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)

May 2025

Disclaimer for the English translation of '*Wymogi ogólnego stosowania wynikające z Rozporządzenia Komisji (UE) 2016/631 z dnia 14 kwietnia 2016 r. ustanawiającego kodeks sieci dotyczący wymogów w zakresie przyłączenia jednostek wytwórczych do sieci (NC RfG) Maj 2025*'

This document is an English translation of '*Wymogi ogólnego stosowania wynikające z Rozporządzenia Komisji (UE) 2016/631 z dnia 14 kwietnia 2016 r. ustanawiającego kodeks sieci dotyczący wymogów w zakresie przyłączenia jednostek wytwórczych do sieci (NC RfG) Maj 2025*' approved by President of Energy Regulatory Office.

This translation is not a legal document and is a translation of the original in English for information purposes only. Polish version of the document is legally binding. In the case of doubt, the Polish document should be referred to. This English translation is not required by law or any regulation.

Table of Contents

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: Requirements) constitute a document containing substantive arrangements concerning the technical requirements resulting from NC RfG[1] and subject to approval by the competent regulatory authority, which PSE S.A. has been obliged to prepare on the basis of NC RfG and Article 9ga (1) of the Energy Law[2]. In line with NC RfG, the requirements of general application are to be developed by the relevant system operator within whose territory the connection is located, i.e. TSO or DSO, as well as the designated transmission system operator. The Republic of Poland has taken advantage of the possibility of transferring the obligation to establish the requirements of general application from relevant system operators to PSE S.A. as the transmission system operator referred to in Article 7(9) of NC RfG. The Requirements developed by PSE S.A. were subject to the process of consultations with DSOs and market participants.

The document has been divided in accordance with the classification included in NC RfG and refers successively to PGMs type A, B, C and D, in line with the classification carried out by the 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).

The President of the Energy Regulatory Authority (Urząd Regulacji Energetyki – URE), by decision of 2 January 2019, ref. DRE_WOSE_7128.550.2.2018.ZJ, approved the document “Requirements for 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)”, hereinafter “**Requirements 2019**".

At the request of the TSO, after working out the changes and consulting them with market participants, including the DSOs, the President of URE, approved the updated requirements of general application presented in this document titled: “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) – May 2025”, hereinafter ”**Requirements 2025**”.

The date of entry into force of **Requirements 2025** has been set for 6 months after the publication in the URE Public Information Bulletin of the decision of the President of URE to amend the decision of 2 January 2019, ref. DRE_WOSE_7128.550.2.2018.ZJ.

Requirements 2025 apply to PGMs:

a) Type D PGMs:

  i. for which connection conditions will be issued after the entry into force of Requirements 2025; or

  ii. in the event of notification of modernisation or modification of a PGM to the relevant system operator affecting changes to the existing technical parameters of a PGM, necessitating a significant amendment to the connection agreement in accordance with Article 4(1)(a), after

[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 2022, item 1385, as amended)

the date of entry into force of Requirements 2025, as appropriate to the extent of the modernisation or replacement.

b) Type C PGMs:

i. for which connection conditions will be issued after the entry into force of Requirements 2025; or

ii. in the event of notification of modernisation or modification of a PGM to the relevant system operator affecting changes to the existing technical parameters of a PGM, necessitating a significant amendment to the connection agreement in accordance with Article 4(1)(a), after the date of entry into force of Requirements 2025, as appropriate to the extent of the modernisation or replacement.

c) Type B PGMs:

i. for which connection conditions will be issued after the entry into force of Requirements 2025.

d) Type A PGMs:

i. for which the connection conditions or notification of grid connection will be issued after 31 December 2026.

Requirements 2019 shall apply to the remaining PGMs subject to NC RfG requirements, to which **Requirements** 2025 do not apply.

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 are not directly defined in NC RfG. The abbreviations and terms used in the Requirements are consistent with the definitions laid down in NC RfG.

FRT	fault-ride-through
NPS	National Power System
PGM	(Power Generating Module) means a synchronous power-generating module or a power park module
PPM	power park module
HO	household operation
RMS	Electromechanical transient phenomena measured by changes in the Root Mean Square (RMS) value of specific physical quantities
EMT	Electromechanical transient phenomena measured by changes in the instantaneous value of specific physical quantities (Electromechanical Transients)
LFC	The central unit of the automatic Load Frequency Control system, sending individual active power change control signals to power generating modules.

Requirements of general application

Article 13(1)(a)(i) – frequency parameters

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

Table 1: Minimum time periods for which a power-generating module has to be capable of operating on different frequencies, deviating from a nominal value, without disconnecting from the network.

Frequency range	Time period for operation
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 in operation at the rate of change of frequency not greater than:

- for PPMs

$$\left|\frac{df_{max}}{dt}\right| = 2.5\left[\frac{Hz}{s}\right].$$

- for synchronous PGMs

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

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

The requirement specified above is a minimum requirement. If the technology applied allows grid connection 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 agreed loss of mains (LOM) protection setting.

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

- Capability of setting the frequency threshold of the LFSM-O in the range: 50.2 Hz–50.5 Hz, default value 50.2 Hz.
- LFSM-O droop setting capability in the range: 2–12%, default value 5%.
- As regards power park modules, the P_{ref} means the actual active power output at the moment the LFSM-O threshold is reached .

The possibility to select, upon the TSO's order, the following setpoints must be ensured:

- frequency threshold for LFSM-O activation,
- droop within the required range.
- the possibility of blocking LFSM-O and the capability of executing contingency operation with set values indicated by the relevant SO, regardless of the LFSM-O power setpoint value.

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

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

The above arrangement does not exclude adapting a PGM type A to LFSM-O through gradual disconnection of individual generating sources included in the PGM, in particular PPM.

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

It is required that following the achievement of the minimum regulating level in LFSM-O, the power-generating module is capable of stable operation at this level insofar as the requirement operation below the minimum regulating level has not been defined by the TSO as part of PGM adaptation to island operation.

P_{ref} means the actual active power output of the PPM at the moment the LFSM-O threshold is reached. Reduction of PPM active power resulting from operation in LFSM-O is executed from the value of active power output at the moment LFSM-O threshold is reached to the power value resulting from the static performance of LFSM-O, provided that the power of the primary energy source has not been decreased below the level that allows reaching the required level of operation.

Article 13(4) – admissible power reduction

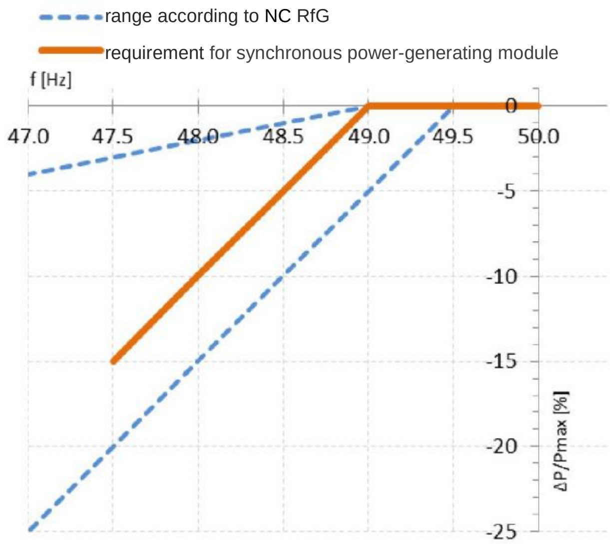
Admissible active power reduction compared to the maximum generated power (defined at the frequency of 50 Hz), is as follows with falling frequency:

a. for synchronous power-generating modules, excluding synchronous power-generating modules referred to in (b): 10% of the maximum capacity per 1 Hz, at a frequency drop below 49 Hz (Fig. 1 a);
b. for synchronous power-generating modules such as gas unit or combined cycle gas turbine unit: 4% of the maximum capacity per 1 Hz, at a frequency drop below 49.5 Hz (Fig. 1 b);
c. for power park modules: 2% of the maximum capacity per 1 Hz, at a frequency drop below 49 Hz (Fig. 1 c);

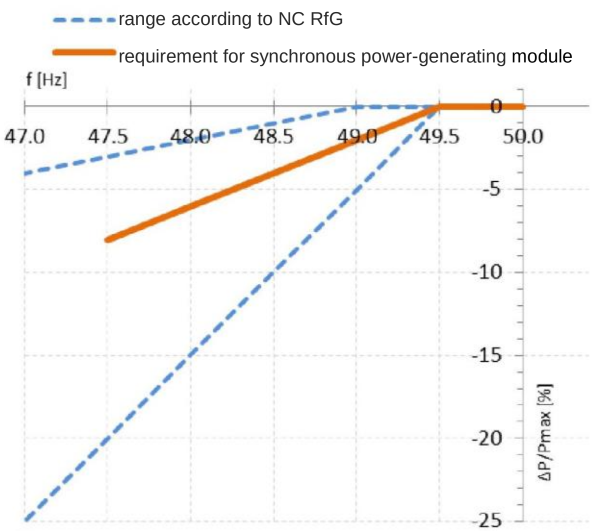
If a given PGM can operate at a lower power reduction rate, it shall ensure such operation (applies to PPMs in particular).

Figure 1: Fig. Maximum power capability reduction
with falling frequency.

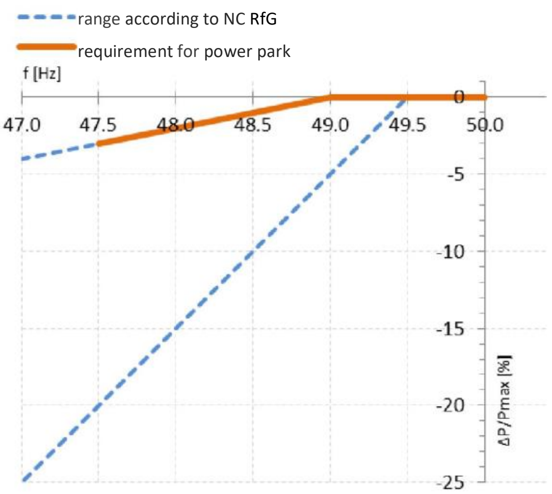
a)



b)



c)



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 PGMs

PGMs are required to be adapted to remote control of the facility by the relevant SO, as regards the discontinuation of active power generation. PGMs are to be equipped with an RS 485 input port supporting, at a minimum, the SUNSPEC communication protocol, unless the relevant SO specifies a different standard.

Article 13(7) – automatic connection to the network

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

- frequency of network voltage falls within the range between 49.00 Hz and 50.05 Hz, and
- time delay (understood as time between the moment frequency value returns to the range defined above and the moment of connecting the power-generating module to the network) – at least 60 s., and
- maximum admissible gradient of increase in active power output is 10% of the maximum capacity per minute.

Article 14(2)(b) – remote control of PGMs type B

PGMs are required to be capable of remote control of the facility for active power reduction at an order of the relevant SO. The reduction requirement remains active also where the primary energy source is insufficient to achieve the set limit value.

In order to enable remote control of generated active power, PGMs are to be equipped with an RS 485 input port supporting, at a minimum, the SUNSPEC communication protocol, unless the relevant SO specifies a different standard. The communication standard for telemechanics is determined by the relevant SO.

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

The fault-ride-through requirement is to be met throughout the required operating area of the PGM as defined by these requirements, that is, when it was operating at any point within the required range of active and reactive power and voltage under pre-fault conditions.

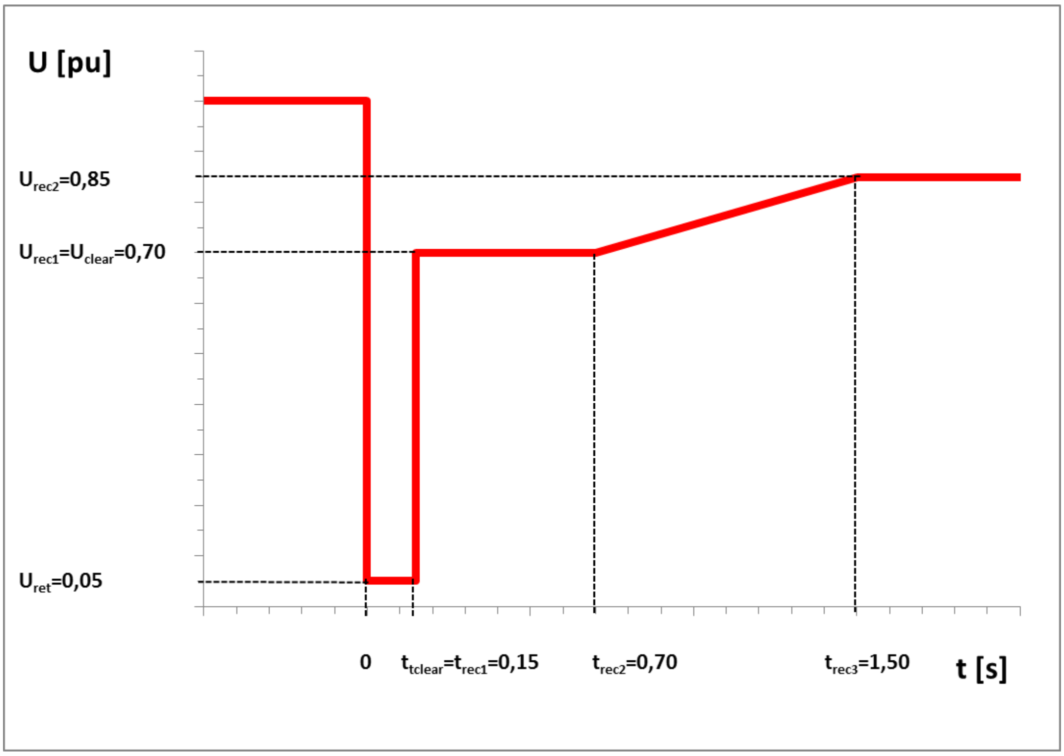
A PGM may disconnect from the network during a fault if phase-to-phase voltage at the connection point falls below the required profile of the fault-ride-through profile and voltages directly before the fault at the connection point exceed the admissible value laid down in relevant laws and regulations.

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

Table 2: Fault-ride-through capability parameters of synchronous power-generating modules

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

Figure 2. Required fault-ride-through profile for the synchronous power-generating module

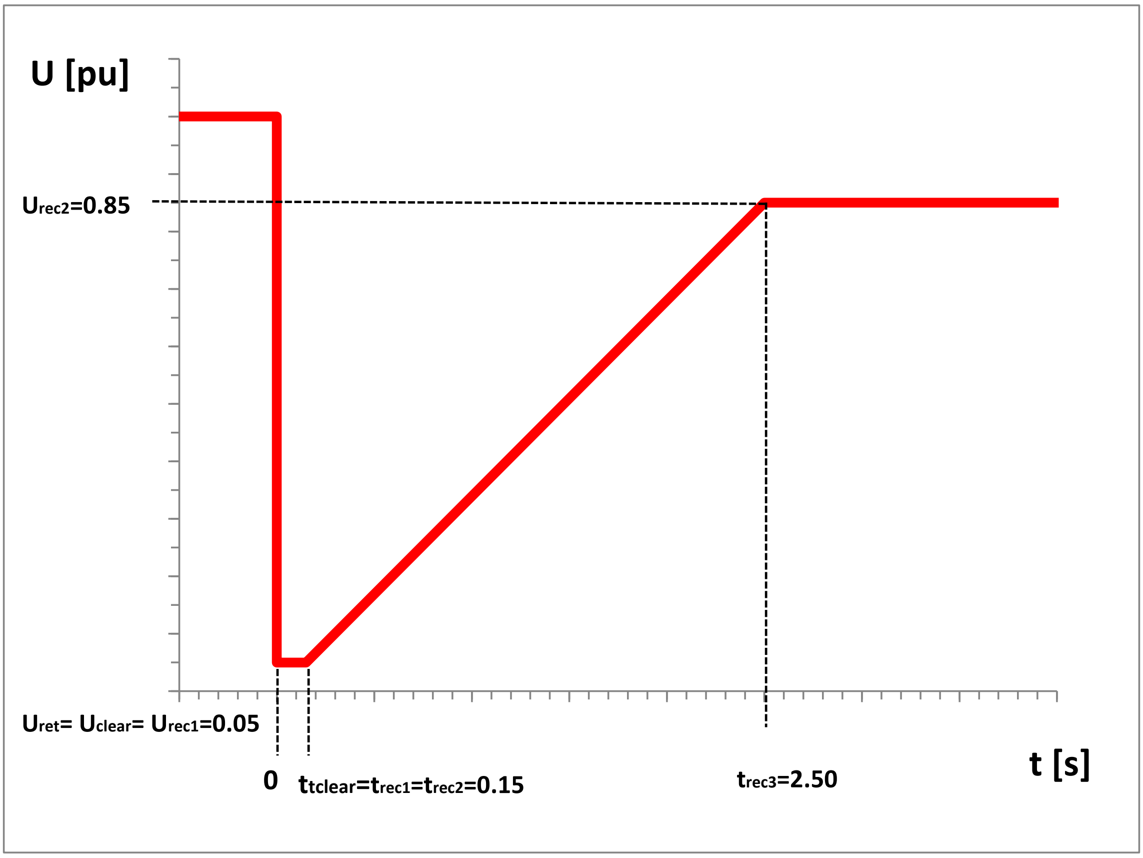


- **Power park modules** must meet the requirements for the fault-ride-through capability that are described in the table below and figure below:

Table 3: Parameters for the fault-ride-through capability of power park modules

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

Figure 3: Required fault-ride-through profile for the power park module:



Article 14(3)(b) – FRT for asymmetrical faults

The fault-ride-through requirement is to be met throughout the required operating area of the PGM as defined by these requirements, that is, when it was operating at any point within the required range of active and reactive power and voltage under pre-fault conditions.

The PGM's required fault-ride-through capabilities in the case of asymmetrical faults concern the phase-to-phase voltage profile with the lowest amplitude.

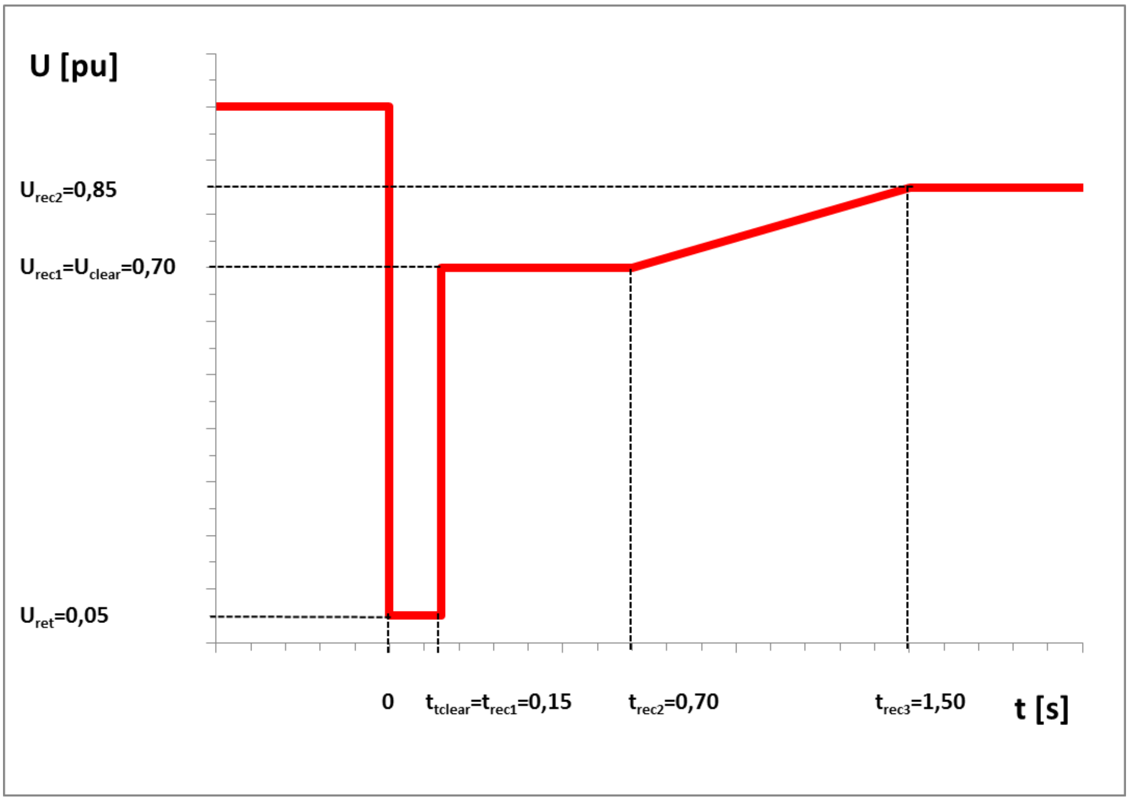
PGM may disconnect from the network during the asymmetrical fault if at least one phase-to-phase voltage at the connection point falls below the required fault-ride-through profile and voltages at the connection point exceed the admissible value laid down in relevant laws and regulations directly before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

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

Table 4: Fault-ride-through capability parameters of synchronous power-generating modules

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

Figure 4: Required fault-ride-through profile for the synchronous power-generating module

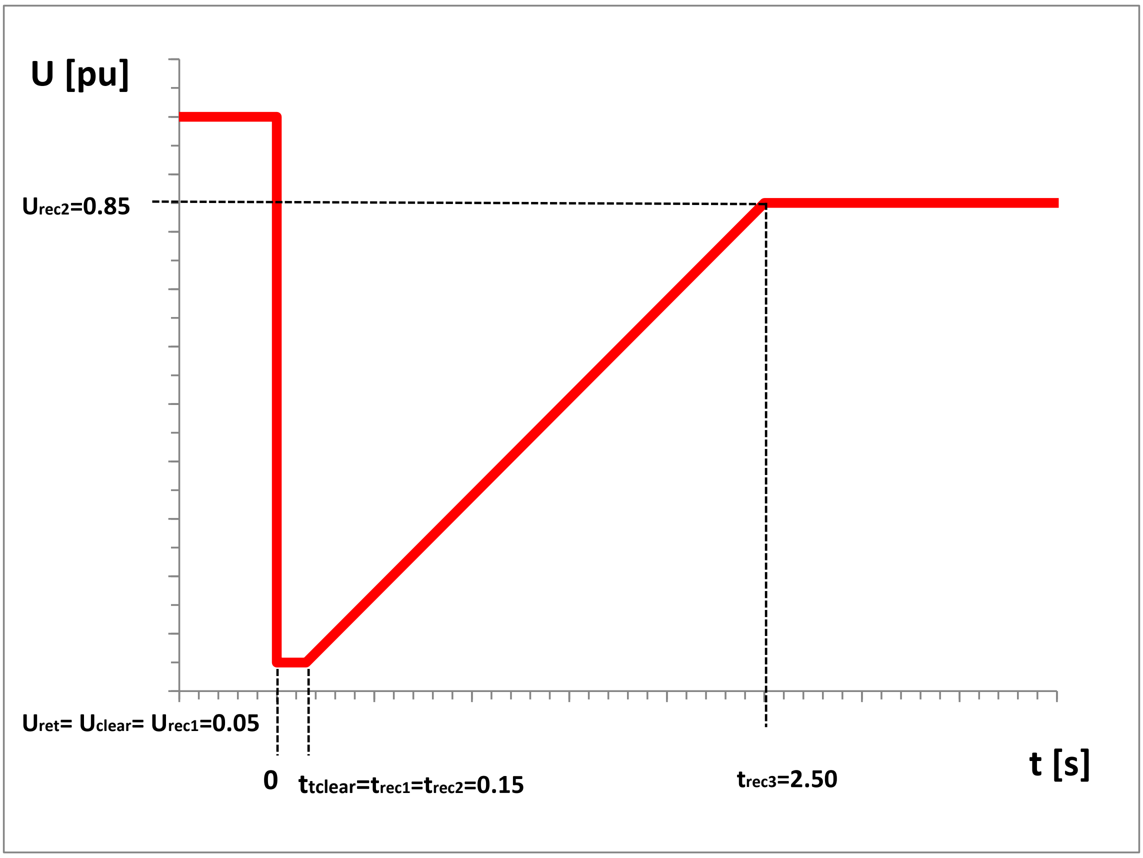


- **Power park modules** must meet the requirements for the fault-ride-through capability that are described in the table below and figure below:

Table 5: Parameters for the fault-ride-through capability of power park modules

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

Figure 5: Required fault-ride-through profile for the power park module:



Article 14(4)(a) – PGM reconnection to the network

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

- frequency of network voltage falls within the range between 49.00 Hz and 50.05 Hz, and

- voltage at the connection point falls into the range of admissible voltages required by the relevant SO under specific laws and regulations, and
- time delay (understood as time between the moment the value of the above parameters returns to the range defined above and the moment of connecting the power-generating module to the network) – at least 60 s.
- conditions for synchronisation with the network are met in terms of:
  - (i) Voltage difference – not more than 5%
  - (ii) Phase angle difference – not more than 10°
  - (iii) Frequency difference – not more than 0.067 Hz for synchronous power-generating modules and 0.2 Hz for power park modules

Unless the relevant operator decides otherwise, in the event that the 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 the relevant SO. It is allowed for the relevant SO to use a time delay in order to block automatic reconnection, depending on the location of the substation and configuration of the network to which the power-generating module is connected.

Article 14(5)(d)(i) – data exchange

Power-generating modules are required to have the ability to exchange real-time information in accordance with the document "Zakres wymienianych danych dla potrzeb planowania pracy i prowadzenia ruchu KSE” [Scope of exchanged data for operation planning and operational management of the NPS] developed pursuant to Article 40(5) of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation. The document is published on the PSE website under the “Dokumenty” tab

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

The scope of real time data exchange shall be in accordance with the document „Zakres wymienianych danych dla potrzeb planowania pracy i prowadzenia ruchu KSE”[Scope of exchanged data for operation planning and operational management of the NPS] developed pursuant to Article 40(5) of Commission Regulation (EU) 2017/1485 of 2 August 2017 establishing a guideline on electricity transmission system operation, with a special focus on the availability of a primary energy source for power-generating modules using wind energy or solar energy. The document is published on the PSE website under the “Dokumenty” tab

Article 15(2)(a) -– automatic active power control

The period in which the modified active power setpoint must be reached shall not be longer than 5 minutes.

The accuracy of the control shall be:

- for synchronous power-generating modules: not less than 1% of the maximum capacity
- for power park modules: not less than 1% of the maximum capacity, with respect to its average 1-minute value.

Article 15(2)(b) - manual active power control

In the event of failure of the remote control system, the PGM active power setpoint is to be reached in no more than 30 minutes from the moment the relevant SO issues a command, regardless of whether the PGM active power control system operates automatically.

In the event of failure of the automatic active power control system at the PGM level, control accuracy shall be not less than 5% of the maximum capacity for synchronous power-generating modules and not less than 5% with respect to its average minute value of maximum capacity for power park modules.

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

- Frequency threshold setting capability for LFSM-O in the range: 49.5 Hz – 49.8 Hz, default value 49.8 Hz.
- LFSM-O droop setting capability in the range: 2–12%, default value 5%.
- For power park modules, the P_{ref} value means the actual active power output at the moment the LFSM-U threshold is reached.

The possibility to select, upon the TSO's order, the following settings must be ensured:

- frequency threshold for LFSM-U activation,
- droop,
- the possibility for the relevant SO to block LFSM-U when congestions occur in real time (and not identified on the basis of forecasts). LFSM-U blocking shall be limited to the system area where congestions occurred. The relevant SO shall pass information to the TSO on active LFSM-U blocking. Network conditions that prevent LFSM-U blocking shall be agreed between the relevant SO and TSO.

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

The required parameters for active power frequency response in FSM:

Table 6: The required parameters for active power frequency response in FSM:

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

For power park modules, the P_{ref} value means the actual active power output at the moment the FSM threshold is reached.

Article 15(2)(d)(iii) – dynamic parameters of FSM

Parameters of full activation of active power frequency response resulting from a frequency step change:

Table 7: Parameters of full activation of active power frequency response resulting from a frequency step change

Parameters	Ranges or values
Active power range related to the maximum capacity (frequency response range) $\frac{\lvert\Delta P_i\rvert}{P_{max}}$	5% -10%
For power-generating modules with inertia, the maximum admissible initial delay $t1$, unless justified otherwise in line with Article 15(2)(d)(iv)	2 s
For power-generating modules without inertia, the maximum admissible initial delay $t1$, unless justified otherwise in line with Article 15(2)(d)(iv)	0.5 s
Maximum admissible choice of full activation time $t2$	30 s

Article 15(2)(d)(iv) – initial delay in FSM

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

Article 15(2)(d)(v) – operating time in FSM

The power-generating module shall be capable of providing full active power frequency response for at least 30 minutes, provided the primary energy source 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 FSM monitoring

Signals for monitoring the performance of FSM active power frequency response shall be sent to the TSO only if a given PGM participates in the FSM frequency control process .

Article 15(2)(g)(ii) – signals for FSM monitoring c

If a given PGM participates in the FSM frequency control 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 provision shall include at least:

- local frequency or rotational speed;

- PGM operating mode (i.e. LFSM-U/LFSM-O, household operation and island operation – if the PGM is adapted it),

whereas, at the stage of connecting a PGM to the network or the TSO starting to use the capability of the PGM to regulate frequency in the system, the relevant SO in agreement with the TSO shall determine additional signals necessary for monitoring, taking account of the power generation technology and the provisions of the document "Standardy systemu LFC" [*LFC System Standards*] available on the TSO website under the https://www.pse.pl/dokumenty tab.

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

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

Household operation must not be interrupted when exceeding the abovementioned 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 to be used in the process of defending and restoring the NPS, in particular those capable of island operation.

Article 15(6)(b)(i) – fault recorder

Unless the relevant SO decides otherwise, power-generating facilities must feature an installation that ensures the recording of the voltage and current shape during failures/faults and monitoring the dynamic behaviour of the system with the following accuracy (for nominal values at steady state):

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

Current and voltage instantaneous values must be recorded at a recording frequency and with time synchronisation required by the relevant SO.

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

Unless specified otherwise, the following thresholds shall be adopted 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 a 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, oscillations with a frequency between 0.1 Hz and 5 Hz and a simultaneous application of the following thresholds that trigger oscillation recording are required to be monitored (simultaneous exceeding of 2 value thresholds is assumed):

- oscillation amplitudes - $A_{rel} > 2\%$

  where $A_{rel}=A/P$, A – oscillation amplitude [MW], P – active power of a generator [MW]

- damping factor – $\xi < 5\%$

  where: $\xi = (A1-A2)/A1$, A1, A2 – successive 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)(c)(iii) – simulation models

The following simulation models that adequately reflect the behaviour of the power-generating module are required to be provided:

a) generic models in accordance with the current CGMES standard (2.4.15 or later) or in the GE PSLF format, which allow mapping the behaviour of the power-generating module:
   - in steady-state power flow calculations,
   - in fault calculations,
   - in RMS dynamic simulations.

b) technical data and parameters of models, in accordance with the format specified by the TSO,

c) detailed models for PGMs with a maximum capacity of 75 MW and above, connected to the 110 kV grid and above:
   - in PowerFactory format (2023 or newer) that allow mapping the behaviour of the power-generating module:
     - in steady-state power flow calculations,
     - in fault calculations according to IEC 60909,
     - in RMS dynamic simulations in terms of detailed models (including representations for the negative and positive components),
     - in harmonic calculations.
   - in PSCAD format (V5 or newer) that allow the mapping of the behaviour of the power-generating module in EMT simulations, in the case of PGMs connected to the TSO's grid, unless otherwise specified by the TSO.

It is permissible, in coordination with the Relevant SO, to provide simulation models in a standard other than those specified in subparagraphs (a) and (c).

Article 15(6)(c)(iii) – data format

The use of COMTRADE is required as the communication protocol for recorded data.

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

Unless otherwise agreed by the relevant SO and the power-generating module owner in coordination with the TSO, the power-generating module shall have the ability to change the active power output at the maximum rate specified in Table 8, taking into consideration the specific characteristics of prime mover technology.

Table 8: Limits of the rate of change of active power output in up and down direction

Type of power-generating module	Rates of change of active power output in up and down direction [% of maximum capacity / minute]
thermal power units (hard coal)	4 ÷ 6
thermal power units (brown coal)	3 ÷ 4
gas-fired thermal power units (closed circuit)	5 ÷ 8
gas-fired thermal power units (open circuit)	12 ÷ 20
combustion engine-driven thermal power units	80 ÷ 100
hydro power units	40 ÷ 50
wind farms	90 ÷ 100
photovoltaic farms	90 ÷ 100

Notwithstanding the above-mentioned ability to change the active power output at the maximum rate specified in Table 8, the power-generating module must be capable of performing the change of the active power output at a rate lower than the maximum rate.

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 the maximum capacity of the PGM. In technically justified cases, for thermal power units in the range between 0.9 of the maximum capacity to 1.0 of the maximum capacity, lower limit rates of change of active power are admissible, however, they must be arranged with the relevant SO, in in coordination with the TSO.

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

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

- for base voltage between 110 kV and 300 kV:

Table 9: The minimum time period during which a power-generating module must be capable of operating for voltages deviating from the reference 1 pu value at the connection point without disconnecting from the network is as follows:

Voltage range	Operating time
1.118 pu – 1.15 pu	60 minutes

- for base voltage between 300 kV and 400 kV:

Table 10. The minimum time period during which a power-generating module must be capable of operating for voltages deviating from the reference 1 pu value at the connection point without disconnecting from the network is as follows:

Voltage range	Operating time
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 period will be shorter, resulting separately from the frequency and voltage requirements.

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

The fault-ride-through requirement is to be met throughout the required operating area of the PGM as defined by these requirements, that is, when it was operating at any point within the required range of active and reactive power and voltage under pre-fault conditions.

The PGM may disconnect from the network during the fault, if phase-to-phase voltage at the connection point falls below the required fault-ride-through profile and voltages at the connection point directly before the fault exceed:

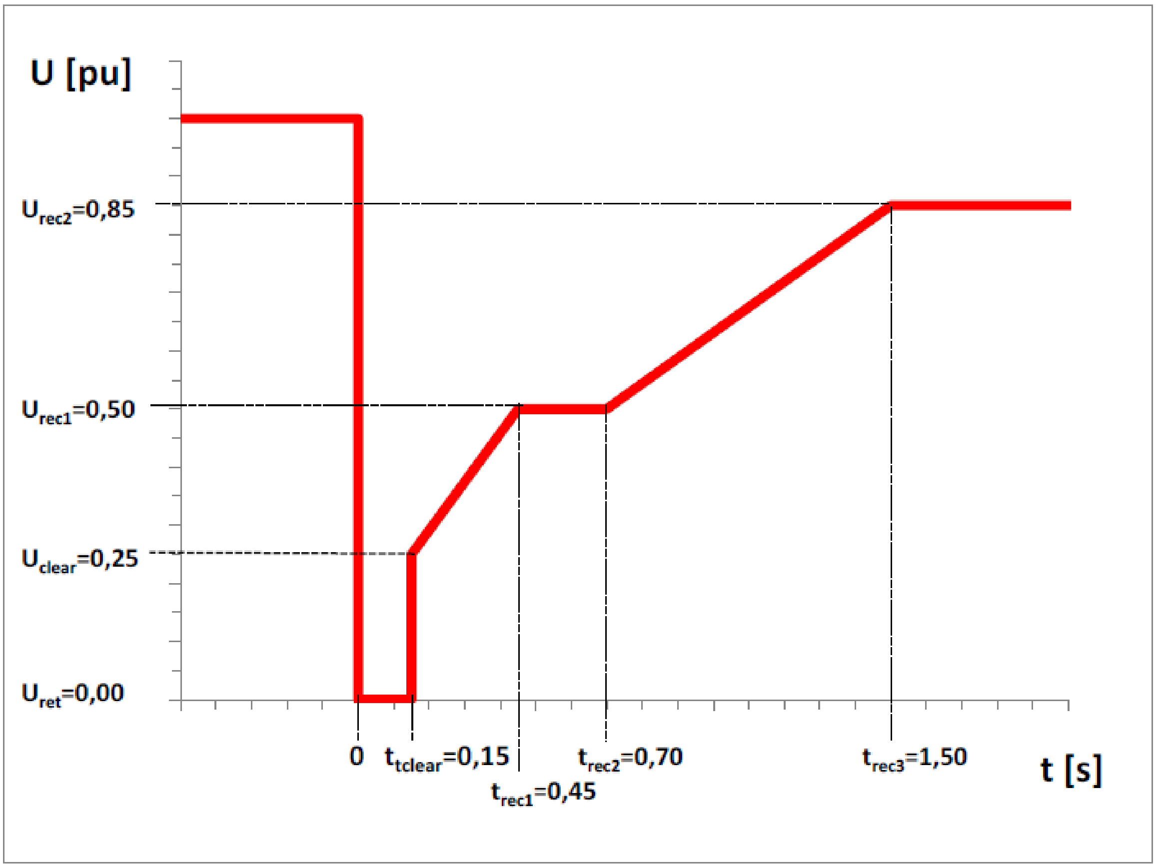
- the value determined in Article 16(2)(a) (for networks of 110 kV and more);
- the admissible value determined in relevant laws and regulations (for networks below 110 kV);

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

Table 11: Parameters for the fault-ride-through capability of synchronous power-generating modules

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

Figure 6: Required fault-ride-through profile for the synchronous power-generating module.

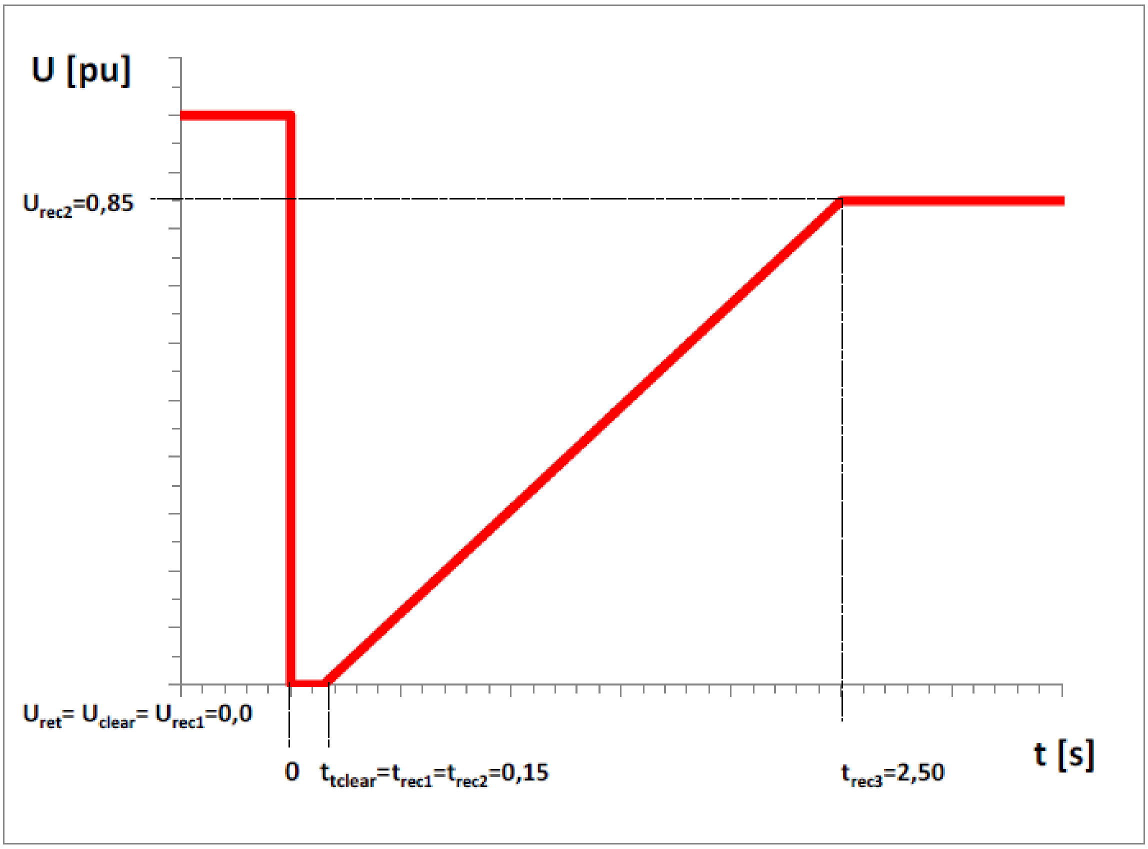


- **PPMs** type D must meet the requirements concerning the fault-ride-through capability that are described in the table and figure below:

Table 12: Parameters for the fault-ride-through capability of power park modules

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

Figure 7: Required fault-ride-through profile for power park modules



Article 16(3)(c) – FRT for asymmetrical faults

The fault-ride-through requirement is to be met throughout the required whole operating range of the PGM as defined by these requirements, that is, when it was operating at any point within the required range of active and reactive power and voltage under pre-fault conditions.

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

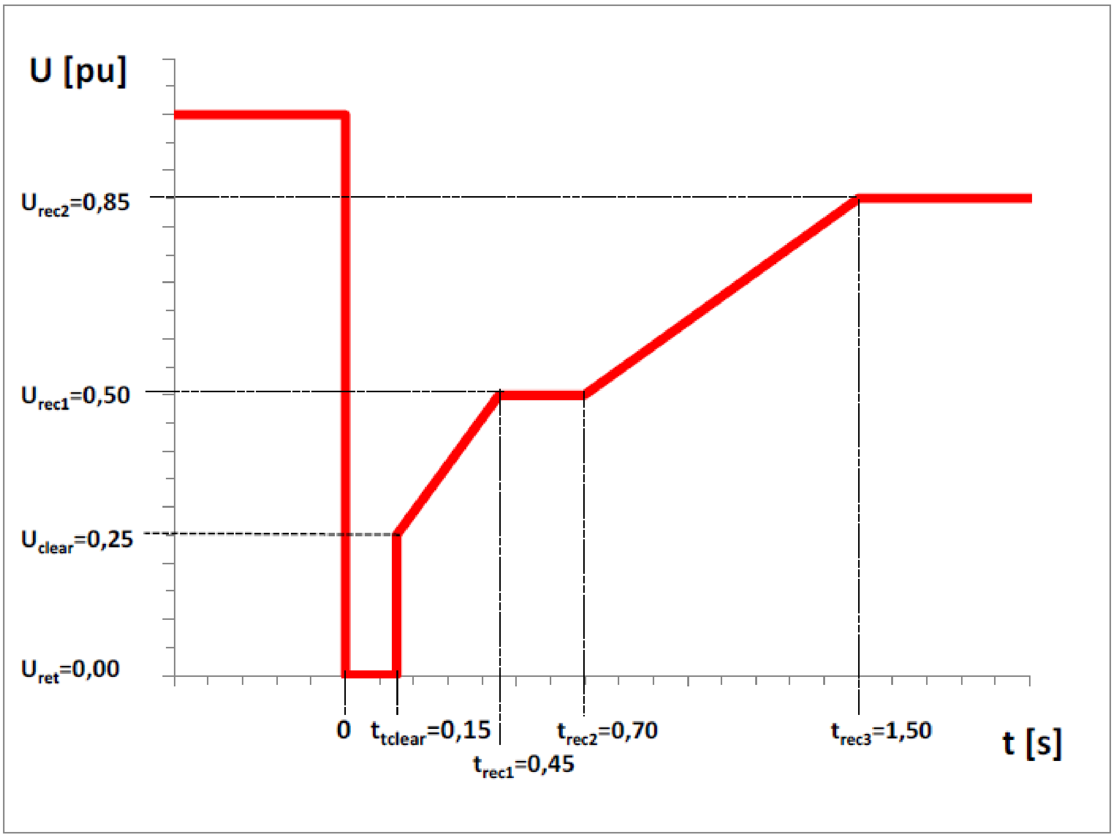
A PGM may disconnect from the network during an asymmetrical fault if at least one phase-to-phase voltage at the connection point falls below the required fault-ride-through profile:

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

Table 13: Parameters for the fault-ride-through capability of synchronous power-generating modules

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

Figure 8: Required fault-ride-through profile for the synchronous power-generating module.

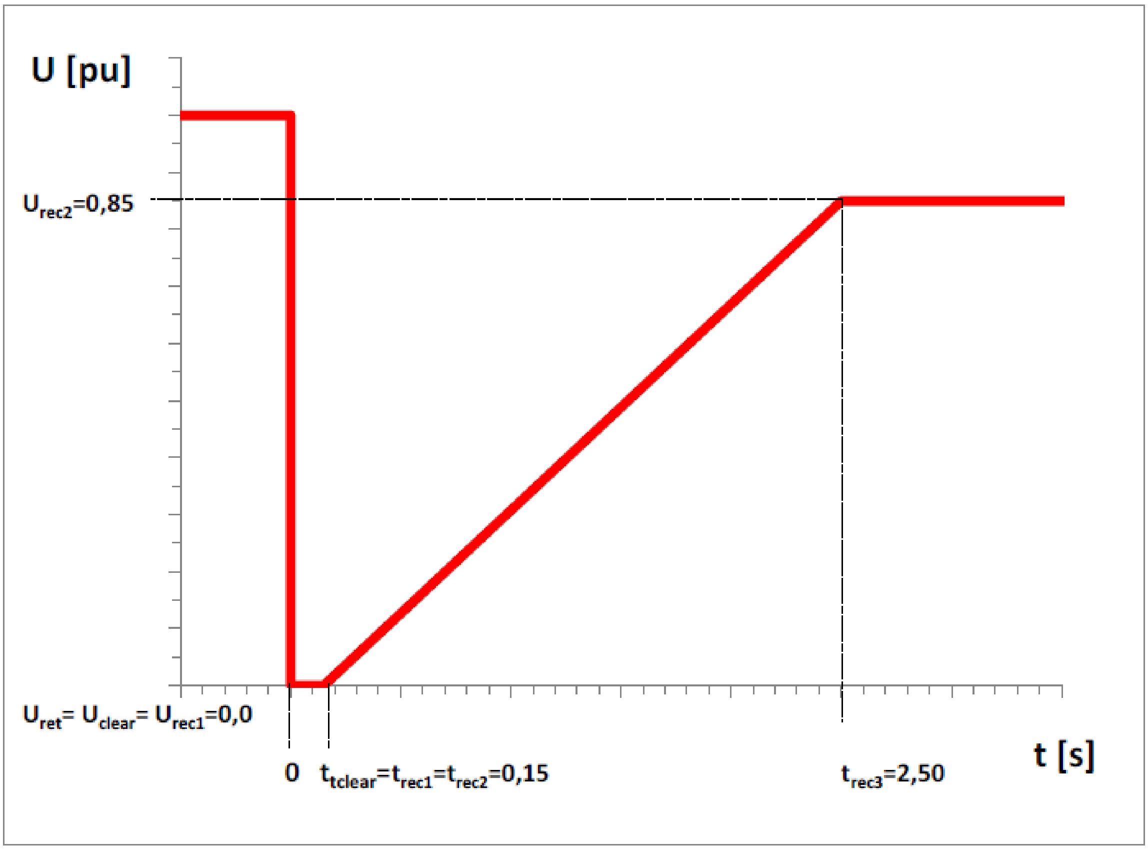


- **PPMs** type D must meet the requirements concerning the fault-ride-through capability that are described in the table and figure below:

Table 14: Parameters for the fault-ride-through capability of power park modules

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

Figure 9: Required fault-ride-through profile for power park modules



Article 16(4)(d) – synchronisation conditions

Unless the relevant SO has arranged otherwise with the power-generating facility owner, the requirements for synchronisation with the network shall be as follows:

(i) voltage, with the agreed voltage difference to fall within the range between 0% and +5% of network voltage;

(ii) frequency, with the agreed frequency difference to be no greater than 0.067 Hz;

(iii) phase angle range, with the agreed phase angle difference to fall within the range between 0° and +10°, where the "+" sign means the generator phase lead relative to the network;

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

(v) voltage and frequency deviations – synchronisation shall be possible within the network frequency range resulting from the provisions of Article 13(1)(a) and within the voltage range

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

Article 17(2)(a) – reactive power

A synchronous power-generating module, at maximum active power output, within the voltage range of 0.95-1.05 pu at device terminals, must be capable of providing (at device terminals) reactive power with a power factor in the range cosφ=0.85 towards reactive power production and cosφ=0.95 towards reactive power consumption.

With the maximum active power output and voltages outside the range of 0.95-1.05 pu at device terminals, the synchronous power-generating module must have the reactive power capability (Mvar) resulting from its technical capabilities resulting from the P-Q(U) characteristic (i.e. circle diagram).

When active power is below the maximum capacity (P<Pmax), the synchronous power-generating unit must have the reactive power capability (Mvar) in the range resulting from the circle diagram of the P-Q(U) capability of the synchronous power-generating module.

Article 17(3) – post-fault active power restoration

Post-fault active power restoration by the synchronous power-generating module shall take place without undue delay, in line with the natural 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 characteristic different from that resulting from the natural characteristics of the synchronous PGM, agreed with the relevant SO, in coordination with the TSO.

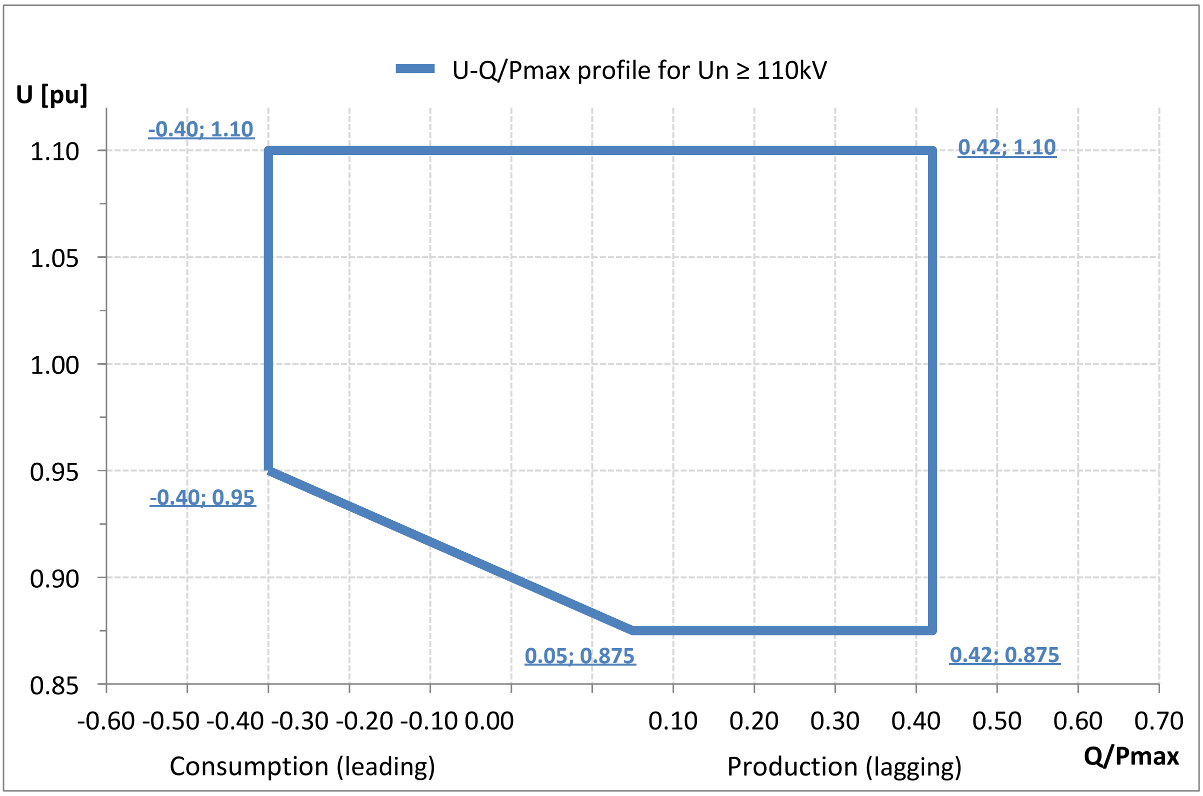
Article 18(2)(b)(i),(ii),(iii) – reactive power

The reactive power capability of a **synchronous power-generating module type D** connected at or above 110 kV at the maximum capacity is defined in the table and figure below. The requirements presented are the minimum requirement, the power-generating facility owner can provide all available reactive power, according to the technical capabilities of the synchronous power-generating module.

Table 15: Inner envelope parameters

Network rated voltage	Maximum range of Q/Pmax	Maximum range of steady-state voltage levels per unit [pu]
400 kV	0.82	0.225
220 kV and 110 kV	0.82	0.225

Figure 10: U-Q/Pmax profile of the synchronous power-generating module



The diagram represents the boundaries of the U-Q/Pmax profile by the voltage at connection point, expressed by the ratio of its actual value and reference 1 pu value, against the ratio of reactive power (Q) and the maximum capacity (Pmax). The relevant SO has the right to modify the presented range of the U-Q/Pmax profile (within the maximum values and fixed outer envelope provided for in the Regulation), should such need be expressed by an expert opinion concerning the connection.

A **synchronous power-generating module type C or D connected to a network with voltage below 110 kV**, at maximum active power output, within the voltage range of 0.95-1.05 pu at device terminals, must be capable of providing (at device terminals) reactive power with a power factor in the range cosφ=0.85 towards reactive power production and cosφ=0.95 towards reactive power consumption.

With the maximum capacity and voltages outside the range of 0.95-1.05 pu at device terminals, the synchronous power-generating module must have the reactive power capability (Mvar) resulting from its technical capabilities resulting from the P-Q characteristic (i.e. circle diagram).

When active power production is below the maximum capacity (P<Pmax), the synchronous power-generating unit must have the reactive power capability (Mvar) in the range resulting from the circle diagram of the P-Q(U) capability of the synchronous power-generating unit.

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

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

The adjustment time is determined individually, if a change in the operating point forces a change in the operational state of static measures for reactive power compensation or a on load change of the gear of the grid transformer of a synchronous power-generating module, if any.

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

Article 19(2)(b)(v) – PSS

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

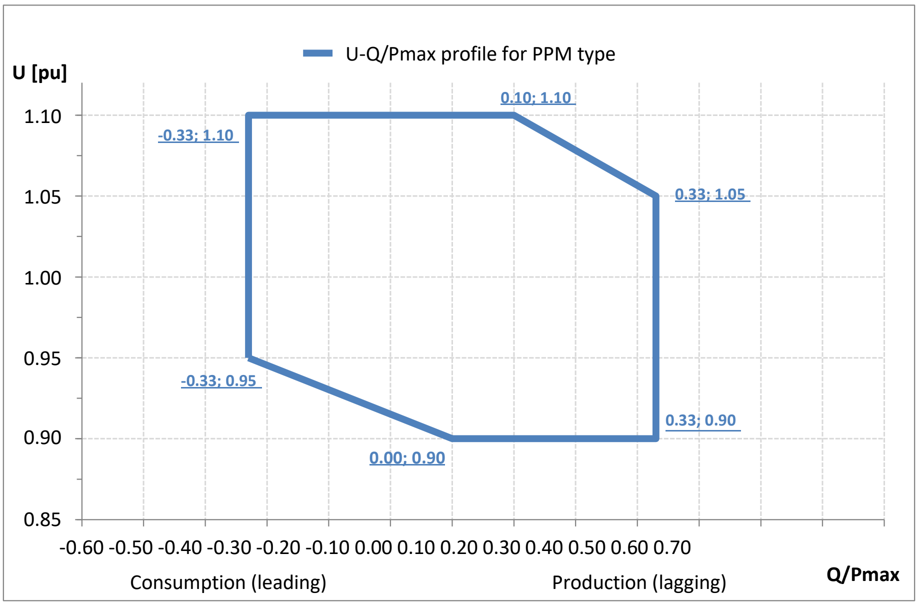
Article 20(2)(a) – reactive power

A PPM type B must be capable of providing at the connection point, at maximum capacity, reactive the power described in the U-Q/Pmax-profile for a power park module type B (Figure 11). The diagram represents the boundaries of the U-Q/Pmax profile , by the voltage at connection point, expressed by the ratio of its actual value and the reference 1 pu value , against the ratio of the reactive power (Q) and the maximum capacity (Pmax).

The requirements presented are the minimum requirement; the power-generating facility owner may provide all available reactive power, according to the PPM's technical capabilities.

If the relevant System Operator requires the PPM to operate at voltages below 0.9 pu at the connection point, then the PPM shall provide all reactive power available according to its technical capabilities.

Figure 11: P-Q/Pmax profile of the power park module type B



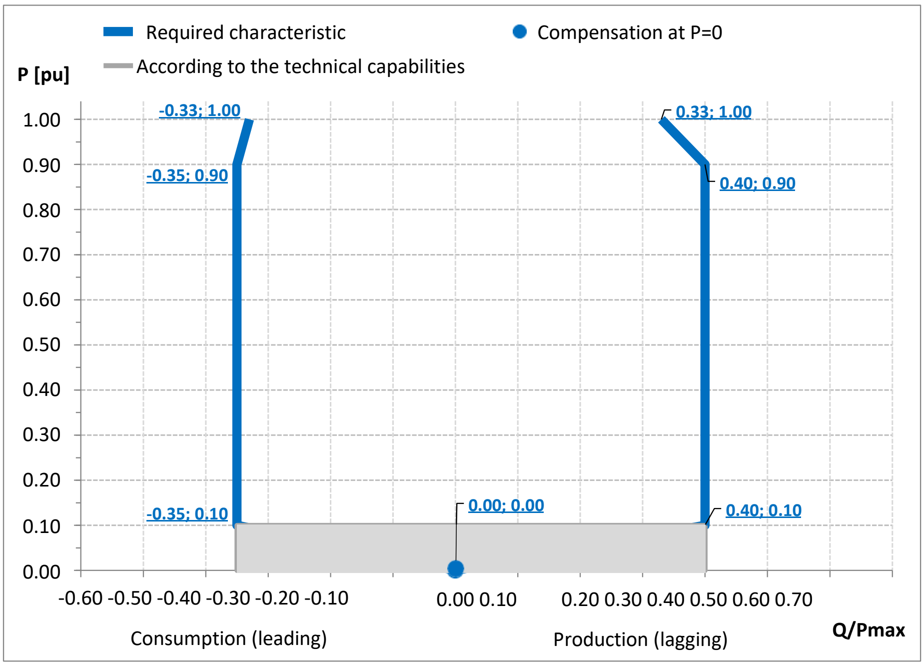
When the PPM is loaded with active power below its maximum capacity, the required reactive power capability at the connection point is shown in Figure 12 below the P-Q/Pmax profile of the power park module type B. This graph shows the limits of the P-Q/Pmax profile at the connection point, expressed by the ratio of its actual active power and the maximum capacity per unit (pu), against the ratio of the reactive power (Q) and maximum capacity (Pmax).

At voltages above 1.05 pu at the connection point, as in operation with maximum capacity, the required value of reactive power production results from the U-Q/Pmax Profile of the type B power park module. At voltages below 0.95 pu at the connection point, as in operation with maximum capacity, the required value of reactive power production results from the U-Q/Pmax Profile of the type B power park module.

When the PPM is loaded with active power below 0.1 of the maximum capacity (the area in the Profile P-Q/Pmax drawing of the power park module type B marked in grey), all available reactive power must be provided, according to the technical capabilities.

The PPM must have the technical capabilities for reactive power compensation at the connection point in the absence of active power output.

Figure 12: P-Q/Pmax profile of the power park module type B



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

Unless the relevant SO, in agreement with the TSO, decides otherwise, in the event of faults outside the internal installation of the PPM, the power generating module shall have the capability to generate additional reactive current. Reactive current support for symmetrical faults shall be:

- proportional to the change in the positive component of voltage at the connection point ΔU_1 caused by the fault; the reference value is the average value of the positive component of voltage for a period of 1 minute before the fault $\overline{U_1}$,
- proportional to the value of the amplification ratio K_1,
- blocked when the value of the voltage positive component is greater than the trigger value U_{trig}

$$\Delta I_{Q1} = K_1 \cdot \Delta U_1, where: \Delta U_1 = \begin{cases} 0; U_1 \geq U_{trig} \\ \dfrac{U_1 - \overline{U_1}}{U_n}; U_1 < U_{trig} \end{cases}$$

In addition:

a) the ability to change the value of the amplification ratio K_1 shall be preserved within the range from 2 to 6 with a step of 0.5; the default value of $K_1 = 2$.

b) the ability to change the value of U_{trig} shall be preserved within the range from 0.8 to 1.0 U_n; the default value of U_{trig} = 0.85 U_n, where U_n is the value of the PPM rate voltage.
c) the ability to block contribution to current response ΔI_{Q1} shall be ensured
d) in the case of faults where fault-ride-through capability is required, generation of reactive power has priority.
e) The capability of the main generating unit to generate additional reactive current shall be achievable within the range of allowable phase current.

The following dynamic characteristics are defined for the additional reactive current control system:

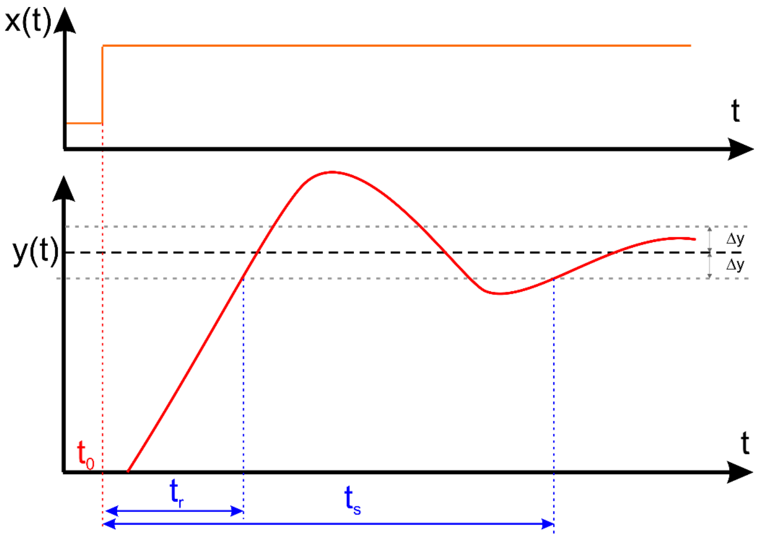
i. time of current response t_r to voltage drop understood as the time from the moment a fault occurs to reaching the value of ΔI_{Q1} with the assumed tolerance: $\leq 30\ ms$,
ii. current response time t_s, defined as the time for the additional reactive current to reach the desired value ΔI_{Q1} with the assumed tolerance: $\leq 60\ ms$,
iii. current response tolerance of -10% to +20% of nominal current I_n is allowed.

No reactive current contribution is required when voltages at main generating units lower than 0.2 Un occur,

A graphical interpretation of the parameters t_r and t_s in the response y(t) of the control system to a unit step input x(t) is provided in the figure below;

Δy - accuracy of the control system.

Figure 13: Graphical interpretation of the parameters tr and ts in the response y(t) of the control system to a unit step input x(t)



Article 20(2)(c) – fast fault current (asymmetrical faults)

Unless the relevant SO, in agreement with the TSO, decides otherwise, the PPM shall be capable of generating additional fast fault current, in line with the following principles.
In case of asymmetrical faults, the PPM shall be capable of generating additional fast reactive fast fault current according to the superposition principle:

- positive component of additional reactive fast fault current, in accordance with the rules defined for Article 20(2)(b),
- negative component of additional reactive fast fault current, the value of which is proportional to the change in the negative component of voltage ΔU_2 (the reference value is the average value of the negative component of voltage for the period of 1 minute before the fault $\overline{U_2}$) and the amplification ratio K_2.

$$\Delta I_{Q2} = K_2 \cdot \Delta U_2, where\ \Delta U_2 = \frac{(U_2 - \overline{U_2})}{U_n}$$

Additionally:

a) If DFIG technology is applied, the generator's natural response additional to ΔI_{Q1} (for the negative component) in the first time instant t_r to faults causing changes in the negative component of voltage is acceptable.
b) In the case all the power output is passed through a converter, it is necessary to maintain the ability to change the value of the amplification ratio K_2 with the range of 2 to 6 with a step of 0.5 throughout the service life of the PPM.
c) The additional reactive fast fault current ΔI_Q, which is the sum of the positive and negative response vectors ($\Delta I_{Q1} + \Delta I_{Q2}$) shall not cause the acceptable value of phase current to be exceeded in any phase.
d) The desired dynamic characteristics of the current response are indicated in the arrangement relating to Article 20(2)(b).

Article 20(3)(a) – active power restoration after a fault

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

(i) Post-fault active power restoration begins when post-fault voltage is restored to the value no less than 90% of Un on the main generating plant forming part of 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 energy source is available.
(iv) Accuracy of active power restoration, understood as a steady-state error: 10%

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

The reactive power capability of a PPM type D at the maximum capacity is defined in the table and figure below. The requirements presented are the minimum requirement; the power-generating facility owner may provide all available reactive power, according to the technical capabilities of the PPM concerned.

Table 16: Inner envelope parameters

Network rated voltage	Maximum range of Q/Pmax	Maximum range of steady-state voltage levels per unit [pu]
400 kV	0.66	0.225
220 kV and 110 kV	0.66	0.225
Less than 110 kV	0.66	0.200

Figure 14: U-Q/Pmax profile of the power park module for Un=400 kV

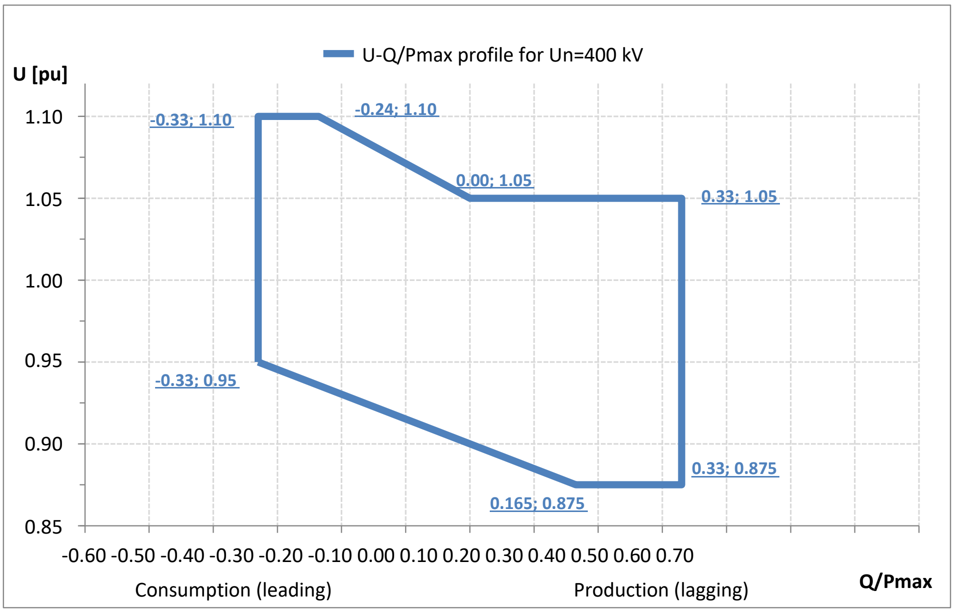


Figure 15: U-Q/Pmax profile of the power park module for Un=220 kV and 110 kV

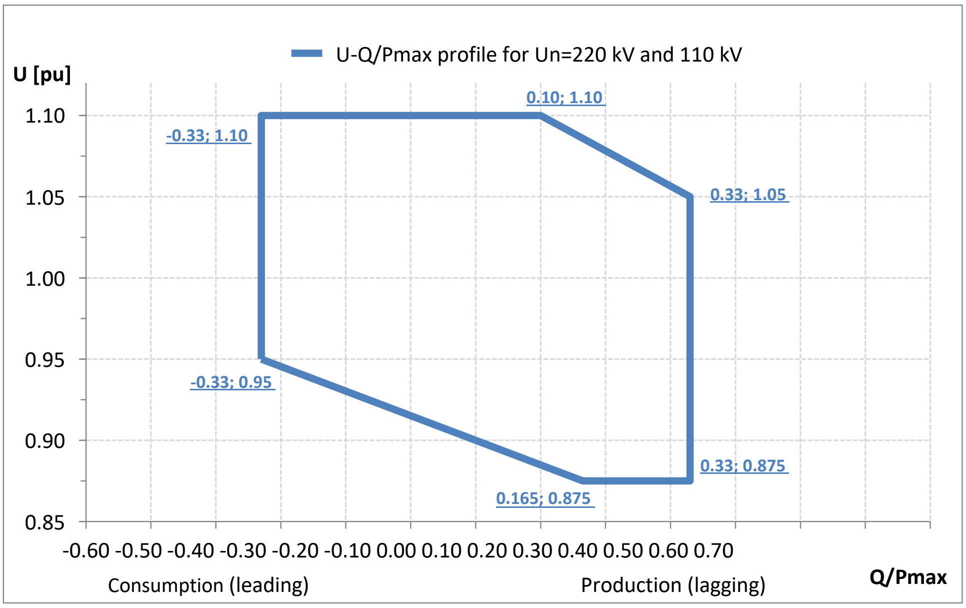
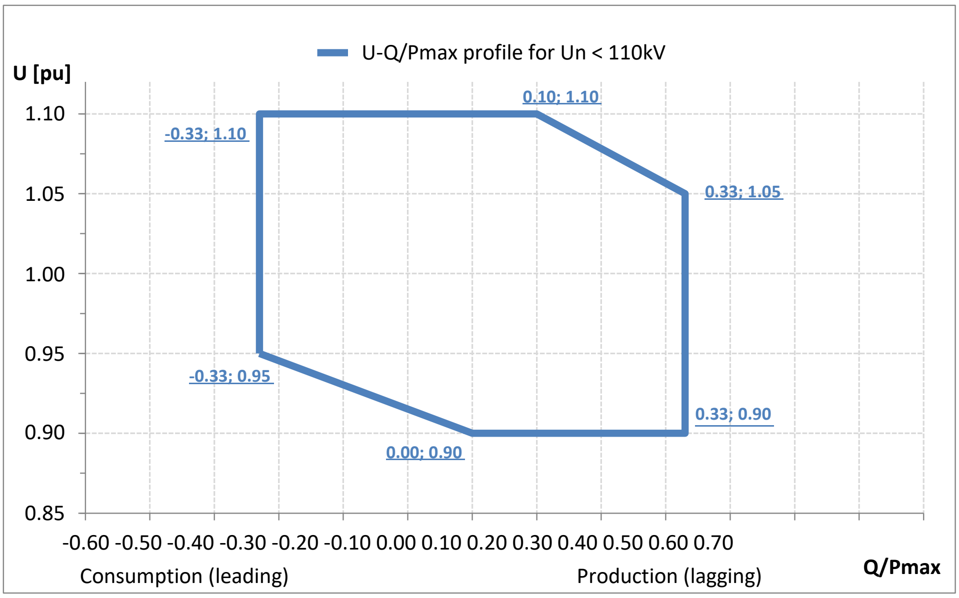


Figure 16: U-Q/Pmax profile of the power park module for Un<110 kV



The diagram represents boundaries of a U-Q/Pmax profile by the voltage at the connection point, expressed by the ratio of its actual value and the reference 1 pu value, against the ratio of the reactive power (Q) and the maximum capacity (Pmax).

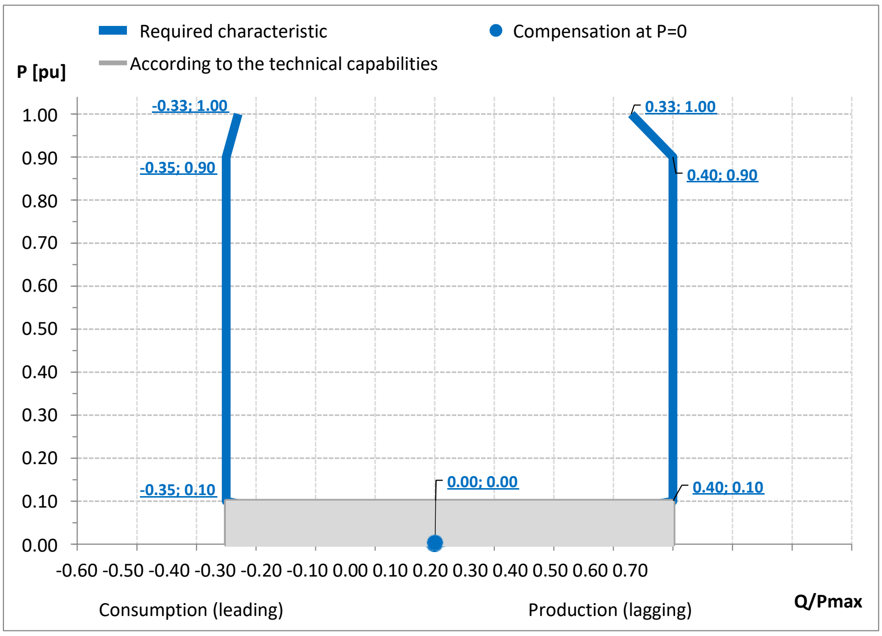
Article 21(3)(c)(i) – reactive power below the maximum capacity

The PPM's required reactive power capability below the maximum capacity is defined below:

Table 17: The required reactive power capability of a PPM below the maximum capacity:

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

Figure 17: P-Q/Pmax profile of the power park module



The diagram represents the boundaries of the P-Q/Pmax profile, expressed by the ratio of its actual active power and the maximum capacity per unit (pu), against the ratio of reactive power (Q) and the maximum capacity (Pmax).

At voltages above 1.05 pu at the connection point, as in operation with maximum capacity, the required value of reactive power production results from the U-Q/Pmax Profile of the power park module.

At voltages below 0.95 pu at the connection point, as in operation with maximum capacity, the required value of reactive power consumption results from the U-Q/Pmax Profile of the power park module.

When the PPM is loaded with active power of 0 to 0.1 of the maximum capacity (the area in the P-Q/Pmax Profile diagram of the power park module marked in grey), all available reactive power must be provided, according to the technical capabilities.

The PPM must have the technical capabilities for reactive power compensation at the connection point in the absence of active power output.

Article 21(3)(c)(iv) – rate of reactive power control

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

In the event static measures are applied to control reactive power, a longer control time is allowed for moving between extreme reactive power values (however no longer than 15 minutes). A longer control time will be agreed between the relevant SO and the power-generating facility owner.

If moving between two PGM operating points requires a change in the position of an on-load tap changer gear 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

When operating in the voltage control mode (in line with the set static characteristics, individually parameterised in the range resulting from Article 21(3)(d)(ii),(iii)), following a step change in voltage, the power park module shall be capable of achieving 90% of the change in reactive power production within a time of not more than t_1=5 seconds and must reach the value determined by the slope within a time of no more than t_2=60 seconds.

Article 21(3)(d)(vi) – dynamics of power factor control

When operating in the power factor control mode, the accuracy of achieving the target power factor following a sudden change of active power output is expressed through the tolerance of the corresponding change in reactive power and shall not exceed 5% of the maximum reactive power or 5 MVAr (whichever is lower) and shall be completed within no more than 150 seconds.

Article 21(3)(d)(vii) – operating modes of reactive power control systems

In order to select the reactive power control mode and define related setpoints, the relevant SO shall be able to remotely select one of three control modes and set an operating point, unless the relevant SO decides otherwise in agreement with the power park module owner.

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

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

Article 25(1) – voltage conditions

An AC-connected offshore power park module shall be capable of staying connected to the network and operating within the ranges of the network voltage at the connection point, expressed by the voltage at the connection point related to reference 1 pu voltage, and for the time periods specified in the table below:

Table 18: Voltage conditions for staying connected to the network and operation

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

(*) For networks with voltage base lower than 300 kV.

(**) For networks with a voltage base between 300 kV and 400 kV.