Technical Guideline

for the Connection of Electricity Storage Modules to the Hellenic Electricity Transmission System

Independent Power Transmission Operator

Strategy & System Planning Department

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Note by IPTO

The installation of battery energy storage systems (BESS) in Greece requires the definition of technical requirements to address system needs and secure system operation.

No technical requirements are foreseen for electricity storage[1] by the Hellenic Electricity Transmission System Grid Code. Electricity storage is also out of the scope of ENTSOe's Connections Network Codes (CNCs)[2].

This Technical Guideline specifies minimum technical requirements for the connection of electricity storage modules (ESM) to the 150/400kV Hellenic Electricity Transmission System (HETS). The Guideline applies to the technologies and the connection topologies of Section 1.

The requirements are based on the proposals of the Expert Group Storage (EG Storage) of ENTSOe (https://www.entsoe.eu/network_codes/cnc/expert-groups/) as well as on drafts of NC-RfG and NC-DCC amendments prepared by ENTSOe and submitted to ACER for approval (November 2022), and they cannot be considered as a part of the CNC requirements in force.

IPTO holds the right to modify the content of this Guideline in line with the technical requirements established by the Regulation (EU) 2016/631 in force or by any other Regulation replacing or supplementing it or by any other technical requirement specified by IPTO.

[1] To avoid confusion, it is noted that this Technical Guideline follows ENTSOe's terminology where BESS are considered as a subset of "electricity storage modules".

[2] The technical requirements set out by Regulation (EU) 631/2016 (NC-RfG) and Regulation (EU) 1388/2016 (NC-DCC) do not apply to storage devices as stated in Article 3.2(d) of the NC-RfG and Article 3.2(b) of the NC-DCC, with the exception for pump-storage which is considered as a Power Generating Module (PGM).

Definitions

“power-generating module” or “PGM”: either a synchronous power-generating module or a power park module;

“main generating plant” means one or more of the principal items of equipment required to convert the primary source of energy into electricity;

“generating unit” or “GU”: the smallest entity of a PGM feeding in electrical power to the grid; this can be a directly coupled synchronous generator, a photovoltaic inverter, a double-fed asynchronous generator, a fully rated converter of a wind turbine or something similar;

“synchronous power-generating module” or “SPGM”: an indivisible set of installations which can generate electrical energy such that the frequency of the generated voltage, the generator speed and the frequency of network voltage are in a constant ratio and thus in synchronism;

“power park module” or “PPM”: a unit or ensemble of units generating electricity, which is not a synchronous power-generating module and which is either non-synchronously connected to the network or connected through power electronics, and that also has a single connection point to a transmission system, distribution system including closed distribution system or HVDC system;

“synchronous generating unit” or (SGU): an alternator along with the associated prime mover, speed and power control, voltage control, excitation control system including, if applicable, a power system stabilizer function;

“power park unit” or “PPU”: a generating unit in the context of a PPM;

“power-generating facility” or “PGF”: a facility that converts primary energy into electrical energy and which consists of one or more power-generating modules connected to a network at one or more connection points;

“power-generating facility owner” or “PGFO”: a natural or legal entity owning a power-generating facility;

“connection point” or “CP”: the electrical interface at which the power-generating module, demand facility, distribution system or HVDC system is connected to a transmission system, offshore network, distribution system, including closed distribution systems, or HVDC system, as identified in the connection agreement;

“maximum capacity” or “Pmax”: the maximum continuous active power which a power-generating module can produce, less any demand or losses associated solely with facilitating the operation of that power-generating module as specified in the connection agreement or as agreed between the relevant system operator and the power-generating facility owner;

“minimum regulating level” or “Pmin”: the minimum active power, as specified in the connection agreement or as agreed between the relevant system operator and the power-generating facility owner, down to which the power-generating module can control active power;

"pump-storage": a hydro unit in which water can be raised by means of pumps and stored to be used for the generation of electrical energy;

"frequency containment reserves" or "FCR": the active power reserves available to contain system frequency after the occurrence of an imbalance;

"frequency restoration reserves" or "FRR": the active power reserves available to restore system frequency to the nominal frequency and, for a synchronous area consisting of more than one LFC area, to restore power balance to the scheduled value;

"load-frequency control area" or "LFC area": a part of a synchronous area or an entire synchronous area, physically demarcated by points of measurement at interconnectors to other LFC areas, operated by one or more TSOs fulfilling the obligations of load-frequency control;

"observability area": a TSO's own transmission system and the relevant parts of distribution systems and neighboring TSOs' transmission systems, on which the TSO implements real-time monitoring and modelling to maintain operational security in its control area including interconnectors;

"k-factor": the ratio $(\Delta I_Q/I_r)/(\Delta U/U_n)$, where ΔI_Q is the PPU reactive current change in a voltage deviation ΔU at PPU terminals and Un and I_r are the nominal voltage and current of a PPU. This ratio defines a PPU's fault current in relation to the remaining voltage during a fault;

"electricity storage": the conversion of electrical energy into a form of energy which can be stored, the storing of that energy and the subsequent reconversion of that energy back into electrical energy;

"electricity storage module" or "ESM": a power generating module which can inject and consume active power to and from the network for electricity storage, excluding pump-storage power-generating modules;

"electricity storage unit" or "ESU": a power generating unit in the context of an ESM;

"maximum consumption capacity": the maximum continuous active power which an electricity storage module can consume, less any demand or losses associated solely with facilitating the operation of that electricity storage module, as specified in the connection agreement or as agreed between the relevant system operator and the power-generating facility owner;

"State Of Charge" or "SOC": the energy available, expressed in percentage (%) of the amount of the ESM nominal capacity, (0% = empty; 100% = full);

"Maximum Charging Ramp Rate" or "Rch": the maximum limit on the rates of change of power that the ESM can achieve during charging, expressed in MW/min;

"Maximum Discharging Ramp rate" or "Rdis": the maximum ramping that the ESM can achieve during discharging, expressed in MW/min;

"Power Plant Controller" or "PPC": a control device that records the difference between desired and actual values of various controlled electrical variables (e.g., voltage, active or reactive power) at the connection point, derives the information of how to change a manipulated variable and forwards it to the controlled generating units or PGM components. A PPC may control several other PPCs in a “master-slave” hierarchy scheme;

“Authorized certifier” or “Certification Body”: an entity that issues equipment certificates and power-generating module documents and whose accreditation is given by the national affiliate of the European cooperation for Accreditation ('EA'), established in accordance with Regulation (EC) No 765/2008[3];

“Equipment certificate” or “EqC”: a document issued by an authorized certifier for any kind of equipment used by a PGM, certifying that this equipment complies with an individual technical requirement, grid code provisions or international standard. The equipment certificate may include simulation models that have been verified by authorized certifiers against actual test results. For the scope of this technical guideline EqCs may cover either a single Additional PGM component (ACPGM certificate), or a generating unit (generating unit certificate);

“Independent Power Transmission Operator” or “IPTO”: the TSO of the Hellenic transmission system;

“Hellenic Electricity Distribution Network Operator” or “HEDNO”: the DSO of the Hellenic distribution system.

[3] Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 setting out the requirements for accreditation and market surveillance relating to the marketing of products and repealing Regulation (EEC) No 339/93

Abbreviations

CP	connection point
GU	generating unit
HV	high voltage
min	minutes
MV	medium voltage
NDC	national or regional dispatch center
HETS	Hellenic electricity transmission system
PGF	power-generating facility
PGFO	power-generating facility owner
PGM	power-generating module
P_{max}	maximum continuous active power of a PGM
P_{min}	minimum active power regulating level of a PGM
PPM	power park module
PPU	power park unit
SGU	synchronous generating unit
SPGM	synchronous power-generating module
PPC	power plant controller
ESM	electricity storage module
ESU	electricity storage unit
FCR	Frequency Containment Reserve
FRR	Frequency Restoration Reserve
RAE	Regulatory Authority of Energy
IPTO	Independent Power Transmission Operator (the Greek TSO)

1 Scope

This document specifies technical requirements for the connection of Electricity Storage Modules (ESM) to the Hellenic Electricity Transmission System (HETS) classified as of type-D significance according to the definitions and criteria set out in Articles 4 and 5 of the NC-RfG for PGMs, as amended by RAE's Decision 1165/2020. This classification is based on the voltage level at the connection point (CP) with the HETS and the ESM maximum capacity (Pmax), according to the threshold values given in Table 1 and Figure 1.

Table 1: Determination of significance for type A, B, C and D PGMs

Type	Nominal voltage at the CP	Maximum capacity thresholds
A	< 110 kV	0,8 kW ≤ Pmax < 1 MW
B	< 110 kV	1 MW ≤ Pmax < 20 MW
C	< 110 kV	20 MW ≤ Pmax <75 MW
D	≥ 110 kV	Pmax ≥75 MW

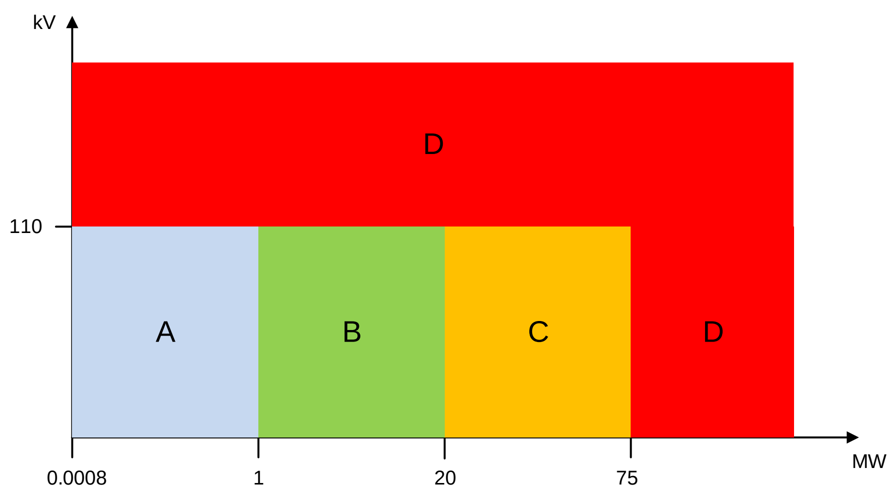


Figure 1: Determination of significance for type A, B, C and D PGMs

1.1 ESM technologies

The technical requirements apply to Electricity Storage Modules (ESMs) consisting of one or more Electricity Storage Units (ESUs) that:

- utilize technologies which allow the absorption of electrical energy from the electricity grid, convert and store the absorbed electrical energy into another intermediate form of energy (energy carrier) and can reconvert the stored energy back into electrical energy and inject it to the transmission system or distribution network at the same connection point at another time.

- allow the controlled activation of charging (consumption - absorption) and discharging (injection - generation) cycles and adjust the injected/absorbed active power following dispatch instructions issued by IPTO.

Such technologies may be (indicatively but not exhaustively) utility scale batteries of any type or chemistry (battery energy storage systems), supercapacitors and superconducting magnetic energy storage.

The Technical Requirements does not apply to:

a) non-controlled electrical energy storage technologies such as (indicatively and non-exhaustively) mechanical flywheels and static synchronous compensators (STATCOMs). Even if these technologies can be used to store electrical energy, their activation is not controlled (in the sense of implementing dispatch instructions issued by the NDC) since they are activated under special system operating conditions (e.g., sharp frequency or voltage drops or rises).

b) Energy storage technologies which can absorb, convert and store electrical energy in another form but cannot reconvert the stored energy back into electrical energy and inject it to the electrical grid at the same connection point (CP). Such technologies can be any form of chemical energy storage such as (indicatively and non-exhaustively) fuel cells, electrolytes, hydrogen and any form of Power to Gas (P2G) energy storage as well as any form of thermal or mechanical energy storage.

c) Electricity Storage Modules that fall under the provisions of Article 3.2.(a),(b) and (c) of Regulation (EU) 631/2016 (NC-RfG), i.e., ESMs either installed in the non-interconnected islands or applicable to emergency uninterruptible power supply or operating in parallel with the system for less than five minutes per calendar month while the system is in normal system state.

d) Pump-storage hydro (PSH). According to Article 6(2) of NC-RfG, pump-storage PGMs shall fulfil all the relevant requirements of the NC-RfG in both generating and pumping operation mode[4]. To avoid confusion, the technical requirements for the connection of Pumped Storage Hydro to the HETS are provided as a separate "Technical Guideline for the Connection of Pump-Storage Hydro", identifying PSH technologies, their specific characteristics and constraints for each operation mode (generation, pumping, synchronous compensation), and clarifying the relevant connection requirements.

This Technical Guideline distinguishes the following modes of operation of an ESM:

[4] NC-RfG, Article 6 (2): "Pump-storage power-generating modules shall fulfil all the relevant requirements in both generating and pumping operation mode. Synchronous compensation operation of pump-storage power-generating modules shall not be limited in time by the technical design of power-generating modules. Pump-storage variable speed power-generating modules shall fulfil the requirements applicable to synchronous power-generating modules as well as those set out in point (b) of Article 20(2), if they qualify as type B, C or D."

- charging (consumption), where the ESM absorbs active power from the CP,
- discharging (generation), where the ESM injects active power to the CP,
- stand by (neutral mode), where there is no intentional power flow to or from the CP. The ESM is neither charging or discharging but it is available (auxiliaries in operation) and ready to switch to the charging or discharging mode or to switch off (turn to the stopped mode),
- stopped (off mode), where the ESM is grid-disconnected.

1.2 ESM typology and connection topologies addressed

There is a wide variety of connection technologies for the Electricity Storage Modules.

This Technical Guideline specifies connection requirements for Electricity Storage Modules with a CP at the HETS (400/150kV) that constitute independent entities from a licensing, operation and control point of view.

ESMs addressed shall be connected to the HETS either via dedicated transformers or may share HV/MV or EHV/MV transformers with other generating or storage entities. These transformers may be installed in existing (i.e., electrified by the time this Technical Guideline comes into force) or future erected HV/MV or EHV/MV substations, Figure 2.

This guideline does not specify requirements for ESMs embedded behind-the-meter of other HETS users' facilities.

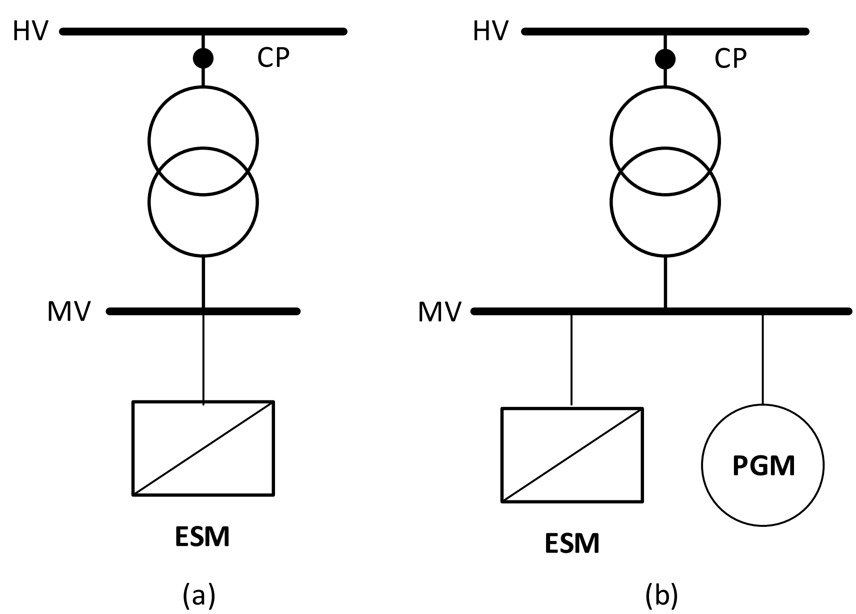


Figure 2: ESM connection topologies, (a) dedicated transformer, and (b) shared transformer with other users (generation or storage stations)

The technical capabilities of an ESM are considered as similar to the ones of Power Park Modules (PPMs) of the NC-RfG as they share similar technical aspects: the PPM is an ensemble of generating units (GUs) connected via an internal network to the electricity grid via power electronics acting as inverter; the ESM is an ensemble of ESUs connected via power electronics acting as inverters/rectifiers under charging or discharging mode, respectively.

The proposed technical requirements are aligned as much as possible with the PPM's exhaustive and non-exhaustive requirements defined in the NC-RfG as amended by RAE's Decision 1165/2020.

The technical requirements specified in this Technical Guideline apply to both injection (discharge) and absorption (charge) operating modes, unless otherwise explicitly stated.

2 General PGF design specifications[5]

During the design phase of a PGF the following fundamental design specifications should be met at the CP with the HETS:

- The transmission system must be effectively earthed on the neutral system with a fault factor to earth of less than 1.4. The line to earth voltage during single line to earth faults should not rise above 80% of the rated line to line voltage.
- Regarding the maximum allowable short circuit currents, it must be considered that the HETS is designed and operated to maintain short circuit levels below the following values:
  - 40kA at any point of the 400kV system, and
  - 31kA at any point of the 150kV system.

  To be on the safe side during the PGF design it is recommended the maximum allowable sub-transient short circuit fault levels at the CP not be greater than 90% of the above limits. For three-phase or single-phase to earth faults, the designed maximum sub-transient short circuit fault levels shall not be greater than 36 kA for 400kV and 28 kA for 150kV. In any case, PGF equipment shall be selected for 40/31kA maximum fault current.
- The thermal limits on all PGF equipment and components shall be as determined by the assumed seasonal ambient conditions. Normal and overload ratings must take account of the ratings of auxiliary and ancillary equipment such as switchgear, bushings, instrument transformers. No overloading on equipment shall be acceptable during equipment selection and design phase, under neither normal nor emergency operation, except in the immediate aftermath of a disturbance, while corrective action, either automatic or manual, is being taken.

The earthing of all PGF components, GU's and other devices and the installation of the earthing system must be made in accordance with the relevant standards. The following general rules apply for the earthing systems:

- the exact specifications of the earthing network to be installed shall be agreed between the PGFO and IPTO
- the earthing devices of the PGF must be earthed by direct earthing with the substation earthing network
- the PGFO must ensure that any fault in the PGF is limited to the confines of the substation and that any dangerous voltage rise shall not be transmitted outside the earthing zone

[5] This is an indicatively list of Power Generating Facility (substation) specifications or recommendations. Some of them may apply only to newly erected substations. The PGF detailed design shall be agreed with IPTO on a case sensitive base.

- the PGFO shall guarantee that the staff working at the earthing system is properly trained for the performance of the relevant works in a safe manner

The design of the PGF components and all connected devices must meet the following minimum specifications for each voltage level:

Table 2: Hellenic Transmission System General specifications

Parameter (minimum)	150kV	400kV
Insulation level for impulse voltage (1.2/50ms)	750 kV	1550 kV, with the following exceptions: Autotransformers: • 1550 kV for bushings, • 1425 kV for windings
Voltage Insulation level (50Hz for 1min)	325kV	680 kV, with the following exceptions Switches: • 620 kV between phase-earth and among phases, • 800 kV along open contacts Disconnectors: • 620 kV between phase-earth and among phases, • 800 kV along the insulation distance Autotransformers: • 680 kV for bushings, • 630 kV for windings
Clearance in air between conductors and metal parts in the area of outdoor HV substations and EHV Centers	1550 mm	• 3100 mm between conductor and metal part • 4100 mm between Rod and metal part
Height of live parts above over pedestrian passageways in the area of outdoor HV substations and EHV Centers	5000 mm	7000 mm
Height of bottom of unscreened live bushings above ground in the area of outdoor HV substations and EHV Centers	2300 mm	2300 mm
Height of live conductors above roadways	9000 mm	11000 mm

It is recommended that the short circuit voltage (uk) of the substation MV/HV main transformers have a value of 17% or higher at OLTC neutral position. Lower values of uk may be accepted subject to IPTO's approval.

The substation MV/HV main transformers shall be equipped with an onload tap-changing mechanism (OLTC) being capable of activating remotely. The design specifications of the OLTC and the applied settings are approved by IPTO.

Unless otherwise specified, the MV/HV main transformers shall operate under voltage control mode on the medium voltage side.

The OLTC function shall always be activated. The de-activation of the OLTC function or modification of its settings is not allowed without prior IPTO's approval.

The substation MV/HV main transformers shall have adequate number of MV/HV tap positions to provide voltage control under a wide range of HV operating conditions. The recommended number of tap positions for MV/HV transformers with a primary winding connected at 150 and 400 kV is given in Table 3.

Table 3: Recommended number of tap positions of the (OLTC) mechanism of the substation MV/HV main transformer

tap position	tap ratio	150kV (HV)	400kV (HV)	MV
10	1,1250	168.7500	-	20 or 30 or 33kV
9	1,1125	166.8750	-	
8	1,1000	165.0000	440.0000	
7	1,0875	163.1250	435.0000	
6	1,0750	161.2500	430.0000	
5	1,0625	159.3750	425.0000	
4	1,0500	157.5000	420.0000	
3	1,0375	155.6250	415.0000	
2	1,0250	153.7500	410.0000	
1	1,0125	151.8750	405.0000	
0	1,0000	150.0000	400.0000	
-1	0,9875	148.1250	395.0000	
-2	0,9750	146.2500	390.0000	
-3	0,9625	144.3750	385.0000	
-4	0,9500	142.5000	380.0000	
-5	0,9375	140.6250	375.0000	
-6	0,9250	138.7500	370.0000	
-7	0,9125	136.8750	365.0000	
-8	0,9000	135.0000	360.0000	
-9	0,8875	133.1250	-	
-10	0,8750	131.2500	-	

The following specifications apply to transformers installed at the CP of type D PGMs:

- for connections at EHV (400kV), substation main transformer windings shall be connected either as:
  - two winding transformers: star (with the neutral brought out) on the system side (EHV side) and delta on the medium voltage side. The neutral nodes of transformers connected to 400kV systems must be solidly earthed.

  - three winding transformers: star on both high and medium voltage sides with the neutral node brought out to a terminal either for direct or resistance earthing, and a tertiary winding connected in delta.
- for connections at HV (150kV), substation main transformer windings may be connected either as:
  - delta on the high voltage and in star on the medium voltage side, with the neutral node brought out to terminals for resistance or direct earthing; or
  - star on the high voltage, with the neutral node brought out to terminals for resistance or direct earthing, and in delta on the medium voltage side;

Provision shall be made for the earthing of the neutral of each transformer connected to the 150kV system by bringing out the neutral. IPTO will consider on a case-by-case basis if the transformer is required to be operated with the MV neutral unearthed or through an earthing resistance and will notify the owner accordingly.

In the case of delta connection on the medium voltage side an earthing transformer (e.g., with zig-zag windings) should be connected at the medium voltage transformer busbars, in order the PGFO's medium voltage connection network to be properly earthed. In general, the connection of unearthed medium voltage connection networks is not allowed prior to IPTO's consent and proper adaptation of the relevant medium voltage protection scheme.

Furter details on the specifications applied for transformers connected to the HV system are to be agreed with IPTO.

3 ESM operating ranges

3.1 Frequency operating ranges

All ESMs connected to the HETS shall be capable of staying connected and operate stably for system frequency values within the ranges and for the minimum operating times specified in Table 4.

Table 4: System frequency ranges and minimum operating times for PGMs connected at HETS

Frequency Ranges	Minimum duration of operation
47,5Hz – 48,5Hz	30 min
48,5Hz – 49,0Hz	30 min
49,0Hz – 51,0Hz	Unlimited
51,0Hz – 51,5Hz	30 min
51,5 Hz-52,5 Hz	10 sec

IPTO and the ESM owner may agree on wider frequency ranges, longer minimum times for operation or specific requirements for combined frequency and voltage deviations to ensure the best use of the technical capabilities of an ESM, if it is required to preserve or to restore system security.

The ESM owner shall not unduly refuse to give his consent to the application of higher frequency values or a longer minimum operating time, considering their economic and technical feasibility.

3.2 Voltage operating ranges

All ESMs connected to the HETS shall be capable of staying connected and operate stably within the phase-to-phase voltage ranges at the CP (expressed in p.u. of the reference voltage) and for the minimum time periods specified in Table 5 (for CP with nominal voltage 150kV) and Table 6 (for CP with nominal voltage 400kV).

Table 5: Minimum time periods during which an ESM must be capable of operating without disconnecting from the HETS for phase-to-phase voltages deviating from the reference value at the CP, voltage values are in p.u. on 150 kV base

Voltage range In p.u.	**Voltage range In kV**	**Minimum duration of operation**
0,85 – 0,90 p.u.	127,5 – 135 kV	60 minutes
0,90 – 1,118 p.u.	135 – 167,7 kV	unlimited
1,118 – 1,15 p.u.	167,7 – 172,5 kV	60 minutes

Table 6: Minimum time periods during which an ESM must be capable of operating without disconnecting from the HETS for phase-to-phase voltages deviating from the reference value at the CP, voltage values are in p.u. on 400 kV base

Voltage range In p.u.	**Voltage range In kV**	**Minimum duration of operation**
0,85– 0,90 p.u.	340 – 360 kV	60 minutes
0,90– 1,05 p.u.	360 – 420 kV	unlimited
1,05– 1,10 p.u.	420 – 440 kV	60 minutes

Wider voltage ranges or longer minimum time periods for operation may be agreed between IPTO and the ESM owner. If wider voltage ranges or longer minimum times for operation are economically and technically feasible, the ESM owner shall not unreasonably withhold an agreement.

3.3 Steady state frequency and voltage operating limits

All ESMs shall stay connected to the HETS and continue to operate stably under frequency and voltage deviations from the nominal values within the specific ranges and for the relevant minimum operating time periods specified by the frequency-voltage diagrams of Figure 3 (CP at 150kV) and Figure 4 (CP at 400kV).

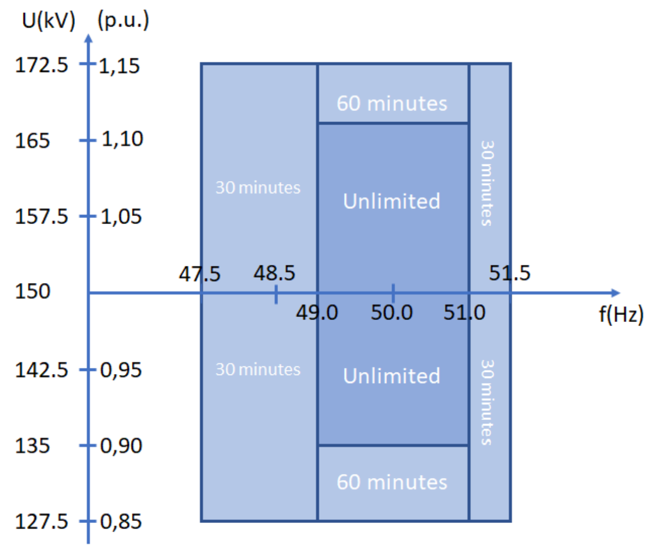


Figure 3: Minimum requirements for steady-state operation of PGMs connected at 150 kV, where U is the voltage at the CP (in kV) and f is the system frequency (in Hz)

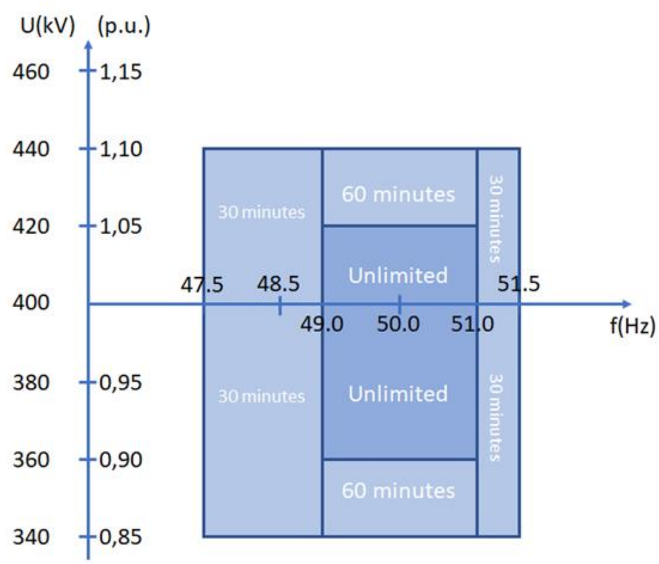


Figure 4: Minimum requirements for steady-state operation of PGMs connected at 400 kV, where U is the voltage at the CP (in kV) and f is the system frequency (in Hz)

3.4 Rate of Change of Frequency (RoCoF) withstand capability

The ESM shall be capable of staying connected to the HETS and operate for rates of change of system frequency (RoCoF) up to 2,0 Hz/sec observed in a sliding window of 500 msec. Without prejudice to that, the ESM shall be capable of staying connected to the network and operate at the sequence of rates of change of frequencies which are defined by the over and under-frequency against time profiles given in

Figure ***5*** for overfrequency (a) and underfrequency (b), respectively. The frequency value should be determined as the average measured value of the past 500 msec (sliding window technique of 500 msec range).

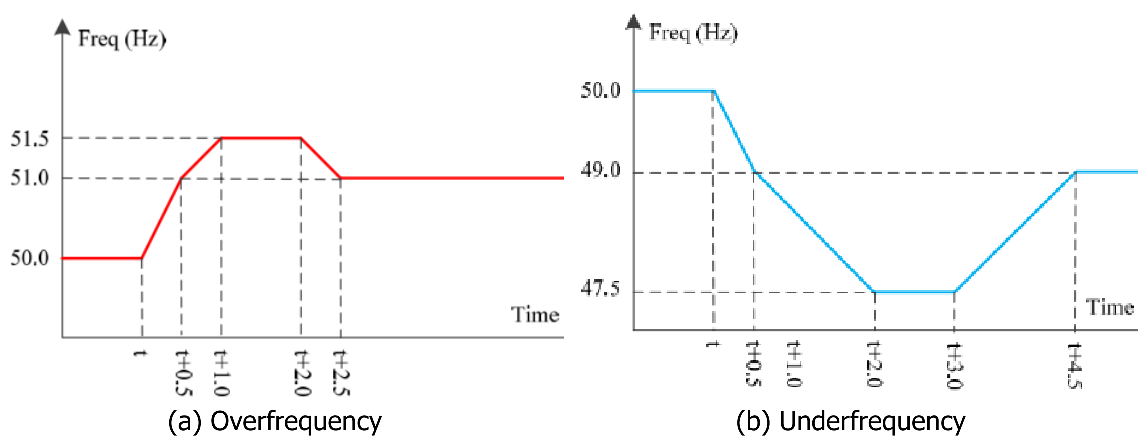


Figure 5: Rate of Change of frequency requirements

3.5 Loss of Mains (LoM) detection

The use of LoM detection based on RoCoF measurement is not allowed for ESMs connected to the HETS. The ESM owner shall provide technical details on the method for LoM detection being used. Any LoM detection methods and their relevant protection settings should not contradict with the requirements on frequency withstand capabilities specified in par. 3.4 and may be used only after IPTO's approval.

4 Active Power control Requirements

Any ESM connected to the HETS shall be capable of participating in system Frequency Restoration Control (FRC) by adjusting the generated or consumed active power in line with set-points (i.e., active power target values) issued remotely and in real time by IPTO's National Dispatch Centre (NDC).

To achieve that, the ESM must be equipped with an active power control system that exchanges signals and information in real time with the NDC and it is capable of automatically applying set point values.

The ESM shall maintain the set-point values regardless of changes in the frequency unless it operates under any of the frequency control modes of Chapter 5.

The minimum period for the ESM to reach an active power set point is defined as 60s. The set points should be reached with a tolerance of ±5% of the active power set point or ±5MW (whichever is smaller). The above requirement is explained graphically in Figure 6.

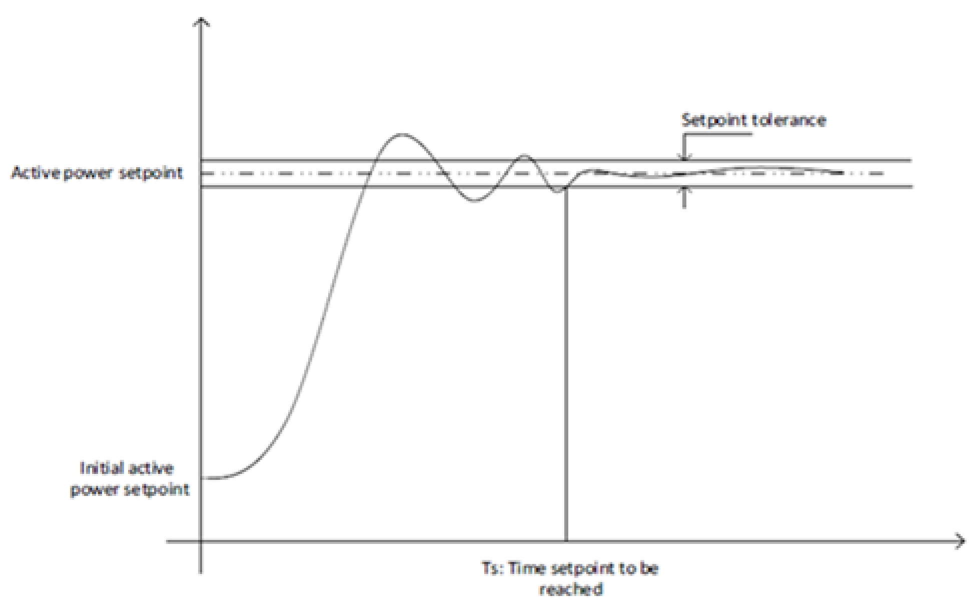


Figure 6: Tolerance and time duration for application of a new active power set point

In case that the automatic remote-control device of the ESM referred above is out of service, the active power set points shall be implemented via manual-local measures. In such a case the minimum period for a ESM to reach an active power setpoint is 15min with a tolerance of ±10% of the active power set-point value or ±10MW (whichever is smaller).

While implementing an active power setpoint, the minimum and maximum limits on rates of change of active power output (ramping limits) in both up and down direction[6] are summarized in Table 7.

Table 7: Maximum ramp up/down limits for ESMs connected to the HETS

Prime mover Technology	Ramp-up rate	Ramp-down rate
ESMs with a power electronic interface	not less than 10,0% Pmax/min when in normal conditions	not less than 10,0% Pmax/min when in normal conditions

[6] It is mentioned that these ramp rates refer to active power responses while applying active power set points and they are not related with any other frequency response phenomena.

5 Frequency control Requirements

All ESMs connected to the HETS shall be capable of maintaining constant active power output at an active power target value (set point) provided that system frequency is within the limits and time periods specified in par. 3.1, Table 4.

The ESM shall be capable of participating in system Frequency Containment Control (FCC) by operating under the modes specified in paragraphs 5.1, 5.2 and 5.3. These requirements apply to both generation (discharge) and consumption (charge) operating modes, unless otherwise explicitly stated.

5.1 Limited Frequency Sensitivity Mode - Over-frequency (LFSM-O)

In case of major system over-frequency all ESMs connected to the HETS shall have the capability of operating under Limited Frequency Sensitive Mode (LFSM-O). The LFSM-O is a special operating mode under which the ESM (regardless of being in charging or discharging mode) continuously adjusts[7] active power generation or consumption under a steady active power – frequency droop (s_2) while system frequency remains above a predefined over-frequency threshold f_1.

The LFSM-O applies at system emergencies where the downwards FCR is fully deployed but system frequency increases further.

In case that system frequency exceeds the threshold value f_1 while the ESM generates active power (operates at discharging mode) the ESM shall reduce the generated active power (and, if necessary, shall switch to charging mode within the shortest technically feasible time) until either system frequency reduces at a value lower than the over-frequency threshold f_1 or the ESM fills the maximum energy content that is able to store or as agreed between the ESM owner and IPTO. Upon reaching the maximum energy that is able to store the ESM shall cease consumption and shall operate under neutral mode.

In case that system frequency exceeds the threshold value f_1 while the ESM consumes active power (operates at charging mode) the ESM shall increase the consumed active power until either system frequency reduces at a value lower than the over-frequency threshold f_1 or the ESM fills the maximum energy content that is able to store or as agreed between the ESM owner and IPTO. Upon reaching the maximum energy that is able to store the ESM shall cease consumption and shall operate under neutral mode.

Switching from consumption (charging) to generation (discharging) and vice versa should be as fast as technically feasible. IPTO has the right to request the demonstration of technical evidence of the required switching time.

[7] Continues adjustment in discharging mode: decrease of active power generation for increasing frequency and increase of active power generation for decreasing frequency.
Continues adjustment in charging mode: increase of active power consumption for increasing frequency and decrease of active power consumption for decreasing frequency.

In case that system frequency exceeds 51,5 Hz for more than 30min, the ESM may disconnect from the grid.

The ESM control system should allow for the implementation of different droop values (adjustable droop between 2-12%, default value s_2 = 5%) while should allow for the implementation of any over-frequency threshold between 50,2 Hz and 50,5 Hz inclusive, with a default over-frequency threshold f_1 = 50,2 Hz, see indicative Figure 7.

The tolerance range of operating under maximum charging level is ±5% of the Pmax or ±5MW (whichever value is smaller).

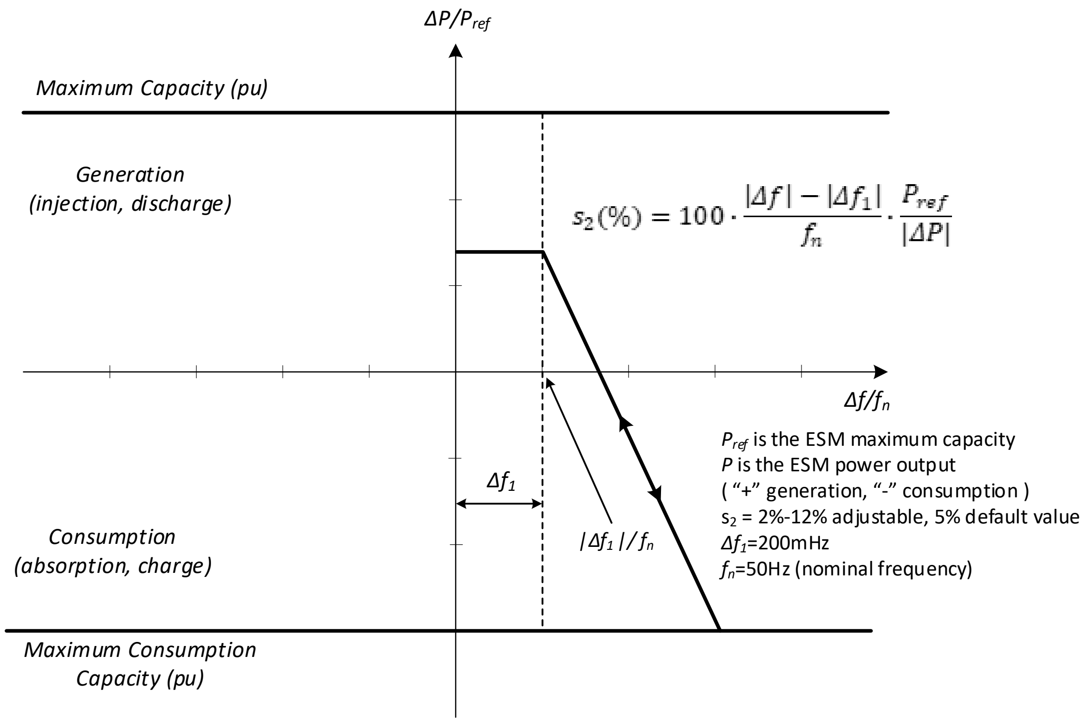


Figure 7: Active power frequency response capability of ESMs in LFSM-O

With regard the LFSM-O dynamic response (time frame) the step response and settling times for ESMs are defined in Table 8.

Table 8: Response times for ESMs under LFSM-O operation

Step response time	≤ 2 sec for a decrease (*) of active power output of 50% Pmax
Settling time	≤ 20 sec for a decrease (*) of active power output; ≤ 30 sec for an increase (**) of active power output;

(*): decrease of active power output in case of increasing frequency while operating under LFSM-O
(**): increase of active power output in case of decreasing frequency while operating under LFSM-O

The ESM shall be capable of operating stably during LFSM-O operation.

When LFSM-O is active, the LFSM-O setpoint will prevail over any other active power setpoints which would result in an increase of active power output.

The actual delivery of active power frequency response in LFSM-O mode shall take into account the ambient conditions when the response is to be triggered, the operating conditions of the ESM, and the available energy content of the ESM.

The ESM shall be able to receive and react on an external signal issued by IPTO allowing blocking active power LFSM-O setpoint in real-time.

The LFSM-O shall be activated with a time delay of less than 2sec. The ESM owner should justify any time delay greater than 2 sec by providing technical evidence to IPTO.

5.2 Limited Frequency Sensitivity Mode – Underfrequency (LFSM-U)

In the case of major system under-frequency, all ESMs connected to the HETS shall have the capability of operating under Limited Frequency Sensitive Mode (LFSM-U). The LFSM-U is a special operating mode under which the ESM (regardless of being in charging or discharging phase) continuously adjusts its active power generation or consumption under a steady active power – frequency droop (s) while system frequency remains below a predefined under-frequency threshold f_1.

The LFSM-U applies at system emergencies where the upwards FCR is fully deployed, but system frequency decreases further.

In case that system frequency decreases below the threshold value f_1 while the ESM generates active power (operates at discharging mode) the ESM shall increase the generated active power until either system frequency restores at a value higher than the under-frequency threshold f_1 or the ESM minimize its energy content or as agreed between the ESM owner and IPTO. Upon reaching minimum energy content the ESM shall operate under neutral mode.

In case that system frequency decreases below the threshold value f_1 while the ESM consumes active power (i.e., operates at charging mode) the ESM shall reduce the consumed active power (and, if necessary, shall switch to discharging mode within the shortest technically feasible time) until either system frequency restores at a value higher than the under-frequency threshold f_1 or the ESM minimize its energy content or as agreed between the ESM owner and IPTO. Upon reaching minimum energy content, the ESM shall operate under neutral mode.

In line with Article 15.3.b of the NC-E&R[8], IPTO has the right to request the capability for electricity storage modules in consumption mode to disconnect either following a signal

[8] Commission Regulation (EU) 2017/2196 of 24 November 2017 establishing a network code on electricity emergency and restoration, available in: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2017.312.01.0054.01.ENG&toc=OJ:L:2017:312:TOC

provided by IPTO or disconnect automatically, at randomized frequencies within the range of 49 Hz and 49,2 Hz.

Switching from consumption (charging) to generation (discharging) and vice versa should be as fast as technically feasible. IPTO has the right to request the demonstration of technical evidence of the required switching time.

The ESM control system should allow for the implementation of different droop values (adjustable droop between 0,2-5%, default value s = 1%) while should allow for the implementation of any under-frequency threshold between 49,5 Hz and 49,8 Hz inclusive, with a default under-frequency threshold f_1 = 49,8 Hz, see indicative Figure 8.

The tolerance range of operating under maximum discharging level is ±5% of the Pmax or ±5MW (whichever value is smaller).

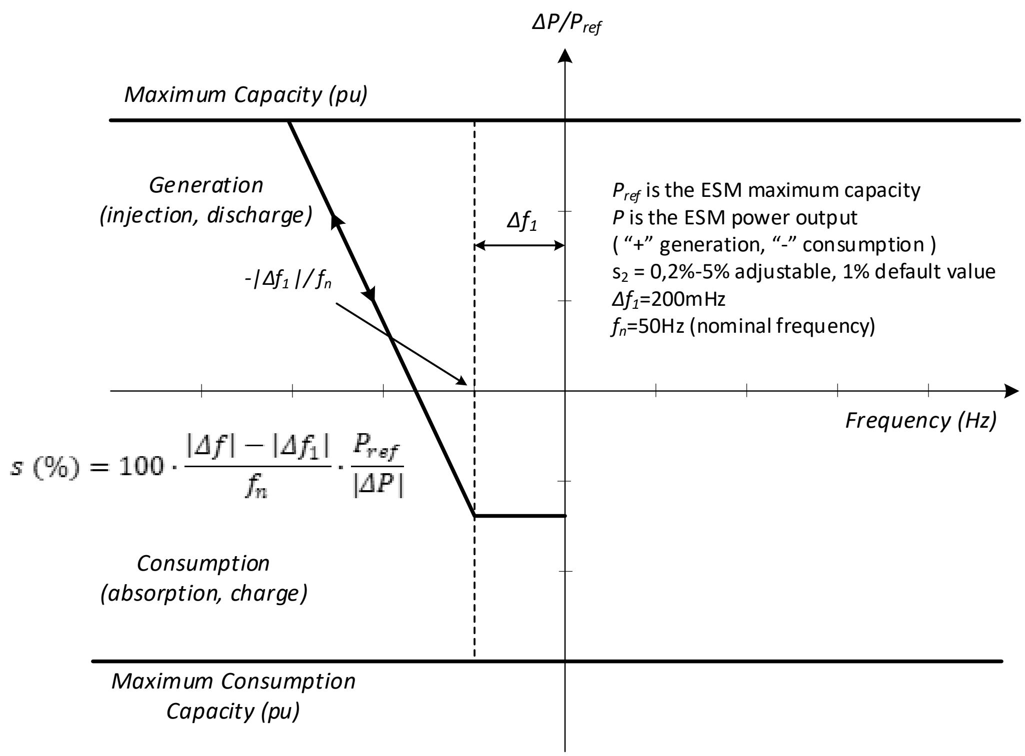


Figure 8: Active power frequency response capability of ESMs in LFSM-U

The ESM shall be capable of operating stably during LFSM-U operation.

When LFSM-U is active, the LFSM-U setpoint will prevail over any other active power setpoints.

The actual delivery of active power frequency response in LFSM-U mode shall take into account the ambient conditions when the response is to be triggered, the operating conditions of the ESM, and the available energy content of the ESM.

The ESM shall be able to receive and react on an external signal allowing IPTO to block active power LFSM-U setpoint in real-time.

With regard the LFSM-U dynamic response (time domain) the step response and settling times for ESMs are defined in Table 9.

Table 9: Response times for ESMs under LFSM-U operation

ESM	Step response time	≤ 10 sec for an increase (*) of active power of 50% Pmax;
	Settling time	≤ 30 sec for an increase (*) of active power; ≤ 20 sec for a decrease (**) of active power

(*): increase of active power output in case of decreasing frequency while operating under LFSM-U
(**): decrease of active power output in case of increasing frequency while operating under LFSM-U

5.3 Frequency Sensitivity Mode

In case of relatively small system frequency deviations around the nominal value (50,0Hz) all ESMs connected to the HETS and within IPTO's control area shall have the capability of operating under Frequency Sensitive Mode (FSM) and participate in system frequency containment control. Under this operating mode, the ESM should properly adjust its active power injection or absorption for frequency deviations inside a predefined frequency range of ±200mHz around 50,0Hz (i.e., for system frequency 49,8 < to < 50,2 Hz).

While frequency remains below 50,0Hz minus a -10mHz dead band[9] the ESM should be capable of continuously increasing its active power output (in discharging mode by increasing active power generation, in charging mode by decreasing active power consumption and, if necessary, switch to discharging mode within the shortest technically feasible time) under a steady active power – frequency droop (s_1).

This increase should last until either system frequency restores at a value within a -10mHz dead band around 50,0Hz or the ESM reaches its maximum capacity (Pmax). Upon reaching maximum capacity the ESM shall keep operating at discharge mode for as long as there is available stored energy content or as agreed between the ESM owner and IPTO. In case that system frequency decreases further below 49,8Hz and the ESM has not reached its maximum capacity, the ESM should operate under the LFSM-U mode according to par. 5.2.

Similarly, while frequency remains above 50,0Hz plus a +10mHz dead band the ESM should be capable of continuously decreasing its active power output (in discharging mode by decreasing active power generation, in charging mode by increasing active power

[9] The active power control system it is characterized by an inherent insensitivity to frequency deviations ("frequency response insensitivity") as well as an intentional dead-band ("frequency response dead-band") to avoid excessive controller activities and turbine mechanical wear for very small system frequency variations. For simplicity, in this Technical Guideline the combined effect of these two characteristics is referred as "dead band". For ESMs connected to the HETS, the dead band shall be limited to ±10mHz (±0,02% p.u. on 50Hz base).

consumption and, if necessary, switch to discharging mode within the shortest technically feasible time) under a steady active power – frequency droop (s_1).

This decrease should last until either system frequency reduces at a value within a +10mHz dead band around 50,0Hz or the ESM reaches its active power maximum consumption capacity. Upon reaching maximum consumption capacity the ESM shall keep operating under discharging mode until the ESM fills the maximum energy content that is able to store or as agreed between the ESM owner and IPTO.

In case that system frequency increases further above 50,2Hz and the ESM has not reached its maximum consumption capacity the ESM shall operate under the LFSM-O mode according to par. 5.1. In the event of a frequency step change (dip or surge), the ESM should be able to provide FCR (upwards or downwards, respectively) within an active power range |ΔP1| expressed as a percentage (%) of their maximum capacity (|ΔP1|/Pmax). This active power range should not be withing the range of 1,5-100% of ESM maximum capacity.

The ESM shall be capable of activating the provision of FSM active power frequency response according to *Figure 9* and with the parameters listed in Table 10 and further analysed below.

Table 10: Parameters for ESM active power frequency response in FSM (explanation for Figure 9 and for full activation of active power frequency response in frequency step change (explanation for Figure 10)

Parameter	Values and ranges
Active power range $\|\Delta P_1\|/P_{max}$	1,5-100% of Pmax
Droop	adjustable between 0,2-27% to guarantee full activation of |ΔP1|/Pmax for maximum frequency activation 200 mHz;
Combined effect of frequency response insensitivity ($\|\Delta f_i\|$, $\|\Delta f_i\|/f_n$) & dead band	max ±10mHz, (0.02% p.u.)
FSM frequency response range	adjustable, between 0-500 mHz; default value 200mHz
Maximum initial delay of FSM activation (t_1)	$t_1 \leq$ 1s (to be justified if > 1s)
Maximum delay of FSM full activation (t_2)	$t_2 \leq$ 30s

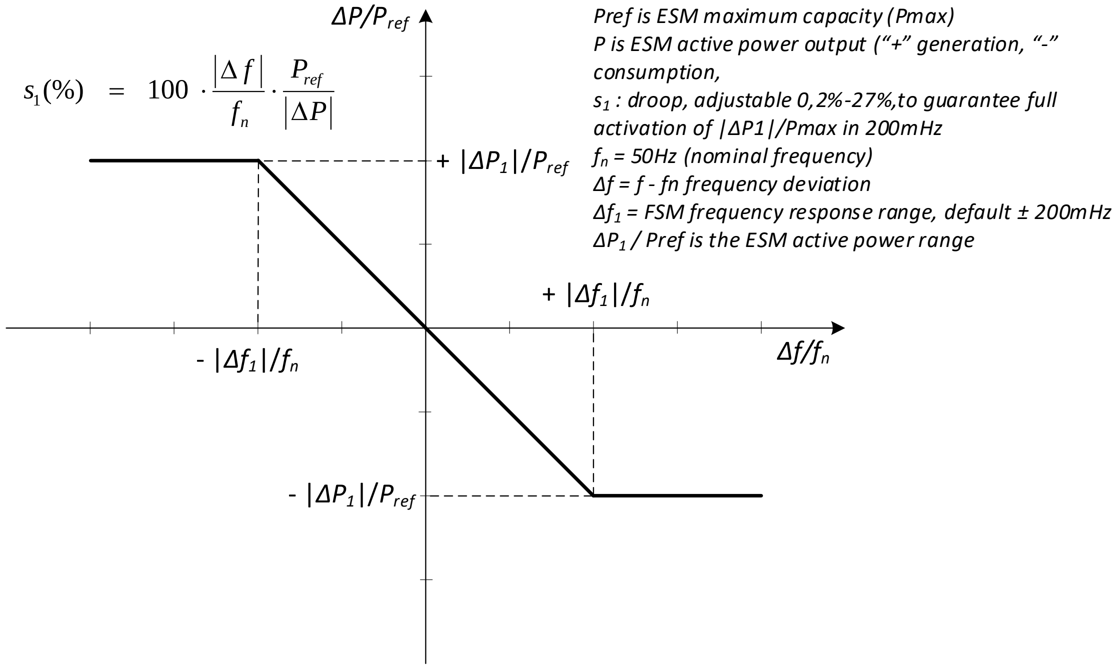


Figure 9: Active power frequency response capability of an ESM in FSM in the case of zero dead-band and zero insensitivity

The active power – frequency droop has the same value for both directions of active power adjustment (increase or decrease) while the droop reference active power (Pref) is by default the maximum capacity of the ESM (Pmax).

The ESM shall be capable of activating full active power frequency response at or above the full line shown in Figure 10 and fully exploit FCR at a quasi-steady system frequency deviation of ±200mHz.

The ESM active power control system should allow for the implementation of different droop values according to IPTO's needs (adjustable droop between 0,2-27%, so as to guarantee |ΔP1|/Pmax for maximum the frequency activation of ±200 mHz) while should allow for the implementation of FSM operating mode within any frequency range between 49,5 Hz and 50,5 Hz excluded.

The initial delay of active power frequency response t_1 should be less than 1sec and shall not intentionally delayed. The ESM owner should justify any time delay greater than t_1=1sec by providing technical evidence to IPTO.

The active power frequency response should be fully supplied and the FCR should be fully exploited within a time t_2 of less than 30sec.

The supply of full active power frequency response should be maintained for a period of at least 15 min after its full deployment unless this is limited by the energy content that the ESM can store or as agreed between the power generating facility and IPTO.

The FCR must be available again 15 min after activation assuming that the nominal frequency has been attained unless this is limited by the energy content that the ESM can store or as agreed between the power generating facility and IPTO.

Within the time limits laid down in Table 10, active power control must not have any adverse impact (e.g., appearance of poorly damped active power oscillations) on the active power frequency response of ESMs.

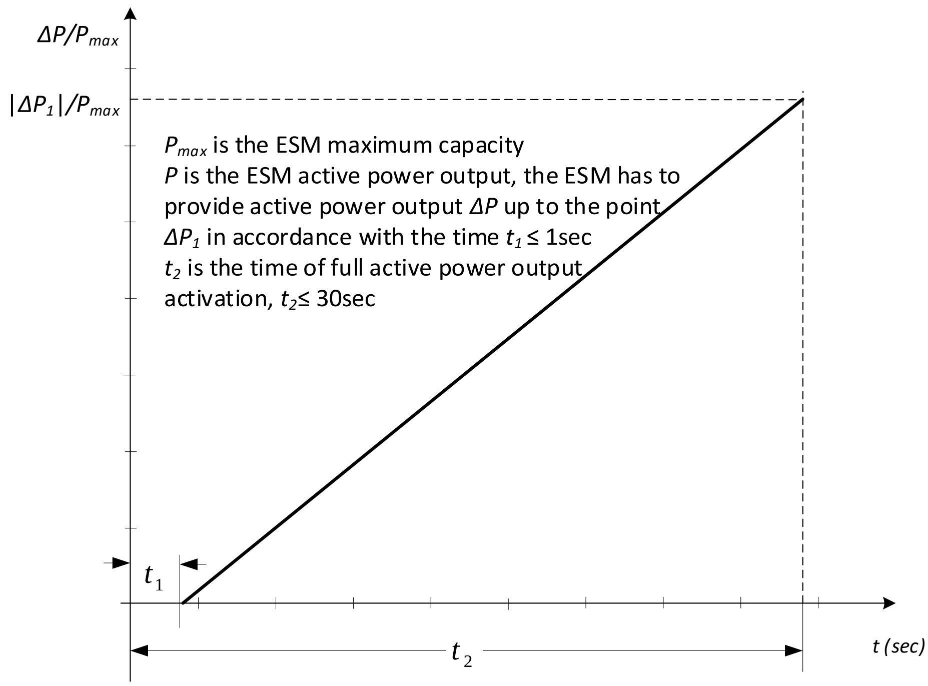


Figure 10: Active power frequency response capability of an ESM in a step frequency dip

Regarding frequency restoration control, the active power control system of the ESM shall provide functionalities complying with specifications provided by IPTO, aiming at restoring frequency to its nominal value or maintaining power exchange flows between control areas at their scheduled values. These requirements shall be in line with the Articles 154, 156, 158, 161, 165 of the System Operation Guidelines (NC-SoGL) and currently applicable requirements of IPTO. Requirements are to be agreed during the connection process with IPTO on a case-sensitive base and fixed in the connection agreement.

In case of underfrequency, ESMs in charging mode shall be capable of disconnecting. This requirement does not extend to auxiliary load supply.

Requirements concerning a real-time monitoring of FSM are specified in chapter 11.

6 Reactive power capability for ESM

All ESMs connected to the HETS should contribute to the voltage control at the CP by providing (injecting or absorbing) reactive power.

In this Technical Guideline, the reactive power capability of an ESM is specified by two complementary curves in the context of both varying voltage at the CP and ESM active power generation.

The first curve considers that the ESM operates at its maximum capacity[10] (P=Pmax) and is defined as a U-Q/Pmax -profile of the voltage at the CP ("U", expressed in p.u. of the reference voltage at the CP), against the ratio of the reactive power flow "Q" at the CP and ESM maximum capacity (Pmax).

The second curve considers that the ESM operates below its maximum capacity (P<Pmax) and is defined as a P-Q/Pmax -profile of the ESM active power generation ("P", expressed in p.u. with regard ESM's maximum capacity), against the ratio of the reactive power flow "Q" at the CP and ESM maximum capacity (Pmax).

In both curves, the reactive power flow is considered as positive (+Q) when injected to the CP and as negative (-Q) when absorbed from the CP.

The voltage profile (U) at the CP (defined by the first curve, P=Pmax) should also be respected when considering ESM operation below its maximum capacity (second curve, P<Pmax).

ESMs connected at a CP of 150kV nominal voltage and while operating at maximum generating capacity (Pmax) shall be capable of supplying or absorbing reactive power at the CP within and including the limits of the red marked U-Q/Pmax profile in Figure 11, where U is the voltage level at the CP expressed in p.u. of the reference value (150kV), Q is the reactive power flow at the CP and Pmax is the maximum capacity of the ESM.

ESMs connected at a CP of 400kV nominal voltage and while operating at maximum generating capacity (Pmax) shall be capable of supplying or absorbing reactive power at the CP within and including the limits of the red marked U-Q/Pmax profile in Figure 12, where U is the voltage level at the CP expressed in p.u. of the reference value (400kV), Q is the reactive power flow at the CP and Pmax is the maximum capacity of the ESM.

The ESM shall be capable of moving to any operating point within its U-Q/Pmax profile in appropriate timescales to target values requested by IPTO. These target values should always consider both the technical availability of the ESUs (i.e., number of ESUs that are available and not out of service due to maintenance or failure) as well as the availability of the energy content stored in the EMS.

[10] It is considered that the maximum capacity (ESM under discharging operating mode) is equal with the maximum consumption capacity (ESM under discharging operating mode). If this assumption does not apply, reactive power capability requirements shall be modified accordingly.

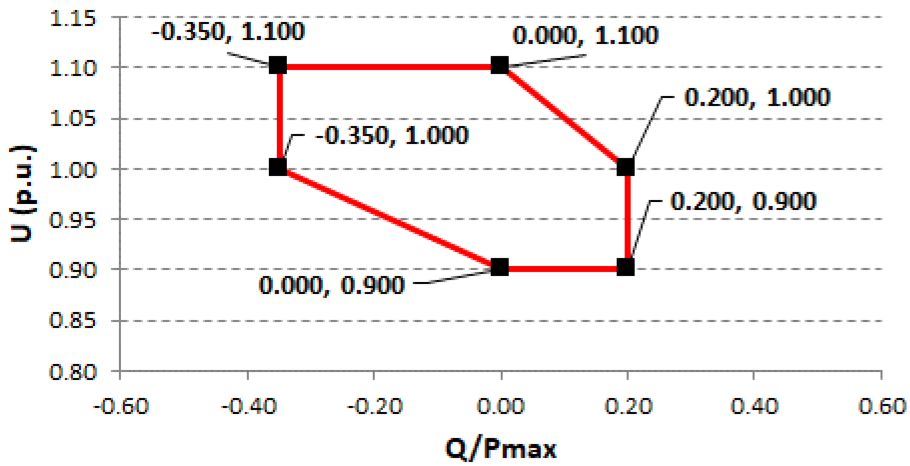


Figure 11: U-Q/Pmax-profile of ESMs connected at 150kV

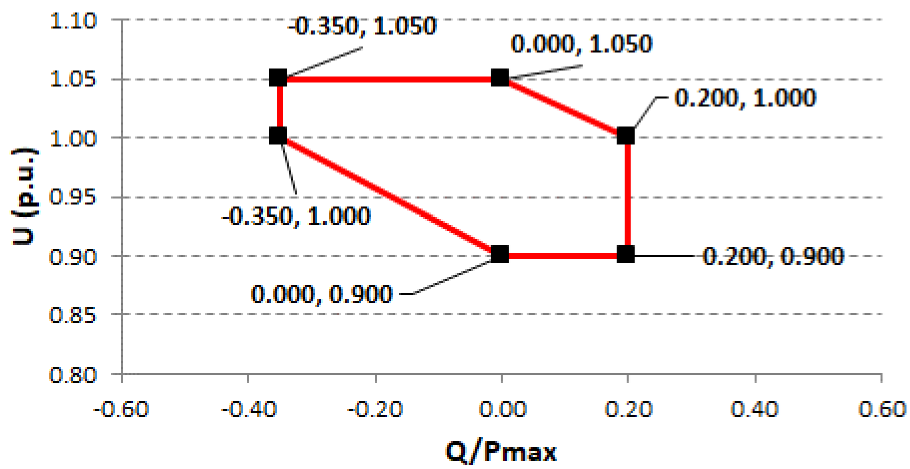


Figure 12: U-Q/Pmax-profile of ESMs connected at 400kV

In this Technical Guideline the extreme values of the Q/Pmax ratio specified in Figure 11 and Figure 12 define the minimum and the maximum reactive power of the ESM.

The ESM minimum reactive power "-Qmin" has a negative value and is the maximum reactive power that is absorbed from the CP.

The ESM maximum reactive power "+Qmax" has a positive value and is the maximum reactive power that is injected to the CP.

Both "-Qmin" and "+Qmax" can be expressed as a percentage (%) of ESM maximum capacity (Pmax) as illustrated in Table 11.

Table 11: Definition of ESM maximum and minimum reactive power

Minimum reactive power ("-Qmin" absorbed from the CP)	**Maximum reactive power ("+Qmax" injected to the CP)**
(%) Pmax	(%) Pmax
-35%	+20%

With regard the ESM reactive power capability when operating below maximum capacity (P<Pmax), the ESM shall be capable of providing reactive power at any operating point within and including the limits of the red marked P-Q/Pmax-profile defined in Figure 13 (for CP either at 150kV or 400kV) while respecting the U-Q/Pmax-profile set-up in Figure 11 and Figure 12 (for CP at 150 and 400kV respectively).

The ESM shall be capable of moving to any operating point within its P-Q/Pmax profile in appropriate timescales to target values requested by IPTO.

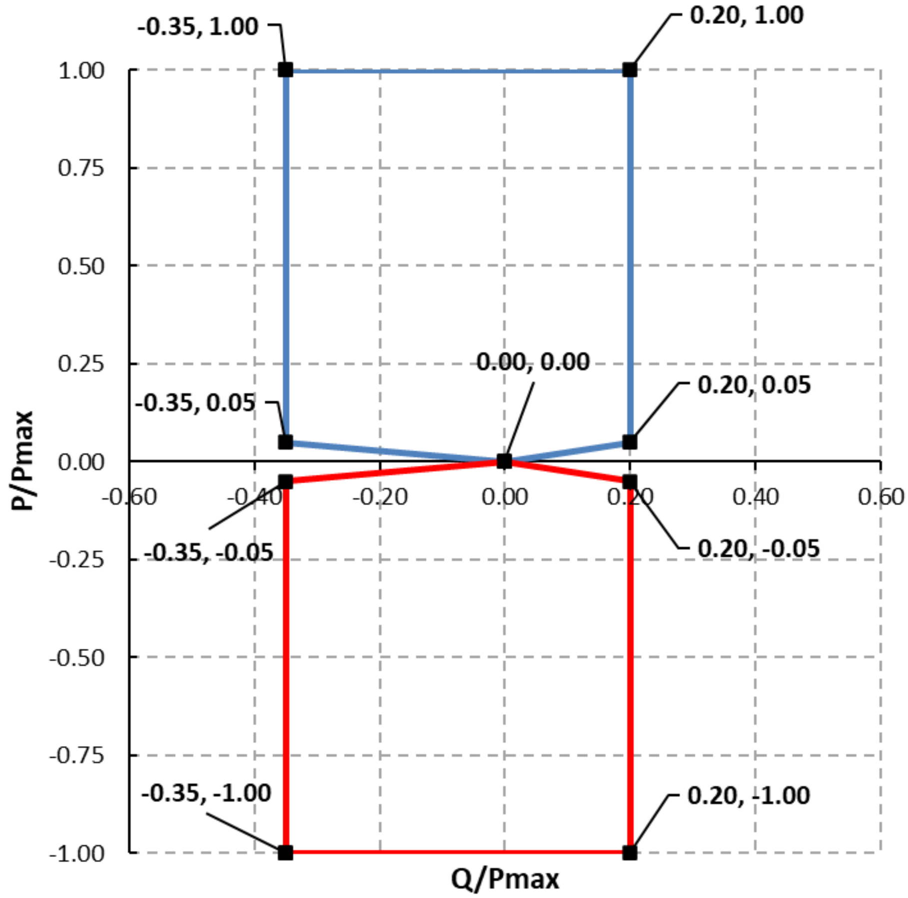


Figure 13: P-Q/Pmax-profile of ESMs connected at 150/400kV

The ESUs of the ESM shall have the capability of providing reactive power at their terminals at least ±80% of their maximum capacity even at zero active power generation or consumption. IPTO holds the right to specify reactive power requirements at the high voltage CP on a site-specific base for active power generation or consumption below 5% of Pmax (0<|P|<5% Pmax).

IPTO may specify supplementary reactive power requirements at the CP of the ESM in case that special needs or conditions apply (indicatively and not exclusively: connections at weak points of HETS, specific reactive power compensation or voltage regulation needs, unusual network connection topologies or seasonal voltage profiles). This supplementary reactive power shall be specified on a site-specific base and shall be provided by the ESM.

For providing the additional required Q at the CP, the ESM may need to supplement its reactive output with automatically (dynamic) regulated VAr devices (such as SVCs or STATCOMs) or automatically switchable static VAr capable devices (such as shunt capacitor or reactor banks). These devices may also be used to compensate for reactive power losses on ESM's connection network behind the CP. Any ESM owner proposals to meet site-specific reactive power requirements with a combination of such devices and ESM capability are subject to IPTO's approval and shall be included in the connection agreement.

7 Reactive Power control for ESM

All ESMs connected to the HETS shall be capable of adjusting reactive power generation contributing to the voltage regulation at the CP. To achieve that, the ESM shall be equipped with voltage control systems capable of providing voltage/reactive power control by operating either under voltage, reactive power or power factor control mode.

The ESM shall be capable of operating and automatically implementing voltage, reactive power or power factor set points at the CP in line with instructions issued remotely and in real time by IPTO's National Dispatch Centre (NDC). To achieve that, the ESM must be capable of exchanging signals and information in real time with the NDC.

On a site specific base, IPTO may require the provision of voltage, reactive power or power factor control mode at the high voltage CP even at zero active power generation or absorption.

IPTO shall agree with the ESM owner which of the above three control mode options and associated set points must be applied and what further equipment is needed to make the adjustment of the relevant set point remotely operable.

In case of loss of communication with the NDC or a failure between the ESM controller and the ESUs the last transmitted value shall be applied, if not otherwise specified by IPTO.

Any other voltage/reactive power control apparatus (such as fixed or regulated capacitor banks, SVCs, STATCOMs or other FACT's devices etc.), shall cooperate stably with the ESMs under these control modes.

If specified by IPTO an ESM connected at HETS shall be capable of contributing positively to the damping of low frequency power oscillations. The voltage/reactive power control characteristics of ESMs must not adversely affect the damping of power oscillations.

7.1 Voltage Control Mode

An ESM connected to the HETS and operating under voltage control mode shall be capable of adjusting the reactive power flow at the CP under a steady voltage – reactive power slope (voltage droop) while the voltage at the CP deviates from a desired set point value, Figure 14.

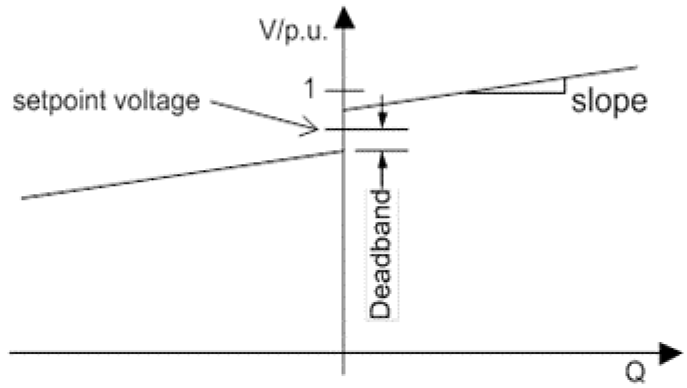


Figure 14: ESM voltage control mode

The ESM shall be capable of implementing set point voltages at the CP within the range of 0,95 to 1,05 (expressed in p.u. of the CP reference voltage) in steps no greater than 0,01 p.u.

The voltage – reactive power slope (ΔV/ΔQ) shall have a range of at least 2% to 7%. This slope is defined as the ratio of the voltage deviation ΔV from the desired value at the CP (expressed in p.u. of the CP reference value) to the corresponding change of the reactive power flow ΔQ at the CP (expressed in p.u. of ESM's maximum reactive power).

The reactive power flow at the CP shall be zero when the voltage at a CP equals a value that is defined on site-specific base. The voltage set point may be operated with or without a dead-band (selectable in a range from zero to ±5% of reference 1 p.u. voltage at the CP), in steps no greater than 0,5%.

Following a step change in the voltage at the CP the ESM shall be capable of achieving 90% of the change in the reactive power flow at the CP specified by the (ΔQ,ΔV) slope within a rise time t_1 in the range of 1 to 5 sec and must settle at this value within a settling time t_2 in the range of 5 to 60 sec, with a steady-state reactive tolerance no greater than 5% of the maximum reactive power.

Table 12: Static and dynamic parameters ESM voltage control mode

Parameters	Value ranges
Set point voltage	0.95 p.u. to 1.05 p.u.
Set point voltage step size	≤ 0.01 p.u.
Dead band	0 to ±5%
Dead band step size	≤ 0.5%
Slope	at least 2% to 7%
slope step size	≤ 0.5%
rise time t_1	1 to 5 sec
settling time t_2	5 to 60 sec
steady-state tolerance	≤ 5% (*)

(*) in % of the ESM maximum reactive power

The static and dynamic parameters of the voltage control mode are summarized in Table 12.

7.2 Reactive Power Control Mode

The ESM when operating under reactive power control mode shall be capable of implementing at the CP a reactive power set point laying at any point within the U-Q/Pmax and P-Q/Pmax profiles specified in Figure 11, Figure 12 and Figure 13.

The reactive power set point steps shall not be greater than ±5Mvar or ±5% of full reactive power (whichever value is smaller) controlling the reactive power at the CP to an accuracy within ±5Mvar or ±5% of full reactive power[11] (whichever is smaller).

7.3 Power Factor Control Mode

The ESM when operating under power factor control mode shall be capable of implementing at the CP a power factor set point laying at any point within the U-Q/Pmax and P-Q/Pmax profiles specified in Figure 11, Figure 12 and Figure 13.

The setpoint value shall be applied in steps over a predefined value with a step width Δcosφ not smaller than 0,005 and not greater than 0,01 (0.005≤ Δcosφ ≤0,01). If there is no predefined power factor value at the CP, then a set-point of cosϕ=1,00 may be used as basis.

When applying power factor control mode at the CP the reactive power exchange is modified as a function of the active power injection. Thus, the tolerance of the power factor control mode can be evaluated on the basis of ESM maximum capacity and should not exceed ±2% Pmax.

The time for the ESM to obtain the set point value within this tolerance, should not exceed 60 sec.

[11] For the scope of this Technical Guideline, full reactive power is considered as the maximum of the absolute value of -Qmin and +Qmax.

8 ESM robustness requirements

The requirements of this chapter specify ESM capabilities during and shortly after symmetrical faults and are considered as complementary to each other. The requirements under concern are:

- the Low Voltage Ride Through (LVRT) capability,
- active power recovery after a fault, and
- provision of a fast fault reactive current (FFCI) during voltage dips or rises.

8.1 Low Voltage Ride Through (LVRT) capability of ESM

All ESMs connected to the HETS shall be capable of staying connected to the network and continuing to operate stably after the power system has been disturbed by secured symmetrical faults, in accordance with the voltage against time profile at the CP (expressed as the ratio of its actual value and its reference 1 p.u. value) of Figure 15. This profile expresses a lower limit of the actual course of the phase-to-phase voltages at the CP during a symmetrical fault, as a function of time before, during and after the fault.

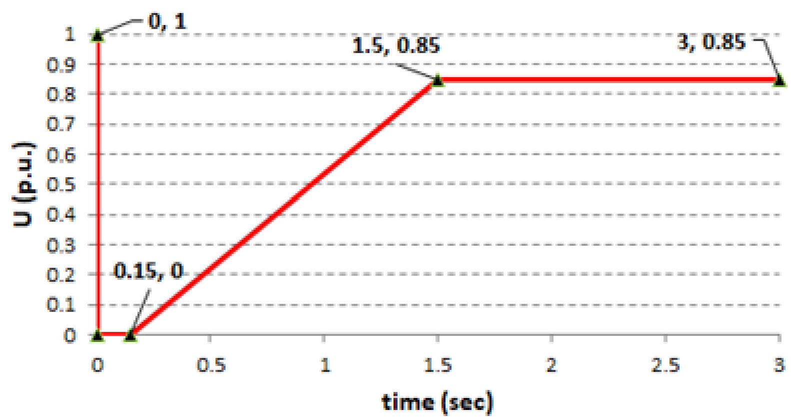


Figure 15: Low voltage ride through profile at the CP for ESMs

This Low Voltage Ride Through capability applies under the following system conditions prior to the fault occurrence:

- the voltage at the CP is within ±10% of CP's nominal value
- the voltage at all ESU terminals is within ±10% of their nominal voltage
- all ESUs operate within their (P,Q) capability curve

The ESM shall be capable of remaining connected to the network and continuing to operate stably when the actual course of the phase-to-phase voltages at the CP during a symmetrical fault remains above the LVRT profile of Figure 15, unless the protection scheme and settings of the generators or the MV/LV electric network downstream the CP under ESM owner responsibility requires the disconnection of the ESM.

The protection schemes and settings under ESM owner responsibility shall not jeopardize the fault-ride-through performance at the CP. Indicatively and non-exclusively:

- Under/over voltage protections (if present downstream the CP) shall be set by the ESM owner according to the widest possible technical capability of the generators, unless IPTO requires narrower settings.
- Under/over frequency protections (if present downstream the CP) shall be set by the ESM owner according to the requirements specified in par. 3.1, Table 4.

Fault-ride-through capabilities in case of asymmetrical faults shall be considered as identical with the capabilities of the symmetrical faults unless otherwise specified by IPTO.

IPTO shall provide the ESM owner necessary data (pre- and post-fault minimum short circuit capacity, grid impedance angle) for the corresponding CP to be considered for the evaluation of the ESM fault-ride-through capability.

8.2 Active power recovery after fault clearance

An ESM that is not disconnected during or immediate after a symmetrical fault clearance, shall be capable of recovering 90% of the pre-fault generated active power in less than 2 sec after fault clearance, provided that the voltage U at the CP settles at a value equal or greater than 0,90 expressed in p.u. of the CP reference value ($U \geq 0,90$ p.u.). The accuracy of the restored active power is ±5% of the generated active power prior to fault occurrence or ± 5 MW (whichever of these values is smaller).

8.3 Fast Fault Reactive Current Injection Capability

ESMs connected to the HETS shall be capable of providing continuous dynamic voltage support during system disturbances leading to significant voltage deviations from the nominal value (dips or rises) at the CP.

To achieve that, the ESUs of the ESM shall be capable of rapidly adjusting (inject during voltage dips or absorb during voltage rises) the generated reactive current at their terminals (Fast Fault Current, FFC). This FFC should be considered as additional to the current injected or absorbed by the ESU before the voltage change at ESU terminals. The sum of the ESU current prior to the voltage changes and of this additional reactive current can take values up to the maximum current of each ESU (Imax).

After the end of the disturbance and the restoration of ESU terminal voltage within normal operating limits, the FFC should be deactivated and the ESU should follow the normal, prior to the disturbance voltage, reactive or power factor control mode.

The requirement for the provision of Fast Fault Reactive Current by the ESUs of an ESM connected to the HETS is as follows:

i) *The FFC requirement applies in conditions where the phase-to-phase voltage at the ESU terminals (U) deviates more than - 15% / +10% from the nominal value (i.e., U < 0,85p.u. or U> 1,10p.u.). If the phase-to-phase voltage at ESU terminals (U) is restored within the limits of 0,85p.u. and 1,10p.u. (i.e., 0,85p.u. ≤ U ≤ 1,10 p.u.), then the ESU should return to their pre-fault operating mode.*

ii) *The FFC requirement does not apply for faults with residual voltages U ≤ 0.15p.u. at ESU terminals.*

iii) *The positive (Δu_1) sequence voltage change is defined as the deviation of the positive sequence voltage at ESU terminals from the value before the occurrence of the symmetric fault, expressed in (p.u.) with regard to the nominal voltage at PPU terminals, (U_N):*

$$\Delta u_1 = \frac{U_1 - U_0}{U_N}$$

where:

U_1 *is the positive sequence voltage during the fault,* U_0 *is the pre-fault voltage and* U_N *is the nominal voltage at ESU terminals, respectively.*

iv) *Similarly, the additional positive (Δi_{B1}) sequence reactive current is expressed in (p.u.) with regard the nominal current (I_r) of each ESU.*

$$\Delta I_{B1} = I_1 - I_0$$

$$\Delta i_{B1} = \frac{I_1 - I_0}{I_r}$$

where:

I_1 *is the positive sequence reactive current during the fault,* I_0 *is the pre-fault reactive current at ESU terminals respectively and* I_r *is the nominal current of the ESU.*

v) *The additional reactive current in the positive-sequence Δi_{B1} shall be proportional to the change of the positive-sequence voltage at ESU terminals. The proportional factor* k_1 *shall be adjustable between 2 and 6 ($2 \leq k_1 \leq 6$) in steps of 0.5. If a proportional factor is not specified by the ESM owner, a default value of 2 at each ESU shall be considered, Figure 16:*

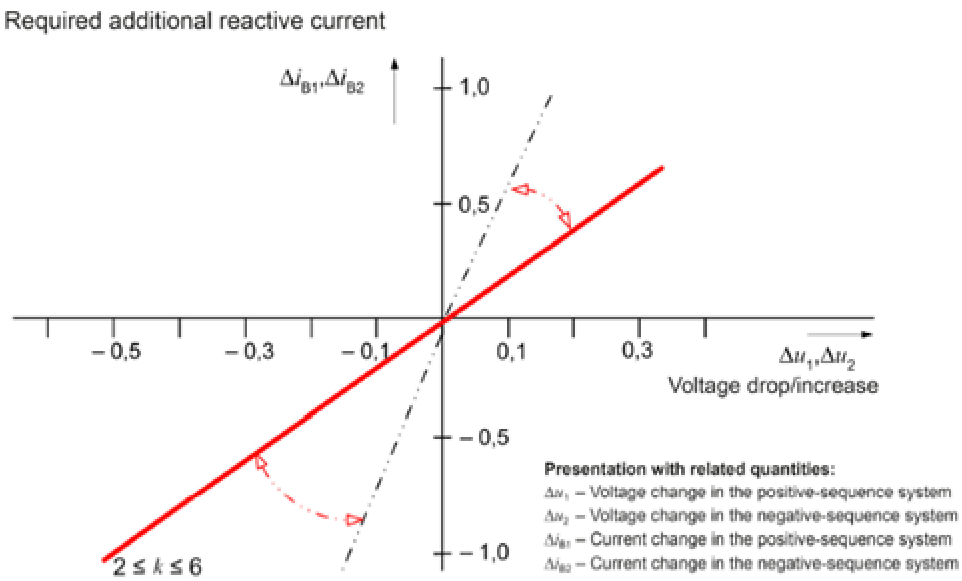


Figure 16: Principle of dynamic voltage support in the event of under/over-voltages at PPU terminals, presenting voltage deviations and additional currents in symmetrical components

vi) *The tolerance band for the additional reactive current Δi_{B1} is shown in green in Figure 17, applicable to the positive sequence component Δi_{B1}. In the case of a sudden voltage increase at ESU terminals (quadrant 1) the tolerance limits are fixed and predefined by the green lines with slopes k = 2 and k = 6, respectively. The lower green line has a distance of -10% · Ir from a straight line passing through the zero point with k = 2. The upper green line has a distance of +10% · Ir from a straight line passing through the zero point with k = 6.*

In the case of a sudden voltage decrease (quadrant 3) at ESU terminals, the tolerance limits are solely determined by the value of the coefficient k (in Figure 17, $k=k_{set\text{-}point}$). The lower green line has a distance of -20% · Ir from a straight line passing through the zero point with slope $k= k_{set\text{-}point}$; similarly, the upper green line has a distance of +10% · Ir from a straight line passing through the zero point with *slope $k_{desired}$*.

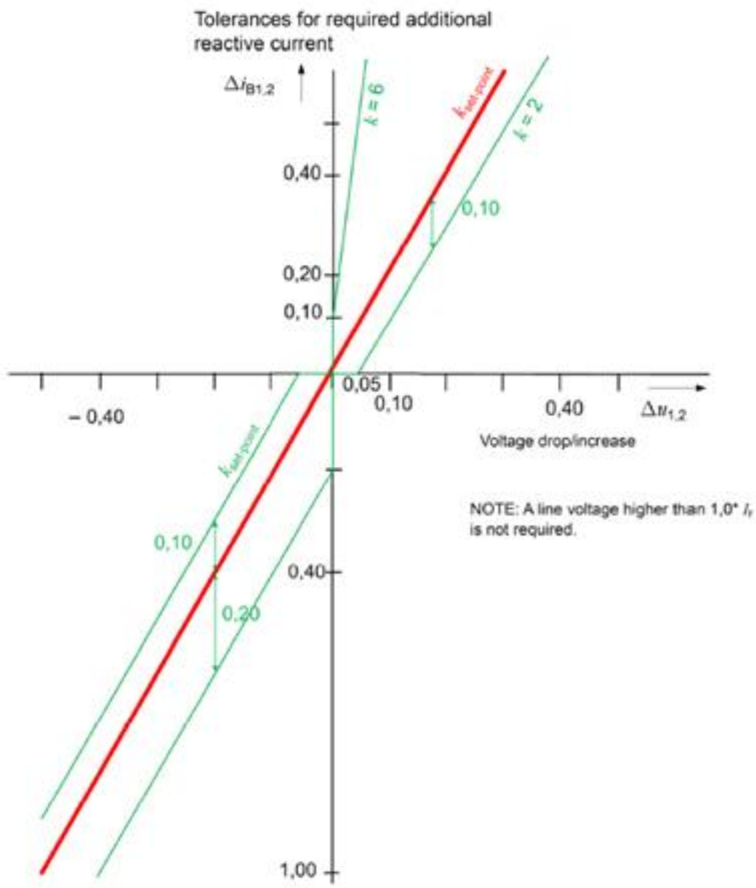


Figure 17: Tolerance range for the additional reactive current ΔI_{B1}

vii) *After the onset of the disturbance, the response times of the reactive current Δi_B at ESU terminals shall be between the following values:*

(a) step response time (i.e., time for the additional current to obtain the 90% of its final stable value) tr ≤ 30 msec, and

(b) settling time (i.e., time for the additional current to remain permanently between +20% and -10% of its final stable value) te ≤ 60 msec

If deemed necessary, these response times may be counted additionally to a fault detection period of ti = 20msec.

viii) *Each ESU should inject or absorb at its terminals current up to ESU maximum current (Imax).*

ix) *the active current may be reduced in favor of the reactive current feed-in (according to the ability and the conditions indicated by the ESU manufacturer); If the active current of the ESU decreases during the disturbance in order to facilitate the injection of fast reactive current then, immediately after the end of the disturbance, it should be continuously and as fast as possible increased in the pre-disturbance value, taking into account the technical capabilities and the operating point of the ESU. In any case,* *the reduction of the active current in favor of the fast reactive current must be as small as possible.*

x) *Reactive power contribution has priority towards active power contribution during faults for which fault-ride-through capability is required by default, if not otherwise agreed with IPTO.*

8.4 High Voltage Ride Through (HVRT) capability of ESM

ESMs connected to the HETS shall be capable of operating stably without disconnecting from the network during temporal symmetrical or non-symmetrical voltage rises at the CP, in accordance with the voltage-against-time-profile (expressed as the ratio of its actual value and its reference 1 p.u. value) of Figure 18.

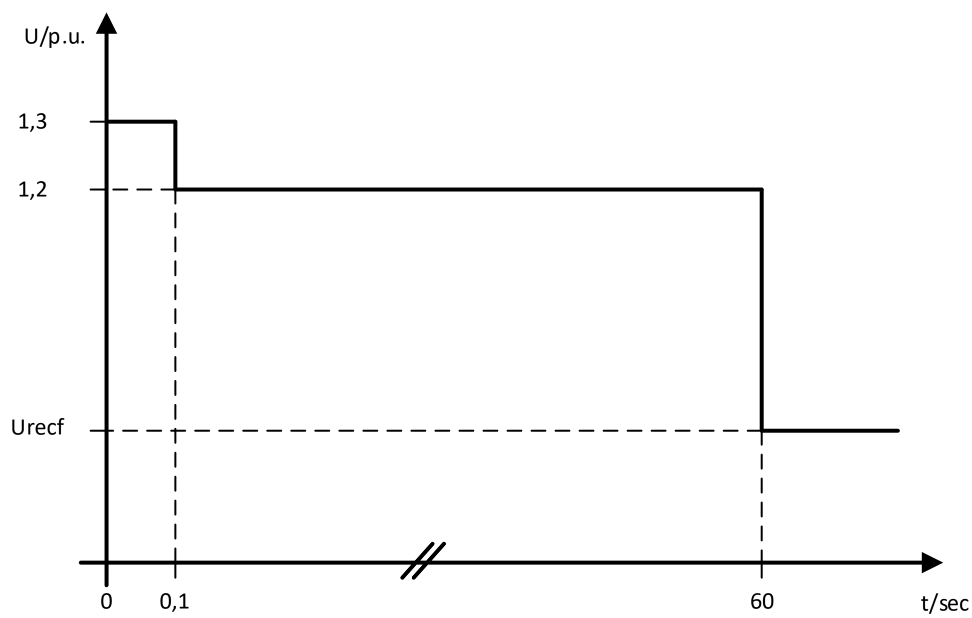


Figure 18: High voltage ride through profile at the CP for ESMs

This profile expresses a higher limit of the actual course of the phase-to-phase voltage at the CP as a function of time, before, during and after a disturbance that causes voltage rise.

Urecf is the maximum voltage at the CP as specified in par. 3.2 and equals with:

- 1,15 p.u. for CP of 150kV nominal voltage
- 1,10 p.u. for CP of 400kV nominal voltage

9 Connection Conditions and System Restoration

9.1 Synchronization

The synchronization of an ESM to the HETS shall be performed after authorization by IPTO. The ESM shall be equipped with the necessary synchronization facilities.

The settings of the synchronization devices shall be agreed between IPTO and the ESM owner. The agreement shall cover the following conditions at the CP:

- voltage
- frequency
- phase angle range and phase sequence
- maximum deviation of voltage and frequency.

As a minimum requirement, the ESM shall be capable to synchronize within the frequency range that is defined for unlimited time operation in Table 4 while the voltage level at the CP is withing the range that is defined for unlimited time operation in Table 5 (150kV) or Table 6 (400kV).

9.2 Automatic disconnection due to loss of angular stability or loss of control

In case of loss of angular stability or loss of control, an ESM shall be capable of disconnecting automatically from the network to help preserve system security or to prevent damage to the power-generating module.

The EMS owner and IPTO shall agree on the criteria for detecting loss of angular stability or loss of control on a site-specific base.

9.3 Automatic reconnection after an incidental disconnection

Unless otherwise specified by IPTO, ESMs connected to the HETS shall be capable of automatically reconnecting to the grid after an incidental disconnection caused by a network disturbance, under the following conditions:

- the HV circuit breaker at the CP is switched on i.e., the connection of the PGM to the HETS has not been interrupted or any interruption has been restored by IPTO
- system frequency is within the range of 49,5 Hz ≤ f ≤ 50,5 Hz;
- the voltage level "U" at the MV side of the substation (main) transformer is within the range of 0,9 p.u. ≤ U ≤ 1,1 p.u.;
- the automatic connection applies after an observation time of 180s
- the maximum allowed gradient of PGM active power generation after the reconnection, is ≤10% Pmax/min

These requirements are shown graphically in Figure 19.

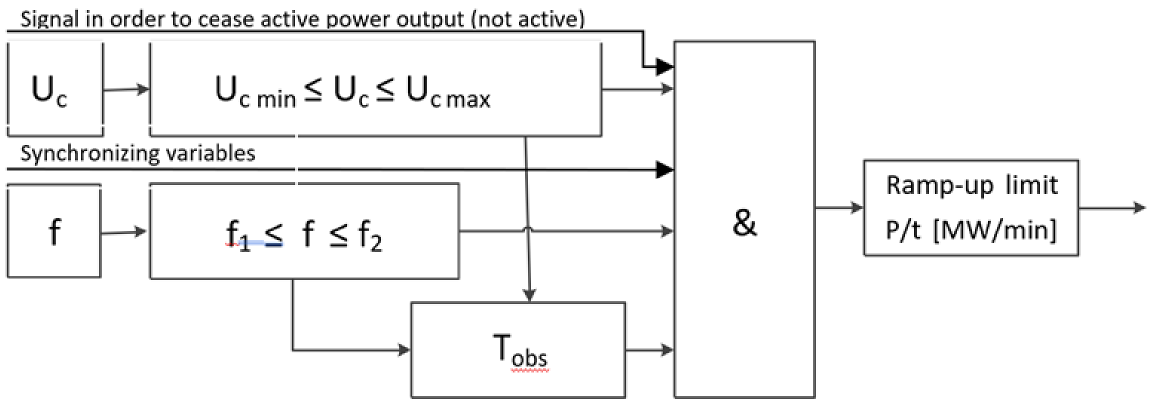


Figure 19: Principle for automatic reconnection after an incidental disconnection

It is noted that automatic reconnection to HV is not permitted unless otherwise specified by IPTO.

The automatic reconnection scheme is ESM owner responsibility and is related to the ESM MV/LV interconnection network.

Any reconnection schemes and their settings must be approved by IPTO. Further details of the reconnection procedure shall be agreed between IPTO and the ESM owner.

9.4 Black Start Capability

Not applicable to ESMs

9.5 Capability to take part in island operation

Not applicable to ESMs

9.6 Quick re-synchronization capability

Not applicable to ESMs

10 Simulation Models

For the purpose of performing static and dynamic simulations the ESM owner is responsible for providing IPTO with an RMS model for the connecting electricity storage facility. The ESM model should be based on an Electricity Storage Unit (ESU) model that is validated against measured laboratory test results, as further analyzed below.

The ESU model must be compatible with the software packages used by IPTO[12] and have no dependencies on additional external commercial or compiler software.

Upon IPTO's discretion, provision of a validated EMT model may also be required.

10.1 Electricity Storage Unit simulation model

The ESU model should represent the performance and dynamic response of a generator that is connected to the grid through power electronics (PE), over its entire operating range.

The model should include any non-wind-up logic, signal limits and non-linearities, blocking, deblocking and protective trip features that are part of the ESU as well as all control loops either inherent to the ESU or achieved by supplementary control systems for providing either continuous or stepwise control, as described by the IEC 61400-27 standard series.

The ESU model should have a level of detail suitable for the root mean square study of load flows, short-circuit analysis, balanced positive phase sequence time-domain responses and the execution of the simulations specified in Title IV (Compliance) of the NC-RfG.

The ESU model must be provided by the owner with ESM site-specific units and parameters.

Ideally the ESU model should be compatible with the PSS/e system analysis software using appropriately parameterized software's standard 2nd generation WECC Generic library models. ESU models in Digsilent Power Factory format are also accepted but it is required to be accompanied with a PSS/e compatible model.

Non-standard library (user defined) models in PSS/e are accepted provided that each separate part of the ESU and of all ESU's functional controllers is clearly shown. Indicatively, sub-models and the relative parameters of the following ESU components and control systems must be identifiable:

- generator/converter, providing at least the dynamic response of active and reactive power and voltage (amplitude and angle) at ESU terminals;
- the controls and regulators that act on the ESU electrical variables as a function of the terminal voltage and/or system frequency (voltage / reactive power / reactive current, active power / active current / frequency), prior, during and at the end of a disturbance;

The PSS/e user defined model shall be submitted in the form of transfer function block diagrams of each model component, accompanied by dynamic and algebraic equations (if necessary) and with a brief description of each model component. The model shall be accompanied by proper initialization and solution settings and should indicate possible numerical limitations imposed by the software solution algorithm.

[12] At present IPTO uses PSS®E and PSCAD for RMS and EMT studies, respectively.

PSS/e user defined models shall be submitted in a format (*.lib) without need of using other compilation software. The user defined model must be accompanied by transfer function block diagrams, input/output data sheets and a documentation of state and algebraic variables and constants.

The use of complete black-box type representation is not acceptable, the model must at the very least show all primary design elements, their inputs and outputs, state variables and constants.

In addition to the submission of PSS/e user defined models or of ESU models developed in DigSilent Power Factory, typical parameters for the generic library models (2nd generation WECC models for power electronic generating units) of the PSS/E shall also be delivered.

The validation of the simulation model is responsibility of the ESM owner and may be done by a third party (manufacturer, consultant, authorized certifier according to Regulation (EC) 765/2008 and ISO/IEC 17065 accreditation standard).

The simulation model should be validated according to the provisions of the FGW-TG4 Guideline[13]. A report on simulation models validation shall be supplied, including (as a minimum) appropriate short-circuit tests.

10.2 Electricity Storage Module simulation model

For the purposes of static and dynamic simulation studies, The ESM owner (or a third party on behalf the ESM owner) should expand the ESU model to the ESM level by incorporating the connection network up to the CP. The ESM model should be properly tuned with site-specific parameters.

The network representation should include the ESUs, the HV/MV (main) substation transformer, the MV network, the ESUs' step-up transformers, the ESM auxiliaries, the reactive power compensation or FACTS (if any), power plant controllers (PPCs) and any other controllers or active components.

The applied voltage and frequency protection settings for both the ESM network and the ESUs should also be part of the PGM model, by using standard PSS/e library protection models.

The ESM model should consider the performance of every single ESU. In general, the use of generating unit aggregates and connecting network equivalents is not accepted without IPTO's approval.

[13] FGW-TG4 Rev. 9 2019," Demands on Modelling and Validating Simulation Models of the Electrical characteristics of Power Generating Units and Systems, Storage Systems as well as for their Components."

10.3 Power Plant Controller model

The model of the PPC should be a proportional integral (PI) controller to regulate output setpoints when in a closed-loop mode. The model should be capable of integrating into full or aggregated ESM representations (i.e., support more than one ESU) and implement as a minimum, the following control functions:

- active power control
- ramp active power control
- active power response to system frequency (LFSM-O/U, FSM)
- power factor / reactive power / voltage droop control

The PPC model should have the proper number of outputs to parse set-point values to the relevant controllers of each PPU and should represent possible signal delays.

The PPC model shall be accompanied by transfer function block diagrams, input/output data sheets and a documentation of state and algebraic variables and constants.

The simulation model should be validated according to the provisions of the FGW-TG4 Guideline. A report on simulation models validation shall be supplied.

11 Information exchange

11.1 Real time data[14]

All ESMs connected to the HETS shall be capable of exchanging information in real time with IPTO's National Dispatch Centre (NDC). This information is distinguished between:

- Position Signals/Alarms: digital signals that indicate the position (on/off) of main controllers, operation switches and protection switches of the ESM and the PGF
- Measurements: analog signals to record the main ESM operational data

Additionally, the ESM shall be capable of accepting and implementing dispatch Instructions, i.e., analog signals that specify operation set points.

Furter details on the communication and facility infrastructure as well as on the content and the technical characteristics of the exchanged signals and information shall be agreed between IPTO and the ESM owner.

11.1.1 ESM analog signals

ESMs shall provide to the NDC at least the following analog signals:

Measurements at the CP with HETS (HV bay of the substation main transformer)

- injected or absorbed active power (±MW)
- injected or absorbed reactive power, ±Mvar
- injected or absorbed current, (Ampere)
- frequency (Hz)
- voltage (kV)

Measurements on the MV bay of the HV/MV main substation transformer

- injected or absorbed active power (±MW)
- injected or absorbed reactive power ±Mvar
- injected or absorbed current (ampere)

Measurements on the medium voltage busbars of the HV/MV main substation transformer

- voltage (kV)
- coupler circuit breaker current (A) (in case of substations with multiple MV busbars)
- reactive power of capacitor/reactor or any other compensation mean (±Mvar)

Measurements on the MV network IPPMs

- injected or absorbed active power (±MW)
- injected or absorbed reactive power (±Mvar)
- injected or absorbed current (Ampere)

[14] According to RAE Decision 864/2022 on information exchange between TSO, DSO and Significant Grid Users

The Power Plant Controller (PPC) and/or the Master Power Plant Controller (MPPC) of each ESM shall receive from the NDC at least the following remote-control signals (dispatch instructions):

- FRR active power set point
- day ahead manual FRR active power set point
- set points for operation under voltage control (V_{ref}), reactive power control (Q_{ref}) or power factor control ($cos\varphi_{ref}$)
- set points for the remote control of any compensation means (e.g. capacitors)
- set points for the provision of Fast Frequency Response (if applied)

The Power Plant Controller (PPC) and/or the Master Power Plant Controller (MPPC) of each ESM shall provide to the NDC at least the following signals with regard generating capability:

- max/min (net) active power generation capacity (MW)
- max/min (net) active power consumption capacity (MW)
- max/min (net) reactive power generation capability (±Mvar)
- max/min state of charge (SOC) (% of energy capacity)
- ramp rate generation capability (MW/min)
- ramp rate consumption capability (MW/min)
- measurements, related to meteorological conditions (indicatively: temperature and solar radiation)
- measurements, related to the EMS energy content (SOC), (% of energy capacity)
- measurements, related to EMS auxiliaries consumption
- the values of the dispatch instruction received

A simplified single line diagram of ESM analog signals is given in the Annexes.

11.1.2 ESM digital signals

ESMs shall provide to the NDC at least the following digital signals:

<u>Position signals/alarms at the CP with HETS (HV bay of main substation transformer)</u>

- switch position of the HV side transformer circuit breaker (on/off)
- position of the HV side transformer disconnector (on/off)
- position of the HV side grounding system, (on/off)
- various alarms (on/off) related to the activation of the HV transformer protection (indicative: differential protection, overcurrent protection, Buchholz relay)

<u>Position signals related to the activation of operating functions and the ability to receive market instructions:</u>

- ESM availability (on/off)
- remote active power control for FRR (on/off)
- remote reactive power control (on/off)

- PoD[15] activation (on/off)
- LFSM-O operation mode activation (on/off)
- FSM operation mode activation (on/off)
- LFSM-U operation mode activation (on/off)
- activation of voltage (Vref), reactive power (Qref) or power factor (cosφref) control mode

Position Signals/Alarms on the MV network IPPMs:

- switch position of the MV line circuit breaker, (on/off)
- position of the MV line disconnector, (on/off)
- position of the MV line grounding system, (on/off)
- switch position of the circuit breaker of any compensation means

A simplified single line diagram of ESM digital signals is given in the Annexes.

[15] If applied

12 Power Plant Controller

For the implementation by the ESMs of remotely issued set points with reference to electrical quantities at the CP with HETS, the PGF shall be equipped with a (central) Master Power Plant Controller (Master PPC). This device records the difference between the desired and the actual values of the controlled electrical quantity at the CP (e.g., voltage, active or reactive power flow), derives the information of how to modify a manipulated variable to minimize this difference and forwards it to the controlled generating units or PGM components.

In the case of several PGMs and/or ESMs sharing the same CP this may be achieved by implementing a control scheme where the central (master) PPC forwards this information to each PPC that supervises the operation of a PGM and/or ESM. This "slave" PPC communicates a proper signal to the generating or storage units and supervises PGM and/or ESM operation at the MV side of the transformer (TM or IPPM), Figure 20.

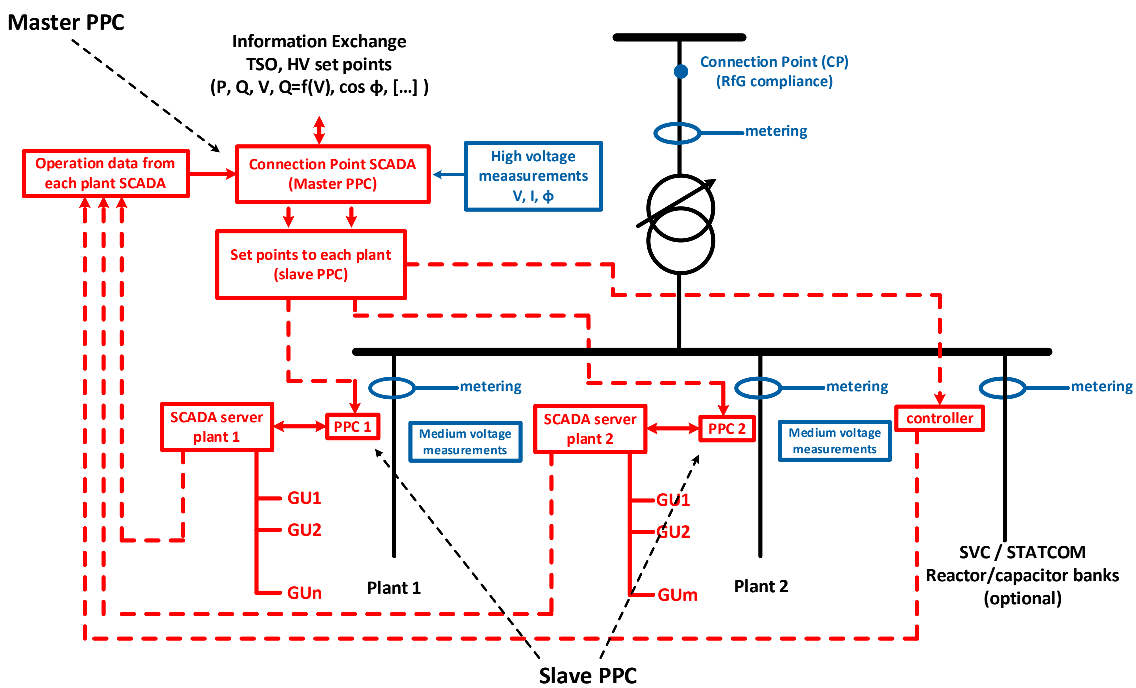


Figure 20: Principle of central (master) and local (slave) Power Plant Controller

The Power Plant Controller shall be closed-loop PI or PID controller capable of implementing at least the following control functions:

- active power control
- frequency control (LFSM-O/U, FSM)
- ramp active power control
- power factor / reactive power / voltage droop control

The PPCs should have the proper number of outputs to parse set-point values to the relevant controllers of each generating unit with signal delays as short as technical possible.

The PPCs shall be capable of operating both in closed and open loop mode.

For the operation of the central PPC the ESM owner should ensure the supply of measurements of electrical quantities at the CP (400/150kV, high voltage side of the substation (main) transformer).

For the operation of the PPC of each PGM and/or ESM, the PGM and/or ESM owner should ensure the provision of measurements of electrical quantities at the connection points of PGM internal network with the medium voltage side of the substation (main) transformer (TM or IPPM).

Further details shall be agreed between IPTO and the ESM owner on a case sensitive base.

13 Protection Principles

The protection schemes and settings of a PGF should be designed and specified according to the following principles:

- IPTO shall specify the schemes and settings necessary to protect the transmission system at the CP considering the characteristics of each connected ESM. System faults or system disturbances should not affect the ESM medium or low voltage network downwards the CP and under ESM owner’s responsibility.
- The protection schemes and settings at the CP and the protection schemes and settings downwards the CP must be coordinated and agreed between IPTO and the ESM owner. Any change shall be communicated and agreed between IPTO and the ESM owner, before being implemented.
- The ESM shall be capable of remaining connected to the HETS during single-phase or three- phase high speed auto-reclosures, characterized by the sudden re-activation of the mains supply after a dead time of approximately 600 msec for connections at 400kV and 500 msec for connections at 150kV. The details of that capability shall be subject to coordination and agreements on protection schemes and settings between IPTO and the ESM owner within the connection agreement.
- The protection settings at the CP shall always prevail. Whether a ESM stays connected to HETS or not shall depend upon those settings. In case of a fault inside the PGF (internal fault), the electrical protection of the ESM shall take precedence over any operational controls prioritizing personnel and public safety, system security as well as mitigating any damage to the PGM and PGF installations. However, the protection schemes and settings for internal electrical faults (PGF self-protection) must not jeopardize the performance of a PGM in line with the requirements set out in this Technical Guideline, especially the ones related to the operating ranges (section 3) and LVRT capabilities (chapter 8.1).
- The requirements for the RoCoF withstand capability, frequency and voltage operating ranges as well as the Low Voltage Ride Through capabilities of this technical guideline should not get overlapped, bypassed or jeopardized by less stringent protection requirements at any point of the PGF internal network.
- All ESM protections shall be set by the ESM owner so as not to overlap the widest possible technical capability of the GUs, unless IPTO requires narrower settings.

13.1 Responsibilities of IPTO

IPTO specifies the requirements deemed appropriate for the protection of the ESMs considering the applicable protection schemes at the CP as well as the technical capabilities of the ESM.

IPTO defines the interface and provides the necessary information and signals for the coordination and operation of the PGM's protection equipment, in accordance with the relevant provisions of the connection agreement.

The settings of distance protection or over-current protection at the circuit breaker at the CP are provided by IPTO. The tuning of the protection devices acting at the CP circuit breaker against grid faults within IPTO's responsibility area, is implemented by IPTO.

13.2 Responsibilities of the ESM owner

The ESM owner shall organize its protection and control devices in accordance with the following priority ranking (from highest to lowest):

- ESM internal network and ESUs protection
- frequency control (active power adjustment)
- power restriction
- power gradient constraint

The ESM owner is responsible for ensuring that faults on ESUs and the internal interconnection network cause minimal disturbance to the system. Faults on the ESUs, the internal network or any devices connected to the system shall be cleared as soon as possible, considering that the maximum period for fault clearance at the CP is 120ms for connections at the 150kV system and 80ms for connections at the 400kV system[16].

The ESM owner must provide a differential protection on the substation main transformer. Details on the protection concept, the design and the parameters of this protection shall be agreed with IPTO.

The ESM owner shall install and maintain, in accordance with good industry practice, all specified protection equipment. An indicative example of possible protection schemes is given in Figure 21.

[16] These clearance times concern primary protection systems only.

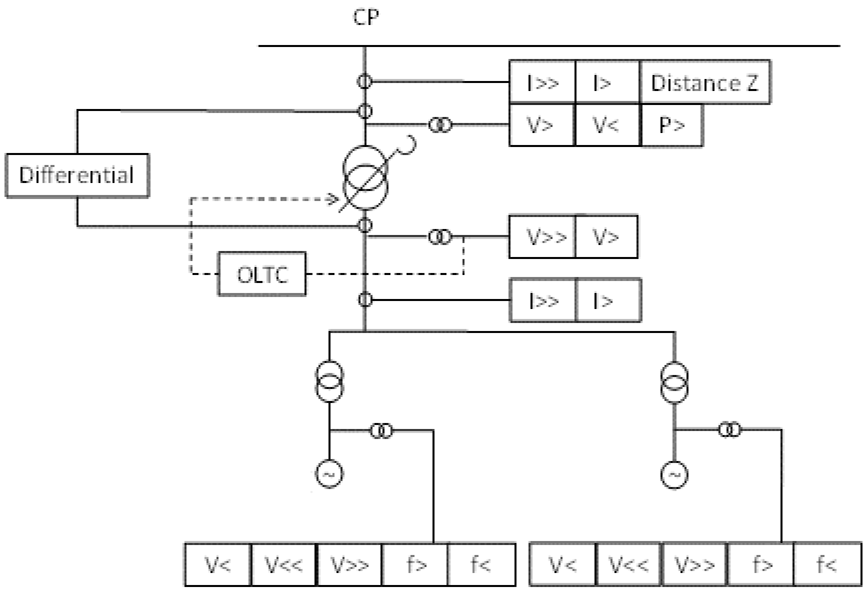


Figure 21: Exemplary protection scheme

Minimum protection requirements for PGMs may vary depending on the type, size, earthing and the connection method, including without limitation protection against:

- internal network short circuit,
- internal network overcurrent protection
- asymmetric load (negative phase sequence),
- ESU overload,
- over-/undervoltage at ESU terminals,
- over-/underfrequency at ESU terminals,
- inter-area oscillations, inrush current,
- asynchronous operation (pole slip),
- main transformer protection,
- back-up against protection and switchgear malfunction,
- rate of change of frequency, and
- neutral voltage displacement

14 Compliance assessment

14.1 Responsibilities of the involved parts

14.1.1 IPTO's responsibilities, obligations and rights

According to the provisions of Title IV (Compliance) of the NC-RfG, IPTO is responsible for assessing the compliance of the ESM with the requirements of this Technical Guideline throughout the lifetime of the ESM and to inform the ESM owner of the outcome of this assessment.

To achieve that, IPTO has the right to request that the ESM owner carry out compliance tests and simulations according to a repeating plan or a general scheme or after any failure, modification or replacement of any equipment which may have an impact on the PGM's compliance with the requirements of this Technical Guideline.

At IPTO's discretion, requirements additional to the ones set in this Technical Guideline as well as additional tests or simulations may be specified. Potential conflicts between this Technical Guideline and the additional requirements shall be resolved with the ESM owner.

IPTO and the ESM owner may agree on an alternative set of tests or simulations, provided that those tests and simulations are efficient and suffice to demonstrate that the ESM complies with the requirements of this Technical Guideline.

Within the framework of the compliance process IPTO shall make publicly available a list of information and documents to be provided, the conditions and procedures for the acceptance of equipment certificates (EqC) issued by an authorized certifier[17] as well as the requirements to be fulfilled by the ESM owner.

IPTO shall inform without delay the ESM owner in any case that discovers that the ESM derogates from the requirements of this Technical Guideline.

If compliance tests or simulations cannot be carried out as agreed between IPTO and the ESM owner due to reasons attributable to IPTO, then IPTO shall not unreasonably withhold the notifications foreseen in Title III of the NC-RfG (Operational Notification Procedure for Connection).

IPTO may totally or partially delegate the performance of its compliance monitoring to third parties. In such cases, the confidentiality provisions of Article 12 of the NC-RfG should apply to all involved parties.

[17] Title IV (Compliance) of the NC-RfG foresees the possibility of using of EqC instead of performing on site testing or providing simulation studies.

14.1.2 ESM owner responsibilities, obligations and rights

The ESM owner is responsible for the fulfillment of the requirements of this Technical Guideline throughout the lifetime of the ESM.

The ESM owner shall notify IPTO of any planned modification of the technical capabilities of the ESM, including modification in protection and control settings, which may affect its compliance with the requirements of this Technical Guideline before initiating that modification.

Any operational incidents or failures that affect ESM compliance shall also be notified to IPTO without undue delay. The evaluation of any modification, incident or failure with regard to this Technical Guideline is IPTO's responsibility.

Testing, testing schedules, simulations, and any procedures to be followed for verifying the compliance of the ESM should be communicated in due time and agreed between the ESM owner (or a third party on behalf on ESM owner) and IPTO. The ESM owner is responsible for submitting to IPTO all relevant reports. All associated costs are borne by the ESM owner.

IPTO has the right to participate in the tests, either on site or remotely from the National Dispatch Center (NDC) and record the performance of the power-generating modules either directly or via a third party. The ESM owner shall be informed of the outcome of those compliance tests.

IPTO has the right to perform its own compliance simulations based on the provided simulation reports, simulation models and compliance test measurements. The ESM owner shall be informed of the outcome of those compliance simulations.

14.1.3 Specific studies

On a case sensitive base IPTO may require specific studies relevant with at least the following issues: sub-synchronous interaction, geomagnetically induced currents, inrush currents, power oscillation damping, harmonics, power quality and low short circuit ratio.

The specific studies are responsibility of the ESM owner and they shall be performed in cooperation with IPTO. In case that the results of the studies indicate that the connection of the ESM requires specific measures to ensure system security these measures shall be treated as additional to the requirements of this Technical Guideline and the ESM owner shall be responsible for their implementation.

14.1.4 Confidentiality

The implementation of the compliance and the compliance monitoring throughout the ESM lifetime requires a large amount of information to be exchanged between IPTO and the ESM owner. According to Article 12 of the NC-RfG any information exchanged shall be subject to an obligation of confidentiality by the subjects involved. No special non-disclosure agreements (NDAs) are needed.

14.1.5 Derogations

Derogations from the fulfilment of the requirements of this Technical Guideline shall be issued according to the provisions of Title V (Derogations) of the NC-RfG.

15 Annexes

15.1 Definition of dynamic response parameters

The time response parameters of a controlled or simulated variable or a measured quantity under a step change, are defined as follows and shown graphically in Figure 22.

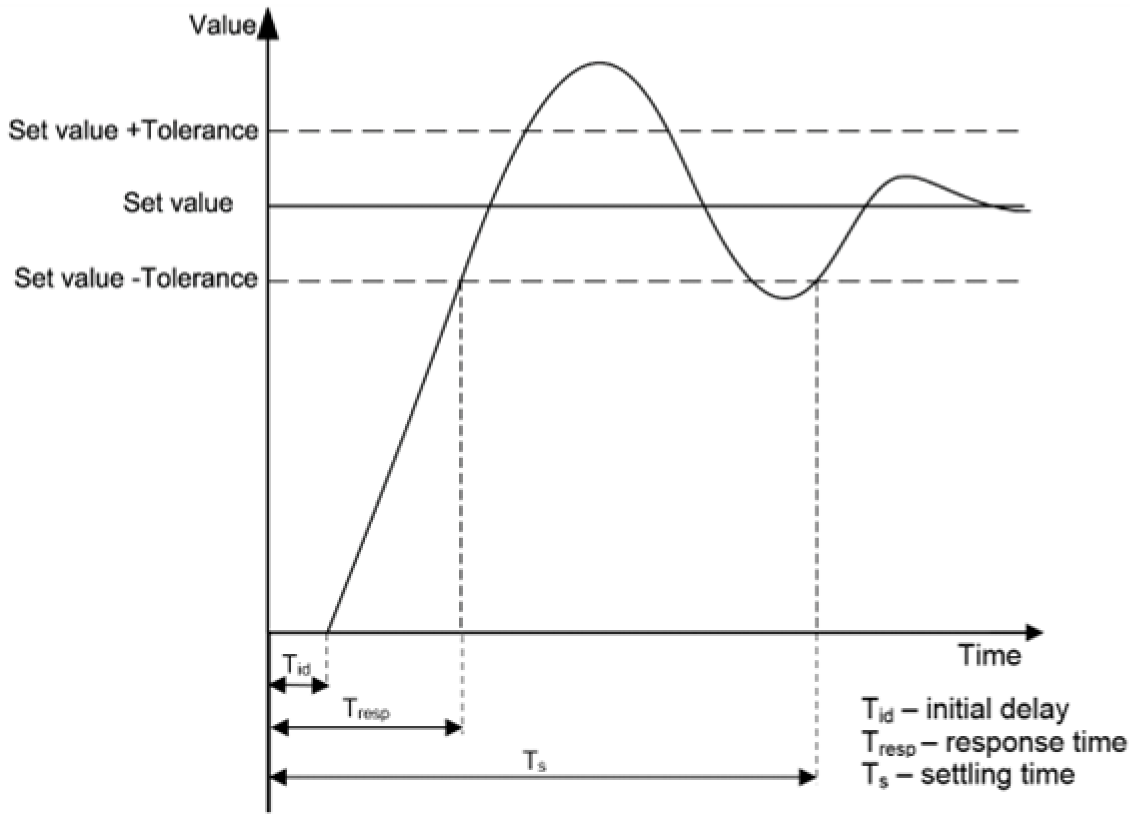


Figure 22: Dynamic response characteristics

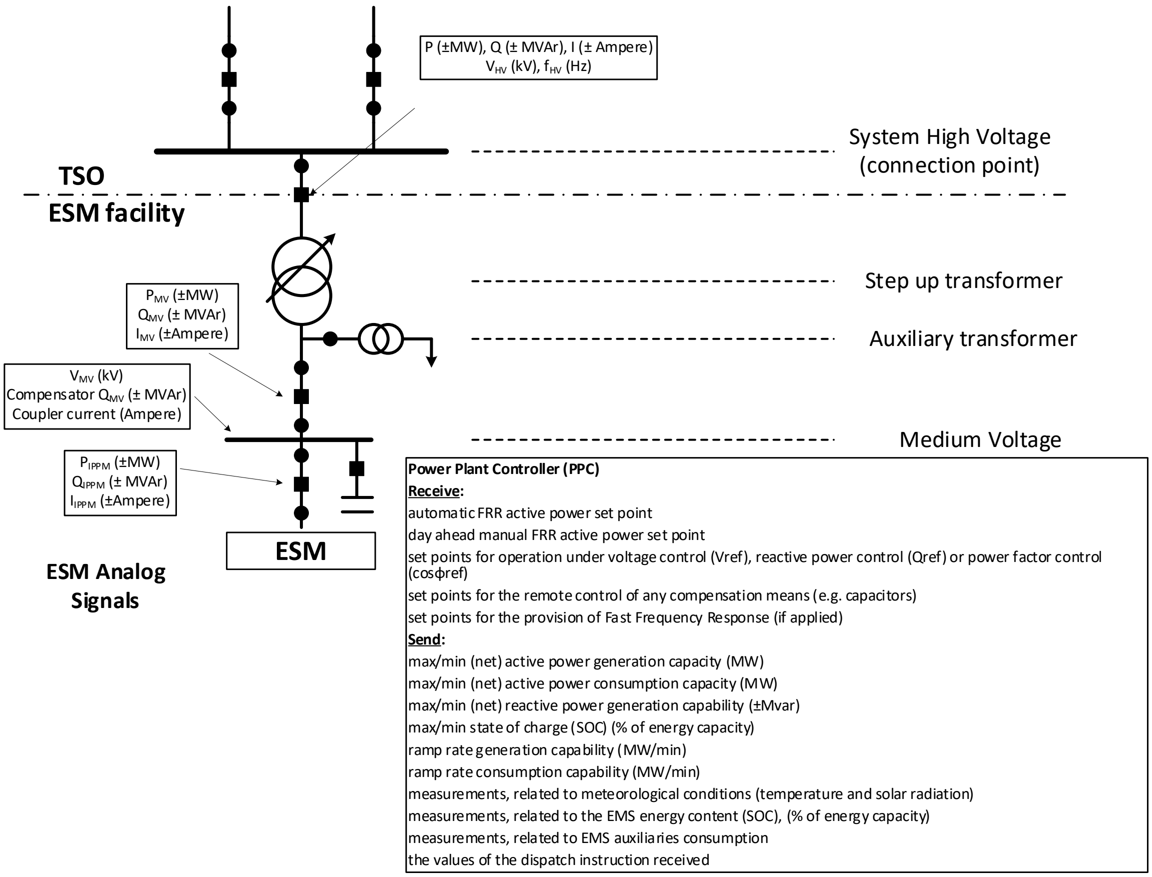
Dead time or reaction time (Tid): the elapsed time from the issue of a step change command until the observed value starts to response.

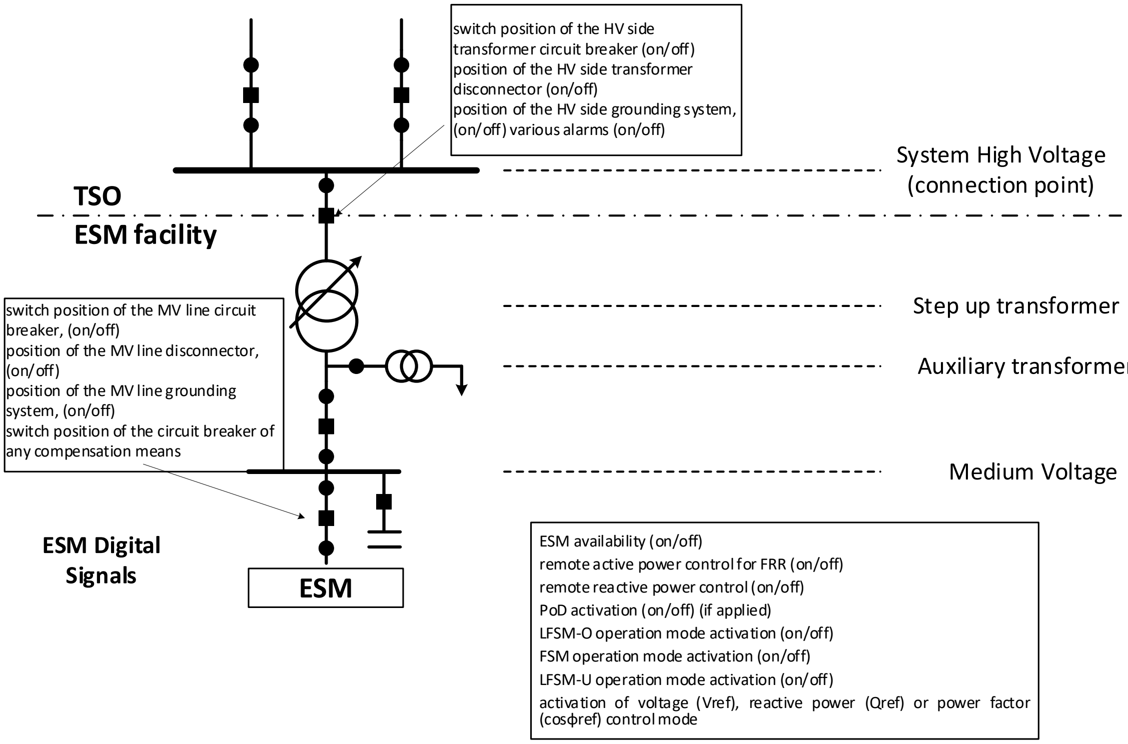
Step response time (Tresp): the elapsed time from the issue of a step change command until the observed value first time enters the predefined tolerance band of the target value.

Settling time (Ts): the elapsed time from the issue of a step change command until the observed value continuously stays within the predefined tolerance band of the target value.

Overshoot: the difference between the maximum value of the response and the steady state final value.

15.2 Analog and digital signals for ESMs




switch position of the HV side
transformer circuit breaker (on/off)
position of the HV side transformer
disconnector (on/off)
position of the HV side grounding system,
(on/off) various alarms (on/off)
System High Voltage
(connection point)
TSO
ESM facility
Step up transformer
switch position of the MV line circuit
breaker, (on/off)
position of the MV line disconnector,
(on/off)
position of the MV line grounding
system, (on/off)
switch position of the circuit breaker of
any compensation means
Auxiliary transformer
Medium Voltage
ESM Digital
Signals
ESM
ESM availability (on/off)
remote active power control for FRR (on/off)
remote reactive power control (on/off)
PoD activation (on/off) (if applied)
LFSM-O operation mode activation (on/off)
FSM operation mode activation (on/off)
LFSM-U operation mode activation (on/off)
activation of voltage (Vref), reactive power (Qref) or power factor
(cosϕref) control mode

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