



REPORT

CONFIDENTIAL

APPROVED

VERSION 1.0

INTERCONNECTION GRID CODE FOR THE PAN ARAB ELECTRICITY MARKET

CONNECTION CODE

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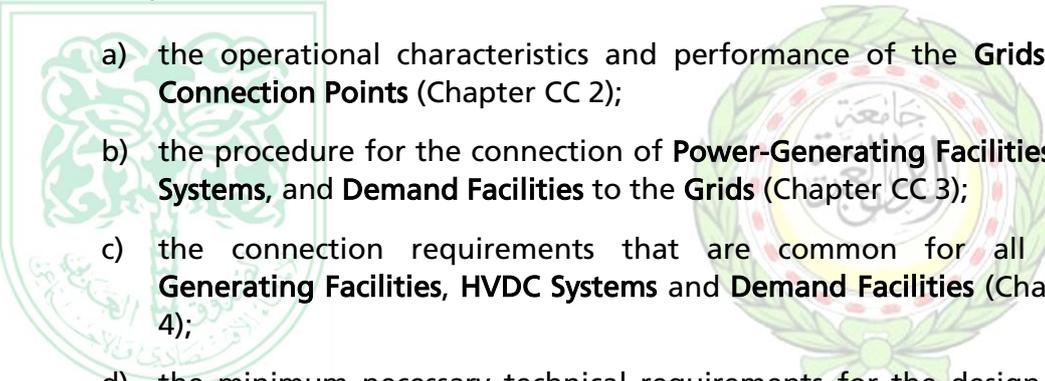
CC 1 SCOPE OF APPLICATION

J.¹ The scope of application identifies which **Facilities** are governed by this **Connection Code**, along with other information for proper understanding of the specific provisions. This **Connection Code** governs the technical conditions for the access of **Power-Generating Facilities, HVDC Systems, and Demand Facilities** to the **Grids** of the **Member States**. The aim is to promote the correct functioning and safety of the **PAEM Electricity System**.

In particular, given the expected growing share of **Generation** based on **VRE-units** and **RES**, requirements for **Inverter-based Power-Generating Facilities** are introduced since they are of paramount importance and shall be acknowledged by the **Member States** in their **National / Regional Grid Codes**.

CC 1.1.1 The **Connection Code** shall undergo thorough revision and harmonization process by **Member States** aiming at setting values/ranges of parameters – as specified in Chapter CC 10 ANNEX B – Reference parameters – and aiming at fine-tuning the necessary procedures.

CC 1.1.2 The subjects of this **Code** include:

- 
- a) the operational characteristics and performance of the **Grids** at the **Connection Points** (Chapter CC 2);
 - b) the procedure for the connection of **Power-Generating Facilities, HVDC Systems, and Demand Facilities** to the **Grids** (Chapter CC 3);
 - c) the connection requirements that are common for all **Power-Generating Facilities, HVDC Systems and Demand Facilities** (Chapter CC 4);
 - d) the minimum necessary technical requirements for the design criteria and operational capabilities of:
 - i. **Power-Generating Facilities** (Chapter CC 5);
 - ii. **HVDC systems** (Chapter CC 6);
 - iii. **Demand Facilities** (Chapter CC 7)
 - e) a set of guidelines for the definition of connection requirements for **Distributed Generation** (Chapter CC 8).

CC 1.1.3 Specifically, the requirements of this **Code** apply to the **Power-Generating Facilities, HVDC Systems, and Demand Facilities** that meet the following criteria:

- a) systems that are not connected to the **Transmission System** as of the adoption date of this **Connection Code**;
- b) existing systems, in case of significant changes or partial/total reconstruction.

¹ J. : Justification

CC 1.1.4 The relevant **TSO** evaluates the significance of a change or reconstruction based on information that are communicated by the **Power-Generating Facility Owner, HVDC System Owner and Demand Facility Owner** to the relevant **TSO** about the planned modifications². The relevant **TSO** shall define a time period from receipt of the communication within which it will make a determination as to whether or not the modification constitutes a significant a change or reconstruction. After this period, absent a communication from the relevant **TSO**, the change or reconstruction is considered not significant.

CC 1.1.5 Concerning **Power-Generating Facilities**, it is specified that the relevant requirements apply to all the **Power-Generating Modules**, both synchronous and inverter-based, connected at the **Transmission System** or having a **Nominal Power** equal to or higher than a given threshold, expressed in MW.

CC 1.1.6 Each **Member State** shall define the effective date at which this **Code** goes into effect, along with:

a) The voltage levels that pertain to the respective **Transmission System** – a threshold value $U_{\text{threshold}}$ [V] shall be defined, harmonized and adopted by **Member States** as the minimum value of operating voltage above which the **Network** is considered as **Transmission System**.

b) The **Nominal Power** threshold, which cannot be higher than a value $P_{\text{threshold}}$ [MW] which shall be defined, harmonized and adopted by **Member States** – i.e. this Code applies by default to **Power-Generating Modules** with **Nominal Power** higher than $P_{\text{threshold}}$.

² A non-exhaustive list of changes that shall be deemed as significant considers the following: for **Synchronous Power-Generating Modules**: replacement of synchronous machine, renewal of voltage and/or frequency control equipment and of protection or control systems, change/replacement of thermal or hydraulic components. For **Inverter-based Power-Generating Modules**: replacement of wind turbines or inverters for a cumulative power of at least 10% of **Nominal Power**, replacement of control equipment. For **HVDC Systems**: change in transfer capacity, technology or configuration (monopolar, bipolar).

CC 2 OPERATIONAL CHARACTERISTICS AND PERFORMANCE OF THE GRIDS AT THE CONNECTION POINTS

J. Operational characteristics and performance of the **Transmission System** at the **Connection Points** affect the design and the operation of **Power-Generating Facilities, HVDC System** and **Demand Facility**. Harmonizing characteristics and performance within the interconnected **PAEM Electricity System** will provide access to the **Transmission System** in a transparent and non-discriminatory manner by potential stakeholders. Moreover, it facilitates the development and standardization of equipment.

CC 2.1.1 The relevant **TSO** shall guarantee defined operational characteristics and performance of the respective **Grid** at the **Connection Points**. **Power-Generating Facilities, HVDC Systems, and Demand Facilities** shall contribute in preserving the **Grid** performance going forward by meeting the technical rules of this **Code**.

CC 2.1.2 The relevant **TSO** shall define the operational characteristics and performance of the respective **Grid** at the **Connection Points**. Accordingly, on an annual basis, the relevant **TSO** will review and make publicly available information pertaining to the operational characteristics and performance of the respective **Grid**.

CC 2.2 Operating Conditions and Frequency Ranges

CC 2.2.1 The relevant **TSO** shall define the nominal frequency as well as the different **Operating Conditions** of the respective **Grid**. For each **Operating Condition**, the relevant **TSO** shall define the respective frequency ranges within which the frequency is maintained.

CC 2.2.2 Provisions concerning the **Operating Conditions** are provided in the **Operation Code**.

CC 2.2.3 For each **Operating Condition**, the relevant **TSO** shall define the respective frequency ranges within which the frequency is maintained.

CC 2.2.4 **Operating Conditions** and respective frequency ranges shall be harmonized among **Member States** within the same **Synchronous Area**.

CC 2.3 Voltage Levels

CC 2.3.1 The relevant **TSO** shall define and make publicly available the values of nominal and operating voltages for each **Connection Point** and for each **Operating Condition**.

CC 2.4 Other Voltage Characteristics

CC 2.4.1 The relevant **TSO** shall define the following voltage characteristics that shall apply to normal **Operating Conditions**:

a) *Total Harmonic Distortion (THD):*

The relevant **TSO** shall define the maximum expected value of the **THD** expressed in percentage for each nominal voltage level of the respective Grid. The limits for **THD** shall be those specified on the standard given in CC 10 ANNEX B – Reference parameters.

b) *Unbalance of the three-phase voltages:*

The relevant **TSO** shall define the maximum expected degree of unbalance of the three-phase voltages for each **Connection Point**. The degree of unbalance is usually defined by the percent ratio of the absolute value of the negative sequence voltage component to the absolute value of the positive sequence component, obtained by the transformation of the unbalanced 3 phase voltage quantities in the 3 symmetrical components (positive, negative, and zero sequences)³. Typical value of maximum unbalance is given in CC 10 ANNEX B – Reference parameters.

Exceptional conditions that may result in higher values can be considered by the relevant **TSO** (e.g. phase interruption).

c) *Flicker:*

The relevant **TSO** shall define the maximum value of short-term flicker severity (P_{st}) and long-term flicker severity (P_{lt}) for each nominal voltage level of the respective **Grid**. The standards for P_{lt} and P_{st} are given in CC 10 ANNEX B – Reference parameters.

d) *Voltage sags and swells:*

The number of voltage sags or swells occurring in each **Connection Point** may vary in the range of tens to some hundreds in a year. Variability depends, among others, on the specific position of the **Connection Point**, on **Short-Circuit Current**, and on voltage level.

³ The decomposition method is based on the Fortescue's Theorem.

CC 2.4.2 Limits for **THD**, unbalance and flicker shall be harmonized among **Member States** within the same **Synchronous Area**.

CC 2.5 Short-Circuit Current

CC 2.5.1 The relevant **TSO** shall calculate and make publicly available the maximum and minimum values of **Short-Circuit Current** for each **Connection Point**. These values shall be updated on an annual basis by the relevant **TSO**.

CC 2.5.2 The procedure for the computation of the maximum and minimum **Short-Circuit Current** shall be made publicly available by the relevant **TSO**. Moreover, the approach for determining these values should be harmonized among the **Member States** within the same **Synchronous Area**.



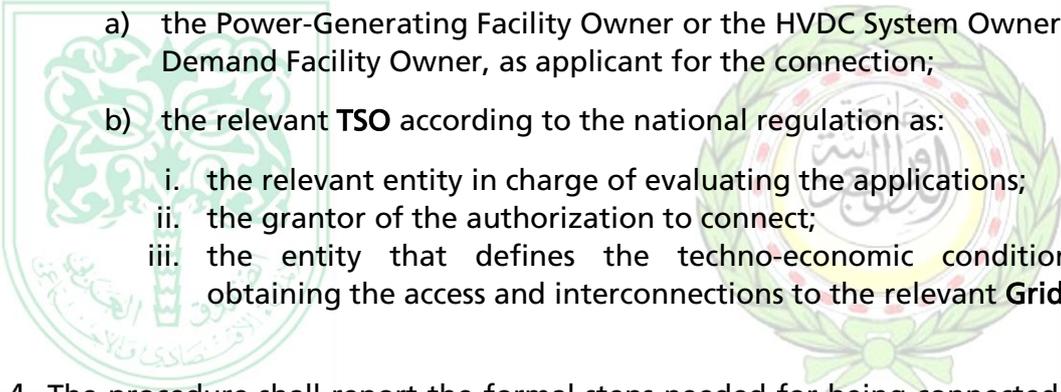
CC 3 CONNECTION PROCEDURE

J. Common procedures for the connection of **Power-Generating Facilities, HVDC Systems and Demand Facility** to an **Integrated Power System**, from the request to the approval of connection, are required among the involved **TSOs**. This contributes to the access in a transparent and non-discriminatory manner across the same **Synchronous Area**.

CC 3.1.1 The relevant **TSO** shall define the procedure for connecting **Power-Generating Facilities, HVDC Systems and Demand Facilities** to the relevant **Grid**.

CC 3.1.2 The procedure for requesting connection shall be made publicly available by the relevant **TSO** at the effective date of this **Code**. Any updates to the procedure must be made public in advance of the actual date of enforcement. The procedure must also be harmonized across the **Member States** to the extent possible.

CC 3.1.3 The procedure shall involve the following parties:

- 
- a) the Power-Generating Facility Owner or the HVDC System Owner or the Demand Facility Owner, as applicant for the connection;
 - b) the relevant **TSO** according to the national regulation as:
 - i. the relevant entity in charge of evaluating the applications;
 - ii. the grantor of the authorization to connect;
 - iii. the entity that defines the techno-economic conditions for obtaining the access and interconnections to the relevant **Grid**.

CC 3.1.4 The procedure shall report the formal steps needed for being connected to the **Grid** of the relevant **TSO** and the related timing. The procedure shall cover the following phases:

- a) Authorization phase: where a request for connection to the **Grid** is made by the applicant.

The authorization procedure shall report the complete list of documents to be provided by the applicant. Such documents shall at least cover the following information:

- i. the company profile of the applicant;
- ii. the proposed **Connection Point** and details on the site of connection;
- iii. the certified technical documentation related to the **Power-Generating Facility** or the **HVDC System** or the **Demand Facility** relevant to the connection to the **Grid**;
- iv. the details of the technical capabilities of the **Power-Generating Facility** or the **HVDC System** or the **Demand Facility** relevant to the connection to the **Grid**;
- v. compliance with the connection requirements set out in the relevant **National Grid Code**.

At a minimum, the authorization document to connect shall report:

- i. the conditions of acceptance by the relevant **TSO**;
- ii. the necessary modifications to the original connection project, if any;
- iii. the cost of connection.

b) Realization phase:

- i. construction of the required **Network System for the Connection** by the relevant **TSO**. This is the set of plants and equipment necessary for the connection of **Power-Generating Facility** and/or the **HVDC System** and/or the **Demand Facility** to the **Transmission System**, to be implemented in the **Transmission System** in the existing configuration to the **Connection Point**.
- ii. construction of the **Power-Generating Facility** or the **HVDC System** or the **Demand Facility** by **Power-Generating Facility Owner** or the **HVDC System Owner** or the **Demand Facility Owner**.

c) Entry-into-service phase: application for the start-up of the **Power-Generating Facility** and/or an **HVDC System** and/or the **Demand Facility**.

CC 3.1.5 The relevant **TSO** shall define an operational notification procedure to entitle a **Power-Generating Facility Owner** or an **HVDC System Owner** or a **Demand Facility Owner** to operate its system. This procedure shall comprise the following three stages:

- a) Operational notification to entitle the **Power-Generating Facility Owner** or the **HVDC System Owner** or the **Demand Facility Owner** to energize its internal electrical network and auxiliaries and connect it to the **Connection Point**.
- b) Operational notification to entitle the **Power-Generating Facility Owner** or the **HVDC System Owner** or the **Demand Facility Owner** to operate its system connected to the **Grid** for a limited time period – to be defined by the relevant **TSO** – necessary to assess at least the technical data of the system and the compliance with requirements.
- c) Operational notification to entitle the **Power-Generating Facility Owner** or the **HVDC System Owner** or the **Demand Facility Owner** to operate its system connected to the **Grid** at the **Connection Point**. This operational notification shall be issued by the relevant **TSO** upon prior removal of all incompatibilities identified for the purpose of the previous point.

CC 4 GENERAL REQUIREMENTS

J. This Chapter covers general requirements that are common to **Power-Generating Facilities, HVDC Systems and Demand Facilities**, e.g. (not exhaustive list), schemes of connections, general scheme for protections.

CC 4.1.1 General requirements apply to **Power-Generating Facilities, HVDC Systems and Demand Facilities** as per Chapter CC 1. Specific requirements for **Power-Generating Facilities, HVDC Systems and Demand Facilities** are given in Chapters CC 5, CC 6 and CC 7 respectively. The relevant **TSO** can define additional requirements to those given in this **Code**.

CC 4.2 Preliminary Provisions

CC 4.2.1 Connecting **Power-Generating Facilities, HVDC Systems and Demand Facilities** to the **Grid** shall not give rise to any degradation in the performance or reliability of the **Grid** itself and shall contribute to the safety and quality of the service according to the capabilities of the **Facility** and the **Electricity System**.

CC 4.2.2 The design of the **Network System for the Connection** shall be executed such that it shall not adversely affect the operation of the **Grid** or damage the other **Facilities**.

CC 4.2.3 Respective materials and components of **Power-Generating Facilities, HVDC Systems and Demand Facilities** shall be designed and manufactured in compliance with the national and international standards in force concerning safety and protection of people and things.

CC 4.3 Technical Documentations

CC 4.3.1 The **Power-Generating Facility Owner, the HVDC System Owner and the Demand Facility** are responsible for the drafting, updating and formal communication to the relevant **TSO** of:

- a) the technical documentation for the **Network System for the Connection** to the **Grid** that shall comprise:
 - i. single-line diagram and planimetry;
 - ii. technical descriptions, manuals and test data for each equipment;
 - iii. schemes and descriptions of control, operation and protection equipment and systems.
- b) the documentation of the **Power-Generating Facility** or the **HVDC System** or and **Demand Facility** that shall comprise the technical data of the equipment belonging to the **Power-Generating Facility Owner, the**

HVDC System Owner and the **Demand Facility Owner** which are relevant to the **Grid** operation.

CC 4.3.2 The Operating Regulation Document shall be signed between the **Power-Generating Facility Owner**, the **HVDC System Owner**, the **Demand Facility Owner** and the relevant **TSO** in order to:

- a) define the respective responsibilities with regards to the operation and control of the facility and system sections which are functional to the **Grid**;
- b) define specific connection requirements, in addition to those given in this **Code** and in the relevant national regulation, if deemed necessary;
- c) define derogations to the requirements of this **Code**.

CC 4.4 Schemes for Connection to the Grid

CC 4.4.1 The relevant **TSO** shall define the procedure for the identification of the technical solution for the connection of the **Power-Generating Facility**, the **HVDC System** and the **Demand Facility** to the **Grid**.

CC 4.4.1.1 As a minimum, the procedure shall consider the following steps:

- a) identification of the connection to the **Grid** and definition of the connection voltage level;
- b) identification of the point and technical configuration of the insertion in the **Grid**;
- c) definition of switching devices and the **Network System for the Connection**;
- d) definition of functional and property limits.

CC 4.5 Protection Systems

CC 4.5.1 The design and operation of **Power-Generating Facilities**, **HVDC Systems** and **Demand Facilities** shall consider the technical features and performance of the **Grid** protection system. Accordingly, the **Operating Regulation Document** shall report the requirements for the protection system.

CC 4.5.2 The protection system for **Power-Generating Facilities**, **HVDC Systems** and **Demand Facilities** shall:

- a) guarantee the following general criteria:

- i. coordination with **Grid** protection system;
 - ii. backup protection where needed;
 - iii. monitoring;
 - iv. contribution to identification of faulty element(s).
- b) be organized according to:
 - i. protection at **Connection Point**;
 - ii. protection against faults that are outside the **Power-Generating Facility, HVDC System** and **Demand Facilities**;
 - iii. protection against faults that are inside the **Power-Generating Facility, HVDC System** and **Demand Facilities**;
 - iv. protection of connection lines between **Connection Point** and the **Grid** (when present).

CC 4.5.3 The **Operating Regulation Document** shall define the calibration of protection equipment.

CC 4.6 Communication System

CC 4.6.1 The **Power-Generating Facility, HVDC System** and **Demand Facility** shall be integrated into the control process and operation (in real-time and in deferred time) of the **Grid**. This is achieved by exchanging data and information between the **Power-Generating Facility, HVDC System, Demand Facility** and the relevant **TSO** facilities.

CC 4.6.2 The **Power-Generating Facility Owner, the HVDC System Owner, and the Demand Facility Owner** are required to provide measurements and signals to ensure:

- a) the real-time observability of the facility itself and the system operation functions;
- b) the availability of historical operations and performance of the **Facility** itself in deferred time.

CC 4.6.3 The relevant **TSO** shall define the detailed list of data, data formats, communication protocols and interfacing modes that must be compatible with its own control system.

CC 4.6.4 The relevant **TSO** may require the **Power-Generating Facility Owner, the HVDC System Owner** and the **Demand Facility Owner** to install dedicated equipment for remote control.

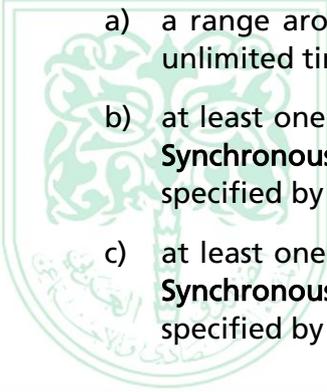
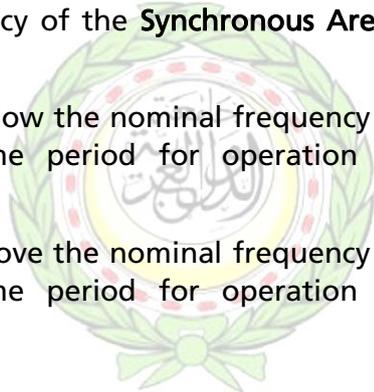
CC 5 REQUIREMENTS FOR POWER-GENERATING FACILITIES

CC 5.1 Operating Ranges

CC 5.1.1 *Frequency Ranges*

J. In an interconnected **Electricity System**, frequency is the parameter with the largest cross-border impact, since deviations from its nominal value occur everywhere at the same time and affects all **Power-Generating Modules** regardless of voltage levels. For this reason, harmonized frequency ranges are fundamental, especially the range for unlimited operation which needs to be identical for sharing the burden of deviations equally.

CC 5.1.1.1 All **Power-Generating Modules** shall be designed, built and operated to be capable of remaining connected to the **Grid** within the frequency ranges, and minimum time periods specified by the relevant **TSO**, according to the following scheme and represented also in Table CC 1:

- 
- 
- a) a range around the nominal frequency of the **Synchronous Area** with unlimited time period of operation;
 - b) at least one range with frequency below the nominal frequency of the **Synchronous Area** with limited time period for operation to be specified by the relevant **TSO**;
 - c) at least one range with frequency above the nominal frequency of the **Synchronous Area** with limited time period for operation to be specified by the relevant **TSO**.

CC 5.1.1.2 The frequency values are considered at the **Connection Point**.

CC 5.1.1.3 In defining frequency ranges and time periods, the relevant **TSO** shall consider the applicable international standards for products on frequency-related capabilities.

CC 5.1.1.4 The relevant **TSO** and the **Power-Generating Facility 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 a **Power-Generating Module**, if it is needed to preserve or to restore **Grid** security. The **Power-Generating Facility Owner** shall not unreasonably withhold consent to such request(s) if economically and technically feasible.

Table CC 1. Minimum time periods for which a Power-Generating Module must be capable of operating for frequency deviating from the nominal value of the Synchronous Area without disconnecting from the Grid

		Frequency range	Time period for operation
<i>f</i> of the Synchronous Area	b)	$F_{f_{low2}}$ Hz – $F_{f_{low1}}$ Hz	To be specified in minutes by the relevant TSO
	a)	$F_{f_{low1}}$ Hz – $F_{f_{high1}}$ Hz	Unlimited
	c)	$F_{f_{high1}}$ Hz – $F_{f_{high2}}$ Hz	To be specified in minutes by the relevant TSO

CC 5.1.1.5 Frequency ranges and time periods shall be harmonized among **Member States** within the same **Synchronous Area**. Indicative frequency ranges and time periods are reported in CC 10 ANNEX B – Reference parameters.

CC 5.1.2 Voltage Ranges

J. Though voltage is a local parameter, voltage ranges are critical to secure operation of an **Integrated Power System** within a **Synchronous Area**. The lack of coordinated ranges between adjacent interconnected **Grids** would lead to uncertainty in operation, especially when beyond normal state.

CC 5.1.2.1 All **Synchronous Power-Generating Modules** shall be designed, built and operated to be capable of remaining connected to the **Grid** within the ranges of the voltage at the **Connection Point** specified by the relevant **TSO** according to the following scheme and represented also in Table CC 2:

- a) a range around the base voltage with unlimited time period of operation;
- b) at least one range with voltage below the base value with limited time period for operation to be specified by the relevant **TSO**;
- c) at least one range with voltage above the base value with limited time period for operation to be specified by the relevant **TSO**.

CC 5.1.2.2 Voltage ranges are expressed by the ratio between the voltage at the **Connection Point** to the base voltage. The relevant **TSO** can define different sets of voltage ranges and respective time periods according to different voltage base levels. In defining voltage ranges and time periods, the relevant **TSO** shall consider the applicable international standards for products on voltage-related capabilities.

CC 5.1.2.3 The relevant **TSO** and the **Power-Generating Facility Owner** may agree on wider voltage ranges, longer minimum times for operation or specific requirements for combined frequency and voltage deviations (simultaneous overvoltage and underfrequency or simultaneous undervoltage and

overfrequency) to ensure the best use of the technical capabilities of a **Power-Generating Module**, if it is needed to preserve or to restore **Grid** security. The **Power-Generating Facility Owner** shall not unreasonably withhold consent to such request(s) if economically and technically feasible.

Table CC 2. Minimum time periods during which a Power-Generating Module must be capable of operating for voltages deviating from the reference 1 pu value at the Connection Point without disconnecting from the Grid.

	Voltage range	Time period for operation
b)	$U_{low2} \text{ pu} - U_{low1} \text{ pu}$	To be specified in minutes by the relevant TSO
a)	$U_{low1} \text{ pu} - U_{high1} \text{ pu}$	Unlimited
c)	$U_{high1} \text{ pu} - U_{high2} \text{ pu}$	To be specified in minutes by the relevant TSO

CC 5.1.2.4 Voltage ranges and time periods shall be harmonized among **Member States** within the same **Synchronous Area**. Indicative voltage ranges and time periods are reported in CC 10 ANNEX B – Reference parameters.

CC 5.2 Immunity to Grid Disturbances

CC 5.2.1 *Fault-Ride-Through Capability*

J. In the case of a fault on the **Transmission System** level a voltage drop will propagate across large geographical interconnected areas. Failure to ride through faults for **Power-Generating Facilities** (i.e. tripping) can create major system instability with cross-border implications. This requirement defines capability for **Power-Generating Facilities** to be tolerant to such faults.

CC 5.2.1.1 **Power-Generating Modules** shall be capable of remaining connected to the **Grid** and continue to operate in a stable manner, when the actual course of the phase-to-phase voltages at the **Connection Point**, during a fault, is maintained over a **Fault-Ride-Through** voltage-against-time profile to be specified by the relevant **TSO** according to Figure CC 1.

CC 5.2.1.2 The relevant **TSO** shall specify the parameters that define each point of **Fault-Ride-Through** voltage-against-time profile of Figure CC 1.

- a) **Synchronous Power-Generating Modules** and **Inverter-based Power-Generating Modules**;
- b) Symmetrical and asymmetrical faults.

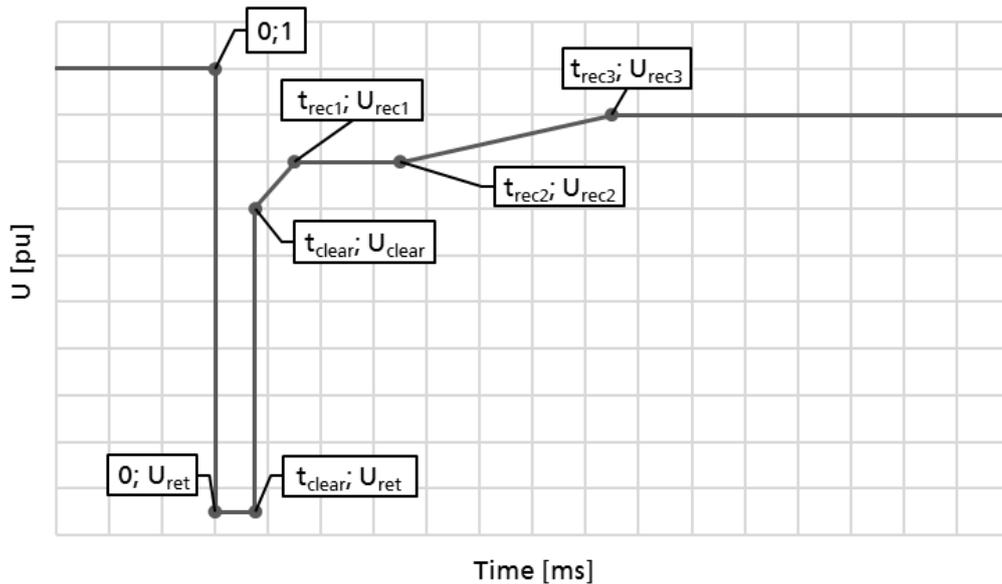


Figure CC 1. Fault-ride-through profile of a Power-Generating Facility. It is expressed as the phase-to-phase voltages on the Transmission System voltage level at the Connection Point during a fault as a function of time before, during and after the fault.

- CC 5.2.1.3 In the area below the **Fault-Ride-Through** voltage-against-time profile, the disconnection of the **Power-Generating Modules** due to the intervention of the protection system referred to Article CC 5.5.3 is acceptable.
- CC 5.2.1.4 The installation of ad-hoc undervoltage protection that traces and implements the described **Fault-Ride-Through** voltage-against-time profile is not permitted. In particular, the under-voltage protection shall be set by the **Power-Generating Facility Owner** according to the technical limits of the **Power-Generating Modules**, unless the relevant **TSO** requests other settings.
- CC 5.2.1.5 **Power-Generating Modules** shall comply with the **Fault-Ride-Through** voltage-against-time profile for any pre-fault or post-fault value of **Short-Circuit Power** between the minimum and maximum values of the **Short-Circuit Power** expected in the **Connection Point**⁴.
- CC 5.2.1.6 The **Fault-Ride-Through** requirement does not consider the disconnection from the **Transmission System** imposed by operating conditions and/or **Transmission System** protection that shall be implemented through equipment and related parameters defined by the relevant **TSO**.
- CC 5.2.1.7 All the **Fault-Ride-Through** voltage-against-time profiles shall be harmonized among **Member States** within the same **Synchronous Area**. Indicative minimum limits of **Fault-Ride-Through** voltage-against-time profiles for

⁴ Refer to Section CC 2.5 for **Short-Circuit Current** values.

Synchronous Power-Generating Modules and Inverter-based Power-Generating Modules are given in CC 10 ANNEX B – Reference parameters.

CC 5.2.2 *Rate-of-change-of-frequency withstand capability*

J. Rate-of-change-of-frequency withstand capability may be relevant during significant **Load-Generation** imbalances (e.g. disconnection of large **Load Facilities** or **Power-Generating Modules**, or system splits) because of low system inertia caused by (amongst others) increasing shares of inverter-based **Power-Generating Facilities**, usually **RES**. Avoiding the disconnection of **Power-Generating Modules** in case of large rate of change of frequency contributes to stabilization and restoration of the **Transmission System** to a normal operating state.

CC 5.2.2.1 A **Power-Generating Module** shall be capable of staying connected to the **Transmission System** and operating at rates of change of frequency up to a value specified by the relevant **TSO**, unless disconnection was triggered by rate-of-change-of-frequency-type loss of mains protection.

CC 5.2.2.2 The rate-of-change-of-frequency withstand capability shall be harmonized among **Member States** within the same **Synchronous Area**. A typical threshold value is given in CC 10 ANNEX B – Reference parameters.

CC 5.3 **Stability and Control of the System Frequency**

CC 5.3.1 *Control of Target Active Power*

J. Changes in active power output around a target value and the behavior during transient of target value variations may result in load imbalances and hence in frequency deviations in a **Synchronous Area**. Requirements defining the performance of **Power-Generating Facilities** in target active power control contribute to maintaining system stability and security by minimizing deviations of frequency.

CC 5.3.1.1 A **Power-Generating Module** shall be capable of maintaining constant output at any value of target active power between the declared minimum and maximum active power output, except where the power output follows the changes specified in Articles CC 5.3.2, CC 5.3.3, and CC 5.3.4 of this **Connection Code**.

CC 5.3.1.2 The relevant **TSO** can define the values of maximum error within which the control system of **Power-Generating Modules** must control the active power with respect to constant target values and during changes in the target value.

CC 5.3.2 *Effects of Environmental and Operating Conditions on the Active Power Capability*

J. Environmental and operating conditions may lead to variations in maximum active power output of **Power-Generating Modules**. Defining admissible variations contributes to limiting load imbalances and hence frequency deviations too.

CC 5.3.2.1 When a **Synchronous Power-Generating Module** is operating in under-frequency condition, a reduction in the maximum active power output from maximum active power declared to the relevant **TSO** is allowed. This practice must be justified by proven technical reasons.

CC 5.3.2.2 The relevant **TSO** shall define the maximum admissible reduction of active power output for under-frequency conditions in its **Control Area** as percentage of the **Generation Capacity** of the **Power-Generating Module**. The **Generation Capacity** of the **Power-Generating Module** minus this defined maximum admissible percentage reduction gives the lower limit on the active power capability above which the maximum active power that can be supplied by **Power-Generating Modules** must always remain.

CC 5.3.2.3 In defining the admissible active power reduction from the maximum output, the relevant **TSO** shall:

- a) clearly specify the ambient conditions applicable; and,
- b) take account of the technical capabilities of **Power-Generating Modules**.

CC 5.3.2.4 Typical values of admissible active power reduction from maximum output in under-frequency conditions fall within the boundaries given in CC 10 ANNEX B – Reference parameters.

- a) below $f_{\text{boundary2}}$ falling by a reduction rate of $\Delta P/P_{\text{MAX}}|_{\text{boundary2}}$ of the maximum capacity at 1 pu per $\Delta f_{\text{boundary2}}$ of frequency drop;
- b) below $f_{\text{boundary1}}$ falling by a reduction rate of $\Delta P/P_{\text{MAX}}|_{\text{boundary1}}$ of the maximum capacity at 1 pu per $\Delta f_{\text{boundary1}}$ frequency drop.

CC 5.3.2.5 Figure CC 2 represents the boundaries in which the capability can be specified by the relevant **TSO** according to the previous specifications. That is: from frequency in the range $1-f_{\text{boundary1}}$, the **Power-Generating Module** shall not show any reduction in maximum power output. With frequency below $f_{\text{boundary1}}$, the area within which the relevant **TSO** can define the capability is given.

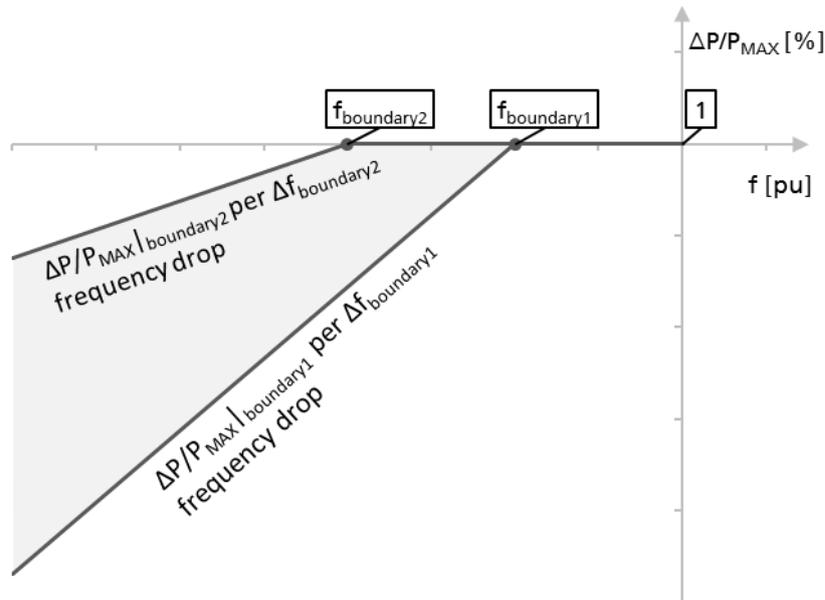


Figure CC 2. Maximum power capability reduction with falling frequency. The percentage value of the reduction refers to the maximum active power of Synchronous Power-Generating Module.

CC 5.3.3 Active Power Reduction at Abnormal Overfrequency and Underfrequency

J. Persistent load imbalances cause frequency deviation to increase leading to deterioration of system stability and security of PAEM Electricity System. Power-Generating Facilities are commonly requested to contribute to removing such imbalances. This requirement defines the capabilities of Power-Generating Facilities to control the variation of their active power output in response to abnormal over-frequency and underfrequency.

CC 5.3.3.1 **Power-Generating Modules** shall be capable of regulating the active power output in response to wide variations of the frequency in over- and underfrequency according to operating modes called **Limited Frequency Sensitive Mode-Overfrequency (LFSM-O)** and **Limited Frequency Sensitive Mode-Underfrequency (LFSM-U)**.

CC 5.3.3.2 The relevant **TSO** shall characterize the frequency threshold and droop that characterize **LFSM-O** and **LFSM-U** operating modes in accordance with Figure CC 3 and Figure CC 4:

- a) P_{MAX} is the maximum active power output of the **Power Generation Module**. ΔP is the variation in the active power production of the **Power Generation Module**. f_n is the nominal frequency of the **Grid** and Δf is the frequency deviation occurring in the **Grid**.
- b) in **LFSM-O** (Figure CC 3), at over-frequencies where Δf is greater than Δf_1 , the **Power-Generation Module** shall provide a negative variation of active power production according to a droop setting equal to s_2 . Typical values for the frequency threshold $\Delta f_1/f_n$ the droop setting s_2 are given in CC 10 ANNEX B – Reference parameters.

- c) in **LFSM-U** (Figure CC 4), at under-frequencies where Δf is lower than Δf_1 , the **Power Generation Module** shall provide a positive variation of active power production according to a droop equal to s_2 . Typical values for the frequency threshold $\Delta f_1/f_n$ the droop setting s_2 are given in CC 10 ANNEX B – Reference parameters.

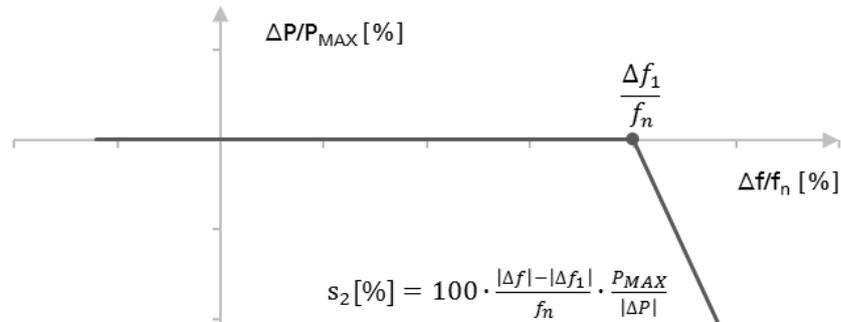


Figure CC 3. Active power frequency response capability of Power-Generating Modules in LFSM-O mode.

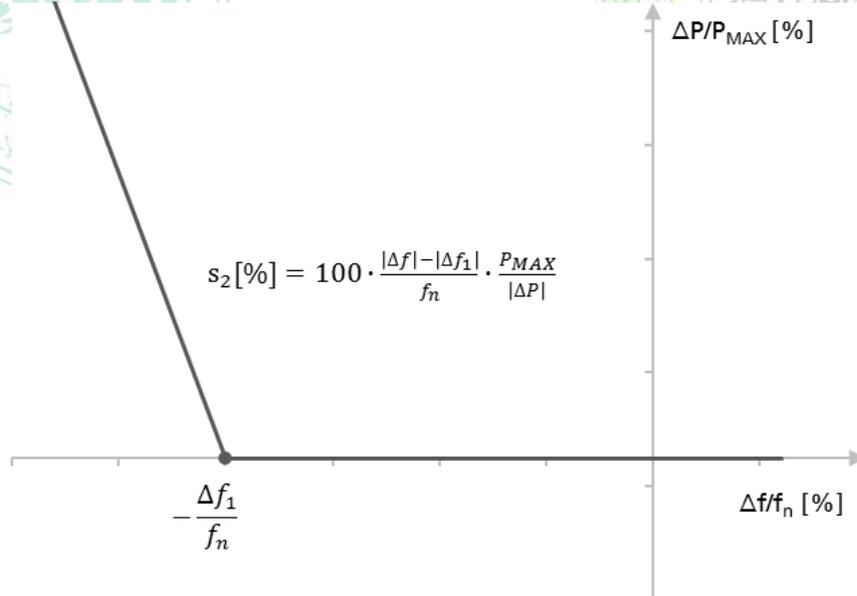


Figure CC 4. Active power frequency response capability of Power-Generating Modules in LFSM-U mode.

CC 5.3.3.3 “ANNEX A – Further specifications on LFSM-O/LFMS-U Calculation” - provides further specifications and an example of the calculation of **LFSM-O** and **LFSM-U**.

CC 5.3.3.4 A **Power-Generating Module** shall be capable of activating the power frequency response as fast as technically feasible with an initial delay that shall not be greater than $\Delta t_{LFSM_activation}$ (a typical value is given in CC 10 ANNEX B – Reference parameters). The **Power-Generating Facility Owner** shall justify larger delay by providing technical evidence to the relevant **TSO**.

CC 5.3.3.5 The **Power-Generating Modules** shall be capable of operating stably during **LFSM-O** and **LFSM-U** operation.

CC 5.3.3.6 With reference to the operation in **LFSM-O** mode:

- a) **Power-Generating Modules** shall be capable of either continuing operation at minimum regulating level when reaching it, or alternatively further decreasing active power output according to the request of the relevant **TSO**.
- b) The **LFSM-O** setpoint will prevail over any other active power setpoints.

CC 5.3.3.7 With reference to the operation in **LFSM-U** mode:

- a) **Power-Generating Modules** shall be capable of providing a power increase up to their maximum capacity.
- b) The actual delivery of active power frequency response shall consider:
 - i. the ambient conditions when the response is to be triggered;
 - ii. the operating conditions of the **Power-Generating Module**, in particular limitations on operation near maximum capacity at low frequencies and the respective impact of ambient conditions according to Article CC 5.3.2; and,
 - iii. the availability of the primary energy sources.

CC 5.3.3.8 **LFSM** operating mode is not required by such **Power-Generating Modules** that do not have the capability of regulating the power output with regards to frequency variations due to technology limitations. Such technology limitations shall be demonstrated by the relevant **Power-Generating Facility Owner**.

CC 5.3.3.9 The relevant **TSOs** within the same **Synchronous Area** shall harmonize the **LFSM modes** settings to minimize unplanned power flow between the interconnected countries in response to a change in system frequency.

CC 5.3.4 *Active Power Response to Normal Frequency Variations*

J. Persistent load imbalances cause an increase in frequency deviation leading to deterioration of system stability and security of **PAEM Electricity System**. **Power-Generating Facilities** are commonly requested to contribute to removing such imbalances.

This requirement defines the capabilities of **Power-Generating Facilities** to control the variation of their active power output in response to normal frequency variations.

CC 5.3.4.1 **Power-Generating Facilities** shall be capable of operating in the **Frequency Sensitive Mode (FSM)**, which determines a variation in the active power output with respect to the programmed value of target active power in response to normal frequency variations of the **Grid**.

CC 5.3.4.2 **FSM** operating mode is not required by such **Power-Generating Modules** that do not have the capability of regulating the power output with regards to frequency variations due to technology limitations. Such technology limitations shall be demonstrated by the relevant **Power-Generating Facility Owner**. Nevertheless, the connection of **Power-Generating Modules** with technology limitation to provide **FSM** shall be evaluated case-by-case by the relevant **TSO**, especially when the lack of **FSM** for a **Module** may be critical for the purpose of maintaining the stability of the **Transmission System** in case of a contingency.

CC 5.3.4.3 The relevant **TSO** shall define the parameters that characterize the **FSM** in accordance with Figure CC 5, considering that:

- a) In case of overfrequency, the active power frequency response is limited by the minimum regulating level of the **Power Generation Module**.
- b) In case of underfrequency, the active power frequency response is limited by the maximum active power output (P_{MAX}) of the **Power Generation Module**.
- c) ΔP is the variation in the active power production of the **Power Generation Module**. f_n is the nominal frequency of the **Grid** and Δf is the frequency deviation in the **Grid**.
- d) In case of frequency variation higher than the **Frequency Response Deadband**, the contribution of active power not supplied must be recovered according to a scheme similar to the one shown in Figure CC 5.
- e) The actual delivery of active power frequency response shall consider:
 - i. the ambient conditions when the response is to be triggered;
 - ii. the operating conditions of the **Power-Generating Module**, in particular limitations on operation near maximum capacity at low frequencies and the respective impact of ambient conditions according to Article CC 5.3.2; and,
 - iii. the availability of the primary energy sources.

CC 5.3.4.4 Typical values for the parameters that characterize the FSM are given in CC 10 ANNEX B – Reference parameters.

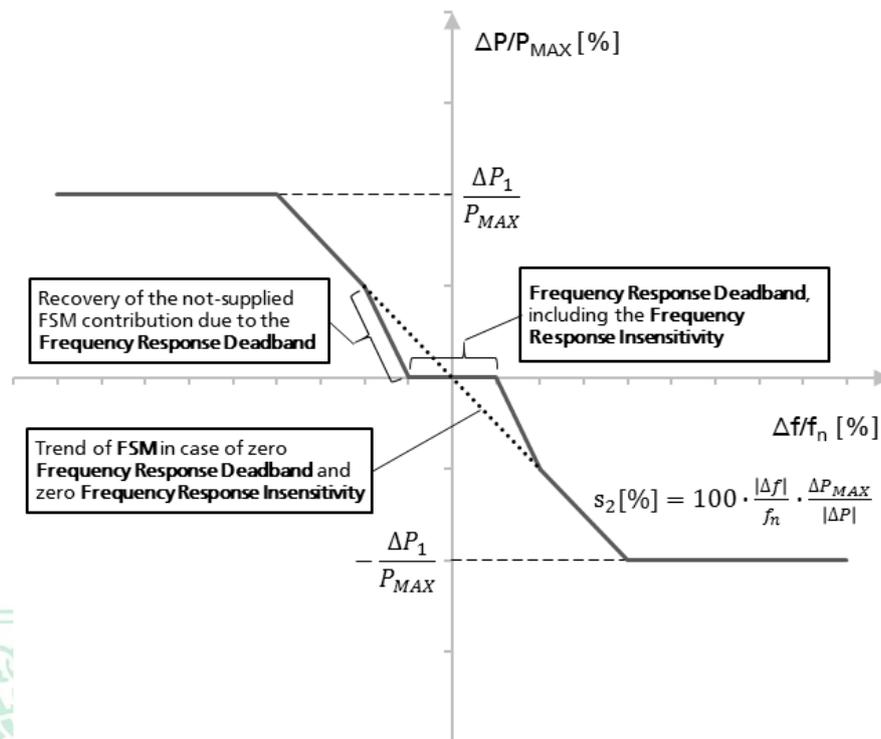


Figure CC 5. Active power frequency response capability of Power-Generating Modules in FSM. The figure represents the changes in active power output that a Power-Generating Module shall be capable of provide according to frequency variations. The Power-Generating Module shall be irresponsive to frequency variations in the range of the Deadband. For frequency deviations larger than the Deadband the Power-Generating Module shall reduce (over-frequency) or increase (under-frequency) the active power charge according to the given droop. The relevant TSO can specify settings of the droop in order to recover not-supplied FSM contribution due to the Deadband.

CC 5.3.4.5 The relevant **TSO** shall define the period during which the **Power-Generating Module** shall be capable of providing full active power frequency response. In specifying the period, the relevant **TSO** shall consider the active power headroom and primary energy source of the **Power-Generating Module**.

CC 5.3.4.6 In the event of frequency step changes, the **FSM** mode shall be activated by the **Power-Generating Module** according to a curve above or at most in correspondence with the line shown in Figure CC 6 and in accordance with the parameters specified by the relevant **TSO** based on the technology-dependent limitations of the **Power-Generating Modules**. Typical values of the parameters are given in CC 10 ANNEX B – Reference parameters.

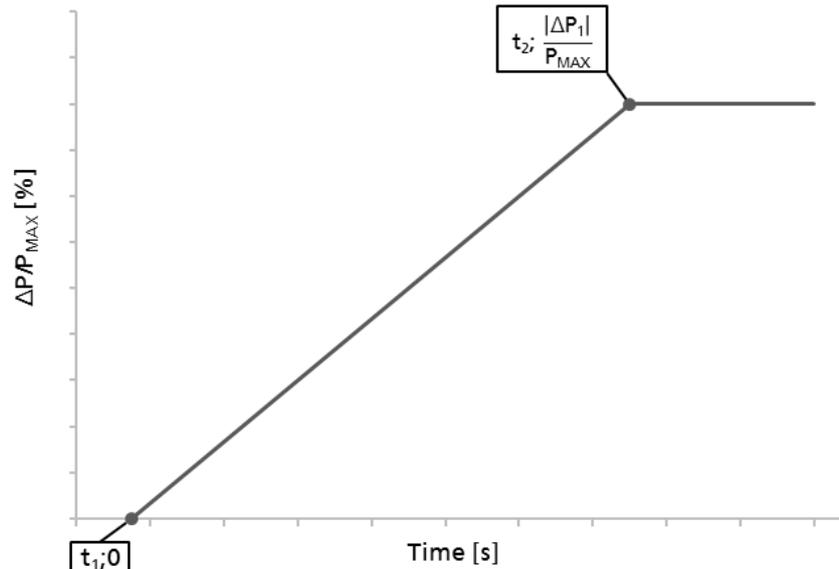


Figure CC 6. Active power frequency response capability.

CC 5.3.4.7 In order to monitor the operation of **FSM**, the **Power-Generating Modules** shall be capable of transferring, in real-time and in a secured manner, at least the following signals to the **National Control Center** of the relevant **TSO**:

- a) status signal of **FSM** (on/off);
- b) scheduled active power output;
- c) actual value of the active power output;
- d) actual parameter settings for active power frequency response; and,
- e) droop and **Frequency Response Deadband**.

CC 5.3.4.8 The relevant **TSOs** within the same **Synchronous Area** shall harmonize the **FSM modes** settings to minimize unplanned power flow between the interconnected countries in response to a change in system frequency.

CC 5.3.5 *Secondary Control*

J. Restoring frequency to the nominal value while releasing reserves activated due to frequency deviations and adjusting cross-border **Energy Exchanges** to target values needs dedicated capabilities from **Power-Generating Facilities**. These requirements need to be coordinated with system **Operation** provisions.

CC 5.3.5.1 The relevant **TSO** defines the technical requirements of **Power-Generating Modules** for the provision of the system service that aims at restoring the frequency to its nominal value and at maintaining the cross-border **Scheduled Energy Exchanges** of a **Synchronous Area**.

CC 5.3.5.2 The relevant **TSOs** of the same **Synchronous Area** shall harmonize the requirements of **Secondary Control** functionalities for **Power-Generating Modules**.

CC 5.3.6 *Synthetic Inertia for Inverter-based Generation*

J. Inverter-based Power-Generating Facilities do not have an inherent capability to resist / slow down frequency changes. This will result in larger **Rate of Change of Frequency** during high energy production from inverter-based **Power-Generating Facilities** and, hence, lead to possible system stability and security issues of the **PAEM Electricity System**. This requirement takes counter measures by introducing, for inverter-based **Power-Generating Facilities**, the capability of providing **Synthetic Inertia** during very fast frequency deviations.

CC 5.3.6.1 The relevant **TSO** shall have the right to specify that **Inverter-based Power-Generating Modules** shall be capable of providing **Synthetic Inertia** during very fast frequency deviations upon request from the relevant **TSO**.

CC 5.3.6.2 The relevant **TSO** shall specify the operating principle of control systems installed to provide **Synthetic Inertia** and the associated performance parameters. Point c) in Chapter CC 10 ANNEX B – Reference parameters , provide element to deal with of this type requirements to be fully developed by the relevant **TSO**.

CC 5.4 **Stability and Control of the System Voltage**

CC 5.4.1 *Reactive Power Capability*

J. Reactive power is a key component in terms for voltage stability, and fundamental for cross-border power trading. Although the influence of **Power-Generating Facilities** on overall system voltage stability varies with location, harmonizing reactive power capabilities contributes to secure planning and operation of the **Integrated Power Systems** within the same **Synchronous Area**.

CC 5.4.1.1 The relevant **TSO** shall specify reactive power capability at maximum capacity and reactive power capability below maximum capacity.

CC 5.4.1.2 *Reactive power capability at maximum capacity*

CC 5.4.1.3 With regards to reactive power capability at maximum capacity, the relevant **TSO** shall identify the $U-Q/P_{MAX}$ -profile, which identifies the boundaries within which a **Power-Generating Module** shall be capable of providing reactive power at its maximum capacity. The $U-Q/P_{MAX}$ -profile shall be

defined according to the following principles and in consistence with Figure CC 7:

- a) the dimensions of the U-Q/P_{MAX}-profile envelope shall be within the Q/P_{MAX} range and voltage range specified by the relevant TSO.
- b) the position of the U-Q/P_{MAX}-profile envelope shall be within the limits of a fixed outer envelope to be defined by the relevant TSO.
- c) the relevant TSO shall define the above-mentioned profiles for (i) **Synchronous Power-Generating Modules** and (ii) **Inverter-based Power-Generating Modules**.

CC 5.4.1.4 The relevant TSOs within the same **Synchronous Area** shall harmonize the dimensions of the inner and outer envelopes. Typical values for the outer envelope, Q/P_{MAX} range and voltage range of the U-Q/P_{MAX}-profile envelope of **Synchronous Power-Generating Modules** and **Inverter-based Power-Generating Modules** are given in CC 10 ANNEX B – Reference parameters.

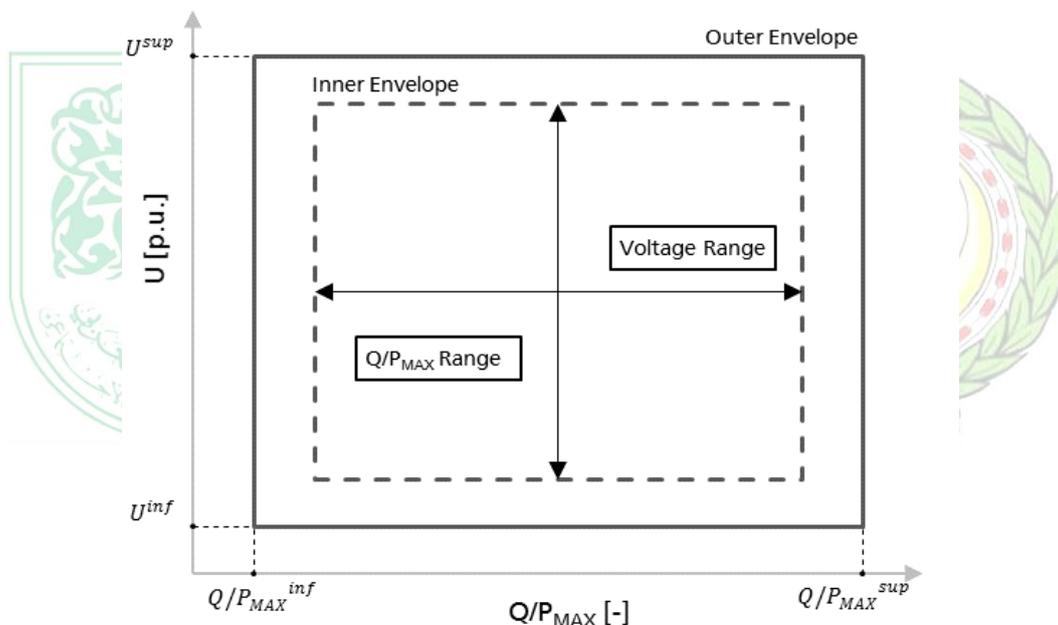


Figure CC 7. U-Q/P_{MAX}-profiles to be defined by the relevant TSO.

CC 5.4.1.5 A **Power-Generating Module** shall be capable of moving to any operating point on the surface within its U-Q/P_{MAX} profile in appropriate timescales to target values requested by the relevant TSO.

CC 5.4.1.6 *Reactive power capability below maximum capacity*

CC 5.4.1.7 **Synchronous Power-Generating Modules** shall be capable of operating at every possible operating point in the P-Q-capability diagram of the alternator of **Synchronous Power-Generating Modules**, at least down to a

minimum stable operating level when operating at an active power output below the maximum capacity ($P < P_{MAX}$).

CC 5.4.1.8 With regards to **Inverter-based Power-Generating Modules**, the relevant **TSO** shall define a **P-Q/ P_{MAX} -profile**, which identifies the boundaries within which an **Inverter-based Power-Generating Module** shall be capable of providing reactive power below its maximum capacity. The **P-Q/ P_{MAX} -profile** shall be defined according to the following principles and in consistence with Figure CC 8:

- the dimensions of the **P-Q/ P_{MAX} -profile** envelope shall be within the **Q/P_{MAX}** range specified by the relevant **TSO**.
- the active power range of the **P-Q/ P_{MAX} -profile** envelope at zero reactive power shall be 1 pu.
- the **P-Q/ P_{MAX} -profile** can be of any shape and shall include conditions for reactive power capability at zero active power.
- the position of the **P-Q/ P_{MAX} -profile** envelope shall be within the limits of a fixed outer envelope to be defined by the relevant **TSO**.

CC 5.4.1.9 The relevant **TSOs** of the same **Synchronous Area** shall harmonize the dimensions of the inner and outer envelopes. Typical values for the **Q/P_{MAX}** range and voltage range of the **U-Q/ P_{MAX} -profile** envelope for **Inverter-based Power-Generating Modules** are given in CC 10 ANNEX B – Reference parameters.

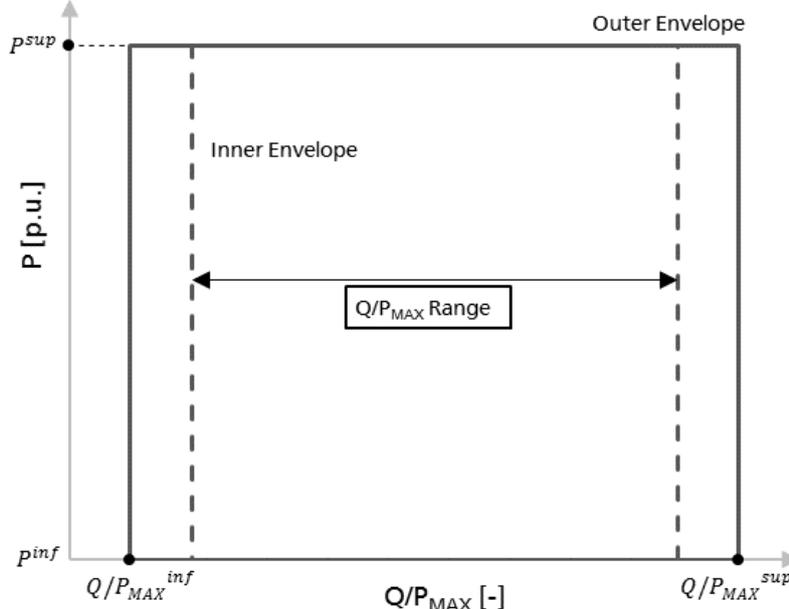


Figure CC 8. **P-Q/ P_{MAX} -profile** to be defined by the relevant **TSO** for **Inverter-based Power-Generating Modules**.

CC 5.4.1.10 When operating at an active power output below maximum capacity ($P < P_{MAX}$), the **Inverter-based Power-Generating Module** shall be capable of providing reactive power at any operating point inside its P-Q/ P_{MAX} -profile.

CC 5.4.1.11 An **Inverter-based Power-Generating Module** shall be capable of moving to any operating point on the surface within its U-Q/ P_{MAX} profile in appropriate timescales to target values requested by the relevant **TSO**.

CC 5.4.1.12 *Reactive power compensation*

CC 5.4.1.13 Where there is a line or a connection cable between the **Connection Point** of the **Power-Generating Facility** and the high-voltage terminals of the step-up transformer, if requested by the relevant **TSO**, the **Power-Generating Facility Owner** shall compensate the reactive power **Demand** of the line or cable.

CC 5.4.2 *Voltage Control Modes*

J. The absence of voltage control for **Power-Generating Modules** can lead to voltage instability which can spread to neighboring **Electricity Systems** and become a cross-border issue.

CC 5.4.2.1 **Synchronous Power-Generating Modules** shall be equipped with an excitation control system – namely the **Automatic Voltage Regulator (AVR)** – that can provide constant alternator terminal voltage at a selectable setpoint without instability over the entire operating range of the **Module**.

CC 5.4.2.2 The parameters and settings of the **AVR** shall be agreed upon by the synchronous **Power-Generating Facility Owner** and the relevant **TSO**. These shall include:

- a) bandwidth limitation of the output signal;
- b) under- and over-excitation limiter;
- c) a stator current limiter;
- d) a **PSS** function to attenuate power oscillations, which includes the specifications on the damping coefficients to be harmonized through dedicated power system studies within the same **Synchronous Area**.

CC 5.4.2.3 **Inverter-based Power-Generating Modules** shall contribute to the voltage control. The following control modes shall be implemented:

- a) Voltage control mode:
 - i. the **Module** shall be capable of contributing to voltage control at the **Connection Point** by providing reactive power exchange with

the **Transmission System** with a setpoint voltage covering a range $[U_{REG_MIN}; U_{REG_MAX}]$ in steps no greater than ΔU_{REG} defined by the relevant **TSO**. Typical values for U_{REG_MIN} , U_{REG_MAX} and ΔU_{REG} are given in CC 10 ANNEX B – Reference parameters.

- ii. The reactive power output shall be zero when the voltage value of the **Transmission System** at the **Connection Point** equals the voltage setpoint.
- iii. The setpoint may be operated with or without a deadband selectable in a range defined by the relevant **TSO**.
- iv. Achieving 90% and 100% of the change in reactive power output requested by the relevant **TSO** within time $t_{REG_90\%}$ and $t_{REG_100\%}$, respectively, to be specified by the relevant **TSO**, with an accuracy of 5% of the value of the maximum reactive power that can be delivered by the **Module**. Typical values of $t_{REG_90\%}$ and $t_{REG_100\%}$ lie within the ranges given in CC 10 ANNEX B – Reference parameters.

b) Reactive power control mode:

- i. The **Module** shall be capable of setting the reactive power setpoint anywhere in the given reactive power range, with setting steps defined by the relevant **TSO**, by controlling the reactive power at the **Connection Point** to an accuracy defined by the relevant **TSO**. Typical steps and typical accuracy are given in CC 10 ANNEX B – Reference parameters.

c) Power factor control mode:

For the purpose of power factor control mode, the **Modules** shall be capable of controlling the power factor at the **Connection Point** within the required reactive power range, specified by the relevant **TSO** according to Article CC 5.4.1.2 for **Inverter-based Power-Generating Modules**, with a target power factor in steps no greater than ΔU_{REG} . The relevant system operator shall specify the target power factor value, its tolerance and the period of time to achieve the target power factor following a sudden change of active power output. The tolerance of the target power factor shall be expressed through the tolerance of its corresponding reactive power. This reactive power tolerance shall be expressed by either an absolute value or by a percentage of the maximum reactive power of the **Inverter-based Power-Generating Modules**.

CC 5.4.2.4 The relevant **TSO** shall define the principles and performance for the switching between the two modes, as well as the modes and procedures for communicating the voltage reference values.

CC 5.4.3 *Short Circuit Contribution During Faults for Inverter-based Generation*

J. This requirement is critical to both restoring voltage immediately after faults and injecting enough current quickly enough for system protections to function reliably.

CC 5.4.3.1 The relevant **TSO** shall have the right to specify that **Inverter-based Power-Generating Modules** shall be capable of providing **Fast Fault Current** at the **Connection Point** in case of balanced (3-phase) and unbalanced (1-phase or 2-phase) faults.

CC 5.4.3.2 The relevant **TSO** shall have the right to define the requirements for **Fast Fault Current**. These shall consider: (i) how and when a voltage deviation is to be determined; (ii) the characteristics of the **Fast Fault Current**; and (iii) the timing and accuracy of the **Fast Fault Current**. Point c) in Chapter CC 10 ANNEX B – Reference parameters provide element to deal with this type requirements to be fully developed by the relevant **TSO**.

CC 5.5 Management of the Electricity System

CC 5.5.1 *Synchronization and Re-synchronization*

J. Conditions for Power-Generating Modules to connect and inject power to the **Grid** after intentional operation interruptions or disconnections due to protection system intervention need to be defined in order to avoid the risk of instability of the **Modules** or negative effects on the security of the **PEAM Electricity System**. Specific conditions can be considered for the **Modules** that are necessary to restore normal operating conditions following disturbances.

CC 5.5.1.1 The entry into service of a **Power-Generating Module**, after an intentional shutdown or following the intervention of the protection system, is allowed only under the following conditions:

- a) authorization given by the relevant **TSO**;
- b) operating frequency and voltage at the **Connection Point** within the ranges specified in Section CC 5.1.

CC 5.5.1.2 The **Module** shall be equipped with synchronization devices. Related settings shall be agreed to by the relevant **TSO** and the **Power-Generating Facility Owner**. They shall include: voltage, frequency, phase angle range, phase sequence, and deviation of voltage and frequency.

CC 5.5.1.3 Once connected to the **Grid**, the **Power-Generating Module** can gradually increase its power output up to the target value in accordance with the gradient agreed to by the relevant **TSO**.

CC 5.5.2 *Ramping Limits*

J. Changes of target active power output must exhibit suitable ramping characteristics (i.e. rate of change of active power) since too fast or too slow of a variation may lead to degradation of the quality of the frequency control service.

CC 5.5.2.1 The rates of change of active power output (ramping limits) for a **Power-Generating Module** shall be controlled in both up and down directions. The value of the minimum and maximum ramping limits shall be agreed upon with the relevant **TSO** considering the specific characteristics of the **Power-Generating Module**, the prime mover technology, and the primary energy resource.

CC 5.5.2.2 Typical values of the ramping limits fall within the range given in CC 10 ANNEX B – Reference parameters.

CC 5.5.2.3 The relevant **TSOs** of the same **Synchronous Area** shall harmonize the requirements on the ramping limits.

CC 5.5.3 *Protection Systems*

J. Proper protection of the **Transmission System** is essential for maintaining stability and security of the **PAEM Electricity System**. Protection schemes shall not aggravate disturbances but limit their consequences within the same **Synchronous Area**.

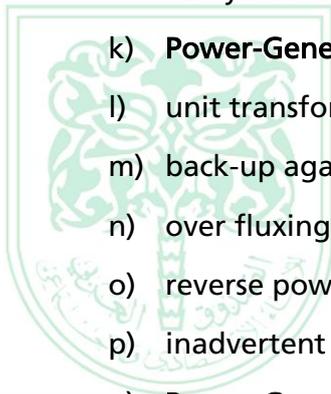
CC 5.5.3.1 The requirements stated in this Article CC 5.5.3 are in addition to the general requirements on the protection already described in Section CC 4.5.

CC 5.5.3.2 The protection schemes needed for protecting the **Grid** shall be specified by the relevant **TSO**, considering the characteristics of the **Module**. The definition of and any change to protection schemes needed for protecting the **Power-Generating Module** and the **Grid** as well as the settings relevant to the **Module** shall be coordinated and agreed to by the relevant **TSO** and the **Power-Generating Facility Owner**. They are reported in the **Operating Regulation Document**.

CC 5.5.3.3 The protection system of a **Power-Generating Module** has priority over operational controls, considering the security of the **Grid** as well as the health and safety of the working personnel and citizens and limiting any potential damage to the **Module**.

CC 5.5.3.4 With reference to internal electrical faults, the protection schemes and settings shall include the following protection (referring available international standards are given in CC 10 ANNEX B – Reference parameters):

- a) external and internal short circuit;
- b) unbalanced load (negative phase sequence);
- c) stator and rotor overload;
- d) over-/under-excitation;
- e) over/under-voltage at the **Connection Point**;
- f) over/under-voltage at the alternator terminals;
- g) inter-area oscillations;
- h) inrush current;
- i) asynchronous operation (pole slip);
- j) protection against inadmissible shaft torsions (for example, subsynchronous resonance);
- k) **Power-Generating Module** line protection;
- l) unit transformer protection;
- m) back-up against protection and switchgear malfunction;
- n) over fluxing (U/f);
- o) reverse power;
- p) inadvertent energizing;
- q) **Power-Generating Module** load unbalance;
- r) rotor earth fault
- s) **Power-Generating Module** stator temperature;
- t) excitation fault;
- u) **Power-Generating Module** rotor vibration;
- v) fault in the **Power-Generating Module** cooling temperature;
- w) rate of change of frequency withstand capability; and,
- x) neutral voltage displacement.



CC 5.5.3.5 With reference to external electrical faults, a **Power-Generating Module** shall be equipped with a protection system capable of separating it from the **Grid** if the external fault cannot be correctly eliminated by **Grid** protection. The schemes and settings shall therefore be coordinated with those of **Grid** protection and are, therefore, established by the relevant **TSO**.

CC 5.5.4 *Control Systems*

J. Control systems are defined individually for **Power-Generating Modules**. Nevertheless, harmonization of the principles and methodology, especially for disturbed system operating conditions, are crucial for guaranteeing the stability of the **PAEM Electricity System**.

CC 5.5.4.1 The schemes and settings of the different control devices of a **Power-Generating Module** shall be coordinated and agreed upon by the relevant **TSO** and the **Power-Generating Facility Owner**. They are reported in the **Operating Regulation Document**.

CC 5.5.4.2 Any changes to the schemes and settings subsequent to the phase of first connection shall be agreed upon with the relevant **TSO**.

CC 5.5.5 *Priority Ranking of Control and Protection Actions*

J. The definition of a ranking is recommended to specify which capabilities shall take precedence (i.e. avoid conflicts) when designing the protection and control schemes of **Power-Generating Modules**. Harmonizing the ranking among the **Member States** is important for achieving a common basis for operational strategies to ensure secure operation of the **PAEM Electricity System**.

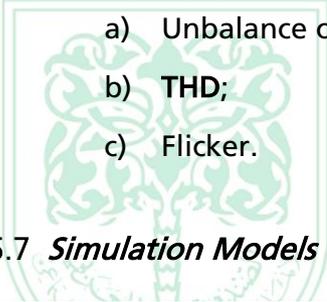
CC 5.5.5.1 The **Power-Generating Facility Owner** shall organize the protection and the control devices of its **Power-Generating Facility** in accordance with the following priority ranking (from highest to lowest):

- a) Grid and Power-Generating Module protection;
- b) **Synthetic Inertia**, where applicable;
- c) frequency control;
- d) power limitation; and,
- e) ramping limits.

CC 5.5.6 *Power Quality*

J. Harmonization of requirements regarding potential disturbances in the electric power supplied by **Power-Generating Modules** contributes to guaranteeing targeted quality of the supply within the **PAEM Electricity System**.

- CC 5.5.6.1 The **Power-Generating Facility Owner** shall provide all the data related to causing disturbances. Based on this data, the relevant **TSO** shall evaluate the effects on the **Grid**, considering the minimum **Short-Circuit Power** on the **Grid** itself.
- CC 5.5.6.2 The maximum levels of emission of disturbances granted to the single **Power-Generating Facility** which connects to the **Grid**, or which intends to make significant modifications to the already existing **Power-Generating Facility** are set by the relevant **TSO**.
- CC 5.5.6.3 Depending on the connection site and **Grid** conditions, the relevant **TSO** has the right, at a later stage, to request that the **Power-Generating Facility Owner** install additional compensation systems in order to guarantee the achievement of target quality standards.
- CC 5.5.6.4 The criteria for the evaluation of the emission limits shall include (refer to Section CC 2.4):

- 
- a) Unbalance of the three-phase voltage;
 - b) THD;
 - c) Flicker.
- 

CC 5.5.7 *Simulation Models*

J. Power system studies are performed by the relevant **TSOs** at different stages of their evaluations (e.g. planning, operational planning, real-time operations). Dedicated provisions define a common set of simulation models and related features that the relevant **TSO** require to implement and update interconnected power system models.

- CC 5.5.7.1 At the request of the relevant **TSO**, a **Power-Generating Facility Owner** shall provide simulation models for its **Power-Generating Modules** with a level of detail adequate to reflect the behavior of the **Module** in:
- a) steady-state simulation;
 - b) electromechanical simulation; and,
 - c) electromagnetic transient simulation.
- CC 5.5.7.2 The request of the relevant **TSO** shall include:
- a) the specification of the format in which models are to be provided by the **Power-Generating Facility Owner**;
 - b) the provision of documentation on a model's structure and its block diagrams;

- c) an estimate of the minimum and maximum short circuit capacity at the Connection Point as a simplified equivalent of the Transmission System;
- d) the parameterizations and limitations of the model; and,
- e) the specific sub-models of the components.

CC 5.5.7.3 Upon request of the relevant **TSO**, the **Power-Generating Facility Owner** shall provide measurement recordings of the **Module's** performance in order to compare the response of the models with those recordings.

CC 5.6 Management of Emergency Situations

CC 5.6.1 *Black Start*

J. Black Start Service is needed from an appropriate number of **Power-generating Facilities** to restore an **Electricity System** to a stable condition following major critical disturbance. Harmonization of this requirement for the **PAEM Electricity System** may be given in principle since details pertain to each single **TSO**.

CC 5.6.1.1 The **Power-Generating Module with Black Start Capability** shall meet the following requirements:

- a) Be capable of starting from shutdown without any external electrical energy supply within the maximum time agreed with the relevant **TSO**.
- b) With reference to frequency:
 - i. be able to synchronize within the limits defined in Article CC 5.1.1;
 - ii. be capable of operating in **LFSM-O** and **LFSM-U**, as specified in Article CC 5.3.3; and,
 - iii. be capable of controlling frequency in case of over-frequency and under-frequency within the whole active power output range between minimum regulating level and maximum power, as well as at such level to continue to supply the in-house loads.
- c) With reference to voltage:
 - i. be able to synchronize within the limits defined in Article CC 5.1.2;
 - ii. be capable of automatically regulating dips in voltage caused by connection of **Demand Facilities**; and,
 - iii. control voltage automatically during the restoration phase of the **Grid**.
- d) Be capable of operating in parallel with other **Power-Generating Modules** within an **Island**.

CC 5.6.2 *Load-Rejection and Quick Re-Synchronization*

J. These capabilities are required to contribute to the restoration of an **Electricity System** after major disturbances. Its absence could lead to cross-border consequences on the **PAEM Electricity System** with large disturbances and inadequate capability for fast restoration (with unequal burden sharing).

CC 5.6.2.1 In case of disconnection from the **Grid**, **Power-Generating Modules** shall be capable of performing the re-synchronization in line with the protection strategy agreed upon by the relevant **TSO** and the **Power-Generating Facility**.

CC 5.6.2.2 If the time for re-synchronization is greater than a threshold $t_{\text{re-synchronization}}$ defined and harmonized among the **TSOs** of the same **Synchronous Area**, the **Power-Generating Module** shall be capable of operating in **Load-rejection** and therefore trip to house load from any operating point in its P-Q-capability diagram. The identification of the operation in **Load-rejection** shall not be based exclusively on the switchgear position signals of the relevant **TSO**, but also on actual measures of the power production of the **Power-Generating Module**.

CC 5.6.2.3 A typical value of $t_{\text{re-synchronization}}$, based on international **Best Utilities Practices** is given in CC 10 ANNEX B – Reference parameters.

CC 5.6.2.4 **Power-Generating Modules** shall be capable of continuing operation in **Load-rejection**, regardless of any auxiliary connection to the **Grid**. The minimum time of operation in **Load-rejection** shall be specified by the relevant **TSO**, taking into consideration the specific characteristics of prime mover technology.

CC 5.6.3 *Remote control for Defense Plan Participation*

J. Critical situations in a **Grid**, which can in turn propagate to the whole **Synchronous Area**, require **TSOs** to have the possibility to remotely instruct **Power-Generating Modules** for specific actions as part of a national **Defense Plan**.

CC 5.6.3.1 **Power-Generating Facility Owners** may be requested by the relevant **TSO** to install remote monitoring and control devices in their **Modules** to provide special functions for preserving or restoring secure system operation. The relevant **TSOs** shall provide the functional and technical characteristics of such additional devices.

CC 5.7 Monitoring and Information Exchange

J. Having adequate and harmonized monitoring and information exchange procedures between the **Power-Generating Facility Owners** and the relevant **TSO** is a prerequisite for appropriate system operation as well as for appropriate operation of the **PAEM Electricity System** and to facilitate the resolution of cross-border issues.

CC 5.7.1 **Power-Generating Facilities** shall be capable of monitoring the operation of, and exchanging information with, the relevant **TSO** in accordance with the different specifications and purposes.

a) Real-time monitoring:

The facility shall be integrated in the control and operations procedures in real-time of the **Grid** by the relevant **TSO**. Accordingly, dedicated equipment (**RTU**) can be requested by the relevant **TSO** to be implemented by the **Power-Generating Facility Owner** to perform remote control, remote monitoring, and remote operations actions. The technical specifications of the **RTU** shall be defined by the relevant **TSO**.

b) Fault recording and monitoring:

To provide recording and monitoring of dynamic system behavior during faults, **Power-Generating Facilities** shall be equipped with dedicated equipment which meets the following requirements:

- i. the capability to record (i) voltage, (ii) current, (iii) active power, (iv) reactive power, and (v) frequency;
- ii. the technical characteristics agreed upon by the **Power-Generating Facility Owner** and the relevant **TSO**.

c) Information exchange for quick return into service:

Following an outage, the **Power-Generating Facility Owner** shall notify the relevant **TSO** about:

- i. the availability of the facility excluded during the outage, the causes that led to the disconnection and those that prevented its return into service;
- ii. the time needed to return into service;
- iii. the recordings of the fault or disturbance which caused the outage.

d) Information exchange for fault reconstruction:

To the purpose of fault reconstruction, the **Power-Generating Facility Owner** shall provide the relevant **TSO** with the following:

- i. the recordings detected by disturbance recorders;
- ii. recordings of electromagnetic transients;
- iii. recordings of local signals.

CC 5.7.2 The detailed list of data and information with respective specifications, and the exchange methods for the above-mentioned elements, are agreed upon by the

Power-Generating Facility Owners and the relevant **TSO**, and they are reported, for each **Power-Generating Facility**, in the **Operating Regulation Document**.

CC 5.8 Compliance Monitoring

J. Requirements that cover compliance procedures are fundamental to establishing procedures in a transparent and non-discriminatory manner across the **PAEM Electricity System**. This contributes to a more competitive market for the electricity sector of the **Member States**.

CC 5.8.1 The **Power-Generating Facility Owner** shall ensure that each **Module** complies with the requirements of this chapter for its entire life.

CC 5.8.2 The relevant **TSO** shall evaluate the compliance of the **Module** and shall keep the **Power-Generating Facility Owner** informed about the outcome of the compliance assessments that shall include:

- a) Information and documentations provided by the **Power-Generating Facility Owner** to the relevant **TSO**;
- b) Verification and compliance tests executed by the relevant **TSO**;
- c) Compliance simulations.

CC 5.8.3 In addition, the **TSO** can consider self-certification tests executed by the **Power-Generating Facility Owner**. The **TSO** shall define the procedures for self-certification tests.

CC 5.8.4 *Information and Documentation*

CC 5.8.4.1 The **Power-Generating Facility Owners** shall provide the relevant **TSO** with information and documents that describe the characteristics of the **Modules** within the **Power-Generating Facility**.

CC 5.8.4.2 The list shall be harmonized by the relevant **TSOs** within the same synchronous area and shall at least include the followings:

- a) General information about the **Facility**;
- b) Primary energy source, energy conversion process, module and facility efficiency;
- c) the technical constraints related to the conversion process which limit the performance of the **Module**, and any environmental constraints;
- d) the main characteristics for identifying flexibility in operation;

- e) the characteristics of the module and facility necessary to characterize the electrical behavior. These are the characteristics needed to perform static and dynamic calculations;
- f) the characteristics of the control systems and the capability curves. These are needed to characterize the capacity for providing system services;
- g) data on failure rates;
- h) the ability to provide emergency operations related capabilities.

CC 5.8.4.3 The **Power-Generating Facility Owner** shall provide the necessary information and documents to the relevant **TSO**:

- a) at the time of connection request in accordance with Chapter CC 3;
- b) following changes to the technical data of the **Modules** resulting from changes in the technical capabilities or operational accidents or faults;
- c) whenever requested by the relevant **TSO**.

CC 5.8.5 ***Verification and Compliance Tests Executed by the Relevant TSO***

CC 5.8.5.1 The relevant **TSO** shall execute verification and compliance tests to ascertain the validity of the declarations issued by the **Power-Generating Facility Owner** and the compliance with the requirements set in this **Code**.

CC 5.8.5.2 The relevant **TSO** communicates the annual plan for the implementation of the verification and compliance tests and the results of the same. In consideration of the importance that the controlling systems and the relative parameters, the **TSO** has the right to execute tests on their functionality at any time.

CC 5.8.5.3 The relevant **TSO** shall define the standard procedures for executing the tests differentiating between synchronous and inverter-based **Power-Generating Modules**. At a minimum, the procedures shall include the followings:

- a) the level and control functions of the active and reactive power injected into the **Grid**;
- b) the performance of systems for frequency and voltage control in emergency conditions;
- c) the functions of automatic disconnection of the **Modules**;
- d) the requirements pertaining to capabilities and actions required during emergency operation and restoration actions;

- e) the functionality of the protection devices which need to coordinate with the protection devices installed on the **Grid**.

CC 5.8.6 *Compliance Simulations*

CC 5.8.6.1 In addition to the verification of the information and the compliance tests as per the above paragraphs, the **TSO** can assess the compliance of a **Power-Generating Facility** with the requirements set forth in this **Connection Code**, and by relying on the simulations of the performance of **Power-Generating Facility** carried out by the **Power-Generating Facility Owner** using the simulation models referred to in Article CC 5.5.7.



CC 6 REQUIREMENTS FOR HIGH-VOLTAGE DIRECT CURRENT SYSTEMS

CC 6.1.1 The requirements of Chapter CC 6 apply to:

- a) **HVDC Systems** connecting **Synchronous Areas** or **Control Areas**, including back-to-back schemes;
- b) **HVDC Systems** connecting Invert-based **Power-Generating Modules** to a **Transmission Network**;
- c) Embedded **HVDC Systems** within one **Control Area** and connected to the **Transmission Network**; and
- d) Embedded **HVDC Systems** within one **Control Area** and connected to the **Distribution Network** when the relevant **TSO** demonstrates a cross-border impact. The relevant **TSO** shall consider the long-term development of the **Network** in this assessment.

CC 6.2 Operating Ranges

CC 6.2.1 *Frequency Ranges*

J. In an interconnected **Electricity System**, frequency is the parameter with the largest cross-border impact, since deviations from its nominal value occur everywhere at the same time and affect all **Power-Generating Modules** regardless of voltage levels. For this reason, harmonized frequency ranges are fundamental, especially the range for unlimited operation which needs to be identical for sharing the burden of deviations equally.

CC 6.2.1.1 **HVDC Systems** shall be designed, built and operated to remain connected to the **Transmission System** within the frequency ranges and minimum time periods specified by the relevant **TSO** – if the **HVDC System** is embedded in the **Grid** – or by the relevant neighboring **TSOs** – if the **HVDC System** interconnects two or more **Grids** – according to the following scheme, which is also presented in Table CC 3:

- a) For an **HVDC System** within the same **Synchronous Area** or connecting two or more asynchronous **Transmission Systems** operating at the same frequency:
 - i. a range around the nominal frequency of the **Synchronous Area** or of the connected asynchronous **Transmission Systems** with unlimited time period of operation;
 - ii. at least one range with frequency below the nominal frequency of the **Synchronous Area** or of the connected asynchronous **Transmission Systems** with limited time period for operation to be specified by the relevant **TSO(s)**;
 - iii. at least one range with frequency above the nominal frequency of the **Synchronous Area** or of the connected asynchronous

Transmission Systems with limited time period for operation to be specified by the relevant **TSO(s)**.

- b) For an **HVDC System** connecting two or more asynchronous **Transmission Systems** operating at different frequencies, the ranges and minimum time periods shall be defined at the **Connection Point** of each terminal of the **HVDC System**:
- i. a range around the nominal frequency of the **Transmission System** connected to the terminals of the **HVDC System** with unlimited time period of operation;
 - ii. at least one range with frequency below the nominal frequency of the **Transmission System** connected to the terminal of the **HVDC System** with limited time period for operation to be specified by the relevant **TSO(s)**;
 - iii. at least one range with frequency above the nominal frequency of the **Transmission System** connected to the terminal of the **HVDC System** with limited time period for operation to be specified by the relevant **TSO(s)**.

CC 6.2.1.2 The frequency ranges are considered at the **Connection Point**.

CC 6.2.1.3 In defining frequency ranges and time periods, the relevant **TSO(s)** shall consider the applicable international standards for products on frequency-related capabilities.

CC 6.2.1.4 The relevant **TSO** and the **HVDC System 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 **HVDC System**, if it is needed to preserve or to restore **Grid** security. The **HVDC System Owner** shall not unreasonably withhold consent to such request(s) if economically and technically feasible.

Table CC 3. Minimum time periods for which an HVDC System must be capable of operating for frequency deviating from the nominal value without disconnecting from the Transmission System.

			Frequency range	Time period for operation
a)	same f at all the terminals of the HVDC System	i.	$F_{f_{low2}}$ Hz – $F_{f_{low1}}$ Hz	To be specified in minutes by the relevant TSO(s)
		ii.	$F_{f_{low1}}$ Hz – $F_{f_{high1}}$ Hz	Unlimited
		iii.	$F_{f_{high1}}$ Hz – $F_{f_{high2}}$ Hz	To be specified in minutes by the relevant TSO(s)
b)	different f at the terminals of the HVDC System	i.	same as above but each range and minimum time period is defined for each terminal of the HVDC System by the relevant TSO in accordance with the f of its Electricity System	
		ii.		
		iii.		

CC 6.2.1.5 Frequency ranges and time periods shall be harmonized among **Member States** within the same **Synchronous Area**. Indicative frequency ranges and time periods are given in CC 10 ANNEX B – Reference parameters.

CC 6.2.1.6 **HVDC Systems** shall be capable of automatic disconnection at frequencies specified by the relevant **TSO**.

CC 6.2.2 *Voltage ranges*

J. J. Though voltage is a local parameter, voltage ranges are critical to securing operation of an **Integrated Power System** within a **Synchronous Area**. Lack of coordinated ranges between adjacent interconnected **Grids** would lead to uncertainty in operation, especially when beyond normal state.

CC 6.2.2.1 An **HVDC Converter Station** shall be designed, built and operated to be capable of remaining connected to the **Transmission System** within the ranges of the voltage at the **Connection Point** specified by the relevant **TSO** in accordance with the following scheme, and also represented in Table CC 4:

- a) a range around the base voltage with unlimited time period of operation;
- b) at least one range with voltage above the base value with limited time period for operation to be specified by the relevant **TSO**.

CC 6.2.2.2 Voltage ranges are expressed by ratio of the voltage at the **Connection Point** to the base voltage. The relevant **TSO** can define a different set of voltage ranges and respective time periods according to different voltage base levels. In defining voltage ranges and time periods, the relevant **TSO** shall consider the applicable international standards for products on voltage-related capabilities.

CC 6.2.2.3 The relevant **TSO** and the **HVDC System Owner** may agree on wider voltage ranges, longer minimum times for operation or specific requirements for combined frequency and voltage deviations (simultaneous overvoltage and underfrequency or simultaneous undervoltage and overfrequency) to ensure the best use of the technical capabilities of an **HVDC System**, if it is needed to preserve or to restore **Grid** security. The **HVDC System Owner** shall not unreasonably withhold consent to such request(s) if economically and technically feasible.

Table CC 4. Minimum time periods during which an HVDC System must be capable of operating for voltages deviating from the reference 1 pu value at the Connection Point without disconnecting from the Transmission System.

	Voltage range	Time period for operation
a)	$U_{low1} \text{ pu} - U_{high1} \text{ pu}$	Unlimited
b)	$U_{high1} \text{ pu} - U_{high2} \text{ pu}$	To be specified in minutes by the relevant TSO at the Connection Point

CC 6.2.2.4 Voltage ranges and time periods shall be harmonized among **Member States** within the same **Synchronous Area**. Indicative voltage ranges and time periods are given in CC 10 ANNEX B – Reference parameters.

CC 6.3 Immunity to Grid Disturbances

CC 6.3.1 Fault Ride Through Capability

J. In the case of a fault on the **Transmission System** level, a voltage drop will propagate across large geographical interconnected areas. Failure to ride through faults for **HVDC Converter Stations** can create major system instability with cross-border implications. This requirement defines capability for **HVDC Converter Stations** to be tolerant to such faults.

CC 6.3.1.1 **HVDC Converter Stations** shall be capable of remaining connected to the **Transmission System** and shall continue to operate in a stable manner in the following conditions:

- a) when the actual course of the phase-to-phase voltages at the **Connection Point** during a symmetrical fault is maintained over a **Fault-Ride-Through** voltage-against-time profile to be specified by the relevant **TSO** according to Figure CC 9; and,
- b) unless the protection scheme for internal faults requires the disconnection of the **HVDC Converter Station** from the **Transmission System**. Such undervoltage protection schemes shall be set by the **HVDC System Owner** to the widest possible technical capability of the **HVDC Converter Station**.

CC 6.3.1.2 The relevant **TSO** shall specify:

- a) The parameters that define each point of **Fault-Ride-Through** voltage-against-time profile of Figure CC 9.
- b) voltage levels (U_{block}) at the **Connection Points** under specific conditions of the **Transmission System** whereby the **HVDC System** is allowed to block, that is remaining connected to the **Transmission System**, with no active and reactive power contribution for a time frame that shall be as

short as technically feasible, and which shall be agreed upon between the relevant TSOs and the HVDC System Owner.

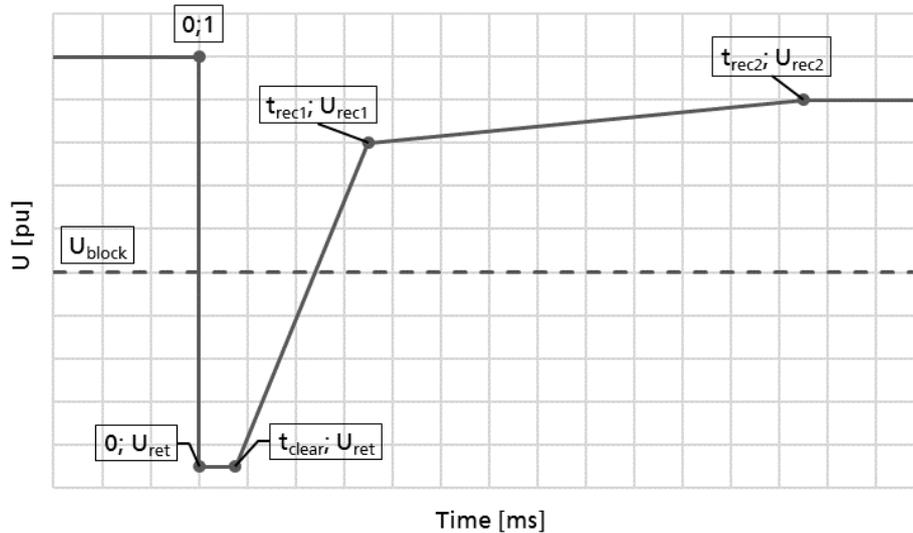


Figure CC 9. Fault-ride-through profile of an HVDC Converter Station.

- CC 6.3.1.3 **HVDC Systems** shall comply with the **Fault-Ride-Through** voltage-against-time profile for any pre-fault and post-fault value of **Short-Circuit Power** between the minimum and maximum values of the **Short-Circuit Power** expected in the **Connection Point**. In this regard, the relevant TSO shall specify and make publicly available such minimum and maximum values of **Short-Circuit Power** expected in each node of the **Transmission System**.
- CC 6.3.1.4 All the **Fault-Ride-Through** voltage-against-time profiles shall be harmonized by the relevant TSOs of all the **Interconnected Member States** no later than 24 months from the effective date of this **Code** and according to a criterion agreed by the **Parties**. A criterion may be the selection of the largest curve among the ones specified by the relevant TSO.
- CC 6.3.1.5 In case no harmonization of the **Fault-Ride-Through** voltage-against-time profiles is agreed by the **Interconnected Member States**, the limits specified in CC 10 ANNEX B – Reference parameters.

CC 6.3.2 *Rate of Change of Frequency Withstand Capability*

J. Rate of change of frequency withstand capability tends to become relevant during significant **Load-Generation** imbalances (e.g. disconnection of large **Load Facilities** or **Power-Generating Modules**, or system splits) because of low system inertia caused by (amongst others) increasing shares of inverter-based **Power-Generating Facilities**, usually **RES**. Avoiding the disconnection of **HVDC Converter Stations** in case of large rate of change of frequency contributes to stabilization and restoration of the **Transmission System** to normal operating states.

CC 6.3.2.1 An **HVDC System** shall be capable of staying connected to the **Transmission System** and operating at rates of change of frequency within a range of values specified by the relevant **TSO**.

CC 6.3.2.2 Rate of change of frequency withstand capability shall be harmonized among **Member States** within to the same **Synchronous Area**. A typical range of values of rate of change of frequency is given in CC 10 ANNEX B – Reference parameters.

CC 6.4 Stability and Control of the System Frequency

CC 6.4.1 *Control of target active power*

J. Changes in active power output around target value and behavior during transient of target value variations may result in load imbalances and hence frequency deviations in a **Synchronous Area**. Requirements defining the performance of an **HVDC System** in target active power control contributes to maintaining system stability and security by minimizing deviations of frequency.

CC 6.4.1.1 An **HVDC System** shall be able to adjust the transmission of active power in each direction of the power flow to a target value communicated by the relevant **TSO(s)**. The detailed technical specifications of control of target active power shall be defined during the connection procedure (Chapter CC 3) of the **HVDC system**, and they shall at least include the following elements:

- a) minimum values of the active power for each power flow direction through the **HVDC System**, below which active power transmission capacity is not requested;
- b) maximum and minimum power step size for adjusting the transmitted active power;
- c) maximum delay within which the **HVDC System** shall be capable of adjusting the transmitted active power upon receipt of request from the relevant **TSO**;
- d) specifications on the expected operation in the event of disturbances at the **Connection Point** of one or more **HVDC Converter Stations**;
- e) capability of fast active power reversal from the maximum active power transmission capacity of the **HVDC System** in one direction to the maximum active power transmission capacity of the **HVDC System** in the other direction, with the related rules, conditions, and time of activations.
- f) control functions enabling the relevant **TSOs** to modify the transmitted active power for the purpose of cross-border balancing among different **Control Areas**;
- g) ramping rate of active power adjustments;

- h) remedial action for activating / blocking frequency regulation.

CC 6.4.2 *Maximum Loss of Active Power*

J. Operating conditions may lead to reduction in active power injection of **HVDC Systems**. Defining admissible reductions contributes in limiting load imbalances and hence frequency deviations.

CC 6.4.2.1 An **HVDC System** shall be configured in such a way that its loss of active power injection in the same **Synchronous Area** shall be limited to a value specified by the relevant **TSOs** for their respective load frequency **Control Area**, based on the **HVDC System's** impact on the **Electricity System**.

CC 6.4.2.2 Where an **HVDC System** connects two or more **Control Areas**, the relevant **TSOs** shall consult each other in order to set a coordinated value of the maximum loss of active power injection, considering common mode failures.

CC 6.4.3 *Participation in Frequency Control*

J. Persistent load imbalances cause frequency deviation to increase leading to deterioration of system stability and **SoS** of the **PAEM Electricity System**. **HVDC Systems** are requested to contribute in removing such imbalances. These requirements define the capabilities of **HVDC Systems** to control the variation of their active power output in response to: (i) abnormal over-frequency, (ii) abnormal under-frequency, (iii) normal frequency variations.

CC 6.4.3.1 The relevant **TSO** has the right to specify that **HVDC Systems** be equipped with the facilities to provide **Synthetic Inertia** during fast frequency deviations upon request of the relevant **TSO**, by rapidly adjusting the active power injected or withdrawn from the **AC** side of the **Transmission System**.

CC 6.4.3.2 The relevant **TSO** shall agree with the **HVDC System Owner** regarding the performance parameters of the control systems installed to provide **Synthetic Inertia**.

CC 6.4.3.3 **HVDC System** shall be capable of operating in the **FSM** which determines a variation in the adjustment of active power with respect to the programmed value of target active power in response to contained variations in the frequency of the **Transmission System**. The adjustment of active power is limited by the minimum and maximum continuous active power, which the **HVDC System** can exchange with the **Transmission System** at each **Connection Point** as agreed between the relevant **TSO** and the **HVDC System Owner**.

CC 6.4.3.4 The relevant **TSO** shall define the parameters that characterize the **FSM** for the **HVDC System** connected to their **Grids** in accordance with Figure CC 10 and considering that P_{MAX} is the maximum active power transmission capacity of the **HVDC System** to which ΔP refers, and it coincides with the maximum continuous active power, which the **HVDC System** can exchange with the **Transmission System** at each **Connection Point**. ΔP is the variation in the active power output from the **HVDC System**. f_n is the nominal frequency in the **AC-side** of the **Transmission System** where the **FSM** service is provided and Δf is the frequency deviation in the **AC-side** of the **Transmission System** where the **FSM** service is provided.

CC 6.4.3.5 Typical values for the parameters that characterize the **FSM** are given in CC 10 ANNEX B – Reference parameters.

CC 6.4.3.6 In case an **HVDC System** connects two or more **Control Areas** or **Synchronous Areas**, in **FSM** operation the **HVDC System** shall be capable of adjusting the full active power frequency response at any time and for a continuous time period.

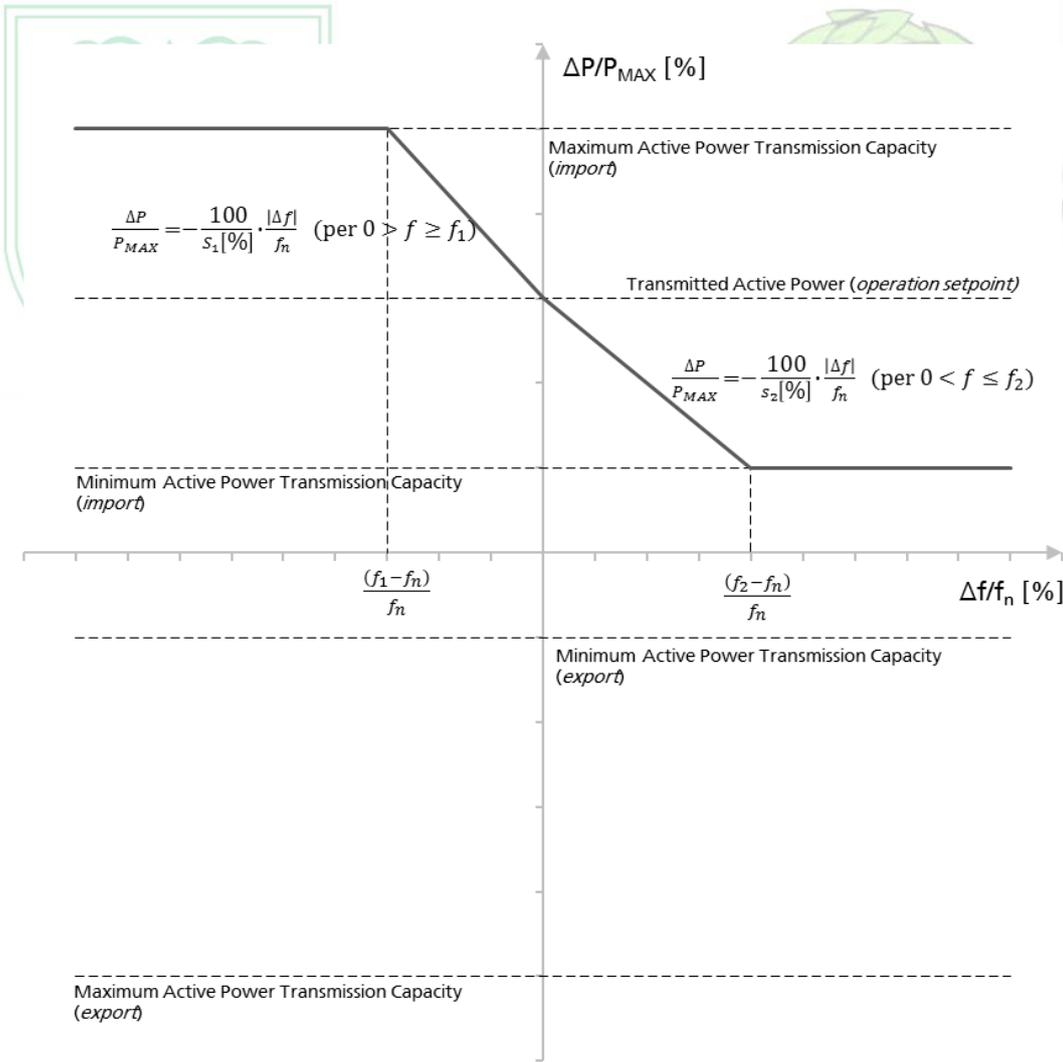


Figure CC 10. Active power frequency response capability of HVDC System in FSM illustrating the case of zero Frequency Response Deadband and insensitivity with a positive active power setpoint.

CC 6.4.3.7 In the event of frequency step changes, the power frequency response of the FSM mode shall be activated by the **HVDC System** in such a way that the response is at or above the solid line shown in Figure CC 11 and in accordance with the parameters specified by the relevant **TSO** based on the technology-dependent limitations of the **HVDC System**. Typical values of the parameters are given in CC 10 ANNEX B – Reference parameters.

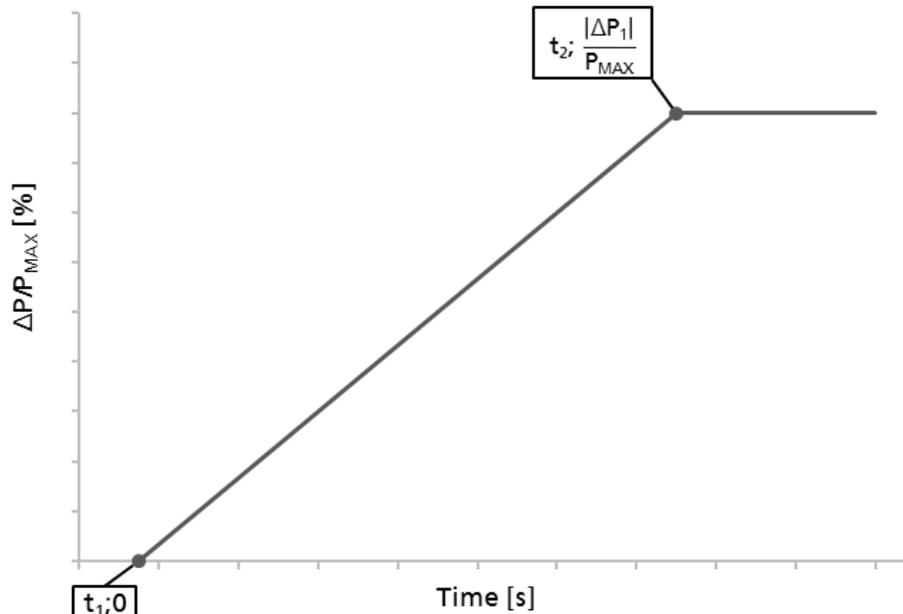


Figure CC 11. Active power frequency response capability.

CC 6.4.3.8 **HVDC Systems** shall regulate the active power output with the **Transmission System** with respect to the programmed value of target active power to transmit in response to the **AC-side** of the **Transmission System(s)**, during both import and export, with the modes called **LFSM-O** and **LFSM-U**.

CC 6.4.3.9 The relevant **TSO** shall define the actual frequency threshold and droop that characterize the **LFSM-O** and **LFSM-U** modes for the **HVDC System** connected to their **Grids** in accordance with Figure CC 12 and Figure CC 13:

- a) P_{MAX} is the maximum active power transmission capacity of the **HVDC System** to which ΔP refers, and it coincides with the maximum continuous active power, which the **HVDC System** can exchange with the **Transmission System** at each **Connection Point**. ΔP is the variation in the active power output from the **HVDC System**. f_n is the nominal frequency in the **AC-side** of the **Transmission System** where the **FSM** service is provided and Δf is the frequency deviation in the **AC-side** of the **Transmission System** where the **FSM** service is provided.
- b) In **LFSM-O** mode, typical values for the frequency threshold $\Delta f_1/f_n$ are given in CC 10 ANNEX B – Reference parameters.
- c) In **LFSM-U** mode, typical values for the frequency threshold $\Delta f_1/f_n$ are given in CC 10 ANNEX B – Reference parameters.

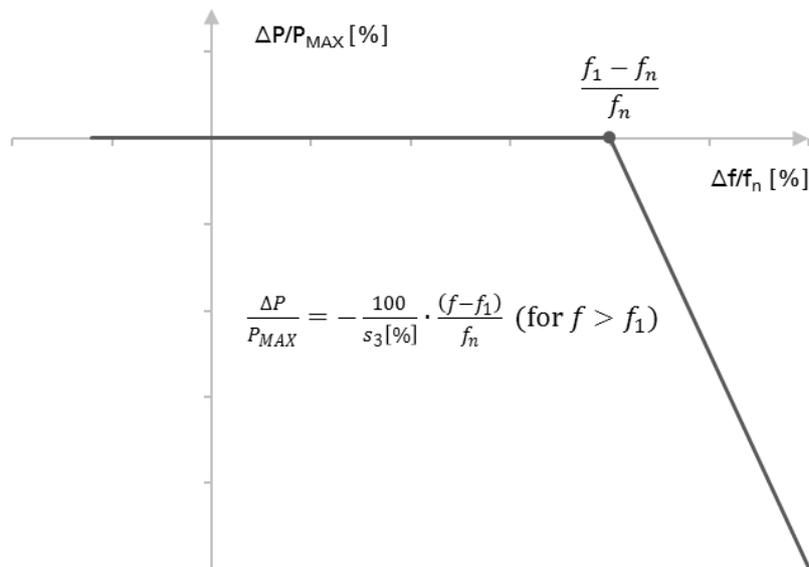


Figure CC 12. Active power frequency response capability of HVDC System in LFSM-O mode.

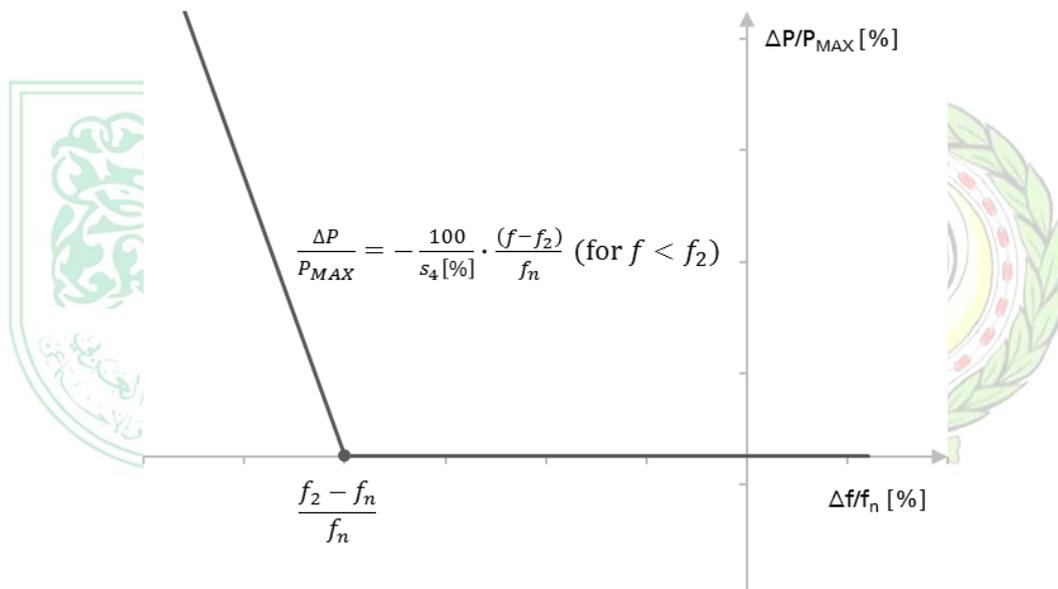


Figure CC 13. Active power frequency response capability of HVDC System in LFSM-U mode.

CC 6.4.3.10 An **HVDC System** shall be capable of activating the active power frequency response as fast as technically feasible with an initial delay for full activation determined by the relevant **TSO**.

CC 6.4.3.11 With reference to the operation in:

- a) **LFSM-O** mode, the **HVDC System** shall be capable of adjusting active power down to the minimum active power transmission capacity of the **HVDC System**.
- b) **LFSM-U** mode, the **HVDC System** shall be capable of adjusting active power up to the maximum active power transmission capacity of the **HVDC System**.

- c) both **LFSM-O** and **LFSM-U**, the **HVDC System** shall be capable of operating stably.

CC 6.4.3.12 The relevant **TSOs** of the same **Synchronous Area** shall harmonize the **LFSM-O** and **LFSM-U** parameters to minimize unplanned power flow between the interconnected countries in response to a change in system frequency.

CC 6.5 Stability and Control of the System Voltage

CC 6.5.1 *Reactive Power Capability*

J. Reactive power is a key component for voltage stability and is fundamental for cross-border power trading. Although the influence of **HVDC Systems** on overall system voltage stability varies with location, harmonizing reactive power capabilities contributes to secure planning and operation of the **Integrated Power Systems** within the same **Synchronous Area**.

CC 6.5.1.1 The relevant **TSO** shall specify reactive power capability at maximum capacity and reactive power capability below maximum capacity at the **Connection Points**, in the context of varying voltage.

CC 6.5.1.2 *Reactive power capability at maximum capacity*

CC 6.5.1.3 Regarding reactive power capability at maximum capacity, the relevant **TSO** shall identify the U - Q/P_{MAX} -profile, which identifies the boundaries within which the **HVDC Converter Station** shall be capable of providing reactive power at its maximum active power transmission capacity of the **HVDC System**. The U - Q/P_{MAX} -profile shall be defined according to the following principles and in consistence with Figure CC 14:

- a) the dimensions of the U - Q/P_{MAX} -profile envelope shall be within the Q/P_{MAX} range and voltage range specified by the relevant **TSO**.
- b) the position of the U - Q/P_{MAX} -profile envelope shall be within the limits of a fixed outer envelope to be defined by the relevant **TSO**.

CC 6.5.1.4 The relevant **TSOs** of the same **Synchronous Area** shall harmonize the dimensions of the inner and outer envelopes. Typical values for the outer envelope, Q/P_{MAX} range and voltage range of the U - Q/P_{MAX} -profile envelope of **HVDC Convert Stations** are given in CC 10 ANNEX B – Reference parameters.

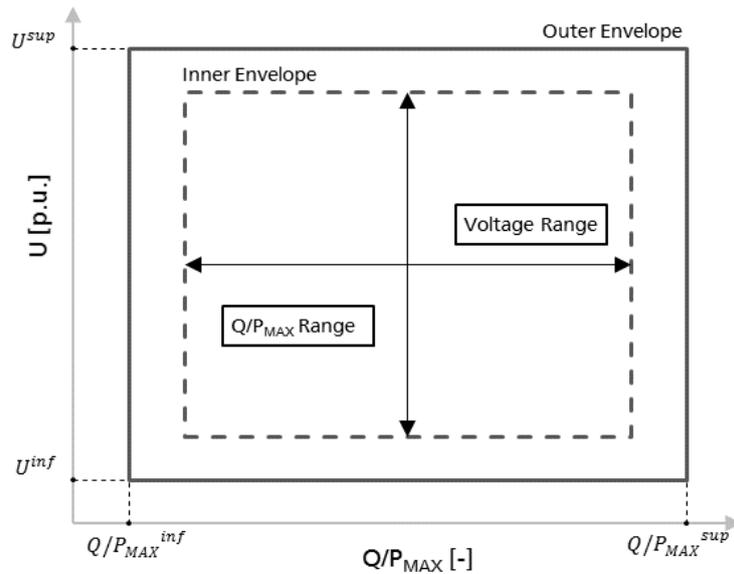


Figure CC 14. U-Q/P_{MAX}-profiles to be defined by the relevant TSO.

CC 6.5.1.5 An **HVDC System** shall be capable of moving to any operating point on the surface within its U-Q/P_{MAX} profile in appropriate timescales to target values requested by the relevant TSO.

CC 6.5.1.6 *Reactive power capability below maximum capacity*

CC 6.5.1.7 When operating at an active power output below the maximum active power transmission capacity of the **HVDC System** ($P < P_{MAX}$), the **HVDC Converter Station** shall be capable of operating in every possible operating point, as specified by the relevant TSO, and in accordance with the reactive power capability set out by the U-Q/P_{MAX} profile specified in Paragraph CC 6.5.1.2.

CC 6.5.2 Voltage Control Modes

J. The absence of voltage control for **HVDC Systems** can lead to voltage instability which can spread to neighboring **Electricity Systems** and become a cross-border issue.

CC 6.5.2.1 **HVDC Systems**, through their **HVDC Converter Stations** shall contribute to the voltage control. The following control modes shall be implemented:

a) Voltage control mode:

- i. the **HVDC Converter Station** shall be capable of contributing to voltage control at the **Connection Point** by providing reactive power exchange with the **Transmission System** to achieve a setpoint voltage covering a range [U_{REG_MIN} ; U_{REG_MAX}] in steps no greater than ΔU_{REG} defined by the relevant TSO. Typical values for U_{REG_MIN} , U_{REG_MAX} and ΔU_{REG} are given in CC 10 ANNEX B – Reference parameters.

- ii. The setpoint may be operated with or without a deadband selectable in a range defined by the relevant **TSO**.
- iii. Achieving 90% and 100% of the change in reactive power output requested by the relevant **TSO** within time $t_{REG_90\%}$ and $t_{REG_100\%}$, respectively, to be specified by the relevant **TSO**, with an accuracy of 5% of the value of the maximum reactive power that can be delivered by the **HVDC System**. Typical values of $t_{REG_90\%}$ and $t_{REG_100\%}$ lay within the ranges given in CC 10 ANNEX B – Reference parameters.

b) Reactive power control mode:

The **HVDC Converter Stations** shall be capable of setting the reactive power setpoint anywhere in the given reactive power range defined in MVAR or in % of maximum reactive power, with setting steps defined by the relevant **TSO**, by controlling the reactive power at the **Connection Point** to an accuracy defined by the relevant **TSO** as a percentage of the full reactive power. The specification of the reactive power range defined by the relevant **TSO** shall consider the capabilities of the **HVDC System**, while respecting Article CC 6.5.1.

c) Power factor control mode:

For the purposes of power factor control mode, the **HVDC Converter Station** shall be capable of controlling the power factor to a target at the connection point, while respecting Article CC 6.5.1. The available setpoints shall be available in steps no greater than a maximum allowed step specified by the relevant **TSO**.

CC 6.5.2.2 The relevant **TSO** shall define the principles and performance for the switching between the two modes as well as the modes and procedures for communicating the voltage reference values.

CC 6.5.3 *Short Circuit Contribution During Faults*

J. This requirement is critical to both restoring voltage immediately following faults and for injecting enough current quickly enough for system protection to function reliably.

CC 6.5.3.1 The relevant **TSO** has the right to specify that **HVDC Systems** be capable of providing **Fast Fault Current** at the **Connection Point** in case of balanced (3-phase) and unbalanced (1-phase or 2-phase) faults.

CC 6.5.3.2 The relevant **TSO** shall have the right to define the requirements for **Fast Fault Current**. These shall consider: (i) how and when a voltage deviation is to be determined; (ii) the characteristics of the **Fast Fault Current**; and (iii) the timing and accuracy of the **Fast Fault Current**.

CC 6.6 Management of the Power System

CC 6.6.1 *Energization and synchronization of converter stations*

J. This requirement is needed to limit the potential disturbances generated by the energization and synchronization of the **HVDC Converter Stations**, which can have cross boarder impacts.

CC 6.6.1.1 The energization or synchronization of an **HVDC Converter Station** to the **AC Transmission System** or the connection of an energized **HVDC Converter Station** to an **HVDC System** shall be performed to limit any voltage transient at the **Connection Point** and its propagation across the **Transmission System**.

CC 6.6.1.2 The relevant **TSO** shall specify the maximum magnitude, duration and measurement window of the voltage transients for the **HVDC Converter Station** within its **Control Area**.

CC 6.6.2 *Protection Systems*

J. Proper protection of the Transmission System is essential for maintaining stability and security of the **PAEM Electricity System**. Protection schemes shall prevent from aggravation of disturbances but limit their consequences within the same **Synchronous Area**.

CC 6.6.2.1 The requirements stated in this Article CC 6.6.2 are in addition to the general requirements on protection already described in Section CC 4.5.

CC 6.6.2.2 The protection system of an **HVDC System** has priority over operational controls, considering the security of the **Electricity System**, as well as the health and safety of working personnel and citizens and limiting any potential damage to the **HVDC System**.

CC 6.6.2.3 The protection schemes needed for protecting the **Grid** shall be specified by the relevant **TSO**, taking into consideration the characteristics of the **HVDC System**. The definition of and any changes to protection schemes needed for protecting the **HVDC System** and the **Grid** as well as the settings relevant to the **Module** shall be coordinated and agreed upon by the relevant **TSO** and the **HVDC System Owner**.

CC 6.6.2.4 The protection system of an **HVDC System** shall be organized according to the following categories:

- a) Protection against internal faults, which shall respect the following conditions:

- i. Any component of an **HVDC System** shall be protected against stresses caused by failures not eliminated by the protection system of the **Transmission System** or not covered by it.
 - ii. Each component, each subsystem, each **HVDC Converter Station** and the **HVDC System** shall be protected with coordinated systems that shall be capable of supporting and counteracting any abnormal operating conditions and any fault event. In particular, the safety measures of the protection systems shall be ensured even in the event of any failure to the telecommunications system.
 - iii. The design of the protection system shall consider the complete duplication of the protection devices.
- b) Protection of the **Transmission System** shall respect the following conditions:
- i. Each **HVDC System** and its **HVDC Converter Units** shall be equipped with a protection system capable of separating them from the **Transmission System** in the event of faults in the **Transmission System** which have not been correctly eliminated.
 - ii. The diagrams and settings of these protection systems shall be coordinated with those of the protection systems of the **Transmission Systems** and therefore established by the relevant **TSO**.
- c) Additional specific protection systems, which include:
- i. Protection systems against power oscillations that cannot be controlled by the **HVDC System**.
 - ii. Protection systems that prevent an **HVDC System** to entry into service in the absence of the minimum conditions for the **Transmission System** operation, and that disconnect the **HVDC System** if the last power link connecting the **HVDC System** to the **Transmission System** is opened.

CC 6.6.2.5 Any modification to the protection systems (schemes and / or settings) shall be agreed upon in advance between the **HVDC System Owner** and the relevant **TSO**. The procedures for modifying the protection schemes are specified in the **Operating Regulation Document**.

CC 6.6.3 *Control Systems*

J. Control systems are defined individually for **HVDC Systems**. Nevertheless, harmonization of the principle/methodology contributes to guaranteeing the stability of the **PAEM Electricity System**.

CC 6.6.3.1 An **HVDC System** shall be equipped with a control system capable of managing and controlling, in a coordinated way, all the **HVDC Converter Units** of the **HVDC System**.

CC 6.6.3.2 During the authorization phase of the connection procedure, the requirements, parameters, and settings of the main control functions of an **HVDC System** will be agreed and formalized between the **HVDC System Owner** and the relevant **TSO**.

CC 6.6.3.3 The parameters and settings shall be implemented within such a control hierarchy that makes their modification possible, if necessary. Those main control functions are at least:

- a) **Synthetic Inertia**, if applicable as referred to in Article CC 6.4.3.
- b) **FSM, LFSM-O, and LFSM-U** referred to in Article CC 6.4.3
- c) reactive power control mode, if applicable as referred to in Article CC 6.5.1;
- d) power oscillation damping capability, if applicable as referred to in Article CC 6.6.5;

CC 6.6.3.4 For **HVDC Systems** linking various **Control Areas** or **Synchronous Areas**, the **HVDC System** shall be equipped with control functions enabling the relevant **TSOs** to modify the transmitted active power for the purpose of cross-border balancing.

CC 6.6.3.5 The development and design of the control system of an **HVDC Converter Station** shall be based on the principle of redundancy and shall consider the complete duplication of the equipment. The redundancy shall include:

- a) the measurement circuits, at least from the side of the transducer;
- b) the systems for signal acquisition;
- c) the telecommunication system;
- d) the main processing units and all the equipment necessary for the command, control and protection of the **HVDC Converter Stations**.

CC 6.6.4 *Priority Ranking of Control and Protection Actions*

J. The definition of a ranking is recommended to specify which capabilities shall take precedence (i.e. avoid conflicts) when designing the protection and control schemes of **HVDC Systems**. Harmonizing the ranking among the **Member States** is important to achieve a common basis for operational strategies to ensure secure operation of the **PAEM Electricity System**.

CC 6.6.4.1 The **HVDC System Owner** shall organize the protection and the control devices of its **HVDC System** in accordance with the following priority ranking (from highest to lowest):

- a) **Transmission System** and **HVDC System** protection;
- b) active power control for emergency assistance;
- c) **Synthetic Inertia**, if applicable;
- d) automatic remedial actions, as specified in Article CC 6.4.1;
- e) **LFSM**;
- f) **FSM** and frequency control; and,
- g) power gradient constraint.

CC 6.6.5 *Power System Stabilizers*

J. Power system oscillations can spread across the borders of adjacent **Electricity Systems** and can result in dynamic instabilities if no harmonized measures are taken.

CC 6.6.5.1 The **HVDC System** shall be capable of contributing to the damping of power oscillations occurring in the **AC** side of the **Transmission System** to which it is connected. The control system of the **HVDC System** shall not reduce the damping of power oscillations. The relevant **TSO** shall specify a frequency range of oscillations that the control scheme shall positively damp and the conditions of the **Transmission System** when this occurs. The selection of the control parameter settings shall be agreed upon by the relevant **TSO** and the **HVDC System Owner**.

CC 6.6.6 *HVDC System Robustness*

CC 6.6.6.1 An **HVDC System** shall be able to find stable operating points with a minimal variation in active power flow and voltage level, during and after any planned or unplanned changes in the **HVDC System** or the **AC Transmission System** to which it is connected. Each **TSO** shall provide detailed information to the **HVDC Facility Owner** during the connection request in accordance with Chapter CC 3 based on the data of the **HVDC System** and the **Connection Point**.

CC 6.6.6.2 The following list suggests the minimum conditions in which the stability of the **HVDC System** shall be verified:

- a) opening and closing of the **Elements** of the **Grid** adjacent to the connection;
- b) energizing and tripping of the harmonic filters;

- c) energizing the transformers near the **HVDC Converter Station** or another pole of the same connection;
- d) variation in over and under voltage due to faults;
- e) loss of portions of the **Grid**;
- f) longitudinal failures in the **Grid**.

CC 6.6.7 *Priority to active or reactive power contribution*

CC 6.6.7.1 Taking into account the capabilities of the **HVDC System** specified in accordance with this **Connection Code**, the relevant **TSO** shall determine whether active power contribution or reactive power contribution shall have priority during low or high voltage operation and during faults for which **Fault-Ride-Through** capability is required. If priority is given to active power contribution, its provision shall be established within a time from the fault inception, as specified by relevant **TSO**.

CC 6.6.8 *Power Quality*

J. Harmonization of requirements regarding potential disturbances in the electric power transferred by HVDC System contributes to ensure the targeted quality of the supply within PAEM Electricity System.

CC 6.6.8.1 An **HVDC System Owner** shall ensure that the connection of its **HVDC System** to the **Transmission System** does not result in a level of distortion or fluctuation of the supply voltage on the **Transmission System**, at the **Connection Point**, exceeding the level specified by the relevant **TSO**.

CC 6.6.8.2 For evaluating the impact on the **HVDC System** connection on the **Grid**, the **HVDC System Owner** shall provide, at the time of connection request, all the project data relating to the emission of disturbances. Based on the data provided, the relevant **TSO** evaluates the effects on the **Grid** in conditions of minimum **Short-Circuit Power** on the **Grid**.

CC 6.6.8.3 The maximum emission levels of distortion or fluctuation of the supply voltage granted to the **HVDC System** are set by the relevant **TSO** taking into account the planning values adopted by the relevant **TSO**, the **Short-Circuit Power** at the **Connection Point**, the characteristic data of the **HVDC System**, the emissions of other **Facilities** already connected to the same **Grid**, the emissions transferred from the rest of the **Grid**, and the forecast future emissions of new **Facilities** who have already begun the connection procedure according to Chapter CC 3.

CC 6.6.9 *Simulation models*

J. Power system studies are performed by the relevant **TSOs** at different stages of their evaluations (e.g. planning, operational planning, real-time operations). Dedicated provisions define a common set of simulation models and related features that the relevant **TSO** require to implement and update interconnected power system models.

CC 6.6.9.1 At the request of the relevant **TSO**, an **HVDC System Owner** shall provide simulation models of its **HVDC System** with a level of detail adequate to reflect the behavior of the **Module** in:

- a) steady-state simulation;
- b) electromechanical simulation; and,
- c) electromagnetic transient simulation.

CC 6.6.9.2 The request of the relevant **TSO** shall include:

- a) the specification of the format in which models are to be provided by the **HVDC System Owner**;
- b) the provision of documentation on a model's structure and block diagrams;
- c) the specific sub-models of the components, which should contain at least, depending on the existence of the mentioned components:
 - i. **HVDC Converter Unit** models;
 - ii. **AC** component models;
 - iii. **HVDC Link** models;
 - iv. Voltage and power controller;
 - v. Special control features, if applicable e.g. power oscillation damping function, subsynchronous torsional interaction control;
 - vi. Multi terminal control, if applicable;
 - vii. **HVDC System** protection models as agreed between the relevant **TSO** and the **HVDC System Owner**.

CC 6.6.9.3 The **HVDC System Owner** shall verify the models against the results of compliance tests carried out according to Section CC 6.9, and a report of this verification shall be submitted to the relevant **TSO**. The models shall then be used for the purpose of verifying compliance with the requirements of this **Code** including, but not limited to, compliance simulations as provided for in CC 6.9.2 and used in studies for continuous evaluation in system planning and operation.

CC 6.6.9.4 Upon request of the relevant **TSO**, the **HVDC System Owner** shall provide measurement recordings of the **HVDC System's** performance in order to compare the response of the models with those recordings.

CC 6.7 Management of Emergency Situations

CC 6.7.1 *Black Start*

J. Black Start Service is needed from an appropriate number of **HVDC Systems** to restore an **Electricity System** to a stable condition following major critical disturbance. Harmonization guidance of this requirement for **PAEM Electricity System** may be given in principle since details pertain to each single relevant **TSO**.

CC 6.7.1.1 The **HVDC System** shall meet the following requirements with respect to **Black Start Capabilities**:

- a) In the instance where one **HVDC Converter Station** is energized, to energization of the busbar of the **AC**-substation to which another **HVDC Converter Station** is connected, within a timeframe after shutting down of the **HVDC System** will be determined by the relevant **TSOs**.
- b) With reference to frequency, the **HVDC System** shall be able to synchronize within the limits defined in Article CC 6.2.1.
- c) With reference to voltage the **HVDC System** shall be able to synchronize within the limits defined in Article CC 6.2.2.

CC 6.7.1.2 The relevant **TSO** and the **HVDC System Owner** shall agree on the capacity and availability of the **Black Start Capability** and the operational procedure.

CC 6.8 Monitoring and Information Exchange

J. Having adequate and harmonized monitoring and information exchange procedures between HVDC System Owners and the relevant TSO is a prerequisite for appropriate system operation as well as for appropriate operation of the PAEM Electricity System and will facilitate the resolution of cross-border issues.

CC 6.8.1.1 **HVDC Systems** shall be capable of monitoring the operation of, and exchanging information with, the relevant **TSO** according to different specifications and purposes.

CC 6.8.1.2 Regarding instrumentation for the operation, each **HVDC Converter Unit** of an **HVDC System** shall be equipped with an automatic controller capable of sending/receiving instructions to/from the relevant **TSO**. This automatic controller shall be capable of operating the **HVDC Converter Units** of the

HVDC System in a coordinated manner. The automatic controller hierarchy per **HVDC Converter Unit** shall be specified by the relevant **TSO**.

CC 6.8.1.3 The automatic controller of the **HVDC System** shall be capable of:

- a) Sending the following signal types to the relevant **TSO**:
 - i. Operational signals, providing at least the following:
 - start-up signals;
 - **AC** and **DC** voltage measurements;
 - **AC** and **DC** current measurements;
 - active and reactive power measurements on the **AC** side;
 - **DC** power measurements;
 - **HVDC Converter Unit** level operation in a multi-pole type **HVDC System**;
 - elements and topology status; and,
 - **FSM**, **LFSM-O** and **LFSM-U** active power ranges.
 - ii. Alarm signals, providing at least the following:
 - emergency blocking;
 - ramp blocking; and,
 - fast active power reversal.

b) Receiving the following signal types from the relevant **TSO**:

- i. Operational signals, providing at least the following:
 - start-up commands;
 - active power set-points;
 - **FSM** settings;
 - reactive power, voltage or similar setpoints;
 - reactive power control modes;
 - power oscillation damping control; and,
 - **Synthetic Inertia**.
- ii. Alarm signals, receiving at least the following:
 - emergency blocking command;
 - ramp blocking command;
 - active power flow direction; and,
 - fast active power reversal command.

CC 6.8.1.4 To provide fault recording and monitoring of dynamic system behavior, **HVDC Systems** shall be equipped with an appropriate instrumentation, which meets the following requirements:

- a) capability of recording (i) **AC** and **DC** voltage, (ii) **AC** and **DC** current, (iii) active power, (iv) reactive power, and (v) frequency;
- b) it shall include an oscillation trigger, specified by the relevant **TSO**, with the purpose of detecting poorly damped power oscillations.

- c) the settings shall be agreed between the **Power-Generating Facility** and the relevant **TSO**; and,
- d) it shall include arrangements for the **HVDC System Owner** and the relevant **TSO** to access the information according to communications protocols for recorded data to be agreed between the **HVDC System Owner** and the relevant **TSO** and harmonized between all the relevant **TSOs**. Typical standards which communication protocols shall comply with the standards given in CC 10 ANNEX B – Reference parameters.

CC 6.9 Compliance Monitoring

J. Requirements that covers compliance procedures are fundamental for establishing procedures in a transparent and non-discriminatory manner across the **PAEM Electricity System**. This contributes to a more competitive market for the electricity sector of the **Member States**.

CC 6.9.1 *Information and documentation*

CC 6.9.1.1 The **HVDC System Owners** shall provide the relevant **TSO** with information and documents that describe the characteristics of their **HVDC Systems**. Such list of information and documents shall be made publicly available by the relevant **TSO** as well as the requirements to be met by the **HVDC System Owners** within the framework of the compliance process. The list shall be harmonized by the relevant **TSOs** and cover at least the following information, documents and requirements:

- a) all the documentation and certificates to be provided by the **HVDC System Owner**;
- b) details of the technical data on the **HVDC System** and **HVDC Converter Station** with relevance to the **Grid** connection;
- c) requirements for models for steady-state and dynamic system studies;
- d) timeline for the provision of system data required to perform the studies;
- e) studies by the **HVDC System Owner** or the **Owner** of **VRE-units** connected through **HVDC Systems** to demonstrate the expected steady-state and dynamic performance in accordance with the requirements set out in the **Connection Code**;
- f) conditions and procedures, including the scope, for registering equipment certificates; and,
- g) conditions and procedures for the use of relevant equipment certificates, issued by an authorized certifier, by the **HVDC System Owner**.

CC 6.9.2 *Verification and Compliance Test of the Relevant TSO*

CC 6.9.2.1 Each **HVDC System Owner** shall comply with the testing procedures for the verification of the compliance with the requirements set forth in this **Connection Code** to be defined by the relevant **TSO**. The tests shall demonstrate the technical capability of **HVDC Systems**:

- a) to provide leading and lagging reactive power capability according to Article CC 6.5.1;
- b) to operate in voltage control mode and reactive power mode in the conditions set forth in Article CC 6.5.2;
- c) to continuously modulate active power over the full operating range between maximum active power transmission capacity of the **HVDC System** and minimum active power transmission capacity of the **HVDC System** of the **HVDC System** to contribute to frequency control; the same test shall verify the steady-state parameters of frequency regulations;
- d) to continuously modulate active power to contribute to frequency control in case of large increase and drop of frequency in the same **Synchronous Area**; the same test shall verify the steady-state parameters of frequency regulations;
- e) to continuously modulate active power over the full operating range according to Article CC 6.2.1;
- f) to adjust the ramping rate of active power variations within its technical capabilities, in accordance with instructions sent out by relevant **TSO**;
- g) to energize the busbar of the remote **AC** substation to which it is connected, within a time frame specified by the relevant **TSO**.

CC 6.9.2.2 In addition to the verification of the information and the compliance tests, as per the above paragraphs, the relevant **TSO** can assess the compliance of an **HVDC System** with the requirements set in this **Connection Code** also by relying on the simulations of the performance of **HVDC System** carried out by the **HVDC System Owner** based on the simulation models referred to in Article CC 6.6.9.

CC 6.10 Additional Requirements

J. This set will include some additional requirements for the mentioned systems.

CC 6.10.1 *Additional Requirements for Remote-End HVDC Converter Stations*

CC 6.10.1.1 Remote-end **HVDC Converter Stations** of an **HVDC System** shall be designed in such a way as to guarantee, at the **HVDC Interface Point**, the frequency and voltage ranges and minimum time periods specified in Section CC 6.2.

CC 6.10.1.2 The relevant **TSO** and the remote-end **HVDC Converter Station Owner** may agree on wider frequency and/or voltage ranges or longer minimum times for operation to ensure the best use of the technical capabilities of an **HVDC System**.

CC 6.10.1.3 The requirements relating to the **Reactive Power Capability** of the remote-end **HVDC Converter Station** shall be agreed with the relevant **TSOs** during the connection procedure (Chapter CC 3) of the **HVDC System**.

CC 6.10.2 *Additional Requirements for VRE-units Connected through HVDC Systems*

CC 6.10.2.1 **VRE-units** connected through **HVDC Systems** shall be designed with the same requirements valid for **Invert-based Power Generating Facilities** defined throughout Chapter CC 5 of this **Connection Code**, applicable at the **HVDC Interface Point** of the **VRE-units**.

CC 6.10.2.2 The detailed requirements shall be defined by the relevant **TSO** during the connection procedure (Chapter CC 3) of the **Power Generating Facility**, in particular those related to the reference frequency and voltage at the **HVDC Interface Point** of the **VRE-units**.

CC 7 REQUIREMENTS FOR DEMAND FACILITIES

CC 7.1 Operating Ranges

CC 7.1.1 *Frequency Ranges*

CC 7.1.1.1 All **Demand Facilities** shall be capable of remaining connected to the **Grid** within the frequency ranges, and minimum time periods specified by the relevant **TSO**, according to the following scheme and represented also in Table CC 5:

- a) a range around the nominal frequency of the **Synchronous Area** with unlimited time period of operation;
- b) at least one range with frequency below the nominal frequency of the **Synchronous Area** with limited time period for operation to be specified by the relevant **TSO**;
- c) at least one range with frequency above the nominal frequency of the **Synchronous Area** with limited time period for operation to be specified by the relevant **TSO**.

CC 7.1.1.2 The frequency values are considered at the **Connection Point**.

CC 7.1.1.3 In defining frequency ranges and time periods, the relevant **TSO** shall consider the applicable international standards for products on frequency-related capabilities.

CC 7.1.1.4 The relevant **TSO** and the **Demand Facility Owner** may agree on wider frequency ranges and longer minimum times for operation. The **Demand Facility Owner** shall not unreasonably withhold consent to such request(s) if technically feasible.

Table CC 5. Minimum time periods for which a Demand Facility must be capable of operating for frequency deviating from the nominal value of the Synchronous Area without disconnecting from the Grid

		Frequency range	Time period for operation
<i>f</i> of the Synchronous Area	b)	$F_{f_{low2}} \text{ Hz} - F_{f_{low1}} \text{ Hz}$	To be specified in minutes by the relevant TSO
	a)	$F_{f_{low1}} \text{ Hz} - F_{f_{high1}} \text{ Hz}$	Unlimited
	c)	$F_{f_{high1}} \text{ Hz} - F_{f_{high2}} \text{ Hz}$	To be specified in minutes by the relevant TSO

CC 7.1.1.5 Frequency ranges and time periods shall be harmonized among **Member States** within the same **Synchronous Area**. Indicative frequency ranges and time periods are reported in CC 10 ANNEX B – Reference parameters.

CC 7.1.2 Voltage Ranges

CC 7.1.2.1 All **Synchronous Power-Generating Modules** shall be capable of remaining connected to the **Grid** within the ranges of the voltage at the **Connection Point** specified by the relevant **TSO** according to the following scheme and represented also in Table CC 6:

- a) a range around the base voltage with unlimited time period of operation;
- b) at least one range with voltage below the base value with limited time period for operation to be specified by the relevant **TSO**;
- c) at least one range with voltage above the base value with limited time period for operation to be specified by the relevant **TSO**.

CC 7.1.2.2 The voltage range at the **Connection Point** shall be expressed by the voltage at the **Connection Point** related to reference 1 per unit (pu) voltage.

CC 7.1.2.3 The relevant **TSO** can define different sets of voltage ranges and respective time periods according to different voltage base levels. In defining voltage ranges and time periods, the relevant **TSO** shall consider the applicable international standards for products on voltage-related capabilities.

CC 7.1.2.4 If required by the relevant **TSO**, a **Demand Facility** shall be capable of automatic disconnection at specified voltages. The terms and settings for automatic disconnection shall be agreed between the relevant **TSO** and the **Demand Facility Owner**.

Table CC 6. Minimum time periods during which a Demand Facility must be capable of operating for voltages deviating from the reference 1 pu value at the Connection Point without disconnecting from the Grid.

	Voltage range	Time period for operation
b)	$U_{low2} \text{ pu} - U_{low1} \text{ pu}$	To be specified in minutes by the relevant TSO
a)	$U_{low1} \text{ pu} - U_{high1} \text{ pu}$	Unlimited
c)	$U_{high1} \text{ pu} - U_{high2} \text{ pu}$	To be specified in minutes by the relevant TSO

CC 7.1.2.5 Voltage ranges and time periods shall be harmonized among **Member States** within the same **Synchronous Area**. Indicative voltage ranges and time periods are reported in CC 10 ANNEX B – Reference parameters.

CC 7.2 Management of the Power System

CC 7.2.1 *Short-circuit Requirements*

CC 7.2.1.1 The relevant TSO shall specify the maximum **Short-Circuit Current** at the **Connection Point** that the **Demand Facility** shall be capable of withstanding.

CC 7.2.1.2 The relevant TSO shall inform the affected **Demand Facility Owner** of the changes above a threshold for the maximum **Short-Circuit Current** that the **Demand Facility** shall be able to withstand from the relevant **Grid**.

CC 7.2.1.3 The relevant TSO shall request information from a **Demand Facility Owner** concerning the contribution in terms of **Short-Circuit Current** from that **Facility**.

CC 7.2.1.4 The **Demand Facility Owner** shall inform the relevant TSO of the changes in short-circuit contribution above the threshold set by the relevant TSO.

CC 7.2.2 *Reactive Power Requirements*

CC 7.2.2.1 **Demand Facilities** shall be capable of maintaining their steady-state operation at their **Connection Point** within a reactive power range specified by the relevant TSO.

CC 7.2.2.2 The actual reactive power range specified by the relevant TSO shall not be wider than a power factor import or export of active power threshold (PF_{load}), except in situations where either technical or financial system benefits are demonstrated by the **Demand Facility Owner** and accepted by the relevant

TSO. An indicative value of PF_{load} is reported in CC 10 ANNEX B – Reference parameters.

CC 7.2.3 *Protection Systems*

CC 7.2.3.1 The relevant **TSO** shall specify the devices and settings to protect the **Transmission System** according to the characteristics of the **Demand Facility**.

CC 7.2.3.2 The relevant **TSO** and the **Demand Facility Owner** shall agree on protection schemes and settings relevant for the **Demand Facility** and on any changes to these schemes and settings.

CC 7.2.3.3 Protection systems of the **Demand Facility** shall take precedence over operational controls while respecting system security, health and safety of staff and the public.

CC 7.2.3.4 Protection systems may include the following (referring available international standards are given in CC 10 ANNEX B – Reference parameters):

- a) external and internal short circuit;
- b) over- and under-voltage at the **Connection Point to the Transmission System**
- c) over- and under-frequency;
- d) **Demand** circuit protection;
- e) unit transformer protection;
- f) back-up against protection and switchgear malfunction.

CC 7.2.4 *Control System*

CC 7.2.4.1 The relevant **TSO** and the **Demand Facility Owner** shall agree on schemes and settings for the different control devices of the **Demand Facility** relevant for system security. The relevant **TSO** and the **Demand Facility Owner** shall agree also on any changes to these schemes and settings.

CC 7.2.4.2 The agreement shall cover at least the following elements:

- a) isolated (**Network**) operation;
- b) damping of oscillations;
- c) disturbances to the **Transmission System**;

- d) automatic switching to emergency supply and **Restoration** to normal topology;
- e) automatic circuit-breaker re-closure (on 1-phase faults).

CC 7.2.5 *Information Exchange*

CC 7.2.5.1 The relevant **TSO** shall define the list of data and respective specifications (standards, time stamping, etc.) that **Demand Facilities** shall meet in order to exchange information during real-time operation.

CC 7.2.6 *Demand Disconnection and Reconnection*

CC 7.2.6.1 All **Demand Facilities** shall provide low frequency **Demand** disconnection capabilities. The relevant **TSO** shall define respective specifications and settings. These include:

- a) capability to enable automatic low frequency disconnection of the whole or a proportion of the **Demand**;
- b) the possibility to specify a disconnection trigger based on a combination of low frequency and rate-of-change-of-frequency;
- c) the possibility to disconnect **Demand** in stages;
- d) operational settings of **Demand** disconnection: frequency ranges, operating time, voltage lock-out;
- e) activation input.

CC 7.2.6.2 The relevant **TSO** has the right to specify low voltage **Demand** disconnection capabilities. The relevant **TSO** shall define respective specifications and settings.

CC 7.2.6.3 With regard to the capability of reconnection after a disconnection of **Demand Facilities**, the relevant **TSO**:

- a) shall specify the conditions under which a **Demand Facility** is entitled to reconnect to the **Transmission System**;
- b) shall authorize the installation of automatic reconnection systems;
- a) shall agree with the **Demand Facility Owner** on the settings of synchronization devices prior to connection of the **Demand Facility**, including voltage, frequency, phase angle range and deviation of voltage and frequency.

CC 7.2.6.4 A **Demand Facility** shall be capable of being remotely disconnected from the **Transmission System** when required by the relevant **TSO**. The relevant **TSO** shall specify the time required for remote disconnection.

CC 7.2.7 *Power Quality*

CC 7.2.7.1 The relevant **TSO** shall define the power quality requirements that the **Demand Facilities** shall guarantee at their **Connection Point** in accordance with the expected **Network** performances (see CC 2.4).

CC 7.2.8 *Simulation Models*

CC 7.2.8.1 At the request of the relevant **TSO**, a **Demand Facility Owner** shall provide simulation models for its **Demand Facility** with a level of detail adequate to reflect the behavior of the facility in:

- a) steady-state simulation;
- b) electromechanical simulation; and,
- c) electromagnetic transient simulation.

CC 7.2.8.2 The request of the relevant **TSO** shall include:

- a) the specification of the format in which models are to be provided by the **Demand Facility Owner**;
- b) the provision of documentation on a model's structure and its block diagrams;
- c) an estimate of the minimum and maximum short circuit capacity at the **Connection Point** as a simplified equivalent of the **Transmission System**;
- d) the parameterizations and limitations of the model; and,
- e) the specific sub-models of the components.

CC 7.2.8.3 Upon request of the relevant **TSO**, the **Demand Facility Owner** shall provide measurement recordings of the **Facility's** performance in order to compare the response of the models with those recordings.

CC 7.3 Compliance Monitoring

CC 7.3.1 The **Demand Facility Owner** shall ensure that the **Facility** complies with the requirements of this Chapter CC 7 for its entire life.

CC 7.3.2 The relevant **TSO** shall evaluate the compliance of the **Demand Facility** and shall keep the **Demand Facility Owner** informed about the outcome of the compliance assessments that shall include:

- a) Information and documentations provided by the **Demand Facility Owner** to the relevant **TSO**;
- b) Verification and compliance tests executed by the relevant **TSO**;
- c) Compliance simulations.

CC 7.3.3 *Information and Documentation*

CC 7.3.3.1 The **Demand Facility Owner** shall provide the relevant **TSO** with information and documents that describe the characteristics of the **Demand Facility**.

CC 7.3.3.2 The list shall be harmonized by the relevant **TSOs** of the same **Synchronous Area** and shall, at a minimum, include the followings:

- a) details of the technical data required from the **Demand Facility** with relevance to the connection or operation;
- b) requirements for models for steady-state and dynamic system studies;
- c) conditions and procedures including scope for registering equipment certificates;
- d) conditions and procedures for the use of relevant equipment certificates issued by an authorized certifier by the **Demand Facility Owner**.

CC 7.3.3.3 The **Demand Facility Owner** shall provide the necessary information and documents to the relevant **TSO**:

- a) at the time of connection request in accordance with Chapter CC 3;
- b) following changes to the technical data of the **Demand Facility** resulting from changes in the technical capabilities or operational accidents or faults;
- c) whenever requested by the relevant **TSO**.

CC 7.3.4 *Verification and Compliance Tests Executed by the Relevant TSO*

CC 7.3.4.1 The relevant **TSO** shall execute verification and compliance tests to ascertain the validity of the declarations issued by the **Demand Facility Owner** and the compliance with the requirements set in this **Code**.

CC 7.3.4.2 The relevant **TSO** communicates the annual plan for the implementation of the verification and compliance tests and the results of the same. In consideration of the importance that the controlling systems and the relative parameters, the **TSO** has the right to execute tests on their functionality at any time.

CC 7.3.4.3 The relevant **TSO** shall define the standard procedures for executing the tests. At a minimum, the procedures shall include the followings:

- a) testing for disconnection and reconnection;
- b) testing for information exchange.

CC 7.3.5 *Compliance Simulations*

CC 7.3.5.1 In addition to the verification of the information and the compliance tests, as per the above paragraphs, the **TSO** can assess the compliance of a **Demand Facility** with the requirements set forth in this **Connection Code**, and by relying on the simulations of the performance of **Demand Facility** carried out by the **Demand Facility Owner** using the simulation models referred to in Article CC 7.2.8.

CC 8 GUIDELINES FOR DEFINITION OF REQUIREMENTS FOR DISTRIBUTED GENERATION

J. Increasing penetration of **Distributed Generation** (i.e. **Power-Generating Modules** connected at distribution level) may affect the reliability of the **Electricity Systems** of the same **Synchronous Areas**. Accordingly, coordinating and harmonizing connection requirements for **Distributed Generation** among **TSOs** contributes to preserving the quality of the supply. This Chapter provides a set of guidelines on the definition of connection requirements for **Distributed Generation**.

CC 8.1.1 The relevant **Network** operator can agree and define with the relevant **TSO** the connection requirements for **Distributed Generation**. This can be justified by impacts at transmission level, and hence for cross-border issues, that a growing penetration of **Distributed Generation** can bring about.

CC 8.1.2 The significance of **Power-Generating Modules** should be based on their size and their effect on the overall system. Accordingly, the relevant **DSO** or **TSO** shall make a distinction between different types of **Power-Generating Modules** by establishing different levels of requirements.

CC 8.1.3 The methodology in distinguishing between different types of **Power-Generating Modules** should be harmonized among **Member States** within the same **Synchronous Area**.

CC 8.1.4 The requirements applicable to **Distributed Generation** should be set at the level necessary to ensure capabilities of **Generation**:

- a) with limited automated response and resilience to operational events;
- b) with limited control from the relevant **DSO** and with a corresponding level of data and information exchange with the local **DSO**;
- c) with capabilities to avoid large-scale loss of **Generation** over system operational ranges;
- d) with requirements necessary for widespread intervention during system-critical events.

CC 8.1.5 The requirements for **Distributed Generation** shall include:

- a) minimum frequency and voltage operating ranges;
- b) **Fault Ride Through capability**;
- c) rate of change of frequency withstand capability;
- d) **LFSM**;
- e) constant output at target power;

- f) active power reduction;
- g) maximum active power reduction at underfrequency;
- h) automatic connection and reconnection;
- i) requirements for control systems;
- j) scheme and settings of protection systems;
- k) information exchanges;
- l) voltage control system and reactive power capability;
- m) post fault active power recovery;
- n) reactive current injection (for **Inverter-based Power-Generating Modules**).



CC 9 ANNEX A – FURTHER SPECIFICATIONS ON LFSM-O/LFMS-U CALCULATION

In principle, **LFSM-O** service can be provided by every **Power-Generating Module** in operation above its minimum regulating level. As it is to be understood as a minimum active power reduction at a specific (high) frequency any further reduction at this frequency, may it be due to a shortfall of the primary energy (e.g. wind) or due to **Grid** constraints is harmless, but would even support the effect of **LFSM-O**.

In contrast, the provision of **LFSM-U** service may be subject to further preconditions. An active power increase is possible only for **Power-Generating Modules** running below their maximum capacity. Typically, **RES Generation** is dispatched according to its maximum available primary energy, unless there are **Network** constraints. **LFSM-U** capability shall not be understood as requiring **RES Generation** to run at a reduced active power output just to be prepared for an increase in case of an unlikely low frequency event. The economic **Generation** dispatch hence shall not be limited by **LFSM-U** performance.

Some numerical examples on **LFSM-U** and **LFSM-O** are reported in Table CC 7.

Table CC 7. Examples for LFSM-O and LFMS-U calculations for Power-Generating Modules.

LFSM-O		LFSM-U	
<p style="text-align: center;">$s_2 [\%] = 100 \cdot \frac{ \Delta f - \Delta f_1 }{f_n} \cdot \frac{\Delta P_{MAX}}{ \Delta P }$</p>		<p style="text-align: center;">$s_2 [\%] = 100 \cdot \frac{ \Delta f - \Delta f_1 }{f_n} \cdot \frac{P_{MAX}}{ \Delta P }$</p>	
$f_n = 50 \text{ Hz}$ $\Delta f_1 = 0.5 \text{ Hz}$ $P_{MAX} = 50 \text{ MW}$ $s = 5\%$		$f_n = 50 \text{ Hz}$ $\Delta f_1 = 0.5 \text{ Hz}$ $P_{MAX} = 50 \text{ MW}$ $s = 5\%$	
The Grid frequency increases of $\Delta f > 0$		The Grid frequency decreases of $\Delta f < 0$	
if $\Delta f < \Delta f_1$	LFSM-O not activated, and the Power-Generating Module shall follow the FSM requirements.	if $ \Delta f < \Delta f_1$	LFSM-U not activated, and the Power-Generating Module shall follow the FSM requirements.
if $\Delta f \geq \Delta f_1$	e.g. $\Delta f = 0.7 \text{ Hz}$ LFSM-O is activated. $s = 100 \cdot \frac{ \Delta f - \Delta f_1 }{f_n} \cdot \frac{P_{MAX}}{ \Delta P }$ $ \Delta P = P_{MAX} \cdot \frac{100}{s} \cdot \frac{ \Delta f - \Delta f_1 }{f_n}$ The Power-Generating Module will react to the positive change of Grid frequency with a decrease in active power equal to:	if $ \Delta f \geq \Delta f_1$	e.g. $\Delta f = -0.9 \text{ Hz}$ LFSM-U is activated. $s = 100 \cdot \frac{ \Delta f - \Delta f_1 }{f_n} \cdot \frac{P_{MAX}}{ \Delta P }$ $ \Delta P = P_{MAX} \cdot \frac{100}{s} \cdot \frac{ \Delta f - \Delta f_1 }{f_n}$ The Power-Generating Module will react to the negative change of Grid frequency with an increase in active power equal to:

$ \Delta P = 50 \text{ MW} \cdot \frac{100}{5\%} \cdot \frac{0.7 \text{ Hz} - 0.5 \text{ Hz}}{50 \text{ Hz}}$ $ \Delta P = 4 \text{ MW}$ <p>The new set-point of the Power-Generating Module will be the initial active power output before the abnormal frequency deviation minus 4 MW</p>	$ \Delta P = 50 \text{ MW} \cdot \frac{100}{5\%} \cdot \frac{0.9 \text{ Hz} - 0.5 \text{ Hz}}{50 \text{ Hz}}$ $ \Delta P = 8 \text{ MW}$ <p>The new set-point of the Power-Generating Module will be the initial active power output before the abnormal frequency deviation plus 8 MW</p>
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CC 10 ANNEX B – REFERENCE PARAMETERS

The Connection Code reports a number of parameters that are introduced in defining the requirements. The following cases apply to the process of setting the values of these parameters:

- a) existence of *international standards* for the parameters: the **TSOs** shall implement the requirements with the given standards in their respective **National / Regional Grid Codes** and the values are not subject to the process of harmonization. As regards this case, the standards are provided in Table CC 8 and they represent the most updated ones at the time of writing of this **Code**. In case of any change on the international standards, the most updated available references shall prevail on the contents of this Table CC 8, as legally approved.
- b) absence of *international standards* but the existence of reference *international best practices* for the parameters, the **TSOs** shall:
 - i. agree upon harmonized values of the parameters for the same **Synchronous Areas**, modify and update this **Code** from time to time, and adapt consistently their respective **National / Regional Grid Codes**. And/or,
 - ii. agree upon harmonized values of the parameters for the same **Synchronous Areas** and directly implement the parameters in their respective **National / Regional Grid Codes**.

In particular, among the international references reported in the **General Conditions**, the main international best practices considered in this **Connection Code** are: (i) ENTSO-e Network Codes for Connection Requirements of Generators and HVDC Systems, (ii) GCCIA Interconnector Transmission Code, (iii) MedTSO Mediterranean Grid Code.

As regards this case, the values referring to the available international best practices are reported in Table CC 9 as suggested and indicative values that may be considered during the process of definition and harmonization of the parameters by the **TSOs**.

- c) absence of both *international standards* and reference *international best practices* for the requirement and respective parameters: in these cases, the requirements define only the rules to be adopted and implemented by the **TSOs** in their **National / Regional Grid Codes**. The definition of details for the requirements, respective parameters and their values is left to the decision of each single **TSO**.

Table CC 8. International standards to be adopted in the Connection Code.

Ref. in the Code	Reference international standard
CC 2.4.1a) – THD	IEEE 519, BS EN 50160:2000, and IEC/TR3 61000-3-6 (1996)
CC 2.4.1c) – Flicker	IEC/TR3 61000-3-7 (1996) and IEC 60868).
CC 6.8.1.4d) – Communication protocols	IEC 60870-5 or equivalent (e.g. European CENELEC standards)
CC 5.5.3.4b) – Asymmetric load (negative phase sequence)	IEC 60255-160

CC 5.5.3.4c) – Stator and rotor overload protection	IEC 60255-149
CC 5.5.3.4d) – Over-/under-excitation protection	IEC 60255-140
CC 5.5.3.4e) – Over-/undervoltage at the Connection Point protection	IEC 60255-127
CC 5.5.3.4f) – Over-/undervoltage at the alternator terminals protection	IEC 60255-127
CC 5.5.3.4g) – Inter-area oscillations protection	IEC 60255-178
CC 5.5.3.4i) – Asynchronous operation (pole slip) protection	IEC 60255-178
CC 5.5.3.4l) – Unit transformer protection	IEC 60255-187
CC 5.5.3.4m) – Back-up against protection and switchgear malfunction	IEC 60255-151, -127
CC 5.5.3.4n) – Over fluxing (U/f) protection	IEC 60255-124
CC 5.5.3.4o) – Reverse power protection	IEC 60255-132, -167
CC 5.5.3.4p) – Inadvertent Energizing	IEC 60255-15
CC 5.5.3.4q) – Power-Generating Module load unbalance	IEC 60255-160
CC 5.5.3.4s) – Power-Generating Module stator temperature	IEC 60255-149
CC 5.5.3.4t) – Exciter Fault	IEC 60255-140
CC 5.5.3.4v) – Fault of the power generating module cooling temperature	IEC 60255-149
CC 5.5.3.4x) – Neutral voltage displacement protection	IEC 60255-150, -159
CC 7.2.3.4a) – External and internal short-circuit	IEC 60255-151
CC 7.2.3.4b) – Over- and under-voltage at the Connection Point	IEC 60255-127
CC 7.2.3.4c) – Over- and under-frequency	IEC 60255-181
CC 7.2.3.4e) – Unit transformer protection	IEC 60255-187
CC 7.2.3.4f) – Back-up against protection and switchgear malfunction	IEC 60255-150

Table CC 9. Suggested indicative values for the parameters based on international best practices.

Ref. in the Code	Parameters	Suggested Values
CC 1.1.6a)	$U_{\text{threshold}}$	110 kV
CC 1.1.6b)	$P_{\text{threshold}}$	75 MW
CC 2.4.1b)	Maximum unbalance of the three-phase voltage	1%

CC 5.1.1.5

	Frequency range	Time period for operation
f of the Synchronous Area	F_{flow2} Hz – F_{flow1} Hz	To be specified in minutes by the relevant TSO
	F_{flow1} Hz – F_{fhigh1} Hz	Unlimited
	F_{fhigh1} Hz – F_{fhigh2} Hz	To be specified in minutes by the relevant TSO

	Frequency range	Time period for operation
$f = 50$ Hz	48.0 Hz – 48.5 Hz	30 minutes
	48.5 Hz – 49.0 Hz	To be specified by each TSO but ≥ 30 minutes
	49.0 Hz – 51.0 Hz	Unlimited
	51.0 Hz – 51.5 Hz	30 minutes

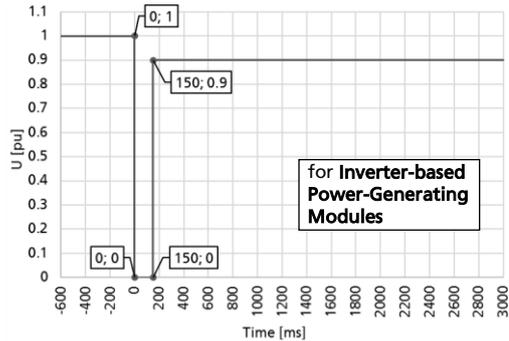
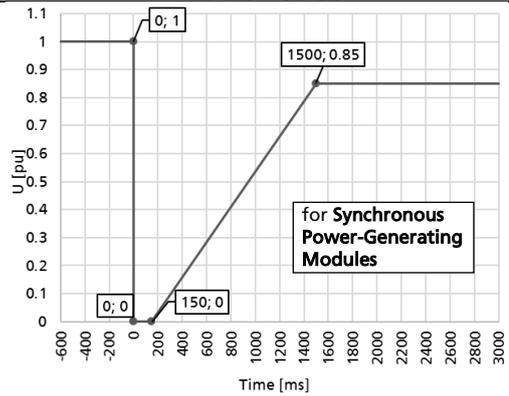
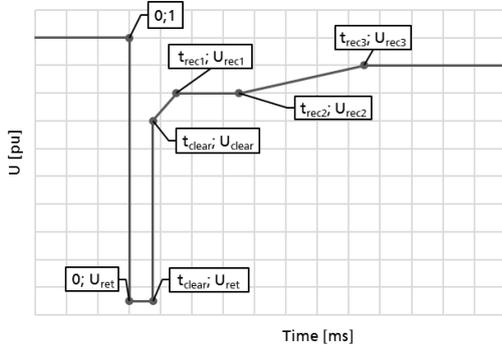
	Frequency range	Time period for operation
$f = 60$ Hz	57.6 Hz – 58.2 Hz	30 minutes
	58.2 Hz – 58.8 Hz	To be specified by each TSO but ≥ 30 minutes
	58.8 Hz – 61.2 Hz	Unlimited
	61.2 Hz – 61.8 Hz	30 minutes

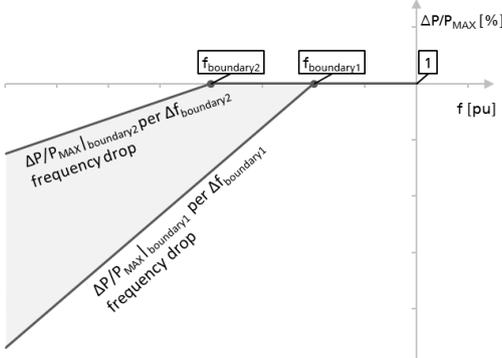
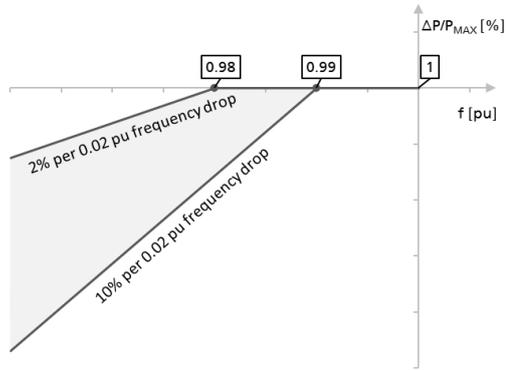
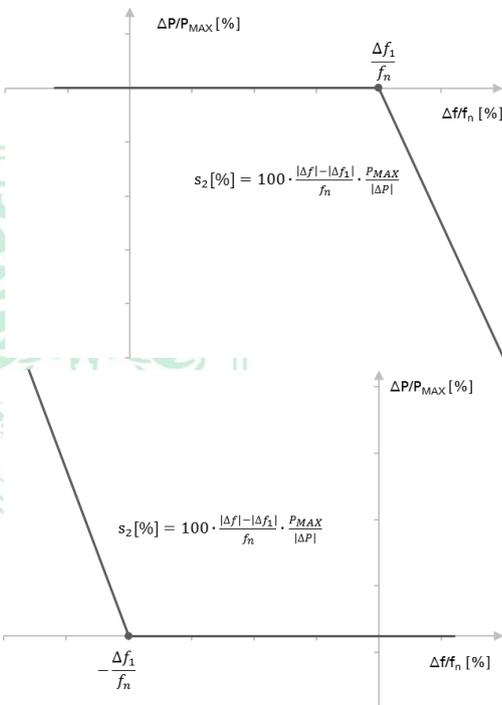
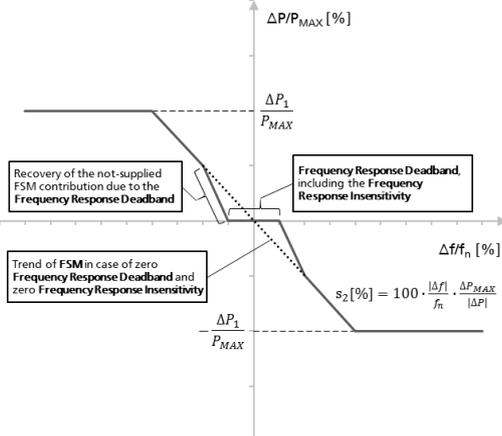
CC 5.1.2.4

Voltage range	Time period for operation
U_{low2} pu – U_{low1} pu	To be specified in minutes by the relevant TSO
U_{low1} pu – U_{high1} pu	Unlimited
U_{high1} pu – U_{high2} pu	To be specified in minutes by the relevant TSO

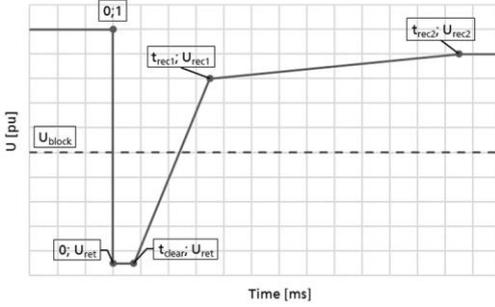
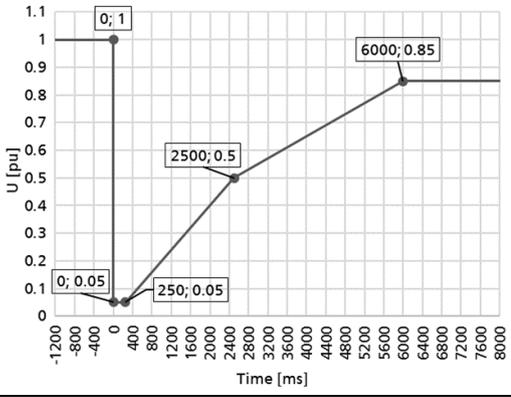
Voltage base for pu values	Voltage range	Time period for operation
110 kV – 400 kV	0.85 pu – 0.90 pu	60 minutes
	0.90 pu – 1.05 pu	Unlimited
	1.05 pu – 1.10 pu	30 minutes

CC 5.2.1.7

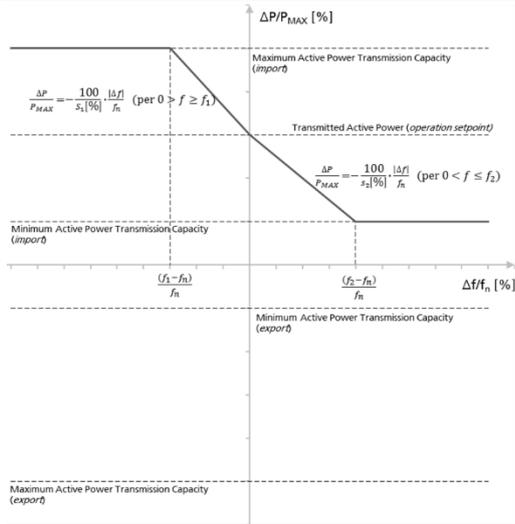


CC 5.2.2.2	Rate-of-change-of-frequency withstand capability	2.5 Hz/s computed over a 5 cycles time																	
CC 5.3.2.4 and CC 5.3.2.5	<p>Effects of environmental and operating conditions on the active power capability</p> 																		
CC 5.3.3.2	<p>LFSM-O and LFSM-U parameters</p>  <p> $s_2 [\%] = 100 \cdot \frac{ \Delta f - \Delta f_1 }{f_n} \cdot \frac{P_{MAX}}{ \Delta P }$ </p> <p> $s_2 [\%] = 100 \cdot \frac{ \Delta f - \Delta f_1 }{f_n} \cdot \frac{P_{MAX}}{ \Delta P }$ </p>	<p>LFSM-O:</p> <ul style="list-style-type: none"> - $\Delta f_1/f_n = [1.004 \text{ pu} - 1.01 \text{ pu}]$ - $s_2 = [2\% - 12\%]$ <p>LFSM-U:</p> <ul style="list-style-type: none"> - $\Delta f_1/f_n = [0.996 \text{ pu} - 0.99 \text{ pu}]$ - $s_2 = [2\% - 12\%]$ 																	
CC 5.3.3.4	$\Delta t_{LFSM_activation}$	2 sec																	
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CC 5.4.1.2	<p>Reactive power capability at maximum capacity</p>	<table border="1"> <thead> <tr> <th>Parameters</th> <th>Synchronous Power-Generating Modules</th> <th>Inverter-based Power-Generating Modules</th> </tr> </thead> <tbody> <tr> <td colspan="3">Definition of Inner Envelope</td> </tr> <tr> <td>Q/P_{MAX} Range</td> <td>0.95 – 1.08</td> <td>0.66 – 0.95</td> </tr> <tr> <td>Voltage Range</td> <td>0.150 – 0.225</td> <td>0.150 – 0.225</td> </tr> <tr> <td colspan="3">Definition of Outer Envelope</td> </tr> <tr> <td>U^{sup}</td> <td colspan="2">1.100</td> </tr> <tr> <td>U^{inf}</td> <td colspan="2">0.875</td> </tr> <tr> <td>Q/P_{MAX}^{inf}</td> <td colspan="2">- 0.500</td> </tr> <tr> <td>Q/P_{MAX}^{sup}</td> <td colspan="2">+ 0.650</td> </tr> </tbody> </table>	Parameters	Synchronous Power-Generating Modules	Inverter-based Power-Generating Modules	Definition of Inner Envelope			Q/P_{MAX} Range	0.95 – 1.08	0.66 – 0.95	Voltage Range	0.150 – 0.225	0.150 – 0.225	Definition of Outer Envelope			U^{sup}	1.100		U^{inf}	0.875		Q/P_{MAX}^{inf}	- 0.500		Q/P_{MAX}^{sup}	+ 0.650	
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CC 5.4.2.3	Voltage control mode	<ul style="list-style-type: none"> - $U_{REG_MIN} = 0.95$ - $U_{REG_MAX} = 1.05$ - $\Delta U_{REG} = 0.01$ - $t_{REG_90\%} = 1 - 5$ sec - $t_{REG_100\%} = 5 - 50$ sec 																											
CC 5.4.2.3b)	Reactive power control mode	<ul style="list-style-type: none"> - Setting steps ≤ 5 MVar of full reactive power - Typical accuracy $\leq \pm 5$ MVar of the full reactive power 																											
CC 5.5.2.3	Ramping limits	1 \div 20% of the Nominal Power per minute																											
CC 5.6.2.2	$t_{re-synchronization}$	15 minutes																											

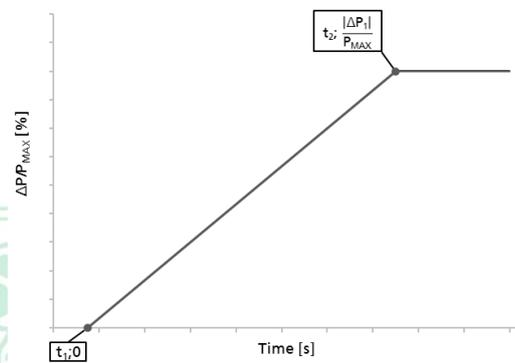
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<p>CC 6.3.2.2</p>	<p>Rate-of-change-of-frequency withstand capability</p>	<p>between – 2.5 and + 2.5 Hz/s (measured at any point in time as an average of the rate of change of frequency for the previous 1 s) computed over a 5 cycles time window</p>																											

CC 6.4.3.5



Parameters	Typical ranges
Frequency Response Insensitivity of the regulators Δf	max 30 mHz
Frequency Response Deadband	0 – ±500 mHz
Droop s_1	min 0.1%
Droop s_2	min 0.1%

CC 6.4.3.7



Parameters	Typical values
Maximum admissible initial delay t_i	0.5 sec
Maximum admissible choice of full activation time t_2 unless longer activation times are allowed by the relevant TSO	30 sec

<p>CC 6.4.3.9</p>	<p>LFSM-O and LFSM-U parameters</p> <p>$\frac{\Delta P}{P_{MAX}} = -\frac{100}{s_3[\%]} \cdot \frac{(f-f_1)}{f_n}$ (for $f > f_1$)</p> <p>$\frac{\Delta P}{P_{MAX}} = -\frac{100}{s_4[\%]} \cdot \frac{(f-f_2)}{f_n}$ (for $f < f_2$)</p>	<p>LFSM-O:</p> <ul style="list-style-type: none"> - $\Delta f_1/f_n = [1.004 \text{ pu} - 1.008 \text{ pu}]$ - $s_3 \geq 0.1\%$ <p>LFSM-U:</p> <ul style="list-style-type: none"> - $\Delta f_2/f_n = [0.996 \text{ pu} - 0.99 \text{ pu}]$ - $s_4 \geq 0.1\%$ 																				
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<p>CC 6.5.2.1a)</p>	<p>Voltage control mode</p>	<ul style="list-style-type: none"> - $U_{REG_MIN} = 0.95$ - $U_{REG_MAX} = 1.05$ - $\Delta U_{REG} = 0.01$ - $t_{REG_90\%} = 0.1 - 10 \text{ sec}$ - $t_{REG_100\%} = 1 - 60 \text{ sec}$ 																				
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