Technical standard for monitoring the compliance of power generating modules according to EU Regulation 2016/631

Review	Reason	Date	Comments
1.0	Publication	18/7/2019	
2.0	Publication version 2	3/11/2020	Adoption of Order TED/749/2020 and Royal Decree 647/2020. English version contains Corrigendum to Spanish version 2 published on 13/4/2021.
2.1	Publication version 2.1	9/7/2021	Relevant modifications to version 2

Index

Contents

1. INTRODUCTION

This procedure for assessing the requirements for network connection[1] of generators, called the **Compliance Monitoring Technical Standard** (hereinafter **Technical Standard**), develops those aspects of Title IV "Compliance monitoring" of EU **Regulation** 2016/631 (hereinafter referred to as "the **Regulation**") [1] that require a greater degree of detail in order to correctly verify compliance with the technical requirements of the **Regulation** by power generating modules (**PGM**).

For this purpose, it will be considered the national definition of the non-exhaustive technical requirements of the **Regulation** in the following documents:

- ***Orden TED/749/2020****, de 16 de julio, por la que se establecen los requisitos técnicos para la conexión a la red necesarios para la implementación de los códigos de red de conexión* [2].
- ***Real Decreto 647/2020****, de 7 de julio, por el que se regulan aspectos necesarios para la implementación de los códigos de red de conexión de determinadas instalaciones eléctricas* [3].

For the purpose of updating this **Technical Standard**, its entry into force will be the date of its publication and will cease to be in force after a **transitional period of 12 months,** following the publication of a new version of this **Technical Standard**. In the event of any substantial amendment to the previous regulation, network operators reserve the right to modify the duration of this transitional period.

PGM certificates for requirements, issued according to version 2.0 of this **Technical Standard,** shall be accepted for the purpose of obtaining the **final PGM certificate** according to this version of the **Technical Standard,** as specified in the equivalences in **Table 67** of subsection 7.1.4.2.

This **Technical Standard** includes the compliance monitoring procedure for any **PGMs** resulting from the application of the Fourth transitional provision of [3], "Application of technical requirements to non-existing installations whose commissioning date 6 months ahead the date of entry into force of this royal decree". In such cases, the **PGM owner** may provide a **reduced final PGM certificate** alternative to the **final PGM certificate** issued by an authorised certifier, as specified in subsection 7.1.2.

The difference between a **final PGM certificate** and a **reduced final PGM certificate** is in what requirements to assess, as well as in their assessment method(s). The remaining aspects defined in this **Technical Standard** for a **final PGM certificate** apply, by default, for a **reduced final PGM certificate**.

The accreditation scopes required of accredited entities for testing and simulation or authorised certifiers are specified in subsection 7.1.3.

[1] The scope of this **Technical Standard** is different from the Access and Connection criteria used to determine the network connection point. Both documents regulate different aspects.

Important:

- This **Technical Standard** may always be modified and updated by the Supervisory Working Group (**GTSUP**), after its publication on the web of the system operator and the web of the Distribution System Operators.
- It is always recommended to consult the current version of this **Technical Standard** before starting the process of assessing the technical requirements of **a PGM**. The assessment by an obsolete **Technical Standard** may be reason for refusal of the **PGM** compliance assessment procedure by the Relevant System Operator (**RSO**).
- Any information received, exchanged or transmitted under this **Technical Standard**, shall be subject to confidentiality by the subjects involved in compliance monitoring and shall be subject to professional secrecy and an obligation of confidentiality referred to in paragraph 2, 3 and 4 of Article 12 of the **Regulation**. Such persons shall ensure the confidentiality of such information and shall take all necessary measures to that end, being liable for the consequences of its non-compliance.
- It is the responsibility of the **owner** of the **PGM** to keep all the information and documentation included in this **Technical Standard** during the entire lifetime of the **PGM**.
- **Disclaimer:**
    - In the event of any inconsistency or discrepancy between the Spanish version and the English version of this document, the Spanish version will prevail.
    - For the avoidance of the doubt, commas will be used for decimal separation in this **Technical Standard**.

2. DEFINITIONS

In addition to the definitions in **Article 2 of the Regulation and Article 3 of [2]**, the following definitions shall be used in this **Technical Standard**:

1. **"Power generating unit (PGU)"**: This term is used in [1] but is not included in the definitions in Article 2 of the **Regulation**. This is the main generation plant, as defined in the **Regulation** and as developed for each technology in [3].
2. **"Additional components of the PGM (ACPGM)"**: any active elements which are part of the **PGM** and are not the **PGUs**, but whose response may have an impact on compliance with the technical requirements of the **Regulation**. For example: FACTS devices (STATCOM, SVC), active or reactive power control devices, hierarchical order controls higher than **PGM** level - for example, Power Plant Controller (**PPC**), synchronous compensators and batteries.

   As a clarification, passive elements that may have an effect on the compliance with technical requirements – for example, capacitor banks and reactances – are not considered **ACPGM**. However, they will be appropriately modelled to perform the corresponding simulations, but their certification under this **Technical Standard** will not be required. The **PGM owner owner** (or the entity designated for that purpose, e.g. manufacturers) shall provide the authorised certifier with the technical datasheets of the existing passive elements in the **PGM** for consideration when assessing tests and/or simulations.

To facilitate understanding of this **Technical Standard**, **Figure 1** shows schematic examples of **a PGM**, consisting of several **PGUs** and an **ACPGM**.

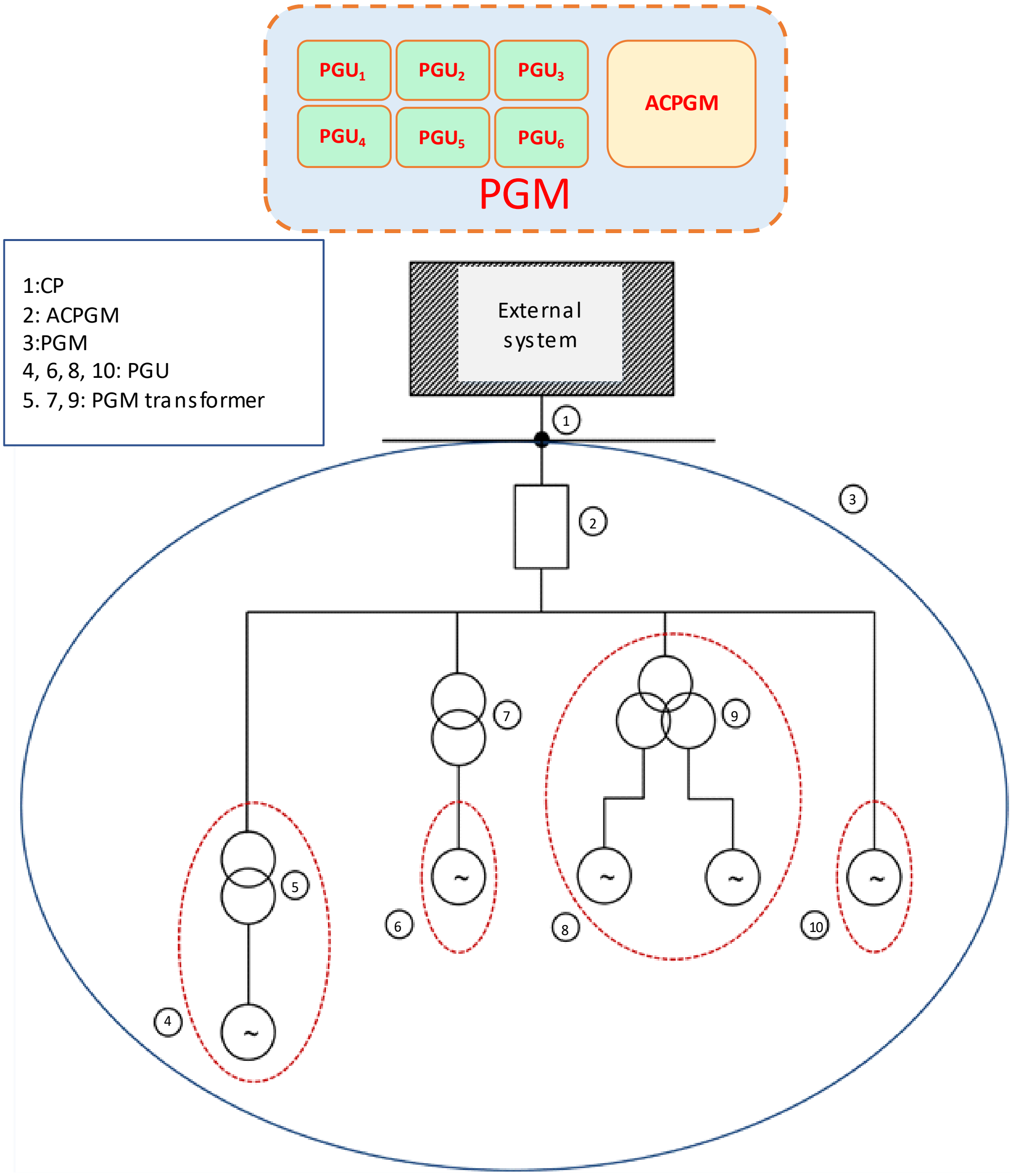


Figure 1. General and detailed schemes of a PGM consisting of several PGUs and an ACPGM.

The hierarchical scheme reflected in **Figure 1** is simplified as follows:

- Power generating facility, as defined in the **Regulation**. It consists of the **SPGM** or **PPM** and the network connection point (**NCP**)[2].
- **SPGM** or **PPM**, which consists of **PGU**(s) and **ACPGM**(s)
- **PGU** is the Main Generation plant, as developed in [3].

3. **"Active, reactive and apparent power of the PGU"**: the active, reactive and apparent power declared by the **PGU** manufacturer respectively.

[2] The network connection point (NCP) used in this **Technical Standard** corresponds to the definition of "connection point" in Article 2.15 of the **Regulation**.

4. **"PGM owner"**: for the purposes of this Technical Standard, the term **PGM owner** shall be used to refer to the physical or legal entity owning an power generating facility as defined in [1] and corresponding to the **PGM** holder in [2] and [3].

5. "**Entities accredited to perform tests and simulations**": Entity that has accreditation in accordance with the **UNE EN ISO/IEC 17025** standard, to perform **PGU** or **ACPGM** field or bench tests, or to perform **PGU, PGM** or **ACPGM** computer model simulations, by the National Accreditation Entity (**ENAC**) or by any other accreditation body with which ENAC has a mutual agreement (ILAC). This figure will be referred to as an "**accredited entity**" throughout this **Technical Standard**. In the case of entities established within the EU, the above definition should be interpreted in such a way that it does not contradict legal requirements; therefore, in such cases, the only acceptable accreditation would be that issued by the National Accreditation Body of the country in which the entity is established.

6. **"Authorised installer":** a natural or legal person performing, maintaining or repairing electrical facilities, in accordance with the definition of **ITC-BT-03 of RD 842/2002 approving the "Reglamento Electrotécnico de Baja Tensión".**

7. **"Installation company"**: a natural or legal person that, in performing the activities of assembly, repair, maintenance, revision and disassembly of high voltage facilities, meets the requirements of supplementary technical directive ITC-RAT 21 of RD 337/2014 **por el que se aprueba el "Reglamento sobre condiciones técnicas y garantías de seguridad en instalaciones eléctricas de alta tensión"**.

8. **"Authorised inspection body" (Organismo de control autorizado, in Spanish)**: the inspection bodies authorised by the competent administration for industry in the region where they carry out their activity, being those natural or legal person who can verify compliance with the safety conditions and requirements established in the safety regulations for high-voltage and low-voltage electrical products and installations; under the conditions described in **Real Decreto 2200/1995** of December 28th, **por el que se aprueba el "Reglamento de la Infraestructura para la Calidad y la Seguridad Industrial".**

9. "**Test**": for the purposes of this Technical Standard, the term **test or trial** shall be used indiscriminately. The first is more common in technical literature and there are other monitoring standards, [4] for example.

10. **"Final PGM certificate"**: a document certifying that the PGM type B (where applicable), C or D complies with the technical requirements to be assessed for this **Technical Standard** and complies with the **Regulation**. It shall be issued by an authorised certifier accredited for this **Technical Standard** in accordance with **UNE EN ISO/IEC 17065**. The **authorised certifier** shall compile the **PGU certificates for each technical requirement** and the **RSO compliance notes for a technical requirement** and provide the **final PGM certificate** to the **PGM owner**, or its representative for appropriate purposes, according to the scheme detailed in **Figure 7**. This **final PGM certificate** shall be delivered to the **RSO** during the Operational Notification process.

11. **"Reduced final PGM certificate"** variant of the previous **"Final PGM certificate"** for any **PGM**s resulting from the application of *Disposición transitoria cuarta* del RD 647/2020 *"Aplicación de requisitos técnicos a instalaciones no existentes cuya fecha de puesta en servicio sea anterior a los seis meses posteriores a la entrada en vigor de este real decreto"*.

12. **"Authorised certifier"**: an entity which issues **equipment certificates and documents for power generating modules** and is accredited by the national subsidiary of the European

Cooperation for Accreditation (EA), established in accordance with (EC) Regulation No. 765/2008 of the European Parliament and of the Council[3].

13. **"PGU, ACPGM or PGM certificate for a technical requirement"**: a document certifying that the **PGU, ACPGM or PGM** complies with an individual technical requirement of the **Regulation** to be assessed. It shall be issued by an **authorised certifier** under the same conditions as the **final PGM certificate**.
14. "**Protection review report**": after the regulatory inspection of the PGM according to ITC RAT-23 by an **Authorised inspection body**. Said **Authorised inspection body** shall issue a specific document accrediting the inspection of the additional protections, i.ethe protection relays located at the point of connection to the high voltage network according to the " *Acuerdo sobre ajustes de los sistemas de protección y control adecuados al punto de conexión entre el gestor de red pertinente y el propietario de la instalación de generación de electricidad* " [3] for Type B, C and D **PGM**, or the particular specifications of the **DSO** for Type A **PGM**.
15. **"RSO compliance document for a technical requirement"**: a document certifying that the **PGU (or PGM)** complies with an individual technical requirement of the **Regulation** assessed by the **RSO (TSO or DSO**, as applicable) instead of the **authorised certifier**. It shall be issued by a **TSO or DSO** as applicable, under the same conditions as the **final PGM certificate**.
16. "**Firmware**": Permanent and unalterable software that has been programmed into a controller and that establishes the lowest level logic that controls all the functions and interfaces necessary for the operation of a device of any type. The definition of its environment shall be part of the **final PGM certificate** when applying type certificates and analysing its impact.
17. "**Software**": Second-level programs and routines that enable the computer to perform certain tasks. The definition of its environment, as regards the algorithms required and related to the requirements of the **Regulation**, shall be part of the **final PGM certificate** when applying type certificates and analysing its condition.
18. **"Supplementary simulation":** Simulation of the **PGM** required to assess compliance with a certain technical requirement and supplementing the **equipment certificates** (from **PGU** or **ACPGM**) by test and/or simulation, for that requirement.
19. **"PGM terminals (BC)"**: for the exclusive purposes of this Technical Standard, PGM terminals shall be understood as the interface point of the **PGM** with the connecting network. This **Technical Standard** shall distinguish between two cases:
    - **Case A**: where the **BC** point is located at the HV side of the **PGM** step-up transformer of the PGM.
    - **Case B**: where the **BC** point is located on the downside of the **PGM** step-up transformer of the PGM, which is shared between several **PGMs**. Consequently, the measurement at the HV side of the transformer would not depend solely on the **PGM** to be assessed.

The **PGU** generation transformer defined in **Figure 1** shall not be considered as **a PGM** step-up transformer. **Figure 2** shows an example scheme to illustrate both cases:

[3] Regulation (EC) No 765/2008 of the European Parliament and of the Council of 9 July 2008 laying down the accreditation and market surveillance requirements for the placing of products on the market and repealing Regulation (EEC) No 339/93 (OJ L 218, 13.8.2008, p. 30).

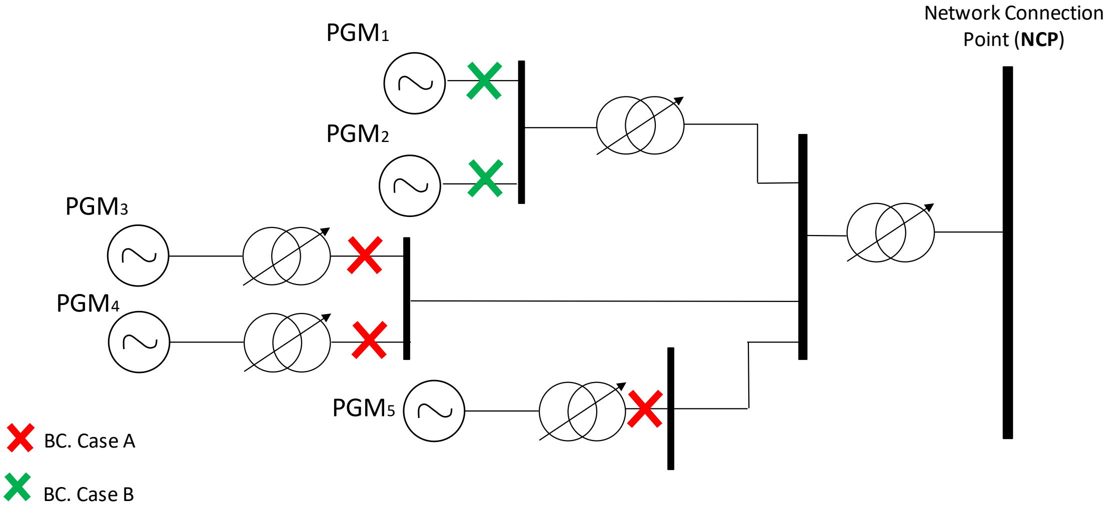


Figure 2. Example diagram of the indicative location of PGM terminals (Case A and Case B).

3. APPLICABILITY

This **Technical Standard** applies to all **PGMs** resulting from the **Regulation** as defined in [1], [2] and [3].

According to [3], the **significance of the PGMs** is assessed according to their **maximum capacity** and the **voltage in their NCP**:

- **Type A**: **PGM** having a connection point of less than 110 kV and a **maximum capacity** of 0,8 kW or more but not more than 100 kW.
- **Type B**: **PGM** whose connection point is less than 110 kV and whose **maximum capacity** is greater than 100 kW and less than or equal to 5 MW.
- **Type C**: **PGM** whose connection point is less than 110 kV and whose **maximum capacity** is greater than 5 MW and less than or equal to 50 MW.
- **Type D**: **PGM** whose connection point is 110 kV or more or whose **maximum capacity** is more than 50 MW.

Similarly, **PGMs** are divided into power park modules (**PPMs**) and synchronous power-generating modules (**PGMSs**). In the **Regulation** there are technical requirements whose compliance by the **PGM** is mandatory, and others whose obligatory nature is determined at the national level by the **TSO**, **RSO** or the relevant **TSO**, as appropriate.

Without prejudice to the provisions of this **Technical Standard**, system operators (**TSO**, **RSO** or **DSO**) may, in accordance with the regulation in force, perform or require additional tests and simulations of **PGMs** to verify compliance with any of the technical requirements established in the regulation in force ([1], [2] and [3] or regulation replacing or supplementing it) before they are commissioned or at any time during their entire lifetime, as stipulated in Articles 42.2 and 43.2 of [1].

4. COMPLIANCE ASSESSMENT PROCEDURE

The purpose of compliance assessment is to obtain a **final PGM certificate**.

4.1. General aspects

According to Title IV of the **Regulation**, **compliance assessment of each requirement** may be carried out by:

- **Compliance tests (T)**: In accordance with Articles 41.5 and 42 of the **Regulation**, the **PGM compliance tests for each requirement** shall be carried out by an **accredited entity** which shall prepare a test report and send the results to an authorised certifier for assessment. For each requirement, compliance of the **PGM** or the **PGU**, as applicable, shall be assessed and the corresponding **certificate of compliance by test of each requirement** or compliance by the **RSO**, as applicable, shall be issued.
- **Compliance simulations (S)**: In accordance with Articles 41.5 and 43 of the **Regulation**, the **compliance simulations of the PGM for each requirement** shall be carried out by an **accredited entity**, from the model certified in accordance with section 6 of this **Technical Standard**. The **accredited entity** shall prepare a report on the simulations and send the results to an **authorised certifier** for assessment. For each requirement, compliance with the **PGM** or **PGU**, as applicable, shall be assessed and the corresponding **certificate of compliance by simulation of each requirement** shall be issued.
- **Equipment certificates (C)**: In accordance with Articles 44 to 57 of the **Regulation**, the **compliance assessment of the PGM for each requirement** may be carried out through **equipment certificates** – based on **PGU** and **ACPGM** tests – issued by an **authorised certifier, taking into account that**:
    - The availability of the **equipment certificates** of all **ACPGMs** and **PGUs** does not always imply automatic compliance of the **PGM** (as a whole), since:
        - The collection of **equipment certificates** (**PGU** and **ACPGM**) does not always guarantee compliance with the technical requirements at the NCP, therefore, depending on the technical requirement to be assessed, it shall be necessary, in general, to perform **supplementary simulations**[4].
        - The **DSO or TSO**, as appropriate, may require the assessment, by test or simulation, of certain technical requirements at **PGM** level. In such cases, if the result of the assessment is satisfactory, the **DSO or TSO** shall notify the **PGM owner** by a **letter of compliance from the DSO or TSO** that the **PGM** complies with the requirement in question. Such compliance shall be attached by the **authorised certifier** in the **final PGM certificate**, where applicable.

[4] **Supplementary simulations** specified in some of the technical requirements to be assessed in section 5 shall require the use of a certified model in accordance with section 6 but shall not be required to be carried out by an **accredited entity**; however, they must be referred to the **authorised certifier** for assessment. Supplementary simulations shall consider the active and reactive power capabilities of the inverter when the ambient temperature is the PGM maximum design temperature, which shall be defined by the **PGM owner**, so that the inverter power shall not exceed these values.

- The validity of the **equipment certificates** of the **PGUs** and **ACPGMs** is conditional on the non-modification, after the certification, of the parameters used in the assessment process that have a relevant impact on the control functionalities necessary to comply with the requirements of this **Technical Standard**.

The compliance assessment shall be carried out at a nominal frequency of 50 Hz.

Table 1 specifies the technical requirements of the **Regulation** to be assessed and the possible form(s) of assessment according to the type of **PGM** to obtain the **Final PGM Certificate**[5], as well as the sections of this **Technical Standard** and the corresponding articles of the **Regulation**:

[5] Subsection 7.1.2 specifies the technical requirements of the Regulation to be assessed and the possible form(s) of assessment to obtain the reduced **Final PGM Certificate** alternative to the **Final PGM Certificate.**

REQUIREMENT				TYPE OF ASSESSMENT	
Article [1]	Definition of Requirement	PGM Type	Subsection of the Technical Standard	PPM	SPGM
13.2	Limited Frequency Sensitive Mode - Overfrequency (LFSM-O)	≥A	5.1	(S and T) or C**	(S and T) or C**
15.2.(a) and (b)	Remote power control capability and range	≥C	5.5	T or C	N/A
15.2.e	Power-frequency control	≥C	5.4	T	T
15.2.d	Frequency Sensitive Mode (FSM)	≥C	5.3	(S and T) or C**	(S and T) or C**
15.2.c	Limited Frequency Sensitive Mode-Underfrequency (LFSM-U)	≥C	5.2	(S and T) or C**	(S and T) or C**
21.2	Synthetic inertia during very fast frequency variations*	≥C	5.6	S	N/A
17.3	Recovery of active power after a fault	≥B	5.11	N/A	T (S***) or C**
14.3	Fault-ride-through capability of synchronous generators connected below 110 kV	≥B	5.11	N/A	T (S***) or C**
16.3	Fault-ride-through capability of synchronous generators connected above 110 kV	D	5.11	N/A	T (S***) or C**
20.3	Recovery of active power after a fault	≥B	5.11	T (S***) or C**	N/A
14.3	Fault-ride-through capability of PPMs connected below 110 kV	≥B	5.11	T (S***) or C**	N/A
16.3	Fault-ride-through capability of PPMs connected above 110 kV	D	5.11	T (S***) or C**	N/A
15.5.a	Black start*	≥C	5.12	N/A	T or C
15.5.b	Capability to take part in island operation*	≥C	5.13	S or C	S or C
15.5.c	Fast re-synchronisation capability	≥C	5.14	N/A	T or C
18.2.b	Reactive power capability at maximum capacity	≥B	5.7	N/A	(P) or C**
18.2.c	Reactive power capability below maximum capacity	≥B	5.7	N/A	(T) or C**
19.2	Power oscillation damping control	D****	5.9	N/A	S or C
20.2.b and 20.2.c	Fast fault current injection at the connection point in case of symmetrical (3-phase) faults	≥B	5.11	T (S***) or C**	N/A
21.3. b	Reactive power capability at maximum capacity	≥B	5.7	(T) or C**	N/A
21.3.c	Reactive power capability below maximum capacity	≥B	5.7	(T) or C**	N/A
21.3.d	Reactive power control modes	≥B	5.8	T or C**	N/A
21.3.f	Oscillation damping control	≥C	5.10	S	N/A

Table 1. Assessment of technical requirements as defined in this Technical Standard.

Legend:

- In the column “**PGM** Type”, the text **≥A** means that it applies to **PGM** Types A, B, C and D. The same applies to the rest. In column “Type of Assessment”: **S** means compliance simulation, **T** means compliance test, **C** means equipment certificate and **N/A** does not apply.
- *: Non mandatory requirement according to [1], [2] and [3].
- **: **Supplementary simulations** may be required for assessment purposes, as described in the pertinent subsection of this **Technical Standard**.
- ***: In those cases, specified as T (S***), the test will be performed in **PGU** and, if it is unsuccessful, the simulation of the complete **PGM** shall be performed, incorporating the **ACPGM** enabling the pertinent requirement to be met.
- ****: Applicable to **SPGM** type D and P_{max}>50 MW.

For any requirements where there are several methods for assessing compliance ("Type of Assessment" column in **Table 1**), the **PGM owner**[6] **shall be entitled to choose the form of its assessment** as stipulated in Title IV of the **Regulation**. In any event, the **final PGM certificate** shall always incorporate the assessment methodology followed for each assessed requirement.

According to the provisions of Article 40.4 of the **Regulation**, the **PGM owner** will apply for authorisation from the **RSO** prior to performing the tests with the connected **PGM**.

At the time of the initial assessment of **a PGM** and throughout its lifetime, network operators may request the **PGM owner** to submit the entire technical certification dossier, i.e. documentation related to tests and simulations carried out by **accredited entities** and **authorised certifiers** in the **PGM** compliance assessment process.

The general compliance assessment scheme is shown in **Figure 3**, and can be divided into two stages, prior to the commercial operation of the **PGM**: 1) obtaining **equipment certificates**, i.e. from **PGU** and **ACPGM**, constituting the **PGM**; 2) Obtaining the **final PGM certificate** and issuing the corresponding **final operational notification (FON)**, which, together with other information, technical and operational requirements, enable to reach the third stage, which is the commercial operation of the **PGM**.

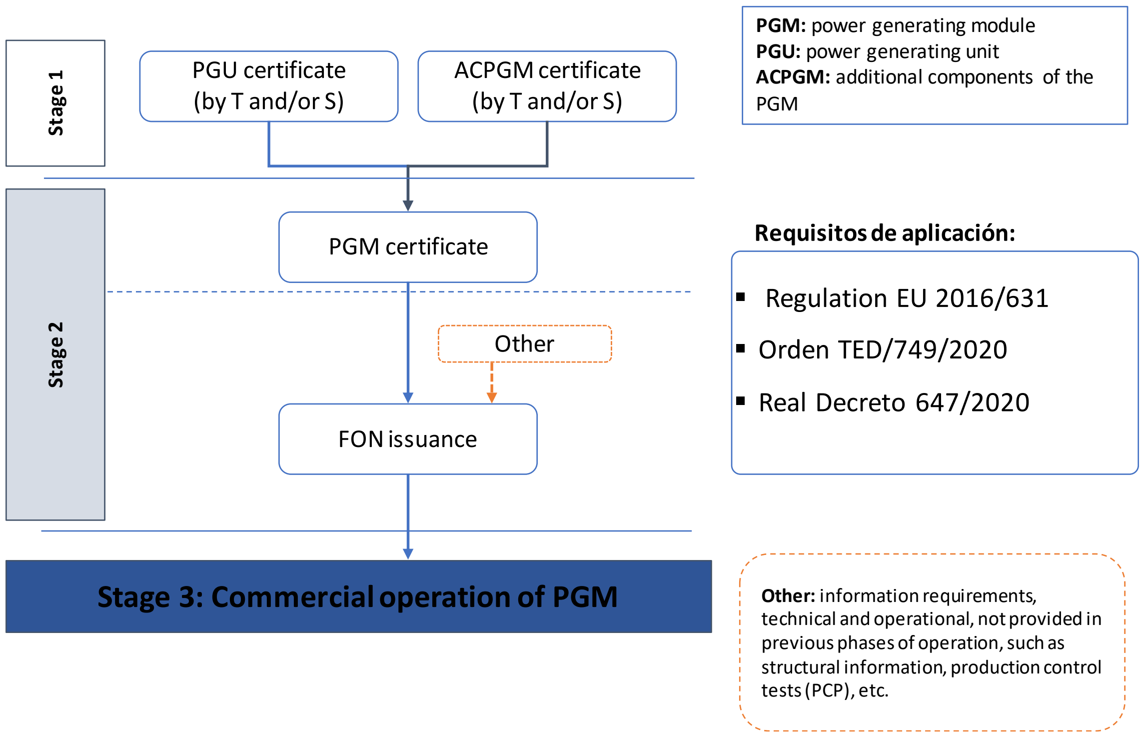


Figure 3. Stages in the general monitoring scheme.

[6] The **Regulation** defines the "**owner of a power generating facility**" as the natural or legal entity owning an electricity generation facility.

The general scheme of stage 1 is shown in **Figure 4** and **Figure 5**:

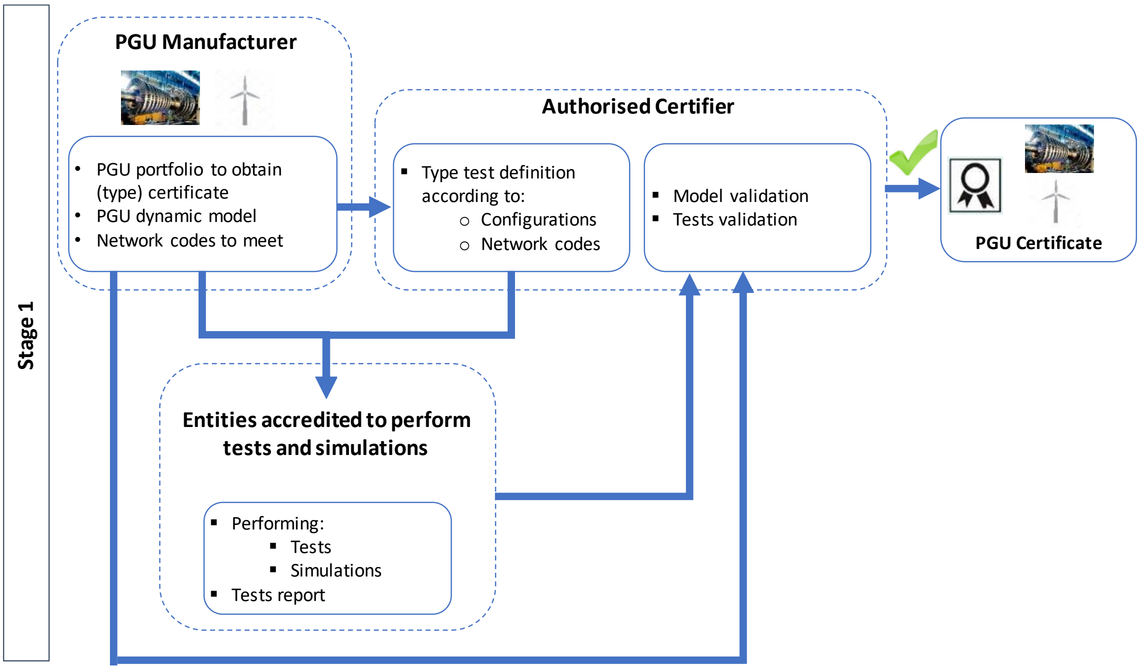


Figure 4. Scheme for obtaining the PGU certificate.

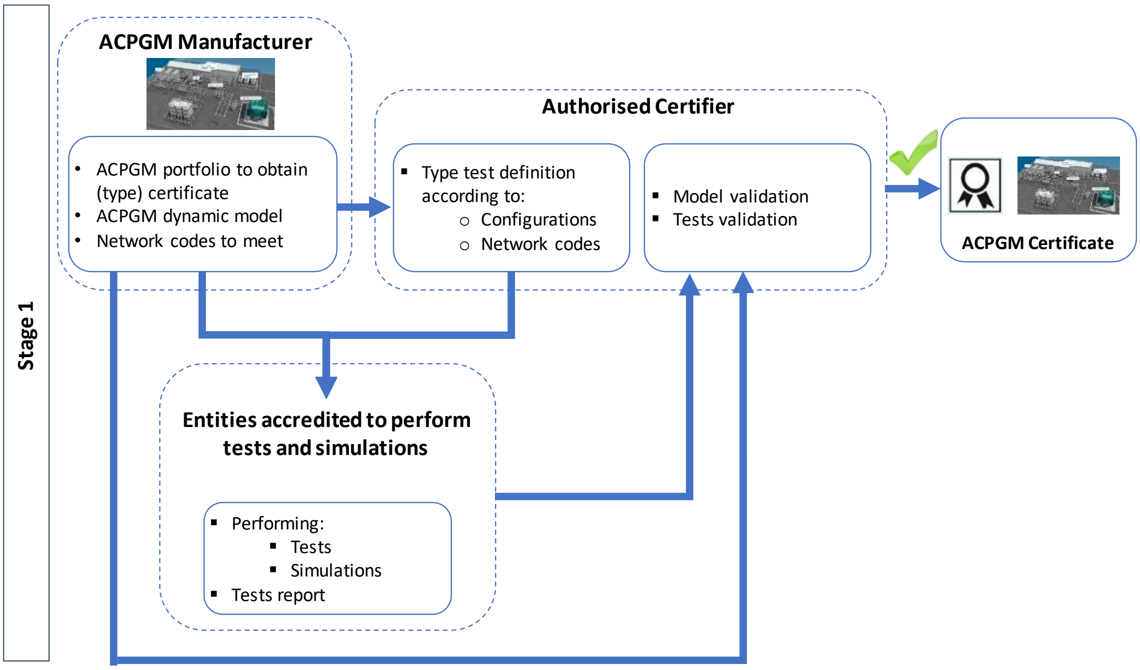


Figure 5. Scheme for obtaining the ACPGM certificate.

The general scheme of stage 2 is shown in **Figure 6**:

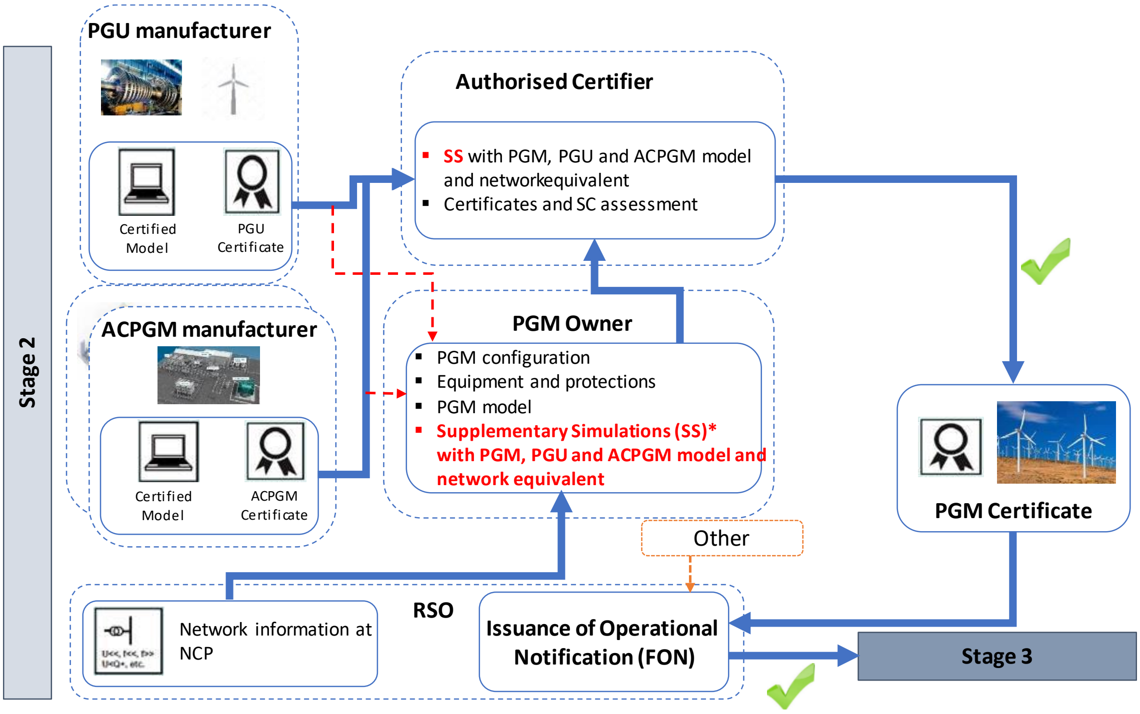


Figure 6. Scheme for obtaining the final PGM certificate from equipment certificates.

The following subsections elaborate on the schemes described in the figures in this section.

4.1.1. Final PGM Certificate

The **final PGM certificate** shall be issued by an **authorised certifier and shall specify that the PGM complies with all requirements to be assessed.** The **PGM owner** must provide it to the **RSO**.

The **PGM owner** shall be entitled to obtain separately, through different **authorised certifiers**, the compliance certificate for each of the requirements applicable to it pursuant to **Table 1.** In such cases, the **final PGM certificate** must clearly indicate which **authorised certifier** has certified each of the requirements. Where the **RSO** grants the compliance to a requirement, the **PGM owner** shall provide the **authorised certifier** with such compliance and the **authorised certifier** shall attach the written compliance of the **RSO** to that requirement in the **final PGM certificate** (see subsection 4.1).

Figure 7 schematically represents the elements that make up the **final PGM certificate**:

1) For each technical requirement, the equipment manufacturer (**PGU and ACPGM**) will provide the **certificates**, by simulation and/or test, which will have been previously issued by an **authorised certifier**. The assessment of these technical requirements shall be carried out by the **authorised certifier** using **supplementary simulations**, in addition to **equipment certificates**, where applicable.
2) For any requirements assessed by the **DSO or TSO**, as appropriate, the latter shall send a written communication in accordance with the **PGM owner**, or the entity designated by the **PGM** (e.g. the manufacturer of **PGU** or **ACPGM**), if the assessment is favourable.

It will be necessary for the **owner** to provide this written communication to the **authorised certifier** for inclusion in the **final PGM certificate**, for any requirements that need to be incorporated into the **final PGM certificate** and that are indicated in **Figure 7**.

3) The **authorised certifier** responsible for issuing the **final PGM certificate** shall assess all **PGM** certificates for compliance. For those mandatory requirements, the **authorised certifier** may issue the **final PGM certificate** when it has all the relevant certificates and notifications of compliance from the **RSO**.

4) Derogations from the fulfilment of technical requirements which have been provided to the **PGM owner** pursuant to Title V of the **Regulation**.

5) Where appropriate, the technical justifications accepted by the **TSO** for non-compliance, in particular with the technical requirement of Articles 13.2(e) and 15.2(c)(iii) of the **Regulation**, shall also be attached to the **final PGM certificate**.

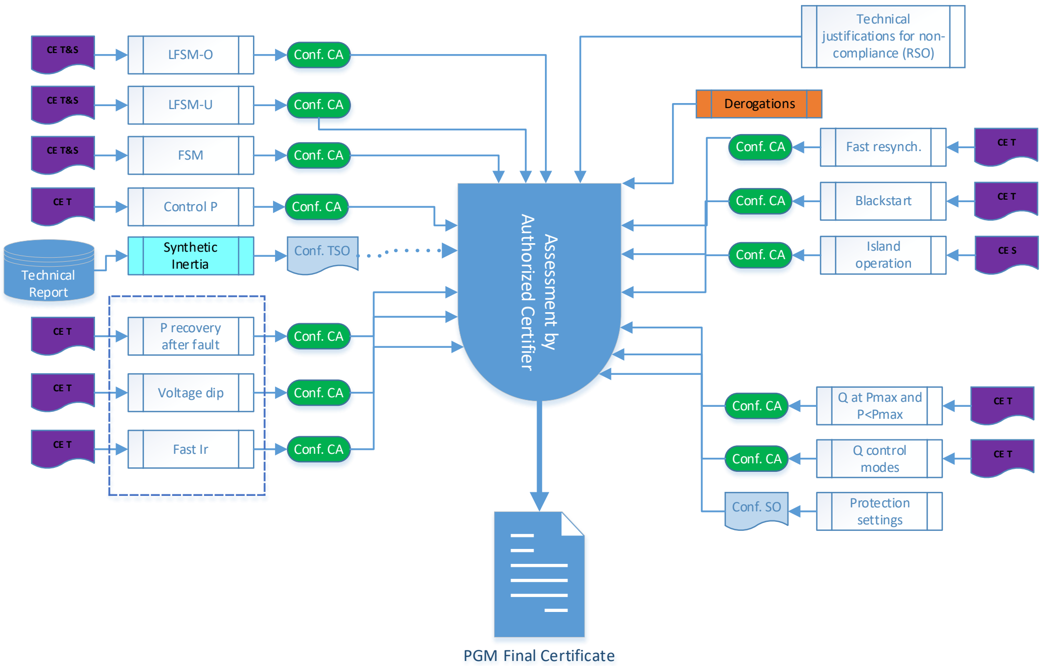


Figure 7. Scheme for obtaining the final PGM certificate from equipment certificates.

Figure 8 shows the general procedures that a **PGM** may follow for the compliance assessment of a given requirement, as described in section 6 of this **Technical Standard**. **Figure 9** details the complete process to be followed by **a PGM** for each requirement to be assessed.
The **PGM** owner may use **equipment certificates** provided **by the PGU** and/or **ACPGM manufacturer**, issued by an **authorised certifier** pursuant to this **Technical Standard**, to demonstrate compliance with a requirement (CAP by C), as provided for in the paragraphs of Title IV of the **Regulation**. In these cases, the tests and simulations indicated in the assessment procedure by test (CAP by T) and simulation (CAP by S) shall be required.

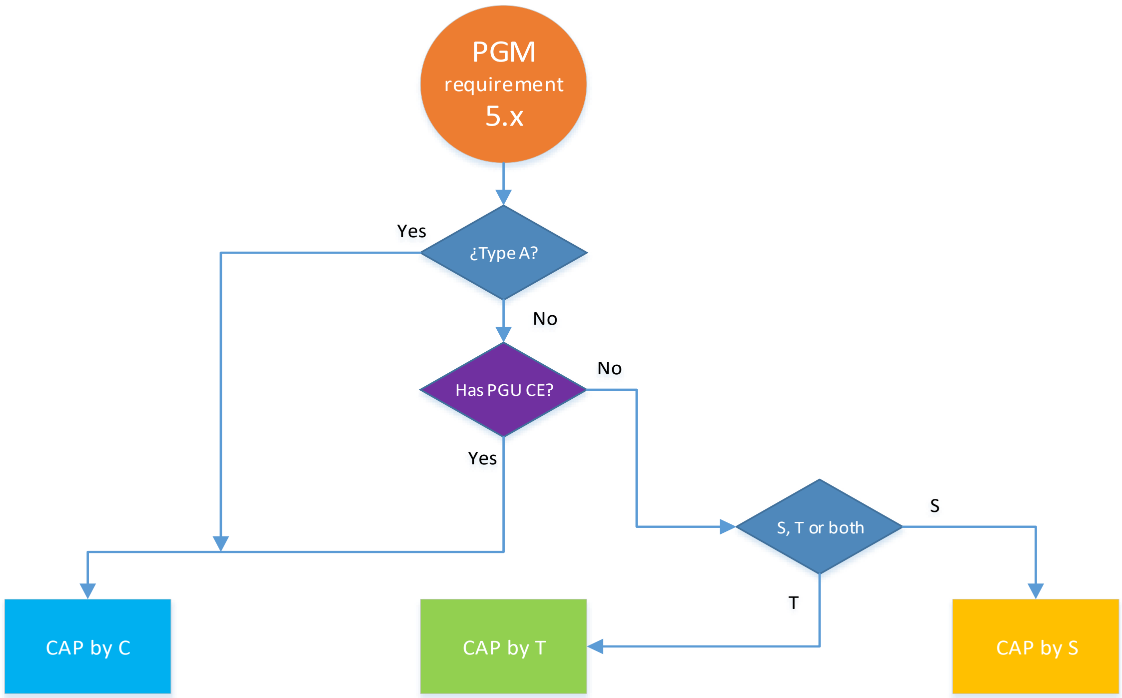


Figure 8. Compliance Assessment Procedures (CAP). General.

The details of the compliance assessment procedures (CAP) – **certificate, test and simulation** – are described in subsections 4.1, 4.2 and 4.3, respectively, and **Figure 9** reflects the entire assessment process that **a PGM** shall follow for each technical requirement.

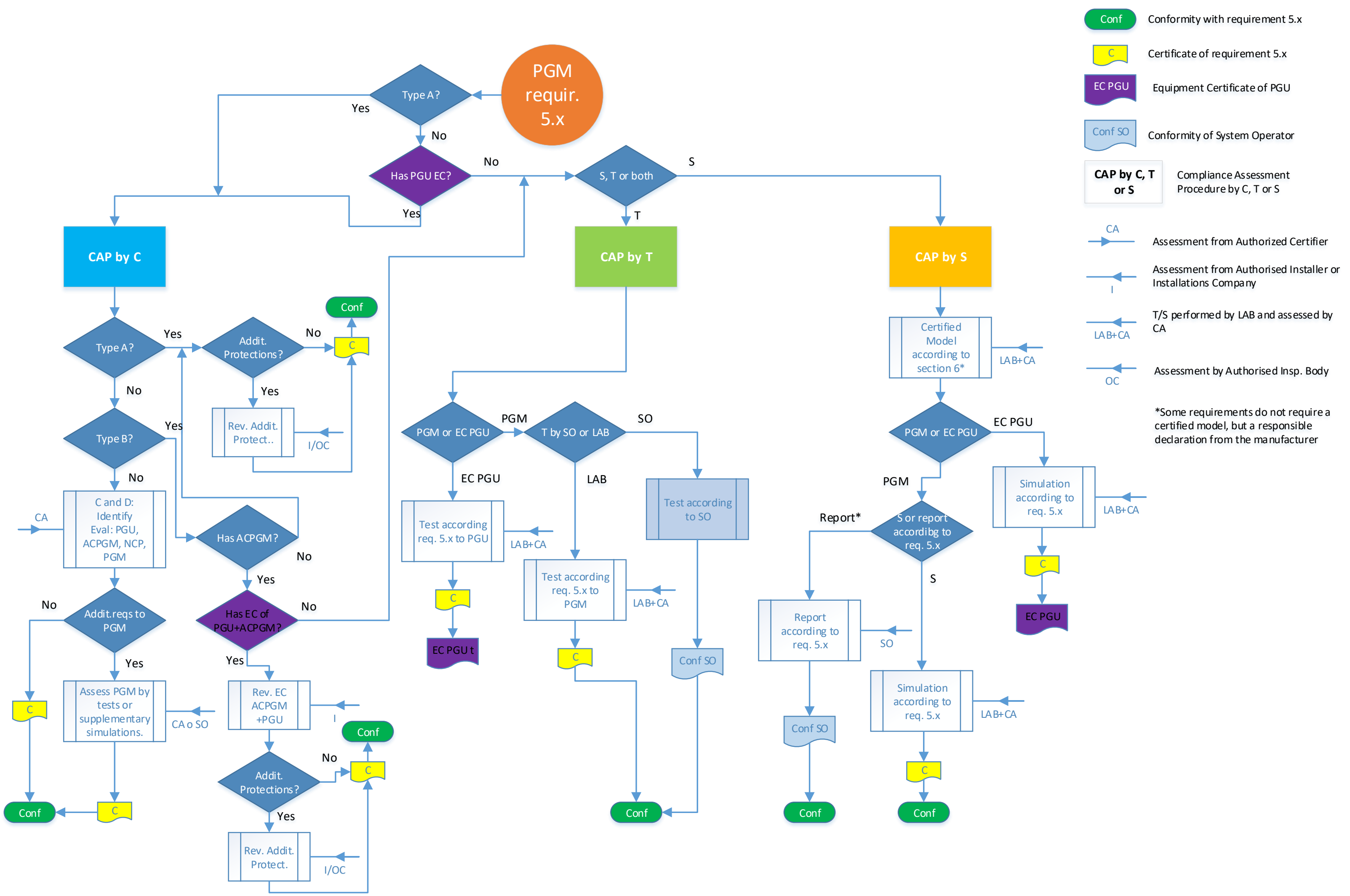


Figure 9. Compliance assessment procedures. Detailed.

4.2. Compliance assessment procedure by equipment certificate (CAP by C)

PGMs are composed of **PGUs** and **ACPGMs** that may affect compliance with the requirements of the **PGM**. If **ACPGMs** could influence compliance with a **PGM** requirement, they must be taken into account when assessing their compliance. In such cases, it will be necessary to have **equipment certificates of all these ACPGMs** in order to issue the **certificate of compliance with a PGM requirement**.

PGU manufacturers may obtain **equipment certificates** through the tests and simulations stipulated in section 5. Moreover, **ACPGM** manufacturers may obtain equipment certificates through the tests and simulations specified in subsection 4.6. Such **equipment certificates** shall be subsequently provided to the **owners** of the **PGMs. Figure 10** details the procedure to obtain **the PGM certificate for a requirement:**

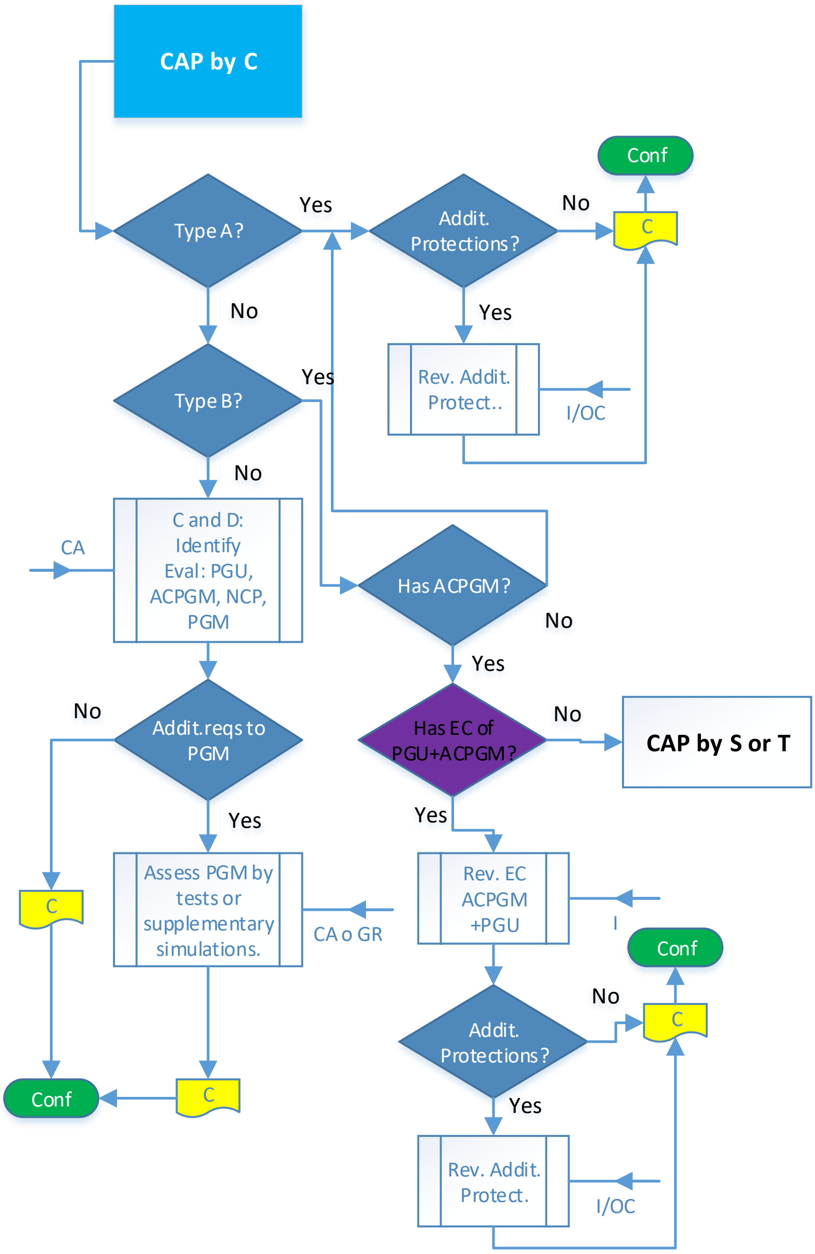


Figure 10. Equipment certificate compliance assessment procedure (CAP by C)

The compliance assessment by **equipment certificate** according to the significance of the **PGM** is specified below, but the last paragraph of section 3 related to the capabilities of the **RSO** to carry out the checks that are necessary in accordance with the legislation in force must be taken into account.

4.2.1. PGM type A

Compliance assessment through **equipment certificates (PGU)** will be performed by an **authorised installer**, if the **NCP** is in low voltage, or an **installation company**, if it is in high voltage, with the corresponding inspection according to **the electrotechnical codes (Reglamentos electrotécnicos de Alta o Baja Tensión)** in its most up-to-date version.

For **PGM** connected to the high voltage network and when the **PGM has protection schemes, additional to the protections of the PGU itself** (connection point protections, zero injection mechanisms, etc.), the compliance assessment shall include the review of the implemented settings to ensure that all technical requirements of [1], [2] and [3] are met, and a **Protection review report** shall be provided according to the minimum content specified in subsection 7.1.5 of this **Technical Standard**.

No **supplementary simulations** will be required.

In any event, the **PGM owner**, or its representative for appropriate purposes, shall always send the **final PGM certificate** within the **Facility Document** to the **RSO**, pursuant to Article 30 of the **Regulation**. Additionally, the **PGM owner** will refer the compliance to the additional protections (to the protections of the **PGM** itself), including a summary of the adjustments implemented.

4.2.2. Type B PGM

Compliance assessment through **equipment certificates** shall be carried out as follows:

- **PGM without ACPGM:** an **authorised installer** or **installation company**, as appropriate, shall collect the **equipment certificates** from the **PGUs** and the inspection certificate from an **Authorised inspection body**[7] for dispatch as the **final PGM certificate**. In this case, no **supplementary simulations** will be required.

- **PGM with ACPGM**: There are two possible situations:

    - Where the **equipment certificates** of the **PGU** clearly specify that the **PGU and ACPGM assembly** meets the relevant requirements, an **authorised installer or installation company**, as applicable, shall collect the **equipment certificates** of the **PGUs** and **ACPGMs** and the inspection certificate from an **Authorised inspection body**[7] for dispatch as the **final PGM certificate**. In those cases where the **authorised installer** or **installation company**, as applicable, cannot guarantee that the **PGU and ACPGM assembly** meets the corresponding requirements[8], it will be necessary to perform **supplementary simulations**, which must be assessed by an **authorised certifier**.

    - For the rest of the situations, the procedure defined in subsection 4.2.3 shall be followed.

For **PGUs with protection schemes additional to the protection devices of the PGM itself** (connection point protection relays or zero injection mechanisms), must be reviewed that the implemented settings comply with the "*Acuerdo sobre ajustes de los sistemas de protección y*

[7] Protection systems are regulated by electrotechnical codes (Reglamentos electrotécnicos).
- Section 3 of ITC-BT-05 establishes its inspection by an authorised inspection body for low voltage PGMs.
- Section 3 of ITC-RAT-22 establishes its inspection by an authorised inspection body for high voltage connected PGMs.

[8] If the PGM has a step-up transformer operating at a fixed tap, it is considered to have no relevant impact for assessing reactive power capability at maximum capacity and below maximum capacity.

control adecuados al punto de conexión entre el gestor de red pertinente y el propietario de la instalación de generación de electricidad" [3]. This review shall consist of a verification carried out by the **authorised installer** or **installation company** with the inspection made by an **Authorised inspection body**[7], and a **Protection Review Report** shall be provided according to the minimum content specified in subsection 7.1.5 of this **Technical Standard**.

In any event, the **PGM owner** or its representative for appropriate purposes shall always send the **final PGM certificate** within the **Power Generating Module Document** to the **RSO**, pursuant to Article 32 of the **Regulation**. Additionally, the **PGM owner** shall send the compliance with the additional protections (to the protections of the **PGM** itself), including a summary of the implemented settings.

4.2.3. PGM Types C and D

The **compliance assessment of each requirement for PGM types C and D** may be performed using the following methods, always considering **Table 1**.

4.2.3.1. Compliance assessment by certificate.

Compliance assessment through equipment certificates shall be carried out as follows:

1) The **authorised certifier** shall identify the components of the **PGM** that may affect the requirement to be assessed: **PGU, ACPGM** and other elements (generation transformer, cables, lines, etc.).

2) Compliance assessment stages for each requirement of **Table 1**:

1. **Assessment of each PGU**: The **PGU** will be checked to be the same as that stated in the **equipment certificate** or belong to the same type (see subsection 4.5), also checking the consistency with its **firmware** and **software** version.
2. **Assessment of ACPGMs**: The **ACPGMs** will be checked to be the same as that stated in the **equipment certificate** or belong to the same type (see subsection 4.6), also checking the consistency with its **firmware** and **software** version.
3. **Assessment of the remaining elements from BC** of the **PGM** up **to** the **NCP**. It shall be assessed by the authorised certifier, on a documentary basis, whether the equipment and other power elements (transformers) up to the **NCP**, have an impact on the assessment of technical requirements and shall be appropriately modelled in the compliance simulations.
4. **Assessment of the PGM as a whole**: It shall encompass all of the above points.

3) For **PGM** connecting to the **distribution network:**

a. As a prerequisite for requesting the energisation of the PGM to the DSO, it should be reviewed that the implemented settings comply with the "*Acuerdo sobre ajustes de los sistemas de protección y control adecuados al punto de conexión entre el gestor de red pertinente y el propietario de la instalación de generación de electricidad*" [3] and a **Protection review report** made by an **Authorised inspection body**[9], shall be provided according to the minimum content specified in subsection 7.1.5 of this **Technical Standard**.

[9] Protection systems are regulated by electrotechnical codes (Reglamentos electrotécnicos). Paragraph 3 of ITC-RAT-22 provides for its inspection by an authorised inspection body.

b. For the **final certificate of PGM**, the **authorised certifier** shall check the compatibility of the settings as described in point 4) below. For this check, the **authorised certifier** may use the **Protection review report**, as referred to in paragraph 2) above, or other information.

For **PGM** connecting to the **transmission grid**, the implementation of the settings of the protection systems requiring coordination with the transmission grid protections shall be provided by the **PGM owner** to the **TSO** and shall be reviewed by the **TSO**, in accordance with the provisions of procedimiento de operación 11.1 **"Criterios generales de protección en la red gestionada"**, with the aim of verifying the coordination in order to grant the selectivity pursuant to Article 32.2 of the **Regulation**.

4) For **PGM** connected to either the **transmission grid** or the **distribution grid**, the **PGM owner** shall submit to the **authorized certifier** the settings or voltage and frequency functions or relays of the **PGM** that may exist. The **authorized certifier** shall verify their compatibility with the non-disconnection requirements set out in [2] below:

- Frequency and time settings compatible with the established in Table 1 of article 1.1 of [2].
- Voltage and time settings compatible with the established in Table 2 and in Table 3 of article 2.1.1 of [2].
- Combined voltage, frequency and time compatibles with Figure 1 and Figure 2 of article 1.1 of [2].
- Combined voltage and time settings compatible with the corresponding **PGM** fault ride through profile as specified in article 3.1.1 of [2].
- Combined voltage and time settings compatible with the corresponding **PGM** transient overvoltage settings, as specified in articles 3.2.3 and 3.3.3 of [2].

This information shall be reflected in the **final PGM certificate**, in subsection 7.1.1.2.

5) In addition, for any technical requirements in section 5 of the **Technical Standard** in which the required collection of **equipment certificates** of the **PGUs** and **ACPGMs** is not sufficient, assessment at the **PGM** level will be required by tests and/or **supplementary simulations** under the conditions established for each requirement.

In any case, for the **issuance of the final PGM certificate**, the requirements specified in subsection 4.1.1 shall be met.

4.2.3.2. Compliance assessment by test and/or simulation.

The **procedure for assessing the compliance of a technical requirement by test and/or simulation** shall have as its objective one of the following two points:

- Directly obtaining compliance with this requirement for the **PGM** by test and/or simulation; or
- obtaining the **equipment certificate** of the **PGU** for such requirement by test and/or simulation.

4.3. Compliance assessment procedure by test (CAP by P)

The **procedure for assessing the compliance of a technical requirement by test** shall aim to one of the following two points:

- To directly obtain compliance with this requirement for the **PGM** by test; or
- to obtain the **equipment certificate** of the **PGU** for such requirement by test.

Figure 11 details the test procedure to be followed to obtain the **final PGM certificate** for a requirement:

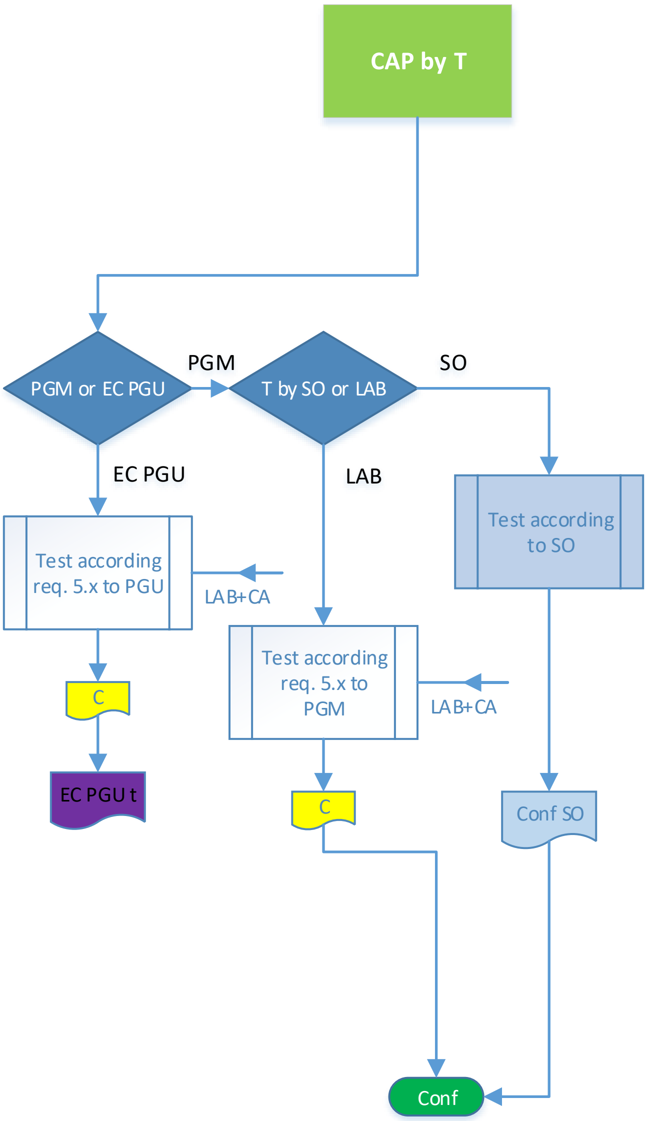


Figure 11. Compliance assessment procedure by test. (CAP by T).

Unlike the compliance assessment procedure by certificate, no differentiated procedures are established according to the significance of the **PGM**. In this case, the **compliance assessment through tests** shall be carried out as follows:

1) The **authorised certifier** shall identify the components of the **PGM**: It shall identify the **PGUs, ACPGMs** and other elements (generation transformer, cables, lines, etc.) that may affect the technical requirement to be assessed. These elements shall be taken into account when conducting the tests.

2) The test of each requirement shall be carried out by the **accredited entity** or the **DSO or TSO**, as appropriate, and may be on:

   - **PGM** in the field: The tests described in section 5 of this Technical Standard shall be performed. It must be identified whether the tests are performed by the **accredited entity** or the **DSO or TSO**, as applicable**.** In the first case, the test results shall be incorporated into a test report for assessment by the **authorised certifier**. In the latter case, the **DSO or TSO**, as appropriate**,** shall assess the results and notify the **PGM owner** in writing of the compliance of the **PGM** with the requirement in question, without the reference to that statement being required to be included in the final certificate.
   - **PGU**: The tests shall be performed on the **PGU** in order to obtain **a PGU equipment certificate** by test for a specific requirement.
   - **ACPGM**: The tests shall be performed on the **ACPGM** and associated **PGU** in order to obtain an **ACPGM equipment certificate (for a given PGU)** by test for a given requirement.

3) The **authorised certifier** shall assess the results of the tests carried out by the **accredited entity** and, if the assessment is positive, issue a **PGU equipment certificate** or a **PGM certificate** for the technical requirement by the **PGM**.

In any case, for the **issuance of the final PGM certificate**, the requirements specified in subsection 4.1.1 shall be met.

4.4. Compliance assessment procedure by simulation (CAP by S)

The **procedure for assessing the compliance of a technical requirement by simulation** shall aim to one of the following two points:

- To obtain compliance with this requirement for the **PGM** by simulation; or
- to obtain the **equipment certificate** of the **PGU or an ACPGM** for such requirement by simulation.

Figure 12 details the simulation procedure to obtain the **PGM certificate** for a requirement:

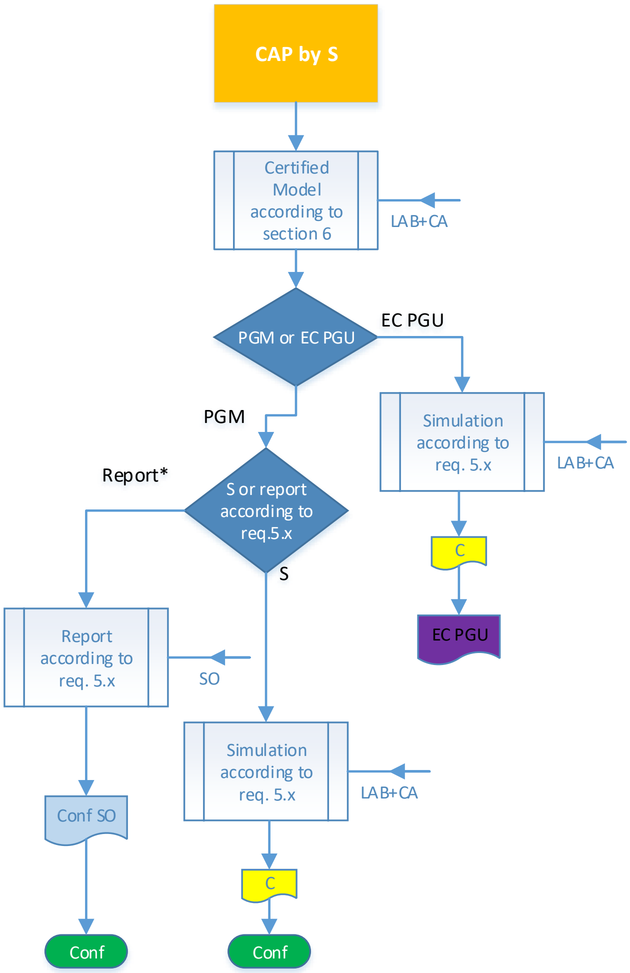


Figure 12. Compliance assessment procedure by simulation. (CAP by S).

Compliance assessment through simulations shall be carried out as follows:

1) First, it will be necessary to have a **PGM**, **PGU** and **ACPGM** model certified by an **authorised certifier** as set out in section 6 of the **Technical Standard**. The characteristics of the model for each requirement to be assessed are stated in section 6.

2) The **simulation of a requirement** shall be performed by the **accredited entity**, with the exception of **supplementary simulations**, and may relate to:
   - **PGM**: The **simulations** described in section 6 of the **Technical Standard** will be performed, and according to the specifications therein, the following shall be done:
     - If the **authorised certifier** requires simulations from an **accredited entity**, they shall be incorporated into a **simulation report** for further assessment.
     - If the **RSO** requires a report from the **accredited entity or the entity designated by the PGM (which could be the manufacturer), the RSO** shall be the one to assess and notify the **PGM owner** in writing of the compliance of the **PGM** for the requirement in question.
   - **PGU**: The **accredited entity** shall perform the simulations on the **PGU** with the aim of obtaining a **simulation equipment certificate from the PGU** for a given requirement.
   - **ACPGM:** Simulations will be performed by an **accredited entity** on **ACPGM** and associated **PGU**, with the aim of obtaining an **ACPGM equipment certificate** (for a given **PGU**) by simulation for a given requirement.
3) The **authorised certifier** shall assess the results of the simulations carried out by the **accredited entity**, as well as the **supplementary simulations**, which need not be carried out by an **accredited entity**, and issue, if the assessment is positive, either **a PGU equipment certificate** for the assessed requirement or a certificate of compliance with the technical requirement by the **PGM**.

In any case, for the **issuance of the final PGM certificate**, the requirements specified in subsection 4.1.1 shall be met.

4.5. PGU type with similar characteristics

Equipment certificates of a PGU may be used for other **PGUs of similar characteristics**, without the need to re-test. In such cases, the original **equipment certificates** shall be referred to as "**type PGU certificates per requirement**" for the purposes of this **Technical Standard**.

The **PGU certificate for a requirement** shall be considered as a **type PGU certificate per requirement** when the following conditions are met. In all cases, the **authorised certifier** shall carry out the assessment:

- **PPM**: The following criteria shall be followed with respect to the tested equipment:
    - <u>Wind technology **PGU**:</u>
        - Electrical generator with the same design specifications:
            - Nominal active power ±25% of the value corresponding to the electrical generator being tested.
            - Same typology (for example: asynchronous squirrel cage, doubly fed, etc.).
            - Same static connection voltage (asynchronous generators only), considering a tolerance in voltage of ±10%.
            - Transformation ratio ±20% (asynchronous generators only).
        - Electronic converter(s), if any, with the same hardware (which could be from different manufacturers) and specifications to support voltage dips.
        - Percentage short-circuit voltage of the transformer, referring to the base of the nominal active power of the wind turbine, within ±20 % of the value of the tested wind turbine. This point shall not apply to **PGUs** without a transformer connected to the medium voltage circuit.
        - Nominal active wind turbine power within ±25 % of the value of the tested wind turbine.

      The **PGU** manufacturer shall assess whether compliance with the technical requirements is affected by **software or firmware** updates and shall provide the **authorised certifier** with any additional information the **authorised certifier** deems appropriate to determine whether such updating has an impact on compliance with the technical requirements.

      Finally, the **authorised certifier** shall issue a favourable report, if appropriate, on the suitability of the proposed change to the wind turbine to further consider the validity of the **PGU type certificates per requirement**.

    - <u>**PGU** of photovoltaic or other technologies:</u>
        - Same topology of power stages. That is, the same arrangement of conversion stages, the same location of filters, the same location of relays, etc.
        - Same isolation class (low-frequency transformer, high-frequency transformer or no transformer).
        - Same AC connection state (1-phase or 3-phase).

- Nominal alternating current ±50% with respect to the type tested.
- Same control algorithm for all technical requirements.
- Groupings of several power stages (modular systems) shall be considered valid without the need for repeating tests.

The **PGU** manufacturer shall assess whether compliance with the technical requirements is affected by **software or firmware** updates and shall provide the **authorised certifier** with any additional information the **authorised certifier** deems appropriate to determine whether such updating has an impact on compliance with the technical requirements.

Finally, the **authorised certifier** shall issue a favourable report, if applicable, on the suitability of the proposed change to the **PGU** in order to further consider the validity of the **PGU type certificates per requirement**.

- **SPGM:** A variation of ±25% of the nominal active power of the **PGU** shall be permitted, where:
  - The **PGU of SPGM** as a whole, i.e. considering all the individual components according to the name used in Article 15.6.c.ii of the **Regulation** (alternator and prime mover, speed and power control, voltage control including PSS, if applicable) has been previously certified in accordance with this **Technical Standard**.
  - The individual components share the same simulation model with the same parameters. However, variations in these parameters shall be permitted if the authorised certifier determines that they have no impact on the outcome of the simulations to be carried out to assess a particular technical requirement.

  The **PGU** manufacturer shall assess whether compliance with the technical requirements is affected by **software or firmware** updates and shall provide the **authorised certifier** with any additional information the **authorised certifier** deems appropriate to determine whether such updating has an impact on compliance with the technical requirements.

  Finally, the **authorised certifier** shall issue a favourable report, if applicable, on the suitability of the proposed change to the **PGU of SPGM** in order to further consider the validity of the **PGU type certificates per requirement.**

The **PGU type certificate per requirement,** both for **PPM** and **SPGM**, **may** contain in its scope all the types of **PGU** for which it is applicable, considering the above criteria to define a **PGU type**. In this way, at the time of issuing the **final PGM certificate**, the **authorised certifier** will use this information to determine the applicability to the **PGU** of the **PGM** under assessment.

4.6. Assessment of the ACPGM

This subsection develops the methodology for obtaining **ACPGM** certificates, depending on their type, and the criteria for their consideration as an **ACPGM** type. In this version of the **Technical Standard**, only typologies for FACTS-type active elements (specified for **STATCOM), PPC, synchronous compensators and batteries** have been developed.

As a general rule, for all **ACPGMs**, whether or not they are **ACPGM** type, the following must be complied with:

- The whole control algorithm related to compliance with the technical requirements of this **Technical Standard** must be referenced with documented version (control algorithm and firmware version). The manufacturer shall provide a responsible declaration to the certifier, which shall be added to the certificate, stating that no modifications shall be made to the control algorithm, with respect to compliance with all technical requirements, in future firmware revisions.

- The **authorised certifier** shall consider the same firmware as long as there are no differences between the functional structure and the modular programming, which includes the same functions without any modification in their activation, functionality or input interface. Changes due to “bug” fixing or specific changes that have no impact on the compliance with technical requirements are considered outside this definition.

- If there is any change that may affect the behaviour of the **ACPGM** that may affect the compliance with the requirements, it must be communicated to the **authorised certifier**. Finally, the **authorised certifier** must issue a favourable report on the suitability of the proposed change to the **ACPGM** in order to further consider the validity of the **ACPGM certificate**.

- In the case of **ACPGM** that can work with different nominal AC voltages, the test shall be performed at the voltage chosen by the manufacturer within the design range of the **ACPGM** and shall be certified only for that voltage.

- It will be possible to obtain an **ACPGM certificate** independently of the **PGU certificate** and in accordance with subsection 4.6.1.1 for **STATCOM**, 4.6.2.1 for the **PPC**, 4.6.3.1 for the **synchronous compensator** and 4.6.4 for the **battery**.

- It is the responsibility of the **authorised certifier** to assess whether the **ACPGM** or passive elements included in this subsection have an impact on the assessment of each of the technical requirements of this **Technical Standard**.

The **ACPGM type certificate per requirement,** both for **PPM** and **SPGM**, **may** contain in its scope all the types of **ACPGM** for which it is applicable, considering the above criteria to define a **ACPGM type**. In this way, at the time of issuing the **final PGM certificate**, the **authorised certifier** will use this information to determine the applicability to the **ACPGM** of the **PGM** under assessment.

The following describes only the process of obtaining **ACPGM** certificates for **STATCOM, PPC, synchronous compensator and batteries**. For other types of **ACPGM**, the **authorised certifier** shall determine the tests to be carried out.

4.6.1. STATCOM

It is a static compensation device (Static Compensator), whose operation is based on a converter that modulates a voltage source of the desired amplitude, phase and frequency, which generates or consumes reactive power.
This subsection has been specified for the FACTS device called STATCOM, but would also be applicable for SVC (Static Var Compensator) devices.

4.6.1.1. Obtaining the STATCOM Certificate

The tests to be performed on **STATCOM** for obtaining the **STATCOM certificate** for this **Technical Standard** are as follows:

1. **Measurement of the reactive power capability exchanged by a STATCOM**

   The following process shall be followed:

   - The capacitive reactive power limits (Q_{cap_max}) and inductive power limits (Q_{ind_max}) of the **STATCOM** must be measured. Power limit measurements must comply with the equipment temperature stability case in both directions.
   - The test shall be carried out in one of the following ways:
     - Connecting the **STATCOM** to a power grid.
     - Connecting the **STATCOM** to a power electronics converter that generates an equivalent network.
   - The Q_{cap_max} and Q_{ind_max} measurements recorded in the test shall be used to validate the calculated limits using theoretical tools and/or simulation models.
   - A report shall be submitted justifying the equivalence of the calculated/simulated values vs. values measured in the test performed on a **STATCOM**.
   - Once the reactive power capability of a **STATCOM** is validated, the remaining operating points required for each application could be calculated using the same theoretical/simulation tool, adjusted to the parameters and characteristics of each case.

   However, instead of the process described, tests performed in accordance with subsection 6.2.1 of [6] shall be permitted, provided that the **authorised certifier** determines that the requirements of this **Technical Standard** are compatible.

2. **Measurement of the response dynamics of a STATCOM against a power/current setpoint change.**

   The following process shall be followed:

   - The response dynamics of a **STATCOM** inverter will be measured in the event of a power/current setpoint change.
   - The test shall be carried out in one of the following ways:
     - Connecting the **STATCOM** to a power grid.
     - Connecting the **STATCOM** to a power electronics converter that generates an equivalent network.
   - The measurements recorded in the test shall be used to validate the response obtained in a simulation environment for the same test configuration.

- A report shall be submitted justifying the equivalence of the simulated values vs. values measured in the test performed on a **STATCOM**.

However, instead of the process described, tests performed in accordance with subsection 6.2.3 of [6] shall be permitted, provided that the **authorised certifier** determines that the requirements of this **Technical Standard** are compatible.

4.6.1.2. STATCOM type of similar characteristics

STATCOM certificates may be used for other **STATCOMs** of similar characteristics. In such cases, such **STATCOM** certificates shall be referred to as "**STATCOM type certificates**" for the purposes of this **Technical Standard** and it shall not be necessary to re-conduct the tests.

A **STATCOM certificate** shall be considered as a **STATCOM type certificate** when the following conditions are met:

- Same topology of power stages.
- Same AC connection state (1-phase or 3-phase).
- Nominal alternating current ±50% with respect to the type tested.
- Same control algorithm for all technical requirements.
- Groupings of several power stages (modular systems) shall be considered valid without the need for repeating tests.

In all cases, the **authorised certifier** shall carry out the assessment.

4.6.2. PPC

The **PPC** (Power Plant Controller) is a control equipment that regulates the response of the **PGU** through analogue and/or digital signals to regulate its response in the different input parameters.

4.6.2.1. Obtaining the PPC Certificate

The tests to be performed on **PPCs** for obtaining the **equivalent certificate** for this **Technical Standard** are as follows. Two alternatives are permitted for testing the **PPC** connected to the **PGU**:

1. PPC test connected to a full **PGU**. Equivalent to "Measuring system configuration B" of subsection 6.1.2 of [6].
2. PPC test connected to a simulated **PGU**. Equivalent to the "Measuring system configuration A" specified in subsection 6.1.2 of [6].

The tests established in section 5 shall be performed on the **PPC** and **PGU** for any cases where the PPC may influence the fulfilment of each requirement, to be determined by the **authorised certifier** in coordination with the **accredited entity** for testing and simulation.

Alternatively, **PPC** certificates corresponding to tests performed pursuant to subsection 6.1 of [6] shall be accepted, provided that the **authorised certifier** determines that there is compatibility with the requirements of this **Technical Standard** as stated in subsection 4.7.

4.6.2.2. PPC type of similar characteristics

PPC equipment certificates may be used for other **PPCs of similar characteristics**, without the need to re-test. In such cases, such **equipment certificates** shall be referred to as "**PPC type certificates per requirement**" for the purposes of this **Technical Standard**.

The **PPC certificate for a requirement** shall be considered as a **PPC type certificate per requirement** when the following conditions are met:

- Same control algorithm regarding all technical requirements and parameter settings that exchanges with **PGUs**.
- Same communication protocol.

In all cases, the **authorised certifier** shall carry out the assessment.

4.6.3. Synchronous Compensator

A **synchronous compensator** is defined as a synchronous machine whose operation, network-coupled, is capable of dynamically regulating the voltage by producing or absorbing reactive power controlled by the excitation system without the need to have a power-driven machine capable of providing active power to the assembly.

4.6.3.1. Obtaining the Synchronous Compensator Certificate

The tests to be performed on the **synchronous compensator** for obtaining the **synchronous compensator certificate** for this **Technical Standard** are as follows:

1. **Measurement of the reactive power capability exchanged by a synchronous compensator.**

   In order to test the reactive power capability exchanged by the synchronous compensator, measurements of the capacitive (Q_{cap_max} - Overexcited) and inductive (Q_{ind_max} - Underexcited) reactive power limits of the **synchronous compensator**.

   The test shall be carried out in one of the following ways:

   a) Connecting the **synchronous compensator** to a power grid. The test shall be coordinated with the power grid manager concerned and the necessary steps shall be taken with regard to the levels and voltage control at the measuring point to maintain the safety of the system and the electrical equipment.

   b) In the case of **synchronous compensators**, where tests originate network voltage levels considered to be hazardous to the system, such tests shall be performed up to the maximum voltage limits agreed with the system operator. In such cases, equivalent point records and/or manufacturing tests may be used to validate their work points, providing a supporting report by the original manufacturer or by a rotary electric machine manufacturer with design and manufacturing capability. The objective of this justification report is to define equivalent points to define and check the P-Q curve of the machine.

   c) Connecting the **synchronous compensator** to a power electronics generator or converter group that generates an equivalent network. In cases where there is insufficient capacity to perform the test, tests conducted at different voltages that are representative of the reactive power limitations of the **synchronous compensator** shall be accepted.

   The Q_{cap_max} and Q_{ind_max} measurements recorded in the test, or failing that, the Q_{cap} and Q_{ind} measurements performed plus the justification report, shall be used to validate the calculated limits using theoretical tools and/or simulation models.
   A report shall be submitted justifying the equivalence of the calculated/simulated values vs. values measured in the test performed on a **synchronous compensator**.
   Once the reactive power capability of a **synchronous compensator** is validated, the remaining operating points required for each application could be calculated using the same theoretical/simulation tool, adjusted to the parameters and characteristics of each case.

2. **Measurement of the response dynamics of a synchronous compensator.**

Measurements of the response dynamics of the **synchronous compensator** shall be taken in the event of a reactive power/current setpoint change.

The test shall be carried out in one of the following ways:

a) Connecting the **synchronous compensator** to a power grid. The change-of-order step module (both positive and negative) shall be determined by consensus with the accredited entity, grid manager and companies involved in that test for each application, in such a way as to ensure the safety of the network or test facility concerned and its corresponding electrical switchgear.

b) Connecting the **synchronous compensator** to a power electronics generator or converter group that generates an equivalent network.

The measurements recorded in the test shall be used to validate the response obtained in a simulation environment for the same test configuration.
A report shall be submitted justifying the equivalence of the simulated values vs. values measured in the test performed on a **synchronous compensator**.

However, instead of the process described, tests performed in accordance with subsection 6.3 of [6] shall be permitted, provided that the **authorised certifier** determines that the requirements of this **Technical Standard** are compatible.

4.6.3.2. Synchronous compensator type of similar characteristics

Synchronous compensator certificates may be used for another **synchronous compensator** of similar characteristics. In such cases, such **synchronous compensator certificates** shall be referred to as "**synchronous compensator type certificates**" for the purposes of this **Technical Standard** and it shall not be necessary to re-conduct the tests.

A **synchronous compensator certificate** shall be considered as a **synchronous compensator type certificate** where the following conditions are met:

- Nominal reactive power of ±25% of the value corresponding to the test set, synchronous compensator and voltage control system.
- Same control algorithm for all technical requirements.

In all cases, the **authorised certifier** shall carry out the assessment.

4.6.4. Battery storage systems

For the purposes of this **Technical Standard**, all requirements related to a **PGU of PPM** detailed in section 5 of this **Technical Standard** shall be applicable to the battery storage systems of a hybrid **PGM.**

In addition, and as long as there is no regulation concerning the technical requirements for battery storage systems, those applicable to **PPMs** shall be maintained.

4.7. Tests and simulations of power generating units according to other regulations

The manufacturer of the **PGU or ACPGM** may submit to the **authorised certifier**:

- **PGU and ACPGM equipment certificates based on test and/or simulation requirements**, always issued by an **authorised certifier**, but according to other technical standards of similar scope to this **Technical Standard**.
- **Test reports and/or simulations per requirement**, performed by an **accredited entity** according to other technical standards similar to those established in this **Technical Standard**.

The **authorised certifier** may accept such reports and/or **equipment certificates** for the compliance assessment of the technical requirement concerned - without the need to repeat the test or simulation - provided that all of the following conditions are met:

1. The **stringency level of the requirement** in question is equal to or greater than that indicated in the **Regulation, in** [2] and [3].
2. The technical standard for certification of the requirement shall be preferably European or, failing that, internationally recognised (IEC, IEEE, etc.).
3. The **test or simulation methods** used in this **Technical Standard** shall be equal to or more demanding[10] than those specified in this **Technical Standard**.
4. The test and/or simulation has been carried out by an **accredited entity** and the **equipment certificate** issued by an **authorised certifier**.

In all cases, the **authorised certifier** shall always indicate in the **equipment certificate** which requirements are assessed in each **test report, simulation or equipment certificate** and under which technical standard they have been issued.

[10] Increased number of tests and simulations and lower tolerance for accepted errors.

5. METHOD OF TESTS AND SIMULATIONS FOR THE ASSESSMENT OF TECHNICAL REQUIREMENTS

Then, from subsection 5.1 to subsection 5.14, the methodology to be followed to perform **tests and simulations** on the **PGM** and **PGU** is explained, according to the procedures stated in section 4.

Measuring and instrumentation equipment (filter set, analogue/digital converter and data acquisition system (oscilloscopes and/or power analysers)), in order to conduct the tests, must be capable of measuring with a maximum error according to **Table 2** and must be calibrated.

Magnitude	Value
Maximum error in voltage measurement	±0,5% of Un
Maximum error in current measurement	±0,5% In
Maximum error in frequency measurement	±10 mHz

Table 2. Maximum errors permitted in measurements due to measurement equipment.

In addition, the **following aspects** will be considered for measuring and instrumentation equipment:

- The accuracy of the equipment used as a voltage source and frequency of the tests that require it shall be assured and verified by the measuring equipment, requiring a THD < 1% (**IEC 61000-3-7**) and an asymmetry of less than µ< 0,5 % (**IEC 61000-3-13**) in stable operation (no switching transients).
- The minimum sampling frequency for voltage and current shall be at least 3 kHz; however, a sampling frequency greater or equal than 10 kHz shall be required for the assessment of robustness requirements.

Transducers (voltage transformers, current transformers, Rogowsky coils, electronically compensated resistive dividers, etc.) required for connection to the **NCP** must be at least class 1 and may be those already installed in the **PGM**.

5.1. Limited Frequency Sensitive Mode-Overfrequency (LFSM-O)

5.1.1. Objective

The objective is to verify that the **PGM** is **capable of activating the power-frequency regulation reserve supply** as stated in:

- Article 13.2 of the **Regulation.**

- Article 1.3 of [2].

Pursuant to Articles 44, 47, 51 and 54 of the **Regulation**, the **compliance of the PGM** with this requirement may be assessed by:

- **test and simulation;** or
- **equipment certificate.**

Type A **PGMs** are exempted from the simulation assessment for this requirement.

Possible **assessment levels** for this requirement are:

- **PGM**
- **PGU when:**
    - The **PGM** does not have a hierarchical power-frequency control higher than the **PGU** itself; and
    - The **ACPGM** does not limit the response of the **PGU** to this requirement.

Where there is a **ACPGM** that may affect the control provided by the **LFSM-O** of the **PGU**, in addition to the **PGU** test or the **PGU test equipment certificates**, a **supplementary simulation** of the **PGM** will be required, as stipulated in 5.1.3, to verify that the **LFSM-O** requirement is met at **BC**, and not only at the **PGU** level.

In the absence of such an **ACPGM**, the test and simulation of the **PGUs**, or their test and simulation **equipment certificates**, shall be required, and the **supplementary simulation** shall not be required.

It is important to take into account the following terms reflected in the **Regulation** and in [2]:

- **Δf**: deviation of frequency f from 50 Hz (Δf = f – 50).
- **ΔP**: expected active power response in the event of a frequency deviation (Δf) calculated according to the following formula:

$$|\Delta P| = \frac{|\Delta f| - |\Delta f_1|}{f_n} \times \frac{P_{max}}{s_2} \times 100$$

For the purposes of this **Technical Standard** and in order to establish the response times, the following terms are introduced:

- **P_0**: active power of the **PGU** prior to performing a test (or frequency change).
- **P_{end}**: final active power of the **PGU after** performing a test (or frequency change).
- **ΔP_{test}:** deviation of the active power compared to the active power (P_0) prior to performing a test: $\Delta P_{test} = P_{end} - P_0$

- **Initial delay time (t_a)**: **LFSM-O** activation time. For the purposes of this **Technical Standard**, the reference to be used to measure this time shall be from the time when a frequency change is detected from which adjustment is expected until a 1% change (of **ΔP_{test}**). If the frequency is modified by means of a power supply connected to the controller, 20 ms must be subtracted from setpoint change to the **PGU**, so that a complete cycle can be detected with this new frequency.
- **Rise time (t_r)**: Concerning this **Technical Standard**, the value of t_r shall be the time to reach 90% of **ΔP_{test}** (not including the initial delay time t_a) taking into account the **measured** active power values prior to the disturbance (P_0) and final (P_{end}). That is, if, for example, P_0=7%P_{max} and the measured final power is P_{end}=14%P_{max}**, ΔP_{test}=7%P_{max},** where 90%ΔP_{test}= 6,3%P_{max}, and the value of t_r will be the corresponding value of P_0+6,3%P_{max} = 13,3% P_{max}.
- **Settling time (t_e):** For the purposes of this **Technical Standard,** the value of t_e shall be the time for the response to remain within a tolerance band less than ±5% of the **ΔP_{test}** (without including the initial delay time t_a) (**Figure 13**). If, for example, P_0=7%P_{max} and the measured final power is P_{end}=14%P_{max}, **ΔP_{test} =7%P_{max},** where 5% **ΔP_{test}** = 0,35%P_{max}, and the t_e value will be the value corresponding to the last P value that enters the band between P_{end}-5%**ΔP_{test}** = 13,65% P_{max} and P_{end}+5% **ΔP_{test}** = 14,35% P_{max}. However, and concerning this **Technical Standard**, in the **tests**, a permanent error between the final measured value and the expected value, less than ±5% of the P_{max} of the **PGU**, shall be considered as admissible. In addition, for the tests where the active power deviation is less than or equal to 20% of P_{max} of the PGU and in case of and oscillatory response that does not allow the assessment of the settling time, a trend line may be used to verify that the response is damped and consistent with the settling time required in the requirement.

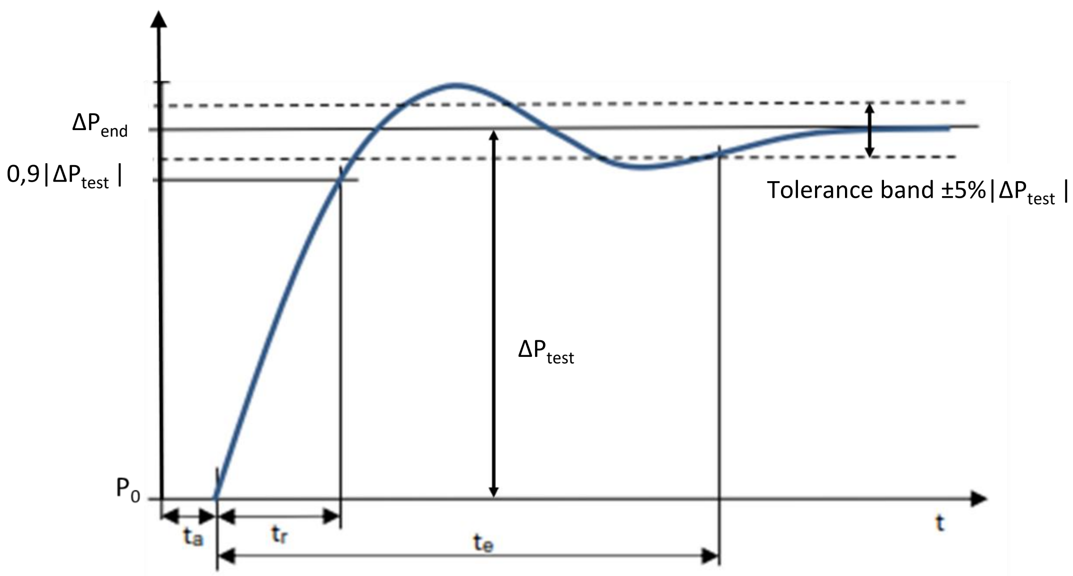


Figure 13. Example of a power response that illustrates the times t_a, t_r, and t_e defined above.

5.1.2. Assessment at PGU level for obtaining PGU certificate

5.1.2.1. PGU test method

This subsection details how the **LFSM-O activation** will be **tested** at the set frequency thresholds and the **LFSM-O activation times**.

The **test conditions** shall be as follows:

- A power supply connected to the **PGU** terminals when the **PGU** is disconnected from the network.
- **A PGU** connected to the network.

Irrespective of whether the **PGU** is connected to the network or not, **the input frequency to the PGU will be modified** using one of the following alternatives:

1. A device (internal or external) to introduce a digital or analogue input into the **PGU** control system.
2. A direct change of the frequency reference value in the **PGU** control system.
3. Direct modification of the frequency in the **PGU** terminals when the power supply has the capacity to modify the output frequency.

To **test this requirement**, the following **sequence of actions** shall be followed:

- The **FSM and LFSM-U** controls of the **PGU** will be **disabled**.
- The **tests** described in the following tables **will be performed**: **Table 3** to **Table 6.**
- For each previous test, **it shall be measured in PGU terminals**, depending on the connection point of the power supply. In any case, the measuring equipment will always record voltage and current, the rest of the magnitudes being calculated from these.
- The **FSM and LFSM-U** controls of the **PGU** will be **enabled**.
- It shall be verified, and recorded in the test report, that the **LFSM-O** has implemented the following adjustments in the **PGU**:
    - The activation threshold Δf_1 shall be equal to 0,2 Hz (50,2 Hz).
    - The droop s_2 shall be equal to 5%.

For this purpose, tests shall be carried out for the extreme frequency ranges (50,2 Hz and 50,5 Hz) and at the extreme droop values (2% and 12%), so that the full capacity is covered.

The initial conditions to perform the test shall be at nominal frequency, f_n (50 Hz ± 10 mHz), nominal voltage (± 5%) and next initial active power (P_{ini}), which shall ensure that the required power increases can be assessed within the time periods established in [2]:

- For laboratory tests**: The initial active power prior to the tests sequence shall correspond to the maximum capacity of the PGU.**

- <u>For field tests</u>: **The initial active power prior to the tests sequence shall correspond, at least, to:**
  - The minimum regulating level of the **PGU** (of a **SPGM**) will be greater than or equal to 45% of the maximum capacity (P_{max}) of the **PGU**. If the minimum level of regulation declared by the manufacturer is greater than 55% of P_{max}, the test shall be carried out at an initial active power equal to P_{max}.
  - The minimum regulating level of the **PGU** (of a **PPM**) will be greater than or equal to 50% of the maximum capacity (P_{max}) of the **PGU**.

Under no circumstances shall the tests involve a reduction in active power below the minimum level of regulation declared by the manufacturer.

As regards the initial reactive power in the test, it shall be null, both for **PPM** and **SPGM**.

Below is a description of how the **LFSM-O activation capacity will be tested** at 50,2 Hz and 50,5 Hz, for droops of 2% and 12%, according to the requirements specified in [1] and [2]. As required by the **Regulation**, the frequency steps generated shall be large enough to activate an active power change equal to or greater than 10% of the P_{max} of the **PGU**. Therefore, for the tests where the expected active power deviation is less than or equal to 10% of the P_{max} of PGU, the response times t_r and t_e shall not be evaluated.

At least 1 minute shall be measured at each frequency step and in any case sufficient time to stabilize the frequency step response, and the average active power (P(%) recorded) and the corresponding times (t_r and t_e) will be recorded.

Tests shall be performed for the entire admissible range of s_2 and of Δf_1, considering the following combinations to assess the **capacity of the PGU for this requirement**. The tests to be carried out shall be called:

- **OS2F2** test: s_2=2% and Δf_1=0,2 Hz (**Table 3**).
- **OS2F5** test: s_2=2% and Δf_1=0,5 Hz (**Table 4**).
- **OS12F2** test: s_2=12% and Δf_1=0,2 Hz (**Table 5**).
- **OS12F5** test: s_2=12% and Δf_1=0,5 Hz (**Table 6**).

The following tables describe these tests and the necessary frequency steps (Δf) and the expected active power variation in each test (ΔP_{test}) and the necessary response times.

The sequence of tests shown in the following tables shall be followed row by row, starting from the frequency final value of the previous test. Tests in which the first column specifies **SPGM** or **PPM** shall only be applicable to **SPGM** or **PPM PGUs** respectively. For example, in the OS2F2 test, **a PGU** of a **PPM** shall perform the tests: 1, 2, 3, 4, 5 and 6b, in this order.

OS2F2									
No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	50,10	0%			N/A	N/A	N/A	N/A
2	50,10	50,50	-30%						
3	50,50	50,70	-20%						
4	50,70	50,50	+20%						
5	50,50	50,10	+30%			N/A	N/A	N/A	N/A
6a SPGM	50,10	50,65	-45%						
6b PPM	50,10	50,70	-50%						

Table 3. LFSM-O Tests. 2% droop and 50,2 Hz frequency threshold.

OS2F5									
No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	50,40	0%			N/A	N/A	N/A	N/A
2	50,40	50,80	-30%						
3	50,80	51,00	-20%						
4	51,00	50,80	+20%						
5	50,80	50,10	+30%			N/A	N/A	N/A	N/A
6a SPGM	50,10	50,95	-45%						
6b PPM	50,10	51,00	-50%						

Table 4. LFSM-O Tests. 2% droop and 50,5 Hz frequency threshold.

OS12F2									
No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	50,10	0%			N/A	N/A	N/A	N/A
2	50,10	51,40	-20%						
3	51,40	50,30	+18,33%						

Table 5. LFSM-O Tests. 12% droop and 50,2 Hz frequency threshold.

OS12F5									
No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	50,40	0%			N/A	N/A	N/A	N/A
2	50,40	51,40	-15%						
3	51,40	50,60	+13,33%						

Table 6. LFSM-O Tests. 12% droop and 50,5 Hz frequency threshold.

5.1.2.2. PGU test acceptance criteria

The **PGU** shall be deemed **capable of activating the power-frequency adjustment reserve supply** if the following conditions are met:

1) No undamped oscillations occur in the response in the transition between test points.
2) The results meet all the requirements established in the **Regulation** and [2].
3) Before **active power reductions** during frequency rise and LFSM-O being active:
   - The **initial delay time (t_a)** shall be:
     - For Type C and D PPM PGUs: t_a will be less than or equal to the power response activation time set for **FSM** mode because it defines the **PPM**'s power response technical capability.
     - If t_a exceeds 2 s: the **PGM owner** shall provide the **TSO** with technical evidence to justify this value as established in the **Regulation**. If the **TSO** accepts the justification, the **TSO** shall give its written consent to the **PGM owner**, who shall forward it to the **authorised certifier** for incorporation in the **final PGM certificate**.
   - The **rise time** (t_r) will be:
     - For **PGU of SPGM**: less than or equal to 8 s for an active power variation of up to 45% of the maximum power.
     - For **PGU of PPM**: less than or equal to 2 s for an active power variation of up to 50% of the maximum power.
   - The **settling time** (t_e) shall be:
     - For **PGU of SPGM**: less than or equal to 30 s.
     - For **PGU of PPM**: less than or equal to 20 s.
4) Before **active power increases** during frequency down and **LFSM-O** being active:
   - The **initial delay time (t_a)** shall be:
     - For Type C and D **PGU of PPMs**: t_a will be less than or equal to the power response activation time set for **FSM** mode because it defines the **PPM**'s power response technical capability.
     - If t_a exceeds 2 s: the **PGM owner** shall provide the **TSO** with technical evidence to justify this value as established in the Regulation. If the **TSO** accepts the justification, the **TSO** shall give its written consent to the PGM owner, who shall forward it to the authorised certifier for incorporation in the final **PGM** certificate.
   - The **rise time** (t_r) will be:
     - For **PGU of SPGM**: less than or equal to 5 minutes for an active power variation of up to 20% of the maximum power. This slow behaviour will not be acceptable if the direction of frequency variation has reversed a few seconds earlier, in which case response times similar to the active power reduction case will be expected.

- For **PGU** of non-wind **PPM**: less than or equal to 10 s for an active power variation of up to 50% of the maximum power.
- For **PGU** of wind **PPM**: less than or equal to 5 s for an active power variation of up to 20% of the maximum power if the power is above 50% of the maximum power. For power less than 50% of the maximum power, the response time shall be as low as technically possible. The **PGM owner** shall provide the **TSO** with technical evidence to justify this value. If the **TSO** accepts the justification, the **TSO** shall give its written consent to the **PGM owner**, who shall forward it to the **authorised certifier** for incorporation in the **final PGM certificate**.

- The **settling time** (t_e) shall be:

  - For **PGU of SPGM**: less than or equal to 6 minutes. This slow behaviour will not be acceptable if the direction of frequency variation has reversed a few seconds earlier, in which case response times similar to the active power reduction case will be expected.
  - For **PGU of PPM**: less than or equal to 30 s.

5) In the tests, a deviation of ±5% of the P_{max} in the active power recorded from the expected active power according to the tables in subsection 5.1.2.1.

The **authorised certifier** shall issue **a PGU test equipment certificate for this requirement**, noting the test method followed, when it positively assesses that:

- The **LFSM-O** requirement is met for the droop and frequency ranges tested.
- The **PGU** adjustment corresponds to the one required in Article 1.3 of [2].

5.1.2.3. PGU simulation method

In the event that the **PGM** does not have an **ACPGM** that can modify the **LFSM-O** response of the **PGU**, the simulation of the **PGU** or its **equipment certificates by simulation** shall be required, and the **supplementary simulation** shall not be required.

This subsection details how the **LFSM-O requirement will be assessed by simulation**.

The **model certified** in accordance with section 6 shall be used and the tests in subsection 5.1.2.1 shall be replicated. The following aspects shall be taken into account in carrying out the simulations:

- Network used in the simulation: an infinite network represented by a 5 s inertia constant (H) generator (in case the simulation tool requires this data) and apparent power at least one hundred times greater than the apparent power of the **PGU** to be analysed shall be used.
- Configuration of other **PGU** control systems: voltage control and power-frequency regulation systems shall remain active. Its parameters will be fixed during the simulation.

The simulation execution process will be as follows:

- The simulation will be initialized correctly, i.e. the derivatives of the system status variables will be null.
- It will start in steady state, establishing:
    - Voltage 1 p.u. in **PGU terminals**.
    - **PGU of SPGM:** Reactive power less than or equal to zero.
    - **PGU of PPM:** Zero reactive power.
    - Three active power levels shall be simulated: minimum regulating level, 20%P_{max} and 90%P_{max}. If the minimum regulating level matches the 20%P_{max}, 30%P_{max} will be chosen as the second active power level.
- The simulation shall be initiated without disturbance. After 100 ms, frequency increments of 0,1 Hz, at most, shall be applied, and if the simulation tool allows, by applying additional mechanical pairs to the generator representing the infinite network (equivalent to reducing system demand) until a new steady state is reached.

5.1.2.4. PGU simulation acceptance criteria

The simulation report to be conducted by the **accredited entity** shall include the results of the simulations stated in subsection 5.1.2.3.

The acceptance criteria of the simulation results shall be the same as those indicated for the tests in subsection 5.1.2.2, except point 5) where only a deviation of ±5 % from the expected and recorded active power of ΔP_{test} (instead of P_{max}) shall be permitted. Additionally, a stable and well-damped active power evolution should be observed.

If the above requirements are met, the **authorised certifier** shall give approval to the report and issue **a PGU certificate by simulation for this requirement.** This certificate shall contain all the information on the simulations in addition to their unequivocal identification.

The **certificate for this requirement** shall be issued by the **authorised certifier** at **PGU** level, depending on the scope of the simulation performed. Licences shall be issued after a positive assessment that:

- The **LFSM-O** requirement is met for the droop and frequency ranges tested.
- The **PGU** adjustment corresponds to the one required in Article 1.3 of [2].

5.1.3. Supplementary simulation for obtaining PGM certificate

If there is a **ACPGM** that may affect the control provided by the **LFSM-O** of the **PGU**, in addition to the **PGU test** or the **PGU equipment certificates**, a **supplementary simulation** of the **PGM** will be required to verify that the **LFSM-O** requirement is met at BC, and not only at the **PGU** level.

With the <u>full model of the **PGM**</u> - equivalent models will not be supported, with the exception specified in subsection 7.5 - simulations will be performed under the following initial conditions:

- $P=P_{max}$ at the **PGM** level.
- Voltage of 1 p.u. at the HV side of the **PGM** transformer.
- Q = 0 at the **PGM** level.
- infinite s_{cc} or network equivalent.
- The activation threshold Δf_1 is 0,2 Hz.
- Droop s_2 equal to 5%.

The simulations will be performed with a stepped frequency sweep according to **Table 7:**

No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected (% P_{max})	ΔP_{test} recorded (% P_{max})	Deviation (% P_{max}) (<5% P_{max})	90% ΔP_{test} recorded (% P_{max})	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	50,20	0%			N/A	N/A	N/A	N/A
2	50,20	50,60	-16%						
3	50,60	51,00	-16%						
4	51,00	51,40	-16%						
5	51,40	51,00	16%						
6	51,00	50,60	16%						
7	50,60	50,30	12%						
8	50,30	50,00	4%			N/A	N/A	N/A	N/A

Table 7. LFSM-O supplementary simulation.

The acceptance criteria will be the same as those stated in subsection 5.1.2.4.

The **PGM certificate** for this requirement shall be issued under the version corresponding to the version of the **PGU** and/or **ACPGM certificates** used, even if the **supplementary** simulations have been performed according to this version of the **Technical Standard**.

The **supplementary simulation** report shall contain at least the following information:

- Description of the **PGM**, including **BC.**
- **PGM** model:
  - Simulation platform and version.
  - Equivalent network characteristics.
  - Data of the **PGU** model(s), including its validation certificate/report, simulation platform and version and parameters used in the simulations.
  - Data of the **ACPGM** model(s), including its validation certificate/report, simulation platform and version and parameters used in the simulations.
  - Description of the modelling of the other components of the **PGM**.
- Outcomes:
  - Table similar to **Table 7** completed, indicating the compliance of each simulation.
  - Exportable simulation packages. Upon request of the **RSO**, the model of the **PGM** used in the simulations will be delivered.
- Conclusions.

5.1.4. Assessment at PGM level for obtaining PGM certificate

In the event that the **PGM owner** does not have or does not wish to use the **equipment certificates** for **PGU** and **ACPGM** for this technical requirement, the tests and simulations described in subsections 5.1.2.1 and 5.1.2.3, respectively, must be performed at **PGM** level. If the acceptance criteria for tests and simulations described in subsections 5.1.2.2 and 5.1.2.4 are met respectively, the **authorised certifier** will issue **a PGM certificate** for this requirement without the need to perform the **supplementary simulations** stipulated in subsection 5.1.3.

5.2. Limited Frequency sensitive mode-Underfrequency (LFSM-U)

5.2.1. Objective.

The objective is to verify that the **PGM** is **capable of activating the power-frequency regulation reserve supply** as stated in:

- Article 15.2.c of the **Regulation.**

- Article 1.7 of [2].

Pursuant to Articles 45, 48, 52 and 55 of the **Regulation**, the **compliance of the PGM** with this requirement may be assessed by:

- **test and simulation;** or
- **equipment certificate**.

Possible **assessment levels** for this requirement are:

- **PGM,** or
- **PGU when:**
  - The **PGM** does not have a hierarchical power-frequency control higher than the **PGU** itself; and
  - The **ACPGM** does not limit the response of the **PGU** to this requirement.

If there is a **ACPGM** that may affect the control provided by the **PGU LFSM-U** in addition to the **PGU test** or the **PGU equipment certificates**, a **supplementary simulation** of the **PGM** will be required, according to 5.2.3 to verify that the **LFSM-U** requirement is met at BC, and not only at the **PGU** level.

In the absence of such **ACPGM**, the test and simulation of the **PGUs** or their **equipment certificates** shall be required, and the **supplementary simulation** shall not be required.

The same terms as defined in subsection 5.1.1 shall be used.

5.2.2. Assessment at PGU level for obtaining PGU certificate

5.2.2.1. PGU test method

This subsection details how the **activation of the LFSM-U** will be **tested** at the set frequency thresholds as well as the **activation times** of the **LFSM-U**.

To **test this requirement**, the terms, test conditions, input frequency modification method and **sequence of actions** analogous to that carried out in subsection 5.1.2.1 (**LFSM-O**) shall be used.

It shall be verified, and reflected in the test report, that the **LFSM-U** has implemented the following adjustments in the **PGU**:

- The activation threshold Δf_1 shall be equal to -0,2 Hz (49,8 Hz).
- The droop s_2 shall be equal to 5%.

For this purpose, tests shall be carried out for the extreme frequency ranges (49,8 Hz and 49,5 Hz) and at the extreme droop values (2% and 12%), so that the full capacity is covered.

The initial conditions to perform the test shall be at nominal frequency, f_n (50 Hz ± 10 mHz), nominal voltage (± 5%) and next initial active power (P_{ini}), which shall ensure that the required power increases can be assessed within the time periods established in [2].

For both laboratory and field tests, the initial active power **prior to the tests sequence** (P_{ini}) must correspond to:

- For **PGU** in **SPGM** and **PGU** in non-wind technology **PPM**: the minimum regulating level of the **PGU**. If the minimum regulating level is so high that the maximum capacity of the **PGU** is reached at any of the frequency steps presented in the tests, the frequency steps shall be readjusted.
- For PGU in wind technology **PPM**: 50% maximum capacity (P_{max}) of the **PGU**.

Under no circumstances shall the tests involve an increase in active power greater than the **maximum capacity** declared by the manufacturer.

As regards the initial reactive power in the test, it shall be null, both for **PPM** and **SPGM**.

Below is a description of how the **LFSM-U activation will be tested** at 49,8 Hz and 49,5 Hz, for 2% and 12% droop, according to the requirements specified in [1] and [2]. As required by the **Regulation**, the frequency steps generated must be large enough to activate an active power change of at least 10% of the P_{max} of the **PGU**. Therefore, for the tests where the expected active power deviation is less than 10% of the P_{max} of **PGU**, the response times t_r and t_e shall not be evaluated.

At least 1 minute shall be measured in each frequency step and, in any case, sufficient time shall be permitted to stabilize the response per frequency step and the average active power and corresponding times shall be recorded.

Tests shall be performed for the entire admissible range of s_2 and Δf_1, considering the following combinations in order to certify the capability of the **PGU**. The tests to be carried out shall be called:

- **US2F2** test: s_2=2% and Δf_1=-0,2 Hz (**Table 8**).
- **US2F5** test: s_2=2% and Δf_1=-0,5 Hz (**Table 9**).
- **US12F2** test: s_2=12% and Δf_1=-0,2 Hz (**Table 10**).
- **US12F5** test: s_2=12% and Δf_1=-0,5 Hz (**Table 11**).

The following tables describe these tests and the necessary frequency steps (Δf) and the expected active power variation. The sequence of tests shown in the following tables shall be followed row by row, starting from the final value of the previous test.

US2F2									
No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	49,90	0%			N/A	N/A	N/A	N/A
2	49,90	49,60	+20%						
3	49,60	49,40	+20%						
4	49,40	49,70	-30%						
5	49,70	50,00	-10%			N/A	N/A	N/A	N/A
6 PPM not wind	50,00	49,30	+50%						

Table 8. LFSM-U Tests. 2% droop and 49,8 Hz frequency threshold.

US2F5									
No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	49,60	0%			N/A	N/A	N/A	N/A
2	49,60	49,30	+20%						
3	49,30	49,10	+20%						
4	49,10	49,40	-30%						
5	49,40	50,00	-10%			N/A	N/A	N/A	N/A
6 PPM not wind	50,00	49,00	+50%						

Table 9. LFSM-U Tests. 2% droop and 49,5 Hz frequency threshold.

US12F2									
No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	49,90	0%			N/A	N/A	N/A	N/A
2	49,90	48,75	17,50%						
3	48.75	47.70	17.50%						
4	47,70	49,70	-33,33%						
5	49,70	50,00	-1,67%	N/A	N/A	N/A	N/A	N/A	N/A
6 PPM Not wind	50,00	47,60	36,67%						

Table 10. LFSM-U Tests. 12% droop and 49,8 Hz frequency threshold.

US12F5									
No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	49,60	0%			N/A	N/A	N/A	N/A
2	49,60	48,60	15%						
3	48,60	47,70	15%						
4	47,70	49,40	-28,33%						
5	49,40	50,00	-1,67%	N/A	N/A	N/A	N/A	N/A	N/A
6 PPM not wind.	50,00	47,70	30%						

Table 11. LFSM-U Tests. 12% droop and 49,5 Hz frequency threshold.

5.2.2.2. PGU test acceptance criteria

The **PGU** shall be deemed **capable of activating the power-frequency adjustment reserve supply** if the following conditions are met:

1) No undamped oscillations occur in the response in the transition between test points.

2) The results meet all the requirements established in the **Regulation** and [2].

3) For **SPGM** whose technology uses gas turbines or gas engines, the possible reduction of the active power from its maximum capacity with the frequency drop shall be considered, as established in subsection 1.4 of [2].

4) For active power increases during the frequency drop, with the **LFSM-U** activated:

- The **initial delay time (t_a)** shall be:

  - For Type C and D **PPM PGUs**: t_a will be less than or equal to the power response activation time set for **FSM** mode because it defines the **PPM**'s power response technical capability.
  - If t_a exceeds 2 s: the **PGM owner** shall provide the **TSO** with technical evidence to justify this value as established in the **Regulation**. If the **TSO** accepts the justification, the **TSO** shall give its written consent to the **PGM owner**, who shall forward it to the **authorised certifier** for incorporation in the **final PGM certificate**.

- The **rise time (t_r)** must be:

  - For **PGU of SPGM**: less than or equal to 5 minutes for an active power variation of up to 20% of the maximum power. This slow behaviour will not be acceptable if the direction of the frequency variation has reversed a few seconds earlier, in which case response times similar to the active power reduction case will be expected.
  - For non-wind **PGU of PPM**: less than or equal to 10 s for an active power variation of up to 50% of the maximum power. In the above tables, the first column indicates the test "Non-wind" Corresponding to the assessment of this rise time.

  - For **PGU of wind PPM**: less than or equal to 5 s for an active power variation of up to 20% of the maximum power if the power is above 50% of the maximum power. For powers below 50% of the maximum power, the rise time is as low as technically possible, however, the system operator must be justified if it exceeds 5 s.

- The **settling time (t_e)** must be:

  - For **PGU of SPGM**: less than or equal to 6 minutes. This slow behaviour will not be acceptable if the direction of the frequency variation has reversed a few seconds earlier, in which case response times similar to the active power reduction case will be expected.
  - For **PGU of PPM**: less than or equal to 30 s.

5) For active power reductions during frequency rise with **LFSM-U** activated:

- The **initial delay time (t_a)** shall be:

  - For Type C and D **PPM PGUs**: t_a will be less than or equal to the power response activation time set for **FSM** mode because it defines the **PPM**'s power response technical capability.
  - If t_a exceeds 2 s: the **PGM owner** shall provide the **TSO** with technical evidence to justify this value as established in the **Regulation**. If the **TSO** accepts the justification, the **TSO** shall give its written consent to the **PGM owner**, who shall forward it to the **authorised certifier** for incorporation in the **final PGM certificate**.

- The **rise time (t_r)** must be:

  - For **PGU of SPGM**: less than or equal to 8 s for an active power variation of up to 45% of the maximum capacity.
  - For **PGU of PPM**: less than or equal to 2 s for an active power variation of up to 50% of the maximum capacity.

- The **settling time (t_e)** shall be:

  - For **PGU of SPGM**: less than or equal to 30 s.
  - For **PGU of PPM**: less than or equal to 20 s.

6) In the tests, a deviation of ±5% of the P_{max} in the active power recorded from the expected active power according to the tables in subsection 5.2.2.1.

The **authorised certifier** shall issue **a PGU test equipment certificate for this requirement**, noting the test method followed, when it positively assesses that:

- The **LFSM-U** requirement is met for the ranges of droop and frequencies tested.
- The adjustment of the **PGU** or **PGM** corresponds to the one required in Article 1.7 of [2].

5.2.2.3. PGU simulation method

In the event that the **PGM** does not have an **ACPGM** that modifies the **LFSM-U** response of the **PGU**, the simulation of the **PGU** or its **equipment certificates by simulation** shall be required, and the **supplementary simulation** shall not be required.

The **model certified** in accordance with section 6 shall be used, i.e. the model whose characteristics enable the power-frequency adjustment capability to be simulated and the tests in subsection 5.2.2.1 shall be replicated. The simulation method shall be similar to that defined in subsection 5.1.2.3, whereas 0,1 Hz frequency decreases must be simulated by means of: at most, and if the simulation tool allows, the application of a negative mechanical torque to the generator representing the infinite network (equivalent to increasing the demand for the system) until a new steady state is reached.

5.2.2.4. PGU simulation acceptance criteria

The acceptance criterion will be similar to that described in subsection 5.1.2.4, considering the differences between the tolerances permitted for tests and simulations set out in that subsection.

5.2.3. Supplementary simulation for obtaining PGM certificate

If there is a **ACPGM** that affects the regulation provided by the **LFSM-U** of the **PGU**, in addition to the **PGU test** or the **PGU equipment certificates**, a **supplementary simulation** of the **PGM** will be required to verify that the **LFSM-U** requirement is met at BC, and not only at the **PGU** level.

With the full model of the **PGM** - equivalent models will not be supported, with the exception specified in subsection 7.5 - simulations will be performed with the following initial conditions:

- P= 60% P_{max} at the **PGM** level.
- A 1 p.u. voltage at the HV side of the **PGM** transformer.
- Q = 0 at the **PGM** level.
- infinite S_{cc} or network equivalent.
- The activation threshold Δf_1 is -0,2 Hz.
- Droop s_2 equal to 5%.

The simulation will perform a stepped frequency sweep according to **Table 12:**

No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%P_{max}$)	90% ΔP_{test} recorded ($\%P_{max}$)	t_r (s) (at 90% ΔP_{test} recorded)	t_a (s)	t_e (s) (Band +/- 5% ΔP_{test} recorded)
1	50,00	49,80	0%			N/A	N/A	N/A	N/A
2	49,80	49,40	16%						
3	49,40	49,00	16%						
4	49,00	48,80	8%						
5*	48,80	48,60	0%			N/A	N/A	N/A	N/A
6	48,60	49,00	-8%						
7	49,00	49,40	-16%						
8	49,40	49,70	-12%						

Table 12. LFSM-U supplementary simulation example.

* The initial active power value of the **PGM** will be equal to 60% of P_{max}, so there will be a saturation of the response of LFSM-U mode after an increase of 40% of P_{max} when the maximum power of the plant is reached.

The acceptance criteria will be the same as those stated in subsection 5.2.2.4.

The **PGM certificate** for this requirement shall be issued under the version corresponding to the version of the **PGU** and/or **ACPGM certificates** used, even if the **supplementary** simulations have been performed according to this version of the **Technical Standard**.

The information to be contained in the **supplementary simulation** report shall be analogous to that established in subsection 5.1.3.

5.2.4. Assessment at PGM level for obtaining PGM certificate

In the event that the **PGM owner** does not have or does not wish to use the **equipment certificates** for **PGU** and **ACPGM** for this technical requirement, the tests and supplementary simulations described in subsections 5.2.2.1 and 5.2.2.3, respectively, must be performed at the **PGM** level. If the acceptance criteria for tests and simulations described in subsections 5.2.2.2 and 5.2.2.4 are met respectively, the **authorised certifier** will issue **a PGM certificate** for this requirement without the need to perform the **supplementary simulations** stipulated in subsection 5.2.3.

5.3. Frequency Sensitive Mode (FSM)

5.3.1. Objective.

The objective is to verify that the **PGM** is **capable of activating the power-frequency regulation reserve supply** as stated in:

- Article 15.2.d of the **Regulation.**

- Article 1.8 of [2].

Pursuant to Articles 45, 48, 52 and 55 of the **Regulation**, the **compliance of the PGM** with this requirement may be assessed by:

- **test and simulation;** or
- **equipment certificate**.

Possible **assessment levels** for this requirement are:

- **PGM,** or
- **PGU when:**
    - The **PGM** does not have a hierarchical power-frequency control higher than the **PGU** itself; and
    - The **ACPGM** does not limit the response of the **PGU** to this requirement.

For the **PPM** to be considered as “**PGM with inertia**”, the **owner** of the **PPM** shall submit to the **authorised certifier** the written compliance of the **TSO** with respect to compliance with the synthetic inertia requirement.

If there is a **ACPGM** that affects the regulation provided by the **PGU FSM**, in addition to the **PGU test** or the **PGU equipment certificates**, a **supplementary simulation** of the **PGM** shall be required, according to 5.3.3 to verify that the **FSM** requirement is met at BC, and not only at the **PGU** level.

In the absence of such **ACPGM**, the test and simulation of the **PGUs** or their **equipment certificates** shall be required, and the **supplementary simulation** shall not be required.

It is important to take into account the following terms reflected in the **Regulation** and in [2] (also see **Figure 14**):

- **Δf**: deviation of frequency f from 50 Hz (Δf = f – 50).
- **ΔP**: expected active power response in the event of a frequency deviation (Δf) calculated according to the following formula:

$$|\Delta P| = \frac{|\Delta f|}{f_n} \times \frac{P_{max}}{s_1} \times 100$$

- **$|\Delta P_1|/P_{max}$**: Frequency response interval corresponding to the current value set by the **TSO**, which, according to [2], is equal to 8%.

For the purposes of this **Technical Standard** and in order to establish the response times, the following terms are introduced:

- **P_0**: active power of the **PGU** prior to performing a test (or frequency change).
- **P_{end}**: final active power of the **PGU after** performing a test (or frequency change).
- **ΔP_{test}:** deviation of the active power compared to the active power (P_0) prior to performing a test: $\Delta P_{test} = P_{end} - P_0$
- **Initial delay (t_1)**: **FSM** activation time. For the purposes of this **Technical Standard,** the reference to be used to measure this time shall be from the time when a frequency change is detected from which adjustment is expected until a 1% change in ΔP_{test}. If the frequency is modified by means of a power supply connected to the controller, 20 ms must be subtracted from setpoint change to the **PGU**, so that a complete cycle can be detected with this new frequency.
- **Full activation time (t_2)**: FSM activation time at a frequency change Δf_1 for which a response equal to $|\Delta P_1|/P_{max}$ (including initial delay t_1) is expected. For the purpose of determining t_2, the time corresponding to the latest value of P within the band ±1% of P_{max} for the tests or ±5% of ΔP_{test} around $|\Delta P_1|/P_{max}$ for simulations. However, and as far as this **Technical Standard** is concerned in the **tests**, a permanent error between the final measured value and the expected value, less than ±1% of the P_{max} of the **PGU**, shall be considered as admissible. If, for example, a frequency change Δf is applied, for which a P response of $8\%P_{max}$ is expected, a test with a measured final P value between $7\%P_{max}$ and $9\%P_{max}$ is acceptable, which corresponds to a tolerance of ±12,5% of $|\Delta P_1|$

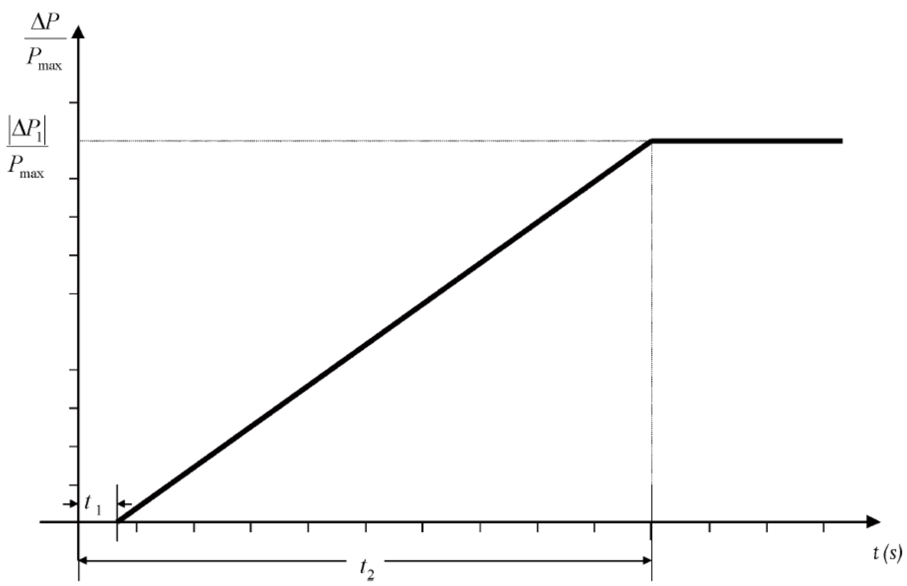


Figure 14. Response capacity of the FSM mode illustrating the times t_1, and t_2 defined above.

5.3.2. Assessment at PGU level for obtaining PGU certificate

5.3.2.1. PGU test method

This subsection describes how to **test the FSM activation time**.

To **test this requirement**, the sequence of actions analogous to subsections 5.1.2.1 (**LFSM-O**) and 5.2.2.1 (**LFSM-U**) shall be carried out.

It shall be verified, and reflected in the test report, that the **FSM** has implemented the following adjustments in the **PGU**:

- Response deadband with frequency variation equal to 0 mHz.
- Response insensitivity with frequency variation $|\Delta f_i|$ less than 10 mHz.
- The droop s_1 shall be equal to 5%.
- Active power interval $|\Delta P_1|$= 8%.

The initial conditions to perform the test shall be at nominal frequency, f_n (50 Hz ± 10 mHz), nominal voltage (± 5%) and next initial active power (P_{ini}), which shall ensure that the required power increases can be assessed within the time periods established in [2]:

- For both laboratory and field tests, the initial active power **prior to the tests sequence** (P_{ini}) must correspond to an intermediate value between the maximum capacity and the minimum level of regulation of the **PGU**, which allows variations in active power not exceeding the previous limits when performing the frequency steps displayed in **Table 13**.

The test shall be performed at zero reactive power. The tests to assess **FSM activation** and its **FSM activation time** are described below.

In **Table 13** the required tests and frequency steps (Δf) are described as well as the expected active power variation in each test (ΔP_{test}) and the required response times. The sequence of tests indicated in the following tables shall be followed, row by row starting from the final value of the previous test.

At least 1 minute shall be measured in each frequency step and in any case sufficient time shall be permitted to stabilize the response per frequency step and the average active power and corresponding times shall be recorded.

No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<1\%P_{max}$)	t_1 (s)	t_2 (s)** (Band +/-1% P_{max})
FSM overfrequency							
1	50,00	50,10	-4%				N/A
2	50,10	50,20	-4%				N/A
3	50,20	50,00	+8%				N/A
4	50,00	50,20	-8%				
5*	50,20	50,30	0%				N/A
FSM underfrequency							
6	50,00	49,90	+4%				N/A
7	49,90	49,80	+4%				N/A
8	49,80	50,00	-8%				N/A
9	50,00	49,80	+8%				
10*	49,80	49,70	0%				N/A

Table 13. FSM Tests. 5% droop and active power interval $|\Delta P_1|$= 8%.

* The active power interval in relation to the maximum capacity $|\Delta P_1|/P_{max}$ will be equal to 8%, so there will be a saturation in this value.

** According to t_2 definition, it shall be measured over a frequency step for which an active power response equal to $|\Delta P_1|$/Pmax is expected. Therefore, t_2 shall be measured only in tests 4 and 9.

5.3.2.2. PGU test acceptance criteria

The **PGM** shall be deemed **capable of activating the power-frequency adjustment reserve supply** if the following conditions are met:

1) No undamped oscillations occur in the response in the transition between test points.
2) The results meet all the requirements established in the **Regulation** and [2].
3) Regarding response times:
    - Increase of active power in relation to the **maximum capacity** $|\Delta P_1|/P_{max}$ (frequency response interval) equal to 8%.
    - In the case of **PGMs** with inertia or synthetic inertia, the maximum admissible initial delay t_1 shall be equal to 2 s.
    - In the case of **PGMs** without inertia or synthetic inertia, the maximum admissible initial delay t_1 shall be equal to 500 ms.
    - The maximum admissible total activation time t_2 shall be 30 s, unless the **TSO** allows longer activation times for system stability reasons.
4) In the tests, a deviation of ±1% of the P_{max} in the active power recorded from the expected active power according to the tables in subsection 5.3.2.1.

5.3.2.3. PGU simulation method

The methodology will be similar to that described in subsections 5.1.2.3 and 5.2.2.3.

5.3.2.4. PGU simulation acceptance criteria

The criteria will be similar to those described in subsections 5.1.2.4 and 5.2.2.4, considering the differences between the tolerances permitted for tests and simulations set out in that subsection.

5.3.3. Supplementary simulation for obtaining PGM certificate

If there is a **ACPGM** that affects the regulation provided by the **FSM** of the **PGU**, in addition to the **PGU test** or the **PGU equipment certificates**, a **supplementary simulation** of the **PGM** will be required to verify that the **FSM** requirement is met at BC, and not only at the **PGU** level.

With the full model of the **PGM** - equivalent models will not be supported, with the exception specified in subsection 7.5 - simulations will be performed with the following initial conditions:

- P= 80% P_{max} at the **PGM** level.
- Voltage of 1 p.u. at the HV side of the **PGM** transformer.
- Q = 0 at the **PGM** level.
- A frequency f = 50 Hz.
- Infinite S_{cc} or network equivalent.
- Active power interval in relation to the maximum capacity $|\Delta P_1|/P_{max}$ equal to 8%.
- Response insensitivity with frequency variation $|\Delta f_i|$ less than 10 mHz.
- Response deadband with frequency variation equal to 0 mHz.
- Droop s_1 equal to 5%.

The simulation shall perform a stepped frequency sweep according to the following tables:

No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%\Delta P_{ensayo}$)	t_1 (s)	t_2 (s)** (Band +/-5% ΔP_{test} recorded)
1	50,00	50,02	-0,8%				N/A
2	50,02	50,10	-3,2%				N/A
3	50,10	50,20	-4%				N/A
4*	50,20	50,30	0%				N/A
5	50,30	50,00	+8%				N/A
6	50,00	50,20	-8%				

Table 14. Supplementary FSM simulation (overfrequency).

No. of test point	f_0 (Hz)	f_{end} (Hz)	ΔP_{test} expected ($\%P_{max}$)	ΔP_{test} recorded ($\%P_{max}$)	Deviation ($\%P_{max}$) ($<5\%\Delta P_{ensayo}$)	t_1 (s)	t_2 (s)** (Band +/-5% ΔP_{test} recorded)
1	50,00	49,98	+0,8%				N/A
2	49,98	49,90	+3,2%				N/A
3	49,90	49,80	+4%				N/A
4*	49,80	49,70	0%				N/A
5	49,70	50,00	-8%				N/A
6	50,00	49,8	+8%				

Table 15. Supplementary FSM simulation (underfrequency).

* The active power interval in relation to the maximum capacity $|\Delta P_1|/P_{max}$will be equal to 8%, so there will be a saturation in this value.

** According to t_2 definition, it shall be measured over a frequency step for which an active power response equal to $|\Delta P_1|$/Pmax is expected. Therefore, t_2 shall be measured only in test 6.

The acceptance criteria will be the same as those stated in subsection 5.3.2.4.

The **PGM certificate** for this requirement shall be issued under the version corresponding to the version of the **PGU** and/or **ACPGM certificates** used, even if the **supplementary** simulations have been performed according to this version of the **Technical Standard**.

The information to be contained in the **supplementary simulation** report shall be analogous to that established in subsection 5.1.3.

5.3.4. Assessment at PGM level for obtaining PGM certificate

In the event that the **PGM owner** does not have or does not wish to use the **equipment certificates** for **PGU** and **ACPGM** for this technical requirement, the tests and supplementary simulations described in subsections 5.3.2.1 and 5.3.2.3, respectively, must be performed at the **PGM** level. If the acceptance criteria for tests and simulations described in subsections 5.3.2.2 and 5.3.2.4 are met respectively, the **authorised certifier** will issue **a PGM certificate** for this requirement without the need to perform the **supplementary simulations** stipulated in subsection 5.3.3.

5.4. Power-frequency control capability

The objective is to verify that **the PGM** is capable of providing functions that comply with the specifications of the **TSO**, with the aim of **restoring the frequency to its nominal value** or of **maintaining the power exchange flows between the control zones at their scheduled values**, as indicated in:

- Article 15.2.e of the **Regulation.**

Pursuant to Article 45 of the **Regulation, compliance of the PGM with this requirement** may be carried out by means of a **test**, both at **PGU** and **PGM** level, or by means of an **equipment certificate**. However, the **assessment of this requirement** shall be made by the **TSO** in accordance with the **test protocols established in the regulations in force at the time the PGM is commissioned**, which shall be indicated by the **TSO** to the **PGM owner.**

5.5. Active power control capability and range

The purpose is to verify that the **PPM** is capable of **adjusting an active power setpoint according to the instructions provided to the PPM owner by the TSO or RSO** as stated in:

- Article 15.2.a of the **Regulation.**

- Article 1.6 of [2].

Pursuant to Article 48 of the **Regulation, compliance of the PPM**[11] **with this requirement** may be achieved by:

- **Test**, or
- **equipment certificate**.

Possible **assessment levels** for this requirement are:

- **PPM**, or
- **PGU when:**
  - The **PPM** does not have a hierarchical power-frequency control higher than the **PGU** itself; and
  - The **ACPGM** does not influence the response of the **PGU** to this requirement.

The test shall be performed by the **accredited entity** in accordance with subsection 8.4.2 of [5], applying it also to **PPM** of photovoltaic technology or **SPGM** as far as possible, i.e. those particular aspects of wind technology that are not applicable to photovoltaic technology must not be considered.

The test report shall be assessed by the **authorised certifier.**

[11] According to the **Regulation**, compliance of the **SPGM** with this requirement is not mandatory and this version of the **Technical Standard** will not be covered.

5.6. Synthetic inertia

5.6.1. Objective.

The objective is to verify that the **PPM** is capable of **emulating inertia during very fast frequency variations** as indicated in:

- Article 21.2 of the **Regulation.**

- Article 1.9 of [2].

As long as this technical capability is not regulated in a system adjustment service, it will be a **voluntary capability** on the part of the **PPM**.

Pursuant to Article 55 of the **Regulation**, **compliance of the PPM with this requirement** may be assessed by **simulation**, at both the **PGU** and **PPM** level, or by **equipment certificate**. However, the assessment of this technical requirement shall be carried out by the **TSO** through simulation. Simulations and the required report need not be performed by an accredited entity.

Simulations shall be performed at the **PGU** level, unless the **PPM owner** declares the existence of a higher hierarchical control at the **PPM** level that may impact the synthetic inertia control.

For the assessment of the technical requirement, the **PPM owner** (or the entity designated by it) shall provide the **TSO** with a report containing the result of a study based on the simulations described below, in subsection 5.6.2.

5.6.2. Simulation method and acceptance criteria for simulations

For the assessment of this control, the **PPM owner** shall provide the **TSO** with a report containing the results obtained following the following studies:

1. Simulations, with the model certified in accordance with section 6, demonstrating the synthetic inertia capability according to [2] or according to the control proposed by the **PPM owner** and approved by the **TSO**. The simulations must show improved response of the **PGU** (or **PPM**) with inertial emulation control activated for the same simulations without such control activated. Two sets of simulations will therefore be performed, in which the existing power-frequency control modes, **FSM** and **FSM limited** (**LFSM-O** and **LFSM-U**), must not be disabled, as it is necessary to check whether the joint response of these modes and the inertia emulation control has a quicker response than with just such modes. Two alternatives are permitted in relation to the simulations to be performed:

    a) Performing simulations based on the tests in subsection 8.4.5 of [5].

    b) Perform an alternative set of simulations, proposed by the **owner of the PPM** (or the entity designated by the PPM), and which must be previously agreed with the **TSO**.

    In both cases, the synthetic inertia control shall be enabled and disabled, as indicated above, to facilitate comparison between responses.

2. Modal analysis based on values specific to the **PPM** model that will incorporate the synthetic inertia control and has been certified according to section 6. In this analysis, it shall be demonstrated, in a manner similar to subsection 5.10, that the oscillation

modes due to the action of the synthetic inertia control have a damping of more than 5%. However, and as in subsection 5.10, if the **PPM** model used for this analysis is a small signal specific model and differs from the certified model according to section 6, it will be permitted to be used at the request of the **PPM** owner (or the entity designated by the owner). In the event of the use of a non-certified model, the **TSO** shall be provided with the open, non-encrypted model, with a functional description of the model and its structure, as well as the studies performed to produce the report.

If the analysis presented in subsection 5.10 is performed with the synthetic inertia module activated, this modal analysis study based on self-values will not be required.

5.6.3. Report acceptance criteria

The **TSO** shall assess the report within two months of the report meeting the conditions set out above. If applicable, because the **PPM** provides a faster response to frequency changes with this control enabled, the **TSO** shall issue the written consent to the **owner** of the **PPM** (or the entity designated by the owner) for this technical requirement. This compliance will be necessary for the **PPM** to be considered by the authorised certifier as an **inertia PGM** in the assessment of the **FSM** requirement (subsection 5.3).

5.7. Reactive power capability at maximum capacity and below maximum capacity

5.7.1. Objective.

The objective is to verify that the **PGM** is **capable of supplying the required reactive power** at maximum capacity of the **PGM** and below maximum capacity of the **PGM** as stated in:

- **Regulation**: Article 18.2 for **SPGM** and 21.3 for **PPM**.
- Articles 2.2.1 for **SPGM** and 2.3.2 for **PPM,** of [2].

The compliance of the **PGM** with these requirements must be assessed by means of the **PGU test**, or by means of the **PGU equipment certificate**, in addition to **supplementary simulations** that verify that the capabilities of the **PGU, or, in the case of PGU with ACPGM and/or passive elements**, they allow compliance of the capability of the **PGM** at the **NCP**, as required by the **Regulation** and [2].

Two alternative methods are proposed for carrying out the **supplementary simulations**:

- a complete modelling procedure described in subsection 5.7.3.1 through which the capabilities of the **PGM** at the **NCP** are assessed,
- an alternative modelling procedure described in subsection 5.7.3.2 specially indicated for the case where there are generation evacuation facilities between the **PGM** and the **NCP** shared by several **PGMs**. This procedure establishes an alternative modelling method of the **supplementary simulation** through which it is possible to assess this capacity at **BC** (**PGM** terminals) of the **PGM** instead of at the **NCP**, allowing to model the **PGM** only up to **BC**. In this way, the reactive power requirement can be monitored individually for each **PGM**.

5.7.2. Assessment at PGU level for obtaining PGU certificate

5.7.2.1. Test method for PGU of PPM

The following tests are applicable to **PPM PGUs**.

The tests described in this subsection are intended to assess the **reactive power capability at the maximum capacity** of the **PGU** as well as the **reactive power capacity below the maximum capacity** of the **PGU**.

The test conditions shall be some of the following:

- A power supply connected to the **PGU** terminals when the **PGU** is disconnected from the network.
- An element or method capable of modifying the voltage at the **PGU** connection point when the **PGU** is connected to the network.
- A fictitious signal that simulates voltage changes connected to the **PGU** controller. The **PGU** must behave as if this signal were the voltage reading on its terminals.
- Test bench, including all reactive power management elements.

The voltage values indicated for the tests are considered nominal values of the configuration under which each step of the test is performed, although configurations with a variation of

±2,5% of the nominal voltage over the proposed values shall be permitted. Since the **PGU** can change the voltage value during the test, this margin of variation over measured values will not be considered.

The following **sequence of actions** shall be followed for **testing this requirement**:

- The **reactive power control mode** of the **PGU** shall be selected at **fixed reactive power** setpoint.
- The tests described in **Table 16** will be performed:
- Without prejudice to the fact that the tests under this subsection must be carried out on **PGU** terminals, in addition, in order to ensure **compliance by the PGM with this requirement at the NCP**, it will always be necessary to carry out **supplementary simulations** to assess the entire **PGM** as a whole as described in subsection 5.7.3.

Through the **PGU** test, the **maximum reactive power capability** of the **PGU** for different operating points of active power and voltage at **PGU** terminals shall be verified, establishing the test parameters listed in **Table 16**. For each operation point specified in **Table 16**, the **maximum reactive power** value in production (leading or capacitive) state or consumption (lagging or inductive) state that the **PGU** can provide must be noted:

P/P_{max} range [%]	U	Qmax inductive measure [MVAr]	Qmax capacitive measure [MVAr]	Duration of test
>90%	95%Un			60 min
>90%	105%Un			60 min
>90%	100%Un			5 min
10-20%*	95%Un			5 min
10-20%*	105%Un			5 min
10-20%*	100%Un			5 min
0-10%*	95%Un			5 min
0-10%*	105%Un			5 min
0-10%*	100%Un			5 min

Table 16. Reactive power test parameters at the maximum capacity of the PGU of PPM.

*In the case of field test where the primary resource cannot be regulated, the limitation by control is permitted to be in the required power range.

5.7.2.2. Test Method for PGU of SPGM

The following tests are applicable to **PGU of SPGM**.

The tests described in this subsection are intended to assess the **reactive power capability at the maximum capacity** of the **PGU** as well as the **reactive power capability below the maximum capacity** of the **PGU**.

The test conditions shall be some of the following:

- A power supply connected to the terminals of the **PGU** when the **PGU** is disconnected from the network.
- An element or method capable of modifying the voltage at the **PGU** connection point when the **PGU** is connected to the network.

- A fictitious signal that simulates voltage changes connected to the **PGU** controller. The **PGU** must behave as if this signal were the voltage reading on its terminals.
- Test bench.

The voltage values indicated for the tests are considered nominal values of the configuration under which each step of the test is performed, although configurations with a variation of ±2,5% of the nominal voltage over the proposed values shall be permitted. Since the **PGU** can change the voltage value during the test, this margin of variation over measured values will not be considered.

The following **sequence of actions** shall be followed for **testing this requirement**:

- The **reactive power control mode** of the **PGU** shall be selected at **fixed reactive power** setpoint.
- The tests described in **Table 17** will be performed.
- Without prejudice to the fact that the tests under this subsection must be carried out on **PGU** terminals, in addition, in order to ensure **compliance by the PGM with this requirement at the NCP**, it will always be necessary to carry out **supplementary simulations** to assess the entire **PGM** as a whole as described in subsection 5.7.3.

Through the **PGU** test, the **maximum reactive power capability** of the **PGU** for different operating points of active power and voltage on terminals of the **PGU** shall be verified, establishing the test parameters listed in **Table 17**. For each operation point specified in **Table 17**, the **maximum reactive power** value in production (leading or capacitive) state or consumption (lagging or inductive) state that the **PGU** can provide must be noted:

P/P_{max} range [%]	U	Qmax inductive measure [MVAr]	Qmax capacitive measure [MVAr]	Duration of test
100%	95%Un			60 min
100%	105%Un			60 min
100%	100%Un			5 min
60-70 %	95%Un			5 min
60-70 %	105%Un			5 min
60-70 %	100%Un			5 min
Technical minimum of stable operation	95%Un			5 min
Technical minimum of stable operation	105%Un			5 min
Technical minimum of stable operation	100%Un			5 min

Table 17. Reactive power test parameters at the maximum capacity of the PGU of SPGM.

5.7.2.3. PGU test acceptance criteria

The **authorised certifier** must verify that the results of the maximum reactive power tests of the **PGU** as stated in **Table 16** or in **Table 17** is consistent with the P-Q diagram of the **PGUs** for the different voltages, i.e., the maximum reactive power values recorded in the tests are greater than or equal to those shown in the P-Q diagrams of the **PGUs**.

Once the above has been verified, in order to ensure **compliance by the PGM with the reactive power requirements** and thus obtain the **PGM certificate**, **supplementary simulations** will always be required to assess the entire **PGM** as described in subsection 4.2 and subsection 5.7.3.

5.7.3. Supplementary simulation for obtaining PGM certificate

The **supplementary simulation** report shall contain, at least, the following information:

- Description of the **PGM**, including **BC.**
- **PGM** model:
  - Simulation platform and version.
  - Description of the modelling of the **PGM** components necessary to perform loadflow simulations.
- Outcomes:
  - Tables completed indicating the compliance of each loadflow simulation.
  - Exportable simulation packages. Upon request of the **RSO**, the model of the **PGM** used in the loadflow simulations will be delivered.
- Conclusions.

5.7.3.1. Complete modelling procedure at NCP

In order to obtain the **PGM certificate** based on **PGU** level tests or **PGU** certificates, it will be necessary to perform a **supplementary simulation** demonstrating that the **PGU** capabilities meet the reactive power requirement at the **NCP**, based on the capacities declared in the **PGU** level tests and simulations and, where applicable, the **ACPGM**.

The **PGM** maximum design temperature, as defined by the **PGM owner**, shall be considered. The capacities (active and reactive power) of the **PGU** at the **PGM** maximum design temperature, according to the information provided by the manufacturer of the **PGU**, shall be used to carry out the supplementary simulations.

Issues related to network modelling to be considered in the **supplementary simulation** and consideration of other **PGMs** that could share **NCP** with the **PGM** to be assessed, are detailed in subsection 7.4.2.1.

With this model, and taking into account the maximum reactive power of the **PGU** and/or **ACPGM**, load flows shall be performed under the active power conditions of the **PGU** and voltage at the **NCP** listed in **Table 18** and **Table 19**, and the reactive power consumed or generated at the **NCP** shall be recorded. The active power value P/P_{max} [%] indicated shall be referred to the active power of the **PGM** under assessment and may be considered at **BC** of the **PGM**.

P/P_{max} [%]	U at NCP	Q at NCP	Required value at NCP Q/P_{max}
*100%	*90%Un		0
100%	95%Un		0
100%	100%Un		-0,15
100%	105%Un		-0,3
*100%	**110%Un or 108,75%Un		-0,3
40%	100%Un		-0,15
20%	100%Un		-0,15
10%	100%Un		-0,15
10%	100%Un		-0,05
*100%	*90%Un		0,3
100%	95%Un		0,3
100%	100%Un		0,15
100%	105%Un		0
*100%	**110%Un or 108,75%Un		0
40%	100%Un		0,15
20%	100%Un		0,15
10%	100%Un		0,15
10%	100%Un		0,05
0%***	100%Un		0,05
0%***	100%Un		-0,05

Table 18. Parameters for supplementary simulation of the reactive power capability of MPEs.

* These simulations shall only be performed if the simulation is performed on a Type D **PPM** or a Type C **PPM** with a maximum capacity greater than 15 MW.
** The maximum voltage value will be 110% if the voltage level of the **NCP** to which the **PPM** is connected is between 110 kV and 300 kV, and 108.75% if the voltage level of the **NCP** to which the **PPM** is connected is greater than 300 kV and up to 400 kV.
***For the verification of the requirement at P=0%, active power consumption, i.e. negative values, of the **PPM** will be permitted.

P/P_{max} [%]	U at NCP	Q at NCP	Required value at NCP Q/P_{max}
*100%	*90%Un		0
100%	95%Un		0
100%	100%Un		-0,15
100%	105%Un		-0,3
*100%	**110%Un or 108,75%Un		-0,3
50%	100%Un		-0,15
Technical minimum of stable operation	100%Un		-0,15
10%	100%Un		-0,15
10%	100%Un		-0,05
*100%	*90%Un		0,3
100%	95%Un		0,3
100%	100%Un		0,15
100%	105%Un		0
*100%	**110%Un or 108,75%Un		0
50%	100%Un		0,15
Technical minimum of stable operation	100%Un		0,15

Table 19. Parameters for supplementary simulation of the reactive power capability of SPGMs.

* These simulations shall only be performed if the simulation is performed on a Type D **SPGM** or a Type C **SPGM** with a maximum capacity greater than 15 MW.
** The maximum voltage value will be 110% if the voltage level of the **NCP** to which the **SPGM** is connected is between 110 kV and 300 kV, and 108,75% if the voltage level of the **NCP** to which the **SPGM** is connected is greater than 300 kV and up to 400 kV.

5.7.3.2. Alternative modelling procedure in case of shared evacuation network

Where there is a shared evacuation network from the **BC** of the **PGM** on which the simulation is being conducted to the **NCP**, the compliance assessment of the reactive power capabilities of the **PGM** at the **NCP** is complex. The reactive power requirements listed in the **Regulation** and in [2] apply at the **NCP**, however, taking into account this casuistry, and in order to simplify the compliance assessment process, this subsection proposes an alternative **PGM** verification procedure to that described in subsection 5.7.3.1.

For the reasons mentioned above, the compliance assessment of the **PGM**'s reactive power capability requirements at **BC** rather than at the **NCP** shall be accepted. However, this simplification of the compliance assessment of the **PGM's BC** requirement means that at some **PGM**'s operating points, the reactive power values required at BC of the **PGM** differ from those required at the **NCP**, i.e. the reactive power values listed in [2].

In order to obtain the **PGM certificate** based on **PGU** level tests or **PGU** certificates, it will be necessary to perform a **supplementary simulation** demonstrating that the capabilities of the **PGU**, and, if applicable, **ACPGM**, meet the reactive power capability values at BC listed in **Table 20**, **Table 21**, **Table 22** or **Table 23**, as applicable.

The **PGM** maximum design temperature, as defined by the **PGM owner**, shall be considered. The capacities (active and reactive power) of the **PGU** at the **PGM** maximum design temperature, according to the information provided by the manufacturer of the **PGU**, shall be used to carry out the supplementary simulations.

The network modelling issues to be considered in the **supplementary simulation** and consideration of other **PGMs**, if applicable, are detailed in subsection 7.4.2.2, in which two cases are distinguished, depending on the location of **BC**[12]:

<u>**Case A:**</u>
If the **BC** of the **PGM** is located at the HV side of the **PGM** step-up transformer (**LAT**)**,** the instructions in the **Case A** alternative modelling procedure described in subsection 7.4.2.2.1 shall be followed, and the reactive power checkpoints listed in **Table 20** and **Table 21** shall be considered for an **PPM** or **SPGM**, respectively.

[12] See definition of **BC**.

P/P_{max} [%]	U at BC (LAT)	Q at BC (LAT)	Required value at BC (LAT) Q/P_{max}
*100%	*90%Un		-0,1
100%	95%Un		-0,3
100%	100%Un		-0,3
100%	105%Un		-0,3
*100%	**110%Un or 108,75%Un		-0,3
40%	100%Un		-0,3
20%	100%Un		-0,3
10%	100%Un		-0,15
10%	100%Un		-0,10
*100%	*90%Un		0,3
100%	95%Un		0,3
100%	100%Un		0,3
100%	105%Un		0,3
*100%	**110%Un or 108,75%Un		0,1
40%	100%Un		0,3
20%	100%Un		0,3
10%	100%Un		0,15
10%	100%Un		0,05
***0%	100%Un		0,05
***0%	100%Un		-0,10

Table 20. Parameters for supplementary simulation of the reactive power capability of SPGMs, alternative in case of shared evacuation network. Case A.

* These simulations shall only be performed if the simulation is performed on a Type D **PPM** or a Type C **PPM** with a maximum capacity greater than 15 MW.
** The maximum voltage value will be 110% if the voltage level of the **NCP** to which the **PPM** is connected is between 110 kV and 300 kV, and 108,75% if the voltage level of the **NCP** to which the **PPM** is connected is greater than 300 kV and up to 400 kV.
***For the verification of the requirement at P=0%, active power consumption, i.e. negative values, of the **PPM** will be permitted.

P/P_{max} [%]	U at NCP	Q at BC (LAT)	Required value at BC (LAT) Q/P_{max}
*100%	*90%Un		-0,1
100%	95%Un		-0,3
100%	100%Un		-0,3
100%	105%Un		-0,3
*100%	**110%Un or 108,75%Un		-0,3
50%	100%Un		-0,3
Technical minimum of stable operation	100%Un		-0,3
*100%	*90%Un		0,3
100%	95%Un		0,3
100%	100%Un		0,3
100%	105%Un		0,3
*100%	**110%Un or 108,75%Un		0,1
50%	100%Un		0,3
Technical minimum of stable operation	100%Un		0,3

Table 21. Parameters for supplementary simulation of the reactive power capability of SPGMs, alternative in case of shared evacuation network. Case A.

* These simulations shall only be performed if the simulation is performed on a Type D **SPGM** or a Type C **SPGM** with a maximum capacity greater than 15 MW.

** The maximum voltage value will be 110% if the voltage level of the **NCP** to which the **SPGM** is connected is between 110 kV and 300 kV, and 108.75% if the voltage level of the **NCP** to which the **SPGM** is connected is greater than 300 kV and up to 400 kV.

Case B:

If the **BC** of the **PGM** is located at the LV side of the **PGM** step-up transformer , the instructions in the Case B alternative modelling procedure described in subsection 7.4.2.2.2 shall be followed, and the reactive power checkpoints listed in **Table 22** and **Table 23** shall be considered for a **PPM** or **SPGM**, respectively.

P/P_{max} [%]	U in LAT	Q at BC	Required value at BC Q/P_{max}
*100%	*90%Un		-0,1
100%	95%Un		-0,3
100%	100%Un		-0,3
100%	105%Un		-0,3
*100%	**110%Un or 108,75%Un		-0,3
40%	100%Un		-0,3
20%	100%Un		-0,3
10%	100%Un		-0,15
10%	100%Un		-0,1
*100%	*90%Un		0,4
100%	95%Un		0,4
100%	100%Un		0,4
100%	105%Un		0,4
*100%	**110%Un or 108,75%Un		0,1
40%	100%Un		0,4
20%	100%Un		0,4
10%	100%Un		0,25
10%	100%Un		0,05
0%***	100%Un		0,05
0%***	100%Un		-0,1

Table 22. Parameters for supplementary simulation of the reactive power capability of SPGMs, alternative in case of shared evacuation network. Case B

* These simulations shall only be performed if the simulation is performed on a Type D **PPM** or a Type C **PPM** with a maximum capacity greater than 15 MW.

** The maximum voltage value will be 110% if the voltage level of the **NCP** to which the **PPM** is connected is between 110 kV and 300 kV, and 108.75% if the voltage level of the **NCP** to which the **PPM** is connected is greater than 300 kV and up to 400 kV.

***For the verification of the requirement at P=0%, active power consumption, i.e. negative values, of the **PPM** will be permitted.

P/P_{max} [%]	U in LAT	Q at BC	Required value at BC Q/P_{max}
*100%	*90%Un		-0,1
100%	95%Un		-0,3
100%	100%Un		-0,3
100%	105%Un		-0,3
*100%	**110%Un or 108,75%Un		-0,3
50%	100%Un		-0,3
Technical minimum of stable operation	100%Un		-0,3
*100%	*90%Un		0,4
100%	95%Un		0,4
100%	100%Un		0,4
100%	105%Un		0,4
*100%	**110%Un or 108,75%Un		0,1
50%	100%Un		0,4
Technical minimum of stable operation	100%Un		0,4

Table 23. Parameters for supplementary simulation of the reactive power capability of SPGMs, alternative in case of shared evacuation network. Case B.

* These simulations shall only be performed if the simulation is performed on a Type D **SPGM** or a Type C **SPGM** with a maximum capacity greater than 15 MW.
** The maximum voltage value will be 110% if the voltage level of the **NCP** to which the **SPGM** is connected is between 110 kV and 300 kV, and 108.75% if the voltage level of the **NCP** to which the **SPGM** is connected is greater than 300 kV and up to 400 kV.

5.7.4. Supplementary simulation acceptance criteria

The **authorised certifier** shall assess:

- **Equipment certificates** of **PGM PGUs**.
- Information about all **PGM ACPGM** according to subsection 4.6.
- Curved P-Q diagrams at different voltages of the **PGUs**.
- That the capacities (active and reactive power) of the **PGUs** have been used to take into account the **PGM** maximum design temperature in the supplementary simulations.
- Results of maximum reactive power tests of the **PGUs**.
- The data and parameters of the cables, lines, and internal transformers of the **PGM**.
- In the case of supplementary simulation by the complete modelling procedure, the data of the connection network from the **PGM** to the **NCP**.
- In the case of supplementary simulation by the alternative modelling procedure, and the **PGM** is Case B, the data of the shared step-up transformer.
- The results of the **supplementary simulation**, taking into account that they may follow the complete or alternative modelling procedure described in subsection 5.7.3.1 and 5.7.3.2, as appropriate.

The **reactive power capability of the PGUs** shall be considered validated when the results of the **supplementary simulation** listed in the relevant table demonstrate that the reactive power capabilities of the **PGUs** and/or **ACPGMs** measured in the tests comply with the values required in the corresponding tables.

Once the **supplementary simulation** has been validated, together with the **PGU** level tests and/or **PGU** certificates and the rest of the documentation, the **authorised certifier** may issue the **PGM certificate** for the reactive power requirement.

5.7.5. Assessment at PGM level for obtaining PGM certificate

In the event that the **PGM owner** does not have or does not wish to use the **equipment certificates** for **PGU** and **ACPGM** for this technical requirement, the tests described in subsection 5.7.2 must be performed, as well as the **supplementary simulations** described in subsection 5.7.3. If the acceptance criteria for each of these subsections are met, the **authorised certifier** shall issue **a PGM certificate** for the reactive power requirement.

5.8. Reactive Power Control in PPM

5.8.1. Objective.

The purpose of this test is to verify that the **PPM** is capable of controlling the reactive power according to:

- Article 21.3.d of the **Regulation.**
- Article 2.3.3 of [2].

Pursuant to Article 48 of the **Regulation**, compliance of the **PPM** with this requirement shall be either by means of **a PGU** level **test** or **a PGU equipment certificate**, for which it will be necessary to complete the test with a **supplementary simulation**, or through testing at the **PPM** level.

5.8.2. Assessment at PGU level for obtaining PGU certificate

It will be necessary to assess the reactive power control modes of the **PGUs** as described in subsections 5.8.2.1, 5.8.2.2 and 5.8.2.3.

The tests shall always be carried out at active power between 20% and 100% of the maximum capacity of the **PGU**.

5.8.2.1. PGU reactive power control mode

5.8.2.1.1. PGU reactive power control mode test

In order to perform the **tests of the reactive power control mode**, the voltage in terminals of the **PGU** shall be the nominal voltage, and the reactive power setpoint shall be null at the time of starting the test. During the test, the reactive power setpoints shall be sequentially set as indicated in **Table 24**.

The following shall be noted in the table:

- In column **Q measured**: the reactive power measured in terminals of the **PGU**.
- In column **t measured**: the time taken to stabilise at the new reactive power value after receipt of a new setpoint, taking into account the tolerances indicated in the **Regulation**.

Q setpoint [%P_{max}]	Q measured	Q required [Q/P_{max} or MVAr]	t measured	t maximum
10%		10% P_{max} ± min (1,5% P_{max} and 5 MVAr)		60 s
-10%		10% P_{max} ± min (1,5% P_{max} and 5 MVAr)		60 s
0%		0 ± min (1,5% P_{max} and 5 MVAr)		60 s

Table 24. Reactive power control mode test parameters

In order to ensure proper stabilization of the electrical parameters of the **PGU**, at least 1 minute shall be reserved before a test is carried out without sending new reactive power commands.

5.8.2.1.2. Acceptance criteria for PGU reactive power control mode tests

The test shall be considered valid when the following conditions are met:

- The **PGU** is capable of modifying the reactive power output of the **PGU** in the event of a reactive power setpoint change.
- The measured values of reactive power are within the range defined in **Table 24**.
- The response time is less than the value indicated in **Table 24** according to the provisions of [2].

5.8.2.2. Voltage control mode

5.8.2.2.1. Voltage control mode test

To **test the voltage control mode**, one of the following options shall be used:

- A power supply capable of maintaining the specified voltage at **PGU** terminals.
- A signal generator capable of injecting a voltage signal into the voltage control of the **PGU**, simulating voltage changes and serving the **PGU** to regulate the reactive production.
- A fictitious signal that simulates voltage changes connected to the **PGU** controller.

For each test, the voltage values in **PGU** terminals or in the control system specified in **Table 25**, and **Table 26** shall be sequentially set, according to which the tests are repeated for control slope values of 2% and 7%.

For each test, the following values shall be noted in the table:

- **Reactive power measured** in terminals of the **PGU** after its stabilization, calculated from the voltage and current measurements.
- **Time t_1 and time t_2**, where t_1 is the time when the reactive power response reaches 90% of the reactive variation, and t_2 is the time when the final value is stabilized, as defined in the **Regulation**.

U at PGU terminals [p.u.]	U setpoint [p.u.]	Q measured	Q required (%P_{max})	t_1 measured	t_1 max	t_2 measured	t_2 max
1,0	1,00		0,0%±1,5% P_{max}	-	-	-	-
1,02	1,00		-8,6%±1,5% P_{max}		1 s		5 s
1,05	1,00		-21,4%±1,5% P_{max}		1 s		5 s
0,98	1,00		8,6%±1,5% P_{max}		1 s		5 s
0,95	1,00		21,4%±1,5% P_{max}		1 s		5 s
1,00	1,00		0,0% ±1,5% P_{max}		1 s		5 s

Table 25. Voltage control mode test parameters for 7% slope.

*These values of column "Q measured" could be saturated in the maximum reactive power capability of the **PGU** and declared in subsection 5.7.2.1 and in the P-Q diagrams at different voltages of the **PGU**.

U at PGU terminals [p.u.]	U setpoint [p.u.]	Q measured	Q required (%P_{max})	t_1 measured	t_1 max	t_2 measured	t_2 max
1,0	1,00		0,0%±1,5% P_{max}	-	-	-	-
1,02	1,00		-30%±1,5% P_{max}		1 s		5 s
1,05	1,00		-75%*±1,5% P_{max}		1 s		5 s
0,98	1,00		30%±1,5% P_{max}		1 s		5 s
0,95	1,00		75%*±1,5% P_{max}		1 s		5 s
1,00	1,00		0,0% ± 1,5% P_{max}		1 s		5 s

Table 26. Test parameters of the voltage control mode for the slope of 2%.

*These values of column "Q measured" could be saturated in the maximum reactive power capability value of the **PGU** declared in the test specified in subsection 5.7.2.1 and in P-Q diagrams at different voltages of the **PGU**.

In order to ensure proper stabilization of the electrical parameters of the **PGU**, at least 1 minute shall be reserved before a test is carried out without sending new reactive power commands.

5.8.2.2.2. Acceptance criteria for PGU voltage control mode tests

The test shall be considered valid when the following conditions are met:

- The **PGU** is capable of modifying the reactive power output in the event of a voltage change.
- The measured values of reactive power once stabilized in the final value are in the range according to the limits established in **Table 25** and **Table 26**.
- The response times t_1 and t_2 are equal to or less than the values specified in each case, according to the provisions of [2].

If any of the above conditions were not met, it would not mean that the test would be invalidated, but it would be necessary to verify, by means of supplementary simulations, that the abilities of the **PGUs** demonstrated in the tests, together with any other **ACPGM** are able to comply with the requirement at **PGM** level.

5.8.2.3. Power factor control mode

5.8.2.3.1. PGU power factor control mode test

For **power factor control mode tests**, the terminal voltage of the **PGU** will be the nominal voltage. If the **PPC** is to be used for the power factor control of the **PGU**, it must be in service for the **PGU** test.

During the test, the power factor logs will be established as stated in **Table 27**. For each test, it will be measured in **PGU** terminals, as applicable, and the measuring equipment will always record voltage and current.

The following values shall be noted in the table:

- Reactive power measured in **PGU** terminals.
- Active power produced by the **PGU** at the time of Q measurement.
- The time it takes to stabilize in the ±5% band, as established in [2] the new power factor value after receiving a new setpoint or a variation in active power.

The values marked in **Table 27** will be set as the power factor setpoint, and measures will be taken to check whether the system reaches the determined value, taking into account the tolerances defined in the **Regulation**.

Setpoint power factor	Active power produced, P ($\%P_{max}$)	Q required (%P)	Tolerance [$\%P_{max}$]	Q measured	t measured	t maximum
0,95 inductive		-32,9%	±1,5% P_{max}			60 s
0,96 inductive		-29,2%	±1,5% P_{max}			60 s
0,97 inductive		-25,1%	±1,5% P_{max}			60 s
0,98 inductive		-20,3%	±1,5% P_{max}			60 s
0,99 inductive		-14,3%	±1,5% P_{max}			60 s
1		0	±1,5% P_{max}			60 s
0,99 capacitive		14,3%	±1,5% P_{max}			60 s
0,98 capacitive		20,3%	±1,5% P_{max}			60 s
0,97 capacitive		25,1%	±1,5% P_{max}			60 s
0,96 capacitive		29,2%	±1,5% P_{max}			60 s
0,95 capacitive		32,9%	±1,5% P_{max}			60 s

Table 27. Acceptance criteria for the tests of the power factor control mode of the PGU.

Each measurement shall be at least 1 minute and at least 1 minute of stabilization shall be left before each recording.

5.8.2.3.2. Acceptance criteria for the tests of the power factor control mode of the PGU

The test shall be considered valid when the following conditions are met:

- The **PGU** is capable of modifying the reactive power output in the event of a power factor change.
- The measured values of the output reactive power of the power factor control are within the range defined in **Table 27**. For the sake of clarity, it is noted that, in such table, the expected Q value is a function of the active power produced by the **PGU** at the time of the test, whereas the tolerance is to be calculated on the basis of the maximum capacity of the **PGU**.
- The response time is less than the value indicated in **Table 27** according to the provisions of [2].

If any of the above conditions were not met, it would not mean that the test would be invalidated, but it would be necessary to verify, by means of supplementary simulations, that the abilities of the **PGUs** demonstrated in the tests, together with any other **ACPGM** are able to comply with the requirement at **PGM** level.

5.8.3. Supplementary simulations for obtaining the PPM certificate

In order to obtain the **PPM certificate** based on **PGU** level tests or **PGU certificates**, **supplementary simulations** will be required for each reactive power control mode, in such a way that it is demonstrated that the **PGUs** comply with the requirement of reactive power control modes within the required times.

The considerations regarding the necessary modelling as well as the consideration of other **PGMs** that may share a connecting point with the **PGM** to be assessed are listed in subsection 7.4.3.

The **supplementary simulation** report shall contain, at least, the following information:

- Description of the **PGM**, including **BC.**
- **PGM** model:
  - Simulation platform and version.
  - Equivalent network characteristics.
  - Data of the **PGU** model(s), including its validation certificate/report, simulation platform and version and parameters used in the simulations.
  - Data of the **ACPGM** model(s), including its validation certificate/report, simulation platform and version and parameters used in the simulations.
  - Description of the modelling of the other components of the **PGM**.
- Outcomes:
  - Tables completed indicating the compliance of each simulation.
  - Exportable simulation packages. Upon request of the **RSO**, the model of the **PGM** used in the simulations will be delivered.
- Conclusions.

In the event that any **ACPGM** is required to comply with any of the reactive power control modes, the authorised certifier must take into account the information provided by each of them pursuant to subsection 4.6 of this **Technical Standard**.

5.8.3.1. Supplementary simulation of reactive power control

For the simulation of the reactive power control, the **PPM** will produce an active power of at least 80% P_{max}, the voltage at the checkpoint will initially be the nominal voltage, and the reactive power setpoint shall be null at the time of commencement of the test.

Changes to the reactive power setpoint of the **PPM** shall be simulated sequentially as set out in **Table 28, Table 29 and Table 30**, depending on the modelling procedure, and the reactive power value of the **PPM** as well as the stabilization time shall be recorded.

5.8.3.1.1. Complete modelling procedure at NCP

Q setpoint [% P_{max}]	Q measured	Q required at NCP [Q/ P_{max} or MVAr]	t measured	t maximum
10%		10% P_{max} ± min (1,5% P_{max} and 5 MVAr)		60 s
-10%		-10% P_{max} ± min (1,5% P_{max} and 5 MVAr)		60 s
0%		0 ± min (1,5% P_{max} and 5 MVAr)		60 s

Table 28. Parameters of the supplementary simulation of the reactive power control mode. Complete modelling procedure at NCP.

5.8.3.1.2. Alternative modelling procedure at BC. Case A.

Q setpoint [% P_{max}]	Q measured	Q required at BC (LAT) [Q/ P_{max} or MVAr]	t measured	t maximum
10%		10% P_{max} ± min (1,5% P_{max} and 5 MVAr)		60 s
-10%		-10% P_{max} ± min (1,5% P_{max} and 5 MVAr)		60 s
0%		0 ± min (1,5% P_{max} and 5 MVAr)		60 s

Table 29. Parameters of the supplementary simulation of the reactive power control mode. Alternative modelling procedure at BC. Case A.

5.8.3.1.3. Alternative modelling procedure at BC. Case B.

Q setpoint [% P_{max}]	Q measured	Q required at BC [Q/ P_{max} or MVAr]	t measured	T maximum
10%		10% P_{max} ± min (2% P_{max} and 5 MVAr)		60 s
-10%		-10% P_{max} ± min (2% P_{max} and 5 MVAr)		60 s
0%		0 ± min (2% P_{max} and 5 MVAr)		60 s

Table 30. Parameters of the supplementary simulation of the reactive power control mode. Alternative modelling procedure at BC. Case B.

5.8.3.2. Acceptance criteria for supplementary simulations of reactive power control.

The **authorised certifier** shall assess:

- Results of the **PGU** reactive power control test.
- That the capacities (active and reactive power) of the **PGUs** have been used to take into account the **PGM** maximum design temperature in the supplementary simulations.
- Information about all **PPM ACPGM** according to subsection 4.6.

- The data and parameters of the cables, lines and transformers of the **PPM** and the connection network to the **NCP**.
- Results of the **supplementary simulation** of the reactive power control.

The **supplementary simulation** of the reactive power control shall be considered valid when all of the following conditions are met:

- The reactive power output of the **PPM** (Q measured) is within the limits defined in **Table 28, Table 29 and Table 30**, depending on the modelling procedure.
- The reactive power output of the **PPM** must be stabilized in a time less than or equal to the time specified in **Table 28**, **Table 29** and **Table 30**.
- The simulation time of each voltage step shall be sufficiently long to verify the settling time in such a way that complete stabilization of the response has been achieved before the simulation of the next step is performed.

5.8.3.3. Supplementary simulation of voltage regulation mode.

For the simulation, the **PPM** will produce an active power of at least 80%$P_{max.}$. Voltage modifications will be simulated as indicated in the relevant tables depending on the modelling procedure, with 2% and 7% voltage control slopes respectively. The response of the control shall be checked by recording the reactive power output after the voltage modification, as well as the response time.

Regardless of this simulation, the **RSO** may request additional tests of the operation of the on-load voltage control. According to the topology of the **PPM** and the **PPM** evacuation network up to the **NCP**, if **BC** is not located at the **NCP**, if necessary, the **RSO** may request voltage setpoint values outside the range from 0,95 p.u. up to 1,05 p.u. to comply with the requirement at the **NCP**.

5.8.3.3.1. Full modelling procedure at NCP

The sequence of **supplementary simulations** indicated in **Table 31 and Table 32** shall be carried out.

U at NCP [p.u.]	Setpoint U at NCP [p.u.]	Q measured	Q required at NCP (%P_{max})	t_1 measured	t_1 max	t_2 measured	t_2 max (s)
1,0	1,00		0,0% ±1,5%P_{max}	-	-	-	-
1,02	1,00		-8,6% ±1,5%P_{max}		1 s		5 s
1,05	1,00		-21,4%±1,5%P_{max}		1 s		5 s
1,02	1,00		-8,6 ±1,5%P_{max}		1 s		5 s
1,0	1,00		0,0% ±1,5%P_{max}		1 s		5 s
0,98	1,00		8,6% ±1,5%P_{max}		1 s		5 s
0,95	1,00		21,4%±1,5%P_{max}		N/A**		60 s
0,98	1,00		8,6% ±1,5%P_{max}		N/A**		60 s
1,0	1,00		0,0% ± 1,5%P_{max}		1 s		5 s

Table 31. Parameters of the supplementary simulation of the 7% voltage control mode in PPM according to the complete modelling procedure at NCP.

U at NCP [p.u.]	U setpoint at NCP [p.u.]	Q measured	Q required at NCP (%P_{max})	t_1 measured	t_1 max	t_2 measured	t_2 max (s)
1,0	1,00		0,0% ±1,5%P_{max}	-	-	-	-
1,02	1,00		-30%±1,5%P_{max}		1 s		5 s
1,05	1,00		-75%*±1,5%P_{max}		1 s		5 s
1,02	1,00		-30%±1,5%P_{max}		1 s		5 s
1,0	1,00		0,0% ±1,5%P_{max}		1 s		5 s
0,98	1,00		30%±1,5%P_{max}		N/A**		60 s
0,95	1,00		75%*±1,5%P_{max}		N/A**		60 s
0,98	1,00		30%±1,5%P_{max}		N/A**		60 s
1,0	1,00		0,0% ± 1,5%P_{max}		N/A**		60 s

Table 32. Parameters of the supplementary simulation of the voltage control mode for slope of 2% in PPM according to the complete modelling procedure at NCP.

*These values of the “Q measured” column could be saturated depending on the maximum reactive power capability of the **PPM**.
** Although it does not apply (N/A) at that operation point because answers of up to 60 seconds are permitted, t_1 must be noted in the table.

5.8.3.3.2. Alternative modelling procedure at BC. Case A

The sequence of **supplementary simulations** indicated in **Table 33 and Table 34** shall be carried out.

U at BC [p.u.]	U setpoint in PPM [p.u.]	Q measured	Q required at BC (%P_{max})	t_1 measured	t_1 max	t_2 measured	t_2 max (s)
1,0	1,00		0,0% ±1,5%P_{max}	-	-	-	-
1,02	1,00		-8,6% ±1,5%P_{max}		1 s		5 s
1,05	1,00		-21,4%±1,5%P_{max}		1 s		5 s
1,02	1,00		-8,6% ±1,5%P_{max}		1 s		5 s
1,0	1,00		0,0% ±1,5%P_{max}		1 s		5 s
0,98	1,00		8,6% ±1,5%P_{max}		1 s		5 s
0,95	1,00		21,4%±1,5%P_{max}		N/A**		60 s
0,98	1,00		8,6% ±1,5%P_{max}		N/A**		60 s
1,0	1,00		0,0% ± 1,5%P_{max}		1 s		5 s

Table 33. Parameters of the supplementary simulation of the voltage control mode for slope of 7% in PPM according to the alternative modelling procedure at BC Case A.

U at BC [p.u.]	U setpoint in PPM [p.u.]	Q measured	Q required at BC (%P_{max})	t_1 measured	t_1 max	t_2 measured	t_2 max (s)
1,0	1,00		0,0% ±1,5%P_{max}	-	-	-	-
1,02	1,00		-30%±1,5%P_{max}		1 s		5 s
1,05	1,00		-75%*±1,5%P_{max}		1 s		5 s
1,02	1,00		-30%±1,5%P_{max}		1 s		5 s
1,0	1,00		0,0% ±1,5%P_{max}		1 s		5 s
0,98	1,00		30%±1,5%P_{max}		N/A**		60 s
0,95	1,00		75%*±1,5%P_{max}		N/A**		60 s
0,98	1,00		30%±1,5%P_{max}		N/A**		60 s
1,0	1,00		0,0% ± 1,5%P_{max}		N/A**		60 s

Table 34. Parameters of the supplementary simulation of the voltage control mode for slope of 2% in PPM according to the alternative modelling procedure at BC Case A.

*These values of the "Q measured" column could be saturated depending on the maximum reactive power capability of the **PPM**.

** Although it does not apply (N/A) at that operation point because answers of up to 60 seconds are permitted, t_1 must be noted in the table.

5.8.3.3.3. Alternative modelling procedure at BC. Case B

A variation of these tests is noted in comparison with those of the previous subsection applicable to the general and special case A procedure: the maximum reactive power capability of the **PPM** is greater, which has a direct impact on the slope value, which, as indicated in the **Regulation**, refers to the maximum reactive power.

U at LAT [p.u.]	U setpointat PPM [p.u.]	Q measured	Q required at BC (%P_{max})	t_1 measured	t_1 max	t_2 measured	t_2 max (s)
1,0	1,00		0,0% ±2%P_{max}	-	-	-	-
1,02	1,00		-11,4% ±2%P_{max}		1 s		5 s
1,05	1,00		-28,6% ±2%P_{max}		1 s		5 s
1,02	1,00		-11,4% ±2%P_{max}		1 s		5 s
1,0	1,00		0,0% ±2%P_{max}		1 s		5 s
0,98	1,00		11,4% ±2%P_{max}		1 s		5 s
0,95	1,00		28,6% ±2%P_{max}		N/A**		60 s
0,98	1,00		11,4% ±2%P_{max}		N/A**		60 s
1,0	1,00		0,0% ± 2%P_{max}		1 s		5 s

Table 35. Parameters of the supplementary simulation of the voltage control mode for slope of 7% at PPM according to the alternative modelling procedure Case B.

U at LAT [p.u.]	U setpoint at PPM [p.u.]	Q measured	Q required at BC (%P_{max})	t_1 measured	t_1 max	t_2 measured	t_2 max (s)
1,0	1,00		0,0% ±2% P_{max}	-	-	-	-
1,02	1,00		-40%*±2%P_{max}		1 s		5 s
1,05	1,00		-100%*±2%P_{max}		1 s		5 s
1,02	1,00		-40%*±2%P_{max}		1 s		5 s
1,0	1,00		0,0% ±2%P_{max}		1 s		5 s
0,98	1,00		40%±2%P_{max}		N/A**		60 s
0,95	1,00		100%*±2%P_{max}		N/A**		60 s
0,98	1,00		40%±2%P_{max}		N/A**		60 s
1,0	1,00		0,0% ± 2%P_{max}		N/A**		60 s

Table 36. Parameters of the supplementary simulation of the voltage control mode for 2% slope at PPM according to the alternative modelling procedure Case B.

*These values of the "Q measured" column could be saturated depending on the maximum reactive power capability of the **PPM**. In case of saturation of the reactive power response, it is sufficient to indicate in the table that the response times are lower than their limiting values without specifying the measured time.
** Although it does not apply (N/A) at that operation point because answers of up to 60 seconds are permitted, t_1 must be noted in the table.

5.8.3.4. Acceptance criterion of the supplementary simulation of the voltage regulation mode.

The **authorised certifier** shall assess:

- The results of the voltage control test of the **PGUs**.
- That the capacities (active and reactive power) of the **PGUs** have been used to take into account the **PGM** maximum design temperature.
- Information about all **PPM ACPGM** according to subsection 4.6.
- Results of maximum reactive power capability of the **PGU** and **PPM** tests.
- The data and parameters of the cables, lines and transformers of the **PPM**.
- In the case of supplementary simulation by the full modelling procedure at **NCP**, the data from the connection network to the **NCP**.
- The results of the **supplementary simulation** of the voltage control of the **PPM**.

The **supplementary simulation** of the voltage control of the **PPM** shall be considered valid when the following conditions are met:

- The reactive power output, for each slope value and each voltage step in **PPM** terminals specified in **Table 33** and **Table 34** or **Table 35** and **Table 36**, as the case may be, is within the required value, taking into account that the maximum deviation will be ±1,5% of Q/P_{max}.
- The **PPM** achieves 90 % of the change in the reactive power output in a time less than or equal to the rise time specified in the above tables and indicated as t_1.
- The reactive power output of the **PPM** is stabilized in a time less than or equal to the settling time specified in the above tables and indicated as t_2.
- The simulation time of each voltage step is sufficient to check the settling time in such a way that complete stabilization of the response has been achieved before the simulation of the next step is performed.

5.8.3.5. Supplementary simulation of power factor control.

For the performance of the **supplementary simulation** of the power factor control mode, the **PPM** will produce an active power of $80\%P_{max}$. The values established in **Table 39** shall be simulated as power factor setpoint, and the **PPM** output reactive power shall be recorded, as well as the stabilization time.

As stated in subsection 5.7.3, the point at which the reactive power must be measured will, as a general rule, be the **NCP**. However, for any **PPMs** connected to a shared evacuation network with other **PGMs**, in order to facilitate the compliance monitoring process, the **PPM**’s **BC** assessment (special procedure, Case A and Case B).

5.8.3.5.1. Complete modelling procedure at NCP

U at NCP	Setpoint power factor	Q required at NCP (%P_{max})	Tolerance [Q/P_{max}]	Q measured	t measured	t maximum
1,05	0,95 inductive	-26,29%	±1,5% P_{max}			60 s
1,05	0,96 inductive	-23,33%	±1,5% P_{max}			60 s
1,05	0,97 inductive	-20,05%	±1,5% P_{max}			60 s
1,00	0,98 inductive	-16,24%*	±1,5% P_{max}			60 s
1,00	0,99 inductive	-11,40%	±1,5% P_{max}			60 s
1,00	1	0,00%	±1,5% P_{max}			60 s
1,00	0,99 capacitive	11,40%	±1,5% P_{max}			60 s
1,00	0,98 capacitive	16,24%*	±1,5% P_{max}			60 s
0,95	0,97 capacitive	20,05%	±1,5% P_{max}			60 s
0,95	0,96 capacitive	23,33%	±1,5% P_{max}			60 s
0,95	0,95 capacitive	26,29%	±1,5% P_{max}			60 s

Table 37. Supplementary simulation parameters of the power factor control mode of the full modelling procedure at NCP.

*These values of the column "Q expected at NCP" could be saturated depending on the maximum reactive power capability of the **PPM** for these voltage levels at NCP.

5.8.3.5.2. Alternative modelling procedure at BC. Case A

U at BC	Setpoint power factor	Q required at BC (%P_{max})	Tolerance [Q/P_{max}]	Q measured	t measured	t maximum
1,05	0,95 inductive	-26,29%	±1,5% P_{max}			60 s
1,05	0,96 inductive	-23,33%	±1,5% P_{max}			60 s
1,05	0,97 inductive	-20,05%	±1,5% P_{max}			60 s
1,00	0,98 inductive	-16,24%	±1,5% P_{max}			60 s
1,00	0,99 inductive	-11,40%	±1,5% P_{max}			60 s
1,00	1	0,00%	±1,5% P_{max}			60 s
1,00	0,99 capacitive	11,40%	±1,5% P_{max}			60 s
1,00	0,98 capacitive	16,24%	±1,5% P_{max}			60 s
0,95	0,97 capacitive	20,05%	±1,5% P_{max}			60 s
0,95	0,96 capacitive	23,33%	±1,5% P_{max}			60 s
0,95	0,95 capacitive	26,29%	±1,5% P_{max}			60 s

Table 38. Power factor control mode supplementary simulation parameters for the alternative modelling procedure at BC. Case A.

5.8.3.5.3. Alternative modelling procedure at BC. Case B

U at LAT	Setpoint power factor	Q required at BC (%P_{max})	Tolerance [Q/P_{max}]	Q measured	t measured	t maximum
1,05	0,95 inductive	-26,29%	±2% P_{max}			60 s
1,05	0,96 inductive	-23,33%	±2% P_{max}			60 s
1,05	0,97 inductive	-20,05%	±2% P_{max}			60 s
1,00	0,98 inductive	-16,24%	±2% P_{max}			60 s
1,00	0,99 inductive	-11,40%	±2% P_{max}			60 s
1,00	1	0,00%	±2% P_{max}			60 s
1,00	0,99 capacitive	11,40%	±2% P_{max}			60 s
1,00	0,98 capacitive	16,24%	±2% P_{max}			60 s
0,95	0,97 capacitive	20,05%	±2% P_{max}			60 s
0,95	0,96 capacitive	23,33%	±2% P_{max}			60 s
0,95	0,95 capacitive	26,29%	±2% P_{max}			60 s

Table 39. Power factor control mode supplementary simulation parameters for the alternative modelling procedure at BC. Case B.

5.8.3.6. Acceptance criterion of the supplementary simulation of power factor control.

The **authorised certifier** shall assess:

- The results of the power factor control test of the **PGUs**.
- That the capacities (active and reactive power) of the **PGUs** have been used to take into account the **PGM** maximum design temperature in the supplementary simulations.
- Information about all **PPM ACPGM** according to subsection 4.6.
- The data and parameters of the cables, lines and transformers of the **PPM**.
- In the case of supplementary simulation by the full modelling procedure at NCP, the data from the connection network to the **NCP**.
- The results of the **supplementary simulation** of the power factor control of the **PPM**.

The **supplementary simulation** of the power factor control mode shall be considered valid when the following conditions are met:

- The reactive power output of the **PPM** for each power factor and voltage value at the NCP is equal to the value stated in **Table 37** is within the required value, taking into account that the maximum deviation indicated in the table.
- The reactive power output of the **PPM** must be stabilized in a time less than or equal to the time specified in **Table 37**.
- The reactive power output of the **PPM** for each power factor and voltage value at the **BC** is equal to the value stated in **Table 38** or **Table 39**, as the case may be, is within the required value, taking into account the maximum deviation stated in each table.
- The **PPM**'s reactive power output must be stabilized in a time less than or equal to the time specified in **Table 38** or **Table 39**, as applicable.
- The simulation time of each voltage step must be sufficient to check the settling time.

5.8.4. Assessment at PPM level for obtaining PPM certificate

In the event that the **PPM owner** does not have or does not wish to use the **equipment certificates** for **PGU** and **ACPGM** for this technical requirement, the tests described in subsection 5.8.2 as well as the **supplementary simulations** described in subsection 5.8.3 must be performed. If the acceptance criteria described in both subsections are met, the **authorised certifier** shall issue a **PPM certificate** for this requirement.

5.9. Power oscillations damping for SPGM

5.9.1. Objective

The objective is to verify that the **SPGM,** if its maximum capacity is greater than 50 MW, is **capable of damping power oscillations**[13] of more than 0,1 Hz through a power system stabiliser (**PSS**), as indicated in:

- Article 19.2 of the **Regulation.**
- Article 2.2.2 of [2][2].

Pursuant to Article 53 of the **Regulation, compliance of the SPGM** with this requirement may be achieved:

1. By means of an equipment certificate based on the assessment methodology described in subsection 5.9.4, it being necessary, in the event that the **owner** of the **SPGM** opts for equipment certificate, for the simulation reports used by the **authorised certifier** to be sent in full to the **TSO** for its information.
2. or by **simulation**, both at **PGU** and **SPGM** level, through the methodology described in subsections 5.9.2 and 5.9.3, it is not necessary for an accredited entity to perform the simulations or report required.

By default, assessment of this requirement shall be at **PGU** level, unless the **SPGM owner** declares the existence of a higher hierarchical control at the **SPGM** level that may impact the PSS function of the **PGU** or perform this function at the **SPGM** level.

For the assessment of the technical requirement, the **owner** of the **SPGM** (or the entity designated by it, e.g. the **SPGM** manufacturer) shall provide the **TSO** with a report containing the results of the **PSS** adjustment study by means of a modal analysis based on eigenvalues to be carried out with a **SPGM** model containing the modules referred to in Article 15.6(c)(ii) of the **Regulation** and that it has been certified according to section 6. However, if the **SPGM** model used for this analysis is a small signal specific model and differs from the certified model according to section 6, it will be permitted to be used at the request of the **SPGM** owner (or the entity designated by the owner). In the event of the use of a non-certified model, the **TSO** shall be provided with the open, non-encrypted model, with a functional description of the model and its structure, as well as the studies performed to produce the **report**.

It will not be necessary for the report and simulations to be performed by an accredited entity.

The **TSO** shall assess the report within two months of the report meeting the conditions set out above.

If the assessment of the requirement by the **TSO** is positive, the **TSO** shall issue a written statement in accordance with the **owner** of the **SPGM**, which shall not be part of the **final PGM certificate**, but which shall be required to obtain the **FON** (within “Others” in **Figure 3**) in the same way as the **final PGM certificate**.

[13] As a clarification, the power oscillations to be damped by the PSS will be electromechanical, as there may be power oscillations of a non-electromechanical nature that cannot be damped by the PSS.

5.9.2. Simulation method

Modal analysis based on the calculation of eigenvalues consists in determining the oscillation modes of a dynamic system. These modes can be represented in the complex plane S (**Figure 15**) through a complex eigenvalue, of the form σ ± jω. The real part, σ, is represented on the X-axis and the imaginary part, ω, on the Y-axis. From these values, its oscillation frequency and damping can be calculated.

The oscillation frequency is defined as:

$$f = \omega / 2\pi$$

Damping is defined as:

$$\zeta = \frac{\sigma}{\sqrt{\sigma^2 + \omega^2}}$$

In the event that σ is negative, i.e. the corresponding eigenvalue is located in the left area of the complex plane "S", the oscillation shall be damped. If the real part is positive, the oscillation will not be damped and the mode will therefore be unstable.

On the complex plane "S" are represented straight lines that pass through the origin and have different slopes, and represent different damping values (-3% y -5% in **Figure 17** and **Figure 18**). The system modes to the left of these lines will have a greater damping than these reference values.

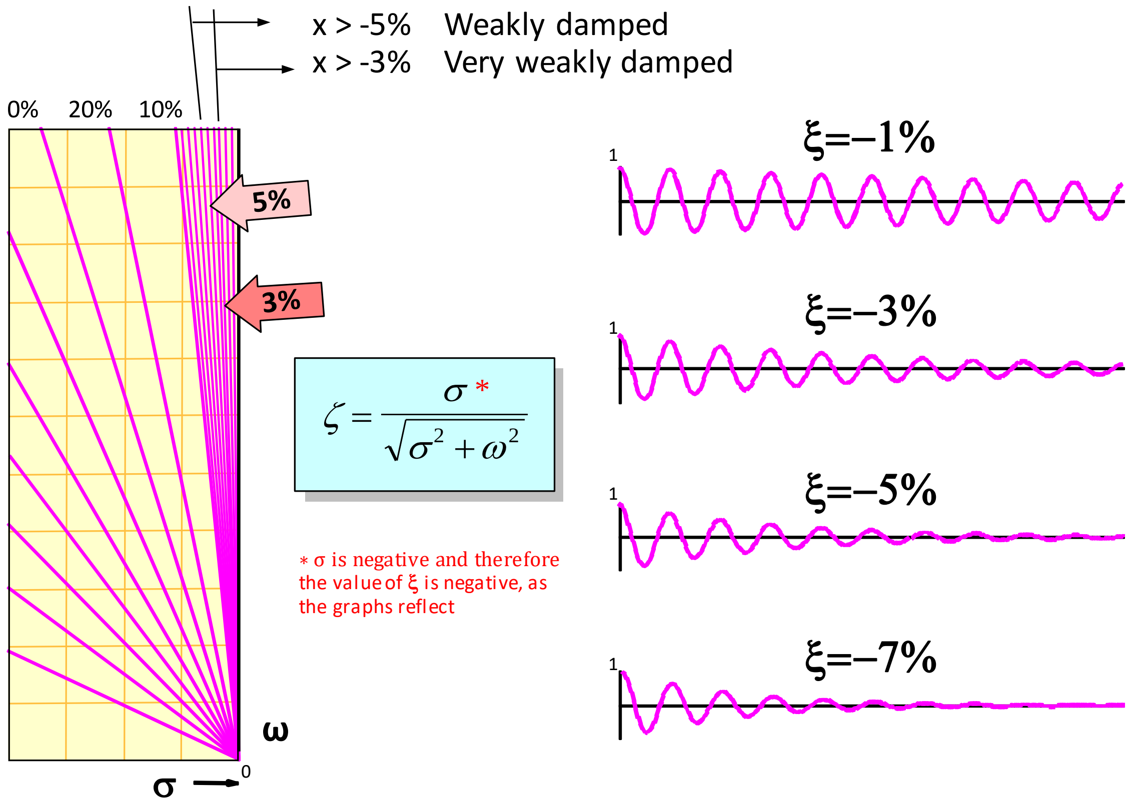


Figure 15. Oscillation modes in the complex plane "S".

In order to carry out the study, a phase compensation network of the stabilizer is designed which will have to override the offset between the excitation system setpoint and the electrical power of the **SPGM** in order to be capable of injecting an additional signal in phase with the electrical power. The magnitude of this additional signal depends on the gain of the stabilizer, which will determine the damping.

To reproduce the slowest inter-area oscillation, a test system of two **SPGM** connected via the group transformers and an electrical line, for which the technical information is detailed below, shall be used. The inter-area oscillation is reproduced with a high value of the interconnection line reactance. Conversely, local oscillation can be reproduced by reducing line reactance. A test system has been developed consisting of two **SPGM** connected via the **SPGM** transformers and a line as shown in **Figure 16**.

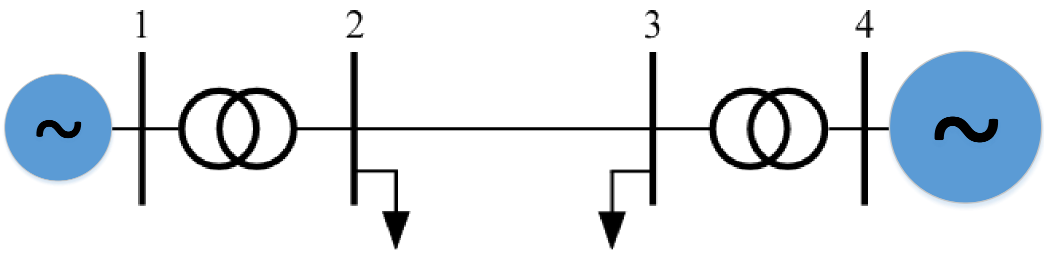


Figure 16. Single-line diagram of the example case of two SPGM.

The **SPGM** in node 1 represents the **SPGM** to be analysed, while the **SPGM** in node 4 represents the external system to which it is connected. The base power of the **SPGM** on node 1 is 1500 MVA and the base power of the **SPGM** on node 4 is 5000 MVA. It is necessary to respect these base powers with the aim of systematically reproducing the range of oscillation frequencies of interest. The power line carries 100 MW from node 1 to node 4. **Table 40** and **Table 41** provide the steady state characteristics of generators and loads.

Generador	PG (MW)	Vt
1	1350	1.0
4	3900	1.0

Table 40. Data for the SPGM.

Carga	PL (MW)	QL (MVar)
2	1250	0.0
3	4000	0.0

Table 41. Load data.

In order to model the study network in the simulation tool selected by the **PGM owner**, the reactance of the line between nodes 2 and 3, X_L shall be considered to have a variable value, as indicated at the end of this subsection, being the basis of the 100 MVA system.

The reactance of the transformer between nodes 3 and 4 shall be 0,003 p.u. and that of the transformer between nodes 1 and 2 shall be 0,01 p.u. (both on 100 MVA basis).

The loads modelled in nodes 2 and 3 shall have a dynamic behaviour peculiar to an **IZ model**, i.e. with constant current for the active power and constant impedance for the reactive power.

The **PGM** representing the external system in node 4 is modelled with an alternator, an excitation system and a speed and steam turbine regulator, the models and parameters of which are described below:

- The **alternator** is a smooth rotor synchronous generator, whose dynamic model is generally available in the libraries of any simulation tool and whose parameters are specified in **Table 42**.

$$H = 6{,}175s\,, D = 0,\ T'_{d0} = 8s,\ T''_{d0} = 0{,}03s,\ T'_{q0} = 0{,}4s,\ T''_{q0} = 0{,}05s$$
$$x_d = 1{,}8\,,\ x_q = 1{,}7\,,\ x'_d = 0{,}3\,,\ x'_q = 0{,}55\,,\ x''_d = x''_q = 0{,}25,\ x_l = 0{,}2$$
$$s_1 = 0{,}0392\,,\ s_2 = 0{,}2227$$

Table 42. Parameters of the alternator model of the PGM representing the external system.

- The **excitation system** is represented by the IEEE type ST1 model (according to IEEE 421.5) available, generally, in the libraries of any simulation tool and whose parameters are stated in **Table 43**.

$$T_R = 0{,}01s,\ T_B = 10,\ T_c = 1,\ K_A = 200, \qquad T_A = 0$$
$$V_{imax} = 999\,, V_{imin} = -999\,, V_{Rmax} = 999\,, V_{Rmin} = -999\,, K_c = K_F = 0, T_F = 1$$

Table 43. Parameters of the excitation system model of the PGM representing the external system.

- The **speed and steam turbine regulation system** is represented by the IEEE type 1 model (IEEEG1) available, generally, in the libraries of any simulation tool and whose parameters are stated in **Table 44**.

$$K = 20,\ K_1 = 0{,}3,\ K_3 = 0{,}3\,, K_5 = 0{,}4\,, K_7 = 0$$
$$T_1 = T_2 = 0,\ T_3 = 0{,}1s\,,\ T_4 = 0{,}3s\,,\ T_5 = 7s\,,\ T_6 = 0{,}6s\,,\ T_7 = 0$$
$$K_2 = K_4 = \ K_6 = K_8 = 0,\ \ U_0 = 0{,}5\,, U_c = -0{,}5\,, P_{max} = 1, P_{min} = 0$$

Table 44. Parameters of the model of the speed and steam turbine regulation system of the PGM representing the external system.

The design of a **PSS** depends on the operating point around which the differential equations of the system have been linearised. Therefore, the effectiveness of a **PSS** may be affected by the change of the system's operating point. In addition, the design of a **PSS** for a particular mode can negatively affect other modes. To ensure a robust design, the gain as well as the phase compensation network of the **PSS** is determined by considering several modes which, each of them, depend on a different operating point.

The value of the line reactance, X_L, shall be modified between 0,01 and 0,6 p.u. (with a step small enough to observe the evolution of oscillation modes, e.g. 0,05 p.u.). As this reactance increases, from the initial value of 0,01 p.u., the frequency of the slow oscillation mode (inter-area) decreases, and as the reactance decreases, the opposite would happen. A robust design should therefore be achieved that damps the inter-area mode without damaging the local modes (any of oscillation frequency of around 1 Hz).

The **TSO** may, upon request, provide the study network to the **PGM owner** or to the **manufacturer of the PGM (or PGU),** always in the format of the simulation tool used by the **TSO**.

5.9.3. Simulation acceptance criteria

The criterion used to accept the **PSS** adjustment will be, once the evolution of the modes is represented in the complex diagram, that the evolution of all modes, for different values of X_L, do not exceed the 5% damping line (towards lower damping), as stated in **Figure 17** (result not accepted) and **Figure 18** (result accepted).

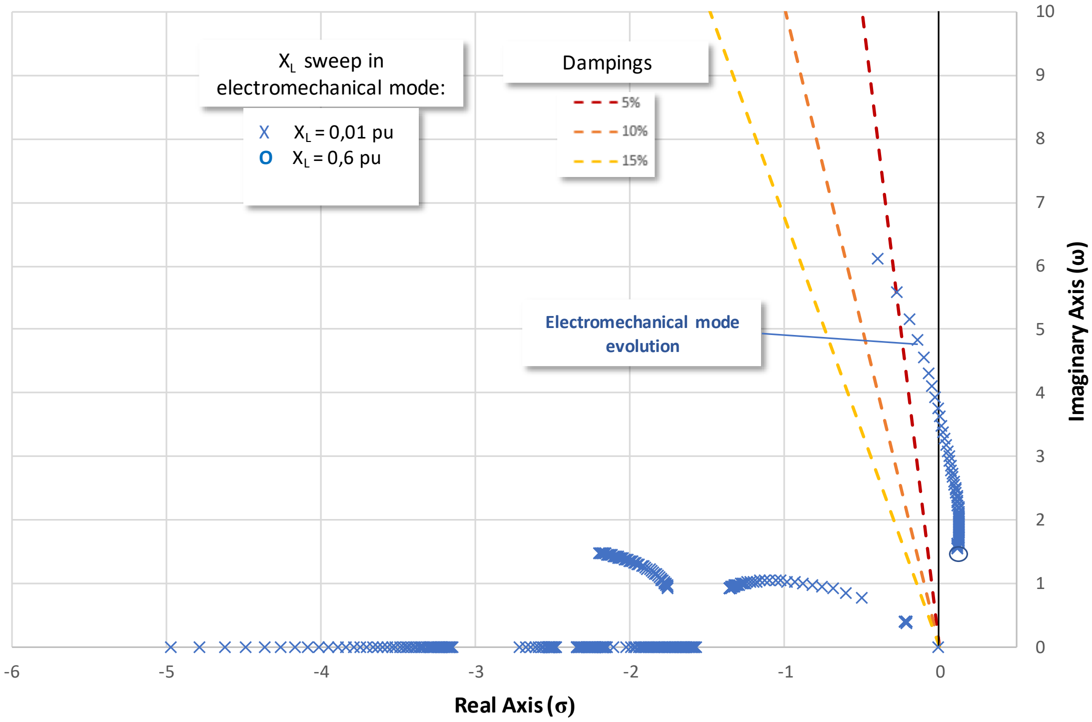


Figure 17. Variation of the modes of a PGM when changing the reactance of the line. Electro-mechanical mode with a damping of less than 5%. Result not accepted.

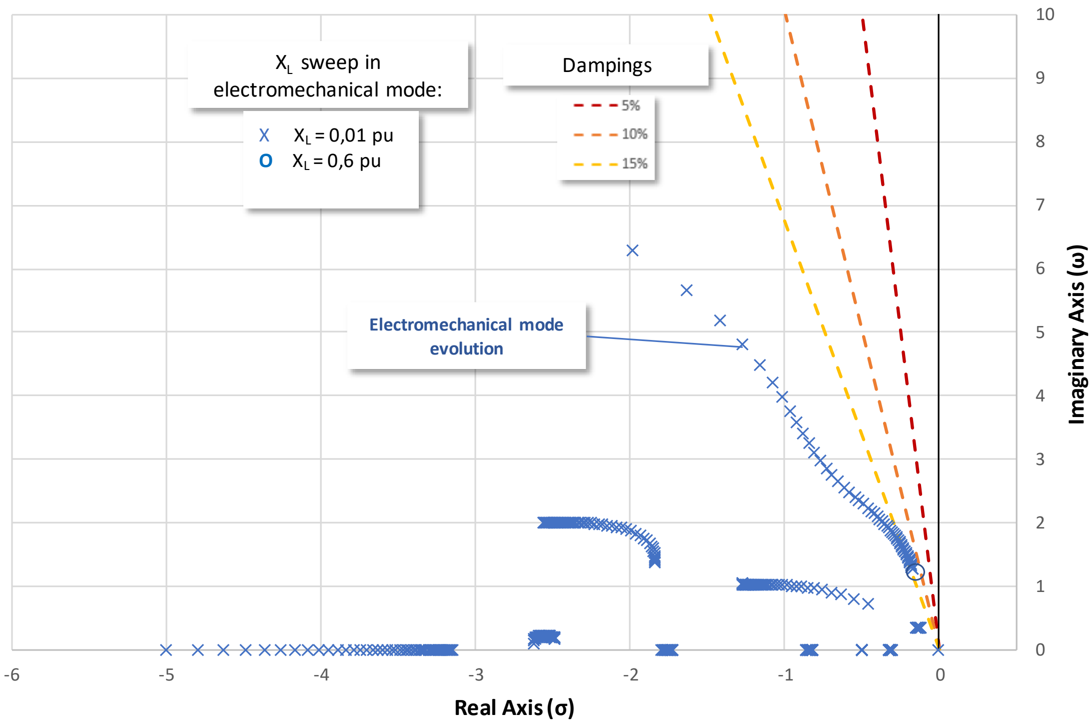


Figure 18. Variation of the modes of a PGM when changing the reactance of the line. Electro-mechanical mode with a damping greater than 5%. Result accepted.

5.9.4. Alternative assessment method

The **TSO** shall accept the stabiliser assessment report based on the requirements of IEEE 421.2 "Guide for identification, testing, and assessment of the dynamic performance of excitation control systems", in its latest version, provided that the **PSS** correctly damps the oscillations of the frequency ranges indicated above.

5.10. Power oscillations damping for PPM

5.10.1. Objective

The aim is to verify that, as stated in:

- Article 21.3.f of the Regulation.
- Article 2.3.5 of [2].

, the **PPM** is capable of:

1. damping frequency power oscillations between 0,1 Hz and 1,5 Hz via a control system for this purpose,

   or, if it does not have such a control system,

2. not deteriorating the damping of existing power oscillations at the connection point between 0,1 Hz and 1,5 Hz.

Pursuant to Article 55 of the **Regulation, compliance of the PPM** with this requirement may be achieved by **simulation**.

By default, the assessment of this requirement shall be carried out at **PGU** level, unless the **PPM owner** declares the existence of a **ACPGM** that has an impact on the **power oscillation damping control system**, in which case the assessment of this requirement shall be carried out at **PPM** level and for each of the voltage control modes of the **ACPGM**, as described in the following subsection.

Simulations and the required report need not be performed by an accredited entity.

For the assessment of the technical requirement, the **owner** of the **PPM** (or the entity designated by the owner) shall provide the **TSO** with a report containing the outcome of a study, the scope of which will depend on the availability in the **PPM** of a module intended to damp oscillations (POD):

1. **If the PPM <u>has</u> a power oscillation damping module**, a study of the adjustment of the **PPM control system** shall be carried out by means of simulations in the time domain showing that: in the particular simulation system referred to in the following section, there is an increase in the magnitude of the active or reactive power, depending on the frequency variation, by activating this control and by simulating a disturbance causing oscillations of frequencies between 0,1 Hz and 1,5 Hz, the control contributes to its damping. These simulations shall have been carried out with a model of the **PPM** containing the modules referred to in Article 15.6(c)(ii) of the **Regulation**, and has been certified according to section 6. Alternatively, a study based on the modal analysis as required below shall also be permitted for the case where the **PPM** does not have a module designed to damp oscillations.

2. **If the PPM <u>does not have</u> a power oscillation damping module**, a study of the adjustment of the **PPM** control system shall be required by means of a modal analysis based on eigenvalues, carried out with a **PPM** model, as described in subsection 5.10.2, which must contain the modules specified in subsection 15.6.(c).(ii) of the Regulation and which has been certified in accordance with section 6.

However, and as in subsection 5.9, if the **PPM** model used for this analysis is a small signal specific model and differs from the certified model according to section 6, it will be permitted to be used at the request of the **PPM** owner (or the entity designated by the owner). In the event of the use of a non-certified model, the **TSO** shall be provided with the open, non-encrypted model, with a functional description of the model and its structure, as well as the studies performed to produce the report.

The **TSO** shall assess the report within two months of the report meeting the conditions set out above.

If the assessment of the requirement by the **TSO** is positive, the **TSO** shall issue a written statement in accordance with the **owner** of the **PPM**, which shall not be part of the **final PGM certificate**, but which shall be required to obtain the **FON** (within "Others" in **Figure 3**) in the same way as the **final PGM certificate**.

5.10.2. Simulation method

5.10.2.1. Calculation of eigenvalues

It will be performed in a manner similar to that stated in subsection 5.9.2 for **SPGM**, but with the following details for incorporating the **PPM** into the study system.
The objective of the study is to assess the impact on the oscillation modes of the inclusion of the **PPM under study** in the system of **Figure 16**, resulting in the scheme of **Figure 19**:

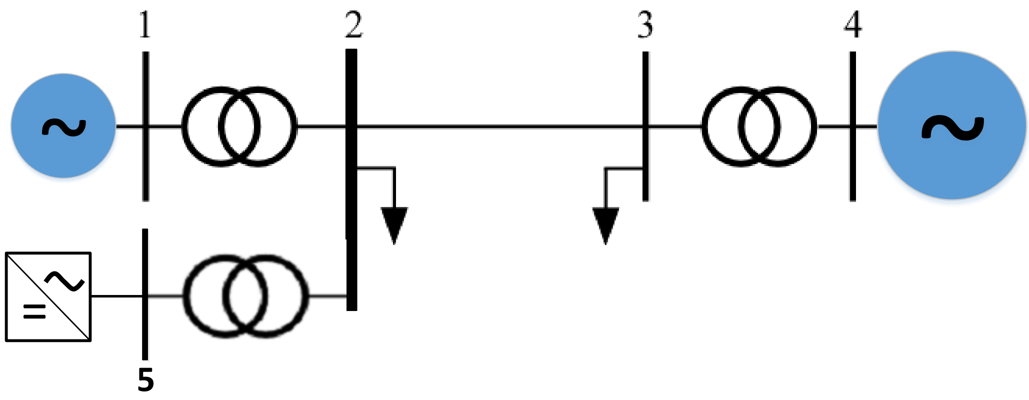


Figure 19. Single-line diagram of the PPM analysis case.

A comparative analysis shall be carried out, initially representing in the complex diagram the oscillation modes calculated with the **SPGM** of nodes 1 and 4, and then the **PPM** shall be connected to node 5, via its **PPM** transformer connected to node 2, and the same analysis shall be performed (without disconnecting the **SPGM** of nodes 1 and 4), which shall also be represented on the complex plane for assessment. It is recommended, to facilitate comparison, to draw the specific values corresponding to each of the two situations (with and without **PPM**) superimposed, and in different colour, on the same diagram. As an example, and taking the results from **Figure 17**, the (**SPGM** only), this superposition is represented in **Figure 20**.

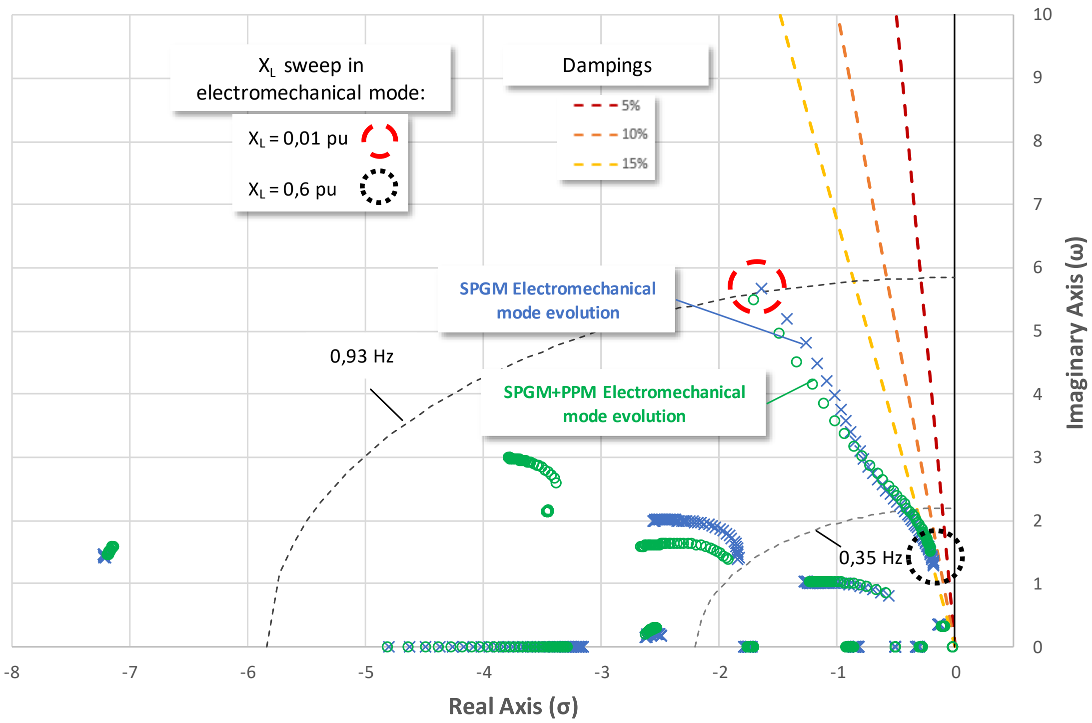


Figure 20. Variation of the oscillation modes of the study system (SPGM on node 1 and 4) by varying the reactance of the line.

This study should consider that the apparent installed power of the **PPM** on node 5 will be 1500 MVA and will generate 1350 MW, the same as the **SPGM** on node 1. The excess active power injected into node 2, compared to the case without the **PPM**, will absorb the load of the node 2. The load flow, both before connecting the **PPM** and after connecting it, it will be resolved by setting the voltage of node 2 to 1,0 p.u.

In addition to the parameters for dynamic models of the **SPGM** of node 4 specified in subsection 5.9.2, and of the parameters of the transformers and the loads, it will be necessary to model a **SPGM** in node 1 whose response is sufficiently well damped, for which it shall be equipped with a power system stabiliser (PSS).

The **SPGM** parameters of node 1 for alternator, excitation and PSS models are provided below:

- The **alternator** is a smooth rotor synchronous generator, whose dynamic model is generally available in the libraries of any simulation tool and whose parameters are specified in **Table 45**.

$$H = 6{,}3s\ , D = 0,\ T'_{d0} = 6{,}47,\ T''_{d0} = 0{,}022,\ T'_{q0} = 0{,}61,\ T''_{q0} = 0{,}034$$
$$x_d = 2{,}135\ ,\ x_q = 2{,}046\ ,\ x'_d = 0{,}34\ ,\ x'_q = 0{,}573,\ x''_d = x''_q = 0{,}269,\ x_l = 0{,}234$$
$$s_1 = 0{,}1275\ ,\ s_2 = 0{,}2706$$

Table 45. Parameters of the node 1 PGM alternator model.

- The **voltage regulator** is represented by the IEEE type ST4B model (according to IEEE 421.5) available, generally, in the libraries of any simulation tool and whose parameters are stated in **Table 46**.

$$T_R = 0{,}02,\ K_{PR} = 3{,}15,\ K_{IR} = 3{,}15\ , V_{RMAX} = 1\ , V_{RMIN} = -0{,}87$$
$$T_A = 0{,}02\ \ K_{PM} = 1,\ K_{IN} = 0\ ,\ V_{MMAX} = 1\ ,\ V_{MMIN} = -0{,}87\ ,\ K_G = \ K_I = 0,\ K_P = 6{,}5$$
$$V_{BMAX} = 8\ ,\ K_C = -0{,}08,\ X_L = 0\ , \theta_P = 0$$

Table 46. Parameters of the node 1 PGM excitation system.

- The **PSS** is represented by the IEEE type PSS2A model (according to IEEE 421.5) available, generally, in the libraries of any simulation tool and whose parameters are stated in **Table 47**.

$$T_{w1} = \ T_{w2} = 2,\ T_6 = 0\ , T_{w3} = 2\ , T_{w4} = 0,\ T_7 = 2\ , K_{s2} = 0{,}158$$
$$K_{s3} = 1\ ,\ T_8 = 0,\ T_9 = 0{,}1\ , m = 5\ , n = 1,\ K_{s1} = 17{,}069,\ T_1 = 0{,}28$$
$$T_2 = 0{,}04\ ,\ T_3 = 0{,}28,\ T_4 = 0{,}12\ , V_{sTmax} = 0{,}1\ , V_{sTmin} = -0{,}1$$
$$Input\ control\ signal\ 1{:}\ rotor\ speed\ deviation;$$
$$Input\ control\ signal\ 2{:}\ generator\ electrical\ power;$$

Table 47. Parameters of the node 1 PGM PSS model.

5.10.2.2. Time domain simulations

These simulations shall be carried out with a model of the **PPM** that has been certified in accordance with section 6, as indicated above.

The simulations will be performed on the system described in subsection 5.10.2.1 and shown in **Figure 19**.

A step or variation in the reference voltage of 2% (positive or negative) shall be applied to the **SPGM** of node 4, and the response of the active power of the **SPGM** in node 2 shall be monitored, for cases already defined in subsection 5.10.2.1:

1) with the **PPM** disconnected, and
2) with the **PPM** connected.

In each of the two cases, the value of the line reactance, X_L, shall be modified between 0,01 and 0,6 p.u. and with a step of 0,05 p.u.

As can be seen in **Figure 21** as an example, the oscillation frequency value decreases as the line reactance value increases, X_L:

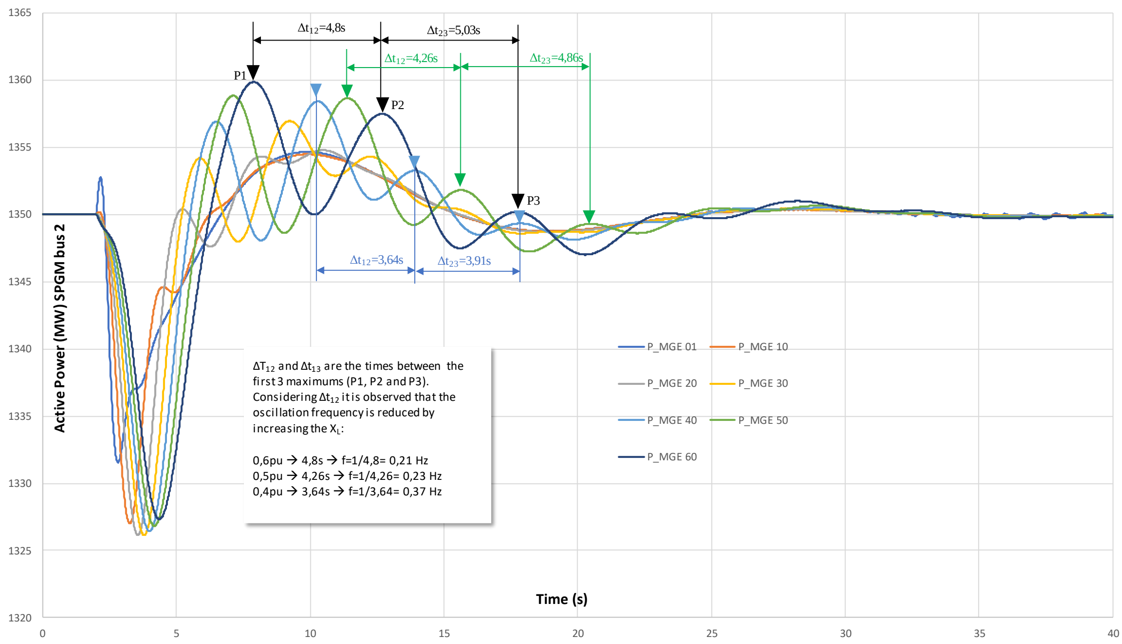


Figure 21. Temporal variation of active power in the SPGM of node 2 by introducing a 2% step in the reference voltage in the SPGM of node 4, for different values of X_L.

It is recommended that each of the graphs should contain a comparison of the two situations (with **PPM** disconnected and with **PPM** connected) for each line reactance value, X_L, used.

The above representation shall be performed **for each of the existing voltage control modes.**

As an example, in **Figure 22** the active power response of the **SPGM** in node 2 is shown for a reactance of 0,6 p.u. with and without **PPM**. Graphs must be provided as follows for each line reactance value, X_L, between 0,01 and 0,6 p.u., and with a step of 0,05 p.u.:

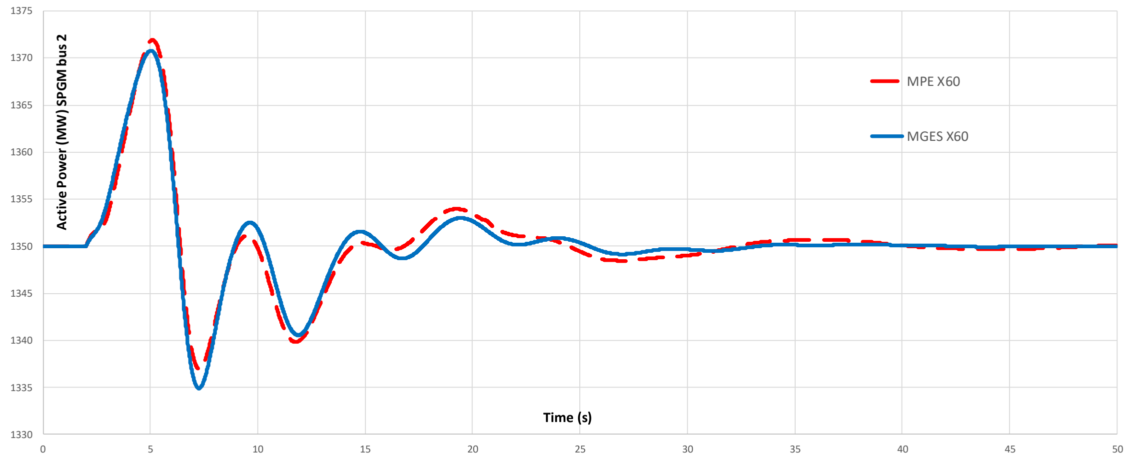


Figure 22. Temporal variation of active power in the SPGM of node 2 by introducing a 2% step in the reference voltage in the SPGM of node 4. Value X_L of 0,6 p.u. PPM connected (red) and disconnected (blue).

In the event that an active power-based oscillation damping module (POD-P) has been implemented, rather than monitoring the active power of the **SPGM** on node 2, the frequency at that same node will be monitored to perform the damping calculations.

5.10.3. Simulation acceptance criteria

5.10.3.1. Acceptance criteria for analysis based on eigenvalues

The criterion for the assessment of the study described in the subsection shall consider that the **PPM** does not adversely contribute to the damping of oscillation modes between 0,1 Hz and 1,5 Hz if the following conditions are met:

- The introduction of a **PPM** in node 1 does not introduce new oscillation modes with a damping of less than 5%.
- Under no circumstances will existing modes reduce their damping below 5%.

5.10.3.2. Acceptance criteria for time domain simulations

In the case of time domain simulations, the report will show the modal decomposition of each of the responses presented according to subsection 5.10.2.2, indicating the methodology followed for such modal decomposition (for example, that indicated in the document IEEE

"Identification of Electromechanical Modes in Power Systems" PES TR15, Feb. 2014), and shall be accepted if modes between 0,1 Hz and 1,5 Hz have a damping greater than 5%.

Alternatively, the following methodology is proposed, not based on modal analysis and therefore without decomposition of responses into different frequency components, to assess damping. The graphical responses presented according to subsection 5.10.2.2 are drawn and calculated according to **Figure 23**:

- All maximums (P1 to P6) and all minimums (M1 to M5) shall be joined with lines with strokes.
- The first maximum (P1) is discarded if the first oscillation is increasing, or the first minimum (M1) is decreasing.
- The first oscillation cycle between M1 and M2 is considered in **Figure 23**.
- The magnitude of ΔP1M1 is measured as shown in **Figure 23**: from point M1, a vertical is drawn to its intersection, with the line joining P1 and P2.
- The magnitude of ΔP5M5 is measured as shown in **Figure 23**: from point M5, a vertical is drawn to its intersection, with the line joining P5 and P6.

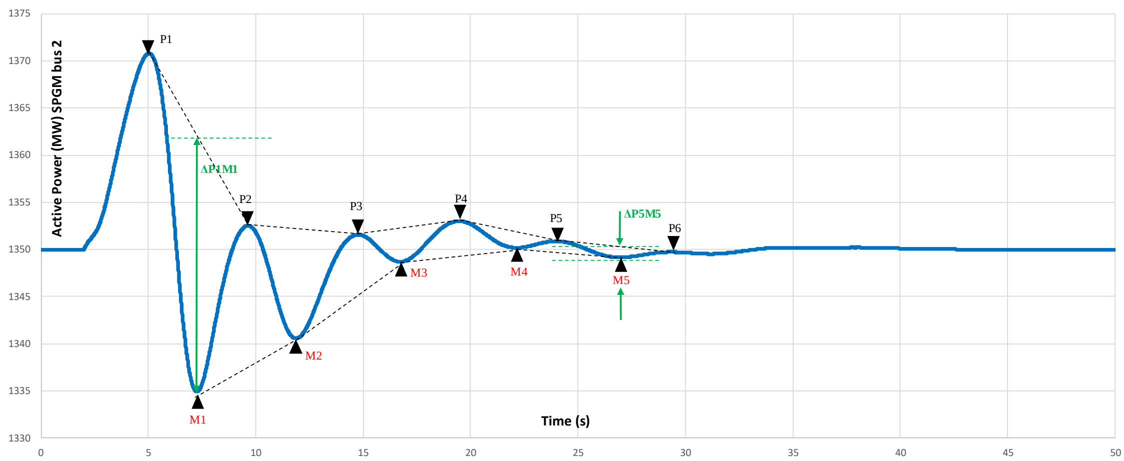


Figure 23. Alternative acceptance criteria for damping of temporal simulations.

The result shall be accepted if, in all cases performed according to subsection 5.10.2.2, the following criterion is met:

$$\Delta P5M5 < 0{,}25 \times \Delta P1M1$$

5.11. Robustness requirements: Active power recovery after a fault, Fault ride Through Capability, and Fast Fault Current Injection Capability

5.11.1. Objective

The objective is to verify that the **PGM** is capable of meeting the following robustness requirements:

1. Support voltage dips, as specified in:
   - Articles 14.3 and 16.3 of the **Regulation.**
   - Articles 3.1.1 and 3.1.2 of [2].

   Pursuant to sections 51.3, 53.3, 54.4 and 56.3 of the **Regulation**, compliance of the **PGM** of this requirement shall be assessed by **simulation** or through **equipment certificates**.

2. Contribute to the recovery of the active power after the fault, as stated in:
   - Article 21.3.d of the **Regulation.**
   - Article 3.3.1 of [2].

   Pursuant to sections 51.3, 53.3, 54.4 and 56.3 of the **Regulation**, compliance of the **PGM** with this requirement shall be assessed by **simulation** or through **equipment certificates**.

3. Fast fault current injection in case of faults, as stated in:
   - Article 21.3.d of the **Regulation.**
   - Article 2.3.1 of [2].

Pursuant to sections 51.3, 53.3, 54.4 and 56.3 of the **Regulation**, compliance of the **PGM** with this requirement shall be assessed by **simulation** or through **equipment certificates**.

The relevant simulations shall be performed by an **accredited entity** using a model certified in accordance with section 6, which describes the tests necessary for the validation of the model.

For the purpose of assessing the requirements related to robustness, in the event that it has not been possible to comply with them by test as stated in subsection 5.11.2, a certified model shall be required to accurately represent the behaviour of the **PGM** in order to perform the compliance simulations specified in those subsections. Due to the technical limitations in the testing of voltage dips and related (active power recovery after fault and Fast Fault Current Injection Capability) in **PGU** of **SPGM** with powers greater than or equal to 5 MW, the scheme to be followed is as follows, shown in **Figure 24**. If the tests specified in subsection 5.11.2.2.1 have been successful and therefore the **PGU** meets the robustness requirements, simulations for the assessment of this requirement at **PGM** level will not be considered necessary as detailed in subsection 5.11.3.

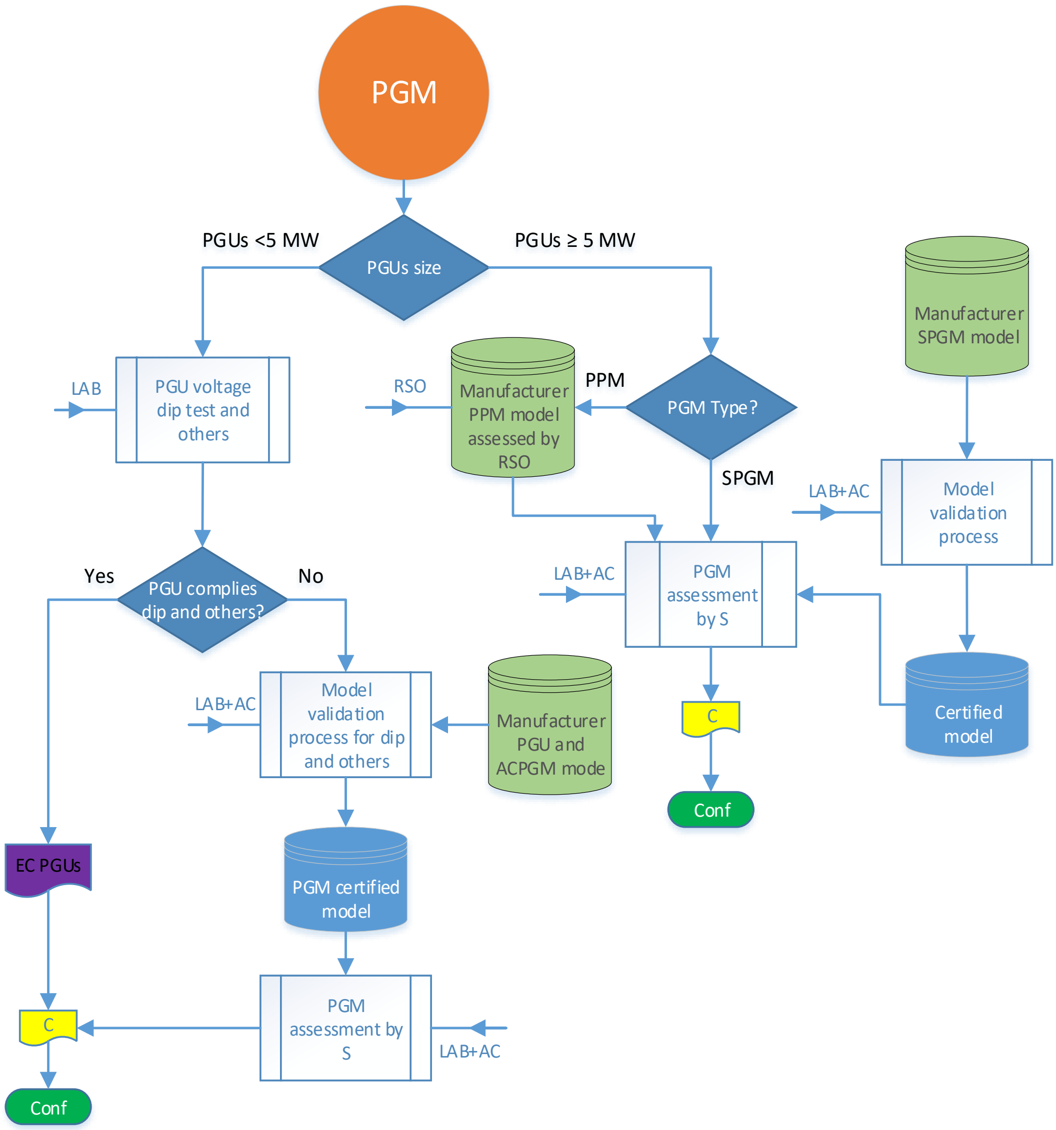


Figure 24. Detailed scheme of assessment of robustness requirements.

The structure presented in the **Figure 24** scheme is developed below.

- In the case of **PPMs** consisting of **PGUs** of powers less than 5 MW, voltage dip (and related) tests shall be carried out on the **PGUs**:

    - If the **PGU** complies with the technical requirements specified in the tests of subsection 5.11.2, the **authorised certifier** shall issue **a PGU** equipment certificate for simulation of dip and related requirements. Therefore, in subsection 5.11, as explicitly stated, supplementary simulations will not be required to assess compliance with these requirements. Compliance at the **PGU** level shall be equivalent to compliance at the **PPM** level.

    - If the **PGU** does not comply with the technical requirements specified in the tests, it will be necessary to have an **ACPGM** in order to comply with them at **PPM** level. In this case, certified models of **PGU** and **ACPGM** will be required in order to construct the model of the **PPM** with which the simulations will be performed in accordance with these requirements, as indicated in subsection 5.11., **PGU** and **ACPGM** models may have application limits beyond which they cease to be valid, e.g. a minimum application voltage. The **authorised certifier** shall verify that the terminal magnitudes of the **PGU** and **ACPGM** are within the above limits. The model of the **PPM** shall be simulated over the network of subsection 7.2.

- In the case of **PPMs** consisting of **PGUs** with a maximum capacity equal to or greater than 5 MW, they may opt to verify by means of a simulation model to carry out the compliance simulations to assess the technical requirements. Such simulation model shall be drawn up on the basis of the tests submitted by the **RSO** or the **owner of the PPM** (or the entity designated for this purpose, which may be the manufacturer) and which shall be approved by the **RSO**. Once the **RSO** accepts the simulation model, the owner of the **PPM** may use it for the assessment of the simulation requirements of this **Technical Standard**.

  Until such time as an assessment procedure for the simulation model is available, which is derived from the conclusions of the working group to be established for this purpose, the **RSO** shall assess the model and the methodology used to validate it on the basis of the tests indicated above, for which it shall have two months from the time the information is complete.

- In the case of **SPGM**:

  - If P_{max} is less than 5 MW, the **PPM** process will be followed.

  - **SPGM** of P_{max} greater than or equal to 5 MW, consisting of **PGUs** of a maximum capacity of 5 MW or more, shall use a certified simulation model (based on the criteria set out in subsection 6.2.2) to carry out compliance simulations allowing technical requirements to be assessed.

5.11.2. Test method

The definition and conditions under which the test shall be carried out shall depend on the purpose of the test. Therefore, the tests may be used for:

- Simulation model validation according to section 6, or
- for direct compliance with the technical requirement described in this subsection.

The tests described below, as indicated above, are intended to assess whether the **PGU** meets the robustness requirements.

This subsection specifies the conditions and validity criteria of the field or test bench test, as well as the definition of the equipment necessary to perform this test. It also specifies the measures to be taken to determine the parameters characteristic of the **PGU** dips response to be assessed.

The processes described in this subsection are valid for **PGU** of any power with a 3-phase connection to an electrical network.

The measurements shall be used to verify the characteristic parameters of the voltage dip response throughout the operating interval of the tested **PGU**.

The measured characteristics are only valid for the tested **PGU**. If the latter is considered to be a type **PGU**, variations in configuration or control that could affect its response to voltage dips would change the type consideration and require additional tests.

5.11.2.1. Test equipment

The use of the test equipment specified in any of the following references is recommended:

- Subsection 6.1 of [4].
- Subsection 8.5.2.2 of [5].
- Subsection 4.6.1.2 of [6].

5.11.2.2. Types of tests on PGU

In either of the two types of **PGMs** to which the **PGU**, **PPM** or **SPGM** belongs, the complete **PGU** must be tested in the field or in a test bench and must be performed considering the operation points defined in **Table 48** for **PGU of PPM** and **Table 54** for **PGU of SPGM**.

The **PGU** to be tested will be connected to the network through the test equipment, which will be capable of producing the voltage dip by applying a short-circuit, as described in the test procedure. The voltage evolution during the tests must remain above the curve indicated in **Figure 25**, considering the tolerances indicated:

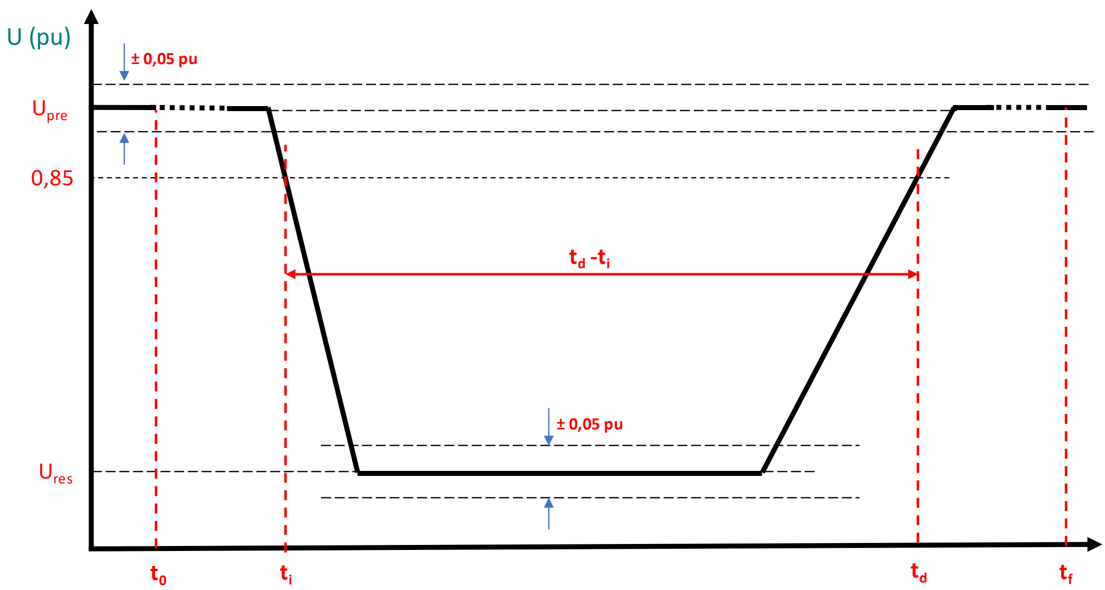


Figure 25. Dip test. Voltages and times. Tolerances.

The tolerances stated in **Figure 25** related to the voltage are expressed in p.u. of the pre-fault voltage (U_{pre}).

As a clarification, the start time of the fault, t_i, defined later in subsection 5.11.2.2.2, has been reflected in **Figure 25**, meeting only the criterion of that the positive voltage sequence drops by 0,85 p.u.

The internal electrical fault protection settings and schemes must not compromise the Fault ride Through Capability.

5.11.2.2.1. Tests to be performed in PGU of PPM

The **PPM**'s **PGU** will be tested in the field, considering the operation points stated in **Table 48**:

Load	**Recorded active power (field or test bench)**	**Recorded reactive power**
Partial load (p_{med})	15%-50% P_{max}	**Table 49** and **Table 50**
Full load	>90% P_{max}	**Table 49** and **Table 50**
Minimum load (p_{min})	<15% P_{max}*	**Table 49** and **Table 50**

Table 48. Operation points prior to the PGU of PPM test.

* In the case of field tests where the primary resource cannot be regulated, the limitation by control is permitted to be in the required power range.

The **accredited entity** shall confirm that the tests have not sought a specific moment of occurrence and clearance of the short circuit, nor a power factor of such a magnitude as to be particularly favourable to the permanence of the coupled **PGU** during the voltage dip. However, for each test, the value of the reactive power that the **PGU** must be generating or consuming is specified.

Several voltage dips corresponding to the requirement set out in **Figure 26** and **Figure 27**, shall be generated and numbered according to the first column of **Table 49** and **Table 50**, “Test Type”, and must be checked later if the records indicated in the tables in subsection 5.11.2.2.2 meet the acceptance criteria. **Two consecutive** tests shall be carried out for each type (or category) of test. This must be understood as between one test and another, no intermediate failed test has been performed under the same conditions.

In order to assess the response time in the most unfavourable situation, the abrupt voltage change adjustment for tests must be parametrized at 0,15 p.u.

Type of Test	U_{res}(p.u.)	T_f(ms)	Type of fault	Load	Q/P_{max}	K[14]
$U5TP_{max.}$	5%Un (±5%)	≥200	3-phase	Full	0 ± 10%	K=3,5
$U5TP_{med}$				Partial	0 ± 10%	K=3,5
$U5BP_{max}$			2-phase	Full	0 ± 10%	K=3,5
$U5BP_{med}$				Partial	0 ± 10%	K=3,5
$U40TP_{max}$	40%Un (±5%)	≥850	3-phase	Full	0 ± 10%	K=3,5
$U40TP_{med}$				Partial	0 ± 10%	K=3,5
$U40BP_{max}$			2-phase	Full	0 ± 10%	K=3,5
$U40BP_{med}$				Partial	0 ± 10%	K=3,5
$U75TP_{max}$	75%Un (±5%)	≥1340	3-phase	Full	0 ± 10%	K=3,5
$U75TP_{med}$				Partial	0 ± 10%	K=3,5
$U75TP_{med}Q_{max}$[15]					Q_{max}/P_{max}	K=3,5
$U75TP_{med}Q_{min}$[16]					Q_{min}/P_{max}	K=3,5
$U75TP_{min}$				P_{min}*	0 ± 10%	K=6
$U75BP_{max}$			2-phase	Full	0 ± 10%	K=3,5
$U75BP_{med}$				Partial	0 ± 10%	K=3,5
$U75BP_{min}$				P_{min}*	0 ± 10%	K=6

Table 49. Tests of voltage dips to be performed for PPM < 110 kV.

*In the case of field test where the primary resource cannot be regulated, the limitation by control is permitted to be in the required power range.

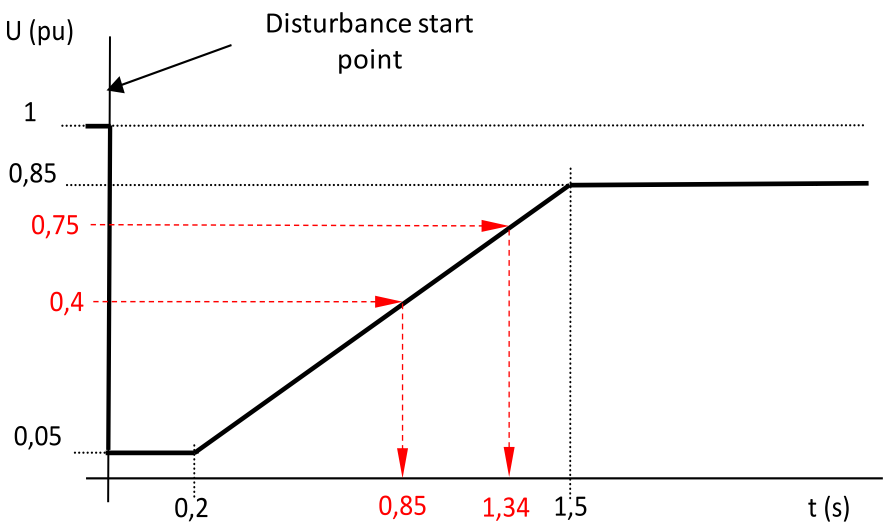


Figure 26. Profile of the fault-ride-through of an PPM below 110kV.

[14] According to [2]: K refers to K_1 or K_2, which are the gains from the fast current injection control, adjustable between 2 and 6 p.u. The default value of K_1 and K_2 shall be 3,5, unless expressly indicated by the system operator.
[15] Q_{max} is the maximum reactive injection capacity of the **PGU**.
[16] Q_{min} is the maximum reactive absorption capacity of the **PGU**.

Type of Test	U_{res}(p.u.)	T_f(ms)	Type of fault	Load	Q/P_{max}	K
$U0TP_{max}$	0%Un (±5%)	≥150	3-phase	Full	0 ± 10%	K=3,5
$U0TP_{med}$				Partial	0 ± 10%	K=3,5
$U0BP_{max}$			2-phase	Full	0 ± 10%	K=3,5
$U0BP_{med}$				Partial	0 ± 10%	K=3,5
$U40TP_{max}$	40%Un (±5%)	≥830	3-phase	Full	0 ± 10%	K=3,5
$U40TP_{med}$				Partial	0 ± 10%	K=3,5
$U40BP_{max}$			2-phase	Full	0 ± 10%	K=3,5
$U40BP_{med}$				Partial	0 ± 10%	K=3,5
$U75TP_{max}$	75%Un (±5%)	≥1340	3-phase	Full	0 ± 10%	K=3,5
$U75TP_{med}$				Partial	0 ± 10%	K=3,5
$U75TP_{med}Q_{max}$					Q_{max}/P_{max}	K=3,5
$U75TP_{med}Q_{min}$					Q_{min}/P_{max}	K=3,5
$U75TP_{min}$				P_{min}*	0 ± 10%	K=6
$U75BP_{max}$			2-phase	Full	0 ± 10%	K=3,5
$U75BP_{med}$				Partial	0 ± 10%	K=3,5
$U75BP_{min}$				P_{min}*	0 ± 10%	K=6

Table 50. Tests of voltage dips to be performed for PPM > 110 kV

*In the case of field test where the primary resource cannot be regulated, the limitation by control is permitted to be in the required power range.

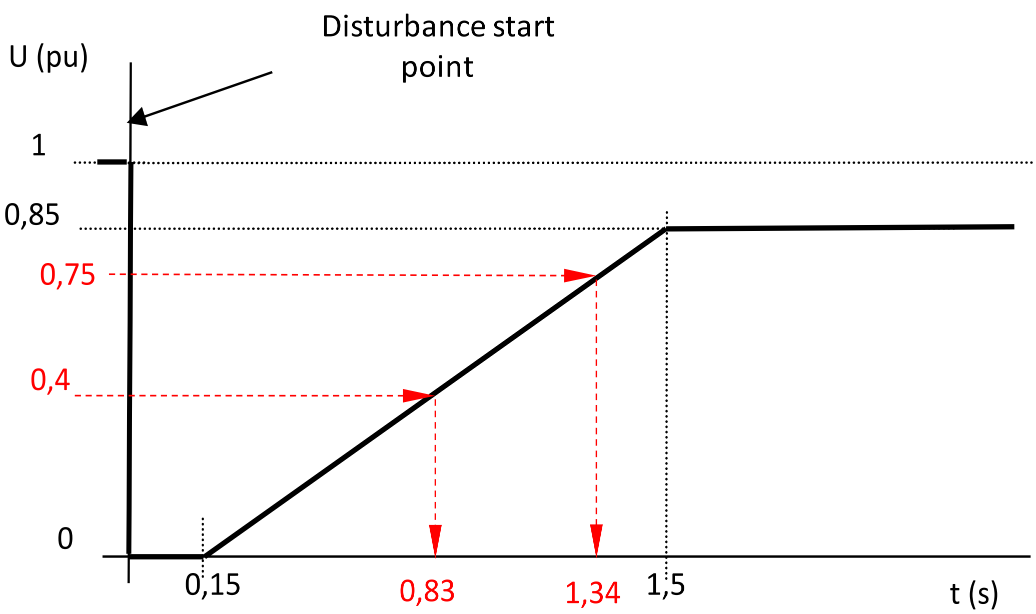


Figure 27. Profile of the fault-ride-through of a PPM connected at 110 kV or above this level.

5.11.2.2.2. Documentation of PPM tests

The active power, reactive power and voltage measurement methodology specified in [5] shall be used.

The following definitions, related to times, in the voltage dip shall be considered:

- t_0: Start of data recording.
- t_i: Time when the positive voltage sequence drops below 0,85 p.u. or current is detected in the short-circuit branch (value greater than 0,01 p.u.).
- t_a: Activation time. Time when the **PGU** is considered to have reacted to the dip. To measure it, the time from t_i until the fast current injection response has a greater variation of 5% of the nominal reactive current relative to its average t_i-60s value to t_i will be used.
- t_r: Rise time. Time counted after t_a until the fast current injection reaches 90% of its target value.
- t_d: Time when the positive voltage sequence exceeds 0,85 p.u.
- t_f: End of data recording.

These times will meet the following requirements:

- The pre-fault recording time (t_i-t_0) must be at least 60 seconds.
- The fault time (t_d-t_i) shall be equal to or greater than those specified in **Table 51**, **Table 52** and **Table 53**.
- The post-fault recording time (t_f-t_d) must be at least 10 seconds or until a buffered response is appreciated.

The following documentation shall be provided for each of the tests performed for the purpose of assessing whether the **PGU** test is valid for direct compliance with the technical requirements for robustness, as shown in the following tables: depending on the criteria established for each technical requirement of robustness, in particular as set out in the following subsections.

	Magnitude	**Description**
General Information	Type of test	
	Type of fault	
	Occurrence of the t_i fault	
	Clearing the t_d fault	
	Duration of the fault	
	t_f registration time	

Table 51. Information tests of voltage dips to PPM (I).

	Magnitude	Sequence	Time reference
PRE-FAULT: Information recorded prior to the operation of the fault to generate the dip (t_i)	Voltage (p.u.)	Pos.	1) t_i-60s to t_i 2) t_i-500ms to t_i -100ms 3) ti-1s to ti
		Neg.	1) t_i-60s to t_i 2) t_i-500ms to t_i -100ms 3) t_i-1s to t_i
	Apparent current (p.u.)	Pos.	t_i-500ms to ti -100ms
	Reactive current	Pos.	t_i-60s to t_i
		Pos.	t_i-1s to t_i
		Neg.	t_i-1s to t_i
	Active current	Pos.	t_i-1s to t_i
	Active power	Total	t_i-10s to t_i
		Total	t_i-2s to t_i
		Pos.	t_i-500ms to t_i -100ms
	Reactive power	Pos.	t_i-500ms to t_i -100ms
	Wind speed (if wind **PGU**)	-	t_i-2s to t_i

Table 52. Information tests of voltage dips to PPM (II).

	Magnitude	Sequence	Time reference
FAULT: Information recorded during the fault (t_i-t_d)	Factor K	Pos. (K_1)	
		Neg. (K_2)	
	Activation time (t_a)	Pos.	
	Rise time (t_r)	Pos.	
		Neg.	
	Settling time (t_e)	Pos.	
		Neg.	
	Voltage (p.u.)	Pos.	t_i+100ms to t_d-20ms
		Neg.	t_i+100ms to t_d-20ms
	Reactive current	Pos.	t_i+100ms to t_d-20ms
		Neg.	t_i+100ms to t_d-20ms
	Active current	Pos.	t_i+100ms to t_d-20ms
	Apparent current	Pos.	t_i+100ms to t_d-20ms
		Neg.	t_i+100ms to t_d-20ms
	Active Power	Total	t_i+100ms to t_d-20ms
		Pos.	t_i+100ms to t_d-20ms
	Reactive Power	Pos.	t_i+100ms to t_d-20ms
	Short-circuit current (for 3-phase fault only). Instant maximum current values	Phases 1, 2 and 3	t_i+20ms
	Short-circuit current (for 3-phase fault only).	Phases 1, 2 and 3	t_i+20ms
		Phases 1, 2 and 3	t_i+100ms
		Phases 1, 2 and 3	t_i+150ms
		Phases 1, 2 and 3	t_i+300ms
		Phases 1, 2 and 3	t_i+500ms
		Phases 1, 2 and 3	t_i+1000ms
	Ability to support the dip	Stays connected	Yes/No
POST-FAULT: Information recorded after the fault has been cleared (t_d) until the end of the recording time (t_f)	Reactive current	Pos.	t_d+1s to t_d+10s
		Neg.	t_d+1s to t_d+10s
	Active current	Pos.	t_d+1s to t_d+10s
	Active Power	Total	t_d+1s to t_d+10s
	Reactive Power	Pos.	t_d+1s to t_d+10s
	Voltage	Pos.	t_d+1s to t_d+10s
		Neg.	t_d+1s to t_d+10s
	Apparent current	Pos.	t_d+1s to t_d+10s
		Neg.	t_d+1s to t_d+10s
	Wind speed (if wind **PGU**)	-	t_d+1s to t_d+10s
	t_e of the active power	Pos.	
	Transient overvoltage capacity	Stays connected	Yes/No

Table 53. Information tests of voltage dips to PPM (III).

5.11.2.2.3. Criteria for assessing the voltage dip requirement

In addition to the information provided in **Table 45**, in **Table 51** and in **Table 52**, in order to assess whether the **PGU** has supported each voltage dip without disconnection, the following shall be taken into account:

Operating point: For each test category, it is necessary that the active and reactive power recorded before the voltage dip is performed is within the range defining partial and full load.

Continuity of supply:

For wind **PGU**:

The field test shall be carried out on the entire **PGU**.

Two consecutive tests shall be carried out for each type (or category) of test identified in the first column of the above tables. It shall be verified that the **PGU** is not disconnected during the application of the voltage dip in two consecutive tests corresponding to the same category.

In the event of at least one disconnection in this test sequence (2 consecutive first tests), the supply continuity condition shall be considered valid only when in the following 3 tests: corresponding to the same category, there is no disconnection of the **PGU**. If any disconnection occurs in this latter series of tests, the test shall be considered invalid. If the active power of the **PGU** is outside the limits set out in the above tables for its corresponding test, and there is no disconnection of the **PGU**, the test shall be considered invalid, but will not be counted for the purposes of considering it consecutive, i.e. will be rejected.

For photovoltaic **PGU**:

The use of a test bench is permitted to perform tests on the **PGU**, the presence of photovoltaic panels is not required and instead, the use of a DC source is permitted.

If the **PGU** is disconnected during the application of the voltage dip, in one of **two consecutive tests** for each test category, the test shall be deemed not to have been passed.

5.11.2.2.4. Criteria for assessing the fast injection requirement of reactive current

The nomenclature, including sign criteria, used in this subsection in terms of voltages and intensities shall correspond to that used in [2].

In the cases where:

- **PPM** power electronics blocks for faults where U_{res} < 20% as indicated in [2], this requirement will not be assessed.
- **PPM** is **doubly fed induction technology**, for faults where U_{res} < 20% this requirement will not be assessed, irrespective of the type of fault (three-phase or two-phase)

Without prejudice to what is indicated for the previous cases as far as the evaluation is concerned, the tests shall be carried out and the results shall be included in the test report. In this way, the **PGU certificate** shall establish the reactive current injection capacities for this type of events determined by the tests.

For current injection graphs, the apparent positive sequence current shall be used.

For the calculation of K-factors and response (t_r) and settling (t_e) times, the depth of the dip (for both 2-phase and 3-phase faults) shall be assessed from positive and negative sequence voltages over a period of 100 ms from the occurrence of the fault (t_i) to 20 ms before its clearance (t_d).

The reactive current increase provided by the **PGU of PPM** in the event of voltage dips shall be determined for each value of K indicated in the tests (K_{set}), according to the tolerances indicated in **Figure 28**[17] and shall be referred to as ΔI_{PGU}.

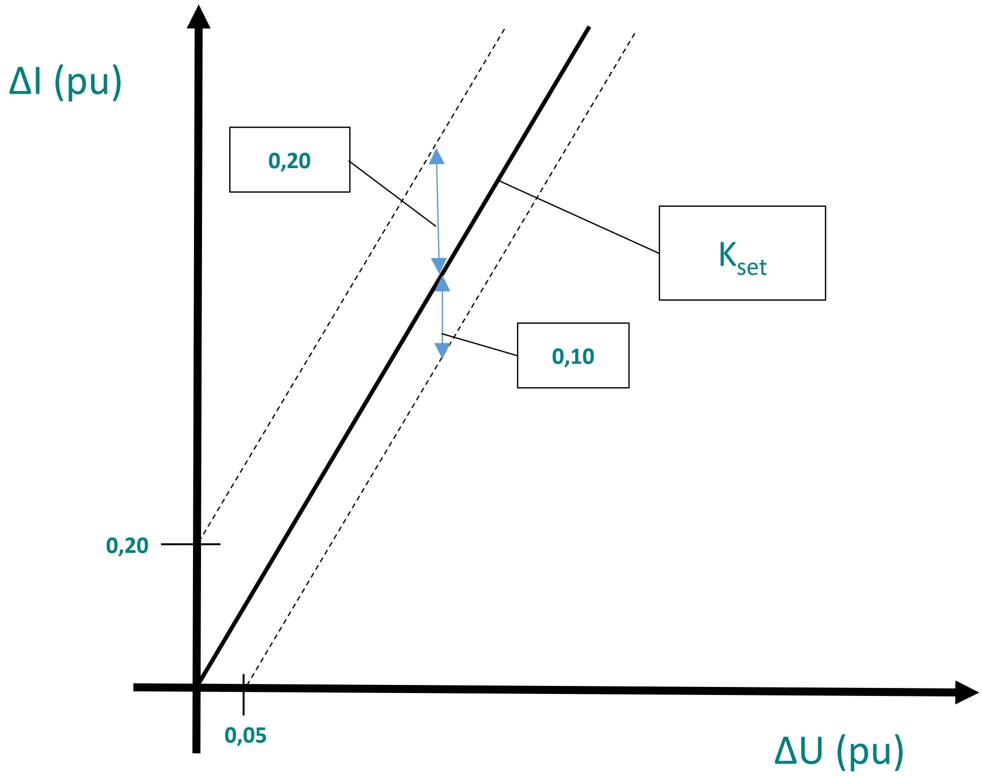


Figure 28. Admissible tolerances in the measurement of reactive fast current increase.

The **PGU of PPM** shall be capable of injecting the required current increase, considering the tolerances, determined according to **Figure 28** (ΔI_{PGU}), according to the times given below (see **Figure 29**), provided that there is no power electronics blocking condition:

- The delay time for the start of current injection/absorption (t_a)[18] must be a maximum of 20 ms.
- The rise time (t_r) from the start of the current injection/absorption until it reaches 90% of the required response corresponding to the voltage error step must be such that $t_a + t_r \leq 50$ ms is met.

[17] There is equivalence between Figure 24 and the third quadrant of Figure 4-28 of [6] and Figure 18 of [9]. However, the previous ones have been adapted to the sign convention of [2].

[18] In [2] t_i has been used instead of t_a. In subsection 5.11.2.2.2, t_i has already been used for another purpose.

- The settling time (t_e) from the start of the current injection/absorption until the response remains in the +20% and -10% bands around the required response must be a maximum of 60 ms.

For the assessment of these times, if the method of current detection in the short-circuit branch was used for the detection of the dip, up to 20 ms are added for the assessment of these times for reasons of calculation of effective value with average values of 20 ms.

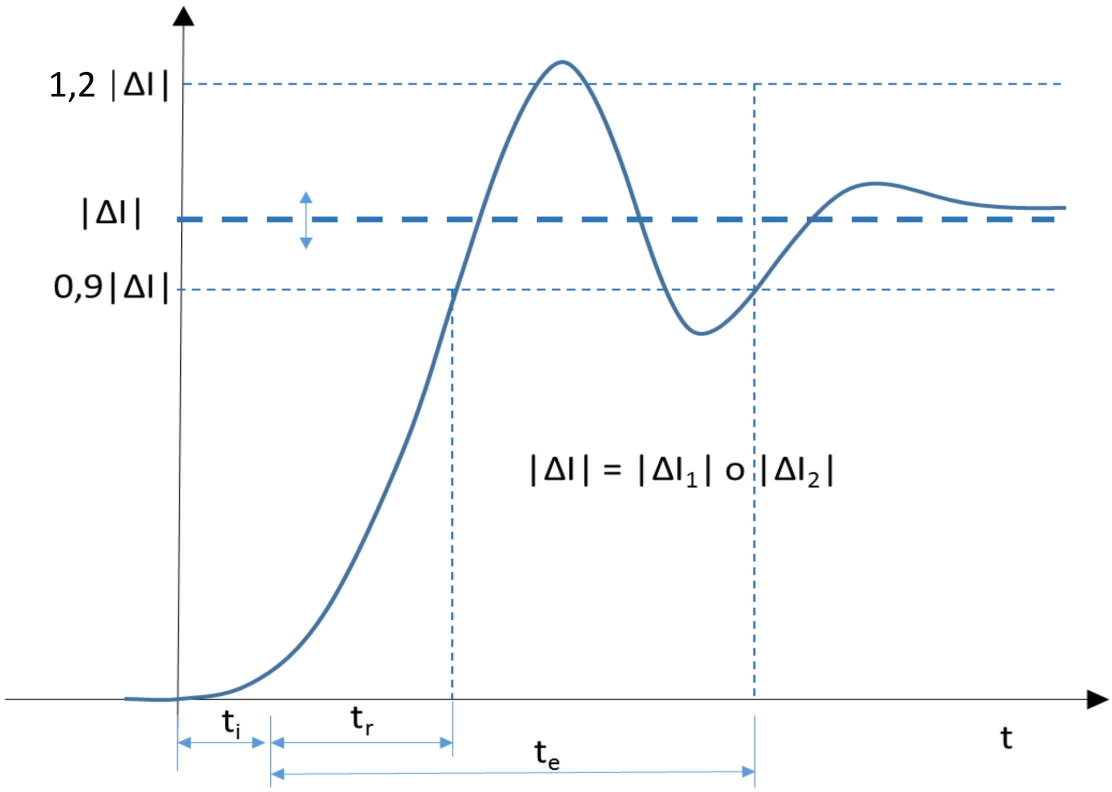


Figure 29. Example of response representing the times defined for fast fault current injection.

During 2-phase faults described in this subsection, a reduction in reactive current in positive and negative sequences from the current values required in **Figure 28** shall be permitted, provided that the injected current is greater than or equal to the nominal apparent current. The test shall be considered valid if one of the following two conditions is met:

- The positive and negative sequence components shall be limited in the same proportion.
- The positive sequence component shall be greater than 40% of the nominal apparent current.

5.11.2.2.5. Criteria for assessing the requirement for recovery of active power after the voltage dip

Once the fault is over, the active power must be recovered as soon as possible in order to maintain the stability of the system.

As a maximum limit, under the corresponding network conditions, before and after the fault, set for the fault-ride-through, the active power recovery must meet the following conditions:

- If the U_{res} in terminals of the **PGU** does not decrease by 0,5 p.u., the **PGU** must reach 95 % of the pre-disruption power in a time of less than 1 s when the voltage reaches or exceeds 0,85 p.u. and must reach pre-disruption power in an additional time of less than 2 s.

- If the U_{res} in terminals of the **PGU** decreases by 0,5 p.u. but not lower by 0,2 p.u., the **PGU** must reach 95% of the power before the disturbance in a time less than 2 s once the voltage reaches or exceeds 0,85 p.u. and must reach pre-disruption power within an additional time of less than 2 s.

- If the U_{res} in terminals of the **PGU** is reduced by 0,2 p.u., the **PGU** must reach 95% of the power before the disturbance in a time less than 3 s once the voltage reaches or exceeds 0,85 p.u. and must reach pre-disruption power within an additional time of less than 2 s.

For the purpose of the assessment of this technical requirement, the pre-fault active power shall be taken as a reference. In the case that the active power after the fault is oscillatory, the trend line of the non-oscillatory component of the active power after fault clearance shall be taken as a reference, consistent with [2]. For the purpose of determining the response times, the time corresponding to an active power 5% of the P_{max} lower than the value of the active power prior to the fault shall be considered.

In addition, a stable and well-damped active power response must be observed.

If the requirement is not met because the voltage is not recovered quickly enough, the **PGU** must be delivering at least the nominal current.

5.11.2.2.6. Criteria for the assessment of the transient overvoltage requirement

For the purpose of fulfilling this requirement, in the event that the active power response is oscillating, the trend line of the non-oscillating component of the active power after the fault is cleared shall be considered.

Additionally, there will be no undamped oscillations.

Compliance with the requirement of subsection 2.3.3 (g) of [2] shall be assessed with the voltage records indicated in the tables of subsections 5.11.2.2.2 after the fault is cleared, i.e. between t_d and t_f. In this regard, the report will reflect the information stated in **Table 53**.

5.11.2.2.7. Tests to be performed in SPGM

The **PGU** will be tested in the field, considering the operation points stated in **Table 54**:

	Recorded active power	Recorded reactive power
PARTIAL LOAD	Pmin-60% P_{max}	**Table 55** and **Table 56**
FULL LOAD	100% P_{max} (>90% in the field)	**Table 55** and **Table 56**

Table 54. Operation points prior to the PGU of SPGM test.

The **accredited entity** shall confirm that the tests have not sought a specific moment of occurrence and clearance of the short-circuit, nor a power factor of such a magnitude as to be particularly favourable to the permanence of the coupled **PGU** during the voltage dip. However, for each test, it is specified the value of the reactive power that the **PGU** must be generating or consuming.

Several voltage dips corresponding to the requirement set out in

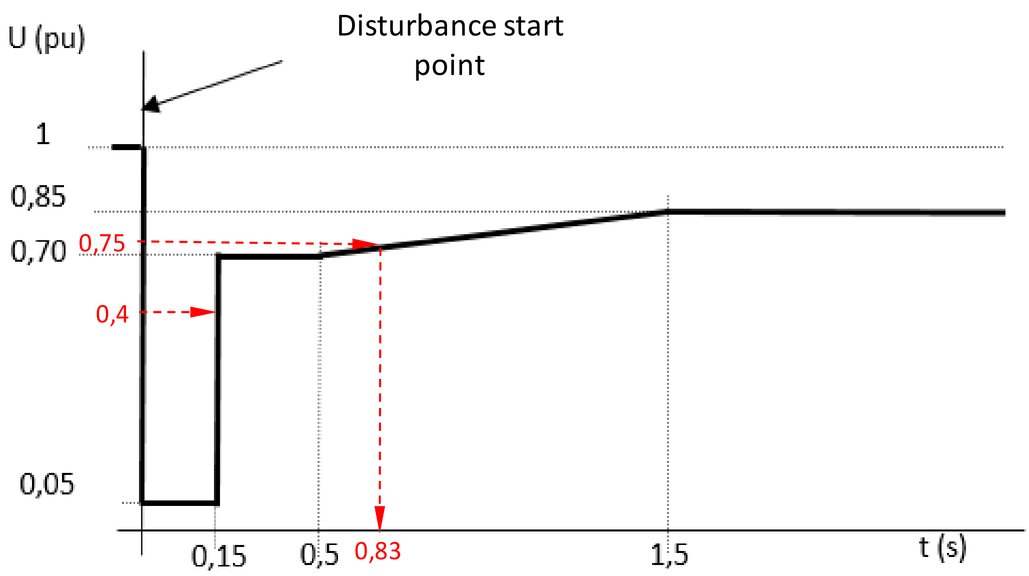


Figure 30 and **Figure 31** shall be generated and numbered according to the first column of **Table 55** and **Table 56**, “Test Type”, and must be checked later if the records indicated in the tables in subsection 5.11.2.2.2 meet the acceptance criteria. **Two consecutive tests** shall be carried out for each type (or category) of test.

Type of Test	U_{res}(p.u.)	T_f(ms)	Type of fault	Load	Q/P_{max}
$U5TP_{max}$	5%Un (±5%)	≥150	3-phase	Full	0 to ±10%
$U5TP_{med}$				Partial	0 to ±10%
$U5BP_{max}$			2-phase	Full	0 to ±10%
$U5BP_{med}$				Partial	0 to ±10%
$U40TP_{max}$	40%Un (±5%)	≥150	3-phase	Full	0 to ±10%
$U40TP_{med}$				Partial	0 to ±10%
$U40BP_{max}$			2-phase	Full	0 to ±10%
$U40BP_{med}$				Partial	0 to ±10%
$U75TP_{max}$	75%Un (±5%)	≥830	3-phase	Full	0 to ±10%
$U75TP_{med}$[19] $_{underexcited}$				Partial	Q_{min}/P_{max}
$U75TP_{med}$					0 to ±10%
$U75BP_{max}$			2-phase	Full	0 to ±10%
$U75BP_{med}$				Partial	0 to ±10%

Table 55. Tests of voltage dips to be performed for SPGM < 110 kV.

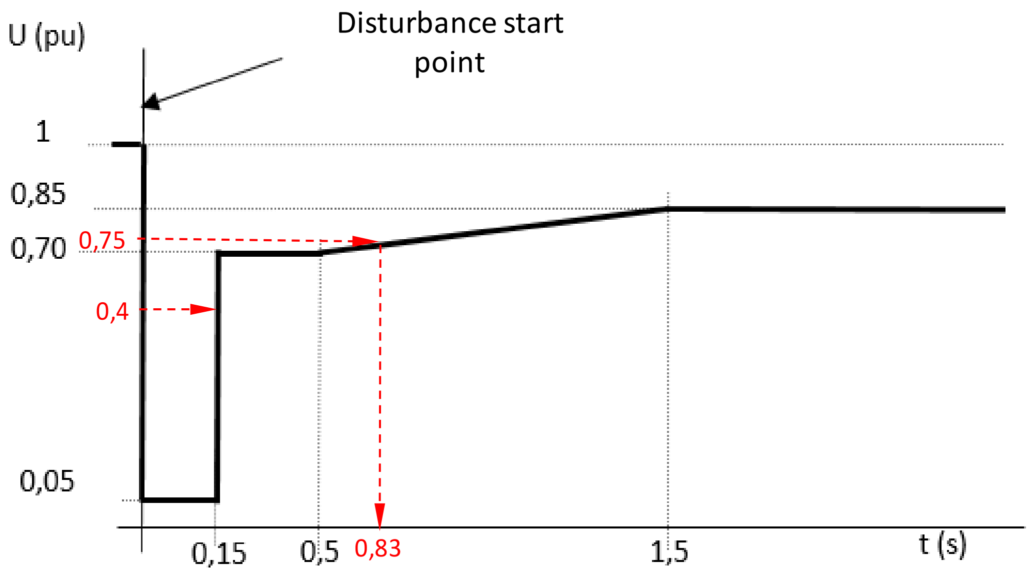


Figure 30. Profile of the fault-ride-through of an SPGM below 110kV.

[19] Q_{min} is the maximum reactive absorption capacity of the **PGU**.

Type of Test	U_{res}(p.u.)	T_f(ms)	Type of fault	Load	Q/P_{max}
$U15TP_{max}$	0%Un (±5%)	≥150	3-phase	Full	0 to ±10%
$U15TP_{med}$				Partial	0 to ±10%
$U15BP_{max}$			2-phase	Full	0 to ±10%
$U15BP_{med}$				Partial	0 to ±10%
$U25TP_{max}$	25%Un (±5%)	≥270	3-phase	Full	0 to ±10%
$U25TP_{med}$				Partial	0 to ±10%
$U25BP_{max}$			2-phase	Full	0 to ±10%
$U25BP_{med}$				Partial	0 to ±10%
$U75TP_{max}$	75%Un (±5%)	≥830	3-phase	Full	0 to ±10%
$U75TP_{med}$ underexcited				Partial	Q_{min}/P_{max}
$U75TP_{med}$					0 to ±10%
$U75BP_{max}$			2-phase	Full	0 to ±10%
$U75BP_{med}$				Partial	0 to ±10%

Table 56: Tests of voltage dips to be performed for SPGM > 110 kV.

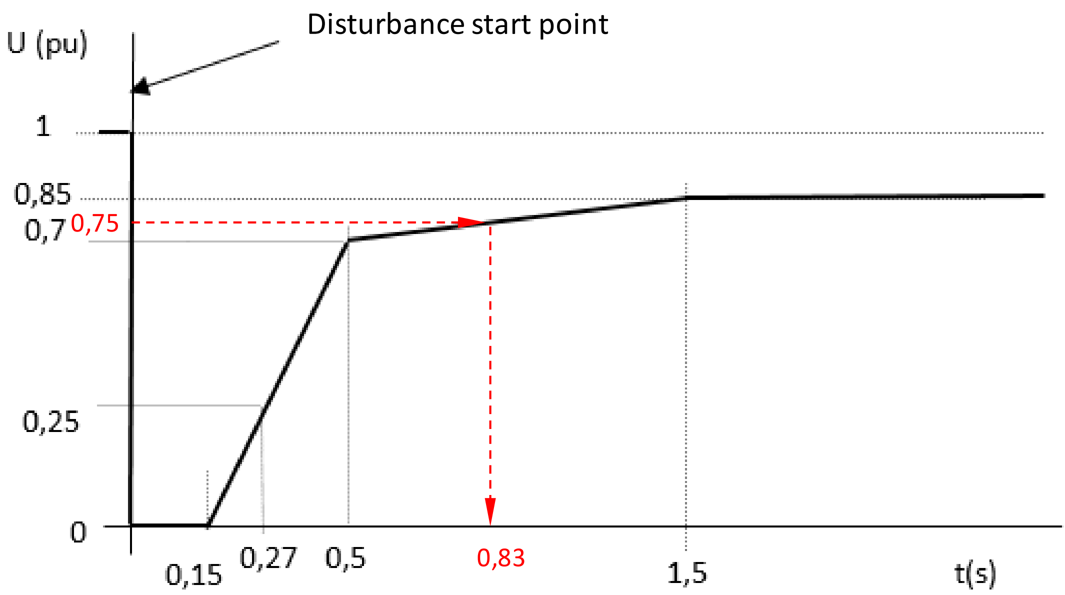


Figure 31. Profile of the fault-ride-through of a type D SPGM connected at 110 kV or above this level.

5.11.2.2.8. Documentation of SPGM tests

Analogous to the documentation generated for the **PPM** in subsection 5.11.2.2.1. Except that it will be necessary to add the load angle to the tables in subsection 5.11.2.2.2 and remove anything that is not applicable to **SPGM**: wind speed, K-factor.

5.11.2.2.9. Criteria for assessing the voltage dip requirement

Analogous to subsection 5.11.2.2.3.

5.11.2.2.10. Criteria for assessing the requirement for recovery of active power after the voltage dip

Analogous to subsection 5.11.2.2.5.

5.11.2.2.11. Criteria for the assessment of the transitional overvoltage requirement

Analogous to subsection 5.11.2.2.6.

5.11.3. Simulation method and acceptance criteria for simulations

As indicated in subsection 5.11.1, simulations will only be required to assess the behaviour of the **PGM** if the **PGU** constituting the **PGM** do not meet the robustness requirements of the tests to validate the model and require an **ACPGM** to meet them.

The simulation models of the dynamic elements of the facility (**PGU** and/or **ACPGM**) will be integrated into a simulation model of the **PGM** once their certificates have been obtained. Using this model, the **accredited entity** will perform the simulation of the **PGM** by assessing its response at BC.

In order to conduct the simulation study of the **PGM**, a tool must be used to enable the phase modelling of the components of the electrical system, since dynamic studies will be conducted in the event of balanced and unbalanced failures. Such tool must be capable of using the certified **PGU** model according to 6 without the need to perform any transformation thereof.

The topology of the electrical system to be used for the simulation and simulation methodology is specified in subsection 7.2 of this **Technical Standard**.

5.12. Black start

5.12.1. Objective

This test is applicable only to **SPGM** (or **PGU of SPGM**) with black start capability, which will provide this service.

The purpose of this test is to verify that the **SPGM (or PGU of SPGM)** is capable of starting up to a stable power, from its total disconnection without external electrical power supply, in a time of less than 15 minutes, as established in:

- Article 15.5.a of the **Regulation.**
- Article 4.2 of [2].

Pursuant to Article 45 of the **Regulation**, compliance of the **SPGM** with this requirement shall be carried out by means of tests, both at **PGU** and **SPGM** level, or by means of **equipment certificates**.

By default, the assessment of this requirement will be at the **SPGM** level.

5.12.2. Test method

This subsection details the procedure to be performed in the following sequence to assess the black start capability. The scheme of **Figure 32** is considered for the interpretation of the sequence:

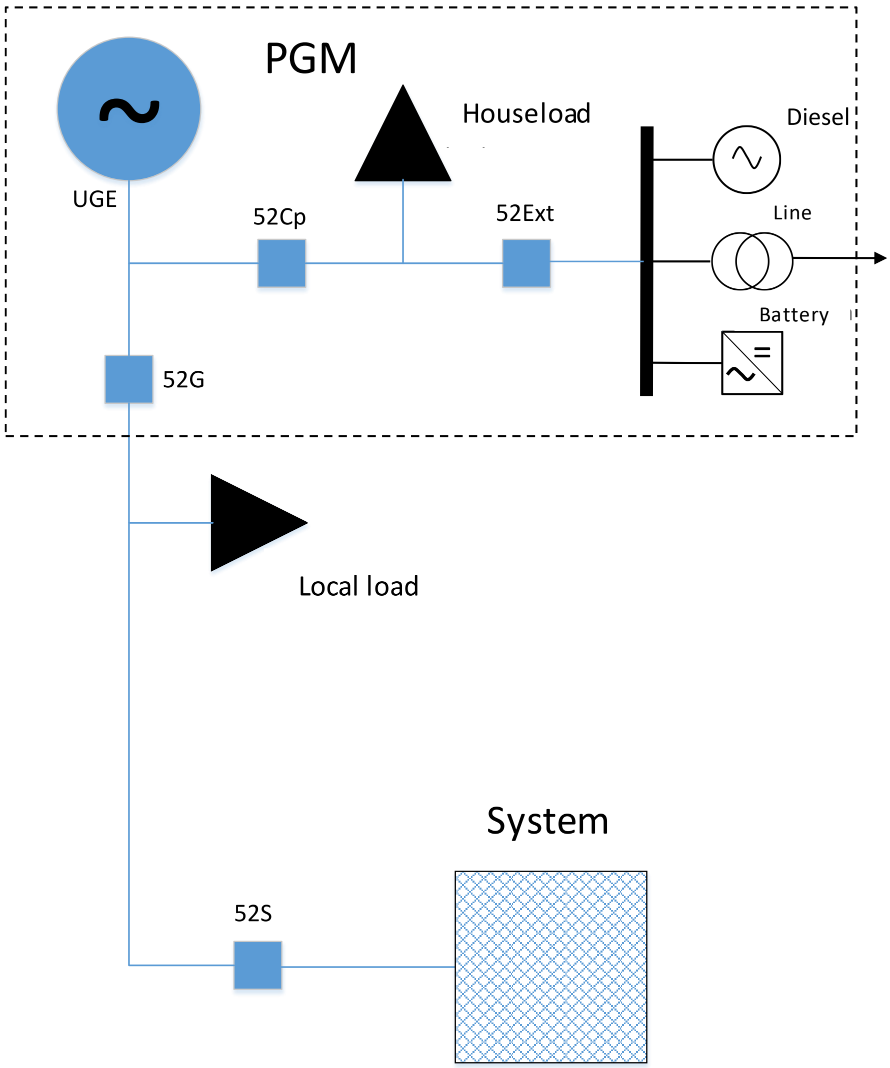


Figure 32. Black start scheme.

1. The **SPGM** will be running in load and in synchronism with the system. The 52G, 52Cp, and 52S switches are closed. The 52 Ext switch, which powers its houseloads from an auxiliary bar, which can be powered for example by: diesel engine, line, battery, etc. is open.
2. Disconnection of all **SPGM PGUs**, if any, that are not to be tested to provide this service.
3. Disconnection of the load (the 52G switch is opened) and opening of the 52Cp switch and all alternative sources that supply electrical power to the **SPGM**' houseloads.
4. Check the capacity of the **SPGM** to connect the **SPGM**' houseload. Close the 52Ext switch for powering the houseload.
5. **SPGM** startup.
6. Close the 52Cp and then close the 52G, or vice versa, according to the equipment specifications. Opening of the 52Ext.

7. Synchronization of the **SPGM** with the system without load coupling.

Once the synchronization is completed, the coupling of the load blocks will be simulated. The **RSO** will define for each **SPGM** to be provided by this service, the local load that must be capable of supplying the **SPGM** and the load blocks to be simulated.

5.12.3. Test acceptance criterion

From point 3 (**SPGM** disconnection) to point 6 (**SPGM** synchronization) of the previous subsection, less than 15 minutes must pass.

5.13. Island Operation

5.13.1. Objective

The objective is to verify that the **PGM (or PGU)** is capable of participating in island operation, **if required by the RSO in coordination with the TSO**, as set out in:

- Article 15.5.b of the **Regulation**.

Pursuant to Articles 52 and 55 of the **Regulation**, compliance of the **PGM** with this requirement must be assessed by simulation, both at **PGU** and **PGM** level, or through **equipment certificates**.

By default, the assessment of this requirement will be at the **PGM** level.

5.13.2. Simulation method

This subsection details how the island performance requirement will be assessed.

The model certified in accordance with section 6 shall be used. To carry out the simulations, the following sequence shall be considered, for which **Figure 32** must be considered.

The scenario for the simulation will be composed of the **PGM**, which is composed of the **PGU** and the load of ancillary services or houseloads, a local load external to the **PGM** and an infinite network (System) formed by multiple generators and loads. The local load therefore represents a very small portion of the total load of the System to which the **PGM** is connected. The value of the local load must be the minimum for which the **PGM** can control the frequency of the island (which will be formed when the switch 52S is opened). In the event of transient frequency excursions above the limits 47,5 Hz and 51,5 Hz, their duration must be minimized to prevent the protection system from disconnecting the **PGM** by underfrequency or overfrequency.

Two simulations shall be performed to verify the ability of the generator to operate on the island under conditions of overfrequency and underfrequency, as described in subsections 5.13.2.1 and 5.13.2.2 respectively.

5.13.2.1. Overfrequency simulation

The simulation starts with the **PGM** at an active power equal to 75% of its maximum capacity. The value of the houseload will be equal to 5% of the power generated by the **PGM** and the value of the local load will be equal to 10% of the power generated by the **PGM**. Under these conditions, the system would absorb an active power of 85% of the power generated by the **PGM** (without considering line losses).

After 100 ms, the 52S switch is opened and the **PGM** of the system is disconnected, the local load is still connected to the **PGM**. Since the 52S switch is external to the **PGM**, the **FSM, LFSM-O, and LFSM-U** control system does not receive any opening signal from this switch. The simulation must be maintained for 30 s, or until the steady state is reached, and the result must show, as a result of the demand reduction, an increase in frequency and a reduction in the active power of the **PGM**.

In the case where the active power reduction at steady-state is less than the minimum **PGM** regulation level, the local load value shall be readjusted until it reaches a steady-state active power value equal to or greater than the minimum regulating level of the **PGM**.

5.13.2.2. Underfrequency simulation

The simulation starts with the **PGM** at an active power equal to 75% of its maximum capacity. The value of the houseload will be equal to 5% of the power generated by the **PGM** and the value of the local load will be equal to the power generated by the **PGM**. Under these conditions, the system would deliver an active power of 5% of the power generated by the **PGM** (without considering line losses).

After 100 ms, the 52S switch is opened and the **PGM** of the system is disconnected, the local load is still connected to the **PGM**. Since the 52S switch is external to the **PGM**, the **FSM, LFSM-O, and LFSM-U** control system does not receive any opening signal from this switch. The simulation must be maintained for 30 s, or until the steady state is reached, and the result must show, as a result of the increase in demand, a reduction in frequency and an increase in the active power of the **PGM**.

If the active power increase exceeds the **PGM** maximum capacity value, the local load value shall be readjusted until it obtains a steady state active power value equal to or less than the **PGM** maximum capacity.

5.13.3. Simulation acceptance criteria

The requirement shall be deemed to be met if:

- For the overfrequency simulation, the simulation results show that the **PGM** reduces its active power from its initial operating point to a new operating point within the P-Q diagram without exceeding the limits set out in Article 15.5.b of the **Regulation**, nor disconnect the **PGM** from the island in case of overfrequency.
- For the underfrequency simulation, the simulation results show that the **PGM** increases its active power from its initial operating point to a new operating point within the P-Q diagram without exceeding the limits set out in Article 15.5.b of the **Regulation**, nor disconnect the **PGM** from the island in case of underfrequency.

5.14. Fast re-synchronization

5.14.1. Objective

The purpose is to verify that the **SPGM (or PGU)** is capable of quickly resynchronizing itself in the event of network disconnection as stated in:

- Article 15.5.c of the **Regulation.**
- Article 4.3 of [2].

Pursuant to Article 45 of the **Regulation**, compliance of the **SPGM** with this requirement shall be carried out by means of **tests**, both at **PGU** and **PGM** level, or by means of **equipment certificates**.

By default, the assessment of this requirement will be at the **PGM** level.

5.14.2. Test method

Specify the operation points of the **SPGM** PQ diagram before switching to houseloads.

Following the scheme of the **Figure 32** and the sequence indicated in the black start, the **SPGM** will change its operation to its houseloads. The 52G would have to be opened and the **SPGM** kept running for 4 hours. Later, if there has been no disconnection, the 52G would be shut down to check for resynchronization.

5.14.3. Test acceptance criterion

The minimum operating time without disconnection, after switching to operation based on houseloads, will be 4 hours.

After 4 hours, the resynchronization must be performed without disconnecting the **SPGM**.

6. VALIDATION OF THE SIMULATION MODEL

6.1. General aspects and purpose of model validation

The aim of a simulation model of **a PGM** is to represent its electrical characteristics with sufficient precision in a simulation computer tool.

This section describes the process of validating the models to be used in the simulations indicated in section 5, which will be necessary to obtain compliance with any technical requirements indicated in **Table 1** which shall be assessed by simulation. Therefore, it is not the purpose of this section to establish requirements or to provide guidance as to the implementation of the simulation model. The level of detail in the design shall be determined in accordance with the accuracy requirements for validation provided in this section.

As long as there is no European legislation on model validation criteria, as far as possible the provisions of [7] shall apply, which will be developed in this section with the aim of being adapted to the specificities of this **Technical Standard**. Accordingly, when [8] is published, the extent of its applicability to other non-wind **PGMs** will be analysed and this section will be updated in accordance with the drafting of this standard, if appropriate.

Generally, the use of both **RMS (root mean square)** and **EMT (electromagnetic transient)** models is considered acceptable. According to the requirement to be assessed, according to the typical frequency of each phenomenon (**Figure 33**), the manufacturer in coordination with the **accredited entities for performing the simulations** and the **authorised certifier** shall determine the suitability of using one or other type of model.

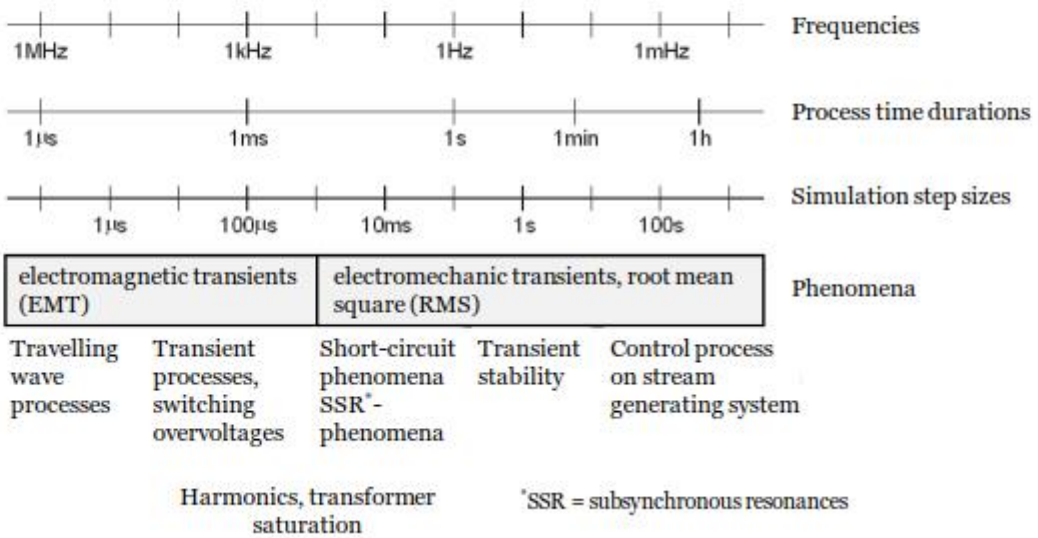


Figure 33. Type of simulation model (RMS, EMT) depending on the phenomenon to be analysed [7].

Requirements to be assessed by simulation have been stated in **Table 1**.

The simulations necessary for the assessment of the technical requirements of 5 which so require shall be performed with the computer simulation tool suitable for the assessment of the requirement and will be agreed between the simulation model sender and receiver, according to the scheme of **Figure 34**.

The validation of the simulation model of the **PGM** for the assessment of a certain technical requirement will be performed according to the scheme of **Figure 34**, i.e., the **accredited entity for carrying out simulations** shall carry out simulations consistent with the tests carried out by an **accredited entity** for carrying out tests (LAB, CA or EA), with the simulation model to be supplied by the **PGM owner** or the manufacturer (FAB). The test report and the results of the simulations consistent with these tests shall be supplied to the **authorised certifier**. If the errors resulting from the comparison between simulation and measurement, for each magnitude, are within the admissible margins specified in subsection 6.2.1.3, the **authorised certifier** shall issue a validated model certificate (Cm, according to **Figure 34**).

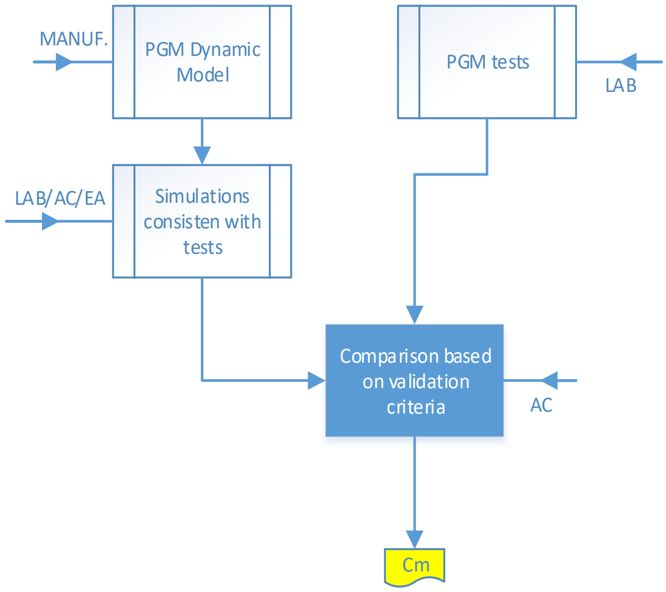


Figure 34. Model validation general scheme for simulations.

The model must be certified according to section 6 in order to perform all the simulations defined in this **Technical Standard** (**Table 1**) in a manner similar to that stated in section 3 of [7]. However, for the purpose of validation and subsequent certification, at least, it must be validated against voltage dip tests defined in subsection 5.11.2.

As regards the development of the **PGM** model, a single model must be supported that can be used to perform all the simulations defined in **Table 1** and therefore, it accurately represents all the functionalities of the **PGM** or, if applicable, different modules per functionality for each of the simulations of **Table 1**.

Since the **PGM** consists of **PGU** and **ACPGM**, the **PGM** model may be replaced by the **PGU** and/or **ACPGM** model for the simulation assessment of certain requirements, according to the pertinent subsections of section 5. Therefore, for those simulations of section 5 to be performed at the **PGU/ACPGM** level, the certified model will be used according to subsection 6.2.

Subsection 6.2.1.3 specifies the acceptance criteria of the simulation model, which will be applicable to all model characteristics.

In the event that the model used for process of assessing the technical requirements by simulation is compatible with the system operator's requirements with respect to dynamic models contained both in **procedimiento de operación 9 "Información intercambiada con el operador del sistema"(P.O.9)** and in the "**Procedimiento de puesta en servicio**" document of the **system operator**, it shall not be necessary for the **PGM owner** to provide the relevant validation report to the **TSO**, according to **P.O.9**, and certification of the model according to this **Technical Standard** shall be accepted. This aspect shall be appropriately stated in the document entitled "**Procedimiento de puesta en servicio**".

This procedure does not support cross-acceptance of the same model between different simulation tools, therefore, it is necessary to perform validation and certification of a model for each simulation tool. Differences between simulation results with different tools are not taken into account in this model certification process. Information will be requested on the format of the model in the model certificate, as although it will not normally be a model that will be requested by the **RSO** (although the authority is reserved), it is necessary to know whether the model certification process has been carried out in accordance with this **Technical Standard**.

6.2. Validation of the PGU model

6.2.1. Validation of the PGM PGU model of P_{max} less than 5 MW

This subsection describes the procedure used in section 5 of [7] for the validation of **PGU** simulation models by comparing the response of the model with the test records. As stated above, these tests will correspond to the voltage dips, and the scheme followed will be that of **Figure 35**, without prejudice to the fact that the remaining capacities of the **PGU** must be accurately represented in the **PGU** model.

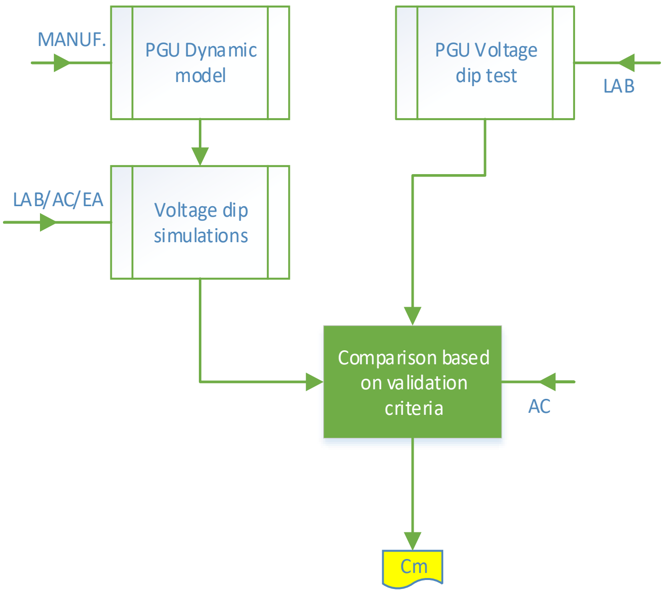


Figure 35. Model validation scheme for simulations in the event of dips.

In the case where all robustness requirements included in subsection 5.11 are fulfilled by testing, and therefore do not require compliance simulations for assessment as described in subsection 5.11.1, the certified dynamic model is allowed to be a positive sequence model. Consequently, the results for negative sequence described in subsection 6.2.1.2 would not need to be considered for model validation and certification.

6.2.1.1. Methodology

The methodology described in subsection [7] and in [8] will be adopted regardless of the type of technology of the **PGU** for the following:

- The tests must be those specified in subsection 5.11.2.2 (voltage dips) based on the **PGU** technology (of **SPGM** or **PPM**).
- In cases where repetitive tests are performed, i.e. the consecutive tests required for the voltage dip, only one of the tests must be validated.
- For **SPGM PGUs** connected below 110 kV, the provisions specified in subsection 5.1 of [7] shall apply in relation to the exception made in the consideration of the equation:

$$x_E(n) = x_{sim}(n) - x_{mea}(n)$$

The magnitudes to be reflected in the results of 6.2.1.2 are summarized below:

Validation of the model requires comparison of time series of some measured magnitudes ($x_{mea}(n)$) with time series of the same simulated magnitudes x_{sim} (n). Therefore, the time series of error $x_E(n)$ shall be calculated using this formula:

$$x_E(n) = x_{sim}(n) - x_{mea}(n)$$

According to the description of the errors in [8], three characteristics can be derived from $x_E(n)$ for each time window defined for each of the magnitudes to be considered in validation:

- Maximum error (MXE), which is mainly aimed at giving a measure of the transient behaviour of the model, but can also indicate the appearance of large errors in steady state.
- Mean error (ME) is used to define the steady state behaviour of the model, both before and after the fault.
- Absolute mean error (MAE) is used to define the steady state behaviour of the model, both before and after fault.

The mean maximum x_{MXE} in a time window with N samples is calculated as the maximum value of the absolute errors within the entire time window according to the formula:

$$x_{MXE} = \max(|x_E(1)|, |x_E(2)|, \ldots, |x_E(N)|)$$

The mean error x_{ME} in a time window is calculated as the mean value of the error within the entire time window according to the formula:

$$x_{ME} = \frac{\sum_{n=1}^{N} x_E(n)}{N}$$

The absolute mean error x_{MAE} in a time window is calculated as the mean value of the absolute error within the entire time window according to the formula:

$$x_{MAE} = \frac{\sum_{n=1}^{N} |x_E(n)|}{N}$$

6.2.1.2. Validation results

The following results shall be provided to the authorised certifier for validation of the **PGU** model of a **PPM**, both for positive and negative sequence:

- Graphs with time series of the following components:
  - Measured and simulated voltage.
  - Measured and simulated active current.
  - Measured and simulated reactive current.
  - Absolute errors of active current and reactive current.

- Tables showing the results (as specified in **Table 57**) for each of the tests indicated in **Table 49** and **Table 50**, as appropriate for the **PGU**, showing MXE, ME and MAE of the following positive sequence components: active power, reactive power, active current and reactive current before the fault, during the fault and after the fault.

Description of the test carried out, according to the name...	Time window	Active Power			Reactive Power			Active Power			Reactive Power		
		MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE
Pre-fault voltage, test name, network impedance, short-circuit impedance	pre-fault												
	fault												
	post-fault												

Table 57. Results for validation for PGU of PPM.

The following results shall be provided to the authorised certifier for validation of the **PGU** model of an **SPGM**, both for positive and negative sequence:

- Graphs with time series of the following components:
    - Measured and simulated voltage.
    - Active current measured and simulated.
    - Reactive current measured and simulated.
    - Absolute errors of active current and reactive current.

- Tables showing the results (as specified in **Table 58**) for each of the tests indicated in **Table 55** and **Table 56**, as appropriate for the **PGU**, showing MXE, ME and MAE of the following positive sequence components: active power, reactive power, active current and reactive current before the fault, during the fault and after the fault. **Table 58**, compared to the previous one, **Table 57**, has been expanded to cover the provisions for **PGU of SPGM** in [7].

Description of the test carried out, according to the name...		Time window	Power Power			Power Power			Active Power			Active Power		
			MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE
Pre-fault voltage, test name, network impedance, short-circuit impedance	According to [8]	pre-fault												
		fault												
		post-fault												
	Relative to measured	pre-fault												
		fault												
		post-fault												
	Assessment (more favourable result)	pre-fault												
		fault												
		post-fault												

Table 58. Results for validation for PGU of SPGM.

6.2.1.3. Assessment

In accordance with the above subsections, the assessment criterion of subsection 5.3 of [7] will be adopted.

For the assessment of the results obtained in subsection 6.2.1.2, for **PGU** of an **PPM**, the criteria stated in subsection 5.3.1 of [7] are taken into account in the special considerations for 2-phase faults, and **Table 59** which sets the maximum thresholds, shall be used, below which (in absolute value) must be the errors obtained in **Table 57**.

PGU of PPM	Time window	Active Power			Reactive Power			Active Current			Reactive Current		
		MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE
Eligible threshold	pre-fault	0,150	±0,100	0,120	0,150	±0,100	0,120	0,150	±0,100	0,120	0,150	±0,100	0,120
	fault	0,170	±0,150	0,170	0,170	±0,150	0,170	0,500	±0,300	0,400	0,170	±0,150	0,170
	post-fault	0,170	±0,150	0,170	0,170	±0,150	0,170	0,170	±0,150	0,170	0,170	±0,150	0,170

Table 59. Eligible limits for validation for PGU of PPM for symmetrical faults.

For the assessment of the results obtained in subsection 6.2.1.2, for **PGU** of an **SPGM**, the criteria stated in subsection 5.3.2 of [7] are taken into account, and **Table 60** which sets the maximum thresholds, shall be used, below which (in absolute value) must be the errors obtained in **Table 57**.

PGU of SPGM:	Time window	Active Power			Reactive Power			Active Current			Reactive Current		
		MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE	MXE	ME	MAE
Eligible threshold	pre-fault	0,150	±0,100	0,120	0,150	±0,100	0,120	0,150	±0,100	0,120	0,150	±0,100	0,120
	fault	0,500	±0,130	0,300	0,550	±0,280	0,380	0,700	±0,300	0,630	0,510	±0,290	0,350
	post-fault	0,500	±0,150	0,170	0,790	±0,150	0,220	0,530	±0,150	0,170	0,760	±0,170	0,220

Table 60. Eligible limits for validation for PGU of SPGM for symmetrical faults.

6.2.2. Validation of the PGU of SPGM model of P_{max} 5 MW or higher

For **SPGM** consisting of **PGUs** with a maximum capacity (P_{max}) greater than or equal to 5 MW, the scheme of **Figure 24** will be followed, given the technical infeasibility of performing voltage dip tests on **PGUs**. Manufacturers of **PGUs** (and **ACPGMs,** if any) shall provide a simulation model of the **PGU** to the **accredited entity** and/or **authorised certifier** to validate and certify it. This certified model will be used to perform the corresponding compliance simulations pursuant to section 5.

As indicated in the introduction to section 6, as long as there is no European legislation on validation criteria for dynamic models for **SPGM**, the procedure analogous to subsection 6.2.1 shall be performed, i.e., **PGU** tests shall be carried out which shall be necessary to compare with the model to be validated and acceptance criteria shall be established for the model.

The tests to be performed shall be those specified in Annex I of [6]. Alternatively, the **SPGM owner** may use the tests for the excitation system and speed-turbine regulator (governor) described in the applicable following international standards, as an example:

- **IEEE Std 421.2** "Guide for identification, testing, and assessment of the dynamic performance of excitation control systems".
- **NERC Reliability Guideline** – Power plant model verification and testing for synchronous machines.
- **IEEE Std 1207** "Guide for the application of turbine governing systems for hydroelectric generating units".

The validation procedure shall be as stated in Annex E.5 of [7].

6.2.3. Conditions for performing simulations

The simulation model used for the **PGM/PGU**:

- It is **recommended** to use the test network provided in subsection 7.2. If it is not used, the simulation report must specify the network used to perform the simulations and describe it in the same degree of detail as the network provided. In addition, the short-circuit power of the **NCP** node must be set to a value such that the short-circuit ratio (SCR) value is equal to 5.
- It will use the same control modes and reference values as the **PGM/PGU** in the tests of subsection 5.11.2.
- It will be initialized under the same conditions (operation point) as the **PGM/PGU** in the tests of subsection 5.11.2.

6.3. Validation of the ACPGM model

As indicated in the introduction to section 6, as long as there is no European legislation on validation criteria for dynamic models for **ACPGM**, the procedure analogous to subsection 6.2.1 shall be performed, i.e., **ACPGM** tests shall be performed and shall be necessary to compare with the model to be validated, and acceptance criteria shall be established for the model, as described below.

The tests to be performed shall be as indicated in:

- Subsection 4.6.2 for the **PPC**. Alternatively, the **PGM owner** may use the tests established in section 6 of [6] for the **PPC**.
- Subsection 4.6.1 for **STATCOM**.
- Subsection 4.6.3 for the **synchronous compensator**.
- Subsection 4.6.4 for **battery storage system**.

In both cases, and in a justified manner, the **authorised certifier** may determine the need for additional or alternative tests to those indicated above, in which case the justification shall be added as a comment on the **final PGM certificate**.

The validation procedure for the **ACPGM** simulation model shall be analogous to that set out in subsection 6.2.1.3, considering the maximum admissible thresholds for the “pre-fault” case **Table 59** for **PPM** and **Table 60** for **SPGM**. Alternatively, when the **ACPGM** is a **PPC**, the validation of the **PPC** model as specified in section 6 of [7] shall be permitted.

7. ANNEXES

7.1. PGM model certificates, other certificates and accreditation scopes

This annex has been intentionally translated into English at informative level, however it has to be considered that the **PGM certificate**, for any of the three possibilities described in subsection 7.1.1, must be provided in Spanish and using the template provided in subsection 7.1.1 in the Spanish version of this **Technical Standard**.

7.1.1. Model certificates of compliance with technical requirements

The following subsections detail the type of **PGM** model certificate of compliance with technical requirements depending on the issuing entity: **authorised installer** or **authorised certifier**.

7.1.1.1. Model certificate of compliance with technical requirements through an authorised installer

For **type A or type B PGMs certified solely by equipment certificates**, the **final PGM certificate model** issued by an **authorised installer or installation company**, which the **DSO** shall receive from the **PGM owner or its representative**, shall contain the information detailed below:

1) <u>Title of form:</u>

Certificate of **PGM** compliance in accordance with the technical requirements set out in the Technical Standard for the Monitoring of Conformity of Power Generating Modules according to EU Regulation 2016/631, issued by an authorised installer or installation company.

2) <u>Header:</u>

Date of issuance

Authorised installer or installation company identification

3) <u>Document body:</u>

File number of the Distribution System Operator [**code provided by DSO**]

Name and identification of the **PGM**

Holder:

- Name
- Address

Characteristics of the PGM:

- Significance level (A or B)
- **PPM** or **SPGM**
- Maximum capacity (kW)
- UTM coordinates
- Maximum design temperature

Characteristics of each type of **PGU** (power generating unit)

- Model
- Manufacturer
- Maximum capacity (kW) of each type
- **PGU** number of each type

Characteristics of each type of **ACPGM** (**PGM** auxiliary component)

- Model
- Manufacturer
- **ACPGM** number of each type

Network Connection Point:

- Voltage (kV)
- Facility of the System Operator to which it is connected [**data provided by the DSO**]
- UTM coordinates

Registration at:

Administrative Register of Electric Power Production Facilities (RAIPEE), if available:

- RAIPEE registration code for final **PGM** certificate
- CIL code (or CIL codes in case of different phases of the same RAIPEE)

Self-consumption facility registry, if available:

- Registration code

, complies with:

Relevant regulations:

- EU Regulation 2016/631
- Real Decreto 647/2020
- Orden Ministerial TED 749/2020

Certification scheme:

- Technical standard for monitoring conformity of power generating modules according to EU Regulation 2016/631
- Version/Date

, according to the documentation provided:

Equipment certificates: to be included in **Table 61** where applicable:

Requirement in the NTS	Certificate reference	Name of authorised certifier	PGM Type
5.1-Limited frequency sensitive mode - Overfrequency (LFSM-O)			A and B
5.11-Fault-ride-through capability of connected generators below 110 kV			B
5.11-Fault-ride-through capability of connected generators above 110 kV			B
5.11-Recovery of active power after a fault			B
5.7-Reactive power capability at maximum capacity and below the maximum capacity			B
5.11-Fast fault current injection at the connection point in case of symmetrical (3-phase) faults			B
5.8- Reactive power control modes			B

Table 61. Final PGM certificate model – authorised installer.

Annexes:

- **PGU** and **ACPGM** certificates issued by an authorised certifier.
- Certificate of inspection of the additional protection system, at high voltage, issued by an **Authorised inspection body.**

The language in which the final **PGM** certificate will be issued shall be Spanish.

In the event that the **DSO** requests any additional information, e.g. **PGU**, **ACPGM** or model certificates, this information must be delivered preferably in Spanish or, in the absence of such information, in English.

7.1.1.2. Model certificate of compliance with technical requirements through an authorised certifier

The **final PGM certificate** model issued by an **authorised certifier,** which the **RSO** shall receive from the PGM owner**,** shall contain at least the information detailed below (any additional information shall be provided in the Annexes) and according to the structure set out, with the aim of standardising the format for easier review.

The language in which the final **PGM** certificate will be issued shall be Spanish.

If the **RSO** requests any additional information, such as **PGU**, **ACPGM** or model certificates, this information must be delivered preferably in Spanish, or, in the absence thereof, in English or any other language agreed between the **RSO** and the **PGM owner**.

The content of the **PGM final certificate** issued by a **certifier** must include the following points:

1) **Header:**

Power generating module (**PGM**) final certificate number

Date of issue

Accreditation Mark, including Accreditation no.

Certification Body logo

2) Title:

Certificate of compliance [**No.**] of **PGM** in accordance with the technical requirements established in [**Rules**]

3) Document body:

The certification body [name] certifies that the following **PGM**:

File number of the System Operator [**code**]

Name and identification of the **PGM**

Holding company:

- Name
- Address

Characteristics of the PGM:

- Significance level (B, C or D)
- **PPM** or **SPGM**
- Maximum capacity (MW)
- Maximum design temperature

Characteristics of each type of **PGU** (power generating unit)

- Model
- Manufacturer
- Characteristics defining the **PGU** unambiguously
- Number of **PGUs** of each type and Maximum Capacity (MW)

Characteristics of each type of **ACPGM** (**PGM** auxiliary component)

- Model
- Manufacturer
- Characteristics that uniquely define the **ACPGM**
- **ACPGM** number of each type

Network Connection Point:

- Voltage (kV)
- Facility of the System Operator to which it is connected
- UTM coordinates

Location of the **PGM**:

- Location description
- UTM coordinates

Registration at:

Registro Administrativo de Instalaciones de Producción de Energía Eléctrica (RAIPEE):

- RAIPEE pre-registration code for final **PGM** certificate
- CIL code (or CIL codes in case of different phases of the same RAIPEE)

Self-Consumption Facility Registry

- Registration code

, complies with:

Relevant regulations:

- EU Regulation 2016/631
- Real Decreto 647/2020
- Orden Ministerial TED 749/2020

Certification scheme:

- Compliance monitoring technical standard approved by the GTSUP
- Version/Date

, according to the documentation provided:

Equipment certificates: to be included in **Table 62** where applicable:

CERTIFICATION OF THE TECHNICAL REQUIREMENT				TYPE OF ASSESSMENT	
Requirement in the NTS	Certificate reference	Issuing Entity Name	No obligation to comply (mark with X, if applicable)	PPM	SPGM
5.1-Limited Frequency Sensitive Mode - Overfrequency (LFSM-O)				(S and T) or C**	(S and T) or C**
5.5-Control capability and remote active power control range				T or C	N/A
5.3-Frequency Sensitive Mode (FSM)				(S and T) or C**	(S and T) or C**
5.2- Limited Frequency Sensitive Mode - Underfrequency (LFSM-U)				(S and T) or C**	(S and T) or C**
5.6-Synthetic inertia during very rapid frequency variations*				S	N/A
5.11-Fault-ride-through capability of connected generators below 110 kV				T (S***) or C**	T (S***) or C**
5.11-Fault-ride-through capability of connected generators above 110 kV				T (S***) or C**C	T (S***) or C**
5.11-Recovery of active power after a fault				T (S***) or C**	T (S***) or C**
5.12-Black start*				N/A	T or C
5.13-Capability to take part in island operation*				S or C	S or C
5.14-Fast re-synchronization capability				N/A	T or C
5.7-Reactive power capability at maximum capacity and below the maximum capacity				(T) or C**	(T) or C**
5.11-Fast fault current injection at the connection point in case of symmetrical (3-phase) faults				T (S***) or C**	N/A
5.8- Reactive power control modes				T or C**	N/A

Table 62. Final PGM certificate model – authorised certifier.

Legend:

- In column "Type of Assessment": **S** means compliance simulation, **T** means compliance test, **C** means equipment certificate and **N/A** does not apply.
- *: Requirement not mandatory according to [1], [2] and [3].
- **: It may require the performance of **supplementary simulations** for assessment purposes, as described in the relevant section of this **Technical Standard**.
- ***: In the cases specified in T (S***), the test will be performed in **PGU** and, if it is unsuccessful, the simulation of the complete **PGM** shall be performed, incorporating the **ACPGM** enabling the pertinent requirement to be met.

Dynamic models: the following shall be indicated for each of the dynamic models used in the certification of each requirement.

- Certified model:
    - Certification reference or number
    - Issuing entity
    - Format (Name of the simulation tool used)

- Model used for carrying out supplementary simulations:
    - Companies that have carried out the supplementary simulations
    - Model developer
    - Format (Name of the simulation tool used)

If the following documentation has been used, please provide references:

- Exceptions
- Technical justifications for non-compliance issued by the **RSO**
- Written in accordance with the **RSO**

Certification of maximum reactive power capability requirement at P_{max} and below P_{max}: option followed for certification.

- General procedure (subsection 5.7.3.1)
- Case A special procedure (subsection 5.7.3.2, Case A)
- Case B special procedure (subsection 5.7.3.2, Case B)

Certification of each of the following points regarding the compatibility of the settings of the voltage and frequency relays of the **PGM**:

- Frequency and time settings compatible with the established in Table 1 of article 1.1 of [2].
- Voltage and time settings compatible with the established in Table 2 and in Table 3 of article 2.1.1 of [2].
- Combined voltage, frequency, and time compatibles with Figure 1 and Figure 2 of article 1.1 of [2].
- Combined voltage and time settings compatible with the corresponding **PGM** fault ride through profile as specified in article 3.1.1 of [2].
- Combined voltage and time settings compatible with the corresponding **PGM** transient overvoltage settings, as specified in articles 3.2.3 and 3.3.3 of [2].

Requirements not met (specified in the table):
    - Exception justifying non-compliance (document reference)

4) <u>Certificate completion:</u>

Comments.

Signature

- City, [Day] of [Month] of [Year]
- [Name and surname of the **authorised certifier/authorised certifiers**]

5) **Annexes:**

For the **authorised certifier**.

The format of the **PGU** and **ACPGM equipment certificate** models shall be agreed between subjects exchanging test reports and simulations and **equipment certificates**: **accredited entity** for tests and/or simulations, laboratories, **authorised certifier**, manufacturer or **PGM owner**. By default, a structure similar to that specified for the **final PGM certificate** will be used.

7.1.2. Reduced final PGM certificate

This annex details the compliance monitoring process for **PGMs** resulting from the application of the fourth transitional provision of [3] and voluntarily opt to provide a **reduced final PGM certificate** alternative to the **final PGM certificate**. Additionally, the requirements that **a PGM** can voluntarily certify are detailed.

7.1.2.1. Compliance assessment procedure

Under the fourth transitional provision of [3], **PGMs** commissioned up to 8 January 2021 are exempt from meeting the technical requirements for network connection developed in [2]. However, the fourth transitional provision of [2] specifies that these **PGMs** must comply with:

- The technical requirements fully defined in the **Regulation**, i.e. those requirements required by *(EU) Regulation 2016/631 of 14 April 2016 (...) whose application does not require, as established in those Regulations, the subsequent development or implementation by each Member State because they are fully defined therein, and are therefore directly applicable [1]*.
- If the requirements of [2] are not met, they must comply with the equivalent requirement of the current regulations, applicable to existing facilities under the **Regulation**.

Table 63 specifies the requirements to be assessed and their assessment method(s) for obtaining the **reduced final PGM certificate**, as well as the relevant Articles of the **Regulation**:

REQUIREMENT			TYPE OF ASSESSMENT	
Article of Regulation	**Definition of Requirement**	**PGM Type**	**PPM**	**SPGM**
13.2	LFSM-O control capability	≥A	According to NTS 5.1 with reduced requirements	
15.2.c	LFSM-U control capability	≥C	According to NTS 5.2 with reduced requirements	
15.2.d	FSM control capability	≥C	According to NTS 5.3 with reduced requirements	
21.3.d	Reactive power control modes:	≥C	According to NTS 5.8 with reduced requirements	N/A
21.3.f	Ability of not adversely affect the damping of power oscillations	≥C	According to NTS 5.10	N/A

Table 63. Regulation requirements to be assessed.

Legend:

- In the column "**PGM** Type", the text **≥A** means that it applies to **PGM** Types A, B, C and D. The same applies to the rest. In column "Type of Assessment": **N/A** means not applicable.

To assess compliance with the technical requirements of Table 63, the complete certification process detailed in section 4 of this **Technical Standard** must be followed.

If the **PGM** owner voluntarily opts to assess compliance with certain requirements of [2], it must submit the certificates obtained according to the process defined in Table 64.

REQUIREMENT				TYPE OF ASSESSMENT	
Article of Regulation	Definition of Requirement	PGM Type	NTS subsection	PPM	SPGM
15.2.(a) and (b)	Remote power control capability and range	≥C	5.5	Tor C	N/A
15.2.e	Power-frequency control	≥C	5.4	T	T
21.2	Synthetic inertia during very rapid frequency variations *	≥C	5.6	S	N/A
17.3	Recovery of active power after a fault	≥B	5.11	N/A	T (S***) or C**
14.3	Fault-ride-through capability of synchronous generators connected below 110 kV	≥B	5.11	N/A	T (S***) or C**
16.3	Fault-ride-through capability of synchronous generators connected at nominal voltage of 110 kV or higher	D	5.11	N/A	T (S***) or C**
20.3	Recovery of active power after a fault	≥B	5.11	T (S***) or C**	N/A
14.3	Fault-ride-through capability of PPMs connected below 110 kV	≥B	5.11	T (S***) or C**	N/A
16.3	Fault-ride-through capability of PPMs connected at nominal voltage of 110 kV or higher	D	5.11	T (S***) or C**	N/A
15.5.a	Black start	≥C	5.12	N/A	T or C
15.5.b	Capability to take part in island operation*	≥C	5.13	S or C	S or C
15.5.c	Fast re-synchronisation capability	≥C	5.14	N/A	T or C
18.2.b	Reactive power capability at maximum capacity	≥B	5.7	N/A	(T) or C**
18.2.c	Reactive power capability below maximum capacity	≥B	5.7	N/A	(T) or C**
19.2	Power oscillation damping control	D****	5.9	N/A	S or C
20.2.b and 20.2.c	Fast fault current injection at the connection point in case of symmetrical (3-phase) faults	≥B	5.11	T (S***) or C**	N/A
21.3. b	Reactive power capability at maximum capacity	≥B	5.7	(T) or C**	N/A
21.3.c	Reactive power capability below maximum capacity	≥B	5.7	(T) or C**	N/A

Table 64. Requirements of the voluntary certification process.

Legend:

- In the column "**PGM** Type", the text **≥A** means that it applies to **PGM** Types A, B, C and D. The same applies to the rest. In column "Type of Assessment": **S** means compliance simulation, **T** means compliance test, **C** means equipment certificate and **N/A** does not apply.
- *: Requirement not mandatory according to [1], [2] and [3].
- **: **Supplementary simulations** may be required for assessment purposes, as described in the pertinent subsection of this **Technical Standard**.
- ***: In the cases specified in T (S***), the test will be performed in **PGU** and, if it is unsuccessful, the simulation of the complete **PGM** shall be performed, incorporating the **ACPGM** enabling the pertinent requirement to be met.
- ****: Applicable to **SPGM** type D and P_{max}>50 MW

If **a PGM** fails to meet the voltage dip requirement as defined in [2], the **PGM** must follow the process detailed in subsection 7.1.2.2.6.

Figure 36 indicates the **PGM** certification process to be followed based on the commissioning date. In addition, the requirements to be assessed for obtaining the **reduced final PGM**

certificate and any requirements that can be voluntarily certified according to this **Technical Standard** are detailed.

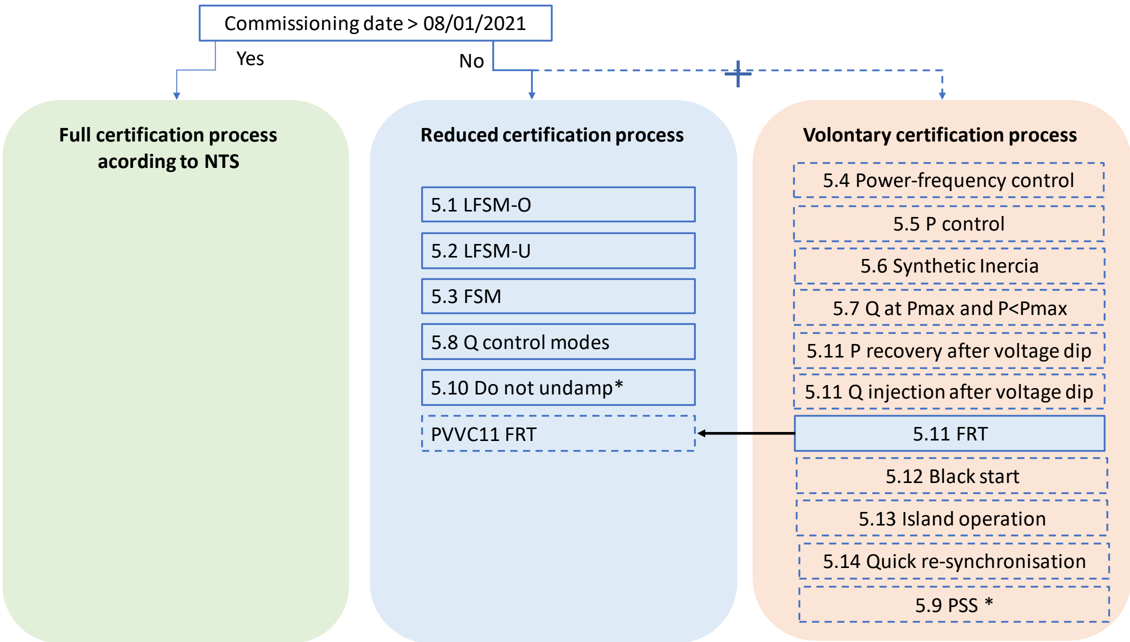


Figure 36. Certification processes according to commissioning date.

Legend:
* Compliance with the oscillation damping requirements will be assessed by the **TSO**, who will issue a written statement in accordance with the owner, which will not be part of the final **PGM** certificate, but which will be required to obtain the FON.

7.1.2.2. Test and simulation methodology for the assessment of technical requirements

This part details each requirement to be assessed according to the reduced certification process.
The compliance simulations detailed below shall be performed using a certified model and in accordance with section 6 of this **Technical Standard**, taking into account that the tests performed they may correspond to those specified in [4].

7.1.2.2.1. Power-frequency-limited-overfrequency (LFSM-O) regulation mode

The aim is to verify that the **PGM** is capable of activating the supply of power-frequency control reserves as indicated in Article 13.2 of the **Regulation**.

In accordance with Article 13.2(c) and (d) of the **Regulation**, the **LFSM-O** of the **PGM** must be capable of being activated from a frequency threshold between 50,2 Hz and 50,5 Hz, with a droop adjustment between 2% and 12%.

Furthermore, under Article 13.2(e) of the **Regulation**, if the activation time of the **LFSM-O** (t_a as defined in this **Technical Standard**) exceeds 2 s, the **PGM owner** shall provide the **TSO** with technical evidence justifying that value.

The assessment of this requirement will be performed according to the process defined in subsection 5.1 of this **Technical Standard**.

However, the acceptance criteria linked to the response dynamics, and in particular to the rise time t_r and the settling time t_e, are not defined in the **Regulation**. In other words, the assessment of compliance with the **LFSM-O** requirement will not have any judgement about the t_r and t_e times, but it is recommended that these times be detailed in the tables provided for this purpose.

It is also recommended to detail the final settings of the activation frequency threshold and droop.

7.1.2.2.2. Power-frequency-limited-underfrequency (LFSM-U) regulation mode

The aim is to verify that the **PGM** is capable of activating the supply of power-frequency regulation reserves as indicated in Article 15.2.c of the **Regulation**.

In accordance with the **Regulation**, the **LFSM-U** of the **PGM** must be capable of being activated from a frequency threshold between 49,5 Hz and 49,8 Hz and with a droop adjustment between 2% and 12%.

In addition, if the activation time of the **LFSM-U** (t_a as defined in the NTS) exceeds 2 s, the **PGM owner** must provide technical evidence to justify this value to the **TSO**.

The assessment of this requirement will be performed according to the process defined in subsection 5.2 of this **Technical Standard**.

However, the acceptance criteria linked to the response dynamics, and in particular to the rise time t_r and the settling time t_e, are not defined in the **Regulation**. In other words, the assessment of compliance with the **LFSM-U** requirement will not have any judgement about the t_r and t_e times, but it is recommended that these times be detailed in the tables provided for this purpose.
It is also recommended to detail the final settings of the activation frequency threshold and droop.

7.1.2.2.3. Frequency power adjustment mode (FSM)

The aim is to verify that the **PGM** is capable of activating the supply of power-frequency control reserves as indicated in Article 15.2.d of the **Regulation**.

As stated in the Regulation, the **PPM FSM** must be capable of activating with a parameter setting within the ranges defined in Table 65.

Parameters		Ranges
Active power interval in relation to maximum capacity	$\|\Delta P_1\|/P_{max}$	1,5-10 %
Response insensitivity with frequency variation	$\|\Delta f_1\|$	10-30 mHz
	$\|\Delta f_1\|/f_n$	0,02-0,06 %
Response deadband with frequency variation equal to 50 mHz.		0-500 mHz
Droop	S_1	2-12 %

Table 65. FSM mode parameters.

In addition, if the activation time of the **FSM** (t_1 as defined in the Regulation) exceeds 2 s, the **PGM owner** shall provide technical evidence to justify this value to the **TSO**.

In order to simplify the assessment of this requirement, it will be performed according to the process defined in subsection 5.3 of this **Technical Standard**.

However, the acceptance criterion linked to the response dynamics and in particular the rise time t_1 in the case of non-inertia **PGMs** is not defined in the **Regulation**. In other words, the assessment of compliance with the **FSM** requirement will not be based on the time t_1 in the case of **PGM** without inertia, but it is recommended that this time be detailed in the tables provided for this purpose.

It is also recommended to detail the final settings of the remaining parameters of **Table 64**.

7.1.2.2.4. Reactive power control modes in PPM

The aim is to verify that the **PPM** is capable of controlling the reactive power in accordance with Article 21.3.d of the **Regulation**.

According to the **Regulation**, the **PPM** must be capable of automatically providing reactive power through a voltage control mode (a), a reactive power control mode (b) and a power factor control mode (c).

If the **PGM** fails to comply with the reactive power capability requirement [2], the **PGM** must be capable of generating the reactive power corresponding to a power factor up to 0,98 inductive and 0,98 capacitive according to [10].

a. Voltage control

With respect to the voltage control mode, the setpoint voltage may be in the range between 0,95 p.u. and 1,05 p.u. and the slope may be in the range between 2% and 7%.
The assessment of this requirement will be performed according to the process defined in subsection 5.8 of this **Technical Standard**. However, the acceptance criteria related to the voltage control mode response dynamics shall be as follows as defined in the **Regulation**:

- Time to reach 90% of reactive power variation t_1 within the range 1 s - 5 s.
- Settling time t_2 within the range 5 s - 60 s.

It is also recommended to detail the final setpoint voltage and slope voltage settings.

b. Reactive power control

The assessment of this requirement will be conducted according to the process defined in subsection 5.8 of this **Technical Standard**. However, the acceptance criterion linked to the response dynamic is not defined in the **Regulation**. In other words, the compliance assessment will have no response time criterion.

c. Power factor control

The assessment of this requirement shall be performed according to the process defined in subsection 5.8 of this **Technical Standard** limited to power factor setpoint values of between 0,98 inductive and 0,98 capacitive, as defined in [10]. However, the acceptance criterion linked to the response dynamic is not defined in the **Regulation**. In other words, the compliance assessment will have no response time criterion.

7.1.2.2.5. Ability not to contribute negatively to power oscillation damping

The objective is to verify that, as indicated in Article 21.3.f of the **Regulation**, the voltage control characteristics and reactive power of the **PPM** do not have adverse effects on power oscillation damping.

The assessment of this requirement will be performed according to the process defined in subsection 5.10 of this **Technical Standard**.

7.1.2.2.6. Fault-ride-through

With regard to the capacity of generators to withstand voltage dips, pursuant to the fourth transitional provision of [3], **PGMs** that do not comply with the requirement developed in [2] must submit the certificate of compliance with the requirements of [11] according to the process detailed in [4].
Otherwise, the assessment of the voltage dip requirement will be assessed according to the process defined in subsection 5.11 of this **Technical Standard**.

7.1.2.3. Reduced certified model

As detailed in 7.1.1.

7.1.3. Scopes of accreditation

In order to ensure that the **accredited entities for carrying out tests and simulations**, or the **authorised certifiers**, are accredited in the activities required by this **Technical Standard**, It is necessary that in its scope of accreditation in addition to being referenced this own **Technical Standard** (if the version is not included, the accrediting entity shall be deemed to have implemented a flexible scope accreditation system, so the entity shall be accredited for the current version) the activities covered by the accreditation are fully reflected, taking into account the following aspects:

- **<u>Entities accredited to carry out tests and simulations according to ISO/IEC 17025</u>**

In the scopes of accreditation, the name of the tests (trials) and/or simulations should be explicitly stated (e.g. power-frequency-limited-super-frequency test, power-frequency-limited-underfrequency simulation, **PGU** model validation simulations , etc.) for those that the laboratory has been accredited, except in the case that all those established in this document are performed, as well as the product (photovoltaic inverters, wind turbines, PPCs, wind turbine models, etc.) subject to the test or simulation.

- **<u>Authorised certifier according to ISO/IEC 17065</u>**

In the scopes of accreditation, the type of product (photovoltaic inverter, wind turbine model validation, wind farm module, etc.) certified should be explicitly stated, together with the assessment activities (testing, simulation, certification, etc.) on which such certification is based in any cases in which this document permits certification based on different assessment activities.

7.1.4. Certificate equivalence tables

7.1.4.1. Equivalence between NTS and NTS SENP certificates

Table 66 is a help table showing the certificate equivalences between the current versions of **NTS SEPE** and **NTS SENP**. The **authorised certifier** shall be responsible for verifying the validity of the certificate equivalence of each of the requirements of **Table 66** and for making it appear in the **final PGM certificate**.

NTS subsection	Definition of Requirement	NTS SEPE	NTS SENP
5.1	Limited Frequency Sensitive Mode- Overfrequency (LFSM-O)	Certificate according to NTS SENP accepted, provided that such certificate certifies compliance with the optional acceptance criteria (t_r and t_e) detailed in 5.1.2.2 of NTS SENP.	Certificate according to NTS SEPE accepted, provided that such certificate certifies compliance with the following requirements: • t_a ≤0,3s for **PGM** with inertia • t_a ≤0,15s for **PGM** without inertia
5.2	Limited Frequency Sensitive Mode- Underfrequency (LFSM-U)	Certificate according to NTS SENP accepted, provided that such certificate certifies compliance with the optional acceptance criteria (t_r and t_e) detailed in 5.2.2.2 of NTS SENP.	Certificate according to NTS SEPE accepted, provided that such certificate certifies compliance with the following requirements: • t_a ≤0,3s for **PGM** with inertia • t_a ≤0,15s for **PGM** without inertia
5.3	Frequency Sensitive Mode (FSM)	Certificate according to NTS SENP accepted, provided that such certificate certifies compliance with the optional test (no deadband and with insensitivity >10mHz) detailed in 5.3.2.1 of the NTS SENP	**Certificate according to NTS SEPE not sufficient**
5.5	Remote power control capability and range	Certificate equivalence according to both Technical Standards	
5.6	Synthetic inertia during very fast frequency variations	Certificate equivalence according to both Technical Standards	
5.7	Reactive Power Capability	**Certificate according to NTS SENP not sufficient**	Certificate according to accepted NTS SEPE
5.8	Reactive power control modes	**Certificate according to NTS SENP not sufficient**	Certificate according to NTS SEPE accepted, provided that such certificate certifies compliance with the voltage control test with deadband detailed in Table 27 of subsection 5.8.2.1.1 of the NTS SENP.
5.9	Power oscillation damping control	Certificate equivalence according to both Technical Standards	
5.10	Oscillation damping control	Certificate equivalence according to both Technical Standards	
5.11	Fault-ride-through capability	Certificate according to NTS SENP accepted, provided that such certificate certifies compliance with the requirement with a 75%Un dip test of a duration greater than 1340ms	**Certificate according to NTS SEPE not sufficient**
5.11	Fast Fault Current Injection	Certificate according to accepted NTS SENP	**Certificate according to NTS SEPE not sufficient**
5.11	Capacity to support transient overvoltage at **PPMs**	Certificate according to accepted NTS SENP	**Certificate according to NTS SEPE not sufficient**
5.11	Recovery of active power after a fault	**Certificate according to NTS SENP not sufficient**	N/A

Table 66. Requirement certificate equivalences between NTS and NTS SENP.

7.1.4.2. Equivalence of PGM certificates by requirement between NTS versions

Table 67 shows the possibilities that the **PGM certificate** of a particular technical requirement, issued under the previous version (v2.0) of this **Technical Standard**, can be used for **PGM** certification under the present version (v2.1) of this **Technical Standard**. In the column "PGM certificates supported for NTS v2.1" it is indicated, for each requirement, whether only the **PGM certificate** of version 2.1 is valid, or whether the **PGM certificate** of version 2.0 is also valid.

NTS Subsection	Definition of Requirement	PGM type	PGM certificates supported for NTS v2.1
5.1	Limited Frequency Sensitive Mode - Overfrequency (LFSM-O)	≥A	≥ v2.0
5.2	Limited Frequency Sensitive Mode - Underfrequency (LFSM-U)	≥C	≥ v2.0
5.3	Frequency Sensitive Mode (FSM)	≥C	≥ v2.0
5.5	Remote power control capability and range	≥C	≥ v2.0
5.7	Reactive Power Capability at Pmax and under Pmax	≥B	**v2.1**
5.8	Reactive power control modes	≥B	**v2.1**
5.11	Recovery of active power after a fault	≥B	≥ v2.0
5.11	Fault-ride-through capability	≥B	≥ v2.0
5.11	Fast Fault Current Injection at NCP in case of faults	≥B	≥ v2.0
5.11	Capacity to support transient overvoltage after a fault	≥B	≥ v2.0
5.12	Blackstart capability	≥C	≥ v2.0
5.13	Island operation capability	≥C	≥ v2.0
5.14	Fast re-synchronization capability	≥C	≥ v2.0

Table 67. Equivalence of PGM certificates by requirement between NTS versions.

As an example, the interpretation of Table **67** should be as follows:

- **PGM certificate** for requirement 5.2 issued under version 2.0 **is valid** to be used for **PGM** certification under version 2.1.
- **PGM certificate** for requirement 5.7 issued under version 2.0 **is not valid** to be used for **PGM** certification under version 2.1.

In the case where the **PGM** certificate of a requirement issued under the previous version of this Technical Standard is used, the authorised certifier is responsible for verifying the validity of this certificate and stating this in the final **PGM** certificate.

7.1.5. Minimum contents of the Protection review report for PGM connected to the distribution network

The contents of the **Protection review report**[20] for those **PGM** connected to the distribution network is the next:

- **PGM data:**
  - DSO File code
  - Installation name and location.
  - Installed power, Authorised generation power in MVA) and Capacity granted in access and connection permits (MW).
  - Network Nominal voltage (kV).
  - Owner and contact person (name and address).
  - High voltage installation company.
  - Engineering company drawing up the executive project.

- Identification of the **Authorised inspection body** in high voltage, both in transformer stations and substations that carries out the report.

- Connection point type and identification (Substation, Feeder or Line, Secondary Substation or Switching Substation)

- **Additional protections:**
  - Reference to “*Acuerdo sobre ajustes de los sistemas de protección y control adecuados al punto de conexión entre el gestor de red pertinente y el propietario de la instalación de generación de electricidad*” [3] and/or, where applicable, distribution company regulation containing the description of protection and settings to be verified.
  - As a minimum, on-site testing of all additional protections and their evaluation must be included, indicating:
    - The setting parameters of each protection function.
    - The test result of the test, indicating at least for a given test value the response time of each protection function.
    - The circuit breaker on which the current and voltage protections, including interlocks, operate.

- **Measurement equipment**: The verification of the measuring equipment, its accuracy class characteristics (voltage and current transformers) must be stated.

- **Protection relays:**
  - Brand
  - Model
  - Serial number

- **Annexes:**

[20] The scope of this report is specified in the definition of “Protection review report” in section 4 of this **Technical Standard**.

- Evidence of "*Acuerdo sobre ajustes de los sistemas de protección y control adecuados al punto de conexión entre el gestor de red pertinente y el propietario de la instalación de generación de electricidad*".
- Protection settings file for the relay or protection relays at the NCP.
- Functional three-wire diagram of the protection system including:
    - Interconnection switch opening and closing control.
    - Voltage and current transformer connections.
    - Power supply, control and command circuits of the protection system (relays and switch).

- In addition, it is advisable to include:
    - Data/photos of transformer and generators nameplates.
    - Photos of the installation:
        - Panoramic view of the system.
        - Details of the connection point breaker.
        - Detail of the protection relay(s), sealing the front access to the relay settings configuration

7.2. Electric network equivalent to the Peninsular Electricity System and the Interconnected European System for simulation

For the performance of compliance simulations related to subsection 5.11, related to robustness requirements, the remainder of the electric network that does not belong to the **PGM** being studied shall be modelled in such a way that clearing the fault at the network connection point reproduces the normal voltage profile of the specific power system. Such profile shall be considered fixed and independent of the geographical location of the **PGM** under study within the specific subsystem. To simulate the equivalent electric network, it is recommended to use the dynamic system provided below.

A dynamic system consisting of an equivalent node of the electrical system (EQ_SISTEMA node) in which an equivalent **PGM**, GEN_EQ, is evacuated shall be considered through an equivalent machine transformer, TFR_EQ, connected between the generation node (GEN_EQ node) and the EQ_SISTEMA node. From the EQ_SISTEMA node, a line starts up to the network connection point (Nudo **PCR**) of the **PGM** to be assessed. This line represents the transmission grid.

The "Nudo PCR" ("**NCP** node" in English) will model the **PGM** to be assessed with the corresponding private network, i.e., evacuation lines and transformers if applicable.

The short-circuit power of the Nudo PCR (SccPCR) must be set to a value such that the short-circuit ratio (SCR) value is equal to 5.

Based on the SccPCR value selected, the maximum **PGM** capacity to be assessed (pMax) and the nominal Nudo PCR voltage (vBasePCR) will be determined for the remaining parameters defined in the equivalent network model. In particular, it highlights the calculation of the maximum apparent power of the **PGM** (mBaseEq) and the impedance of the transmission line (R + jX) so that the short-circuit power of the Nudo PCR is set to the set value. In this way, it is ensured that all connected **PGMs** will be simulated in the event of a disturbance of the same characteristics.

The characteristics of the elements included in the equivalent electrical network are shown in the following figure:

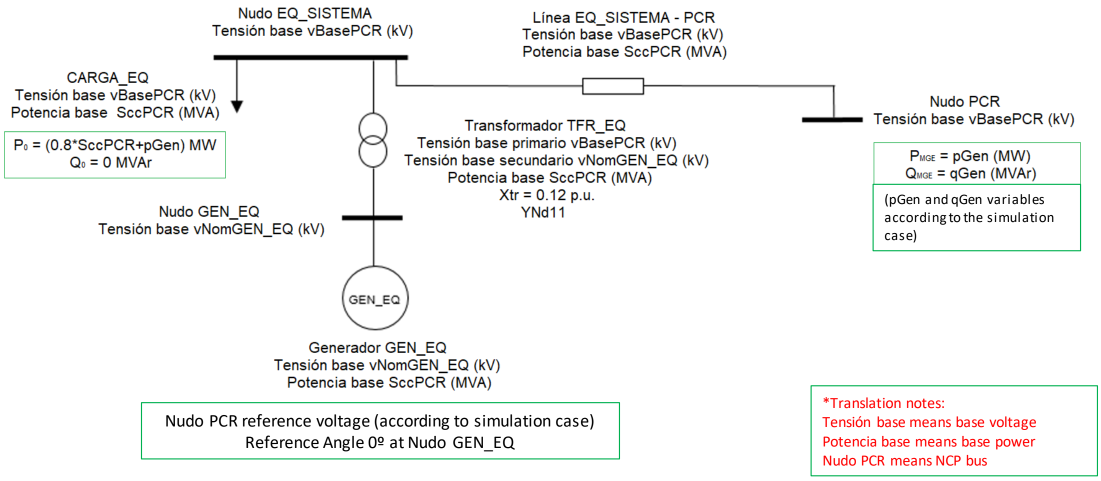


Figure 37. Equivalent electric network model (single-line scheme). Adjustments to resolve green framed load flow.

7.2.1. Node data and network equivalent passive elements

According to the nomenclature considered in **Figure 37**, the following data will be considered:

Nodes:
For the **Nudo PCR**, the nominal voltage of the network to which it belongs in reality (vBasePCR) will be considered as the voltage base.

For the EQ_SISTEMA node, the same voltage base as that of the **Nudo PCR** (vBasePCR) will be taken.

The nominal voltage of the GEN_EQ node shall be chosen as follows:

- 20 kV if the voltage base of the **Nudo PCR** is greater than or equal to 110 kV.
- 5 kV if the voltage base of the **Nudo PCR** is greater than or equal to 10 kV and less than 110 kV.
- If the stress base of the **Nudo PCR** e is less than 10 kV, the GENERATOR GEN_EQ is considered to evacuate directly to the EQ SYSTEM node, therefore the node GEN_EQ and the machine transformer are not modelled.

Loads:
For the EQ_SISTEMA node, a null reactive power consumption will be considered, and the active power of the load will be the sum of the active power produced by the equivalent **PGM** (pGenEq) plus the active power injected into the **PCR** by the **PGM** to be assessed by simulation (pGen), i.e.:

- Active power consumed, P_0 = (pGenEq + pGen) MW.
- Reactive power consumed, Q_0 = 0 MVAr.

The load model shall take into account the voltage dependence as follows:

- The active part P of the load of the EQ_SYSTEM node must be modelled with the characteristic of constant current, i.e.:

$$P(V) = P_1 \times V\ (p.u.)$$
$$Q(V) = Q_1 \times V^2 (p.u.)$$

- Where P_1 and Q_1 are the load values corresponding to a voltage of 1 p.u. These values are calculated from the initial demand values of the LOAD P_0 = (pGenEq+ pGen) MW and Q_0 = 0 MVAr node corresponding to the initial voltage of the V_0 node resulting from the previous load flow (value maintained during initialization). If V_0 is expressed in p.u., then:

$$P_1 = \frac{P_0}{V_0} \quad (p.u)$$

$$Q_1 = \frac{Q_0}{V_0^2} \quad (p.u)$$

PGM equivalent GEN_EQ:

The equivalent **PGM** will be an **SPGM** and will meet the following parameters:

- Maximum apparent power equal to the short-circuit power to be considered (SccPCR) which will be considered as the machine base (mBaseEq).
- Nominal voltage equal to the nominal voltage of the GEN_EQ node (vNomGEN_EQ), which shall be considered as the base (kV).
- Maximum capacity (pMaxEq) = 0,8*mBaseEq (MW).
- Minimum active power (pMinEq) = 0,2*mBaseEq (MW).
- Maximum reactive power (qMax) = 0,5*mBaseEq (MVAr).
- Minimum reactive power (qMin) = -0,25*mBaseEq (MVAr).
- Generated power (pGenEq) = 0,8*pMaxEq (MW).
- Subtransient reactance (X”) = 0,2 p.u. (mBaseEq and vNomGEN_EQ bases).
- The voltage set for **PCR** remote node voltage control will be adjusted to the value required for each simulation (dips, overvoltage, step response, etc.).

The data required to model this **SPGM** are specified in **Table 68** per unit (mBaseEq base) and with unsaturated characteristic values, the model to be used must not include magnetic saturation.

T'do	4,61	Transient time constant to direct axis open circuit (s)
T''do	0,054	Sub-transient time constant to direct axis open circuit (s)
T'qo	1,5	Transient time constant to open circuit quadrature axis (s)
T''qo	0,107	Sub-transient time constant to open-circuit quadrature axis (s)
Ra	negligible	Armature resistance
Xd	1,85	Direct axis synchronous reactance (p.u.)
Xq	1,74	Quadrature axis synchronous reactance (p.u.)
X'd	0,225	Direct axis transient reactance (p.u.)
X'q	0,306	Quadrature axis transient reactance (p.u.)
X''d = X''q	0,2	Direct and Quadrature axis sub-transient reactance (p.u.)
Xl	0,113	Leakage reactance (p.u.)
H	2,5	Inertia Constant [s] (Nominal Apparent Power base)

Table 68. SPGM data.

The required data for the excitation and voltage regulation system (SEXS type, see **Figure 38**) is that indicated in **Table 69**:

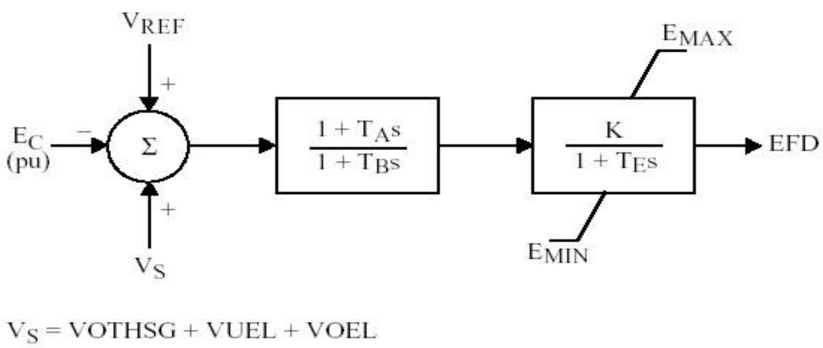


Figure 38. SPGM excitation system-voltage regulator.

T_E	0,1	Excitation regulator time constant (s)
K	100	Excitation regulator gain
Emin	0	Lower limit of excitation voltage (p.u. mBaseEq)
Emax	5,0	Upper limit of excitation voltage (p.u. mBaseEq)
T_A	1,0	Advance-delay network lead time constant (s)
T_B	10,0	Advance-delay network lead time constant (s)

Table 69. Data for the SPGM excitation system-voltage regulator

Also, the required data for the speed regulation system (TGOV1 type, see **Figure 39**) is that indicated in **Table 70**:

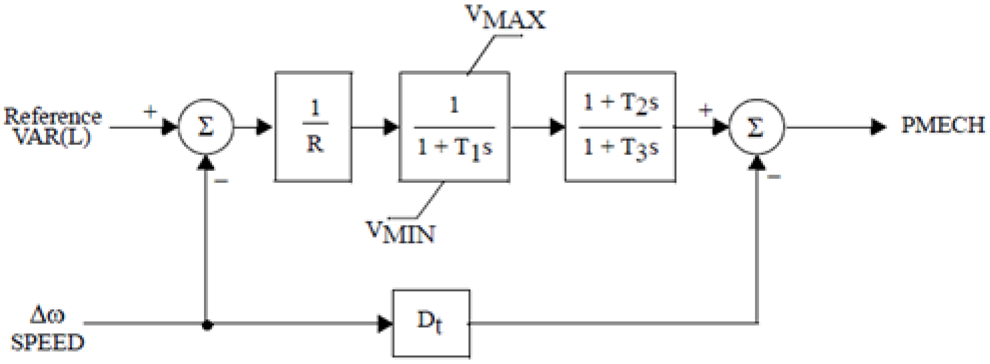


Figure 39. SPGM speed control system.

R	0,05	Regulator droop (inverse of gain) (p.u. mBaseEq)
T_1	0,5	Regular time constant (s); T1 > 0
Vmax	1	Maximum valve aperture (u.a. mBaseEq)
Vmin	0,15	Minimum valve aperture (u.a. mBaseEq)
T_2	3	Time constant (s) being T2/T3 the high pressure fraction
T_3	10	Overheating time constant(s)
D_t	0	Turbine damping (p.u. mBaseEq)

Table 70. Data of the SPGM speed control system.

GEN_EQ equivalent generator machine transformer:

For this transformer, the same maximum apparent power and base machine shall be considered as the one considered for the **SPGM** equivalent GEN_EQ. It shall be modelled with a reactance of value X_{tr} = 0,12 p.u. on a machine base. Additionally, it will be considered with the YNd11 connection group with grounded neutral. The nominal voltages of the primary and secondary winding of the transformer shall correspond to the values vBasePCR and vNomGEN_EQ respectively.

EQ_SISTEMA - PCR line:

The nominal voltage of the Nudo PCR (vBasePCR) shall be considered. A simple R + jX impedance shall be used with the following characteristics:

- Calculation of X:

It shall be obtained by the resolution of the following quadratic equation (reactances are considered in p.u. based on mBaseEq):

$X^2 + [2X_m/(1+r^2)]\,X + [X_m^2 – (SccPCR/mBaseEq)] / (1+r^2)] = 0$

Where r = is the resistance/reactance ratio of the line. It shall be chosen according to the base voltage of the Nudo PCR as follows:

- 0,1 if the voltage base of the Nudo PCR is 400 kV.
- 0,2 if the voltage base of the Nudo PCR is 220 kV.
- 0,5 if the voltage base of the Nudo PCR is 45 kV or more.
- 1 if the voltage base of the Nudo PCR is less than 45 kV.

The value of X_m corresponds to the sum of the subtransient reactance of the bGEN_EQ **SPGM** on the machine base plus the corresponding machine transformer reactance, i.e.:

$X_m = X'' + X_{tr} = 0{,}2 + 0{,}12 = 0{,}32$ p.u. (based on mBaseEq and vNameGEN_EQ)

, whose solution is (taking only the resulting solution of adding the square root of the discriminant of the quadratic equation):

$X = -[X_m/(1+r^2)] + root\{ [X_m/(1+r^2)]^2 - [(X_m^2 – (SccPCR/mBaseEq)) / (1+r^2)] \}$

- For R, R = rX shall be considered.

PCR equivalent PGM:

The **PGM** to be assessed shall meet the following parameters in order to include the plant in the equivalent Electric Network model:

- Maximum apparent power (mBasePCR) in MVA.
- Nominal voltage equal to the nominal Nudo PCR voltage (vBasePCR) in kV.
- Maximum active power (pMaxPCR) in MW.
- Minimum active power (pMinPCR) in MW.
- Maximum reactive power (qMaxPCR) in MVAr.
- Minimum reactive power (qMinPCR) in MVAr.
- Depending on the simulation case:
  - Generated active power (pGen) in MW.
  - Reactive power generated (qGen) in MVAr.
  - The load flow voltage will be defined in each simulation case and controlled by the balance generator (vPCR) in p.u.

7.2.2. Generation to be tested by simulation

The operating point of the **PGM** to be assessed by simulation shall be such that it meets the following conditions:

- The **Nudo PCR** voltage will be defined for each simulation case to be tested.
- The active power generated by the **PGM** to be assessed will depend on the simulation case, and the following cases may occur:
    - Minimum load (pminEq): 0% pMaxNCP < pGen < 10% pMaxPCR.
    - Partial load (pmed): 10% pMaxNCP < pGen < 50% pMaxPCR.
    - Full load: 80% pMaxNCP < pGen < 100% pMaxPCR.
- The reactive power generated by the **PGM** to be assessed will depend on the simulation case.

7.2.3. Initial load flow

Before running the simulation, a load flow must be run to obtain the initial conditions in steady state. This is because the network model changes depending on the facility to be assessed by simulation, so the initial electrical state will vary slightly. The aspects to be considered at the node level are as follows:

- In relation to the load dependence on the voltage for the initial load flow, all loads shall be considered as constant power, i.e., both the load of the EQ_SISTEMA node and all loads modelled on the network corresponding to the generation facility to be tested.

- The EQ_SISTEMA node will be a PQ type node:
    - Data:
        - Active power consumed, P_0 = (pGenEq + pGen) MW.
        - Reactive power consumed, Q_0 = 0 MVAr.
    - Unknowns to be resolved after load flow:
        - EQ_SISTEMA node voltage module.
        - EQ_SISTEMA node voltage angle.

- The GEN_EQ node (equivalent **SPGM** node) will be a balance type node:
    - Data:
        - Voltage module:
            - The value will depend on the simulation case.
            - The node to be controlled will be the Nudo PCR.
        - Voltage angle at the GEN_EQ node (δ = 0º angle reference)
    - Unknowns to be resolved after load flow:
        - Active power delivered by the equivalent **SPGM**.
        - Reactive power delivered by the equivalent **SPGM**.

- The **Nudo PCR** (PGM network connection point to be assessed by simulation) will be PQ type node:
  - Data:
    - Steady state active power produced by the **PGM** to be assessed by simulation.
    - Steady state reactive power injected by the **PGM** to be assessed by simulation.
  - Unknowns to be resolved after load flow:
    - **Nudo PCR** voltage module.
    - **Nudo PCR** voltage angle.

- The convergence tolerance must be adjusted to the power of the system according to the recommendations of the tool to solve the load flow.

- Successive convergences must be performed by iteratively adjusting the transformation ratio of the machine transformer of the **SPGM** equivalent GEN_EQ until V = 1,05 p.u. at NCP with the **PGM** to be assessed by simulation by absorbing the maximum Q required at V = 1,05 p.u. and at maximum power (pMaxEq). In the event that it is not necessary to model the GEN_EQ node or the machine transformer, the **Nudo PCR** voltage shall be adjusted with successive convergences, and the **SPGM** GEN_EQ setpoint voltage shall be modified as appropriate.

7.2.4. Initializing dynamic simulation

As a general rule, before simulation, the dynamic models must be initialized in order to place the dynamic state variables in the initial conditions corresponding to the solution of the obtained electrical state of the previous load flow. Therefore, after the initialization process, all network electrical status variables must be kept at the values of the previous load flow.

During the initialization process, the modelled loads must be maintained as constant power (without using voltage-dependent dynamic models) in order not to alter the value of the load to the initialization voltage. Also, during the initialization process, the **Nudo PCR** must maintain its initial electrical state and the dynamic model of the **PGM** to be assessed must maintain its active and reactive power injection at the static load flow values.

7.2.5. Dynamic simulation

For the dynamic simulation of balanced fault, a 3-phase fault at the NCP shall be simulated, with a ground reactance. The reactance value shall be such that the voltage at the NCP drops to the value set in the voltage-time profile of the dip to be simulated at the time the fault is cleared.

For the dynamic simulation of an unbalanced fault, an isolated 2-phase ground fault at the NCP shall be simulated, with a reactance between phases such that the phase-to-ground voltage of the fault phases at the NCP lowers to half the value set in the voltage-time profile of the dip for balanced faults, increased by 0,5 p.u., at the time the fault is cleared.

In the particular case of the EMT model:

- The 3-phase fault simulation balanced fault shall be applied when the voltage of one of the phases is maximum.
- In the case of an isolated 2-phase ground fault simulation, the fault will be applied when the voltages of the phases in which the fault is to be simulated match.
- The fault will be cleared by means of an automatic switch that opens in step by step from the current.

7.3. Data exchange format between entities accredited to conduct tests and simulations

7.3.1. Objective

Each **PGU, ACPGM** or **PGM** certification requires the exchange of information between the **accredited entities for the conduct of tests and simulations**, the **authorised certifier**, the **PGM owner** and the **RSO**. It is therefore important that the structure of this information be as uniform as possible to allow for the automation of data processing. In particular, the data to which this subsection would apply would be the measured data and the results of the analysis thereof, including the analysis of robustness test data. It is therefore **recommended**, in order to facilitate the exchange of information between those involved, that the format of the information exchanged be in accordance with the following points.

7.3.2. Definition of the register

The data format must be COMTRADE, internationally recognised, alternatively, * .dat or * .mat can be used, as they are common formats between test laboratories, **authorised certifiers** and simulation entities, can easily process these formats. The decimal separator shall be the point according to the international standard.

7.3.3. Structure

The measured data and the results of the analysis shall be transferred separately, in order to clearly distinguish between raw and processed data. If a measurement occurs at more than one voltage level, it must be specified, MT (Media Tensión in Spanish means Medium Voltage) for the higher voltage level and BT (Baja Tensión in Spanish means Low Voltage) for the lower voltage level. In the case of a single voltage level, this designation shall be omitted.

Together with the data, a summary document in pdf format containing the main results, such as the calculated k-factor, power recovery, rise time, settling time, etc. shall be delivered.

Raw data are given using the following structure of **Table 71**:

	t/s	U1/V	U2/V	U3/V	I1/A	I2/A	I3/A	v/(m/s)	Δ /º	P_{DC}/W
Raw data	0,0001	11547	11547	11547	256	261	259	6,9	...	...
	0,0002	11548	11546	11548	262	265	264	7,2	...	...
	...									

Table 71. Raw data structure

The special signals used here for the wind speed (v), the load angle (δ) and the primary power (PDC) are given individually, depending on the situation. If line voltages are measured, the denomination will be U12, U23 and U31 respectively.

The following table shows the structure of the calculated values, as well as the names of the channels to be used and the units in which they should appear:

Results	t/s	0,02	0,04	...
	U12/V	19999	20001	
	U23/V	19999	20001	
	U31/V	19999	20001	
	U1/V	11547	11548	
	U2/V	11547	11547	
	U3/V	11547	11547	
	U_{pos}/V	...	...	
	U_{neg}/V			
	U_{zero}/V			
	I1/V			
	I2/V			
	I3/V			
	Ia_{pos}/A			
	Ia_{neg}/A			
	Ia_{zero}/A			
	Ir_{pos}/A			
	Ir_{neg}/A			
	Ir_{zero}/A			
	P_{tot}/W			
	Q_{tot}/var			
	P_{pos}/W			
	P_{neg}/W			
	P_{zero}/W			
	Q_{pos}/var			
	Q_{neg}/var			
	Q_{zero}/var			

Table 72. Results structure

Being:

- U12 / V Effective voltage value line 1-2
- U23 / V Effective voltage value line 2-3
- U31 / V Effective voltage value line 3-1
- Upos, neg, zero / V Symmetric components of voltage
- Iapos, aneg, azero / A Symmetric components of active current
- Irpos, rneg, rzero / A Symmetric components of reactive current
- Ptot / W Total active power
- Qtot / var Total reactive power
- Ppos, neg, zero / W Symmetric components of active power
- Qpos, neg, zero / W Symmetric components of reactive power

7.3.4. Sending data

To ensure consistency of records, checksums should be used and sent along with the records. The result of these tests must form part of the summary document.

They can be transmitted by various means (sharepoint, sftp server, DVD). Given the sensitivity of the data, as well as the accreditation requirements, special care must be taken to ensure that the medium has a sufficient level of encryption to prevent third-party access. If necessary, an additional confidentiality agreement should be considered.

7.3.5. File nomenclature

Variables, as required above, are recorded (sampling rate), named, averaged or classified normally throughout the record.

The file names selected must be relevant and include at least the **PGU** designation, voltage level, manufacturer, date and time, a sequential number and information on whether the data is unprocessed or analysed. Raw data and results should be transmitted in separate registers, thus leaving the following example structure:

EGUx-FABRICANTEy_MV_RES_2014_03_21_051328_ (0001).dat

EGUx-FABRICANTEy _LV_BRU_2014_03_21_051328_ (0001) .dat).

7.4. Modelling procedure for complementary reactive power capability simulations and reactive power control modes

7.4.1. Purpose

The purpose of this subsection is to provide details of the modelling to be considered for the performance of **supplementary simulations** to verify the **reactive power capability** of **PGMs** according to subsection 5.7, and the **capability to control the reactive power** of **PPMs** according to subsection 5.8.

To this end, two modelling options are proposed for each capacity to be verified, which will be selected, and which are detailed in the following sections:

- Complete modelling procedure at NCP.
- Alternative modelling procedure at **PGM terminals (BC)**.

7.4.2. Modelling procedure for supplementary simulations of reactive power capability

7.4.2.1. Complete modelling procedure at NCP

The validation of reactive power capability by the full modelling procedure at NCP aims to verify that the **PGM** meets the reactive power capability requirements at the **NCP**, based on the declared capabilities of the **PGUs**, either by means of the tests listed in 5.7.2, or by means of certificates issued for **PGU** and, if applicable, for **ACPGM**.

An infinite network or ideal voltage source will be used at the NCP to modify its voltage values. The simulation model must include the details of the **PGM** topology from the **PGU** up to the **NCP**, i.e. cables, lines, power transformers, tap changers, any **ACPGM** that alters the reactive capacity, or any electrical equipment that may involve the consumption or generation of reactive power of the **PGM** at the NCP, whether belonging to the connection network from the **PGM** up to the **NCP**, or the internal network of the **PGM** from the **PGU** up to the PGM terminals (**BC)**. Therefore, the use of an equivalent model of the **PGM** shall not be allowed, with the exception specified in subsection 7.5.

If the network modelled from the **NCP** to the **PGM** is shared or is planned to be shared with more **PGMs**, these must be taken into account in the supplementary simulation and must be modelled. In order to avoid the need and the transfer and verification of third-party information, and to deal with different cases in the temporal evolution of the **PGMs** connected at such **NCP**, these must be fictitiously modelled according to the structural parameters of the shared evacuation network, and more particularly according to the power of the power transformers.

In order to represent the modelling of the ficticious **PGMs** that share the connection at the NCP, the following must be considered:

- The connection scheme must be available from the **PGM** being assessed up to the **NCP**.
- If **PGM terminals (BC)** is located on the low voltage side of the step-up transformer, a **fictitious PGM** must be modelled in parallel, whose maximum capacity is the difference

between the nominal power of the transformer and the maximum capacity of the **PGM** to be assessed.

- Following the connection scheme from the **BC** of the **PGM** under assessment up to the **NCP**, at each point where there is a transformer, a **fictitious PGM** must be modelled on the low voltage side, whose maximum capacity is equal to the difference between the nominal transformer power and the sum of the downstream modelled **fictitious PGMs**, i.e. the nominal power of the previous transformer.
- The above shall be repeated until the **NCP** is reached, which for the purpose of fictitious generator modelling is considered to occur when the nominal voltage on the high voltage side of the last transformer in which a **fictitious PGM** has already been modelled on the low voltage side coincides with the **NCP** voltage.
- Following the proposed procedure, only in the case of the first **fictitious PGM** modelled, its maximum capacity calculation will consider the power of the upstream transformer as $0{,}9*S_{trafo}$.

Below are five examples that illustrate the fictitious modelling of **PGMs** that share a connection network. Black shows the connection infrastructure from **BC** up to **NCP** that must be modelled to perform the supplementary simulations, grey shows the rest of the facilities and **PGMs** that share the connection at the same **NCP**, which shall not be modelled, and in red the fictitious **PGMs** are shown which need to be modelled according to the above mentioned considerations.

<u>Example I</u>

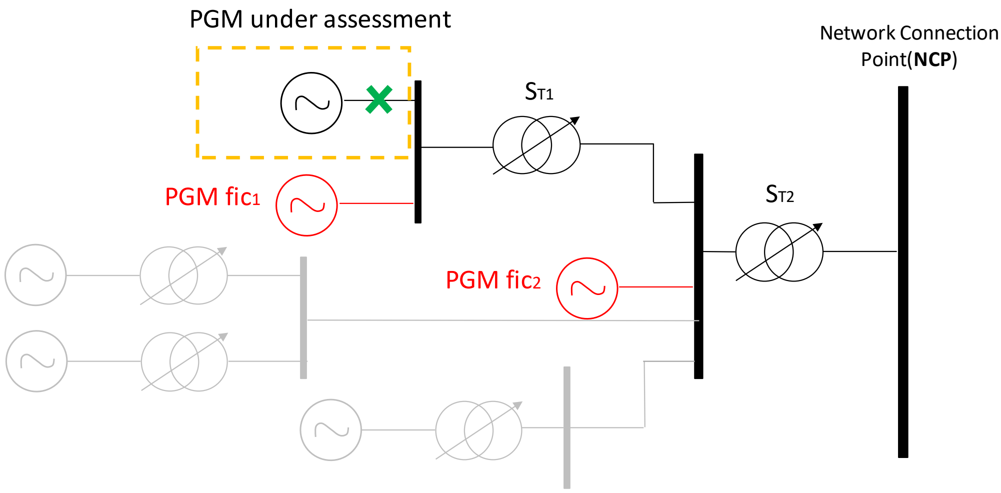
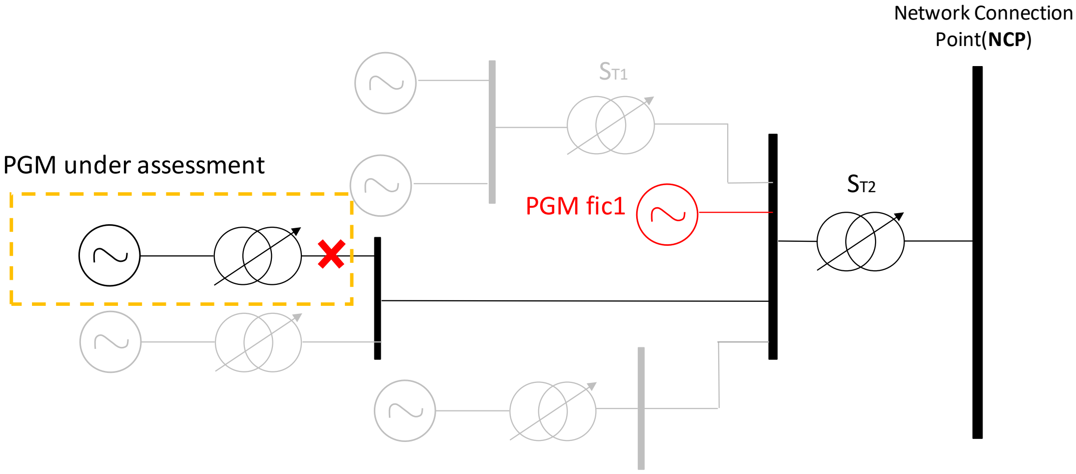


Figure 40. Illustrative diagram Example I of modelling for the performance of supplementary simulations for verifying the reactive power capability of PGMs according to the full modelling procedure at NCP.

Example II

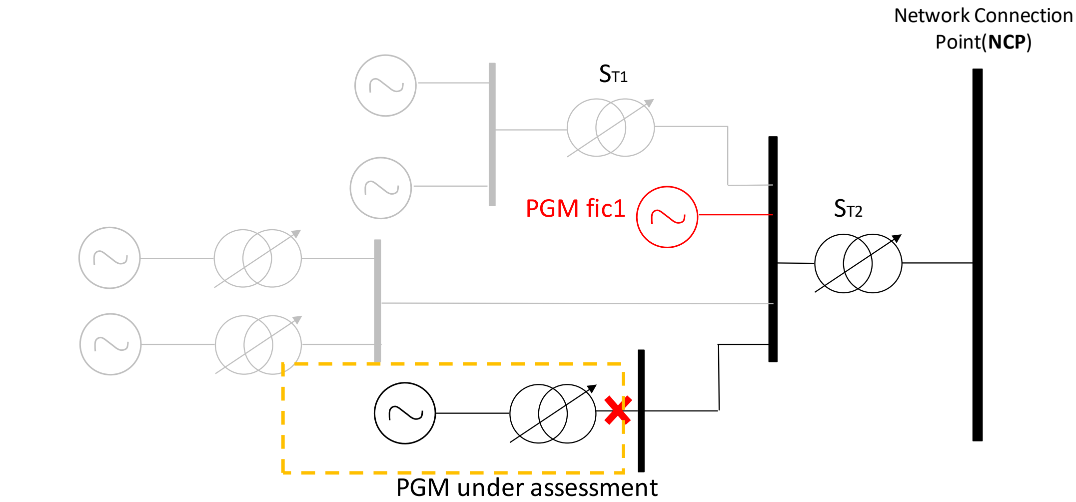


Pmax (PGM under assessment) =PmaxPGM

Pmax (PGM fic$_1$)=0,9*ST2- PmaxPGM

Figure 41. Illustrative diagram Example II of modelling for the performance of supplementary simulations to verify the reactive power capability of PGMs according to the complete modelling procedure at NCP.

Example III

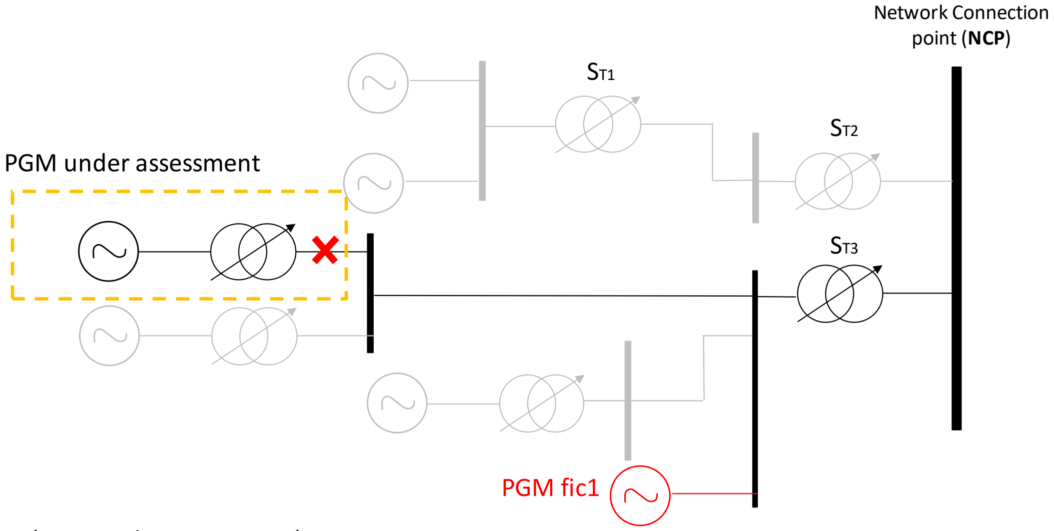


Pmax (PGM under assessment) =PmaxPGM

Pmax (PGM fic$_1$)=0,9*ST2- PmaxPGM

Figure 42. Illustrative diagram Example III of modelling for the performance of supplementary simulations to verify the reactive power capability of PGMs according to the complete modelling procedure at NCP.

Example IV



Pmax (PGM under assessment) =PmaxPGM

Pmax (PGM fic1)=0,9*ST3- PmaxPGM

Figure 43. Illustrative diagram Example IV of modelling for the performance of supplementary simulations to verify the reactive power capability of PGMs according to the complete modelling procedure at NCP.

Example V

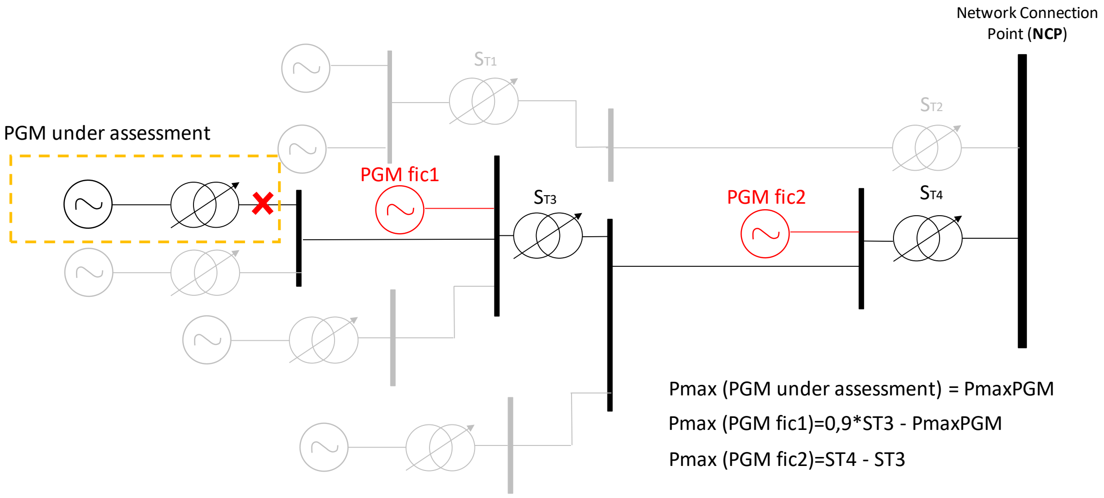


Figure 44. Illustrative diagram Example V of modelling for the performance of supplementary simulations to verify the reactive power capability of the PGMs the complete modelling procedure at NCP.

With the model described above, the **supplementary simulations** necessary to verify the maximum reactive power requirements shall be carried out, for which a static model is accepted for the realization of a load flow including the reactive power capabilities of the **PGUs**.

As regards the operation points of the **fictitious PGMs** to be considered for the performance of supplementary simulations:

- As regards the active power operation point of **fictitious PGMs**, the same active power (in p.u., P/P_{max}) as that requested for the **PGM** under assessment shall be considered for each supplementary simulation.
- As regards the reactive power operation point of **fictitious PGMs**, any reactive power operation point between 0,98 capacitive power factor and 0,98 inductive power factor may be considered.

By means of the complete modelling procedure at **NCP**, using the modelling methodology described above, and by means of the simulations listed in the tables of 5.7.3.1 the reactive power capabilities of the **PGM** must be checked at the checkpoints illustrated in **Figure 45**.

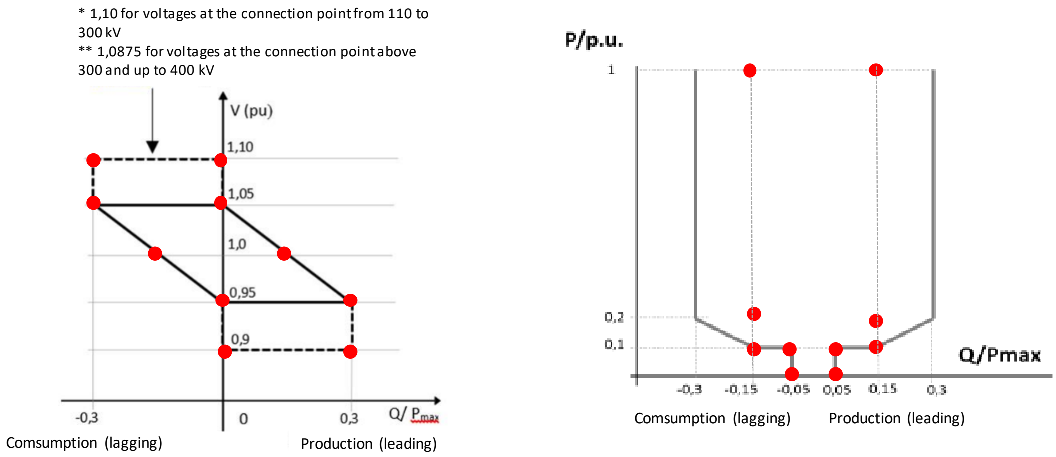


Figure 45. Graphical representation of the checkpoints of the reactive power capability at the maximum capacity of the PGMs (left) and of the checkpoints of the capacity of reactive power at active powers less than maximum capacity (right) according to the full modelling procedure at NCP.

7.4.2.2. Alternative modelling procedure at BC.

In the event that there is a shared evacuation network from the **BC** of the **PGM** under verification up to the **NCP**, or in anticipation of being shared with other **PGMs**, the assessment of the compliance of the reactive power capabilities of **PGM** at the NCP becomes complicated. The reactive power requirements listed in the **Regulation**, in [2] and in [3] apply at the **NCP**; however, taking into account that assessment at the **NCP** will not always be possible, and in order to simplify the compliance assessment process, this subsection proposes an alternative procedure to that described in subsection 5.7.3.1.

The compliance assessment of the **PGM**'s reactive power capability requirements at **BC** instead of **NCP** will be accepted. However, it should be noted that this simplification of the compliance assessment at the **PGM terminals** means that for some of the **PGM**'s operating points, the reactive power values required at BC of the **PGM** differ from those required in [2], i.e. those required at the **NCP**.

In order to obtain the **PGM certificate** based on **PGU** level tests or **PGU** certificates, it will be necessary to perform a **supplementary simulation** demonstrating that the capabilities of the **PGU**, as declared in the tests and simulations at **PGU** level and, if applicable, **ACPGM**, meet the reactive power capability values at BC listed in **Table 20**, **Table 21**, **Table 22** or **Table 23**, as applicable.

Two cases are distinguished, depending on the location of **BC**[21].

7.4.2.2.1. Case A.

In the event that **BC** of the **PGM** is located at the HV side of the step-up transformer (**LAT**) of the **PGM**, the **supplementary simulation** shall be carried out considering both the voltage and the reactive power at BC (i.e. **LAT** in this case) in such a way that it will be necessary to model the collector network from the **PGU** up to **BC**, but not the evacuation network up to the **NCP**. The simulation model must include the details of the **PGM** topology from **PGU** to **BC**, downstream of BC i.e. cables, lines, power transformers, tap changers, any **ACPGM** that changes the reactive power capability of the **PGM** at **BC**. Therefore, the use of an equivalent model of the **PGM** shall not be allowed, with the exception specified in subsection 7.5.

The diagram shows an example in which the topology of the connection network that has not been modelled has been coloured in grey, and the **PGM** to be assessed has been coloured in black, as well as the network that has to be modelled up to **BC** where an infinite network or ideal voltage source will be used to vary the voltage values at that point.

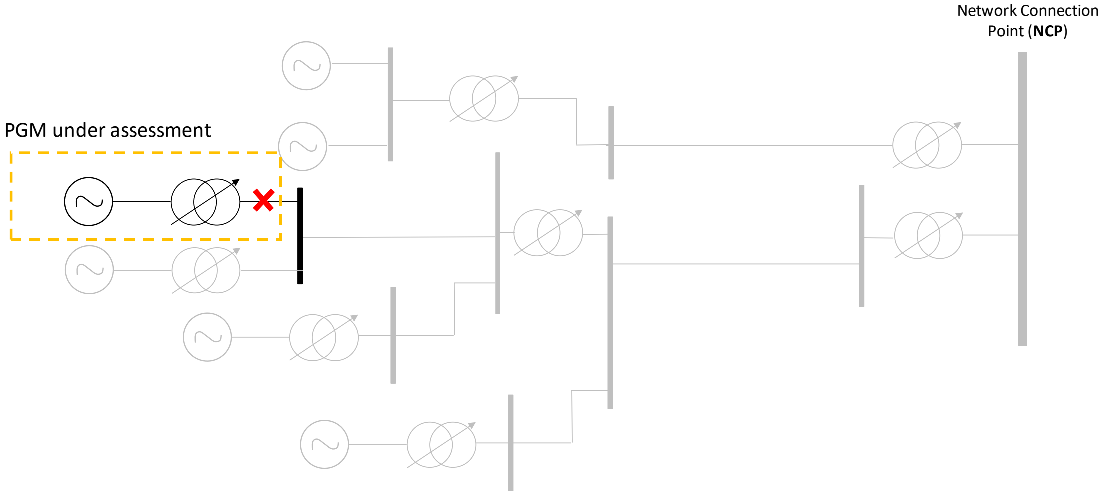


Figure 46. Illustrative diagram of modelling for the performance of supplementary simulations for verifying the reactive power capability of PGMs according to the alternative modelling procedure at BC Case A.

Through the alternative modelling procedure at **BC**, Case A, using the modelling methodology described above, and through the simulations listed in the tables of subsection 5.7.3.2 the **PGM**'s reactive power capabilities must be checked at the checkpoints illustrated by **Figure 47**.

[21] See the definition of PGM terminals (BC) for the purposes of Technical Standard.

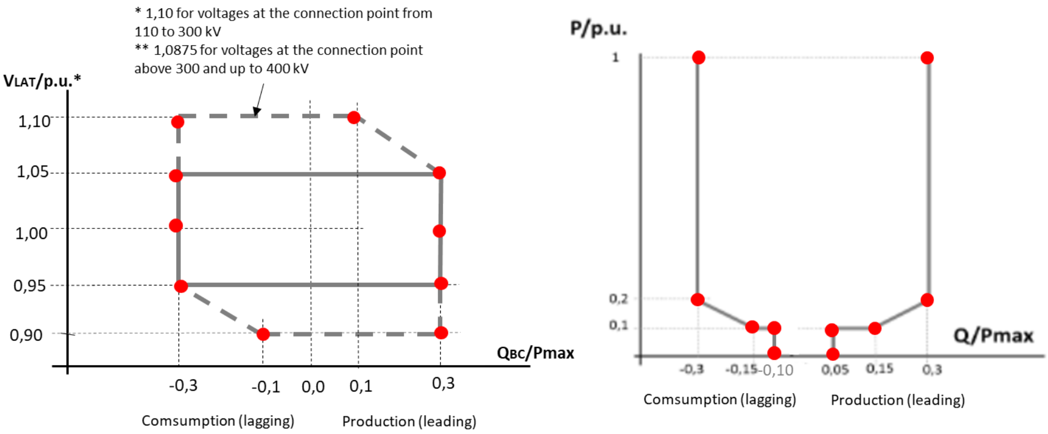


Figure 47. Graphical representation of the checkpoints of the reactive power capability at the maximum capacity of the PGMs (left) and of the checkpoints of the capacity of reactive power at active powers less than the maximum capacity of PPMs (right) according to the alternative modelling procedure at BC Case A.

For clarification purposes, according to the values of the checkpoints stated in **Figure 47**, in this case A of the alternative modelling procedure, it is required that the **PPM** with generating active power in the range from 10%P_{max} to 0%P_{max} (included) has the ability to move its reactive power between +5% capacitive and -10% inductive. This capacity can be provided through the following two alternatives:

- Through a dynamic control, in which it is understood that the **PGUs** and/or **ACPGMs** are capable of performing it.
- Through a passive element, usually a reactance. The passive element, in such a low production situation, must bring the **PGM** to the operation point in reactive power of -5% inductive (when the voltage at BC is nominal), to which the dynamic control capability (which it is understood must be provided by the **PGU** and/or **ACPGM**) of ±5% as provided in the P-Q/P_{max} diagram must be superimposed. In the event that the voltage at BC is outside the admissible range and such passive element is in operation, the **PGM** must first disconnect the passive element in order to attempt to recover the voltages and not trip the **PGM**.

7.4.2.2.2. Case B

If the **BC** of the **PGM** is located at the LV side of the **PGM** step-up transformer, the **supplementary simulation** shall be performed by measuring the reactive power at BC and considering the voltage at the HV side of the shared step-up transformer, so that it will be necessary to model the collector network from the **PGU** to **BC** and the shared transformer, but not the rest of the evacuation network up to the **NCP**. The simulation model must include, downstream of **BC,** the details of the **PGM** topology from **PGU** up to **BC**, i.e. cables, lines, power transformers, tap changers, any **ACPGM** that changes the reactive power capability of the **PGM** at BC, in addition to the step-up transformer. Therefore, the use of an equivalent model of the **PGM** shall not be allowed, with the exception specified in subsection 7.5.

In order to model the remaining **PGMs** that share a step-up transformer with the **PGM** to be assessed, they will be considered as a **fictitious PGM**, the maximum capacity of which will be the difference between the power of the transformer and the maximum capacity of the **PGM** to be assessed; that is, the fictitious **PGM** will be of maximum capacity $Pf_{ic}=P_{trafo}-P_{PGM}$, where P_{trafo} will be the $0,9*S_{trafo}$.

The diagram shows an example of a topology for which the network should be modelled up to the **LAT** of the shared step-up transformer has been coloured black, and the **fictitious PGM** has been coloured red, and grey the rest of the network topology that does not need to be modelled.

At the **LAT**, an ideal source of voltage or an infinite network shall be considered to vary the voltage in each simulation.

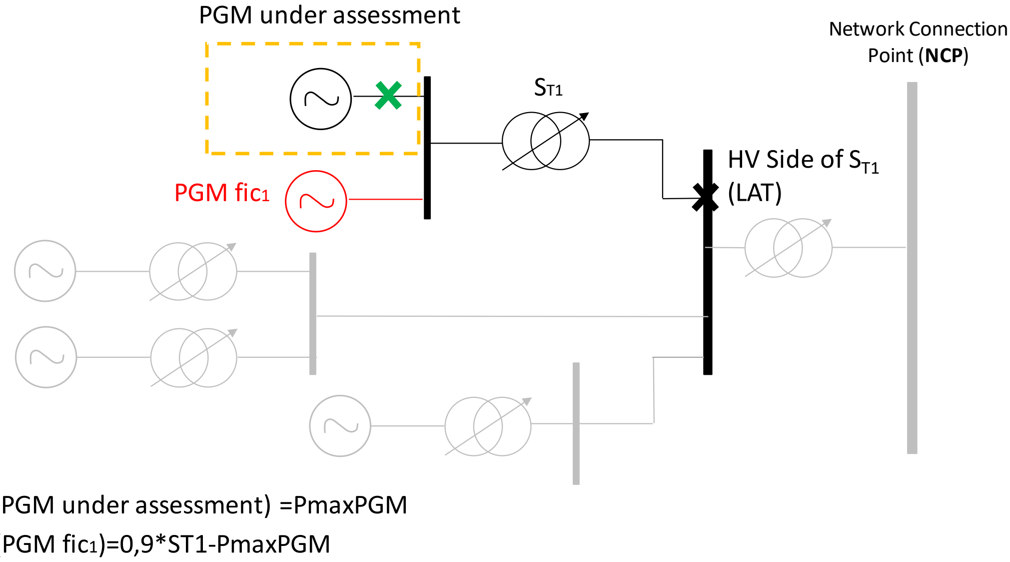


Figure 48. Illustrative diagram of modelling for the performance of supplementary simulations for verifying the reactive power capability of PGMs according to the alternative modelling procedure at BC Case B.

As regards the operation points of the **fictitious PGM** sharing a transformer to be considered for the performance of the supplementary simulations:

- The active power operation point of the **fictitious PGM** for each supplementary simulation shall be considered the same active power (in p.u., P/P_{max}) as that requested for the **PGM** under assessment.
- The operation point in reactive power of the **fictitious PGM** for each simulation will be the same (in p.u., Q/P_{max}) as that ordered to the **PGM** under assessment.

Through the alternative modelling procedure at BC, Case A, using the modelling methodology described above, and through the simulations listed in the tables of subsection 5.7.3.2 the **PGM**'s reactive power capabilities must be checked at the checkpoints illustrated by **Figure 49**.

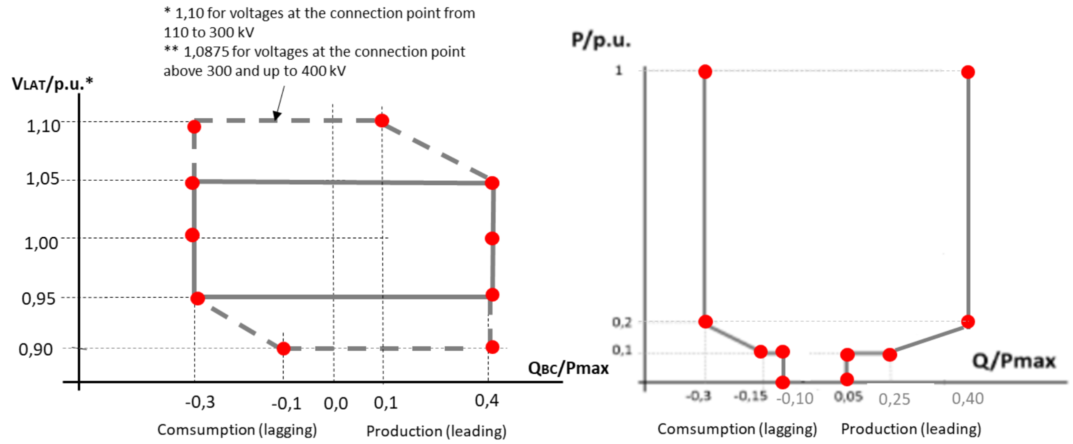


Figure 49. Graphical representation of the checkpoints of the reactive power capability at the maximum capacity of the PGMs (left) and of the checkpoints of the capacity of reactive power at active powers less than the maximum capacity of PPMs (right) according to the alternative modelling procedure at BC Case B.

For clarification purposes, according to the checkpoints stated in **Figure 49**, in this case B of the alternative modelling procedure at BC, it is required that the **PPM** generating active power in the range from 10%P_{max} to 0%P_{max} (included) has the ability to move its reactive power between +5% capacitive and -10% inductive. This capacity can be provided through the following two alternatives:

- Through a dynamic control, in which it is understood that the **PGUs** and/or **ACPGMs** are capable of performing it.
- Through a passive element, usually a reactance. The passive element, in such a low production situation, must bring the **PGM** to the operation point in reactive power of -5% inductive (when the voltage at BC is nominal), to which the dynamic control capability (which it is understood must be provided by the **PGU** and/or **ACPGM**) of ±5% as provided in the P-Q/P_{max} diagram must be superimposed. In the event that the voltage at **BC** is outside the admissible range and such passive element is in operation, the **PGM** must first disconnect the passive element in order to attempt to recover the voltages and not trip the **PGM**.

In addition, and unlike Case A, a different reactive power checkpoints at the maximum reactive power capability of the **PGM** is also set in order to compensate the losses of the **PGM**'s step-up transformer. This reactive power capability may also be supplied dynamically or statically.

7.4.3. Modelling procedure for supplementary simulations of reactive power control modes

As for the assessment of the reactive power capability of **PGMs**, two possible modalities for carrying out **supplementary simulations** are also foreseen for the reactive power control modes, which verify that the reactive power control capability of **PGUs** is adequate to carry out the control at **PGM** level.

7.4.3.1. Complete modelling procedure at NCP

When this procedure is selected to perform supplementary simulations to verify the reactive power control modes, it is assumed that, for the purpose of supplementary simulations of voltage control, the control point is at **NCP**, and it at this point that the reactive power response is verified.

The network shall be modelled as described in the additional reactive power capability simulations described in subsection 7.4.2.1, with the following modifications:

- An ideal source of voltage shall be modelled at the **NCP** in order to keep it constant, or with which voltage variations can be simulated. Such ideal voltage source may have short-circuit power values such that the short-circuit ratio (**SCR**) value is equal to or greater than 6[22].
- The active power operation point of the **fictitious PGMs** modelled shall be considered the same (in p.u., P/P_{max}) as that of the **PGM** under assessment.
- The reactive power control mode of such **fictitious PGMs** shall be considered as a constant power factor.

7.4.3.2. Alternative modelling procedure at BC

When this procedure is selected to perform **supplementary simulations** to verify the reactive power control modes, it is assumed that the control point is at **LAT** of the **PGM** step-up transformer.

The network will be modelled as described in the supplementary simulations of reactive power capability in 7.4.2.2, with the following modifications:

- At the electrical point where a voltage, or voltage variations, i.e., at **LAT** for the purpose of supplementary simulations of voltage control, required to be maintained at the control point, i.e. **BC**, an ideal voltage source shall be modelled. Such ideal voltage source may have short-circuit power values such that the short-circuit ratio (**SCR**) value is equal to or greater than 6[23].
- In particular, in Case B, it will not be necessary to model the **PGMs** that share a connection transformer with the **PGM** to be assessed.

The following is an example illustrating the modelling of supplementary voltage control simulations for each case.

[22] If an ideal voltage source with an SCR value other than infinity is chosen, the voltage variation caused by the PGM's own reactive power response must be taken into account, in such a way that the simulated voltage step is in absolute terms the same as that shown in the tables of the corresponding supplementary simulations.

[23] Same as the last one.

7.4.3.2.1. Case A

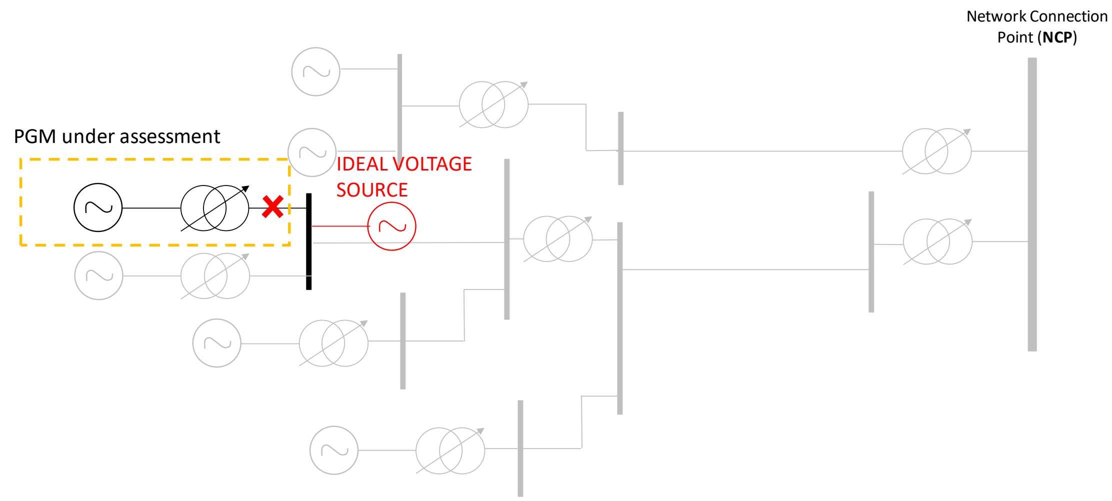


Figure 50. Illustrative diagram of modelling for the performance of supplementary simulations of the PPM reactive power control modes according to the alternative modelling procedure at BC Case A.

7.4.3.2.2. Case B

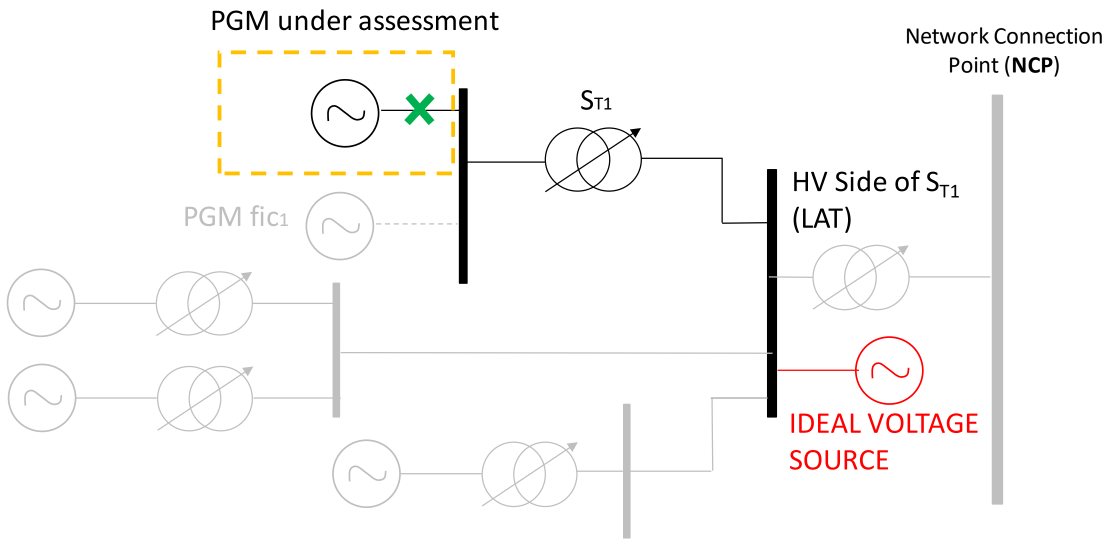


Figure 51. Illustrative diagram of modelling for the performance of supplementary simulations for verification of the PPM reactive power control modes according to the alternative modelling procedure at BC Case B.

7.5. Equivalent model for photovoltaic PPMs by low voltage aggregation

Generally speaking, the use of an equivalent model is not permitted for the simulation of **PGMs**. If the **PGM** is a photovoltaic **PPM** made up of **PGU** (inverters), in which there is usually a significant number of **PGUs**, the **PPM** will be modelled using low voltage aggregates per block using the methodology described in this annex.

According to **Figure 52**, from the transformation centres (MV/LV TRFV) to the **PGM** transformer (PGM TRFV), both included, the photovoltaic **PPM** shall be modelled in detail, as required for the rest of **PGM**.

Figure 52 shows the layout of **PGUs** in a photovoltaic **PPM**:

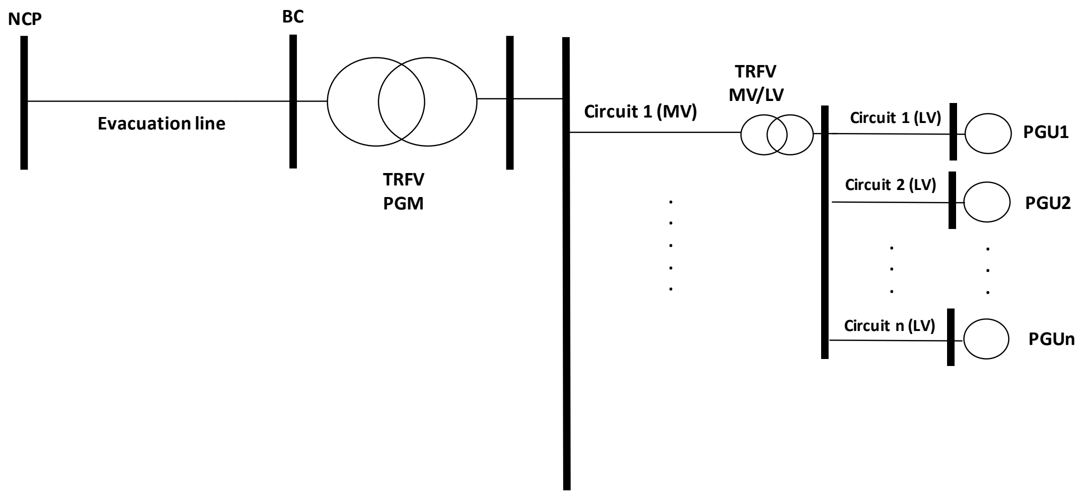


Figure 52. Single-line representation of a block of inverters up to NCP.

The aggregation of the **PGUs** (PGU1, PGU2,..., PGUn) and the circuits connecting the **PGUs** to the LV side of the MV/LV transformer shall be performed on the LV bar of such transformer, as shown in **Figure 53**:

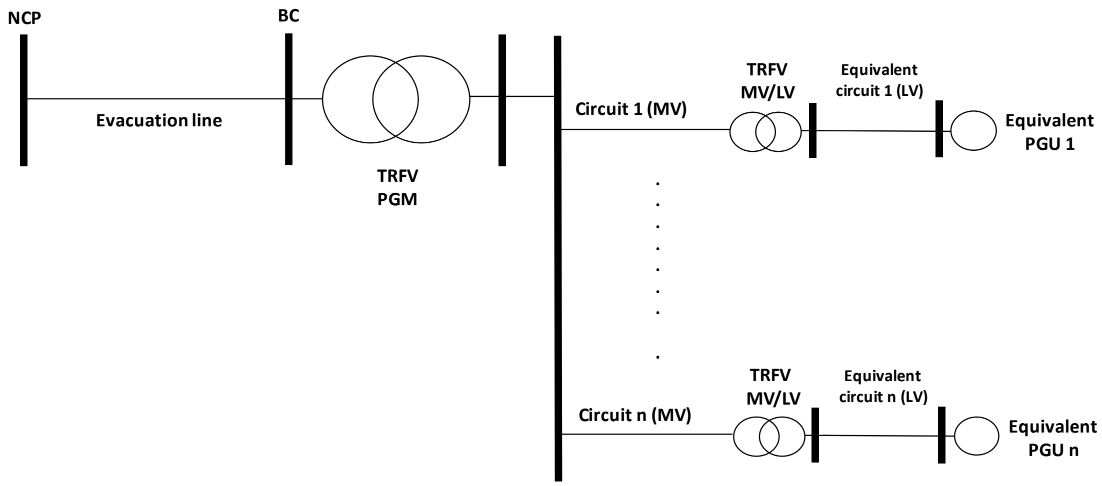


Figure 53. Single-line representation of the photovoltaic plant with low voltage aggregate blocks.

That is, for each of the MV circuits, the following must be modelled:

- The detailed MV circuit itself, as indicated above.
- The detailed MV/LV transformer corresponding to each MV circuit.
- On the LV side of the MV/LV transformer, the following equivalent model shall be permitted:
    - Replace the LV circuits of the **Figure 53** with a LV circuit that is its electrical equivalent.
    - Replace all **PGUs** that are exactly the same with an aggregated equivalent **PGU**.

The authorised certifier shall assess the correct modelling of all the detailed elements and the correct completion of this equivalent model.

8. REFERENCES

[1] (EU) **Regulation** 2016/631 of the Commission of 14 April 2016 establishing a network code on requirements for grid connection of generators. (http://eur-lex.europa.eu/legal-content/ES/TXT/PDF/?uri=CELEX:32016R0631&from=EN).

[2] Orden TED/749/2020, de 16 de julio, por la que se establecen los requisitos técnicos para la conexión a la red necesarios para la implementación de los códigos de red de conexión.

[3] Real Decreto 647/2020, de 7 de julio, por el que se regulan aspectos necesarios para la implementación de los códigos de red de conexión de determinadas instalaciones eléctricas.

[4] Procedimiento de verificación, validación y certificación (PVVC) de los requisitos del P.O.12.3 sobre la respuesta de las instalaciones eólicas y fotovoltaicas ante huecos de tensión. Version 11 or higher.

[5] IEC 61400-21-1 Measurement and assessment of electrical characteristics - Wind turbines. Version May 2019.

[6] Technical Guidelines for Power Generating Units and Systems. Part 3 (TG3). Determination of the electrical characteristics of power generating units and systems, storage systems as well for their components in medium-, high- and extra-high voltage grids. Revision 25. FGW.

[7] Technical Guidelines for Power Generating Units and Systems. Part 4 (TG4). Demands on modelling and validating simulation models of the electrical characteristics of power generating units and systems, storage systems as well for their components. Revision 09. FGW.

[8] IEC 61400-27-2: Wind Energy generation systems Part 27-2: Electrical simulation models – Model validation. July 2020 version.

[9] EN 50549-2:2019 – CLC/TC 8X. Requirements for generating plants to be connected in parallel with distribution networks – Part 2: Connection to a MV distribution network – Generating plants up to and including Type B.

[10] Real Decreto 413/2014, de 6 de junio, por el que se regula la actividad de producción de energía eléctrica a partir de Fuentes de energía renovables, cogeneración y residuos.

[11] P.O. 12.3 Requisitos de respuesta frente a huecos de tensión de las instalaciones eólicas. Resolución de 04-10-2006, BOE 24/10/06.

9. TABLES AND FIGURES

9.1. List of figures

9.2. List of tables