in the case of a power-generating facility consuming energy for other purposes than household operation - net active power and net reactive power at the connection point or another point of interaction agreed with TSO.

TSO has the right to require a broader scope of information exchanged in real time that is necessary for planning the system operation and system management.

Article 15(2)(a) - automatic power adjustment

A period in which the modified active power setpoint has to be reached must not be longer than 15 minutes.

Accuracy of the adjustment should be no less than 1% of the maximum power for synchronous power-generating modules and 2% of the active power setpoint for power park modules.

Article 15(2)(b) - manual power adjustment

A period in which the modified active power setpoint has to be reached when automatic power adjustment devices are not in operation must not be longer than 30 minutes from the moment an instruction has been issued by a relevant SO. Accuracy of the adjustment should be no less than 2% of the maximum power for synchronous power-generating modules and 5% of the active power setpoint for power park modules.

Article 15(2)(c)(i) - static parameters of the LFSM-U

- Capability of setting the frequency threshold of the LFSM-U in the range: 49.5 Hz - 49.8 Hz, default value 49.8 Hz.
- Capability of making droop settings of the LFSM-U in the range: 2-12%, default value 5%.
- As regards power park modules (PPM), the P_{ref} value means maximum active power.

A possibility of selecting, upon TSO order, the setting of the following must be ensured:

- frequency threshold for LFSM-U activation,

- droop.

A possibility of blocking LFSM-U functions by a relevant SO should be ensured when network congestion are observed in real time (and not identified on the basis of forecasts). Application of LFSM-U protection should be limited to the system area where network limitations occurred. A relevant SO should pass information to TSO on active LFSM-U protection. Network conditions to block the LFSM-U should be agreed between relevant SO and TSO.

Article 15(2)(d)(i) - static parameters of the FSM mode

The required parameters concerning active power frequency response in the FSM.

Parameters		Ranges or values
Active power range related to maximum power $\frac{\lvert\Delta P_i\rvert}{P_{max}}$		5%
Frequency response insensitivity	$\lvert\Delta f_t\rvert$	10 mHz
	$\frac{\lvert\Delta f_t\rvert}{f_n}$	0.02%
Frequency response deadband		0-500 mHz
Droop s_1		2-12%

Article 15(2)(d)(iii) - dynamic parameters of the FSM mode

parameters of full active power activation in response to a change in frequency, resulting from a frequency step change:

Parameters	Ranges or values
Active power range related to maximum power (frequency response range) $\frac{\lvert\Delta P_1\rvert}{P_{ref}}$	5%
For power-generating modules with inertia, the maximum admissible initial delay *t*1, unless justified otherwise in line with Article 15(2)(d)(iv)	2 s
For power-generating modules without inertia, the maximum admissible initial delay *t*1, unless justified otherwise in line with Article 15(2)(d)(iv)	0.5 s
Maximum admissible choice of full activation time *t*2	30 s

Article 15(2)(d)(iv) - initial delay of the FSM mode

For power-generating modules without inertia, the maximum admissible initial delay t_1 should amount to 0.5 s, in line with the Table 5 of NC RfG.

Article 15(2)(d)(v) - operating time of the FSM mode

The power-generating module must be capable of providing full active power frequency response for at least 30 minutes, provided the primary source of energy is available.

Power correction signal following a change in frequency must remain active until there are frequency conditions for the operation of FSM automation. It is not allowed to withdraw the power correction signal following a change in frequency in the case of a temporary loss of the primary source of energy.

Article 15(2)(g)(i) - transmission of signals for the monitoring of the FSM mode

If a given PGM participates in the FSM frequency adjustment process, signals for the monitoring of FSM active power frequency response shall be sent to the TSO.

Article 15(2)(g)(ii) - signals for the monitoring of the FSM mode

If a given PGM participates in the FSM frequency adjustment process, additional signals that are to be sent by the power-generating module by means of monitoring devices and recording devices for the purpose of verifying the operation of the active power frequency response back-up, shall include at least:

- local frequency or rotational velocity;
- PGM operating mode (i.e. LFSM-U/LFSM-O, household operation and island operation - if PGM is adapted thereto),

whereas, in the phase of connecting the facility to the network or activating the capability of PGM to

adjust the frequency in the system by TSO, a relevant SO in agreement with TSO shall determine additional signals necessary for monitoring, taking account of the power generation technology.

Article 15(3) - voltage protection

Terms and conditions for actual disconnection of power-generating modules:

If a relevant SO, in agreement with TSO, decides on admitting, for systemic reasons, the use of these protective devices, then the voltage threshold values at the point of connection at which an automatic disconnection of the facility can take place should be correlated with voltage limits admissible by a relevant SO in the MV network administered, i.e.:

- undervoltage protection setpoint should be lower than the minimum voltage at which PGM should maintain the capability of operating within the network
- whereas overvoltage protection setpoint should be higher than the maximum voltage at which PGM should maintain the capability of operating within the network.

Voltage protection devices at the connection point should not be active, unless they are used to prepare the unit to defend/restore the PPS, e.g. through an pre-emptive switch into household operation. They should not be used for protecting PGM from damage - protection devices installed directly on the device, referred to in Article 14(5)(b)(iii), serve this very purpose.

Voltage level settings of protection devices are determined individually as facility-specific.

Article 15(5)(c)(iii) - household operation

The minimum required household operation time of power-generating modules incapable of quick resynchronization shall be determined individually, taking account of the execution technology, whereas the said time must not be shorter than 2 hours.

Household operation must not be intentionally interrupted when exceeding the above mentioned minimum time limit of 2 hours, as long as its further operation does not pose a threat to the safety of persons and devices.

Longer household operation will be required, as part of separate arrangements, for PGMs provided for being used in the process of defending and restoring PPS, in particular the ones adapted to island operation.

Article 15(6)(a) - angular stability

Synchronous power-generating modules must feature protection devices that react to rotor pole slip, where impedance is a criterial value. The application of another, equivalent protection device for detecting the loss of angular stability is allowed.

Article 15(6)(b)(i) - fault recorder

Unless a relevant SO decides otherwise, power-generating facilities must feature an installation that

safeguards recording of the voltage and current wave shape during failures/faults and monitoring the dynamic behaviour of the system with the following accuracy (for nominal values at steady state):

- voltage - accuracy 0.5%,
- current - accuracy 0.5%,
- active power - accuracy 1.0%,
- reactive power - accuracy 1.0%,
- frequency - accuracy 0.02%.

Current and voltage temporary values must be recorded at a recording frequency and time synchronization required by a relevant SO.

Article 15(6)(b)(ii) - triggering criteria and sampling rates

Unless specified otherwise, it is proposed to assume the following thresholds that trigger recording for the purpose of making arrangements with the power-generating facility owner:

- for voltage (single-period RMS value, updated every 10 ms in a shiftable measurement window):
  a) for a network with voltage of 400 kV and higher: U_{RMS}<0.9 pu or U_{RMS}>1.05 pu,
  b) for a network with voltage of 220 kV and 110 kV: U_{RMS}<0.9 pu or U_{RMS}>1.118 pu,
  c) for a network with voltage lower than 110 kV: U_{RMS}<0.9 pu or U_{RMS}>1.1 pu
- for frequency:

  f< 49.8 Hz or f>50.2 Hz.

Article 15(6)(b)(iii) - oscillation trigger

As part of detecting poorly damped power oscillations, the monitoring of oscillations with a frequency between 0.1 Hz and 5 Hz and a simultaneous application of the following thresholds that trigger oscillation recording has been assumed (a simultaneous exceeding of 2 value thresholds has been assumed):

- oscillation amplitudes - Arel > 2%

  where Arel=A/P, A - oscillation amplitude [MW], P - active power of a generator [MW]
- damping factor - ξ < 5%

  where: ξ =(A1-A2)/A1, A1, A2 - subsequent oscillation amplitudes

The abovementioned approach does not exclude the application of ongoing recording, subject to processing, during which cases of exceeding the arranged thresholds will be identified.

Article 15(6)(b)(iv) - communication protocols

Simulation models that appropriately reflect the power-generating module's behaviour, both at a steady state and for dynamic simulations (50 Hz component) or in short electromagnetic simulations,

should comply with the CGMES 2.4.15 standard or newer, unless arranged otherwise between a power-generating facility owner and a relevant SO and TSO.

Article 15(6)(c)(iii) - simulation models

On request of a relevant SO, a power-generating facility owner must provide simulation models. Simulation models that appropriately reflect the power-generating module's behaviour, both at a steady state and for dynamic simulations (50 Hz component) or in short electromagnetic simulations, should comply with the CGMES 2.4.15 standard or newer, unless decided otherwise by a relevant SO, in coordination with TSO.

Article 15(6)(e) - rate of change of power

Unless a relevant SO and a power-generating module owner, in agreement with TSO, arrange otherwise, the minimum and maximum limits of the rate of change of generated active power (limit values), in both up and down direction of active power generated by the power-generating module, taking account of the specificity of technology of the prime mover, shall fall into the ranges laid down in the table below.

Type of power-generating module	Limits of the rate of change of generated active power in the negative and positive direction [% of maximum power / minute]
Thermal power units (hard coal)	4 ÷ 6
thermal power units (brown coal)	3 ÷ 4
gas-fired thermal power units (Combined Cycle Gas Turbine)	5 ÷ 8
gas-fired thermal power units (Simple Cycle Gas Turbine)	12 ÷ 20
combustion engine-driven thermal power units	80 ÷ 100
hydro power units	40 ÷ 50
wind PPM	90 ÷ 100
photovoltaic PPM	90 ÷ 100

Limits of the rates of change of active power provided in the table mean average values of the rate of change of base load from technical minimum to maximum power of the PGM. In technically justified cases, for thermal power units in the range between 0.9 of the maximum power to 1.0 of the maximum power, lower limit rates of change of active power are admissible, however, they must be arranged with a relevant SO, in agreement with TSO.

Article 16(2)(a)(i) - voltage conditions

Minimum time during which a power-generating module must be capable of operating at voltages deviating from the reference voltage 1 pu at the connection point without disconnecting from the network is as follows:

- for base voltage between 110 kV and 300 kV:

Voltage range	Time period for operation
1.118 pu - 1.15 pu	60 minutes

- for base voltage between 300 kV and 400 kV:

Voltage range	Time period for operation
1.05 pu - 1.10 pu	60 minutes

Article 16(2)(a)(ii) - voltage and frequency conditions

In the event of a simultaneous overvoltage and underfrequency or simultaneous overvoltage and overfrequency, the required operating time will be shorter time, considering separately frequency and voltage requirements.

Article 16(2)(c) - voltage protection

If a relevant SO, in agreement with TSO, decides on admitting, for system reasons, the use of protection devices, then the voltage threshold values at the connection point at which an automatic disconnection of the facility can take place should be correlated with voltage limits defined for undervoltage and overvoltage setpoints (pursuant to Article 16(2)(a)(i)) for PGM connected to the network of 110 kV and more and determined by a relevant SO for PGM connected to the network with a voltage below 110 kV, i.e.:

- undervoltage protection setpoint should be lower than the minimum voltage at which PGM should maintain the capability of operating within the network;
- overvoltage protection setpoint should be higher than the maximum voltage at which PGM should maintain the capability of operating within the network.

Undervoltage protection devices at the connection point should not be active, unless they are used to prepare the PGM to defend/restore the PPS, e.g. through an anticipative switch into household operation. They should not be used for protecting PGM from damage - protection devices installed directly on the device, referred to in Article 14(5)(b)(iii), serve this very purpose. Settings for automatic disconnection of PGM are determined individually as facility-specific setpoints.

Article 16(3)(a)(i) - FRT for symmetrical faults

PGM may disconnect from the network during the fault, if phase-to-phase voltage at the connection

point falls below the required profile of the fault ride through and voltages at the connection point directly before the fault exceed:

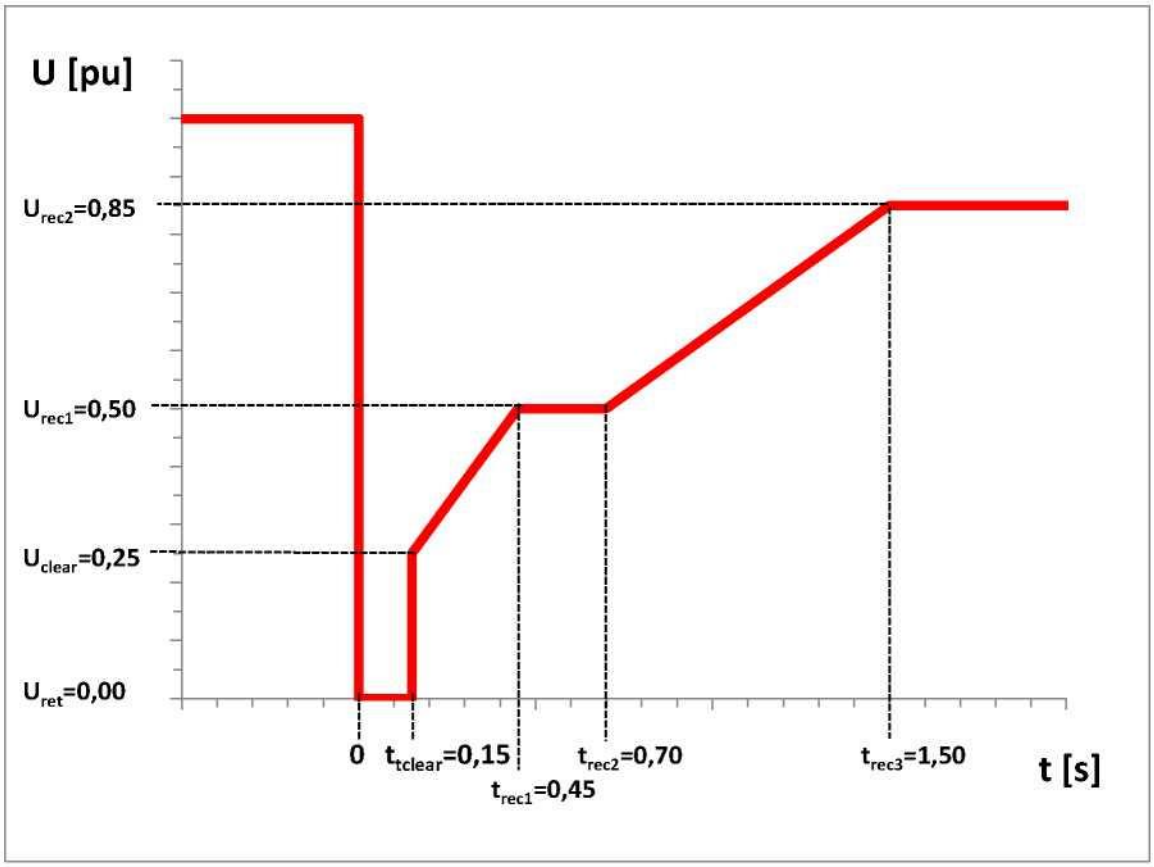
- the value determined in Article 16(2)(a) (for networks of 110 kV and more);
- the admissible value determined in relevant legal regulations (for networks below 110 kV);

- **Synchronous PGM** type D must meet the requirements concerning the capability of fault ride through that are described in the table below and in the figure below.

Parameters referring to the capability of synchronous power-generating modules of fault ride through

Voltage parameters [pu]		Time parameters [s]	
Uret:	0.00	tclear:	0.15
Uclear:	0.25	trec1:	0.45
Urec1:	0.50	trec2:	0.70
Urec2:	0.85	trec3:	1.50

Required fault ride through profile for synchronous power-generating module.

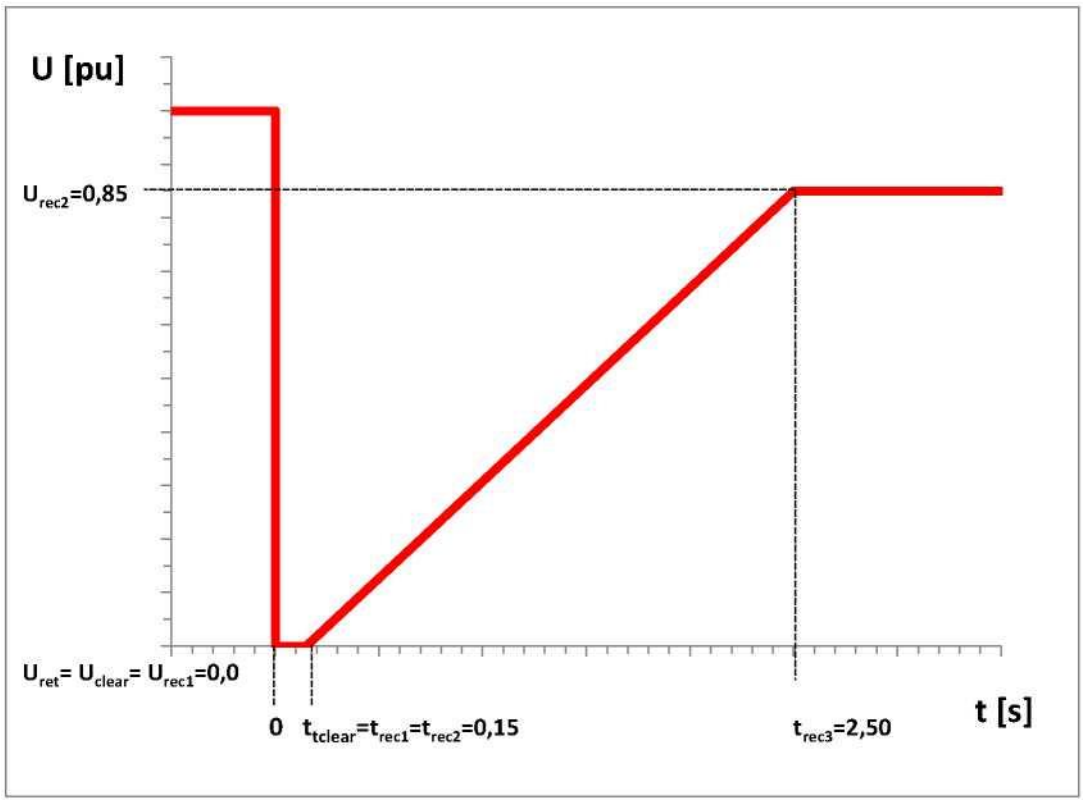


- **PPM** type D must meet the requirements concerning the capability of fault ride through that are described in the table below and in the figure below:

Parameters referring to the capability of power park modules of fault ride through

Voltage parameters [pu]		Time parameters [s]	
Uret:	0.00	tclear:	0.15
Uclear:	0.00	trec1:	0.15
Urec1:	0.00	trec2:	0.15
Urec2:	0.85	trec3:	2.5

Required fault ride through profile for the power park modules.



Article 16(3)(c) - FRT for non-symmetrical faults

Requirements for fault ride through in the case of non-symmetrical faults refer to the phase-to-phase voltage profile with the lowest amplitude.

A power-generating module may disconnect from the network during the non-symmetrical fault, if at least one phase-to-phase voltage at the connection point falls below the curve presented in the relevant figure below and voltage at the connection point directly before the fault exceeds:

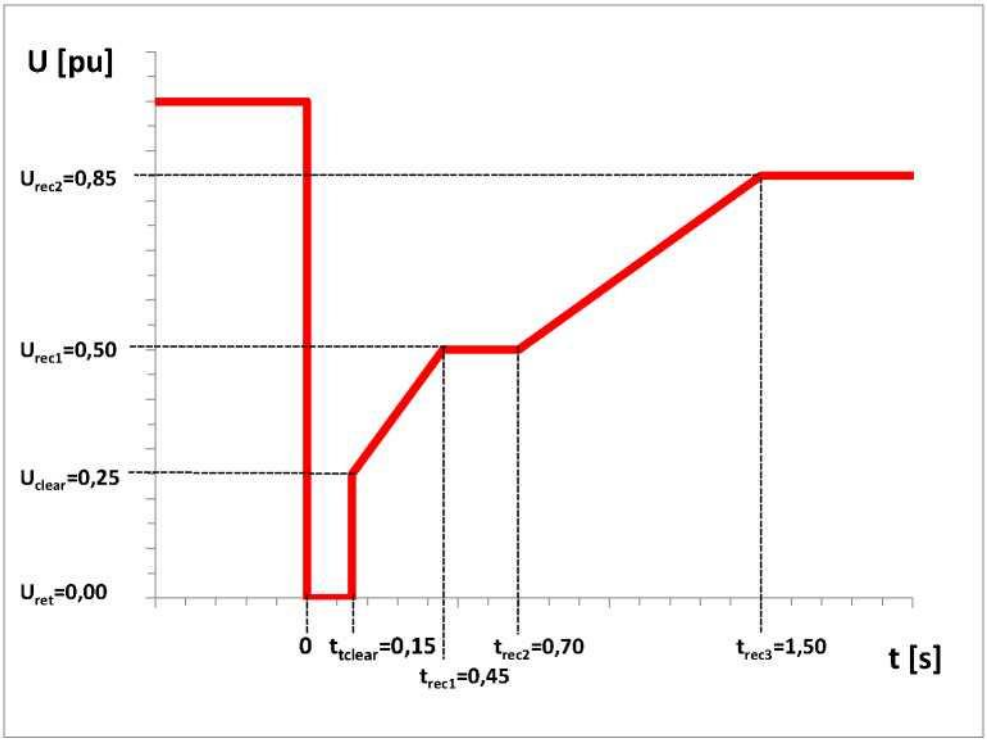
- the value determined in Article 16(2)(a) (for networks of 110 kV and more);
- the admissible value determined in relevant legal regulations (for networks of 110 kV and less);

- **Synchronous PGM** type D must meet the requirements concerning the capability of fault ride through that are described in the table below and in the figure below.

Parameters referring to the capability of synchronous power-generating modules of fault ride through

Voltage parameters [pu]		Time parameters [s]	
Uret:	0.00	tclear:	0.15
Uclear:	0.25	trec1:	0.45
Urec1:	0.50	trec2:	0.70
Urec2:	0.85	trec3:	1.50

Required fault ride through profile for synchronous power-generating module.

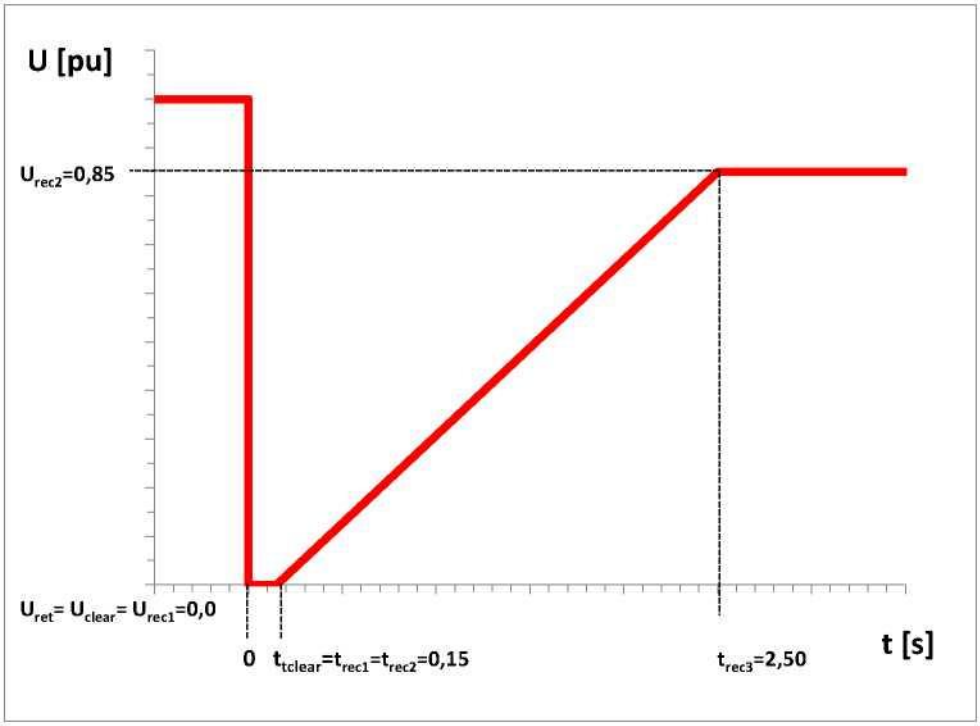


- **PPM** type D must meet the requirements concerning the capability of fault ride through that are described in the table below and in the figure below:

Parameters referring to the capability of power park modules of fault ride through

Voltage parameters [pu]		Time parameters [s]	
Uret:	0.00	tclear:	0.15
Uclear:	0.00	trec1:	0.15
Urec1:	0.00	trec2:	0.15
Urec2:	0.85	trec3:	2.5

Required fault ride through profile for the power park modules.



Article 16(4)(d) - synchronization conditions

Unless a relevant SO has arranged otherwise with a power-generating facility owner, the following requirements concerning the synchronization with the network shall be specified:

(i) voltage, whereas the agreed voltage difference should fall in the range between 0% and +5% of network voltage;

(ii) frequency, whereas the agreed frequency difference should not exceed 0.067 Hz;

(iii) phase angle range, whereas the agreed phase angle difference should fall in the range between 0° and +10°, whereas the "+" sign means leading of the generator phase compared to the network;

(iv) phase sequence (checking phase sequence before synchronization);

(v) voltage and frequency deviations - synchronization should be possible in the scope of network frequencies resulting from the provisions of Article 13(1)(a) and in the scope of voltages:

- defined in Article 16(2)(a)(i) (for PGM connected to the network of 110 kV and more),
- defined by a relevant SO (for PGM connected to the network with a voltage lower than 110 kV).

Article 17(2)(a) - reactive power

Unless a relevant SO determines otherwise, a synchronous power-generating module, at maximum generated active power, must be capable of providing (on device terminals) reactive power with a power factor in the range cosφ=0.85 towards reactive power generation and cosφ=0.95 towards reactive power consumption. When active power generated is below the maximum power (P<Pmax), the synchronous power-generating unit must be capable of generating reactive power (Mvar) in the range resulting from the pie chart of the P-Q capability of the synchronous power-generating unit.

Article 17(3) - post-fault active power recovery

Post-fault active power recovery by the synchronous power-generating module should take place without undue delay, in line with the natural (inherent) characteristics of a synchronous machine.

In the case of applying fast valving automation, the post-fault restoration of active power may take place according to a different characteristics than the one resulting from natural characteristics of the synchronous PGM, agreed with a relevant SO, in agreement with TSO.

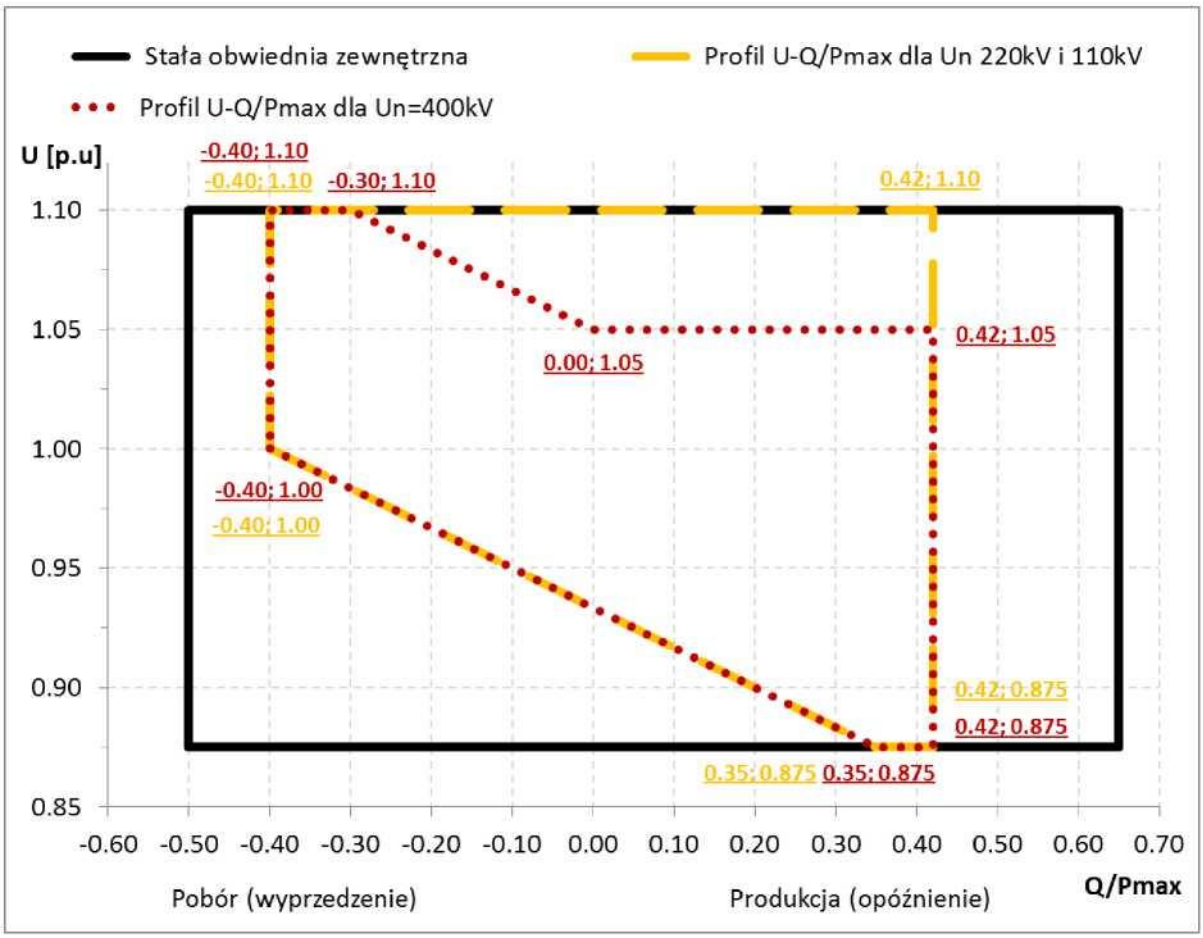
Article 18(2)(b)(i),(ii),(iii) - reactive power

Capability of a synchronous power-generating module type D, connected at or above 110 kV, to generate reactive power at the maximum power has been defined in the table below and in the figure below.

Inner envelope parameters

Network rated voltage	Maximum range Q/Pmax	Maximum range of the voltage level at steady state in relative units
400 kV	0.82	0.225
220 kV and 110 kV	0.82	0.225

U-Q/Pmax profile of the synchronous power-generating module



Stała obwiednia zewnętrzna	Fixed inner envelope
Profil U-Q/Pmax dla Un=400kV	U-Q/Pmax profile for Un=400 kV
Profil U-Q/Pmax dla Un 220kV i 110kV	U-Q/Pmax profile for Un=220 kV and 110 kV
Pobór (wyprzedzanie)	Consumption (leading)
Produkcja (opóźnienie)	Production (lagging)

The chart presents the boundaries of the U-Q/Pmax profile, divided into voltages at connection point, expressed as a ratio of its actual value to reference voltage 1 pu, compared to the ratio of reactive power (Q) to maximum power (Pmax). Location, size and shape of the inner envelope are separately marked for 400 kV network voltage (with a dotted red line) and for a 220 kV and 110 kV network voltage (with a dashed orange line). A relevant SO has the right to modify the presented range of the U-Q/Pmax profile (within the framework of maximum values and fixed outer envelope provided for in the Regulation), should such need be expressed by an expert opinion concerning the connection.

Unless a relevant SO determines otherwise, a synchronous power-generating module type C or D connected to a network with a voltage below 110 kV, at maximum generated active power, must be capable of providing (on device terminals) reactive power with a power factor in the range $\cos\varphi$=0.85 towards reactive power generation and $\cos\varphi$=0.95 towards reactive power consumption.

Article 18(2)(b)(iv) - rate of change of reactive power

A synchronous power-generating unit must be capable of moving to any operating point set by a relevant SO within its U-Q/Pmax profile in a time of up to 150 seconds.

The adjustment time is determined individually, if a change in the operating point forces a change in the operating status of static measures for compensating reactive power or a change of a gear of a network transformer of a synchronous power-generating module, if exists.

The abovementioned requirement defines the maximum capacity and does not exclude slower activation of reactive power, if it results from the properties of the superior voltage adjustment system or other network conditions.

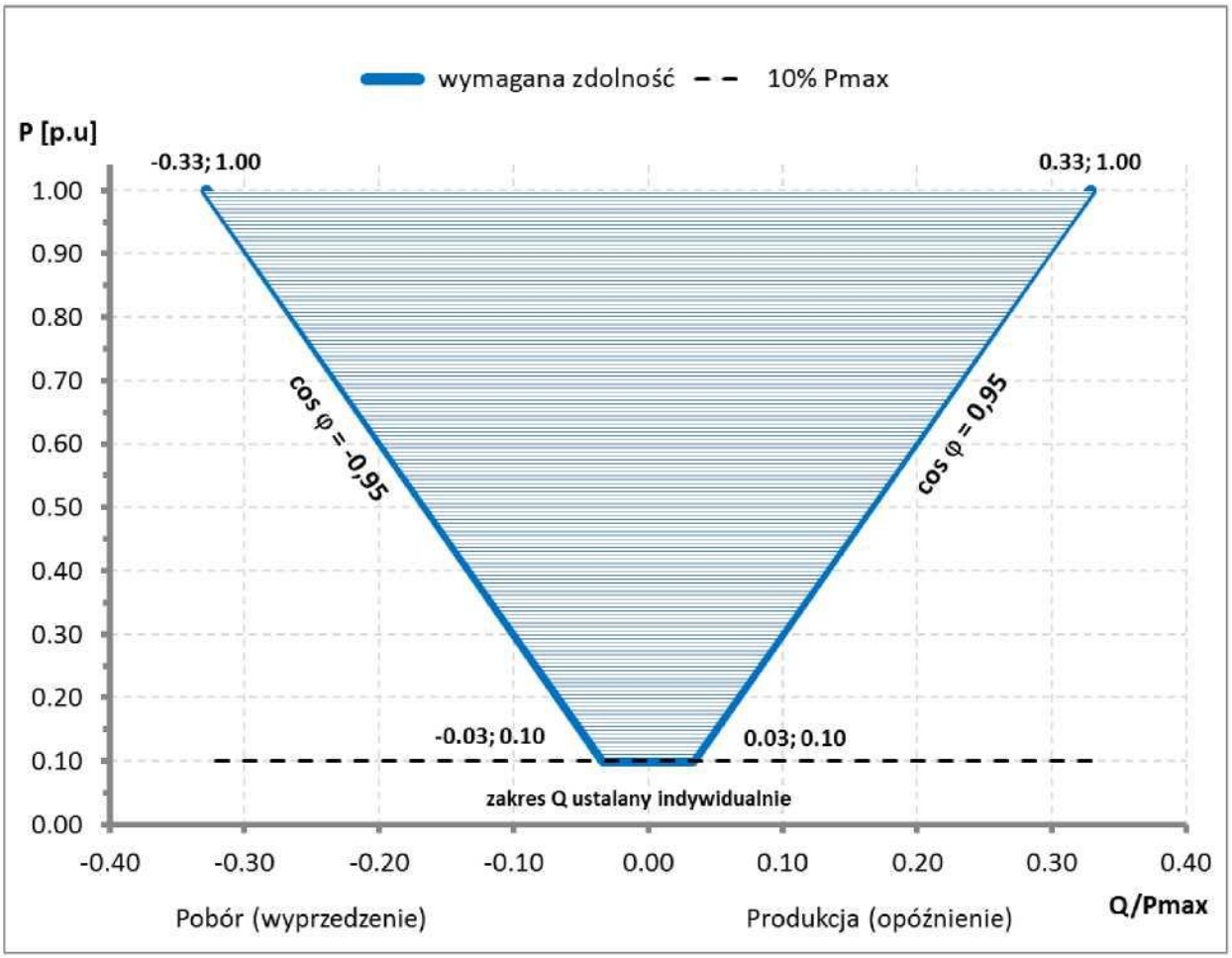
Article 19(2)(b)(v) - PSS

In order to guarantee stable operation of the system, all synchronous power-generating modules type D, with maximum power of 20 MW and more, must be equipped with a PSS function (power oscillation damping).

Article 20(2)(a) - reactive power

Unless a relevant SO decides otherwise, PPM type B must be capable of providing reactive power at the connection point, at maximum power, resulting from $\cos\varphi=0.95$ towards reactive power consumption and generation. When PPM operates at active power in the range below the maximum power to 0.1 of the maximum power, the entire remaining reactive power shall be made available, in line with technical capabilities, however no less than resulting from $\cos\varphi=0.95$ (for current active power), both towards reactive power consumption and generation. When PPM operates at active power in the range below 0.1 of the maximum power, the entire remaining reactive power shall be made available, in line with technical capabilities, however detailed requirements from the power-generating module for the purpose of reactive power generation will be arranged individually with a relevant SO.

P-Q/Pmax profile of the power park module type B



wymagana zdolność	required capability
zakres Q ustalany indywidualnie	Q range arranged individually
Pobór (wyprzedzanie)	Consumption (leading)
Produkcja (opóźnienie)	Production (lagging)

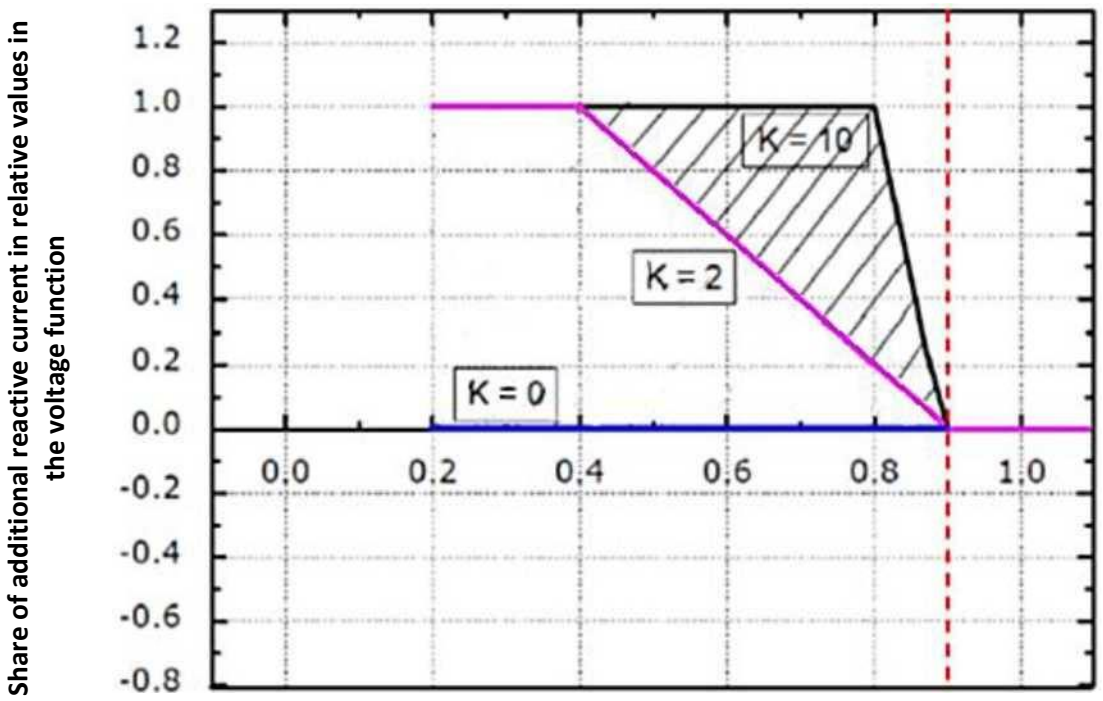
Article 20(2)(b) - fast fault current (symmetrical faults)

Unless a relevant SO, in agreement with TSO, decides otherwise, PPM should be capable of generating additional fast fault current, in line with the below static characteristics with a settable K factor value in the range between 2 and 10, in the following time:

(i) 90% of additional reactive current on terminals of basic power-generating systems in time no longer than 60 ms.

(ii) The target value of this current should be reached with accuracy of -10%/+20% within 100 ms from the moment the voltage deviation has occurred.

At faults resulting in voltage dips below 0.2 Un on terminals of the basic generation unit, no generation of additional reactive current is admissible.



Voltage on terminals of the basic power-generating system

Article 20(2)(c) - fast fault current (non-symmetrical faults)

Unless a relevant SO, in agreement with TSO, decides otherwise, power park module should be capable of generating fast fault current during non-symmetrical faults in phases affected by undervoltage. The capability in question shall be provided while meeting the requirements as regards static and dynamic parameters as well as symmetrical faults and taking account of limitations resulting from a non-symmetrical load on the basic power-generating system.

Article 20(3)(a) - active power restoration following a fault

As regards the post-fault restoration of active power, PPM must meet the following requirements:

(i) Post-fault active power restoration begins when post-fault voltage is restored to the value no lower than 90% Un on the basic power-generating system included in the PPM.
(ii) Maximum time for post-fault active power restoration (time counted from the removal of fault): 5 seconds.
(iii) Volume of restored active power: 90% of pre-fault power, if the primary source of energy is available.
(iv) Accuracy of active power restoration, understood as offset: 10%
(v) Undamped oscillations after the active power restoration are not allowed.

Article 21(2)(a) - synthetic inertia

It is not required to apply synthetic inertia, therefore its operating parameters are not defined.

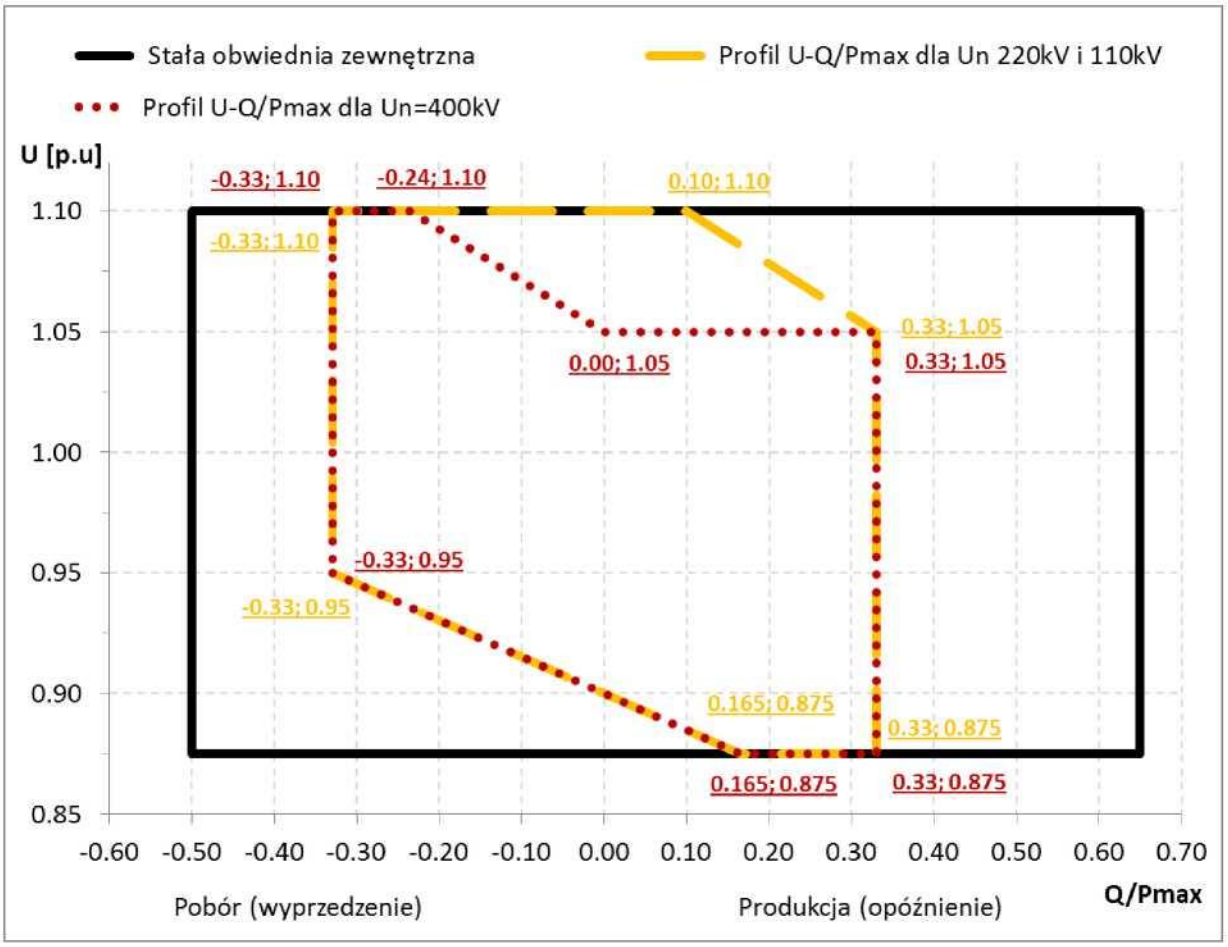
Article 21(3)(b)(i) - reactive power at the maximum power

Capability of a PPM type D, connected to a network of 110 kV and more, to generate reactive power at the maximum power has been defined in the table below and in the figure below.

Inner envelope parameters

Network rated voltage	Maximum range Q/Pmax	Maximum range of the voltage level at steady state in relative units
400 kV	0.66	0.225
220 kV and 110 kV	0.66	0.225

U-Q/Pmax profile of the power park module



Stała obwiednia zewnętrzna	Fixed inner envelope
Profil U-Q/Pmax dla Un=400kV	U-Q/Pmax profile for Un=400 kV
Profil U-Q/Pmax dla Un 220kV i 110kV	U-Q/Pmax profile for Un=220 kV and 110 kV
Pobór (wyprzedzanie)	Consumption (leading)
Produkcja (opóźnienie)	Production (lagging)

The chart presents the boundaries of the U-Q/Pmax profile, divided into voltages at connection point, expressed as a ratio of its actual value to reference voltage 1 pu, compared to the ratio of reactive power (Q) to maximum power (Pmax). Location, size and shape of the inner envelope are separately

marked for 400 kV network voltage (with a dotted red line) and for a 220 kV and 110 kV network voltage (with a dashed orange line). A relevant SO may modify the presented range of the U-Q/Pmax profile (within the framework of maximum values and fixed outer envelope provided for in the Regulation), should such need be expressed by an expert opinion concerning the connection.

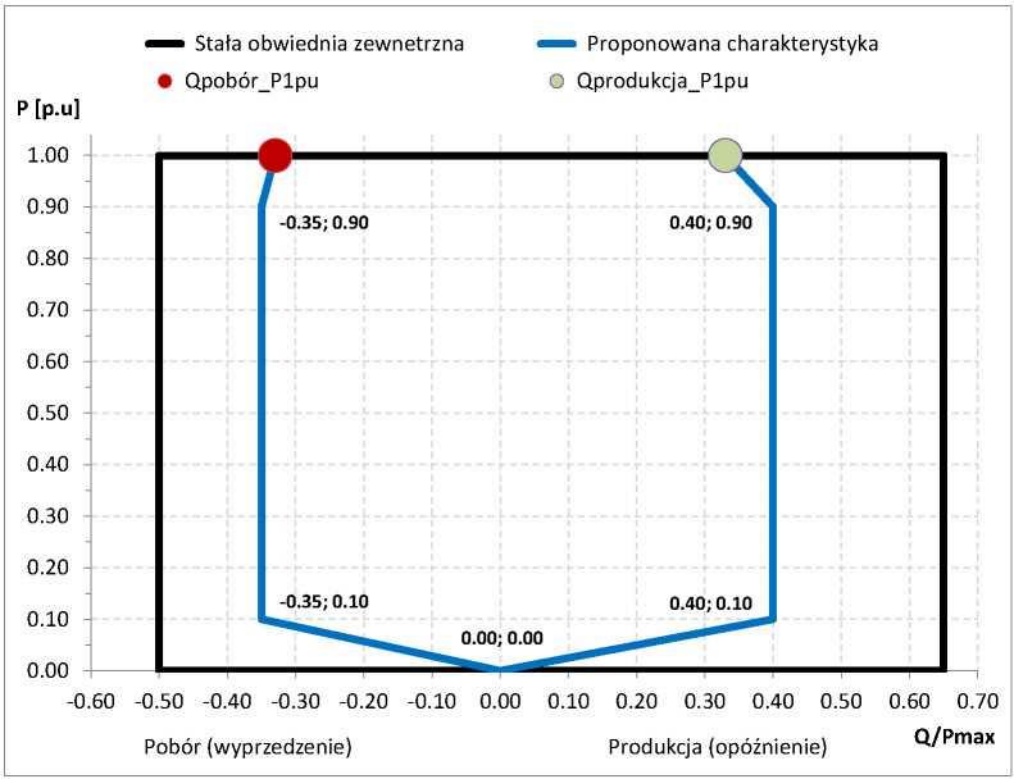
Unless a relevant SO decides otherwise, PPM type C or D, connected to the network with a voltage below 110 kV, must be capable of providing reactive power at the connection point, at maximum power, resulting from cosφ=0.95 towards reactive power consumption and generation.

Article 21(3)(c)(i) - reactive power below the maximum power

The required capability of PPM to generate reactive power below the maximum power has been defined below:

Network rated voltage	Maximum range Q/Pmax
400 kV	0.75
220 kV and 110 kV	0.75

P-Q/Pmax profile of the power park module

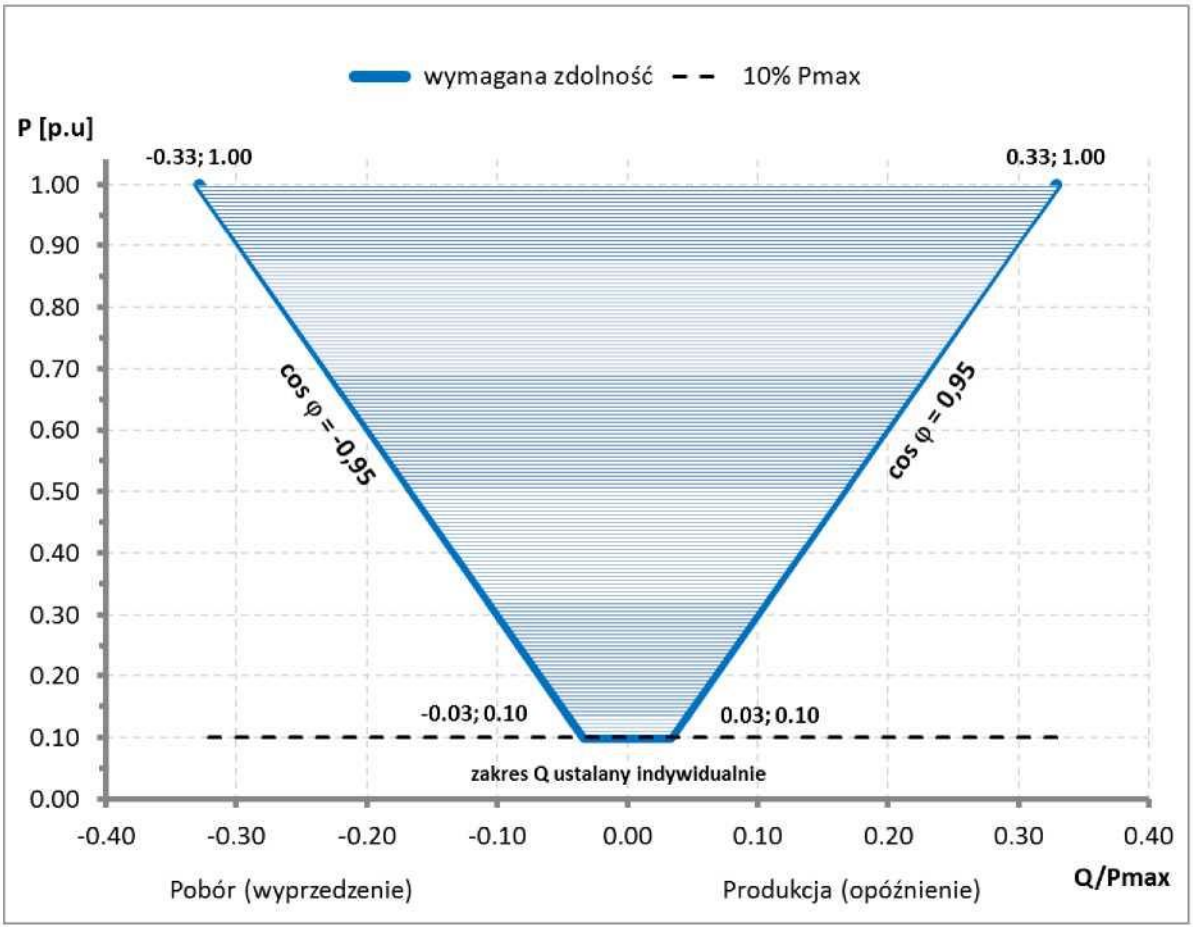


Stała obwiednia zewnętrzna	Fixed inner envelope
Qpobór_P1pu	Qconsumption_P1pu
Proponowana charakterystyka	Proposed characteristics
Qprodukcja_P1pu	Qproduction_P1pu
Pobór (wyprzedzanie)	Consumption (leading)
Produkcja (opóźnienie)	Production (lagging)

The chart presents the boundaries of the P-Q/Pmax profile, expressed as a ratio of its actual active power to maximum power in relative units (pu), compared to the ratio of reactive power (Q) to maximum power (Pmax). A relevant SO may modify the presented range of the P-Q/Pmax profile (within the framework of maximum values and fixed outer envelope provided for in NC RfG), should such need be expressed by an expert opinion concerning the connection.

Unless a relevant SO decides otherwise, PPM type C or D, connected to the network with a voltage below 110 kV, must be capable of providing full reactive power at the connection point, in the range below the maximum power to 0.1 of the maximum power, in line with technical capabilities, however no less than resulting from cosφ=0.95 (for current active power), both towards reactive power consumption and generation. When PPM operates at active power in the range below 0.1 of Pmax, the entire remaining reactive power shall be made available, in line with technical capabilities, however detailed requirements from the power-generating module for the purpose of reactive power generation will be arranged individually with a relevant SO.

P-Q/Pmax profile of the power park module type C or D connected to the network with voltage below 110 kV



wymagana zdolność - - 10% Pmax	required capability - - 10% Pmax
zakres Q ustalany indywidualnie	Q range arranged individually
Pobór (wyprzedzanie)	Consumption (leading)
Produkcja (opóźnienie)	Production (lagging)

Article 21(3)(c)(iv) - rate of adjustment of reactive power

The power park module must be capable of moving to any operating point within the confines of the P-Q/Pmax profile, defined pursuant to Article 21(3)(c)(i), within 150 seconds, unless specified otherwise for a given adjustment type, in line with the requirements laid down on the basis of Article 21(3)(d).

In the event of applying static measures for adjusting reactive power, longer adjustment time of moving between extreme reactive power values (however no longer than 15 minutes). Longer adjustment time will be agreed between a relevant SO and a power-generating facility owner. If moving between two PGM operating points requires a change in the position of a gear of on-load tap changer of the PGM transformer, then the indicated time shall be extended by the time of adjusting the position of the tap changer.

Article 21(3)(d)(iv) - dynamics of reactive power activation in the voltage function

PPM must meet the following additional requirements concerning the stable voltage level:

- When working in the voltage adjustment mode (in line with the set static characteristics, individually parameterized in the range resulting from Article 21(3)(d)(ii),(iii)), following a voltage step change the power park module must be capable of reaching 90% of the change in the generated reactive power in no more than t_1=5 seconds and must reach the value determined by the slope in no more than t_2=60 seconds.

Article 21(3)(d)(vi) - dynamics of power factor adjustment

At operation in the power factor adjustment mode, the accuracy of reaching target power factor value following a sudden change in the generated active power is expressed by tolerance concerning the equivalent change in the reactive power and should not exceed 5% of the maximum reactive power or 5 MVAr (depending on which of these values is lower) and should be completed in no more than 150 seconds.

Article 21(3)(d)(vii) - operating modes of reactive power adjustment systems

In order to select the reactive power adjustment mode and define related setpoints, a relevant SO should have a possibility of remotely selecting one of three adjustment modes and requesting an operating point, unless a relevant SO decides otherwise in agreement with a power park module owner.

Article 21(3)(e) - active or reactive power contribution priority

During faults, where fault ride through is required, generation of reactive power has priority.

Article 21(3)(f) - oscillation damping

PPM contribution to power oscillation damping capability is not required.

Article 25(1) - voltage conditions

An offshore power park module must be capable of remaining in connection with the network and operating in the network voltage ranges at the connection point, expressed as a ratio of voltage at the connection point to reference voltage 1 pu and in periods defined in the table below:

Voltage range	Operating time
1.118 pu - 1.15 pu (*)	60 minutes
1.05 pu - 1.10 pu (**)	60 minutes

(*) Concerns a network with base voltage lower than 300 kV.
(**) Concerns a network with base voltage between 300 kV and 400 kV.