Technical requirements for a standalone Battery Energy Storage System (BESS) connected to High voltage system and managed by the System Operator

The purpose of this document is to specify the main technical requirements for an energy storage facility connected to a High voltage system.

General comments are listed below:

- The following requirements apply only to Battery Energy Storage Systems ("BESS"s). If a proposal based on another storage technology is submitted, it will be in accordance with the relevant requirements, by the type of the technology.
- When technical requirements are in accordance with international standards, the document specifies only the standards and not the requirements.
- The requirements for High voltage switchyard of the storage facility (such as protections, DC and AC systems, short circuit currents etc.) are specified in the "High Voltage Customer Connection Procedure" of Noga and IECo.
- The storage facilities will be fully controlled by the System Operator ("NOGA – Israel ISO") and will operate according to the instructions of the System Operator and the functions required from the storage facility.
- The converters of the storage facility must be of the GRID FORMING type, capable of generating and regulating voltage and frequency independently, and able to supply the local load in a stable, reliable and secure manner, in island mode, with no synchronous machines present.
- The System Operator expects that additional grid auxiliary services will be needed, such as synthetic inertia and black startup. It is suggested that the BESS owner (by this "BESS owner" term hereafter we refer to the BESS owner / bidder / entrepreneur / BESS operator) will be prepared to provide such services, pursuant to the regulation.
- The storage capacity of the system will be at least 4 times the connection size, in units of MW, of the BESS facility.
- The "Nominal power of the facility" is the power it can supply during the specified time of discharge hours (The System Operator will review, from time to time, the above data during the discharge, at the point of connection to the grid).
- The "storage capacity of the facility" (in terms of MWh) is the product of the nominal power of the facility by the number of operating hours in which the facility will continuously supply energy to the grid at its nominal power. The measurement will be conducted at the point of connection to the grid.

Note: The internal design of the facility will not be limited due to the above requirements concerning power and energy/storage capacity.

- For the avoidance of doubt, the facility is required to meet legal, safety (Home Front Command etc.), regulatory and other requirements.

1. Characteristics of the transmission grid

At the connection points of the generation/storage facilities to the High voltage grid, the values of the main electrical parameters are as follows:

1.1. Frequency:

a. Nominal frequency: 50Hz

b. Frequency limits in normal operation range: 49.8 - 50.1 Hz

c. Frequency limits during disturbance (steady state): 49.6 - 50.2 Hz

d. Frequency limits during disturbance (transients, instantaneous values) 47 – 53 Hz

e. Maximum Rate of Change of Frequency (ROCOF) during oscillations: 3.0 Hz/s

1.2. Voltage:

a. Nominal voltage: 161 kV (High voltage).

b. Normal operation range: 153 – 170 kV (High voltage).

c. Voltage limits in an abnormal condition: 150 – 170 kV (High voltage).

1.3. Voltage drops/surges: up to 1000 events per year in the entire system. The System Operator will provide the BESS owner, if possible, with statistic data concerning the supposed connection point.

1.4. Transient disturbances: up to 300 events per year in the entire system; The System Operator will provide the BESS owner, if possible, with statistic data concerning the supposed connection point.

2. Technical requirements from the generation / storage facilities

Every new facility must meet the following requirements:

2.1. Frequency withstand capability:

a. Continuous operation: the facility will operate continuously in the frequency range between 47 Hz and 53 Hz ($47 < f < 53$ Hz).

b. Minimum value of frequency: at a frequency of 47.0 Hz or lower ($f \leq 47$ Hz), the facility will reduce the active power output to 0 MW within 1 second.

c. Maximum value of frequency: at a frequency of 53 Hz or higher ($f \geq 53$ Hz) the facility will reduce the active power output to 0 MW within 0.2 second.

d. The reconnection of the facility after its disconnection, or the resuming of discharging / charging of active power after a disturbance, will be carried out according to section 2.10.

e. Rate of Change of Frequency: the facility will operate normally for Rate of Change of Frequency of up to 3 Hz/s.

2.2. Frequency Response:

a. The facility will have primary frequency response capability of the discharged / charged power, according to a measurement accuracy of -/+ 0.01 Hz or less.

b. The facility will be equipped with a frequency-power regulator or a similar regulator that allows a response to frequency change.

c. The System Operator will determine the operating regime of the storage facility remotely:

1. Basic operating mode - LFSM (Limited Frequency Sensitive Mode)

2. Operating mode sensitive to frequency changes - FSM (Frequency Sensitive Mode)

d. Regulation of the converters of the facility in basic operating regime LFSM - Limited Frequency Sensitive Mode:

1. For the frequency range of continuous operation between 47 Hz and 53 Hz, the facility will operate in a stable manner and adjust the discharged / charged active power according to the system frequency in each operating regime (charging, discharging, STANDBY).

   STANDBY - When the facility is connected to the system, it is required to respond, subject to its available power.

2. Within the frequency range of [(50 - DB_{UF}) < f < (50 + DB_{OF})] the facility will discharge or will be charged with active power according to $P_{setpoint}$ determined by the System Operator.

3. In case of frequency increase, the facility will decrease the discharged power or increase the charging power at the connection point.

4. In case of frequency decrease, the facility will increase the discharged power or decrease the charging power at the connection point.

5. In case of frequency decrease/increase, the storage facility will allow a change of operating regime from charging to discharging and vice versa continuously and with no delay. The facility will respond to decrease/increase in frequency also in STANDBY mode.

6. When frequency increases above 50Hz+DB_{OF} (OF - Over-Frequency), the facility will adjust the active power delivered to (or consumed from) the grid according to the following equation:

$$P = \max\left\{P_{min}\,, P_{pre} + min\left(0, \frac{f_{nom} - f + DB_{OF}}{f_{nom} \times R_{OF}}\right)\right\}$$

7. When frequency decreases below 50Hz-DB_{UF} (UF - Under-Frequency) the facility will adjust the active power delivered to (or consumed from) the grid according to the following equation:

$$P = \min\left\{P_{avl}, P_{pre} + max\left(0, \frac{f_{nom} - f - DB_{UF}}{f_{nom} \times R_{UF}}\right)\right\}$$

Where:

f - actual system frequency (Hz)

f_{nom} - nominal frequency (50 Hz)

P – required active power output, in per unit (p.u.) of P_{nom}.

P_{nom} - the steady state, continuous active power rating of the facility, considering the size of the connection, determined and registered in the agreement between the BESS owner and the System Operator (MW).

Note: Technical requirements, such as frequency response, are referring to the value of P_{nom}.

P_{pre} – the pre-disturbance active power output, in p.u. of P_{nom}.

P_{min} – minimum active power output, in p.u. of P_{nom}.

Note: the minimum power in a storage facility is negative in charging regime, or "0" when the battery is fully charged (according to SOC - State of Charge).

P_{avl} – available active power, in p.u. of P_{nom}.

Note: The available active power of the facility P_{avl} is defined as the active power that the facility can deliver to (or consume from) the grid, subject to the availability of the primary energy source, the nameplate ratings P_{nom} or P_{STR} (if any), and the service status.

P_{STR} – the temporary, short-term active power rating (STR - Short-Term Rating), determined and registered in the agreement between the BESS owner and the System Operator.

Note: The P_{STR} is not a mandatory requirement. It may be used to accommodate services such as primary frequency response, up to value P_{STR} for maximum time duration, as checked and specified by the System Operator during the technical coordination phase.

D_{BOF}, D_{BUF} – values of deadband for over-frequency and under-frequency respectively (Hz).

R_{OF}, R_{UF} - regulation constants (frequency droop) for over-frequency and under-frequency respectively (p.u.)

8. The deadband value is between 0 and 0.5 Hz and will be determined by the System Operator during the technical coordination phase:

   The default deadband value is set to:
   DB_{OF} = 0.2 Hz
   DB_{UF} = 0.2 Hz

9. The value of the primary regulation constant - frequency droop, is between 2% and 5% and will be determined by the System Operator during the technical coordination phase:

   The default frequency droop value of the facility is set to 2% (R_{OF} = R_{UF} = 0.02 p.u.) referred to the nominal power P_{nom} of the facility.

10. The values of frequency droop and deadband will be adjustable by remote command from the System Operator.

11. The facility's frequency control is required to operate continuously and immediately.

    The response time $T_{Response90\%}$ for a step-type disturbance, defined as the time required to reach a value of 90% of the final value, including the frequency measurement time, shall not exceed one second.

In accordance with the above, the facility will allow regulation of the active power, in all hours of the day, subject to active power limits and State of Charge. See Figure 1 below for an illustration:

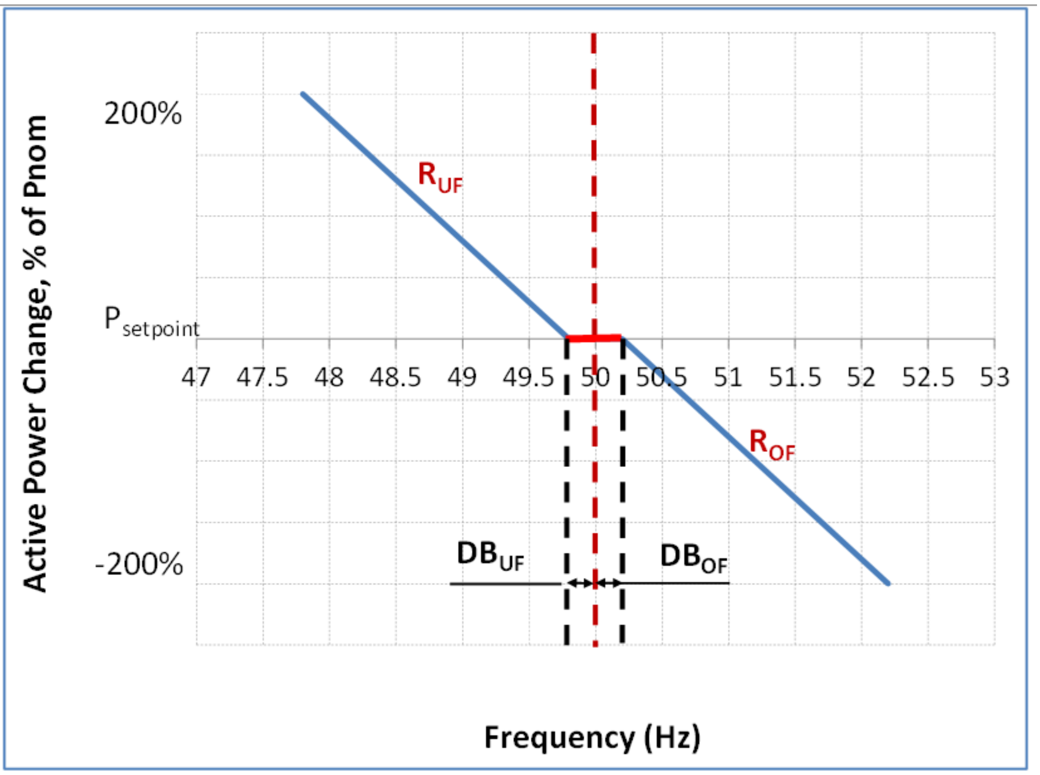

Figure 1: Frequency-power regulation characteristic in LFSM regime

Note 1: The indicated power levels, regulation constants and frequency values will be determined by the System Operator during the technical coordination phase of the facility, and later according to the requirements of the System Operator. The values marked in Figure 1 are for the sake of illustration only.

Note 2: $P_{setpoint}$ - the operating active power of the facility at the connection point.

e. Regulation of the converters of the facility in an operating regime sensitive to frequency changes FSM - Frequency Sensitive Mode:

FSM operating regime will be set remotely according to the instructions of the System Operator, and subject to the future regulatory framework.

1. In the FSM operating mode, the facility will allow a continuous response to the frequency, with deadband=0.
2. In the FSM operating mode, the reference value of the frequency $f_{SetPoint}$ will be determined according to the requirement of the System Operator (the $f_{SetPoint}$ value changes according to the needs of the System Operator).
3. In the FSM operating regime, the facility is required to operate according to the characteristic shown in Figure 2 and the parameters listed in Table 1:

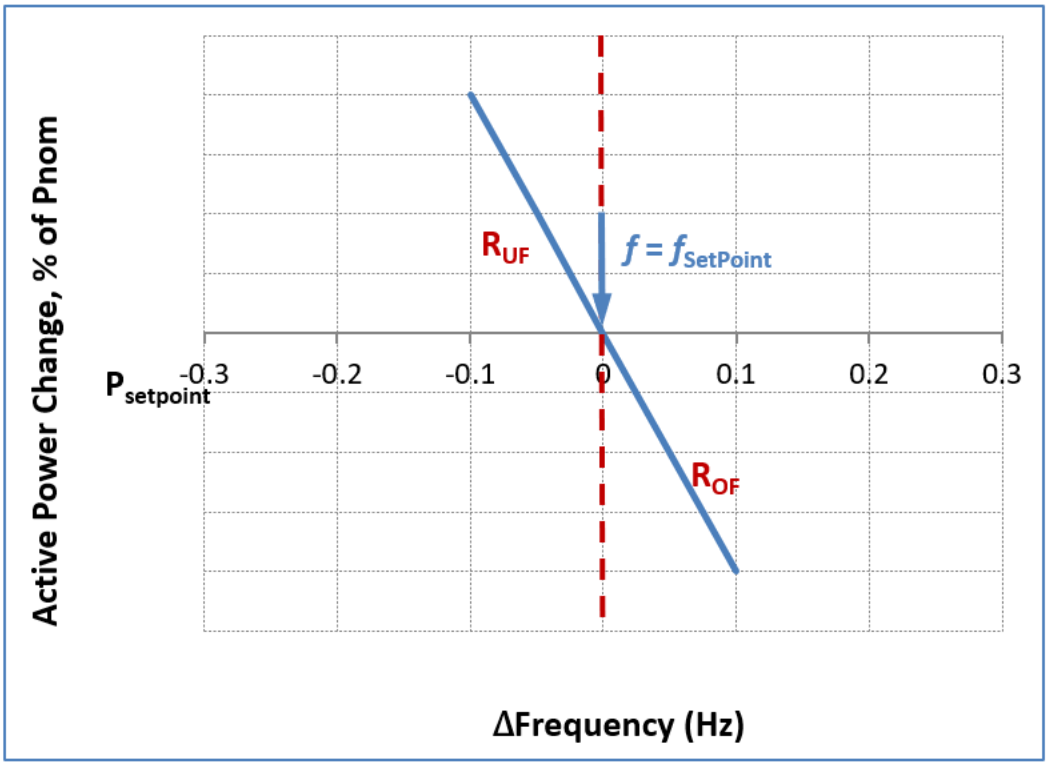

Figure 2: Frequency-power regulation characteristic in FSM regime

Note 1: The indicated power levels, regulation constants and frequency values will be determined by the System Operator during the technical coordination phase of the facility, and later on according to the requirements of the System Operator. The values marked in Figure 2 are for the sake of illustration only.

Table 1: Parameters for FSM

Parameter	Default value
Frequency change Δf in relation to the reference value ($f_{SetPoint}$) (Hz)	--
Power change due to a frequency change, in relation to the nominal power ΔP/Pnom (%)	according to frequency droop
Deadband(Hz)	0
Permissible insensitivity to frequency changes (mHz)	± 15 mHz
Frequency droop (%)	2 %
Maximum response time $T_{Response90\%}$ (s)	1 s

The power levels, regulation constants and frequency values will be determined by the System Operator during the technical coordination phase of the facility, and later on according to the requirements of the System Operator.

2.3. Voltage withstand capability

a. The facility will operate continuously (discharging/charging) when the voltage at the connection point to the transmission system is within the normal operation range (150 - 170kV).

b. The facility will continue to operate stably (discharging/charging) during and after a fault in the transmission system, which causes an over/under voltage at the connection point of the facility to the transmission system, according to the LVRT/HVRT (Low/High Voltage Ride Through) curve shown below:

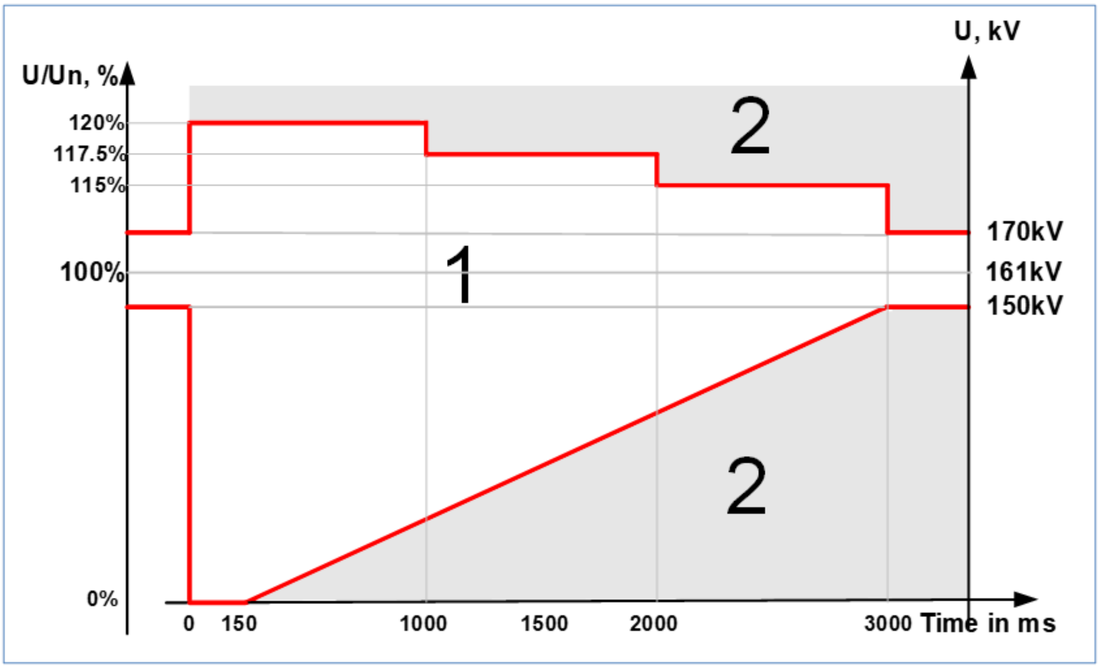

Figure 3: LVRT/HVRT curve

Where:

Zone 1:

The facility will not disconnect from the grid and will continue to operate (charging/discharging).

After the fault was cleared, the active current value that the facility delivered/consumed before the fault should return to its pre-fault value. The response time $T_{Response90\%}$ for a step-type disturbance, defined as the time required to reach 90% of the final value, shall not exceed one second.

Zone 2:

The facility may disconnect for a short time until the disturbance is removed, and according to the instructions of section 2.10.

If the facility did not disconnect from the grid - after the fault was cleared, the active current value that the facility delivered/consumed before the fault should return to its pre-fault value. The response time $T_{Response90\%}$ for a step-type disturbance, defined as the time required to reach 90% of the final value, shall not exceed one second.

2.4. Dynamic response of the facility in abnormal conditions, when voltage is outside of normal operation range, i.e. $U<Un-\Delta$, $U>Un+\Delta$:

   a. The facility is required to have the ability to provide dynamic support to the power grid, by reactive current injection during the disturbance, according to the diagram below:

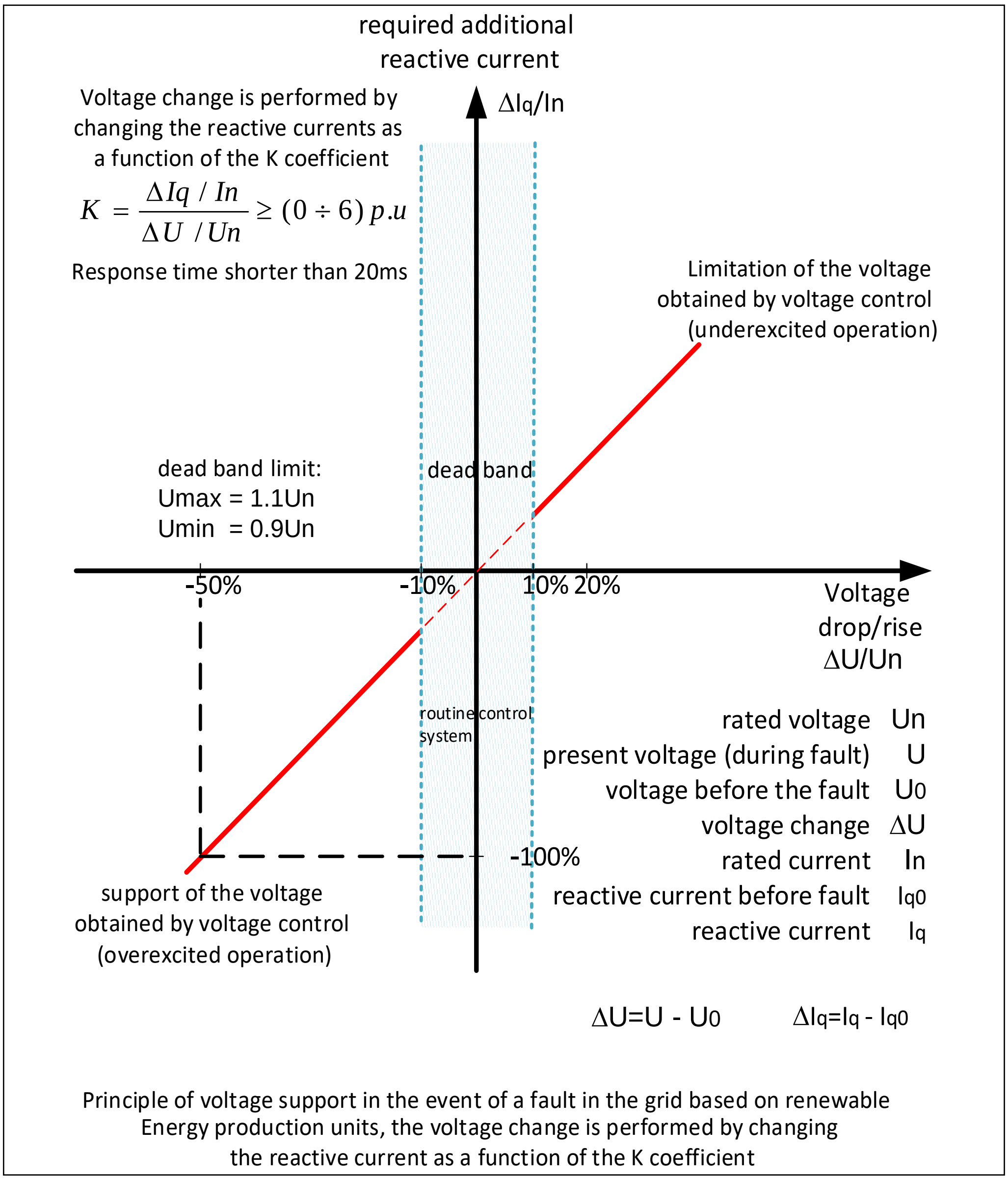

Figure 4: Dynamic support principle of the converter

For example: the coefficient K-FACTOR = 2 defines that when voltage deviates from the defined limits - for every drop of 1% in voltage, the reactive current injection will increase by 2% of the nominal current.

b. The facility's voltage control is required to operate within 20ms from the disturbance detection, unless determined otherwise by the System Operator.

c. The additional reactive current ΔIq will be proportional to the voltage change in the positive sequence and the negative sequence - the additional reactive current in the positive sequence will be proportional to the voltage deviation in the positive sequence, and accordingly the additional reactive current in the negative sequence will be proportional to the voltage deviation in the negative sequence.

d. The facility should allow the reactive current injection up to 100% of the facility's maximum current.

e. The DEAD BAND (U<Un-Δ, U>Un+Δ) and the K-FACTOR coefficient will be determined after facility simulations presentation made by BESS owner and in coordination with the System Operator. The default value of the K-FACTOR coefficient will be set to 1.

   These values will be adjustable and modified as required by the System Operator, including during operational phase, (due to possible changes in the power system).

f. Detailed instructions for determining the dynamic requirements will be established at the beginning of the technical coordination phase.

2.5. The facility will meet the harmonics requirements according to the Israeli standard 50160 and Israeli standard 61000 part 3.6, for flickers according to Israeli standard 61000 part 3.7, and according to ISO standards and the requirements defined in the standards for storage facilities.

2.6 The facility will have the ability to synchronize to the grid under the following conditions:

a. System frequency in the range of 47 Hz < f < 53 Hz.

b. Voltage at the point of connection to the grid is in the 150 - 170 kV range (High voltage).

2.7 The facility will have the ability to inject/absorb reactive power at the point of connection to the grid. The reactive power range that the facility is required to inject/absorb will be in accordance with the guidelines below:

a. In an over-excited and under-excited regime -

   In the range between (-0.43*Snom) MVAR and (+0.43*Snom) MVAR.

   S_{nom} - the facility's connection size in MVA,

   P_{nom} - the steady state, continuous active power rating of the facility, P_{nom}=0.9 S_{nom}

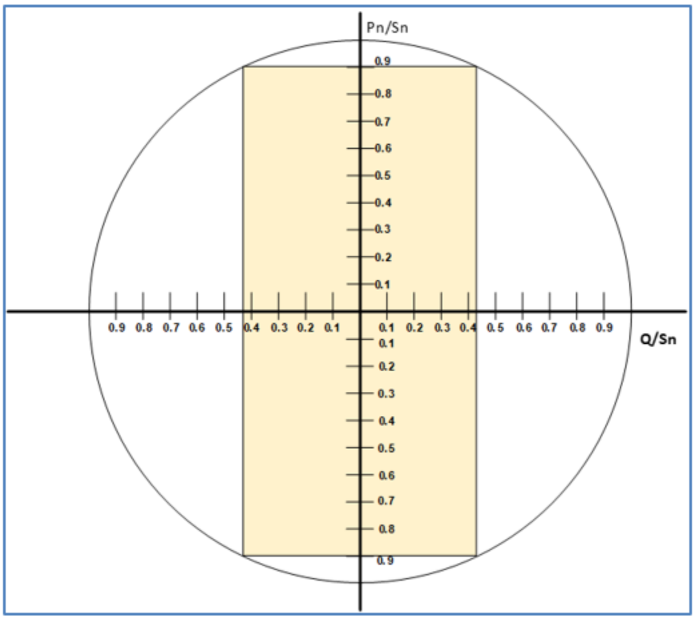

Figure 5: P/Q capability of the storage facility

Note: The facility will have the capability to inject/absorb reactive power without reducing the generation capability of the active power (P_{nom}).

b. In case of abnormal conditions in the transmission system, when the facility is required to respond in accordance with section 2.2, the requirements for reactive power will be defined in coordination with the System Operator.

c. The facility will have capability to supply reactive power at all hours of the day, independent from the active power being charged or discharged to the grid, in accordance with the requirement in section a above.

The facility will have capability to inject/absorb reactive power without reducing from the generation capability of the active power (P_{nom}).

d. The reactive power regulation will be continuous and under the control of the System Operator, see also section 2.11.

2.8. The facility will be suitable for single-phase reconnection and for the operational conditions of the grid.

2.9. The facility must be able to operate in an electrical island without connection to the grid, and maintain normal parameters as specified in sections 2.1 and 2.3 above. The technical details will be determined in the technical coordination phase.

2.10. Conditions for connecting the facility to the grid:

The connection of the facility or the reconnection of the facility after trip from the power grid due to operational action or automatic protection, will be in accordance with the instructions of the System Operator.

Connecting the facility will be possible when the grid voltage and frequency are within the range as specified in section 2.6, or in accordance with the instructions of the System Operator.

After the facility was disconnected from the grid due to disturbances, the facility will be connected to the system with a delay of 5 minutes (or another period of time defined by the System Operator) as long as the voltage and frequency conditions specified in this section are met. The connection conditions will be defined with the System Operator during the technical coordination phase.

The rate of change of the active power after connecting the facility or after the facility returns to discharge/charge active power, will be adjustable by the System Operator and will be not more than 40% and not less than 10% of the rated power per minute.

The operating regime of the facility – charging / discharging / STANDBY - will be determined by the System Operator.

2.11. The facility will participate in the system voltage regulation in continuous operation range in the following ways:

a. Constant reactive power

b. Reactive power as a function of the voltage

c. Constant power factor

d. Constant voltage at the connection point

The facility will be capable to remotely change the control mode and the required value of the controlled parameter up to the limit of injection/absorption of the reactive power as detailed in section 2.7.

If necessary, the System Operator may require another control function.

2.12. The facility will allow <u>continuous</u> active power regulation, by the System Operator, remotely, in one of two ways:

1. By entering a SETPOINT value relative to the facility's nominal power.

2. By remote LFC (Load Frequency Control) system (Set Point).

a. The upper/lower operational limits and rate of increase/decrease will be sent by the facility to the System Operator.

b. Upper/lower limit – the capability of the facility at any given moment for regulation in the LFC system, considering the charging limitations.

c. The facility will provide the increase/decrease rates to the System Operator. The System Operator will select the desired rate according to his considerations.

d. The facility should be capable to receive a command to change the loading at least once every 4 seconds.

e. The facility must respond to a signal sent within a time frame of no more than 4 seconds.

2.13. Facility protections should:

a. Be equipped with protections in accordance with the relevant standards.

b. Be equipped with protections whose operation will be coordinated with the existing protections in the switchyard and with the existing protections in the grid.

c. Ensure the protection of the facility in case of faults and malfunctions within the facility.

d. Ensure the protection of the facility in case of grid faults, which were not cleared by the protections installed in the High/extra-high voltage switchyard of the facility.

e. Include at least under-frequency / over-frequency, under-voltage / over-voltage, over-current protections, and protection to detect an island mode condition (operational areas will be defined later).

2.14. The transformer at the point of connection of the facility to the transmission grid should:

a. Be designed, manufactured and tested in accordance with IEC 60076 or IEEE C57.12.00 standards.

b. Withstand short circuit currents determinate according to the location of the storage facility in the grid.

c. Have a connection group with Y connections on the high voltage side (point of connection to the transmission system), with the possibility of grounding the zero point; The zero-point regime will be defined by the System Operator according to the location of the facility in the system (usually effectively grounded).

d. Have a connection group that will ensure the prevention of the transfer of third harmonic to the grid.

e. Have an insulation level on the grid side that is compatible with the insulation level of the High voltage grid.

f. Be equipped with a Tap Changer; The maximum tap size should not exceed 2.5% of the rated voltage of the winding.

g. Have an impedance that meet the requirements of the facility's withstand capability to short circuit currents.

h. Be equipped with the appropriate protections according to the System Operator's instructions. The full instructions will be provided during the technical coordination phase.

2.15 Dynamic study

In order to perform simulations to examine the dynamic responses and their effect on the system, it is required to provide detailed models of the facility and its control systems. The BESS owner will be given a form containing the list of data required for simulating the facility (see appendix).

Simulation of the facility's behavior at various conditions should check the compliance of the facility with the requirements, for example, the ability to control P, Q and U, compliance with LVRT/HVRT and frequency response.

Before the operational phase, the BESS owner must provide the installed/updated data, as specified in the appendix, and the simulations that prove the facility's compliance with the dynamic requirements detailed in this document.

2.16. The storage facility

The converters of the storage facility must be of the GRID FORMING type, capable of generating and regulating voltage and frequency independently, and able to serve the local load in a stable, reliable and secure manner, under isolation from the rest of the power system with no synchronous machines present.

The storage facility must comply with international standards such as: standards institutions accepted by the European Union or the federal authorities in the USA or the relevant authorities in Australia.

The BESS owner must provide Test Reports, Type Tests and calibration sheet of the converters to the System Operator.

The complete requirements will be defined during the technical coordination phase.

- During the connection study and the technical coordination phase, the detailed requirements will be agreed upon.

3. Site technical requirements

A generation facility must meet the requirements described in this section, in addition to the specific conditions for High voltage switchyard, which are defined in the System Operator's customer connection procedure.

3.1. Power quality monitoring

A system for power quality monitoring will be installed in the storage facility. The requirements and the communication interface of the power quality monitoring system will be defined in the technical coordination phase.

3.2. Information exchange

The management of the national power system is carried out through the control and monitoring system of the national dispatch department (EMS – Energy Management System). As part of the national power system, the storage facilities should exchange real-time data with the EMS system. The data exchange is carried out using an end unit of the EMS system that will be installed in the storage facility and that will be connected to the EMS system via two communication interfaces. The main requirements regarding the transfer of data are as follows:

a. The storage facility should be designed, constructed and maintained in a way that ensures the data exchange required for the management and operation of the power system, in accordance with the procedures approved by the authorized entities.

b. The data will include at least, but not limited to:

   - Indications: the statuses of the facility, the statuses of the switching devices at the extra-high/High voltage switchyard, operations of protections in the switchyard and the storage facility, automation modes and relevant control systems.

   - Measurements: active and reactive power supplies in the lines and main transformers in the switchyard, voltages at the switchyard busbars, state of charge data.

   - Operations: switching devices in the switchyard, regulating the loading of the storage facility (active / reactive / voltage / power factor).

c. The end unit will be installed in a separate room inside the facility, preferably near the "relays" room, where the communication cabinets will be also installed; In some cases, according to the general layout of the storage facility (in the context of the distances between the storage facility and the switchyard), two end units will be installed, one close to the units and the other in the switchgyard's command building.

d. The room will allow the installation of four (4) 19" cabinets (including communication cabinets) and will be air-conditioned.

3.3. Data Security

Being part of the national power system, the storage facility is subject to all the guidelines of the National Cyber Headquarters regarding the power system facilities and the EMS.

In light of these guidelines, the necessary steps must be taken to secure the information to the EMS on a physical and logical level.

At the physical level, the room where the EMS end unit will be installed will be accessible only to people authorized by the national dispatch.

At the logical level, in the event that some of the data that reaches the end unit arrives serially from different controllers of the storage facility, all necessary measures must be taken by the national dispatch, both hardware and software, in order to prevent potential intrusion into the dispatch's control and monitoring system.

4. Administrative instructions

4.1. Data delivery

The BESS owner of the storage facility must provide data to the System Operator. This data is used to design the connection of the storage facility to the power system and to the supervisory control system of national dispatch as well as to operate the facility throughout its life span.

The System Operator will define the data that must be provided at each stage (feasibility study, connection study, technical coordination phase, construction, commissioning, operation) and will define the required level of data specification at each stage.

In addition to providing the data to the System Operator as required at each stage, the owner of the facility (or its operator) is responsible for providing information to the System Operator about any change in this data as soon as the change occurs.

4.2. Obligations of the BESS owner

The obligations of the facility owner towards the System Operator are usually described in the commercial agreement entered between the two parties. In the current document, the duties of the BESS owner are emphasized during the planning, construction and operation phases from the point of view of system management and operation:

a. The estimated technical data of the storage facility will be provided to the System Operator at the earliest possible stage of the project for the purpose of checking the compliance of the storage facility to the system's requirements; The System Operator is entitled to request changes in parameters, which can have a negative impact on the system's behavior. The facility's equipment will be ordered in accordance with the requirements listed in the customer connection procedure (switchyard equipment) and the current document (storage facility, transformer, protections). The design and equipment list of the switchyard will be provided for approval by the System Operator.

b. The end unit of the EMS will be supplied by the System Operator; the planning and the commissioning of the connection of the end unit to the facility is the responsibility of the BESS owner. The design will be brought to the approval of the System Operator and the BESS owner must implement the changes that the System Operator requires (if any).

c. The design, delivery and connection of an end unit to the System Operator's communication system are the responsibility of the System Operator, at the BESS owner's expense.

d. Calibration of the protection systems of the switchyard and the storage facility will be coordinated with the IECo; The duty of the BESS owner to implement the requirements of the IECo - as long as these requirements do not affect the availability and reliability of the facility.

Energy Storage Generation Units - Data Requirements

1. Storage Units:
    a. Manufacturer
    b. Model number
2. Converters:
    a. Manufacturer
    b. Model number
3. Storage & converters connection description and diagram.
4. Low/High Voltage Ride Through (LVRT/HVRT) curve
5. Manufacturer model specific to the supplied Storage generation unit for PSS/E ver. 35 or higher

   or

   PSS/E Generic Storage Data Model for program ver. 35 or higher

(REGCA1, REECCU1, REPCA1, PLNTBU1, etc.).

6. EMTP-RV Storage System Model for program ver. 4.2 or higher