Contents

1 Introduction and background

Electric storage systems are out of the scope of Connections Network Codes (CNCs) as referred in the Art 3-2 (d) in the RfG NC [1] and the Art 3-2 (b) in the DCC NC [2] with the exception of pump-storage which is considered as a Power Generating Module (PGM).

Expected new storage capacities to be installed in Belgium would therefore require the development of adequate technical capabilities to close such gap with the aim to address system needs and to contribute to secure system operation. In this document we propose a set of minimum technical connection requirements for Storage Park Modules (SPM) as per the scope, the relevant terminologies and definitions used in the section 2 which cannot be considered as a part of the set of the general Requirements requested within the CNCs. The proposed technical requirements are based on categories reflecting the significance and the expected capabilities of the storage system coherently with the ABCD limits defined for PGMs.

In general the possible technical capabilities of a SPM are similar to the ones of Power Park Modules (PPM) as they share similar technical aspects as modules connected to electricity networks through power electronics acting as inverter and rectifier for the case of SPM. Therefore, the proposed technical capabilities are aligned as much as possible with the PPM's exhaustive and non-exhaustive requirements defined in the RfG NC [1].

The main focus of this document is to define the minimal technical requirements specifically applicable to storage systems taking into consideration specific intrinsic behavior of SPM, as well as the different operational modes as charging or discharging modes. Therefore, whenever no specific distinct provisions are required for SPM, the exhaustive and non-exhaustive requirements for PPM would be of application.

This document fixes the technical requirements that are subject to definition by the relevant TSO (Elia) and Elia as a Relevant System Operator. They are therefore applicable to the SPM connected to transmission network and whenever relevant to SPM connected to DSO or CDSO networks for requirements covering frequency stability and system robustness in alignment with ENTSO-e guidance document for National Implementation of connection Network Codes [3].

2 Definitions and applicability

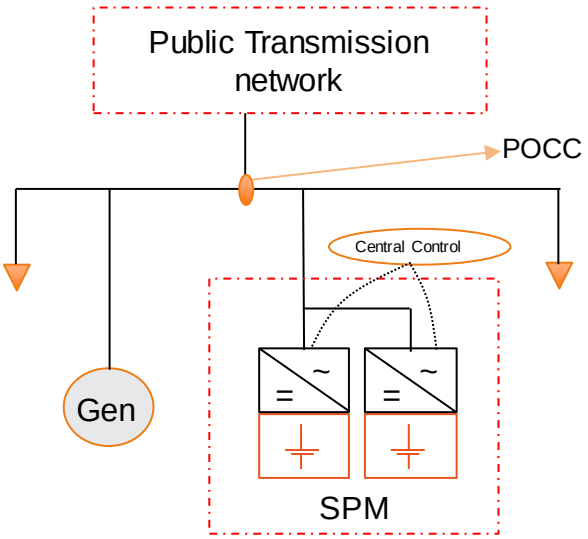

Figure 1 Example of Storage Park Module grid connection

Figure 1 illustrates possible grid connection of a SPM and the Point Of Common Coupling (referred in this document as the connection point) to the transmission grid. The same facility could include other Power Generation Modules or demand units as auxiliary supply.

Below is a set of applicable definitions covering intrinsic capabilities of a SPM or relevant operational modes addressed within the current technical connection requirements:

a. **Storage Park Module (SPM):** An electric system composed of a single or multiple electrical storage units capable of storing~~,~~ delivering electrical energy into a single electrical point of connection.
b. **Power max (Pmax):** the maximum active power which the SPM is technically designed to deliver or absorb at the connection point.
c. **State Of Charge (SOC)**: Whenever technically available, the measure of the amount of the available capacity expressed in percentage points (0% = empty; 100% = full~~).~~) .
d. **Maximum Charging Ramp Rate (Rch)**: the maximum limit on the rates of change of power that the SPM is capable of achieving during charging expressed in MW/minute.
e. **Maximum Discharging Ramp rate (Rdis)**: the maximum ramping that the SPM is capable of achieving during discharging expressed in MW/minute.

The current connection requirements are applicable to both stationary and non-stationary storage applications - which includes for example Vehicles-to-Grid (V2G) applications. On the other hand railway traction in generative mode are not within the scope of this document. The current connection requirements are applicable to new installations and existing installations to which substantial modifications will be made.

The current connection requirements in this document are not applicable to emergency Uninterruptible Power Supply and any specific electrical storage application not providing ancillary services and operating in parallel less than five minutes per calendar month while the system is in normal system state, in alignment with the RfG NC provisions of the Article 3(2) [1].

3 SPM categories types

The present technical requirements are defined per each of the following categories taking into consideration the Pmax characteristic of the SPM in the connection point:

- Type A
  - $0.8kW \leq Pmax < 1\ MW$
- Type B
  - $1\ MW \leq Pmax < 25MW$
- Type C
  - $25MW \leq Pmax < 75MW$
- Type D
  - $75MW \leq Pmax$

4 SPM Type A

4.1 Frequency stability & active power management

4.1.1 Frequency withstand capability

PGM exhaustive and non-exhaustive requirements on frequency withstanding capabilities [see Art. 13-1 (a) RfG NC] are of application for all SPM of type A, B, C and D in the Belgian Control Area.

4.1.2 Rate Of Change Of Frequency (ROCOF) withstand capability and Loss of Main protection

PGM exhaustive and non-exhaustive requirements on Rate Of Change Of Frequency (ROCOF) withstand capability and Loss of Main Protection triggered by rate-of-change-of-frequency-type [see Art 13.1(b) RfG NC] are of application for all SPM type A, B, C and D in the Belgian Control Area.

4.1.3 Limited Frequency Sensitive Mode (LFSM-O and LFSM-U)

Considering the principles of the Art. 15-3 of the Emergency and Restoration Network Code [4] , all SPM type A, B, C and D in the Belgian Control Area, should have LFSM-O and LFSM-U technical capabilities [see Art. 13-2 (a-g) and Art. 15-2 RfG NC].

In the event of large frequency deviations, the SPM must in priority contribute to ensuring frequency stability by automatically increasing or reducing active power injection or absorption at grid frequencies below or above the reference frequencies f1 and f2, in accordance with Figure 2 and the parameters defined in Table 1.

In application of the article 15.3 (b) of the Emergency and Restoration NC, a SPM that cannot achieve a reverse into discharging mode prior to automatic low frequency demand disconnection scheme shall disconnect. The disconnection shall not be enforced by default, but only allowed in the case that a discharging mode cannot be achieved prior to the frequency threshold of 49 Hz.

For justified safety or technical security reasons, the owner of the SPM might agree with the relevant system operator on applicable minimum and/or maximum SOC limits on his connection agreement.

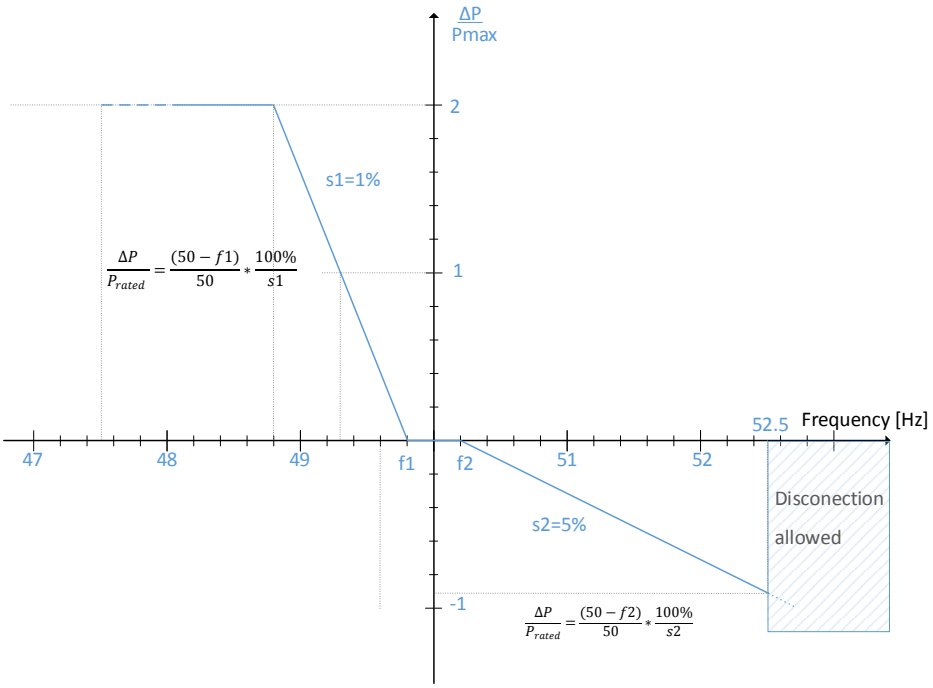

Figure 2 Limited Frequency Sensitive response capabilities for a SPM

The requirements are subject to the default values and ranges summarized in the Table 1, where the:
First Reaction refers to the time from a sudden change of a control quantity until the instant the corresponding change of an output quantity begins;
Settling time refers to the time needed from sudden change of a control quantity until the instant, from where on the corresponding change of an output quantity remains within the tolerance band of 10 % of the set value.

Table 1 Limited Frequency Sensitive response parameters for a SPM

Parameters	**Default value**
f1	49.8 Hz
f2	50.2 Hz
s1	1% Selectable within a range of ~~0.~~1 and 12%
s2	5 % Selectable within a range of ~~0.~~1 and 12%
Settling time	As fast as possible maximum 30 seconds
First reaction	By default as fast as technically possible (no intentional delay), specific provisions could be applicable by the DSOs in agreement with Elia.

4.1.4 Admissible maximum power reduction with falling frequency

This requirement set in Art. 13-4 RfG NC is not applicable for a SPM as they do not have technical limitation with that respect.

4.1.5 Logical interface to cease active power injection

SPM of type A and B connected the transmission network shall be equipped with a logical interface to cease active power injection or absorption, as per the requirement for PGM type A [see Art 13-6 RfG NC]. The SPM shall be capable of ceasing power injection or

absorption to zero within 5 seconds after instruction is given via the reception of an external signal. The remote operation is site specific: Elia can request remote operation as per the provisions in the subsection 4.2.

4.1.6 Automatic connection

The general condition for connection of SPM in the Belgian Control Area are defined as following:

- Frequency range between: 49.9 and 50.1 Hz and
- Voltage range between: 0.85 and 1.1 pu of Nominal voltage and
- Temporization: 60 seconds

Automatic Connection to transmission network ~~-~~is only allowed for SPM Type A, like this is allowed to the PGM type A [see Art 13-7 RfG NC]. Subsequent to the connection, the SPM shall be capable to limit the maximum admissible gradient of active power (unless subject to LFSM requirement) as following:

- Charging mode: <=20 % Pmax per minute
- Discharging mode: <=20% Pmax per minute

The active power gradient restriction is only applicable following the connection of the overall SPM system ~~and not~~to the main connection point as per the Figure 1. Note that during normal ~~operational~~operation mode~~. Note that~~, the connection of a single non-stationary storage unit, as an electric vehicle (not the overall SPM), would not therefore require an active power gradient restriction on either charging or discharging modes.

4.1.7 Rates of change of active power output

Unless subject to emergency operation and frequency control requirements, Elia (or the RSO) have the right to specify a maximum ramping limitation of active power output for fast charging and discharging rates expressed in percentage point of Pmax per second, similarly to PGM type C [see Art 15-6(e) RfG NC].

4.2 Information exchange

There are no requested capabilities to establish real time communication: SPM of type A shall be equipped to receive and comply to an external signal sent by Elia to cease charging or discharging.

Signal#	Request to cease active Power absorption or injection	Binary 1: Request Active 0: End of request

4.3 Voltage withstand Capabilities

This requirement should be met at the connection point.
Voltage withstand capabilities is requested from SPM for both charging and discharging modes in alignment with the PGM requirement to guaranty secure operation of the grid and the security of supply. The requirement in the Table 2 are applicable for all SPM of Type, A, B, C which are connected to the Transmission network.

	Voltage Range	**Time period for operation**
Voltage ranges below 300kV	0.85 pu – 0.90 pu	60 minutes
	0.90 pu – 1.118 pu	Unlimited
	1.118 pu – 1.15 pu	To be agreed between the TSO and the facility owner in the connection agreement
Voltage ranges above 300kV	0.85 pu – 0.90 pu	60 minutes
	0.90 pu – 1.05 pu	Unlimited
	1.05 pu – 1.10 pu	To be agreed between the

		TSO and the facility owner in the connection agreement

Table 2: Voltage withstand capabilities

The following base values are to be considered for PGM connected to TSO network:

- 400kV
- 220kV
- 150kV
- 110kV
- 70kV
- 36kV

In case of broader or longer voltage withstand capabilities technically and economically feasible, the owner of the installation should put this at disposal of the relevant system operator.

5 SPM Type B

In addition to the specifications for SPM type A, the following is requested.

5.1 Frequency stability and active power management

5.1.1 Remote control reduction of active power

The SPM shall be capable, like the PGMs of type B [see Art 14 -2 RfG NC], of reducing its power injection or absorption. The setpoint sent by Elia must be reached within a maximum duration of 1 minute and a precision of 5% after instruction is given via the reception of an external signal. Elia can request remote operation as per the provisions in subsection 5.2.3.

5.1.1 Automatic reconnection

The general condition for reconnection of SPM in the Belgian Control area are defined as following

- Frequency range between: 49.9 and 50.1 Hz and
- Voltage range between: 0.9 and 1.1 pu of Nominal voltage and
- Temporization: 60 seconds

For SPM units of Type B, C and D connected the Transmission Network, automatic reconnection is prohibited and subject to authorization in their connection contracts, like the PGMs of Type B, C and D [see Art 14 -4 (a-b) RfG NC].

Note that a signal allowing the reconnection is foreseen in the sub-section 5.2.3. Subsequent to the reconnection the SPM is required to limit the admissible gradient of active power to the following (unless subject to LFSM requirement):

Charging mode: 10 % Pmax per minute
Discharging mode: 10% Pmax per minute

5.2 Instrumentation and information exchange

Beside what is being requested for PGM in general in Art. 14-5(a, b and d) RfG NC, the following is requested for SPM connected to transmission network:

5.2.1 Structural data

Beside what is being requested for PGM in general, the following is requested for SPM connected to transmission network:

EG	Gross Energy Capacity	[MWh]
Enet	Net Energy Capacity	[MWh]
Pmax	Maximum rated active power capacity	[MW]
SOCmin	Minimum State of Charge	[%]
SOCmax	Maximum State of Charge	[%]
Rch	Maximum charging rate	[MW/min]
Rdis	Maximum discharging rate	[MW/min]

5.2.2 Real-time measurements

Beside what is being requested for PGM in general, the following is requested for SPM connected o transmission level:

SOC	State of charge	[%]

5.2.3 Data to be received

Beside what is being requested for PGM in general, the following is requested for SPM :

Signal#	Clearance to reconnect	Binary 0: No reconnection 1: Clearance
Signal#	Request to reduce Active Power absorption or injection	Binary 1: Request Active 0: End of request
Signal#	Active power setpoint expressed in MW	Value Charging/discharging

5.3 Fault-ride through for symmetrical and asymmetrical faults

PPM *type B* exhaustive and non-exhaustive requirements on fault-ride through for symmetrical and asymmetrical faults [see Art 20-3 RfG NC] are of application for SPM type B.

5.4 Reactive capabilities

The required reactive capabilities of SPM connected at transmission network should be met at the HV side of the step up transformer if existing; otherwise they should be met at the convertor terminals.

A SPM type B shall be capable of providing, like the PPM type B [see Art 20-2(a) RfG NC], the reactive power capabilities determined by the Q-P profile as represented in the Figure 3 adapted for both charging and discharging modes.
The limitations are based on nominal current at high active power and by a power factor (cos(phi)) defined by the 2 points at Q= -33% and +33% of PD, where PD is the maximum active power that can be produced or absorbed in case of the maximum requested reactive power output (hence equal to 0.95*Snom). For voltage different from 1 p.u, the capabilities are defined as per the U-Q/P_D profile represented in Figure 4. Note that the available capability of the SPM (which could be wider than the minimum requirement) should be communicated, demonstrated and put at disposal of the relevant system operator. The owner of the SPM is not allowed to refuse the use of the reactive capability without a technical justification. The SPM is therefore expected to not limit its capabilities to comply with the minimum requirement but to use the full capability to support the system stability as stated in its agreement. In case the SPM has already the capability of voltage regulation, one should not refuse

the relevant system operator to make use of it. In this case, the settings of the controllers should be agreed with the relevant system operator.

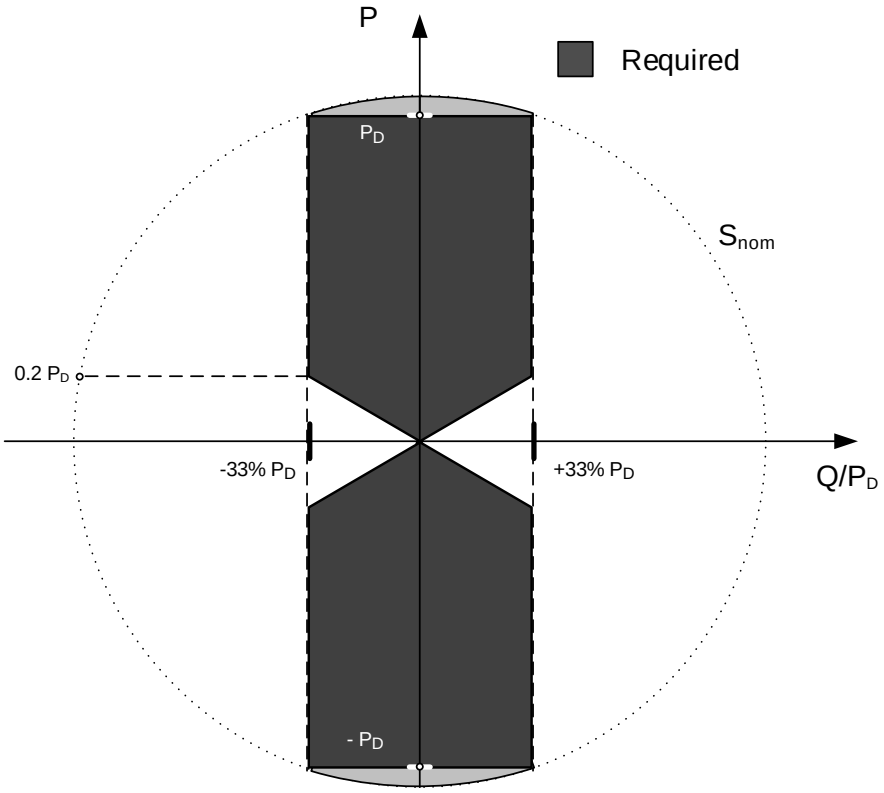

Figure 3: Capability curve for SPM type B

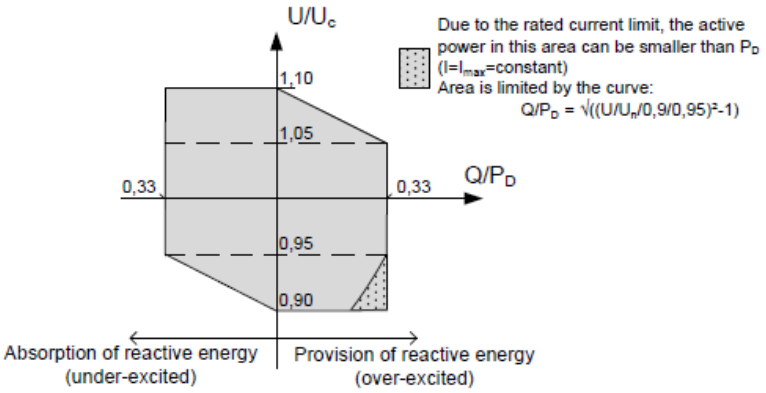

Figure 4: U-Q/P_D profile for type B ~~PPM~~SPM in order to visualize reactive power requirements for voltages different from 1pu.

5.5 Fault Current & dynamic voltage support (optional)

The requirement is optional for SPM, if requested the PPM *type B* exhaustive and non-exhaustive requirements on Fault Current & dynamic voltage support [see Art 20-2 (b and c) RfG NC] would be of application for both charging and discharging modes if it is decided to be applied~~.~~ taking into consideration the SPM technical capabilities and system stability needs.

5.6 Post-fault active power recovery (optional)

The requirement is optional for SPM, if requested the PPM *type B* exhaustive and non-exhaustive requirements on post-fault active power recovery [see Art 20-3 RfG NC] are of application for both

charging and discharging modes if it is decided to be applied taking into consideration the SPM technical capabilities and system stability needs.

6 SPM Type C

In addition to the specifications for SPM type B, the following is requested.

6.1 Frequency stability& Active Power management

6.1.1 Active Power Controllability and Control Range

The SPM type C connected to transmission network, like the PGM type C [see Art. 15-2 (a) RfG NC], shall be capable of controlling active power injection or absorption to a requested setpoint within a maximum duration of 1 minute (Ts) and a precision of 5% (Setpoint tolerance) after instruction is given as per the Figure 5.

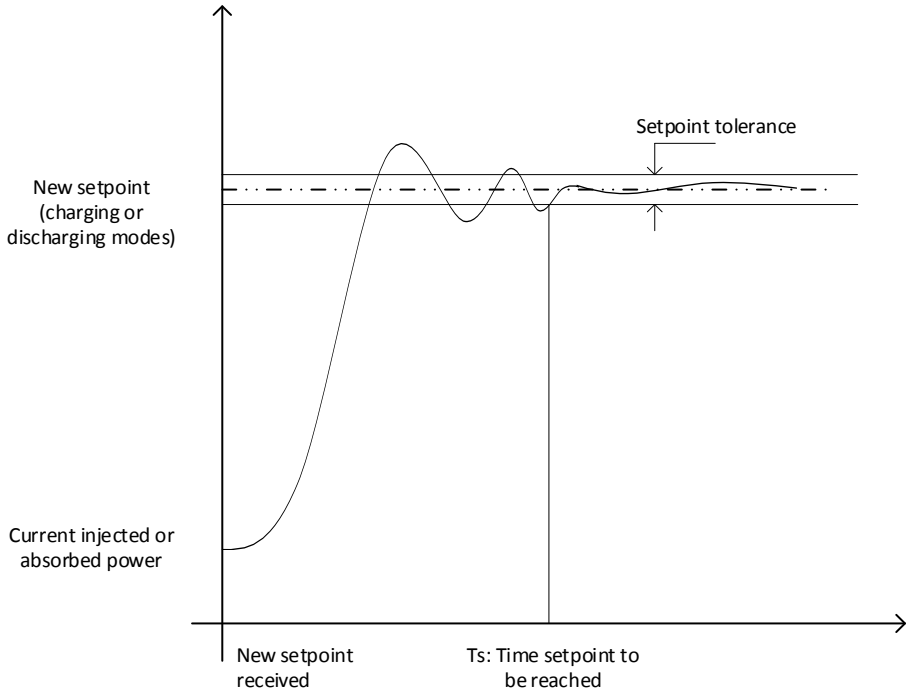

Figure 5 Tolerance and time duration for SPM application of new set point of active power.

6.1.2 Limited frequency sensitive mode – under frequency (LFSM-U)

This requirement on Limited frequency sensitive mode – under frequency (LFSM-U) [see Art. 15-2 (c) RfG NC for the PGM type C] is already covered by the requirements fixed in the section 4.1.3 and therefore applicable to all SPM types A, B, C and D in the Belgian Control Area.

6.1.3 Frequency Sensitive Mode

PPM type C exhaustive and non-exhaustive requirements on Frequency Sensitive Mode [see Art. 15.2.d RfG NC] are applicable to SPM of type C and D in the Belgian Control Area, taking into consideration applicable provisions for units with limited energy reservoirs as defined in the System Operation Guidelines and Elia's FCR General Framework Agreement.

6.1.4 Frequency restoration control

As per PPM type C exhaustive and non-exhaustive requirements on Frequency restoration control [see Art 15-2.(e) RfG NC] and Elia's aFRR General Framework Agreement.

6.1.5 Real-time monitoring of FSM

As per PPM *type C* exhaustive and non-exhaustive requirements on Real-time monitoring of FSM [see Art 15-2.(g) RfG NC] and Elia's General Framework Agreement.

~~6.1~~6.2 Automatic disconnection for voltage outside ranges

As per PPM *type C* exhaustive and non-exhaustive requirements on Automatic disconnection for voltage outside ranges [see Art 15-3 RfG NC~~].~~] to be specified in the connection agreement.

~~6.2~~6.3 System restoration

As per PPM *type C* exhaustive and non-exhaustive requirements on capability to take part in island operation [see Art 15-5 (b) RfG NC] and the capability of quick resynchronization [see Art 15-5 (c) RfG NC~~].~~] to be specified in the connection agreement.

~~6.3~~6.4 Reactive capabilities

This requirement should be met at the connection point.

A type C SPM connected to transmission network shall be capable of providing like the PPM Type C requirements [see Art 21-3(a-c) RfG NC], the reactive power within the Q-P profile described in Figure 6 for both charging and discharging modes. This profile has an obligated span of 0.6p.u. with regards to Q/Pmax, but can move within an area of [-0.3p.u., +0.35p.u.] represented by the outer envelope when accepted by Elia (based on the connection point, size and the characteristic of the SPM) as defined in the Figure 6. The reactive power can be uncontrolled within the shaded area, however, injected/absorbed values must be limited within a range of Q = [-0.0329 ;+0.0329] p.u. of Pmax[1].

[1] 2002 FGC Article 209 §3: 3,29 % = 10 % of the reactive range at cos(phi) = 0.95.

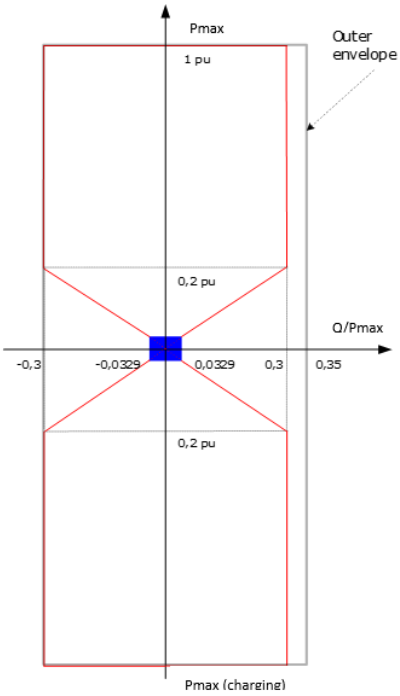

Figure 6: Reactive power capability for a Type C and D SPM.

For voltage different from 1 p.u, the capabilities are defined as per the U-Q/P_D profile represented in Figure 7.

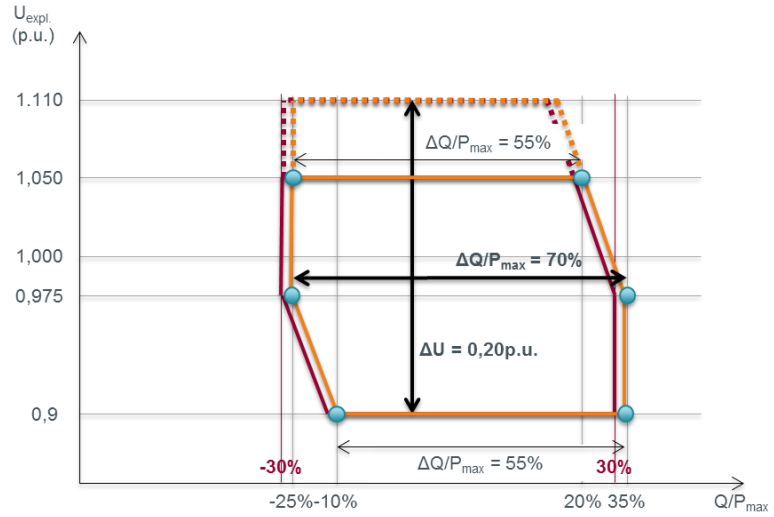

Figure 7 U-Q/Pmax profile for a type C and D SPM (dashed for nominal voltages above 300kV).

Note that the available capability of the SPM (which could be wider than the minimum requirement) should be communicated, demonstrated and put at disposal of the relevant system operator.
The owner of the PPM is not allowed to refuse the use of the reactive capability without a technical justification. The SPM is therefore expected to not limit its capabilities to comply with the minimum requirement but to use the full capability to support the system stability as stated in its agreement.

~~6.4~~6.5 Voltage control

As per PPM *type C* exhaustive and non-exhaustive requirements on Voltage control [see Art 21-3 (d) and (e) RfG NC] for both charging and discharging modes.

7 SPM Type D

7.1 Fault-ride through for symmetrical and asymmetrical faults

As per PPM *type D* exhaustive and non-exhaustive requirements on Fault-ride through for symmetrical and asymmetrical faults [see Art 22 RfG NC] for both charging and discharging modes.

7.2 Voltage withstand capabilities

As per PPM *type D* exhaustive and non-exhaustive requirements on voltage withstand capability and automatic-disconnection [see Art 16- 2 (a-b-c) RfG NC] for both charging and discharging modes.

7.3 Resynchronization

As per PPM *type D* exhaustive and non-exhaustive requirements on settings of synchronization devices [see Art 16- 4 (a) RfG NC] for both charging and discharging modes.

8 References

[1] "'Network Code Requirements for Generators' or 'NC RfG': Commission Regulation (EU) 2016/631 of 14 April 2016 establishing a network code on requirements for grid connection of generators,," http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:JOL_2016_112_R_0001.

[2] "'Network Code on Demand Connection': Commission Regulation (EU) 2016/1388 of 17 August 2016 establishing a Network Code on Demand Connection".

[3] "Parameters of Non-exhaustive requirements: ENTSO-E Guidance document for national implementation for network codes on grid connection".

[4] "'Network Code on Electricity Emergency and Restoration ': Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration," http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32017R2196&from=EN.